Final Report

Final Baseline GHG Emission Estimates for the Rimba Raya Biodiversity Reserve Project

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ACRONYMS AND COMMONLY USED INDONESIAN TERMS

Bupati	head of a district, also called a regent
CAA	carbon accounting area, also called in CCBA the project area
CCBS	Carbon, Community, and Biodiversity Standard
CPO	Crude palm oil
DBH	diameter at breast height (1.3 m from ground)
GHG	green house gasses
HGU	HakGuna Usaha – long-term agro-industrial estate license
MENHUT	Minister of Forestry abbreviation in Indonesian
MoF	Ministry of Forestry (technically it is the Department of Forestry, but commonly referred as a Ministerial level
PT	Indonesian abbreviation for limited responsibility corporation
REDD	Reduced emissions from deforestation
SK	Indonesian initials for a decree emitted by minister, governor or Bupati
TGHK	Indonesian initials for the Dephut national spatial plan
TPNP	Tanjung Puting National Park
VCS	Voluntary Carbon Standard
Padustrasi	Process by which the provincial level spatial plans are harmonized with the National Forestry Spatial
OFI	Orangutan Foundation International

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Project Profile Highlights

Project Owner	**PT Rimba Raya Conservation**
Project Developer	Infinite-Earth Limited
NGO Partner & Project Beneficiary	Orangutan Foundation International
Host Country	**Indonesia**
Region	Kalimantan (Island of Borneo)
Province	Central Kalimantan
Regency	Seruyan
Forest Type	HCV Tropical Peat Swamp Forest
Total Project Management Zone	**91,215 ha**
Estimated Total Avoided Emissions in Project Management Zone	**>350 million t CO_2e**
Total Area at Risk of Deforestation	91,215 ha
Project Area (Carbon Accounting Area)	**47,237 ha**
Total Reduced Emissions in Project Area (Carbon Accounting Area)	**104,886,254 t CO_2e**
Project Start Date by Project Developer	November 2008
Crediting Period Start Date	**July 2009**
Primary Deforestation Driver	**Planned Deforestation**(Palm Oil supported by government policy)
REDD Standards	**VCS & CCBA**
Methodology	*"VM0004 Methodology for Conservation Projects that Avoid Planned Land Use Conversion in Peat Swamp Forests, v1-0"*
Endangered, Threatened & Vulnerable Mammals in Project Zone	**29** including the Endangered Bornean Orangutan
Endangered, Threatened & Vulnerable Species (All) in Project Zone	**94+**
Communities in Project Area and Project Zone	0 in Project Area. 14 in Project Zone

1. INTRODUCTION

Various initiatives related to reducing emissions from deforestation and degradation (REDD) have begun in Indonesia with one of the more promising projects, Rimba Raya Biodiversity Reserve, located adjacent to Tanjung Puting National Park (TPNP). Infinite Earth is the parent company and project proponent for PT Rimba Raya, which has formally solicited the Ministry of Forestry for an Ecosystem Restoration concession comprising 91,215 ha of mostly peat swamp forest adjacent to the eastern boundary of TPNP. The granting of the license will provide a legal basis to begin substantial on-the-ground operations, and the license will serve as one strategy to demonstrate permanence related to GHG reductions. Infinite Earth is committed to developing a cutting edge REDD pilot site that provides substantial benefits not only for conservation, but also for the nearby communities and local government. To demonstrate that the project has been designed to meet the highest standards, Infinite Earth plans to validate and verify the Rimba Raya Biodiversity Reserve under the Voluntary Carbon Standard (VCS) and the Climate Community and Biodiversity Standard (CCB).

Central Kalimantan is experiencing one of the highest rates of deforestation in Indonesia (Hansen 2008). Much of the deforestation in the province initially took place on mineral soils since these areas don't require the digging of drainage canals. But in the most recent years, with much of the lowland forest being claimed by oil palm developers, the wave of deforestation has moved into peat areas. This report provides documentation that without the Rimba Raya project intervention, the forest in the project site will be converted in the next few years, releasing massive amounts of GHG emissions.

Infinite Earth contracted Forest Carbon (FC) to conduct the initial desktop study of potential above and belowground carbon stocks in the Rimba Raya project site. After production of that report, Winrock International was contracted to produce a preliminary baseline estimate of the GHG reductions generated from an avoided deforestation project. The methodology that Winrock used to estimate GHG reductions was taken from their work with the Mawas Project, a large peat swamp area also located in Central Kalimantan. This methodology has now gone through the double approval process required by VCS and the Approved VCS Methodology *"VM0004 Version 1.0 Methodology for Conservation Projects that Avoid Planned Land Use Conversion in Peat Swamp Forests"*, Sectoral Scope 14 has been applied in the baseline assessment. Forest Carbon applied this methodology in conducting both field-based and aerial-based surveys to assess the carbon stocks in the project area. Forest Carbon and InfiniteEARTH jointly developed the final GHG baseline calculations.

This report is divided into the following sections: 2. project site description, 3. stratification of the project area, 4. biomass survey and estimation methods, 5. results of field biomass survey, 6. results of aerial biomass survey, 7. project additionality, 8. applicability of the methodology, 9. baseline CO2 emissions estimate, 10. methodological pathways and data parameters, 11. literature cited.

2. PROJECT SITE DESCRIPTION

2.1 Project Location

The project is located in the Seruyan District in Central Kalimantan (Figure 1) and comprises 91,215 ha of logged over peat swamp forest with kerangas (heath) appearing mostly in the southern part. The peat in this area was thought to be shallow, less than one meter deep, but surveys in the field showed that the peat is much deeper, averaging at least 3 meters throughout the survey area.

Figure 1. Rimba Raya Biodiversity Reserve location. Central Kalimantan, Indonesia

2.2 Project Borders

The eastern border of Rimba Raya coincides with the Seruyan River for almost 100 km. Locating the concession borders from TPNP to the Seruyan River includes several habitat types, such as a small amount of lowland Dipterocarp, *kerangas* (health), peat swamp, and riverine forests, which provides a strong conservation rational for the border location.

In 1996, the border of Tanjung Puting National Park (TPNP) was set comprising 396,000ha[1]. Each province and district is required to conduct ten-year spatial plans and the 2003 plan for Central Kalimantan indicated a different, smaller border. The Minister of Forestry agreed to this revision to the border of the Park in 2005[2]. The GIS file for the 2005 TPNP boundary was obtained from government sources and is used in project development and mapping for Rimba Raya, as shown on Rimba Raya Area Verification maps from the Ministry of Forestry.

TPNP harbors a substantial population of Bornean orangutans among other endangered wildlife and the adjacent Rimba Raya area provides additional critical orangutan habitat. Orangutan nests were frequently spotted during the biomass surveys.

In the Rimba Raya concession during the 1980s and 1990s, two timber concessions selectively logged the area, PT BinaSamaktha[3] in the northeast portion and PT MulungBasidi[4] in the southeast and the companies stopped operations in 1998 and 2000, respectively. Since then much of the easily accessed forest has been illegally logged by nearby villagers.

In 2004, five oil palm estates were formally proposed to the Bupati and the Governor that partially occupy the ex-timber concessions adjacent to the Park. All five of these proposed estates have received the initial stage of oil palm permits from the Seruyan Bupati with the northern most estate having been granted the estate license (HGU – Indonesian acronym). The odd notch-shaped northern part of the Project Zone is due to the area being excised because the northern most oil palm estate is now operational.

The Carbon Accounting Area coincides exactly with the borders of the proposed oil palm estates to ensure additionality, except in the north where the Rimba Raya project area was moved to avoid any impacts from drainage canals in the operational palm oil estate. As required by the approved methodology, the Carbon Accounting border was relocated three km south of the estate borders, reducing the Carbon Accounting Area.

[1] Minister of Forestry's SK No. 687/Kpts-II/1996
[2] Minister of Forestry's SK No.292/MENHUT-VII/2005 Tanggal 13 Mei 2005
[3] SK HPH No. 33/KPTS/Um/I/1978 tanggal 8 Januari 1978 seluas ± 50.000 Ha
[4] SK HPH No. 26/KPTS/Um/I/1980 tanggal 14 Januari 1980 seluas ± 98.000 Ha)

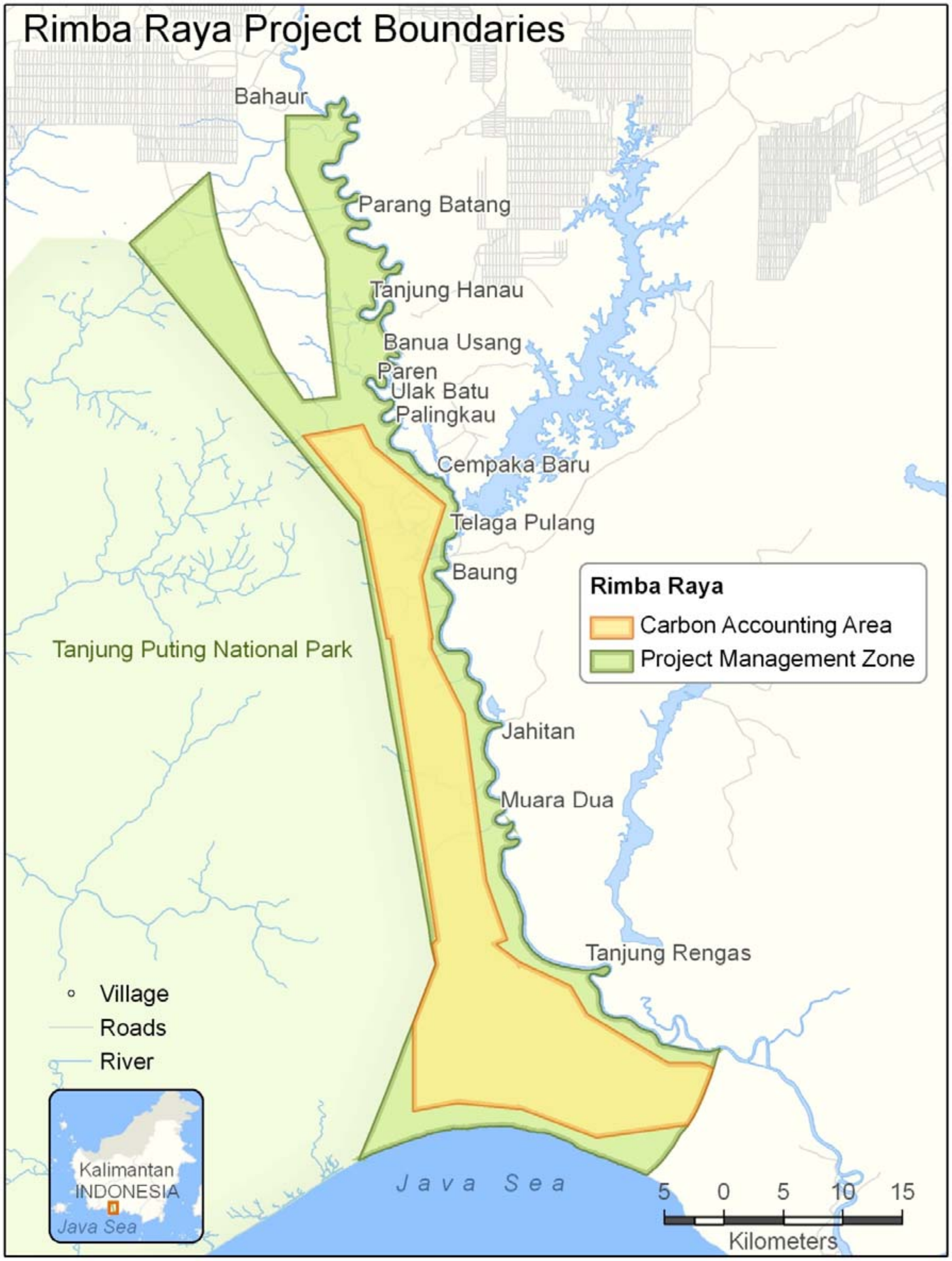


Figure 2. Rimba Raya Project Management Zone and Carbon Accounting Area. Tanjung Puting National Park shown abutting the project's western boundary.

3. STRATIFICATION OF THE CARBON ACCOUNTING AREA

3.1 Stratification by Palm Oil Concession

Two different types of strata were used in the baseline emissions estimate. The first strata is comprised of the proposed borders of the oil palm estates and is important in determining when the area would have been converted under the baseline scenario (industrial oil palm). These boundaries were obtained in GIS format, and overlaid on the project area to stratify the Carbon Accounting Area by concession (Figure 3). The section on additionality provides more detail on the expected conversion process under the baseline scenario.

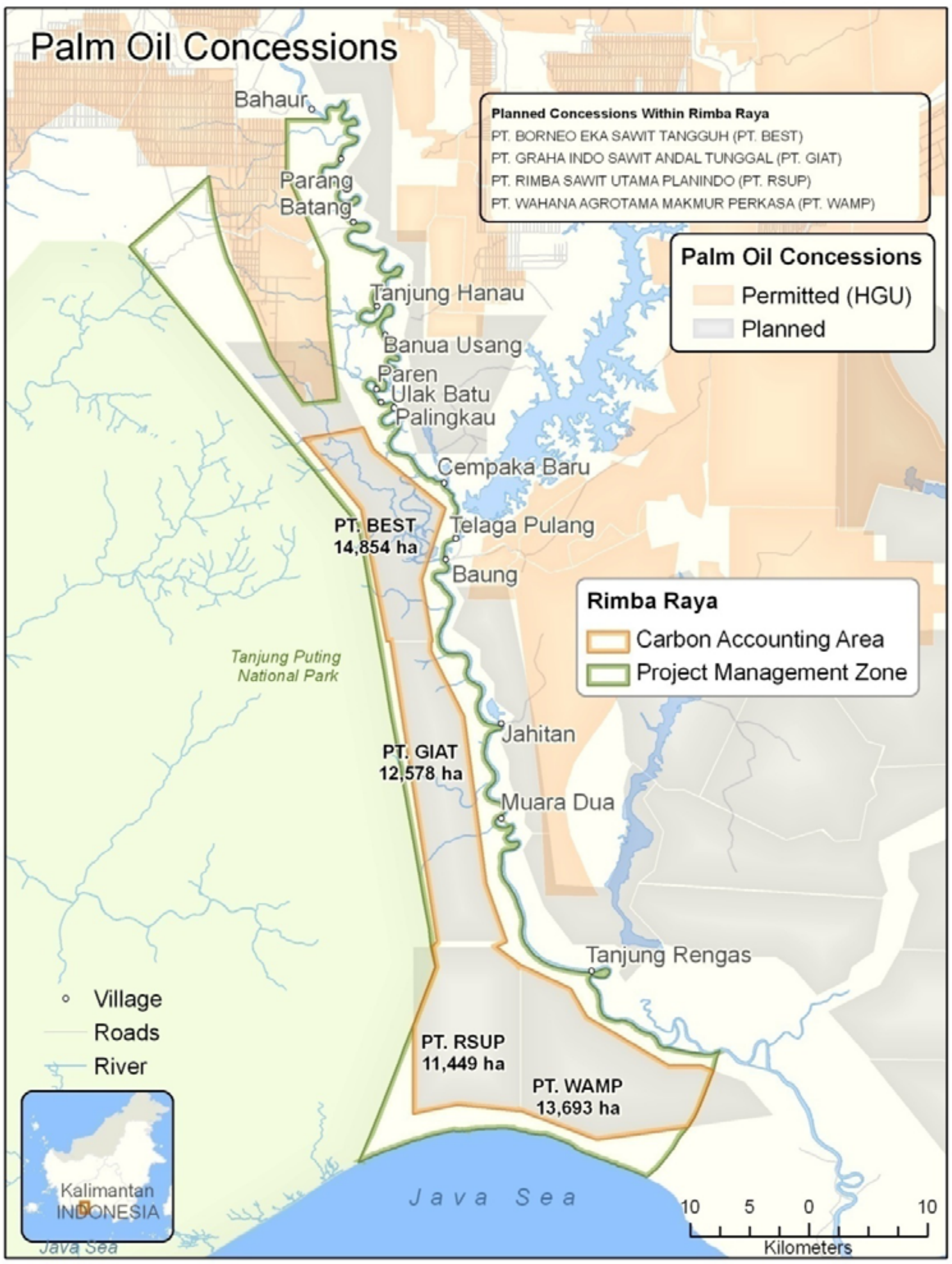


Figure 3. Map indicating borders for the four proposed oil palm estates, used to stratify the project area according to baseline projections.

3.2 Stratification by Landcover Classification

The second strata is comprised of landcover and land use (LCLU) classes. A classification system modified from the Ministry of Forestry (MoF) LCLU classes was used to allow for comparisons with other analyses throughout Indonesia. Several phases of land cover stratification were conducted. The first phase was conducted in January 2009 using LANDSAT 7 and SPOT 5 imagery from 2006 and 2008, and was used to gain a preliminary estimate of baseline emissions. This stratification was refined May 2009 based on ALOS 2008 imagery to plan field surveys.

After the biomass surveys were completed, a post-survey stratification was conducted using 2009 LANDSAT, field data, and aerial photographs. This LC/LU classification provides the benchmark map to detect any changes in carbon stocks from annual monitoring. Methods and results of land cover classification and accuracy assessment are summarized below and described in detail in reports (Annex 1 and Annex 2).

3.2.1 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 classification scheme for Indonesia, but the Ministry of Forestry's LCLU 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 1) expands on the MoF scheme to include more detailed 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.

Since the baseline GHG estimate is restricted to the Carbon Accounting Area, only the LCLU classes found there will be discussed in this report, and are described in the following table.

Table 1. Land cover and land use classes in the Carbon Accounting Area of Rimba Raya

Land Cover Class Name	Description
Peat swamp forest (none to light degradation)	Typically 20 to 25 m tall with small compact tree crowns, dominated by the Sapotaceae and Diptocarpaceae families. This class also denotes that a peat substrate is present. Land use includes virgin to moderately degraded, most typically by logging with canopy cover exceeding 70%. Industrial logging in peat is typically done using a light rail system without roads that causes minimum impact and thus is difficult to distinguish virgin from areas logged more than 10 years ago using medium resolution imagery.
Peat swamp forest (heavily degraded)	Heavily degraded typically due to wildfires in El Nino, drought-prone years. Percent canopy cover from 30% to 70%.
Peat shrubland (deforested)	Deforested peat swamp, usually by severe fires resulting in canopy cover less than 30%. Dense, shrubby and vine infested with scattered trees; seasonally flooded.
Seasonally inundated wetlands	Seasonal lakes, it is thought that most of these areas were formerly peat swamps that have been logged and burned, and continue to be periodically burned, normally by fishermen to keep these areas as grassy lakes. Where these are adjacent to rivers, flooding may be semi-permanent
Kerangas forest	Tropical heath forest on xeric sandy soils, and frequently seen as a transition zone between peat or lowland forest and kerangas scrubland. Similar biomass to degraded peat swamp but species composition dominated by Ericaceae family. Typically found in small patches close to coastal areas.
Open Kerangas Scrub	Open heath scrub forest with little to no leaf litter and exposed sand. Highly xeric soils dominated by the Ericaceae family and tree statue commonly not exceeding 10 m. These areas may have been kerangas forests that have burned or on very deep sands with little to no fertility. Bright white sand may be apparent on imagery and originated from shifting beach areas thousands of years ago.
Bare soil to low, sparse vegetation (deforested)	Typically caused by shifting agriculture and found along rivers, in areas being cleared for agriculture or other areas of burning.

3.2.2 Satellite Image Analysis

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 classification, which produced a more accurate map than could have been obtained from a fully-automated process.

3.2.3 Image Interpretation and Attributing

An ArcMap edit session was used to display vector and raster spatial data and create the 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 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 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.

3.2.4 Map Edits and Validation

Because the LANDSAT 2003 image was very clear without the image gaps found in later imagery, it was used to create the original LCLU map. The final version of the 2003 map was then copied to a new 2009 file. This map was displayed with 2009Landsat imagery with the data gaps filled in using other 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. 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 map.

The second complete pass of the entire classified map using 2009 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, and all polygons less than six 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, less than 2 ha in size were merged with larger surrounding 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.

3.2.5 LULC Map Accuracy Assessment

A landcover accuracy assessment was conducted of 2009 land cover classification for the Rimba Raya Project Management Zone and Carbon Accounting Area (See Annex 2). Map accuracy was quantified based on comparing the satellite image-based landcover map to reference data from aerial photos flown July

2009. Aerial survey flight lines cover approximately 40% of the Rimba Raya Project Management Zone and all major landcover classes were represented in the aerial photos. Lowland forest classes, representing 5.9% of the total Project Management Zone, were not represented by aerial photos. All classes in the Carbon Accounting Area were represented in the aerial photo reference data. A total of 342 sample points were used for the accuracy assessment.

Allocation of sample points to land cover classes was through stratified random sampling based on land cover class area, with a 20-sample minimum for the smallest classes where reference data were available. Reference labels containing the land cover class name interpreted from aerial photos were created for sample points. An initial set of 250 reference labels was created by an independent GIS analyst familiar with ground conditions and map interpretation in peat swamp forest. Map labels for the sample points were compared with reference labels and an error (confusion) matrix generated.

An overall classification accuracy of 81.3% was obtained. The predominant class by area, lightly degraded peat swamp forest which covers 30,445 ha or 33.5% of Rimba Raya, was mapped with **90.0% accuracy**. A weighted kappa coefficient of 0.78 indicated there is good agreement between map classes interpreted from satellite imagery and aerial photo data.

3.3 Results: Landcover/Land use Stratification

The resulting land use / land cover map for Rimba Raya (Figure 4) shows the same delineations of major forest blocks compared to MoF and previous project mapping efforts, but the borders have been better defined and kerangas classes added. Table 2 provides a summary of area (ha) in each LCLU class by proposed oil palm estate. This information was used to estimate the GHG emissions baseline described later in this report.

Table 2. Landcover and land use classes post-survey by proposed oil palm estate.

Landcover/Land Use Classes	**PT. BORNEO EKA SAWIT TANGGUH (ha)**	**PT. GRAHA INDO SAWIT ANDAL TUNGGAL (ha)**	**PT. RIMBA SAWIT UTAMA PLANINDO (ha)**	**PT. WAHANA AGROTAMA MAKMUR PERKASA (ha)**	**Total (ha)**
Peat Swamp Forest (lightly degraded)	5,718	8,302	97	4,911	**19,028**
Peat Swamp Forest Degraded (highly)	427	97	27	1,183	**1,734**
Peat Shrubland (<20% Tree Cover)	314	3,265	3,104	5,464	**12,147**
Kerangas Forest	142	0	4,494	174	**4,810**
Kerangas Open Scrub	774	328	3,959	368	**5,429**
Low, sparse vegetation cover	944	33	0	365	**1,342**
Seasonally Inundated Wetlands	924	552	0	1,228	**2,704**
Open Water	43				**43**
Grand Total	**9,286**	**12,577**	**11,681**	**13,693**	**47,237**

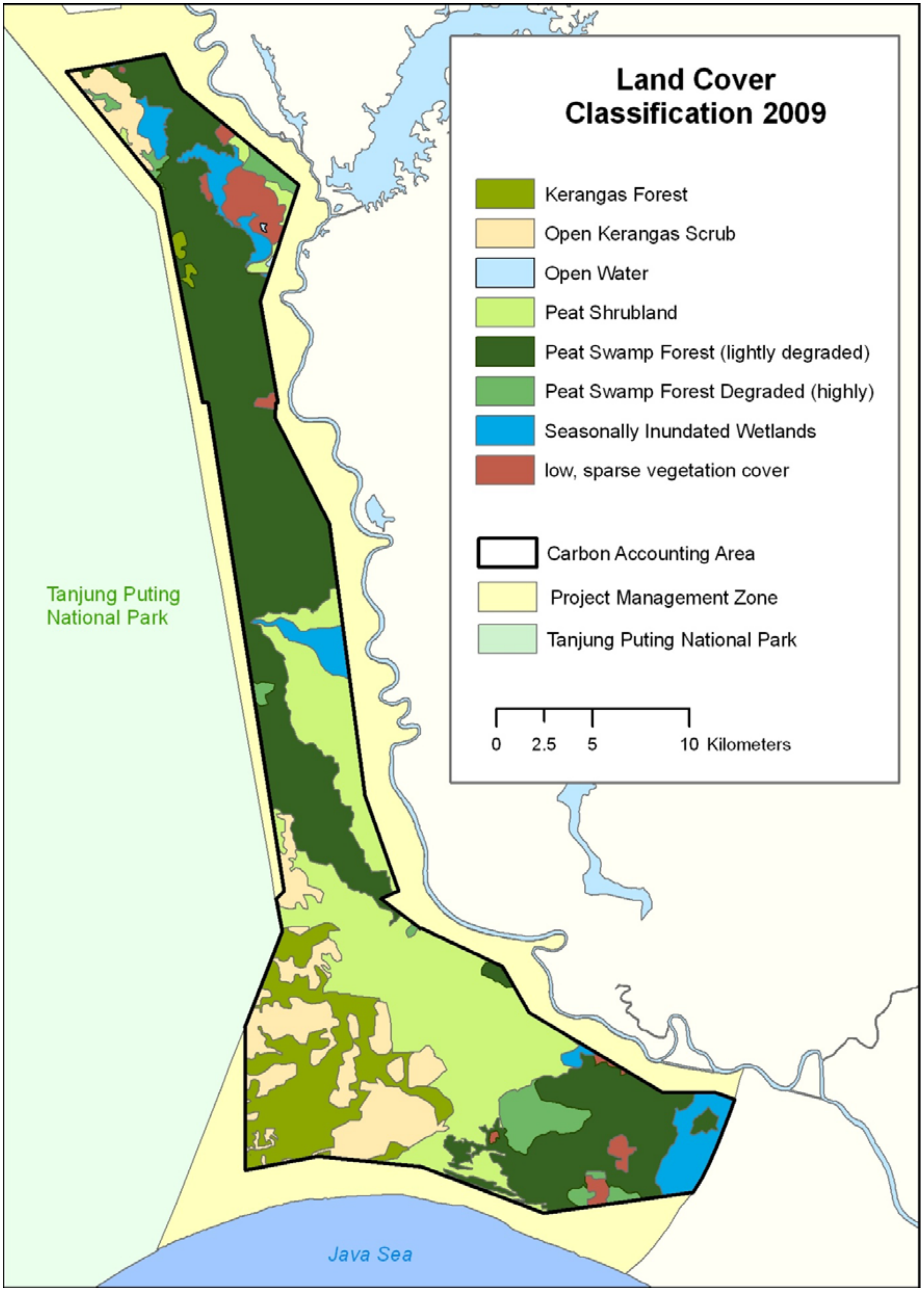


Figure 4. Map of Land cover/land use classes in Rimba Raya used to stratify the project area

4. BIOMASS SURVEY AND ESTIMATION METHODS

Biomass surveys were conducted in two phases. An aerial survey collected low altitude, high resolution, digital photographs across Rimba Raya focusing on the Carbon Accounting Area. The aerial survey data represents the primary data set used to estimate aboveground biomass from analysis of tree crown diameters in randomly distributed aerial plots across all land cover types. A field-based survey was conducted to validate aboveground biomass estimation models and sample peat depth in systematically placed transects in peat swamp forest. The field-based methods and results are presented first here to provide background on the approach and project conditions followed by the aerial image methods of tree biomass estimation.

4.1 Carbon Pools

Of the available carbon pools making up total biomass in Rimba Raya, significant pools consist of belowground peat layers, and aboveground biomass contained in live trees above 10 cm DBH. The methodology excludes belowground biomass since this is contained in the peat component of carbon accounting. The methodology also excludes litter, dead wood and herbaceous vegetation as these carbon pools have been found in other studies to comprise an insignificant amount of total emissions (<5%) according to A/R CDM project guidelines.

“Tool for testing significance of GHG emissions in A/R CDM project activities”

“The sum of decreases in carbon pools and increases in emissions that may be neglected shall be less than 5% of the total decreases in carbon pools and increases in emissions, or less than 5% of net anthropogenic removals by sinks, whichever is lower.”

The same tool used by the Methodology “Tool for testing significance of GHG emissions in A/R CDM project activities” was used to test for significance of the non-tree biomass carbon pool in Rimba Raya which is comprised of understory growth of woody vegetation. Non-tree biomass was surveyed in 150 small plots and found to contribute an insignificant amount to total above ground biomass (3.72 – 5.60%), representing <0.5% of GHG emissions. These data are presented in the field biomass survey section.

Carbon pools included in carbon accounting are: peat, above ground tree biomass (including palm oil tree biomass) and wood products (see Methodology Table A).

4.2 Field Survey Methods

4.2.1 Field Planning

To plan the survey, the original landcover/land use analysis was used and is shown in Figure 5. From this map (and subsequent versions of the land cover stratification) the majority of Rimba Raya was determined to be light to moderately degraded **peat swamp, which accounts for >96% of all emissions (primarily from belowground biomass).** Therefore, the decision was made to focus exclusively on this LCLU class in the field survey.

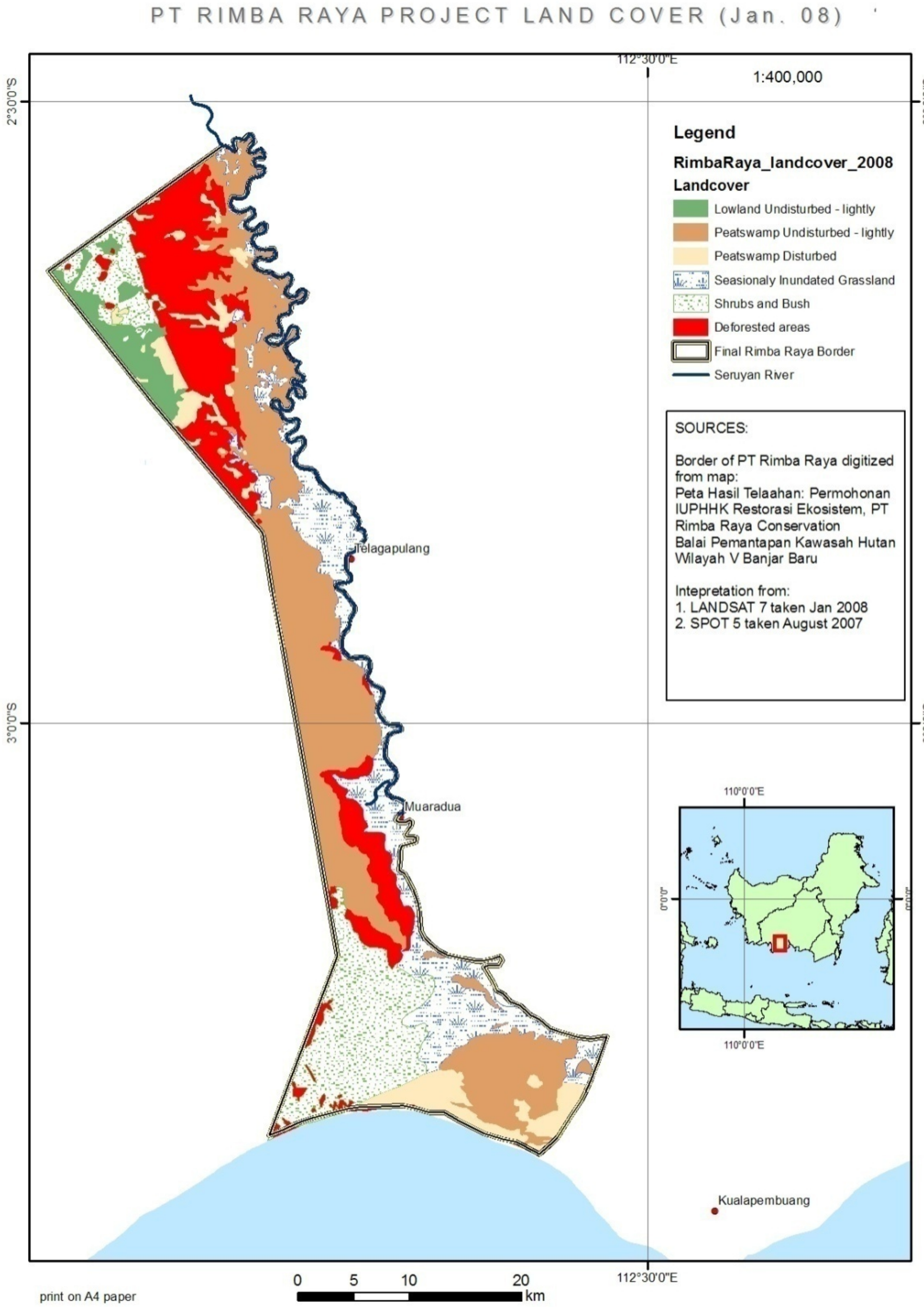


Figure 5. Original landcover/land use map for Rimba Raya used to plan field surveys

4.2.2 Objectives of the Field Survey

The primary purpose of the ground survey was to assess peat depth in Rimba Raya, and provide ground-truthing for an aerial image-based tree biomass assessment. The field survey had the following objectives:

1. Survey peat depth for use in belowground biomass estimation
2. Gain an idea by strata of the variation in tree biomass and use this to compute a coefficient of variation for the aerial survey assuming a 10% sample error with a 90% CI.
3. Gather data on tree canopy diameter and DBH throughout a range of diameters and crown illumination classes, to provide data for allometric models of tree biomass estimation and to calibrate aerial image-based tree biomass estimates.

4.2.3 Survey Methods and Field Protocols

Procedures and protocols were written for the biomass survey, and are presented in the Carbon Survey Assessment reports and Carbon Survey SOP (See Annex 3). A description of the approach is reported here for the following aspects of the survey:

- Plot size
- Plot shape
- Nested plot design
- Sample scheme
- Sample intensity
- Tree measurements
- Peat measurements
- Data Quality Control

4.2.4 Plot Size

Most references on forest sampling link plot size with tree density – as density increases plot size should decrease. Equally important is that increasing the plot size decreases inter-plot variability (Freese, 1962), and can be mathematically shown as:

$$CV_2^2 = CV_1^2 \cdot \sqrt{\frac{AP_1}{AP_2}} \qquad (1)$$

where:
CV^2_2 = coefficient of variation for plot size 2
CV^2_1 = coefficient of variation for plot size 1
AP_1 = area of plot size 1
AP_2 = area of plot size 2

Considering that a large portion of the biomass is found in a few dominant trees, and that these large trees are sparsely distributed, a sample design with larger area plots should more effectively capture the variation present in the population. This was shown to be true in a biomass study in the Amazon where plots 1000 m^2 or smaller had at least a 75% chance of being outside the CI of the global mean (Brown, Wayt Thomas, Moreira, C., & Victoria, 1995). In addition, the same study showed that the Coefficient of Variation dropped from 14% for 2000m^2 plots to 4% for 2500m^2 plots.

Furthermore, fewer large plots have the advantage of being more efficient to survey, especially in extenisve forest that is difficult to access. Utilizing many small plots would require the survey team to spend an excessive amount of time traveling from one plot to the next, which is especially true in peat swamps, which are difficult to traverse.

Lastly, patterns of logging will greatly affect the biomass distribution and increase the population variance for biomass. Therefore large plots are needed to capture potential heterogeneity in biomass due to logging. Given the above reasons, a plot size of 2,500m^2 was chosen.

4.2.5 Plot Shape

In the abovementioned study by Brown et al (1995), the authors recommend rectangular plots or transects over square or circular plots since rectangular plots increase the linear distance over which trees are sampled. Rectangular plots tend to include more of the within-plot heterogeneity, and thus provide a more representative sample than square or circular plots of the same area. Linear plots or transects also allow more information to be recorded about the forest site since the team is taking notes while traversing the forest. Additionally transects are more efficient, taking less time than square plots to measure. For transects, in most cases, plot corners do not have to be marked, but rather only the distance of borderline trees measured from the transect centerline.

Some practitioners have recommended circular plots (MacDicken, 1997), but given the chosen plot size of 2,500m^2 a circular plot would have a diameter of 56m, which would be exceptionally difficult to determine whether to include trees near the plot border. The disadvantage of being able to accurately and repeatedly measure horizontal distances to 50 meters is more problematic in the hummocked terrain of peat swamps where the likelihood of calling an 'out' tree 'in' or vice versa is increased thereby greatly biasing the sample.

Given the advantages of using long, rectangular plots, plot dimensions of 250m x 10m were chosen to make efficient use of a transect line-based field survey. The disadvantage of long transects is that the ratio of edge to area is greater than square or circular plots; thus, increasing the likelihood of encountering border-line trees, which could introduce substantial error in the biomass estimates. An additional disadvantage is that long linear plots increase the likelihood of including two separate forest types. To reduce these disadvantages first, all border-line trees were measured using a Leica laser range finder with the measurer standing on the transect center line, perpendicular to the measured tree. Second, plots were entirely located within a single strata based on satellite image analysis and plot length was restricted to 250meters by 10meters – totaling 2,500m^2 or ¼ hectare.

4.2.6 Nested Plot Design

An appropriate sample design should place more emphasis on measuring the carbon pools that contain the highest biomass and are most subject to change through anthropological disturbance. Trees make up the majority of the aboveground biomass in lowland forest and within this carbon pool, large trees account for the bulk of the biomass per unit area. In a study in the Amazon, the largest trees, equaling only 3% of the total abundance, contained 50% of the aboveground biomass (Brown, Wayt Thomas, Moreira, C., & Victoria, 1995). To account for this skewed distribution in biomass, more resources and time should be focused on sampling larger trees, which was accomplished through a nested plot design, where larger trees were measured across the entire plot (250 x 10 m) and smaller trees were measured in two nested subplots (20 x 10m) at the ends of each plot (Figure 6.)

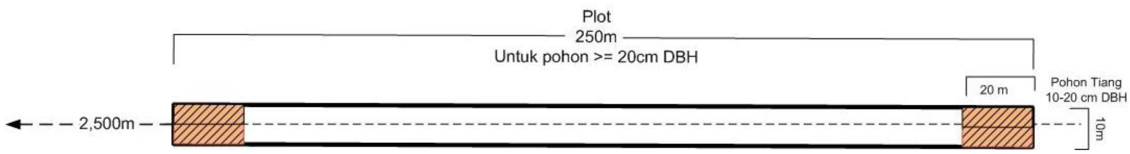


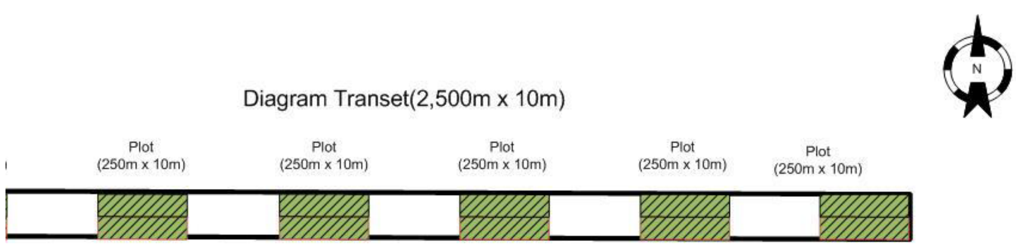
Figure 6. Schematic of one plot 250m x 10m that includes two nested subplots each of 20m x 10m for smaller trees 10-19.9cm DBH.

4.2.7 Sample Scheme (plot placement)

The Seruyan River forms the eastern boundary of the proposed Rimba Raya concession and the area is mostly peat swamp. It is hypothesized that peat depth is determined by the distance away from the primary drainage source and that large differences in peat depth may have an effect on aboveground tree biomass. Therefore, positioning transects that run perpendicular (east-west) to the river, so that they traverse any elevational gradient, should best capture the variation in biomass within one stratum. This should have the added benefit of capturing the greatest variation in peat depth.

A stratified systematic sampling scheme with a **random start** was applied. Systematic placement of plots offers various advantages and is the recommended method under the IPCC guidelines. The sampling scheme was designed to place plots systematically along a 2.5 km transect in order to accommodate 5 plots spaced 250 m apart (Figure 7). The transect length is designed to maximize efficiency in hard to access areas and provides a systematic method to measure peat depth across large areas.

Figure 7. Schematic of biomass transect with alternating plots every 500m shown in green.



4.2.8 Sample intensity

Based on experience inventorying peat swamps for timber volumes, a decision was made to install 6 transects, each with 5 plots that would provide a total of 30 plots spread north to south. In the field, forest extent limited two transects T1 and T2 to 4 plots each. A second carbon survey was conducted to add two transects, each with 4 plots. In total 8 transects and 36 biomass plots were surveyed (Figure 8).

An emphasis was placed on locating field biomass plots in unlogged to lightly degraded peat swamp forest since that class comprises the majority of the Carbon Accounting Area. Overlaying survey transects on LCLU classes confirms they are located in the lightly degraded peat swamp class (Figure 9).

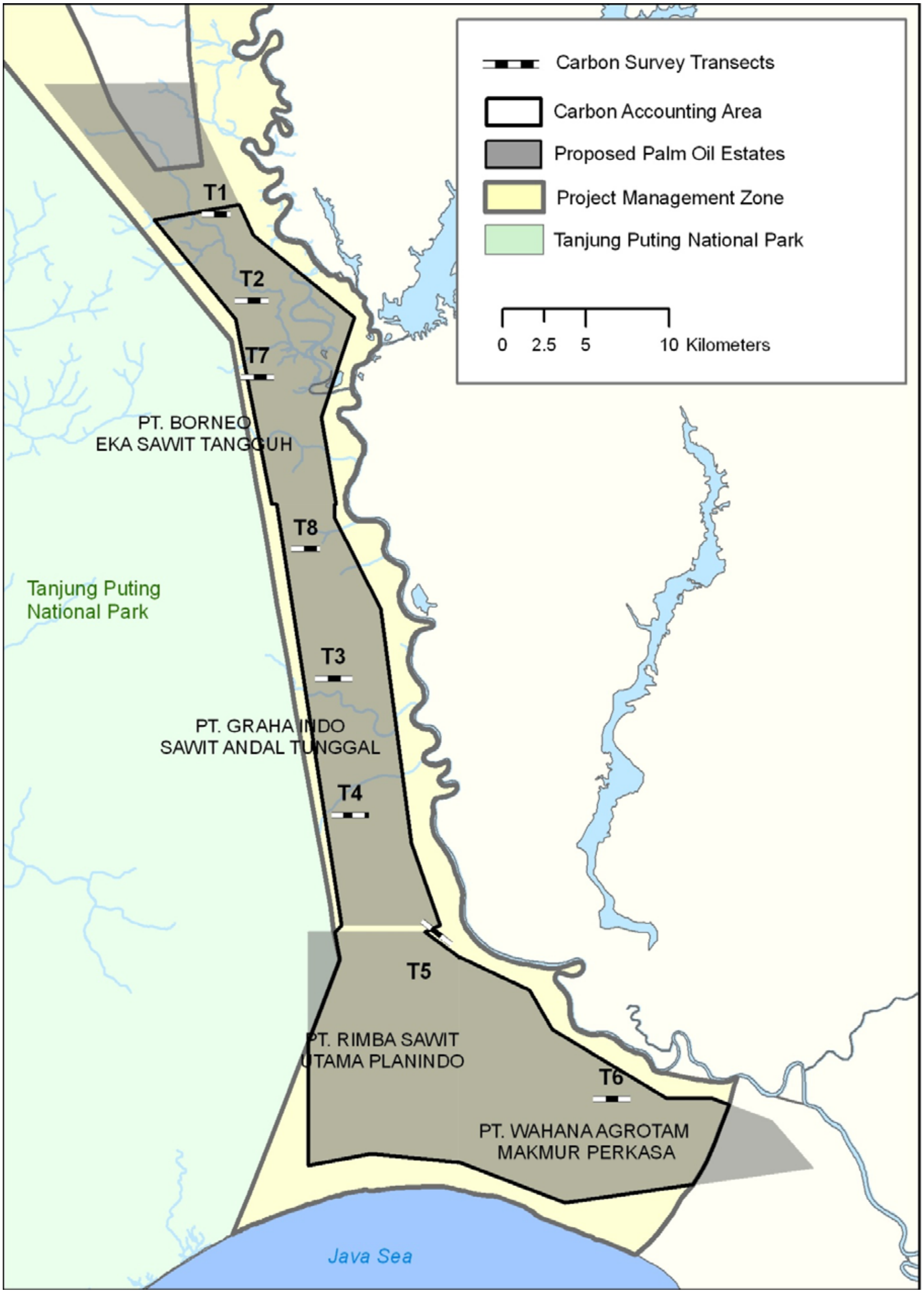


Figure 8. Map of Rimba Raya indicating transect locations. Transects numbered T1 – T6 were surveyed July 2009. Transects T7-T8 were added to the Carbon Assessment Survey September 2009.

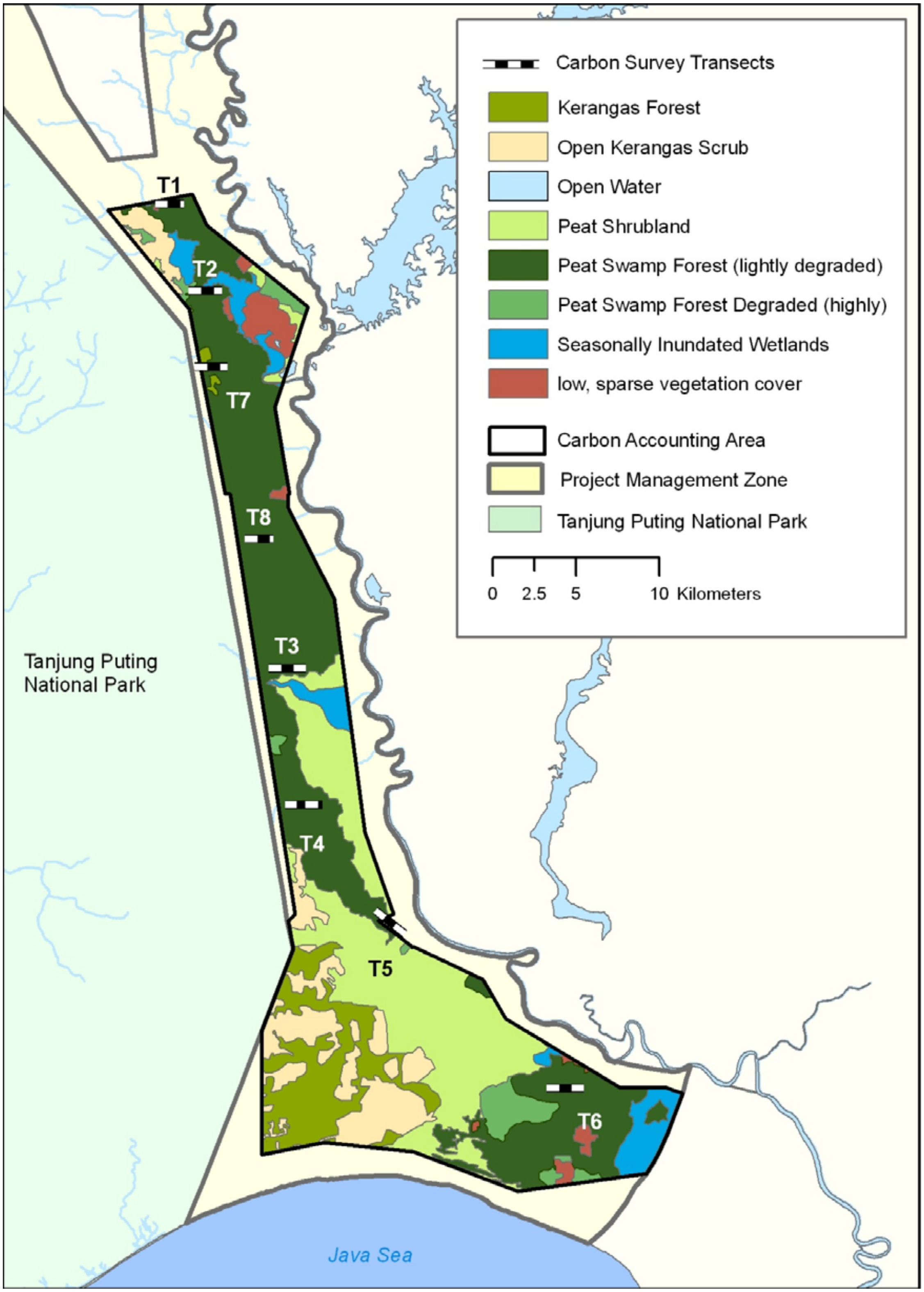


Figure 9. Location of survey transects (T1 – T8) across all forest blocks of peat swamp forest in the Carbon Accounting Area.

4.2.9 Tree Measurements

Tree measurements were recorded in five 50x10m subplots to manage workflow across 250 x 10 meter plots. Nested subplots 20 x 10m were used to record smaller tree data at plot ends. The transect centerline and 10 meter marks were used to define subplot boundaries. A laser range finder was used to determine exact distances from transect centerline to determine whether to include borderline trees in the survey. Tree diameter and the local tree name was recorded for all trees ≥ 20 cm DBH in 50x10m plots (the entire 2500m2 plot) and for all trees ≥ 10 cm DBH in 20x10m subplots.

Within each subplot, two trees were selected for which additional measurements including tree height, crown dimensions and canopy class. Crown dimension was measured at the broadest radius and the radius perpendicular to the first measurement (Figure 10) using a laser range finder and clinometer to record distance from canopy edge to the tree stem. Tree height data were collected by measuring observer distance and angle to the tree, also using a laser range finder and clinometer. Canopy class was visually estimated where class 5 was assigned to an understory tree receiving no direct sunlight and class 1 was assigned to a canopy emergent receiving full sunlight (Figure 7). The sketches below were printed on the tally sheets to aid tree crown data collection. The Field SOP (Annex 3) details survey procedures and describes equipment used.

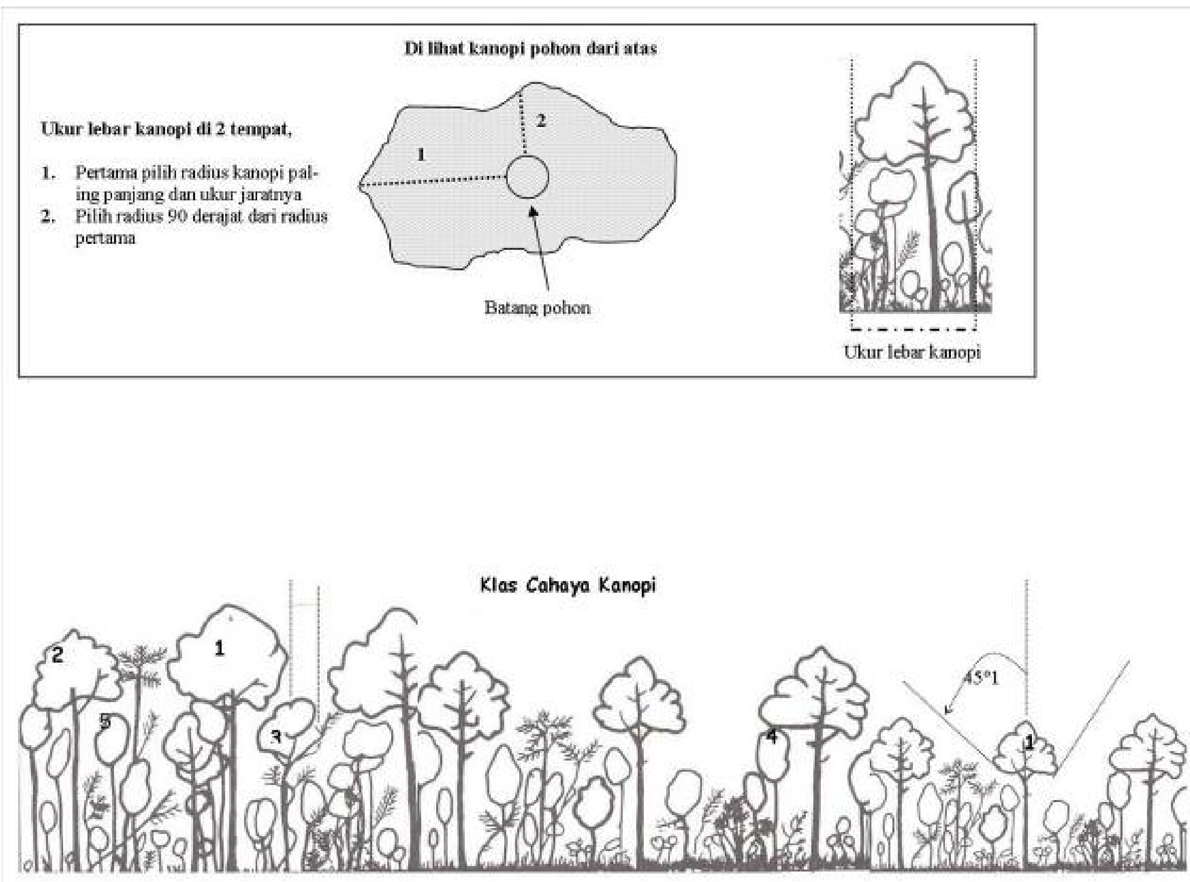


Figure 10. Crown canopy measurement diagrams

4.2.10 Peat Depth Measurements

Every 100 meters along the transect peat depth was measured and recorded using a peat probe. The peat probes were constructed in 1-meter sections with a total length of 5 meters. (A 6-meter peat probe was constructed and used on Transects T7 and T8 after learning that moderately deep peats encountered on T1-T6 routinely exceeded the reach of the 5-meter peat probe.) Since six transects were planned and each transect could have a maximum of 25 points assuming that peat was encountered throughout the transect; therefore, 150 total measurement points would be the theoretical maximum.

The purpose for these measurements was to test whether the average peat depth is over 1 meter throughout the survey area since the methodology is based on a minimum depth of one meter. The purpose was not to construct a peat depth map, which would require numerous transects within one km of each other.

4.2.11 Data Quality Control

Once the team returned from the field, the data sheets were photocopied with the originals being stored in Forest Carbon's office and the photocopies kept at the OFI office in Pangkalan Bun. The data sheets were inputted into MS Excel that used validity checks in the columns that would not accept spurious data (e.g. DBH of 423cm). A 1% random sample of the data entry rows was cross-checked by a person different that the original data enterer to test the accuracy of data entry.

In quality control, one week of hands-on training was conducted in the field for the two teams. The training entailed use of Suunto clinometer, laser rangefinder, diameter tapes, and measuring horizontal distance. Additional training was provided for the note takers on correct manner to complete the tally sheets. Table 3. provides details on the acceptable error designed into the training.

Table 3. Acceptable measurement errors in forest sampling (Peterson, 1982)

Measurement	Allowable error
Tie lines	
Bearing	$\pm 2^{o}$ of the true bearing
Distance	$\pm 2^{o}$ of the true horizontal distance
Permanent plots	
Missed or extra trees	No error within the plot
Tree species or groups	No error
Breast height	± 5 cm of the true height (1.3 m)
D.B.H.	± 0.1 cm or 1% whichever is greater
Circular plot radius	±1% of horizontal

4.3 Field-Based Tree Biomass Estimation (AIM Step 1)

Tree biomass was estimated using the Aerial Image Method (AIM) described in the methodology. In AIM Step 1, tree biomass was estimated using the allometric equation method that relates DBH or DBH and Tree Height to biomass. Site and/or species-specific allometric equations can be developed through destructive sampling or appropriate published allometric equations can be applied. Destructive sampling requires a large investment in resources and time, along with a license to cut the trees, and was out of the scope of this project. Therefore published allometric equations were applied.

4.3.1 Allometric Equations for Biomass Estimation

Commonly published allometric equations vary around the basic formula:

$$B\ (kg per tree) = aD^b \qquad (2)$$

where:
B = biomass,
D = diameter in cm (DBH),
and a and b are parameters

In a biomass study of secondary forest in Sumatra (Ketterings et al. 2001) suggested that using the relationship between diameter and height at each site would be a way to generate a more precise model that incorporates site-specific differences. These authors also suggest that incorporating wood density can further improve the model, since this may vary substantially by species and site:

$$B\ (\text{kg per tree}) = r\rho D^{c+2} \qquad (3)$$

Where: *p* is the wood density using a weighted average for all species in the strata, weighting based on abundance of the species and percent basal area it occupies[5].

Ketterings et al. (2001) tested their model versus models used in commonly cited studies with the results shown in Figure 11.

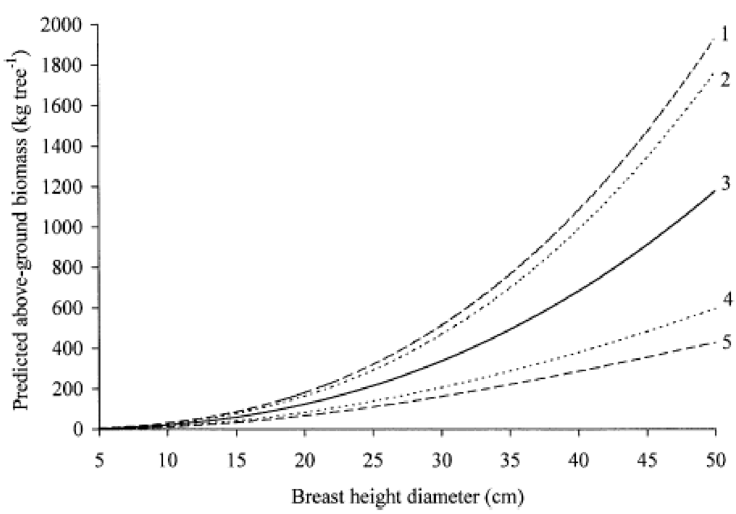


Figure 11. Graph illustrating model variance (expressed as predicted value +/- the standard deviation of the model error) introduced when assuming a wood density of 0.71 kg dm^{-3} shown in (1 & 5) and a density of 0.60kg dm^{-3} (2 & 4) compared to the Ketterings et al model (3).

[5] ICRAF database for 2,500 species http://www.worldagroforestry.org/sea/Products/AFDbases/WD/Index.htm)

This parameterized equation for secondary forest in Sumatra was found to overpredict biomass in Rimba Raya, and its more generalized form cannot easily be specified for Rimba Raya which is more diverse than secondary forest, and for which many taxa are only identified to genus. Therefore a more general allometric equation is needed.

Chave et al (2005) use an extensive tropical dataset to test the generality of simple allometric models for biomass estimation since it is often impossible to independently build or quality test site-specific models. These authors published one of the most comprehensive articles on assessing the quality and robustness of regression formulas for estimating biomass across several continents. They found that the most important predictors of AGB were in decreasing order of importance, DBH, wood specific gravity, total height and Holdrege Life Zones (dry, moist, and wet forest). Chave et al (2005) suggest that high species diversity in the tropics precludes using species-specific regression models used in simpler systems, most often in the temperate zone. Instead, these authors suggest mixed species regression models are more appropriate. One of the salient points from their study was that including continent or region into the equations did not improve the quality of the fit; thus, we assumed that equations developed in the neotropics could be used in Kalimantan.

4.3.2 Biomass Equations Applied

Chave et al. (2005) derived the following regression formulas (exp read as *e* to the power of) for tropical moist forest based on tree diameter (D):

$$AGB = \rho \times \exp\left(-1.499 + 2.148 \ln(D) + 0.207 (\ln D)^2 - 0.0281 (\ln D)^3\right) \quad (4)$$

and tree diameter (D) and tree height (H)

$$\langle AGB \rangle_{est} = \exp\left(-2.977 + \ln\left(\rho D^2 H\right)\right) \equiv 0.0509 \times \rho D^2 H \quad (5)$$

Note that some authors found that including tree height in the biomass equations did not significantly improve the fit of the model (Ketterings, Coe, van Noordwijk, Ambagau, & Palm, 2001), while others showed that height did improved the predictive power of the model (Chave, Andalo, Brown, Cairns, Chambers, & Fromard, 2005). From a practical standpoint, accurately measuring tree heights in dense forest can be difficult; thus, the measurement error could outweigh the gain in predictive power of including height data.

Another widely used allometric equation used for tree biomass estimation in the tropics is the general tropical moist biomass equation (Brown 1997) based on DBH:

$$AGB = \exp(-2.289+2.649*\ln(dbh)-0.021*(\ln(dbh)_2)) \quad (6)$$

These three biomass equations, represented as [Chave D], [Chave DH] and [Brown D] in allometric models were calculated to estimate tree biomass from ground plot data.

4.4 Allometric Equations Linking Ground and Aerial Biomass Estimation (AIM Step 2)

4.4.1 Background

Various studies have shown that aerial assessments of aboveground carbon stocks are possible (Drake, et al., 2003)(Gibbs, S., O Niles, & Foley, 2007), but should be tied to ground surveys to provide validation. Since the 1960s, aerial photography has been used to assess timber potential in lowland tropical forests. Dawkins (1962) showed that there was a strong linear relationship between crown and bole diameters for 17 tropical species that could be expressed by the following linear regression equation:

$$crowndiameter\ (CD) = a + b * DBH \tag{7}$$

Other studies have confirmed that a linear relationship in tree dimensions exists for many tropical species in different locations (e.g. O'Brien et al. 1995, Basuki et al. 2009, Foli et al. 2002). Foli et al (2002) examined bole to crown relationships in five tropical tree species in Ghana and regression model developed for all species explained 77% of the variation in crown diameter eq. (5].

$$CD = 0.829 + 0.168 * DBH \tag{8}$$

But the variability in species allometries across diverse tropical forest, limit the application of these models to image-derived tree crowns. Palace, Keller, Asner, Hagen, & Braswell (2008) note that most work on estimating biomass from remotely sensed imagery has focused on temperate and boreal forests and plantations, with a strong bias toward less diverse systems and those with relatively geometric tree crowns. This likely explains the weaker allometric relationships observed in more structurally complex and compositionally diverse tropical forest stands. Palace et al. (2008) developed a relationship (R^2 = 0.57) between crown width (m) and DBH (cm) from 300 trees:

DBH = 0.0381 x (crown width)2 + 2.33 x (crown width) + 15.5 (9)

The Methodology was based on techniques developed for oak-pine savanna in Belize with 10% forest cover where geometric oak canopies with well-studied allometric relationships could be easily differentiated (see Brown et al. 2005). While theoretically applicable to tropical forest, these methods are not likely to perform as well. The Brown et al. (2005) methods were not successful in a follow-on study in tropical forest in Puerto Rico, but similar methods were successfully employed by and extended in a neotropical site by Broadbent et al. (2008). These authors developed 216 allometric equations between forest structural variables, with the most explanatory relationships between DBH and crown area (R2 = 0.66 for all trees and R2 = 0.73 for emergent trees).

4.4.2 Advantages of Aerial Methods

Despite the limitations of applying aerial image methods for carbon stock assessment in tropical forest, the advantage is that low-altitude high resolution aerial imagery provides a detailed, top-down and synoptic view of all landcover types, which is especially important across remote and inaccessible areas (Brown et al 2005). This enables tree data to be collected across a statistically significant stratified random sample of large (1km2) plots, which has been carried out in AIM steps 3-6 for the project, and enables comparisons of tree stem density, tree crown size and inferences about relative biomass to be made across landcover types.

4.4.3 Site-specific Models for Rimba Raya

For Rimba Raya, allometric models were developed to relate tree biomass (TB) to some combination of Tree Height (H) and/or Tree Crown Area (A) from ground plot data. Using collected data, all equation types were tested. Tree height was not used as a predictor in allometric models where the response variable, biomass was also based on tree height to avoid redundancy in the regression models.

The 7 models tested (n=340) are listed below:

1. TB [Chave D] = f(H)
2. TB [Brown D] = f(H)
3. TB [Chave D] = f(A)
4. TB [Chave D-H] = f(A)
5. TB [Brown D] = f(A)
6. TB [Chave D] = f(A*H)
7. TB [Brown D] = f(A*H)

4.5 Aerial Survey and Biomass Estimation Methods

4.5.1 Aerial Data Collection

Forest Carbon has developed an airborne digital camera system that provides high resolution imagery and utilizes unique self-leveling camera housings. Normally, the roll and pitch of the airplane introduces error in geo-referencing the aerial photos since the lens isn't exactly perpendicular to the ground. Frequently, to correct for this error a series of ground control points (landmarks that can be seen from the aerial photos) are located in the field, recording latitude, longitude, and elevation and then the photos are ortho-rectified based on the control points. However, in extensive remote forest areas, especially in peat swamps where roads are absent, this method can be problematic.

Forest Carbon decided on a different method whereby the camera housing is maintained perpendicular to the ground using an infrared sensor that detects minute temperature differences between the horizon and earth and automatically levels the camera housing using servo motors (Figure 12).

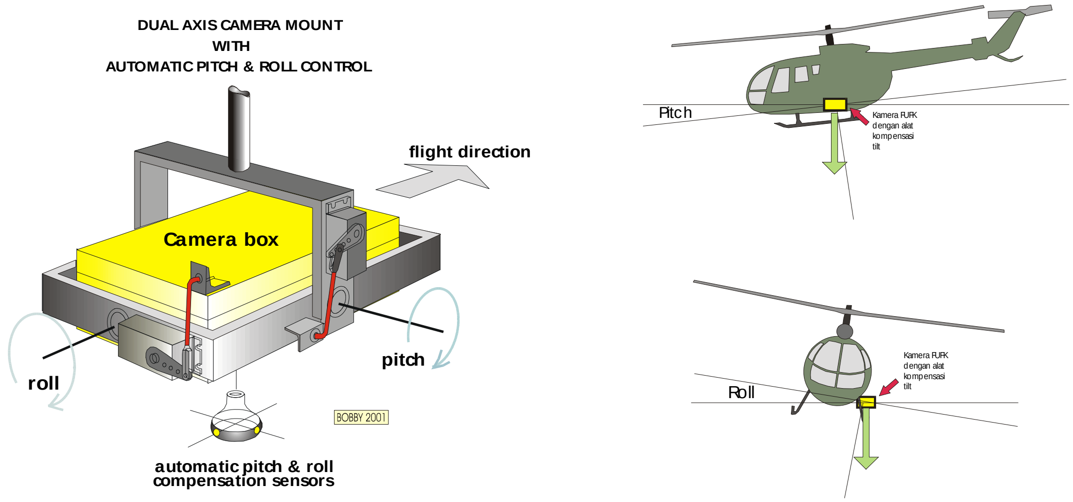


Figure 12. Schematic of automatic system to control for error associated with plane roll and pitch. On right, photograph of Forest Carbon airplane used in aerial survey.

Forest Carbon utilized a CT2K Flight Design aircraft that it owns and operates and flew at 3,200 ft elevation. This altitude is a good compromise between sufficient image resolution and efficiency of area coverage.

A Nikon D700 full format camera with a Zeis lens connected to a GPS and laptop were used to record the photographs, and each high-resolution image was directly stored in the laptop computer with its geographic coordinates.

4.5.2 Ortho-rectification of Aerial Photos

A Garmin 60CSX GPS with built-in barometer was used to record the GPS points directly into the Nikon camera's EXIF file. The barometer was calibrated at the Pangkalanbun airport and elevation above mean sea level (a.m.s.l.) was also directly recorded on each photo's EXIF file. Using the 90m resolution SRTM data a digital elevation model was created for the survey area. For each photo, the elevation of the ground from the DEM was subtracted from the plane's elevation (a.m.s.l.) to obtain the elevation above ground. It has been shown that the average vertical error in the SRTM data is approximately 5m (16.4ft) which equates to less than 1% vertical error if flying at 2,000ft[6].

4.5.3 Establishing virtual plots (AIM Step 3)

Once ortho-rectification took place, the photos were projected in ARCGIS 9.2 at a scale of 1:1,000 and one-hectare square digital plots were systematically installed at the center of each photo to minimize any effects from lens distortion. Photos with high cloud cover were not used in the assessment.

Ground survey data were used to develop the sampling scheme for aerial plots. The overall objective of sampling is to gain a robust estimate of the true mean of the population of interest, and in this case, tree biomass; and to do this some information is necessary about the population variance (the spread of the

[6] http://srtm.csi.cgiar.org/SRTMdataProcessingMethodology.asp

population about its mean). Information about the variance can either be obtained from published studies of similar forest or by conducting a pilot study first. No published biomass studies have been found in similar forest to Rimba Raya. Therefore, the ground-based biomass assessment served as a pilot study to gain an idea of population variance in tree biomass. Following data analysis, CV was calculated and input into the following equations (Loetsch & Haller, 1964) in order to estimate sample size of aerial plots.

$$n = \left(\frac{t_{st}}{E}\right)^2 \left[\sum_{i=1}^{m_p} W_i \cdot S_i \cdot \sqrt{C_i}\right] \cdot \left[\sum_{i=1}^{m_p} W_i \cdot S_i / \sqrt{C_i} \cdot\right]$$

$$n_i = n \cdot \frac{W_i \cdot S_i / \sqrt{C_i}}{\sum_{i=1}^{m_p} W_i \cdot S_i / \sqrt{C_i}} \tag{10}$$

Where:

i	=	1, 2, 3, … L *LU/LC classes*
L	=	total number of *LU/LC classes*
t_{st}	=	t-student value for a 95% confidence level, with n-2 degrees of freedom
E	=	allowable error (±10% of the mean)
S_i	=	standard deviation of *LU/LC class i*
n_i	=	number of samples units to be measured in *LU/LC class i* that is allocated proportional to $W_i \cdot S_i / \sqrt{C_i}$. If $n_i < 3$, set $n_i = 3$
W_i	=	N_i/N
n	=	total number of sample units to be measured (in all *LU/LC classes*)
N_i	=	maximum number of possible sample units for *LU/LC class i*, calculated by dividing the area of *LU/LC class i* by the measurement plot area
N	=	population size or maximum number of possible sample units (all strata), $N = \sum_{i=1}^{m_p} N_i$
C_i	=	cost to select and measure a plot of the *LU/LC class i*

VCS guidelines state a maximum acceptable sample error of 10% with a 90% probability and these criteria were used in the above formula to determine the number of plots needed for the aerial survey.

4.5.4 Measurement of Crown Diameter (AIM Step 3)

Software code was written to run in ARCGIS that allowed the GIS operator to click with the mouse on three different points of the outline of each visible tree crown and the software would automatically create a circle polygon using the averaged radius from the three points. The GIS operators were instructed to not measure crowns less than 5m in diameter, which is approximately equivalent to a DBH of 25cm or less and coincides with the minimum bole diameter measured in the ground-based plots. All tree crowns overlapping any portion of the aerial plot boundary were digitized and areas calculated based on the measured tree crown radius. Then tree crowns were clipped to the plot boundary and areas recalculated in ArcGIS. Only the portion of crown areas falling inside the 1 ha plot boundary were included in plot-based tree-crown area assessments.

Nadir photographs or imagery cannot record all tree crowns in the plots since some crowns will be obscured from view. Therefore remotely sensed biomass estimates will under-represent the true biomass present. This issue was addressed in a recent study (Broadbent, Asner, Pena-Carlos, Palace, & Soriano, 2008) that linked biomass estimates from Quickbird imagery with biomass measured in ground plots. The results showed a discrepancy between 30-50% between remotely sensed biomass estimates and ground plots. However, Broadbent et al (2008) were able to construct linear equations relating crown exposure class and the amount of obscured biomass and incorporated this into their allometric model of biomass derived from tree crown area delineated on imagery: ($r^2 = 0.65$, $p < 0.001$).

$$\text{Biomass} = 148.37 + 37.92 \times A \qquad (11)$$

5. RESULTS: FIELD BIOMASS SURVEY

5.1 Peat Depth Measurements

In measuring peat depth, 160 sample sites were recorded and produced a mean depth of **4.3 meters.**

In about 20% of the sample points along the transects, peat depth exceeded the maximum reach of the probe (5m on T1-T6 and 6m on T7-T8).

5.2 Non-tree Biomass Estimation

According to the methodology (p. 18), the non-tree woody aboveground biomass component includes trees smaller than the minimum tree size measured in the tree biomass pool, all shrubs, and all other non-herbaceous (woody) live vegetation. In the project, flooding, soil-type conditions and overstory canopy are not conducive to understory growth and it was expected that this carbon pool represented an insignificant amount of carbon stocks compared to the aboveground and total carbon pools.

In an independent study in Rimba Raya, non-tree biomass was surveyed in 150 small plots (78.5m2) on 30 0.5 km transects spaced 100m apart and located perpendicular to carbon survey transects T4, T7, T8. Twenty transects were located in lightly degraded peat swamp forest and ten transects were located in transitional kerangas forest. In Rimba Raya, woody vegetation is primarily comprised of mature trees and tree saplings, therefore the "non-tree biomass" class is dominated by very small trees 5-10 cm DBH. All trees of this size class were measured in five plots per transect, and plots pooled by transect. Biomass was calculated for each transect by applying the Chave et al. (2005) regression equation cited above.

Results showed that in peat swamp forest, average estimated non-tree biomass is 7965.74 tdm/ha representing 3.72% of total estimated biomass for this landcover type. In transitional kerangas forest, non-tree biomass is 6644.88 tdm/ha representing 5.60% of total estimated biomass in kerangas forest. Based on this data, the dominant component of non-tree biomass contributes <0.5% to total GHG emissions (all biomass burning represents 7.1% of total GHG emissions).

The non-tree biomass in the baseline scenario of palm oil plantations understory growth is even more sparse than in the project case, since active weeding and clearing are used to maintain worker access to the oil palm tree crop. The accumulation of carbon stock in the non-tree biomass carbon pool in the project scenario is therefore expected to be positive but very small. Given the level of effort required to carry out this intensive sampling across Rimba Raya and pursuant to guidelines in the "Tool for testing significance ofof GHG emissions in A/R CDM project activities" (Version 01), it was determined that non-tree biomass would be excluded from the carbon accounting.

Note that oil palm trees in the baseline scenario are considered to be "tree biomass" and are accounted as a major carbon pool and CO2 sequestration by palm oil growth is taken as a deduction against the baseline avoided CO2 emissions presented in the Baseline emissions section of this report.

5.3 Tree Biomass Estimation (AIM Step 1)

5.3.1 Tree Diameter Results

A total of 1,555 trees over 20 cm DBH were measured in 36 biomass plots. The mean was 30.8 cm DBH and the largest tree measured was 120cm DBH, which was cross checked with the original field tally sheet to make sure that it wasn't a data input error (Figure 13).

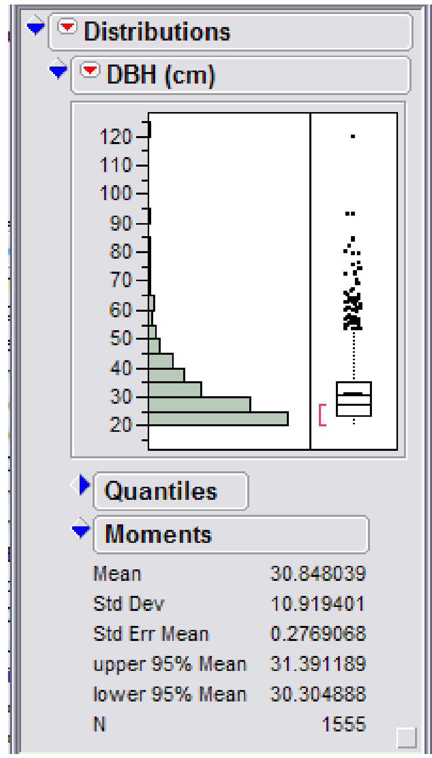


Figure 13. Histogram and box plot of the distribution of tree diameters (DBH) in the 36 biomass plots (trees >= 20cm DBH)

5.3.2 Tree Biomass Estimates

Tree biomass was estimated using three allometric equations, two by Chave et al. (2005) and one by Brown (1997). A stand averaged specific gravity of 0.57 g/cm2 was used for the wood density parameter in the Chave et al. (2005) equations. This value has been used in Kalimantan studies, and represents the mean for 425 Asian tropical species summarized in another study (Reyes, Brown, Chapman, & Lugo, 1992).

Table 4 below shows the primary statistics generated during the analysis of biomass based on the [Chave D] equation. Using the this equation, total biomass in live trees was estimated to be 206 t C/ha, which is comparable to other logged over peat swamp forests in Kalimantan. A 12% sample error was estimated with a 90% level of confidence for trees greater than 20cm DBH. This error is quite close to the IPCC suggested sample error of 10% and is acceptable given that field plots are only used to generate comparative models for aerial based estimates.

Table 4. Summary statistics for the biomass plots for small and large live trees

Statistical Results	Small trees (10 - 19.9 cm DBH)	Large trees (>= 20 cm DBH)	TOTAL BIOMASS/ (Propagated Error)
Number of plots installed (n)	70	35	
Mean biomass (ton/ha)	41.2	164.9	206.1
Standard error of the mean (t/ha)	0.4	2.95	
Coefficient of variation (%)	43.4	42.3	
Sample error at 90% CI (%)	8.7	12.1	(14.9)

5.4 Site-specific Allometric Equations Relating Biomass to Tree Structure (AIM Step 2)

Allometric relationships relating Tree Biomass (TB) to some combination of Tree Height (H) and/or Tree Crown Area (A) from ground plot data were constructed using biomass plot data (n=340 for trees with height and canopy structure data); all equation types were tested.

The 7 models tested (n=340) are listed below with regression results. Model 6 output is shown right in Figure 14.

1. TB [Chave D] = f(H) $R^2 = 0.336$

2. TB [Brown D] = f(H) $R^2 = 0.322$

3. TB [Chave D] = f(A) $R^2 = 0.176$

4. TB [Chave D-H] = f(A) $R^2 = 0.193$

5. TB [Brown D] = f(A) $R^2 = 0.170$

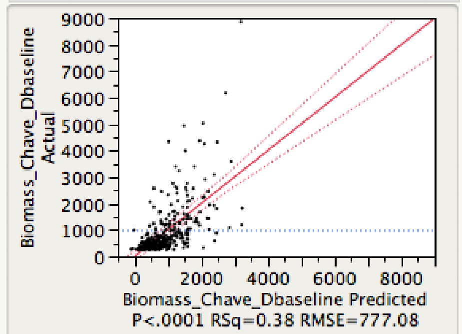
6. TB [Chave D] = f(A*H) $R^2 = 0.379$

7. TB [Brown D] = f(A*H) $R^2 = 0.364$

Response Biomass_Chave_Dbaseline

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.378591
RSquare Adj	0.374903
Root Mean Square Error	777.0847
Mean of Response	962.8094
Observations (or Sum Wgts)	340

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	123981946	61990973	102.6578
Error	337	203501026	603860.61	Prob > F
C. Total	339	327482972		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-1147.476	163.8166	-7.00	<.0001*
CA	4.3973552	0.911908	4.82	<.0001*
HTcalc	78.675178	7.509802	10.48	<.0001*

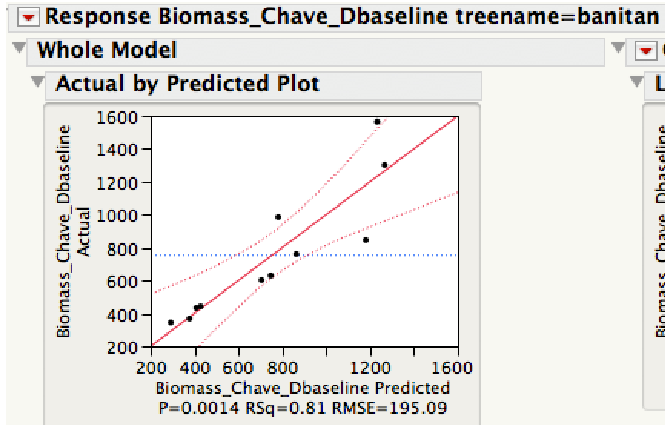
Figure 14. Regression equation of tree biomass (TB) as a function of crown area (A) and tree height (H), for all trees with canopy structure data n=340, R^2 = 0.379, p<.0001

The biomass models including tree height explained 32%-38% of the variability in DBH-based biomass estimates for the plot trees. The improved explanatory power of these models over those based only on tree crown area is not surprising since DBH sets a mechanical constraint on tree height (O'Brien et al. 1995). The DBH-Height allometric relationship has been found to hold across a number of study sites, biomes and species and shows less variation than the DBH-Tree crown area relationship since tree crown area can vary depending on species, individual age, successional status and light environment (O'Brien et al. 1995, Asner et al. 2002, Palace et al. 2008).

Given expected species-related crown characteristics, these same models were tested for the most common taxa surveyed in biomass plots. In the field survey of biomass plots, ca. 140 local names were recorded representing ca. 100 taxa (genus or species). Tabulation of these data show that only 8 taxa occur with > 3% frequency. The dominant species occurs at a frequency of 8.39%. 20 taxa comprise ca. 60% of all observations and most of these are proportionally represented in the subset of trees for which tree height and crown area were measured. 16 taxa (n=7 to n=28) representing >52% of all tree data were used in the species biomass models (16 species x 7 models shown above = 112 models total were tested).

Results show that models 6 and 7 above perform best for the 16 common taxa. Nine of these species models show that tree height and crown area are good predictors of biomass (R^2 = 0.655 - 0.886).

The model for one of the 16 common species, ”Banitan” or *Polyalthia* sp. (Annon) is shown in Figure 15.



Summary of Fit

RSquare	0.806665
RSquare Adj	0.758332
Root Mean Square Error	195.0936
Mean of Response	752.7862
Observations (or Sum Wgts)	11

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	1270456.8	635228	16.6895
Error	8	304492.2	38062	Prob > F
C. Total	10	1574949.0		0.0014*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-1129.705	334.85	-3.37	0.0097*
CA	5.8490755	2.195747	2.66	0.0286*
HTcalc	62.095633	12.15728	5.11	0.0009*

Figure 15. Regression equation of tree biomass (TB) as a function of crown area (A) and tree height (H), for all Polyalthia n=11, R^2 = 0.807, p<.001

There are however several limitations that prevent applying these species models to predict biomass from aerial-based tree crown delineations in AIM Step 7:

Taxa in diverse tropical forests cannot be identified in aerial photos, so species-specific models cannot be applied. Regression slopes vary among these models and a combined-species model is not a good estimator of biomass (R^2 = 0.322) in this dataset. Furthermore, height data is not available from aerial image analysis and is difficult to derive in dense canopy (Asner et al. 2002) forest limiting the feasibility of this approach.

Given the limitations is applying a site-specific allometric model for estimating tree biomass from aerial imagery in Rimba Raya, it was determined that the Broadbent et al. (2008) equation provided the best alternative. While this represents a deviation in AIM Step 2 of the methodology, this approach should provide a more robust assessment of tree biomass and can be adjusted to ground-based biomass estimates as described in the following sections.

6. RESULTS: AERIAL BIOMASS SURVEY

6.1 Aerial Plot Data

The biomass survey using aerial plots was planned so that photographs would be taken systematically over Rimba Raya concession, with a focus on the Carbon Accounting Area. A total of 3,382 photos were taken over the Rimba Raya concession, each one covering approximately 120 ha (see Figure 16 which shows the aerial survey flight lines). Photos with high cloud cover were excluded and remaining photos were ortho-rectified and projected in ARCGIS.

One-hectare plots were installed in the center of each photo and tree crowns were identified and measured using Forest Carbon developed software. The following four photographs (Figures 17-20) show the differences in vegetation and texture between four of the most common LCLU classes in Rimba Raya.

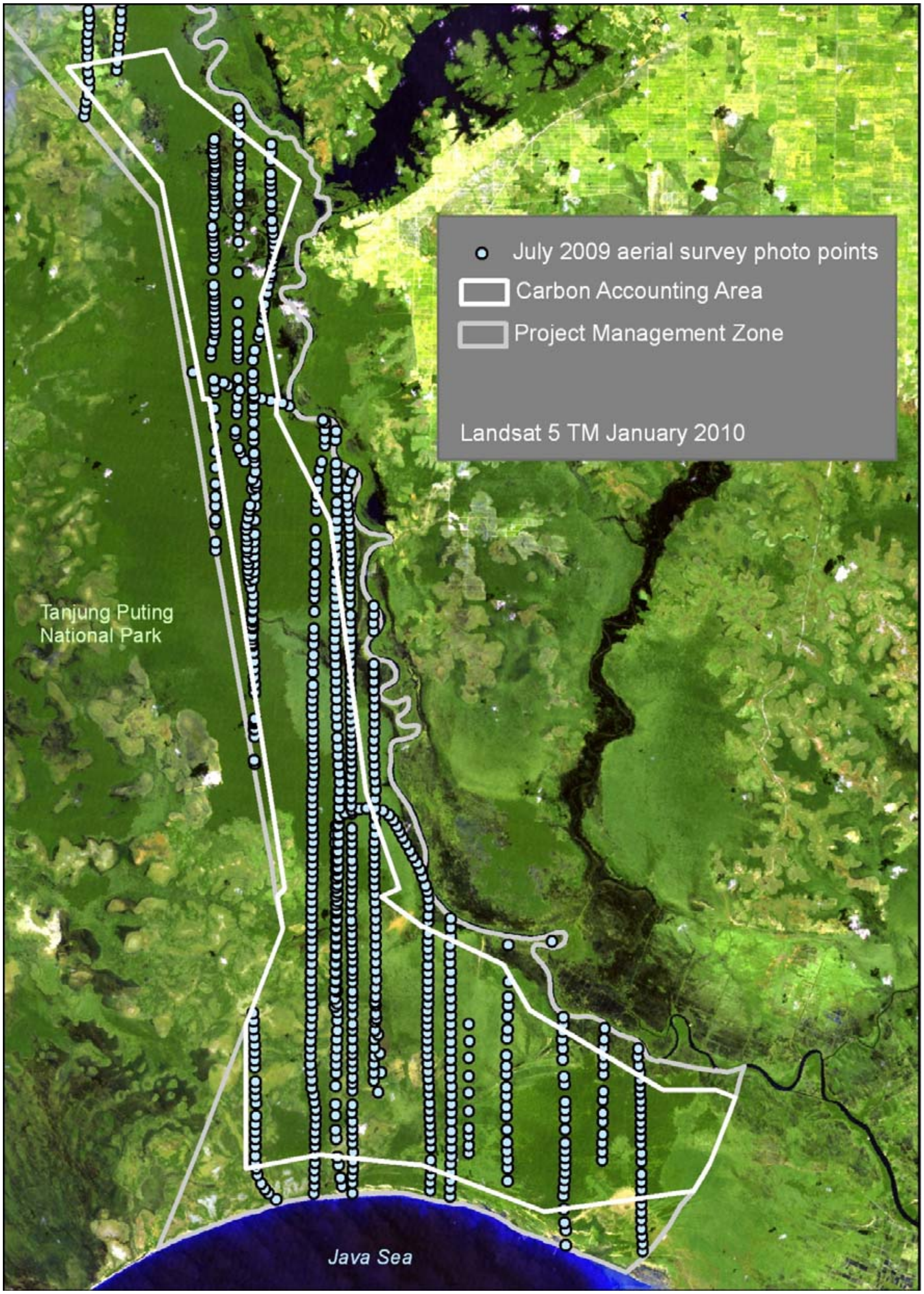


Figure 16. Aerial survey flight-lines and photo location points

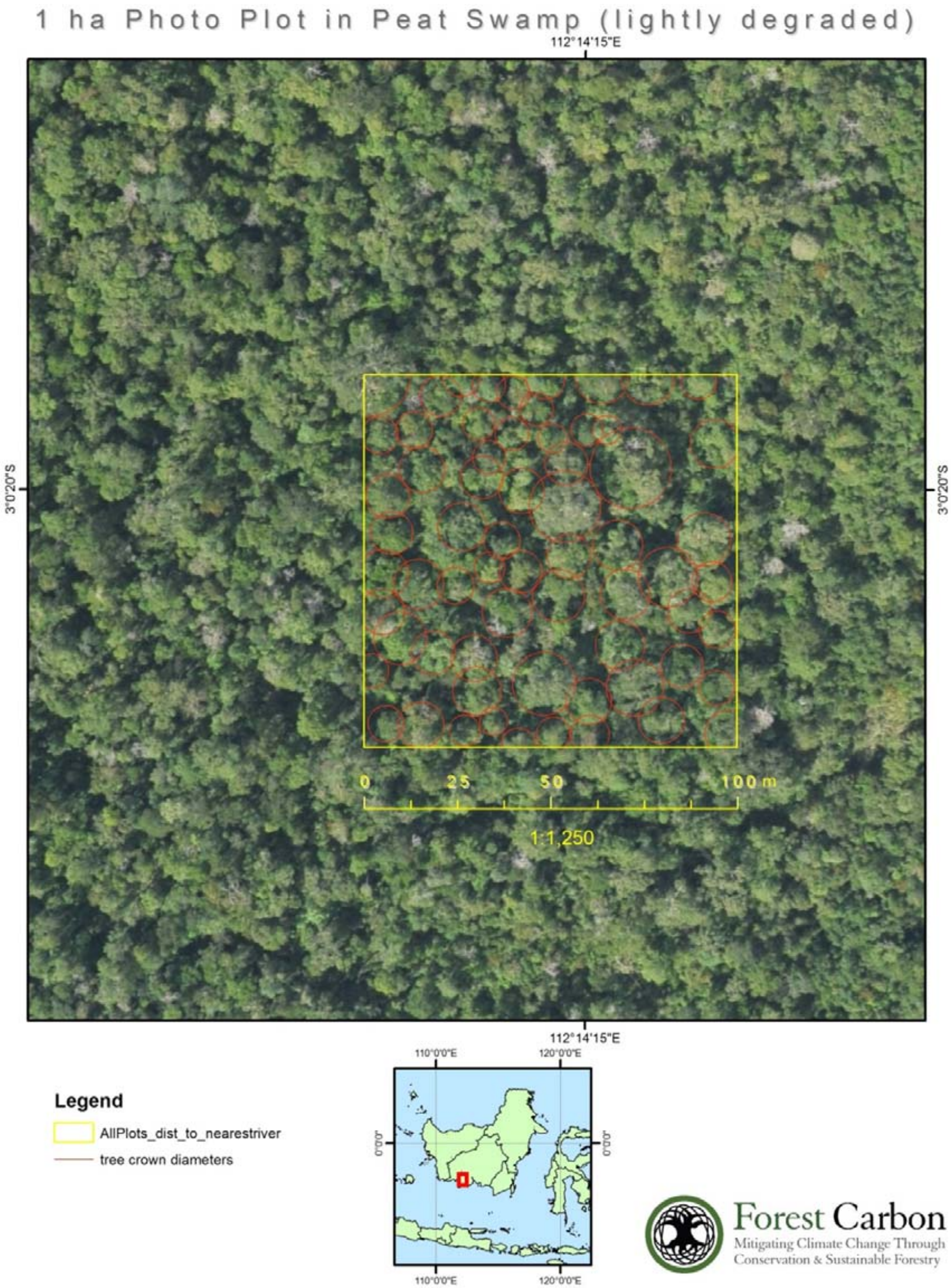


Figure 17. Cropped and enlarged aerial photo taken at 3,200 ft elevation over lightly degraded peat swamp with 1 ha plot (yellow) and tree crowns outlined (red).

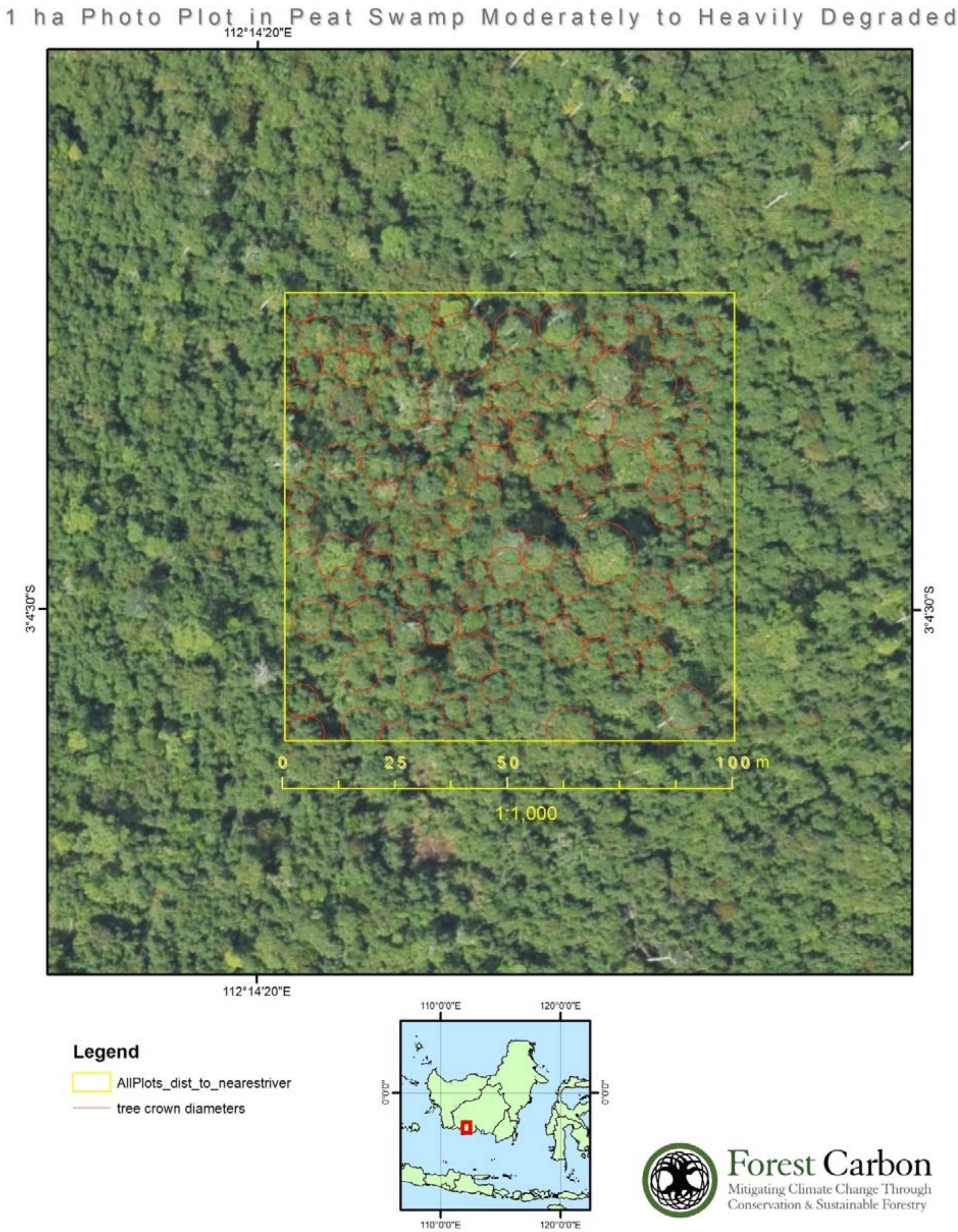


Figure 18. Cropped and enlarged aerial photo taken over moderately to heavily degraded peat swamp

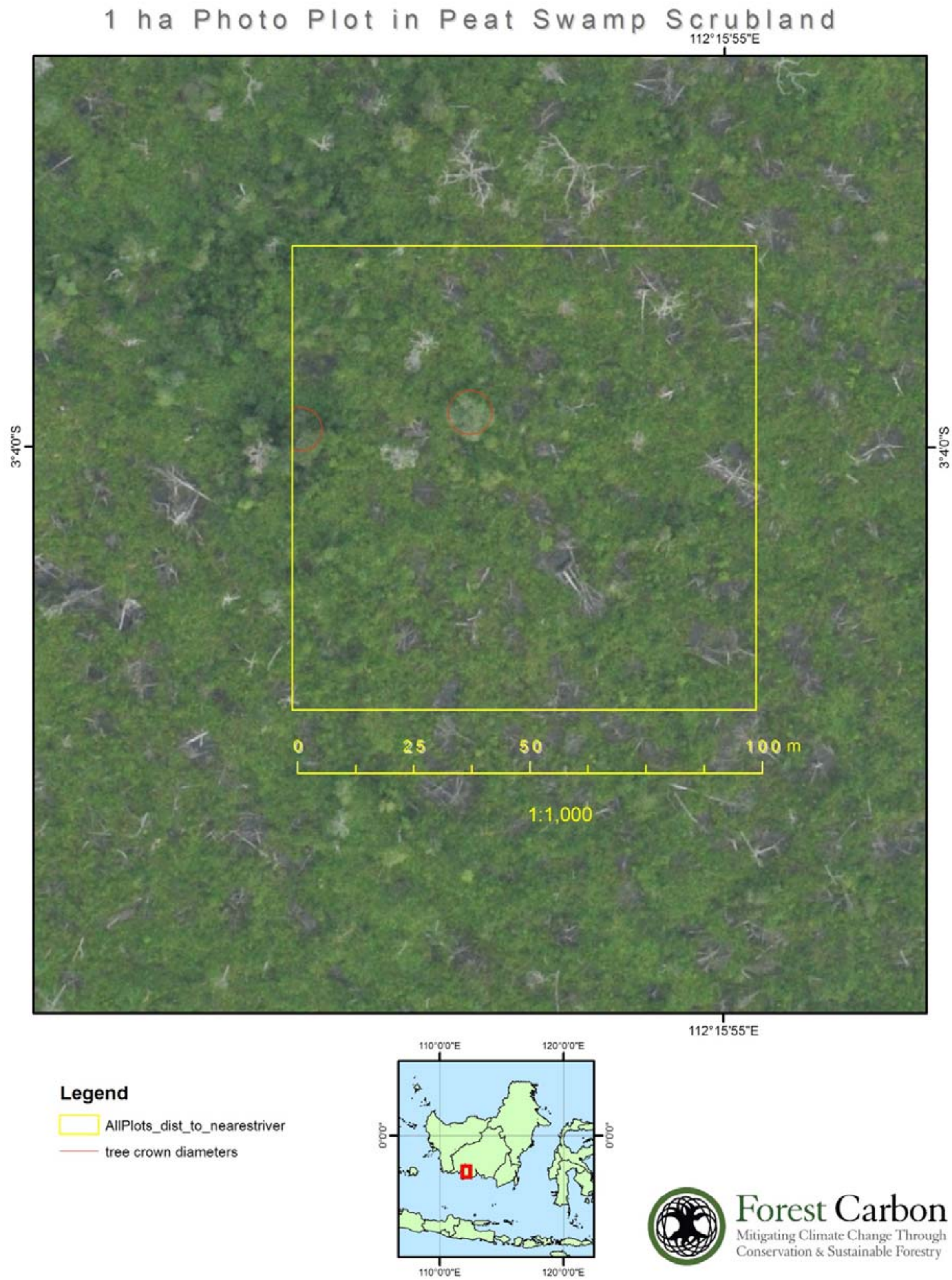


Figure 19. Cropped and enlarged photo of peat scrubland

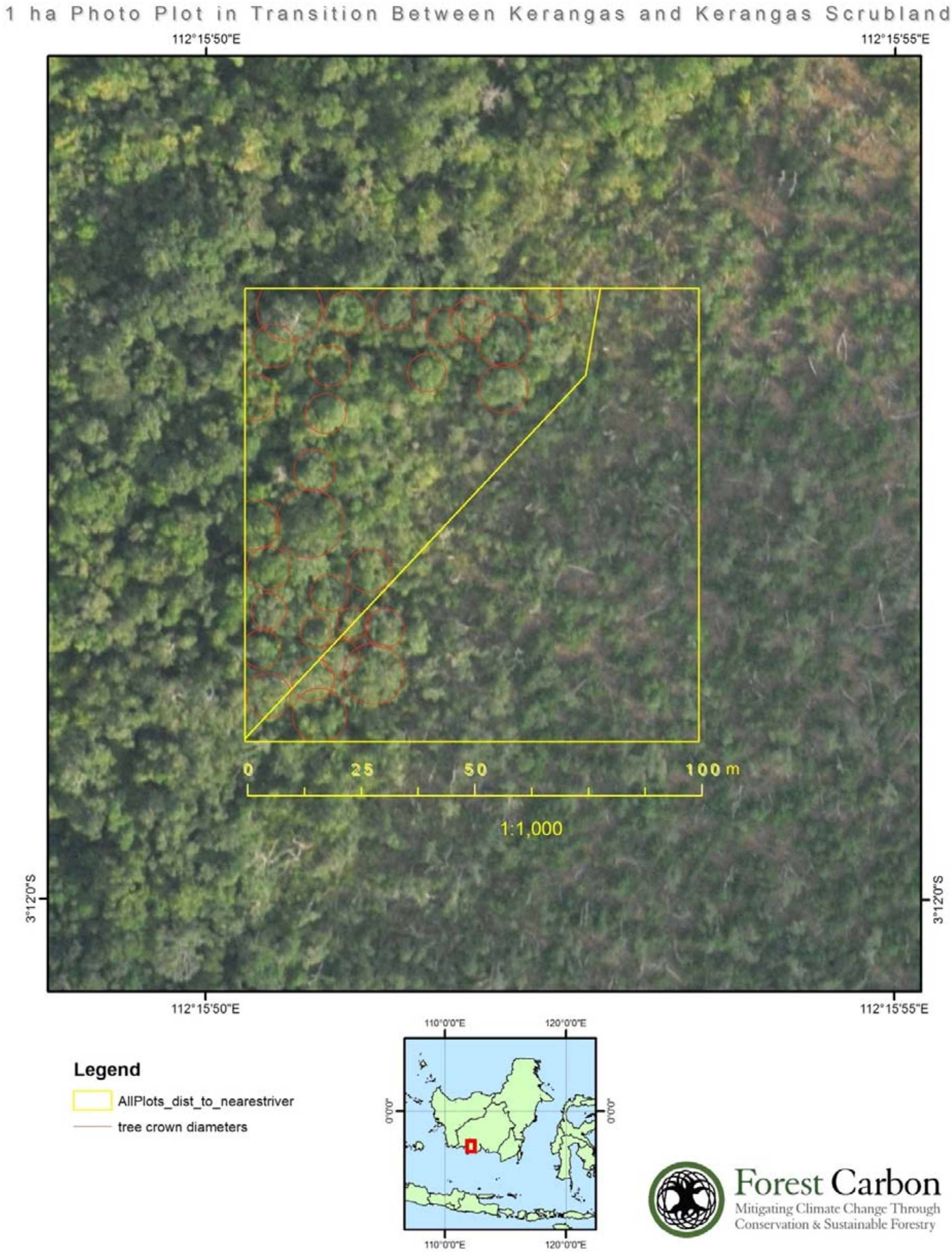


Figure 20. Cropped and enlarged photo of a transition between kerangas forest (to the left) and kerangas scrub (to the right). Note: this plot was excluded from the biomass analysis.

An initial pilot study was conducted to establish plots on 20 randomly selected aerial photos per land cover/land use strata, delineate tree crowns and quantify tree biomass in order to gain an estimate of the standard deviation of biomass per strata. This initial sample generated the following statistics (Table 5):

Table 5. Results from pilot sample of tree biomass (n = 20 per LC/LU strata).

	Mean Biomass	**Std Err**	**Std Dev**	Number of
LC/LU Classes	**(tdm/ha)**	**(tdm/ha)**	**(tdm/ha)**	plots needed
Peat (lightly degraded)	262,722	4,688	46,489	58
Peat (highly degraded)	96,140	20,677	63,584	49
Peat Scrubland	no photo plots			
River and Coastal Forest	228,296	31,803	80,122	77
Kerangas	87,117	25,423	76,253	70
Open sandy scrub	40,863	8,877	41,914	74
Seasonally inundated wetlands	no photo plots			
Bare or sparsely vegetated	24,592	5,683	16,072	78

The Std Deviation of pilot study biomass estimates was used to generate the number of plots needed in each strata with a sample error set to 10%. (Note, after this pilot was conducted, LC/LU strata were redone using a 2009 satellite image and the River and Coastal Forest class was merged with Lightly Degraded Peat Swamp.) Additional aerial plots were added to meet the recommended number of plots needed to keep sample error <10%.

Aerial plots were located throughout the carbon accounting area in a stratified random design based on areal proportion of land cover classes, so these should provide a representative dataset for biomass estimation. Note that only in the strata classed as deforested does the sample error exceed the recommended 10% (at a 90% level of confidence). The strata with the highest biomass has a very low sample error due to the large number of plots installed (the coastal and riverine forest plots were merged into this class).

6.2 Tree Crown Statistics

The advantage of applying aerial image methods for carbon stock assessment in tropical forest, is that low-altitude high resolution aerial imagery provides a detailed, top-down and synoptic view of all landcover types, which is especially important across remote and inaccessible areas (Brown et al 2005). This enables tree data to be collected across a statistically significant stratified random sample of large (1ha) plots, which has been carried out in AIM steps 3-6 for the project, and also enables comparisons of tree stem density and tree crown size to be made across landcover types.

Table 6 below summarizes the statistics from the aerial based analysis of tree crown diameters. As one would expect mean crown diameters are largest in the unlogged/lightly degraded peat swamp and decrease with increasing degradation and deforestation.

Table 6. Summary statistics for mean crown diameter (m) by landcover/land use class based on aerial image analysis.

Land Cover/ Land Use Classes	n	Mean Crown Dia. (m)	CV (%)
Peat Swamp Forest (lightly degraded)	9666	10.3	29.0
Peat Swamp Forest Degraded (highly)	3125	9.1	33.2
Peat Shrubland (<20% Tree Cover)	2422	6.8	29.0
Kerangas Forest	3416	7.8	30.2
Open Kerangas Scrub	1800	8.0	30.9
Low, sparse vegetation cover	3	7.2	14.6
Seasonally Inundated Wetlands	7	8.9	16.2

6.3 Aerial Biomass Estimation Calibrated to Field Survey Data

Results of biomass estimation using the Broadbent et al. (2008) formula are shown in Column 1 of Table 7. Tree biomass estimates were then calibrated to site-specific biomass estimates based on field survey data. Peat swamp forest biomass, estimated to be 267 tdm/ha using the Broadbent et al. equation was reduced 22.85% to match the field surveyed biomass estimate of 206 tdm/ha. This same 22.85% reduction was applied to all landcover types. Revised biomass estimates are shown column 2 of Table 7.

Table 7. Rimba Raya Tree Biomass Estimation from Aerial and Ground Surveys

	Broadbent et al. 2008 Formula	**Calibrated to Ground-based Biomass Estimates**
Land Cover/Land Use Classes	**Mean (tdm/ha)**	**Mean (tdm/ha)**
Peat Swamp Forest - lightly degraded	**267**	206
Peat Swamp Forest Degraded (highly)	**166**	128
Peat Shrubland (<20% Tree Cover)	**63**	49
Kerangas Forest	**112**	86
Kerangas Open Scrub	**75**	58
Low, Sparse vegetation cover	**13**	10
Seasonally Inundated Wetlands	**18**	14

This reduction in aboveground tree biomass essentially incorporates a confidence deduction associated with the AIM Step 2 deviation into the baseline calculations. Although this change made <1% difference in overall carbon credits since the project is overwhelmingly dominated by the peat carbon pool, it is nonetheless conservative compared to IPCC default values for carbon stock in tropical moist forest which is 247 tdm/ha.

7. PROJECT ADDITIONALITY & BASELINE SCENARIO

As required by the approved methodology, the most current version of the VCS "Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities"[7], was used to determine the most plausible baseline scenario. Step 1 of this tool was used to identify and select the baseline scenario through a series of sub-steps.

Of the alternative scenarios identified for the project, complete conversion of the peat swamp forest to palm oil plantations was determined to be the most plausible scenario to occur in the absence of the project, and was therefore selected as the baseline scenario.

After identifying alternative land use scenarios and determining the baseline scenario (Step 1), Steps 2-4 were carried out to determine whether the reduction in emissions gained by implementing the project is additional to the most likely business-as-usual scenario. The results of applying the step-wise approach is presented below together with documentation and supporting data, which clearly demonstrate additionality. That is, the project activity (conservation of peat swamp forest) reduces GHG emissions in the baseline scenario (conversion of peat swamp forest to palm oil) and is therefore determined to be additional.

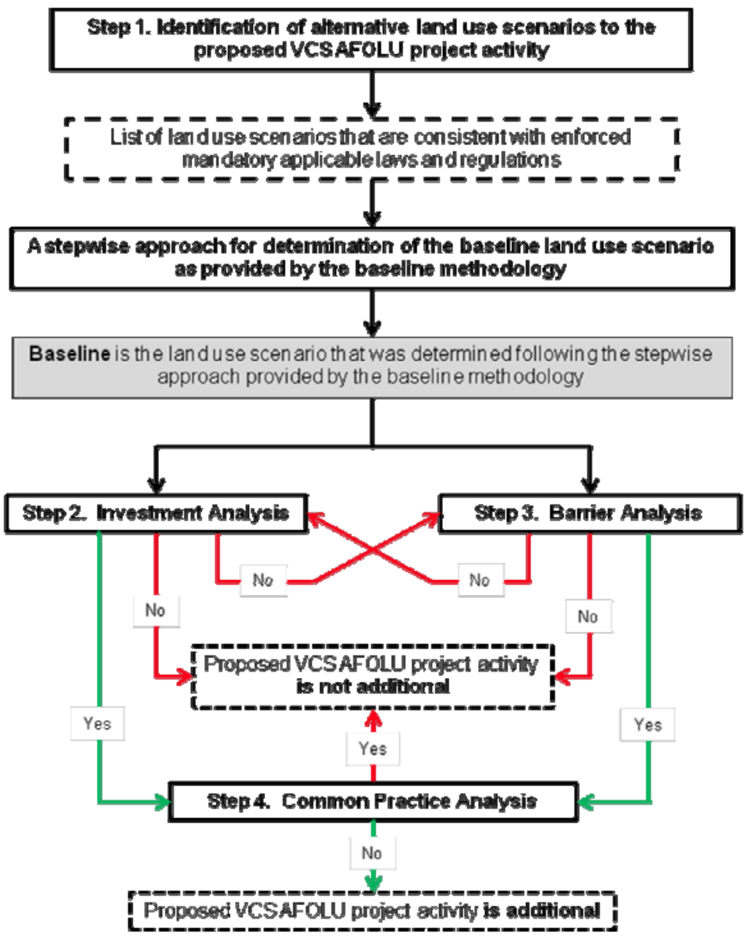


Figure 21. Step-wise approach toward determining project additionality

7 *"VCS-Tool-VT0001_Tool-for-Demonstration-and-Assessment-of-Additionality-in-AFOLU-Project-Acitivities"* last accessed December 8, 2010 at: http://wBw,itw.v-c-s.org/docs/VCS-Tool-VT0001_Tool-for-Demonstration-and-Assessment-of-Additionality-in-AFOLU-Project-Acitivities.pdf

Step 0: Preliminary Screening Based on Starting Date

The project starting date is 2008; thus, it meets the criteria for VCS that projects have to start after 2002.

Step 1: Identification of Alternative Land Use Scenarios

Sub-step 1a: Identify of Alternative Land Use Scenarios

Six potential land use scenarios were identified in addition to the proposed project activity and are listed below:

1. **Conversion to palm oil estates:** The project lands are zoned on provincial and district spatial plans for conversion and the acquisition process for obtaining four oil palm estate licenses has begun for the project site.
2. **Conversion to pulp plantations:** Indonesia's two largest pulp and paper companies, APP and APRIL over the last several years have been expanding their holdings into Kalimantan. Large, industrial pulp plantations are consistent with the provincial government's strategy to provide sustained tax and employment benefits.
3. **Conversion to agriculture:** Project site is deforested and industrial scale planting of crops takes place (e.g. rice, pineapple, aloe vera, etc.).
4. **Status Quo:** Project site remains zoned as production forest with continued illegal logging taking place.
5. **Protection in the absence of carbon financing:** The project site is added into Tanjung Puting NP or gains protection under a different status.
6. **Conservation/protection with carbon financing:** project site is conserved as intact peat swamp forest with funding from carbon financing. Illegal logging no longer significant.

Sub-step 1b: Consistency of credible land use scenarios with enforced mandatory laws and regulations.

The first criteria in the step-wise test of additionality is to examine whether each alternative is consistent with the enforced applicable laws and regulations at the appropriate levels of government.

Alternative 1 above is currently not consistent with the legislated MoF National Spatial Plan that shows the project site as "Production Forest", which cannot be converted to agricultural use without the Ministry of Forestry's approval and release. However, throughout Indonesia, the vast majority of conversions have been authorized at the local and provincial levels and the 2006 provincial and district land-use plans allocate the project site for conversion (Figure 22). Both plans are currently going through a harmonization process at the national level (*process padustrasi*). There is ample evidence that the Minister has approved the conversion of "production forests" to oil palm concessions.

Additionally, the Wetlands International Peat Atlas for Indonesia suggests that the Rimba Raya area is situated on shallow peats, mostly less than two meters deep. Therefore, the Presidential Decree classifying peat swamps over three meters deep as protection forest has not and would not be in effect[8]. In summary, alternatives 1 – 3 would be in compliance with applicable laws and regulations and in particular with common historical practice.

[8] Presidential Decree 32/1990

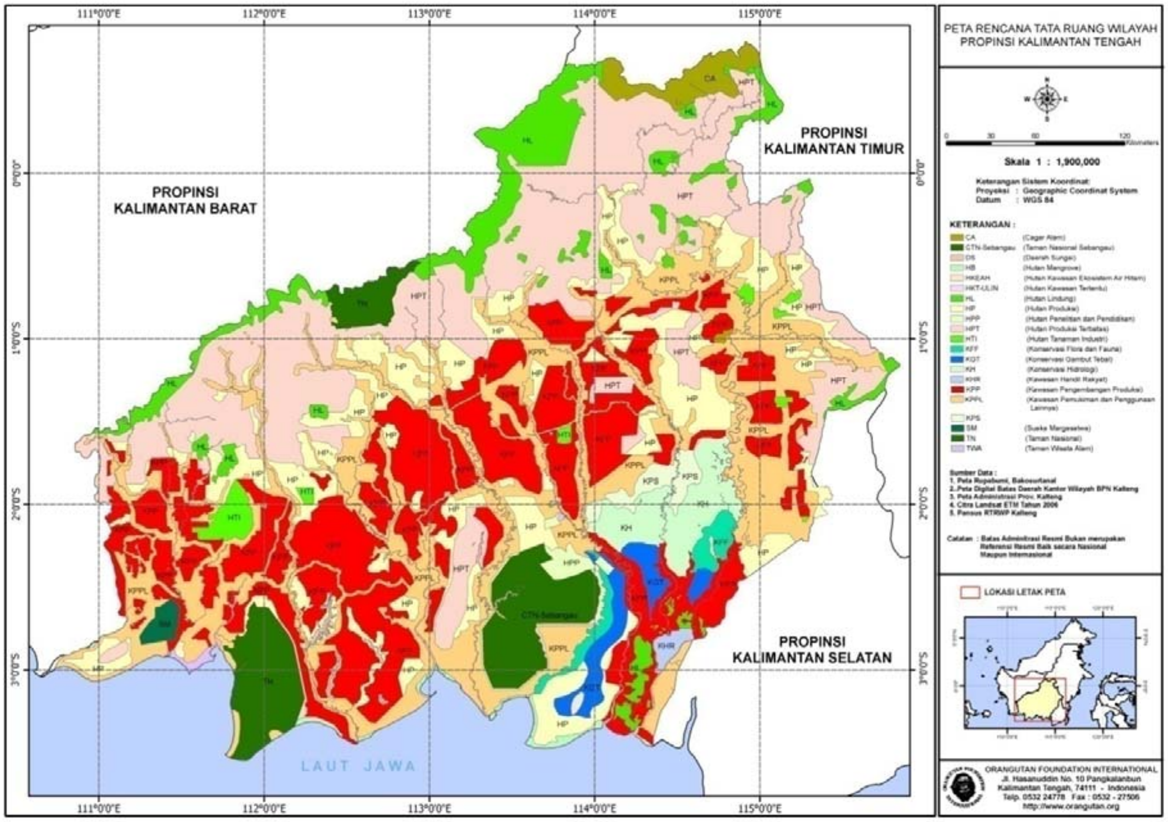


Figure 22. 2006 Provincial Land-Use Plan showing all of Rimba Raya as gazetted for conversion (red).

Alternative scenario 4 is in full compliance with current laws and regulations, the status quo being that at the national level, the area could continue to be logged and the status quo at the local and provincial level that the area could be logged initially, prior to clearing for palm oil.

Alternatives 5 and 6 would require that the current spatial plans and the draft plans be changed from production forestry to a conservation status. Indonesia has a poor record of being able to defend its National Parks. Tanjung Puting, in particular, has suffered at the lands of commercial scale illegal logging and the deforestation agent has encroached into the park boundaries by illegally expanding their concessions beyond their borders.

Another method consistent with the laws and regulations for conserving the forest in the project site is to apply for a Restoration Ecosystem Concession (IUPHHK) to the Minister of Forestry. This type of concession is designed for production forest lands that have been repeatedly logged, but still possess significant conservation values. In fact, the project proponent has solicited the MoF for such a concession[9].

Sub-step 1c: Selection of baseline scenario

From the assessment above, **all six scenarios are feasible** under the relevant Indonesian laws and regulations.

[9] Proposal available upon request to Infinite Earth

STEP 2: Investment Analysis

Conducted barriers analysis instead, as allowed in **Approved VCS Tool VT0001 Version 1.0:** ***"Tool for the Demonstration and Assessment of Additionality in VCS Agriculture, Forestry and Other Land Use (AFOLU) Project Activities"*****1**

"Barrier analysis maybe performed instead of or as an extension of investment analysis" (pg 6).

STEP 3: Barrier analysis

Barriers can take various forms such as institutional, technological, ecological, cultural, and sociological. This section identifies if barriers are in place and what type of barrier it is for each alternative scenario.

Sub-step 3a. Identify barriers that would prevent the implementation of the type of proposed project activity

Sub-step 3a. Show that the identified barriers would not prevent the implementation of at least one of the alternative land use scenarios (except the proposed project activity):

For superior clarity, sub-steps 3a & 3b are best reviewed jointly. Both criteria have been applied to each barrier identified.

Barriers to Alternative Scenario #1 (conversion to palm oil plantations):

There are no barriers to alternative scenario #1. Rather, there are several incentives for this land use scenario, all of which would prevent the implementation of the proposed project activities, summarized below:

- Indonesia is the world's largest producer of palm oil, with Malaysia close behind it. Together they account for 87 percent of global production[10]. Indonesia's palm oil production has been steadily growing, primarily for export. In 2006, of the estimated 14-16 million tons produced, some 11 million tons were exported, according to the Indonesian Palm Oil Producers Association (Gapki)[11]. An estimated 19.5 million tons of palm oil are expected to be produced in Indonesia in 2009[12].
- Indonesia currently has an estimated 5.5 million hectares of palm oil plantations, and the area under cultivation through the development of an additional 6.1 million hectares in Kalimantan, Papua and other provinces[13]. Table 8 lists the amount of land available for oil palm by province with Central Kalimantan possessing the third most extensive area.

[10] US Department of Agriculture Commodity Intelligence Report, 31 December 2007.
[11] Indonesia's palm oil production expected to rise in 2006. Xinhua, 06 March, 2006
[12] The Jakarta Post, Feb. 13, 2009. Government to allow peatland plantations.
[13] Guerin, B. A who's who of Indonesian biofuel. Asian Times, 22 May 2007.

Table 8. Extent of area (ha) suitable for the development of oil palm (source: Hasibuan 2006)

Province	Area (ha)
Nanggroe Aceh Darussalam	384,871
North Sumatera	37,000
West Sumatera	355,814
Riau	2,563,156
Jambi	1,818,118
South Sumatera	1,483,959
Bangka Belitung	593,038
Bengkulu	208,794
Lampung	336,872
Banten	63,742
West Jawa	224,708
West Kalimantan	1,681,186
Central Kalimantan	3,610,819
South Kalimantan	1,162,959
East Kalimantan	4,700,333
Central Sulawesi	256,238
South Sulawesi	192,370
Southeast Sulawesi	10,264
Papua	6,331,128
TOTAL	26,015,372

- While about three quarters of Indonesia's production comes from Sumatra, the provinces with the greatest potential for continued growth are Kalimantan and Irian Jaya, due to the relative availability of land for conversion to plantations. According to the Indonesian Chamber of Commerce, in 2006 East and Central Kalimantan together accounted for over 30 percent of the remaining land area in Indonesia suitable for conversion to oil palm plantations10. This has resulted in an increasing area within Central Kalimantan that supports industrial oil palm, going from no formal plantations in 1967 to 200-300,000 ha of planted area in 2002. The Indonesian Chamber of Commerce reports that palm oil area in Central Kalimantan grew from 240,000 hectares in 2003 to nearly 270,000 hectares in 2005.
- In July 2008, the Central Kalimantan government reported 2,847,720 ha of proposed oil palm plantations in the region, by 186 companies, with investments on the order of US$25M planned[14]
- Specifically, regarding the Rimba Raya site, the only technical/financial barrier that could exist is the lack of a CPO processing facility nearby. However, a processing plant is now under construction at the district capital of Kuala Pembuang less than 20 km away.

Barriers to Alternative Scenario #2 (conversion to pulp/paper plantation):

The barriers analysis applied to oil palm is also relevant for establishing a pulp and paper tree plantation. As already mentioned, over the last several years, there has been a rapid expansion of the holdings of the two largest Indonesian pulp and paper companies. APP purchased PT Finnantara and PT Surya Hutani Jaya II, a 180,000ha pulp tree plantation in East Kalimantan. APRIL acquired PT Adindo, a 219,000 ha plantation in East Kalimantan. The most common species planted on peat swamps for production of pulp is *Acacia crassicarpa*.

[14] http://www.kalteng.go.id/INDO/Kebun_investor.htm

One barrier that a pulp company would have to overcome is with transporting the logs or chips to a pulp mill, the closest being located in Banjarmasin in South Kalimantan, 300 km away. Currently, there isn't a road system that connects the Rimba Raya area with the main road to Banjarmasin. However, one possible solution would be to use barges towed up the Seruyan River with the logs being chipped at the log pond. From the log pond, the chips could be shipped by barge to the pulp mill.

There are institutional barriers to this scenario. The northern section of Rimba Raya already has an active oil palm estate and the remaining area has permits that recognize their preliminary borders. Therefore, there would be an institutional barrier in place, given the provisional commitment from local government to the oil palm developers. Additionally, pulp plantations haven't been established in this area and are not the prevailing practice.

This barrier would have prevented the proposed project activities.

Barriers to Alternative Scenario #3 (conversion to agriculture that is not palm oil):
There appear to be barriers due to local ecological conditions: The project area is not suitable for agricultural development other than palm oil due to its presence on peat. The failed Mega Rice Project was halted in the late 1990s in Central Kalimantan after it was drained due to the realization that areas of deep peat were unsuitable for agriculture other than palm oil.

Barriers due to prevailing practice: growing crops other than palm oil is not a common land use within the project region.

Barriers to Alternative Scenario #4 (Status Quo):
There appear to be institutional barriers: Though the project land was zoned as production forest in the past, in 2006 individual permits were issued by the district governments to develop at least 4 palm oil concessions in the project area. One concession is already active. Central Kalimantan's 2006 Spatial Plan (RTRWP), currently undergoing approval by the Indonesian government, shows the entire carbon accounting boundary area zoned for agricultural development, thereby supporting the notion that the project region was re-designated from production forest to development land, likely because much of the valuable timber in the region has already been extracted. Therefore, continued classification as production forest faces institutional barriers because local and provincial government plans seek to convert the forest.

This barrier would have prevented the proposed project activities.

Barriers to Alternative Scenario #5 (conservation in the absence of carbon financing):
There appear to be institutional barriers: the conservation forest scenario faces institutional barriers because conserving this area would go against the ground swell of government support for increased oil palm tax and employment benefits. Additionally, given Indonesia's government debt and budget restrictions, allocating additional funds to protect this area and without the support of provincial authorities would be exceptionally difficult.

Barriers to Alternative Scenario #6 (proposed project activity):
Investment barriers: There is currently no formal national or international capital market for this type of activity. A key intent of the project is to demonstrate the viability of harnessing carbon finance for the purpose of strengthening the case for conservation.

Institutional barriers: The project activity faces no institutional barriers given that Indonesia has taken a leadership position in the development of a regulatory framework to support REDD.

Barriers due to prevailing practice: No project activity of this type is currently operational in the region.

Technological barriers: Fire is the most significant threat to the project area. The project proponent's partner, OFI, has had a long history in providing for forest conservation protection inside Tanjung Puting National Park around Camp Leakey including the construction and staffing of 20 permanent guard posts.

Sub-step 3b. Elimination of land use scenarios that are prevented by the identified barriers

The land use scenarios identified in Sub-step 1b that are prevented by at least one of the barriers listed in Sub-step 2a include:

Scenario #2: Conversion to pulp plantations
Scenario #3: Conversion to agriculture
Scenario #4: Status Quo
Scenario #5: Conservation in the absence of carbon financing
Scenario #6: Conservation with carbon financing (proposed project activity)

Thus the only remaining plausible land use scenario is: **Scenario #1: Conversion to oil palm plantations**

Sub-step 3c. Determination of baseline scenario (if allowed by the barrier analysis)

The decision tree under Sub-step 2c in the combined tool was applied:

- Is forest protection without being registered as a voluntary project activity included in the list of land use scenarios that are not prevented by any barrier? Decision: **No**
- If no, then: Does the list contain only one land use scenario? Decision: **YES**
- If yes, then **the remaining land-use (Conversion to Palm Oil) is the baseline scenario**.

STEP 4: Common practice analysis

Conservation activities such as Rimba Raya are not common in the region. One other conservation project, the Mawas Conservation Project, is carrying out conservation activities in southeastern Central Kalimantan, but this project is not fully operational due to implementation challenges. Although the investment analysis was not necessary to determine the most likely baseline scenario, additional evidence demonstrating that the project lands are under threat of conversion to plantations is summarized below. It should be noted that government documents are not publically available. While copies of some permits were obtained, it wasn't possible to get copies of all outstanding permits in the Rimba Raya area.

Supporting Documentation

1. During a public hearing on TPNP and provincial government plans, the head of the Central Kalimantan Forestry Office in a presentation made in December of 2006, presented a map showing the oil palm estate borders.

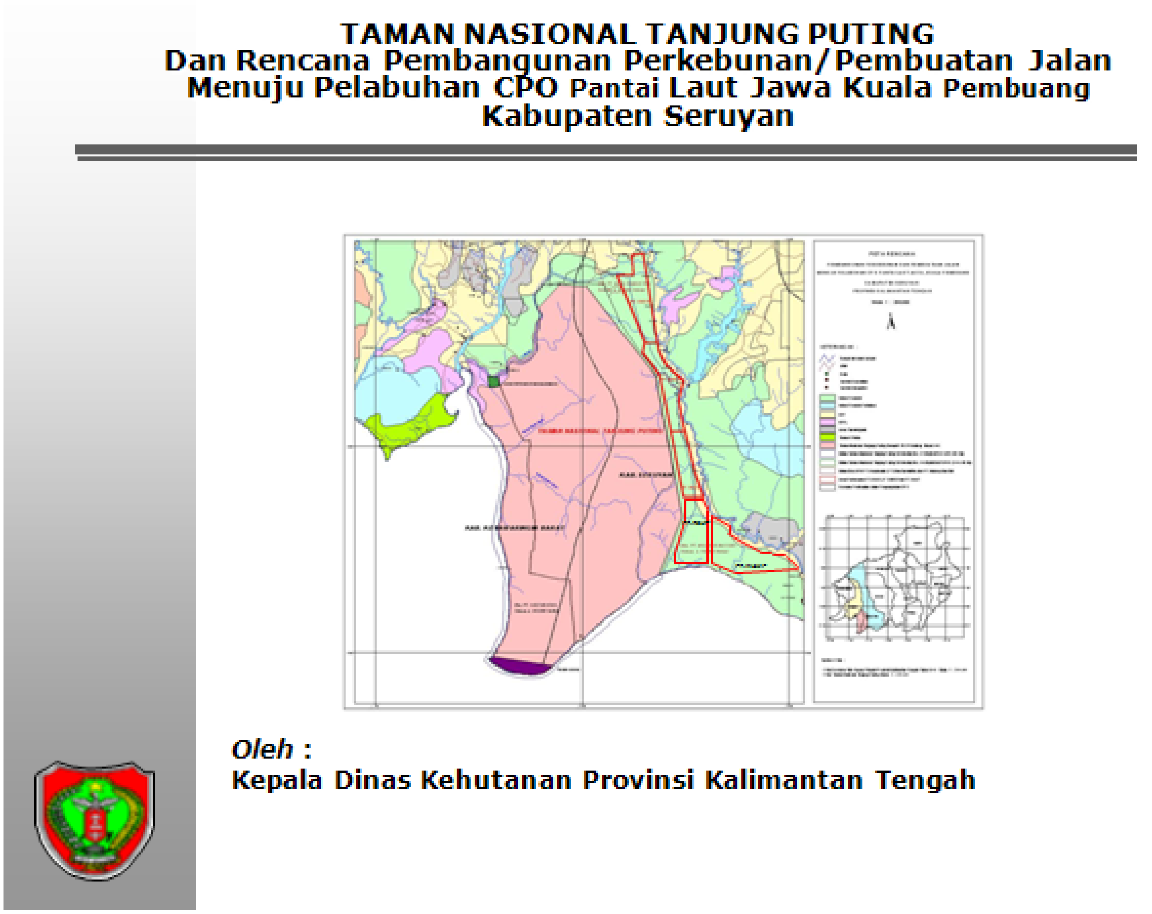


Figure 23. Map of TPNP (in pink) and planned oil palm estates (red outline) presented by Provincial Forestry Office Head.

2. Additional Supporting Government Documents (Annex 4)
    a. In 2004 The Surayan Bupati has issued location permits for all 4 oil estates with copies being obtained for PT EkaSawit
    b. On January 18, 2005 The Central Kalimantan Governor has sent a letter (522.2/073/EK) as a follow up to (525 not in our possession) to the Minister of Forestry requesting that the planned four other estates in the Rimba Raya area be changed from production forest to conversion status
    c. On May 13, 2005 the Minister in response to letter No. 525(July 2004) from the Governor that he is in basic agreement with the conversion but request the Governor to swap forest areas that were formally classified for conversion to production
    d. In 2006 the Minister of Forestry has set a precedent of issuing decrees allowing the conversion of production forest and specifically issued a decree allowing the conversion of production forest in the buffer zone of TPNP for the establishment of PT Kharisma Unggu Centraultama,

3. In February 2009, the Joint Spatial Planning Team appointed to resolve the conflict between the 2006 Provincial Spatial Plan and the MoF spatial plan presented their conclusions, which included a recommendation that for Production Forest areas that already possess an '*ijinlokasi*' the status should be changed to Conversion Forest. This includes all four planned oil estates in Rimba Raya.

4. During a recent field trip to Rimba Raya, a newly dug canal and road was observed connecting the PT Kharisma oil palm estate with the Seruyan River. Installing these canals is common practice in oil palm estates to provide access to the estate, and allow for drainage of the peat swamp, and undoubtedly more will be dug further south.

Figure 24. Photograph of recently dug canal and road from Seruyan River to PT Kharisma oil palm estate (coordinates: 2.68 degrees South, 112.204 degrees East)

8. APPLICABILITY OF EXISTING METHODOLOGY TO THE RIMBA RAYA PROJECT

The project activity of peat swamp forest conservation is taking place in an area that was slated for conversion to palm oil plantations by the Indonesian government. Without the project, the Carbon Accounting Area would have been deforested and drained, releasing vast amounts of CO^2 into the atmosphere. The selected methodology is currently the only VCS-approved methodology for avoided deforestation in tropical peat swamp forests and was designed based on Central Kalimantan peat swamps in particular.

Conditions in Rimba Raya meet all the applicability criteria listed in the approved methodology. These criteria and a description of how they are met by the project are presented in Table 9 below.

Table 9. Applicability Criteria

Applicability Criteria	Description and References of how project meets Applicability Criteria
A. The methodology was developed for (and is applicable to) preventing land use change on undrained tropical peat swamp forests in Southeast Asia only; it is not applicable to peatlands in other regions or climatic zones (boreal peat bogs, etc.) or to previously drained peatlands. Forest shall be defined according to the host country's forest definition as agreed upon under UNFCCC participation that includes minimum thresholds for area, height and crown cover. Peat shall be defined as organic soils with at least 65% organic matter and a minimum thickness of 50 cm^2.	The project is located on an undrained tropical peat swamp forest in Southeast Asia between 112°01'12 "- 112°28'12" east longitude and 02°31'48"- 03°21'00" south latitude. The Ministry of Forestry mapped the project area as undeveloped peat swamp forest with varying levels of degradation. Project-specific landcover analysis confirmed and updated Ministry of Forestry mapping (Bolick 2009a). In Indonesia, forest is defined as follows: land area of at least 0.25 ha, 30 percent crown cover and 5 m tree height (Ministry of Forestry, 2004). Wetlands International (2004) mapped the entire project area as shallow peat. Carbon surveys (Bolick 2009b, 2009c) confirmed the extensive distribution of peat and documented an average peat depth of >3 meters. The peat survey (Dwiastuti et al. 2010) showed the peat soils contained at least 65% organic matter.
B. The application of the procedure for determining the baseline scenario in Section 6 leads to the conclusion that baseline approach (c) is the most appropriate choice for determination of the baseline scenario (see Kyoto Protocol Decision 5/CMP.1 paragraph 22).	The procedure for determining the baseline scenario was applied as described in section 2.5 of the VCS PD. The application of this tool produced the conclusion that baseline approach 22(c) from the Kyoto Protocol Decision 5/CMP.1 is the most appropriate choice for determination of the baseline scenario. This decision takes into account national, sectoral, and local policies influencing the land use prior to the start of the project activity; the scope of project alternatives relative to the baseline; and barriers to implement the avoided deforestation project activity. This approach, which is adopted by the methodology is: "Changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts."
C. The methodology is applicable only for avoiding complete conversion of peat swamp forests to another known land use; it is not applicable for avoiding forest degradation. It is	The project area was slated for complete conversion to palm oil as shown in provincial planning maps (presented

assumed that land preparation during the conversion of peat forest would have removed all existing aboveground biomass stocks through logging and/or burning.	in sections 1.5 and 2.5 of this document). Four concessions covering the carbon accounting area had been granted to a well-known deforestation agent (PT BEST) with industrial oil palm estates immediately to the north of the project area. This well financed agent uses industrial / mechanical slash (bulldozers) and burn techniques to clear land in preparation for planting. Review of satellite imagery and analysis of historical land conversion by PT. BEST confirmed that all existing aboveground biomass stocks are removed during palm oil estate development.
D. The methodology is applicable only for preventing planned land use conversion in known, discrete parcel(s) of peatland, not for deforestation trends that follow a frontier approach. The land use conversion avoided must be in areas officially and legally designated for and under direct threat of such conversion, and the area and specific geographic location of all planned land use conversions in the baseline must be known and come from written documentation including land use conversion permits, government records, concession maps, etc. Planned deforestation must be projected to occur within ten years of the project start date.	The carbon accounting area matches the discrete parcels of proposed palm oil concessions shown in official government maps issued by the department of forestry. In the absence of the project, deforestation would have already occurred in year one of the project, with total conversion occurring within ten years of the start date or sooner. Review of satellite imagery and analysis of historical land conversion by the deforestation agent confirmed that the entire concessions boundary is cleared during palm oil estate development.
E. The methodology is applicable only for avoiding land use change that would be caused by corporate or governmental entities (plantation companies, national or provincial forestry departments, etc.) and not by community groups, community-based organizations, individuals or households.	The primary deforestation agent is an industrial conglomerate (PT BEST Group). This corporate entity was driving planned deforestation and land use change in the project area. Local, provincial and national government policy and common practice facilitated and accelerated conversion to palm oil in the region. In summary, this project avoids land use change by a corporate entity facilitated by government policy and practice, not by community groups, community-based organizations, individuals or households.
F. Peat drainage emissions in the baseline scenario shall be calculated using a net peat drainage depth of no more than one meter.	The baseline scenario was calculated using a net peat drainage depth of 1 meter as shown in the Baseline calculations spreadsheet and as referenced in the description of methodological parameters.
G. Carbon stocks in dead wood and litter can be	

expected to further decrease (or increase less) in the absence of the project activity during the time frame that coincides with the crediting period of the project activity.	Carbon stocks in dead wood and litter would be expected to decrease substantially in the absence of the project by being burned as part of forest conversion to palm oil. This would be expected to occur within the first eight years of the baseline scenario based on the conversion rate assessment (see section 4.2 of this document), thus this is within the time frame of the crediting period.
H. The parcel(s) of peat swamp forest to be converted to another land use must not contain human settlements (towns, villages, etc.) or human activities that lead directly to deforestation, such as clearing for agriculture or grazing land. Activities that involve the utilization of natural resources within the project boundary that do not lead to deforestation are permitted (e.g., selective logging, collection of NTFPs, fuelwood collection, etc.) as this degradation is accounted for in the monitoring methodology.	There are no settlements within the Carbon Accounting Area (CAA) or the surrounding Project Management Zone (PMZ), which serves as a buffer to the project. Communities, including 14 villages, are located adjacent to the PMZ and some residents utilize natural resources in the project area to meet subsistence needs. None of the activities lead to deforestation and all are related to selective logging and collection of forest products. Degradation associated with these activities is accounted by the monitoring methodology and documented in annual monitoring reports.
I. The biomass of vegetation within the project boundary at the start of the project is at steady state, or is increasing due to recovery from past disturbance, and so monitoring project GHG removals by vegetation can be conservatively neglected if desired.	The project area has historically suffered degradation by fire and selective logging, and is now at steady state or in the process of natural recovery. Ongoing biomass accumulation is conservatively neglected in carbon accounting for the project scenario as allowed by this applicability criterion and as noted in this document and the VCS PD.
J. The volume of trees extracted as timber per hectare prior to land conversion in the baseline is conservatively assumed to be equivalent to the total volume (or biomass) of all trees of commercial value above the minimum size class sold in the local timber market.	In the baseline calculations, the volume of trees extracted as timber per hectare is assumed to be equivalent to the total volume of all commercially valuable trees ≥ 30 cm, which is the minimum size class sold in the local timber market. The size limit and definition of merchantable timber for solid wood production is legally defined and regulated by the license of Forest Utilization. The regulation is quoted below:

	Minister of Forestry Regulation Number: **P. 11/Menhut-II/2009:** Silvicultural System on the Area of Business License on Wooden Forest Products Utilization in Production Forest Area. Article 8. Cutting cycle and diameter limit of cutting referred to in paragraph (2) is: a. On dry land forest land: (1) 30 (thirty) years with diameter limit ≥ 40 cm (forty centimeters) in production forest area or convertible forest area, and ≥ 50cm (fifty centimeters) in limited production forests with the TPTI or TR silviculture system. (2) 25 (twenty five) years for the TPTJ silvicultural system with 3 (three) meters line plantation of ex clear-cutting forest with diameter limit ≥ 40 cm (forty centimeters). b. 40 (forty) years for **diameter limit ≥ 30 cm** (thirty centimeters) in **swamp forests**. Merchantable timber was estimated to be 36% of total biomass in trees ≥ 30cm based on the Mawas logging gap dataset (Winrock 2008). This value is used in the baseline to calculate the total amount of extracted timber and corresponding carbon stocks that would <u>not</u> have been subsequently burned.
K. The project boundary shall be hydrologically intact such that the project area is not affected by drainage activities that are occurring outside the project area in a defined buffer zone (if applicable) at the start of the project (as detected from satellite or other remote sensing imagery). Both the project boundary and the buffer zone (if applicable) shall be monitored for new drainage activities over the life of the project. The width of the buffer zone to be monitored shall be set to a default value of 3 km from the edge of the project boundary or the distance to the edge of the peat dome, whichever is smaller. The monitoring methodology accounts for the impacts of future	The project boundary is hydrologically intact and includes one buffer zone set to a default value of 3 km from the northern edge of the project boundary. This buffer was established after the project start as required by the methodology and separates the project from one drainage canal at the southernmost end of the already-developed ex-KUCC palm oil plantation. The monitoring methodology and plan includes remote and ground-based survey and detection of any new drainage activity and accounts for the impacts of any such future activity.

drainage activities that occur within the project boundary, but if future monitoring detects significant new drainage within the buffer zone (such as that associated with new canals designed for transportation by boat or for developing plantations), then this methodology is no longer applicable in its current form and it shall be revised to take into consideration the extent of the outside drainage activity's impact on GHG emissions occurring within the project boundary. This drainage impact shall be determined using a combination of hydrological modeling and field measurements and shall be done in collaboration with at least two peat experts. If new scientific findings suggest influences for which the prescribed buffer zone would not offer effective separation between the project boundary and external drainage activities, the methodology should be revised to reflect a revised buffer width.	
L. The total land area allocated to the deforestation agent for planned deforestation must be shown not to have increased solely for the purpose of eliciting REDD credits.	The deforestation agent is a well-established company dating back to the 1980s and has no connection to the project proponents. Additionally, the concession areas were granted to the agent several years before the project proponent ever visited Indonesia for the first time. There is a well-documented battle between the agent and Orangutan Foundation International (OFI) over the exploitation vs. conservation of the project area, which lies adjacent to Tanjung Puting National Park (Smith et al. 2006). Maps of the region, show that the deforestation plans of PT BEST were status quo for the Seruyan Regency (see Figure 3) and Central Kalimantan Province (see Figure 22) which had plans to convert extensive land and forest areas to palm oil.

9. BASELINE CO2E EMISSIONS FROM PLANNED PALM OIL CONCESSIONS

This section includes a description of the methodology and how GHG emissions and removals for the baseline scenario were quantified. Calculations are summarized for each component of baseline carbon stock changes and GHG emissions at the end of each subsection. Full calculations can be found in the associated Excel spreadsheet (Annex 7). Methodological pathways taken and parameter descriptions for all calculations are included in the diagram and table in Section 10 at the end of this document.

9.1 Explanation of methodological choice

The methodology for this project follows the Approved VCS Methodology ***"VM0004 Methodology for Conservation Projects that Avoid Planned Land Use Conversion in Peat Swamp Forests, v1-0".*** The full report[15]of the methodology should be used as a reference when reading this section along with the Final Baseline Emission Estimate for the PT Rimba Raya Restoration Concession[16].

The selected methodology is currently the only VCS-approved methodology for avoided deforestation in peat swamp forests and was designed for the Mawas peat swamp, an ecosystem almost identical to Rimba Raya that is located less than 150km from the project site. Rimba Raya project activity is focused on peat swamp forest conservation in an area that was slated for conversion to palm oil plantations by the Indonesian government. The project will directly avoid GHG emissions from clearing, fire, drainage and conversion of peat forest to oil palm estates.

9.2 Quantifying GHG emissions and/or removals for the baseline scenario

In accordance with the methodology, five main steps were taken to estimate baseline net avoided GHG emissions:

1. Stratification and sampling;
2. Assessment of deforestation and conversion rate;
3. Assessment of mean carbon stocks in aboveground biomass, including two components:
    a. Tree biomass; and
    b. Non-tree biomass
4. Estimation of GHG emissions from changes in aboveground biomass, including four components:
    a. emissions from timber extraction before land clearing;
    b. emissions from burning remaining aboveground biomass for land clearing;
    c. sequestration by replacement vegetation (palm oil); and
    d. emissions from harvest rotations. (As palm oil plantations operate on a 25-30 year timeframe, and as data are not available for quantifying carbon emissions associated with decaying trees and harvest rotation activities at the end of this cycle, emissions from harvest rotations were conservatively excluded from calculations and biomass and carbon accumulation conservatively extrapolated to 30 years and included in the baseline).
5. Estimation of GHG emissions from peat, including two components:
    a. emissions from burning for site preparation; and
    b. emissions from drainage.

[15] Methodology accessed September 30, 2010 at http://www.v-c-s.org/VM0004.html
[16] Final Baseline GHG Emission Estimates for the PT Rimba Raya Conservation Project, Version 8.0

Each of these steps and components is summarized below with reference to more detailed discussions in the Baseline Report and other supporting technical documents.

9.3 Stratification and Sampling

Geo-referenced spatial datasets were used to stratify the project area by palm oil concession and land cover/peat distribution. Land cover and proposed palm oil concession strata summarized in Table 10 were used as the basis for area assessments of annual baseline emissions. It was assumed that conversion of these areas would have occurred in a sequential manner starting with the two northernmost estates, PT. Borneo and PT. Graha proceeding the following year with the next two estates.

Sampling of carbon stock inventories was conducted in plots on permanent transects to calibrate an aerial-based biomass assessment in all land cover classes. Stratified random aerial image plots were used to quantify carbon stocks based on the Broadbent et al. (2008) regression equation relating tree crown area delineated in aerial image sample plots to biomass.

Table 10. Land Cover/Land Use Classes in Proposed Palm Oil Concessions

These represent the two strata used to estimate baseline emissions. Extent and type of land cover classes described in the Land Cover Assessment and Land Cover Accuracy Assessment reports.

Land Cover/Land Use Classes	PT. BORNEO EKA SAWIT TANGGUH (ha)	PT. GRAHA INDO SAWIT ANDAL TUNGGAL (ha)	PT. RIMBA SAWIT UTAMA PLANINDO (ha)	PT. WAHANA AGROTAMA MAKMUR PERKASA (ha)	Total (ha)
Peat Swamp Forest (lightly degraded)	5,718	8,302	97	4,911	**19,028**
Peat Swamp Forest Degraded (highly)	427	97	27	1,183	**1,734**
Peat Shrubland (<20% Tree Cover)	314	3,265	3,104	5,464	**12,147**
Kerangas Forest	142	0	4,494	174	**4,810**
Kerangas Open Scrub	774	328	3,959	368	**5,429**
Low, sparse vegetation cover	944	33	0	365	**1,342**
Seasonally Inundated Wetlands	924	552	0	1,228	**2,704**
Open Water	43				**43**
Grand Total	**9,286**	**12,577**	**11,681**	**13,693**	**47,237**

9.4 Assessment of Deforestation and Conversion Rate

The rate of plantation conversion was analyzed in order to incorporate the rate of aboveground biomass emissions into annual baseline emissions estimates for timber extraction, biomass burning, peat burning, peat drainage and palm oil growth/sequestration.

To gain a transparent and conservative estimate of the annual rate of conversion expected for Rimba Raya concessions formerly held by PT. BEST, a satellite image-based GIS analysis was conducted of historic conversion of all known concessions owned by the agent of deforestation. Note that in Kalimantan, this represents the best available information for demonstrating a valid, verifiable plan by the agent of deforestation. In this analysis, eleven of 15 existing PT BEST concession areas were examined by overlaying concession boundaries on Landsat imagery, to delineate plantation boundaries in each year from 2003 to 2009.

Three of the estates in this study were already developed by 2003 and one remained undeveloped in 2009 (Figure 25). The remaining seven estates were developed 2003-2009 (Figure 26). All concessions examined are within 100 km of the project and are located on single Landsat ETM+ scene at path-row 119-62. Image dates were: April 2003, August 2004, March 2005, May 2007, January 2008, and February 2009.

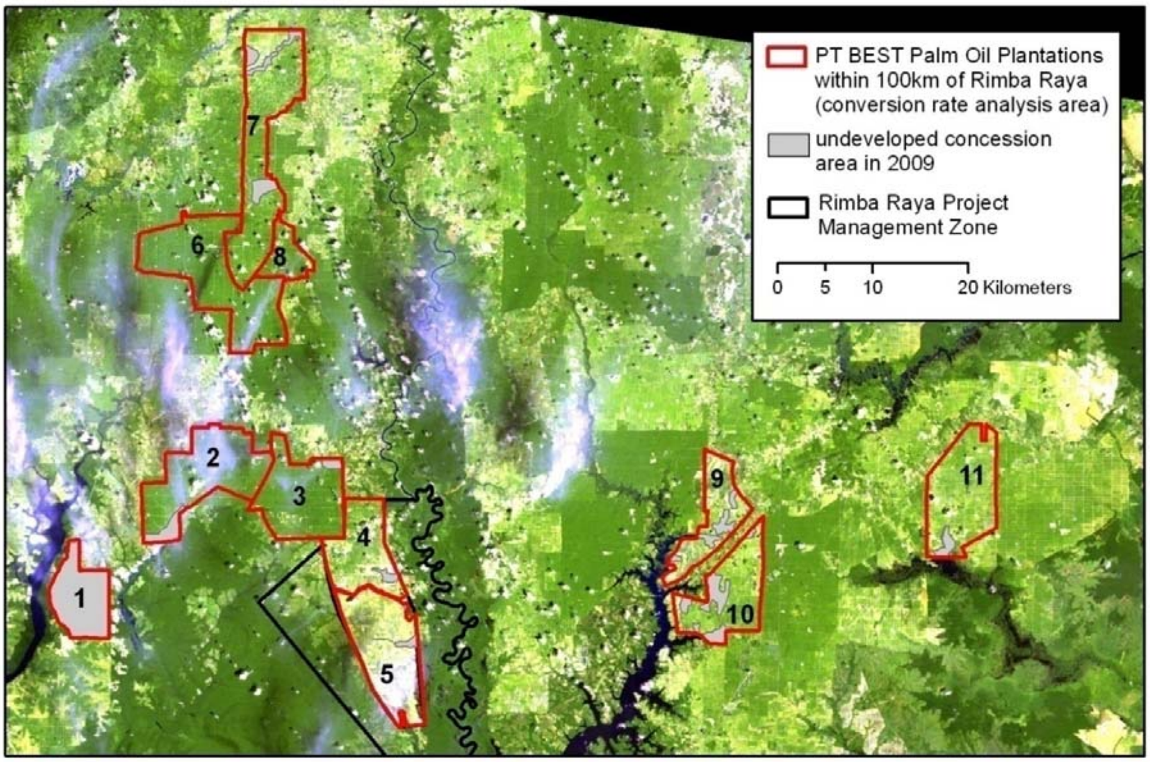


Figure 25. PT BEST palm oil plantations within 100km of Rimba Raya. These 11 concessions were analyzed for rate of conversion to plantation (See Table below for estate names).

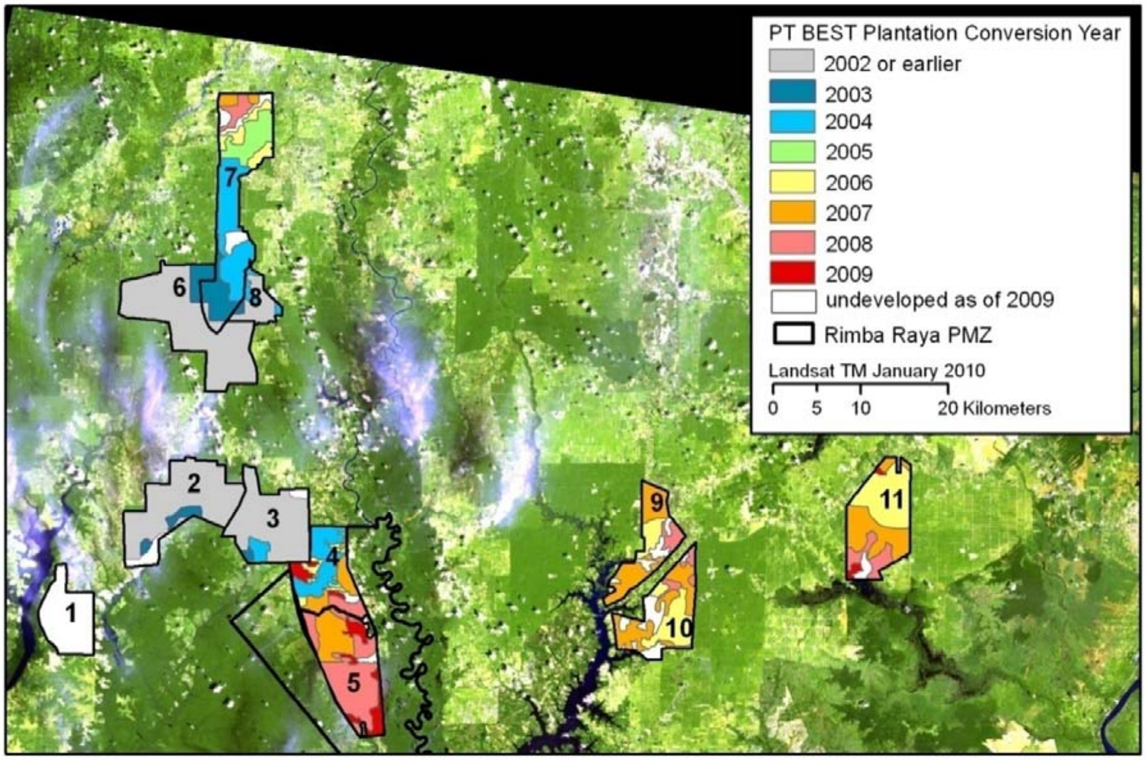


Figure 26. PT BEST plantation conversion year for 11 estates within 100km of Rimba Raya. (See Table below for estate names).

Results show that the average area under conversion during this period was 6,114 ha/year (Table 11). Inter-annual variation is due to concessions being in various stages of the 3-4 year conversion process in any given year. For example, in 2005, development on PT. Wanasawit was stalled and PT. Bangun Jaya Alam already completed, so overall plantation area increased by only 2,123 ha that year. In 2006, after obtaining licenses for 3 adjacent estates under the company name PT. Hamparan Masawit Bangun Persada, development increased dramatically to 7,948 ha/yr and peaked in 2008 at 11,569 ha/yr when all 6 estates were being planted concurrently.

By concession, 74.1% of the estate areas were developed to oil palm within the first two years, representing an average annual conversion rate of 2030.2 ha/yr in Year 1 and 2868.3 ha/yr in Year 2 (Table 12). By Year 3, these estates were 88% built out and nearly completed (94% built) by Year 4.

It is expected that the former concessions comprising Rimba Raya were slated to begin focused development in 2009 as the three large concessions to the east comprising PT. Hamparan Masawit Bangun Persada, were already totally developed and KUCC north and south were finishing development. (Note that the other four concessions not included in this quantitative analysis are two fully developed estates 50km to the north and two undeveloped estates (with no surrounding infrastructure) 135 km to the southeast.

Table 11. Annual Area of New Conversion by Estate

Historical Area of New Conversion by the Baseline Agent of Deforestation											
Map #	**Estate Name**	**already converted in 2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**remaining undeveloped in 2009**	**Grand Total**
1	**PT. WANA SAWIT SUBUR LESTARI SK74 north**	0								4486.6	**4486.6**
2	**PT. WANA SAWIT SUBUR LESTARI SK74 south**	7663.9	501.3							670.4	**8835.5**
3	**PT. WANA SAWIT SUBUR LESTARI SK73**	6402.4	150.4	507.7						229.6	**7290.1**
4	**PT. WANASAWIT SUBUR LESTARI KUCC north**	0		2432.2	250	486.4	1166.3	619.8	570.5	183.1	**5708.3**
5	**PT. WANASAWIT SUBUR LESTARI KUCC south**	0					1866.1	4729.3	1347.6	217.6	**8160.6**
6	**PT. BANGUN JAYA ALAM PERMAI south**	10049.5	774.3								**10823.8**
7	**PT. BANGUN JAYA ALAM PERMAI north**	356.5	1595	4141	1873.6	1172.4	447.5	652		1119.6	**11357.5**
8	**PT. BANGUN JAYA ALAM PERMAI east**	1532.2	120.3	463.3							**2115.9**
9	**PT. HAMPARAN MASAWIT BANGUN PERSADA north**	0				766.1	2599.7	553		719.2	**4638.1**
10	**PT. HAMPARAN MASAWIT BANGUN PERSADA south**	0				2123.2	2577.4	526.2		1414.9	**6641.7**
11	**PT. HAMPARAN MASAWIT BANGUN PERSADA east**	0				3399.9	2912.3	1194.7	276.2	351.8	**8134.9**
Grand Total	**Total conversion by calendar year**	**26004.4**	**3141.3**	**7544.2**	**2123.6**	**7948**	**11569.2**	**8275.1**	**2194.3**		**78193**
	average conversion (ha/yr) 2003-2009										**6113.7**

Table 12. Area of Conversion by Plantation Year

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	total 2009
KUCC N	2431.2	250.0	486.4	1166.3	619.8	570.5	5525.2
KUCCC S	1866.1	4729.3	1347.6	BUILT	BUILT	BUILT	7943.0
BANGUN north	1595.0	4141.0	1873.6	1172.4	447.5	652.0	10238.0
HAMP north	766.1	2599.7	553.0	BUILT	BUILT	BUILT	3918.9
HAMP south	2123.2	2577.4	526.2	BUILT	BUILT	BUILT	5226.8
HAMP east	3399.9	2912.3	1194.7	276.2	BUILT	BUILT	7783.1
Average ha/yr	2030.2	2868.3	996.9	435.8	177.9	203.8	
Average % developed	31.2%	74.1%	88.0%	94.0%	97.2%	100%	
sd	12.7	16.8	17.5	8.8	4.3	0	
se	5.2	6.8	7.1	3.6	1.8	0	
uncertainty	22	11.5	10	5.6	3.5	1.7	
lowest expected rate	18.4%	57.3%	70.6%	85.3%	92.4%	100%	

Note that proposed concessions for Rimba Raya are 75% larger than previously developed concessions (avg 11,809 ha compared to avg 6,746 ha). Rapid build-out on relatively small concessions limits conversion rate analysis based on annual area of conversion. In order to extend this analysis to future scenarios, the cumulative proportion of build-out is applied to Rimba Raya concessions, shown in Table 13

Table 13. Average Percent Area Developed applied to Rimba Raya Concessions

AVERAGE						
	yr1	yr2	yr3	yr4	yr5	yr6
RR1	2884.6	6878.9	8176.9	8740.8	8984.6	9286.0
RR2	3906.9	9316.8	11074.9	11838.6	12168.7	12577.0
RR3	3628.6	8653.1	10285.9	10995.2	11301.8	11681.0
RR4	4253.6	10143.6	12057.6	12889.1	13248.5	13693.0
total	14673.7	34992.4	41595.3	44463.8	45703.6	47237.0

There is a moderate amount of variation and uncertainty associated with these averages in Table 10, so to incorporate this uncertainty for a conservative estimate of development rate, the low expected average % development (18.4% in year 1, 57.3% in year 2 etc) was applied to RR concessions to quantify minimum expected rate of development (Table 14).

Table 14. Minimum expected Conversion Rate for Rimba Raya Concessions

LOW	yr1	yr2	yr3	yr4	yr5	yr6
RR1	1707.2	5322.3	6553.2	7923.0	8583.1	9286.0
RR2	2312.2	7208.6	8875.7	10731.0	11624.9	12577.0
RR3	2147.5	6695.0	8243.4	9966.5	10796.8	11681.0
RR4	2517.4	7848.2	9663.3	11683.2	12656.4	13693.0
total	8684.2	27074.1	33335.7	40303.8	43661.2	47237.0

This scenario accounts for the uncertainty around the mean proportion of area converted. From these data its evident the rate of development is not linear, peaking around year 2 then tapering close to build-out. However, applying a linear deforestation rate is conservative and makes baseline calculations more straight-forward and transparent. By delaying expected plantation development in the south (concessions 3 and 4) by one year and by applying a linear rate of conversion of 2,800 ha per year, the baseline scenario shows a 6-year build-out scenario similar to that of the expected rate under the maximum level of uncertainty (Table 15). This rate of deforestation, **2,800 ha per year** is used to estimate baseline CO_2 emissions.

Table 15. Baseline Scenario Oil Palm conversion and Deforestation Rate

BASELINE	yr1	yr2	yr3	yr4	yr5	yr6
RR1	2800.0	5600.0	8400.0	9286.0	9286.0	9286.0
RR2	2800.0	5600.0	8400.0	11200.0	12577.0	12577.0
RR3		2800.0	5600.0	8400.0	11200.0	11681.0
RR4		2800.0	5600.0	8400.0	11200.0	13693.0
TOTAL	5600.0	16800.0	28000.0	37286.0	44263.0	47237.0

9.5 Assessment of Mean Carbon Stocks in Aboveground Biomass

Mean carbon stocks in aboveground biomass are expressed as the sum of biomass in the tree and non-tree components:

$$MC_{B,AG,it} = MC_{B,AG\_tree,it} + MC_{B,AG\_nontree,it} \quad (17)$$

where:

$MC_{B,AG,it}$ = Mean carbon stock in above-ground biomass under the baseline scenario in stratum *i*, time *t*; t C ha^{-1}.

$MC_{B,AG\_tree,it}$ = Mean aboveground biomass carbon stock in tree biomass in stratum *i* at time *t*; t C ha^{-1} (Eq. 33, 34, or 39)

$MC_{B,AG\_nontree,it}$ = Mean aboveground biomass carbon stock in non-tree biomass in stratum *i* at time *t*; t C ha^{-1} (Eq. 18)

Estimation of these components are summarized below.

9.5.1 Tree biomass

The methodology provides three alternatives for measuring aboveground tree biomass. Given the large extent and inaccessibility of Rimba Raya's peat swamp forests, the Aerial Image Method (AIM) was selected as recommended in the methodology (see p. 20). Methods applied are based on Brown et al. (2005) and Slaymaker (2003) and the original technical work was conducted by Forest Carbon. AIM steps and deviations are summarized below. Also see methodological pathways diagram and data parameters table in Section 10 at the end of this document.

AIM Step 1. Tree biomass surveys were conducted in permanent plots on eight transects distributed throughout the Carbon Accounting Area. Measurements were made of tree diameter (D), tree height (H) and tree crown area (A). Field protocols followed standard forestry procedures and are described in the carbon survey SOP (Annex 3). Field methods were identical to those prescribed in the methodology except for slight differences in measurements of tree height (calculated from distance to stem and angles to base and top of tree – deviation in eq.26) and crown area (measured at 2 points rather than 4 - deviation in eq. 23). These deviations did not affect biomass estimates as neither parameter was used in the selected biomass model.

AIM Step 2. Allometric relationships were created to relate Tree Biomass to some combination of Tree Height (H) and /or Tree Crown Area (A) from ground plot data. All equation types were tested using all data and species-specific models were constructed using 16 of the most common species. Results of regression analysis showed that tree species diversity and variation in allometries limited the explanatory power of a single site-specific regression model (R2 = 0.379) . Broadbent et al (2008) conducted a similar exercise but for a larger dataset in the neotropics for the purpose of applying a site-specific regression model to aerial image data. The Broadbent model represents a good alternative to site-specific model and was applied as a deviation in AIM Step 2. In order to account for possible over-estimation of biomass, the results were then calibrated to match biomass estimated from ground-plot data. Results of biomass estimation were reduced over landcover classes by 22.85%, ensuring a conservative estimate.

AIM Step 3. Aerial photography was flown of the project area to collect high resolution imagery in systematically spaced transects over Rimba Raya concession. A total of 3,380 photographs were taken over Rimba Raya, each one covering approximately 120 ha, with a focus on the carbon accounting area. Photos were ortho-rectified in preparation for tree crown assessment.

AIM Step 4. ArcGIS software was used to view and analyze aerial imagery. 2D aerial image files were processed since only tree crown (not tree height) was used in biomass estimation modelling as allowed by the methodology.

AIM Step 5. Virtual plots were established on images in a stratified random manner. 1 ha square plots were systematically installed at the center of each photo to avoid any effects from lens distortion.

The sampling framework followed methodology requirements as follows:

Sample size was established by conducting a pilot study with n=20 plots for each land cover strata and calculating biomass variance. A 10% sample error with a 90% Confidence Interval was applied to generate the number of plots needed in each strata. A total of 364 aerial plots were analyzed for biomass estimation.

Plot size was sufficiently large to minimize between-plot variation in biomass for the number of sample plots established. The CDM Tool suggests plot sizes of at least 100-1000 m2 (depending on stand density) to adequately capture biomass variation, and subsequently reduce sample size. Aerial plot size at Rimba Raya was 10,000 m^2, so each plot is expected to be highly representative of the vegetation within its boundaries.

Plot location followed a stratified random design with all Carbon Accounting Area land cover classes represented. Plots centers are located at the center point of aerial images as recommended by the Methodology.

Stratification was performed based on available land cover mapping (e.g. Ministry of Forestry and Orangutan Foundation International) and satellite imagery (e.g. Landsat and ALOS 2008). Initial stratification included all major forest blocks and transects were located throughout these blocks to maximize sample size for ground measurements including tree DBH, crown diameter and peat depth. Final stratification was performed based on improved data and supplementary sampling (e.g. 2009 Landsat imagery and aerial image and ground reference data).

Accuracy assessment was performed on final stratification and a confusion matrix generated as required by the Methodology. An overall classification accuracy of 81.3% was obtained. The predominant class by area, lightly degraded peat swamp forest covering 30,445 ha or 33.5% of Rimba Raya, was mapped with 90.0% accuracy. A weighted kappa coefficient of 0.78 indicated there is good agreement between all map classes interpreted from satellite imagery and aerial photo data. This stratification was used in the final sample design for aerial plot locations.

AIM Step 6. For each plot, tree crown areas were digitized using standard and customized tools in ArcGIS software. Code was written to run in ARCGIS that allowed the GIS operator to click with the mouse on three different points of the outline of each visible tree crown and the software would automatically create a circle polygon using the averaged radius from the three points.

AIM Step 7. Tree biomass was estimated using the Broadbent et al. (2008) regression equation (deviation in eq. 28 and eq. 30) using tree crown areas digitized in virtual plots. Nadir photographs or imagery cannot record all tree crowns in the plots since some crowns will be obscured from view, therefore remotely sensed biomass estimates will under-represent the true biomass present. This issue was addressed in a recent study (Broadbent, Asner, Pena-Carlos, Palace, & Soriano, 2008) that linked biomass estimates from Quickbird imagery with biomass measured in ground plots. The results showed a discrepancy between 30-50% between remotely sensed biomass estimates and ground plots. However, Broadbent et al (2008) were able to construct correction equations relating crown exposure class and the amount of obscured biomass and showed that the relationship was linear ($r2 = 0.65$, $p < 0.001$). Application of the Broadbent regression equation is expected to provide a more accurate estimation of tree biomass.

AIM Step 8. Above ground biomass was calculated per plot.

AIM Step 9. Mean biomass was calculated for each stratum by averaging across plots in a stratum (column 1 in Table 16). In order to account for possible overestimation, biomass estimates were then reduced by 28.5% to match biomass estimates from field plots (column 2 in Table 16). Biomass was converted to carbon in subsequent baseline spreadsheet calculations.

Table 16. Tree Biomass estimation by strata

	Broadbent et al. 2008 Formula	**Calibrated to Ground-based Biomass Estimates**
Land Cover/Land Use Classes	**Mean (tdm/ha)**	**Mean (tdm/ha)**
Peat Swamp Forest - lightly degraded	**267**	206
Peat Swamp Forest Degraded (highly)	**166**	128
Peat Shrubland (<20% Tree Cover)	**63**	49
Kerangas Forest	**112**	86
Kerangas Open Scrub	**75**	58
Low, Sparse vegetation cover	**13**	10
Seasonally Inundated Wetlands	**18**	14

9.5.2 Non-tree biomass

According to the methodology, non-tree biomass includes trees smaller than the minimum tree size measured in the tree biomass pool, and all other non-herbaceous (woody) live vegetation. At Rimba Raya, non-tree biomass is dominated by tree saplings 5-10 cm DBH. All trees of this size class were measured in 150 small plots (78.5m2) on 30 transects totaling 15 km in the carbon survey area. Biomass was calculated for each transect by applying the Chave et al. (2005) regression equation (eq. 4).

Results showed that in peat swamp forest, average estimated non-tree biomass is 7965.74 tdm/ha representing 3.72% of total aboveground (tree + non-tree) biomass. In transitional kerangas forest, non-tree biomass is 6644.88 tdm/ha representing 5.60% of total aboveground biomass. Based on this study, non-tree biomass contributes <0.5% to total GHG emissions (all biomass burning represents 7.1% of total GHG emissions). Given the level of effort required to carry out this intensive sampling across Rimba Raya and pursuant to guidelines in the "Tool for testing significance of GHG emissions in A/R CDM project activities" (Version 01), it was determined that non-tree biomass would be excluded from mean carbon stock assessment.

9.6 Estimation of GHG Emissions from changes in Aboveground Biomass

Calculations for carbon stock change in aboveground biomass are explained in full in methodology section 8.1 and are 1) the sum of carbon stock changes due to timber extraction prior to land clearing, 2) biomass burning of the remaining vegetation and 3) re-growth of replacement vegetation (palm oil). Each of these components are presented below. Note that since palm oil plantations operate on a 25-30 year timeframe, emissions from harvest rotations were conservatively excluded from calculations.

$$\Delta C_{B,AG,it} = E_{timber,it} + E_{B,BiomassBun,it} - R_{B,growthit} + E_{harvest,it} \quad (3)$$

where:

$\Delta C_{B,AG,it}$ = sum of carbon stock changes in aboveground biomass under the baseline scenario in stratum *i* at time *t*; t CO_2-e

$E_{timber,it}$ = sum of carbon stock changes in aboveground biomass due to timber extraction prior to land clearing in stratum *i* at time *t*; t CO_2-e

$E_{B,BiomassBun,it}$ = sum of carbon stock changes in aboveground biomass due to biomass burning for stratum *i* at time *t* under the baseline scenario; t CO_2-e

$R_{B,growthit}$ = sum of carbon stock changes in aboveground biomass due to biomass growth of living vegetation on the future land-use for stratum *i* at time *t*; t CO_2-e

$E_{harvest,it}$ = sum of carbon stock changes in aboveground biomass due to harvest activities at rotation on baseline future land-use for stratum *i* at time *t*; t CO_2-e

9.7 Emissions from timber

The biomass of timber extracted under the baseline scenario was estimated by implementing the steps outlined in section 8.1.1 in the methodology. Per applicability condition J of this methodology, in the baseline scenario the project land is assumed to be logged for timber prior to land clearing. Emissions from timber extraction are calculated as:

$$E_{timber,it} = (C_{B,it}^{extracted} - C_{B,it}^{woodproducts}) \cdot \frac{44}{12} \quad (4)$$

and

$$C_{B,it}^{extracted} = B_{B,it}^{logged} \cdot CF \cdot A_{B,it}^{logged} \quad (5)$$

$$C_{B,it}^{woodprodus} = C_{B,it}^{extracted} \cdot p \quad (6)$$

where:

$C_{B,it}^{extracted}$	= carbon stocks from trees extracted under the baseline scenario in stratum i at time t; t C
$C_{B,it}^{woodprodus}$	= carbon stocks moving into long-term wood products under the baseline scenario for stratum i at time t; t C
$B_{B,it}^{logged}$	= timber biomass logged under the baseline scenario for stratum i at time t; t d.m. ha^{-1}
CF	= carbon fraction of dry matter (0.5 t C / t biomass); dimensionless
$A_{B,it}^{logged}$	= Area of land logged under the baseline scenario for stratum i, in time t; ha
p	= percent of harvest industrial roundwood going into long term wood products

9.7.1 Estimation of area cleared and logged

The annual area of clearing was estimated to be 2,800 ha/year based on the deforestation rate assessment. This annual rate of clearing was applied to land cover types classed as forest to estimate area logged. The assumption has been made that forest conversion will happen relatively sequentially with clearing of the four concessions beginning in Years 1-4 and continuing at a rate of 2,800 ha yr-1 for a total clearing of 47,237 ha. Because there are multiple land cover types within each concession, area-weighted carbon stocks were used in the calculations.

9.7.2 Estimation biomass logged

All tree species above the minimum diameter threshold were assumed to be harvested. It is conservative to assume a larger proportion of trees extracted before the remaining trees are burned, because some of the carbon in the extracted timber is stored as long-term wood products. The minimum diameter that would have been harvested under the baseline scenario was assumed to be 30 cm. This threshold is based on market survey information collected by BOSF on common practice in the region.

Biomass in the commercial component of tree species logged was estimated based on Mawas plot data. Based on measurements of 93 logging gaps in the Mawas project region, **36%** of the total aboveground biomass per tree is assumed to be extracted as timber (Table 17). This proportion was conservatively applied to the total biomass of trees larger than 10 cm, estimated based on aerial image method described above, to derive an estimation of biomass logged for Rimba Raya.

9.7.3 Estimation of proportion of wood products

For the purpose of estimating long-term wood products, “long-lived” is assumed to be >5 years. In the project region, the proportion of harvested wood that goes into long-term wood products was obtained using FAO (1995) data for Indonesia cited in Winjum et al. (1998).[17]:

- Table 4 of this study gives a net production of industrial roundwood (IR) of 12 Tg C in 1990.
- Table 5 gives a value of 3 Tg of wood going into long-term wood products (use >5 yr; definition of long-term according to FAO definition)
- Thus, the percent of harvest logs (IR produced for all of Indonesia) going into long-term wood products is 3/12= **25%**. The remainder (short-term use <5 yr) is assumed to be oxidized in the base year.
- It was further assumed that the efficiency of milling and the proportion going into long term wood products has not changed and will not change over the next 30 years
- Wood waste generated at each stage of the conversion of timber to products was assumed to be decomposed in the year of harvest; none of the wood waste is used for cogeneration.

Wood products are therefore assumed to account for **25%** of the extracted timber (Table 17).

9.7.4 Timber Emissions Calculations

Table 17. Calculations of CO2 emissions from timber extraction for each land cover stratum in the Rimba Raya project boundary. An area-weighted average of all land cover types was used in the final calculations.

Substratum	Total Biomass in trees >10 cm diameter (t d.m. ha^{-1})	Biomass Extracted as Merchantable Timber >30cm (% total biomass) 36%	Carbon extracted as timber (t C ha^{-1})	Carbon Carbon Preserved as Solid Wood Products as a % yield of log 25%	Net Carbon Extracted (t C ha-^{1})	Area Weighted CO_2 emissions (t CO_2 ha^{-1})
Peat Forest (lightly degraded)	206	74.16	37.08	9.27	27.81	92.74
Peat Swamp Forest Degraded (highly)	128	46.08	23.04	5.76	17.28	4.30
Peat Shrubland (<20% Tree Cover)	49	NA	NA	NA	NA	NA
Kerangas Forest	86	30.96	15.48	3.87	11.61	0.96
Kerangas Open Scrub	58	NA	NA	NA	NA	NA
Low, sparse vegetation cover	10	NA	NA	NA	NA	NA
Seasonally Inundated Wetlands	14	NA	NA	NA	NA	NA
Open Water	0	NA	NA	NA	NA	NA

[17] FAO 1995. FAO Yearbook: Forest products. FAO For. Serv. No. 28, FAO, Rome, 422 p

Based on a clearing rate of **2,800 ha yr^{-1}** for the establishment of four oil palm plantations over ten years annual baseline emissions from timber extraction are **558,684 t CO2e in year 1**, with an accumulative total of **2,254,913 t CO_2e** over the first ten years and the same accumulative total for the 30 year life of the project.

In all the following tables, starting in year 11, the rows are shaded since these estimates are to be considered approximates and a revised baseline will need to be calculated before year 10 and re-validated.

Table 18. Annual CO2e emissions from timber extraction (t CO2e yr-1)

Year of Project	Hectares of Timber Extracted per year	Annual emissions (t CO_2e)	Cumulative
1	5,600	558,684	558,684
2	11200	942,209	1,500,894
3	8104	691,873	2,192,766
4	668	62,147	2,254,913
5	0	0	2,254,913
6	0	0	2,254,913
7	0	0	2,254,913
8	0	0	2,254,913
9	0	0	2,254,913
10	0	0	**2,254,913**
11	0	0	2,254,913
12	0	0	2,254,913
13	0	0	2,254,913
14	0	0	2,254,913
15	0	0	2,254,913
16	0	0	2,254,913
17	0	0	2,254,913
18	0	0	2,254,913
19	0	0	2,254,913
20	0	0	2,254,913
21	0	0	2,254,913
22	0	0	2,254,913
23	0	0	2,254,913
24	0	0	2,254,913
25	0	0	2,254,913
26	0	0	2,254,913
27	0	0	2,254,913
28	0	0	2,254,913
29	0	0	2,254,913
30	0	0	2,254,913
Total	25,572	**2,254,913**	

9.8 Emissions from biomass burning for land clearing

The carbon stocks remaining in the aboveground biomass pool that are left to burn after timber extraction was estimated by implementing the steps outlined in section 8.1.2 in the methodology. Per applicability condition C it is assumed in the baseline scenario that all remaining biomass that is not harvested as timber would be cleared by fire to prepare the site for new land use activity. GHG emissions from biomass burning are estimated as:

$$E_{B,BiomassBun,it} = E_{B,BiomassBun,CO2,it} + E_{B,BiomassBun,N2O,it} + E_{B,BiomassBun,CH4,it} \quad (12)$$

and

$$E_{B,BiomassBun,CO2,it} = \left(C_{B,AC,it} \cdot PBB_{B,it} \cdot CE\right) \cdot \frac{44}{12} \quad (13)$$

The carbon extracted as timber was subtracted from total aboveground carbon stocks, and the remainder was assumed to burn (proportion burned or $PBB_{B,it}$ = 1) with a combustion efficiency of 0.5 (IPCC default) as per the methodology.

Emissions of non-CO2 gases are given by:

$$E_{B,BiomassBun,N2O,it} = E_{B,BiomassBun,CO2,it} \cdot \frac{12}{44} \cdot \left(N/Cratio\right) \cdot ER_{N_2O} \cdot \frac{44}{28} \cdot GWP_{N_2O} \quad (15)$$

and

$$E_{B,BiomassBun,CH4,it} = E_{B,BiomassBun,CO2,it} \cdot \frac{12}{44} \cdot ER_{CH_4} \cdot \frac{16}{12} \cdot GWP_{CH_4} \quad (16)$$

N/C Ratio, Emission Ratios and Global Warming Potential used default values prescribed by the methodology:

$N/Cratio$	= nitrogen-carbon ratio (IPCC default = 0.01); dimensionless
ER_{N2O}	= emission ratio for N_2O (IPCC default value = 0.007); t CO_2-e (t C)$^{-1}$
ER_{CH4}	= emission ratio for CH_4 (IPCC default value = 0.012); t CO_2-e (t C)$^{-1}$
GWP_{N2O}	= Global Warming Potential for N_2O (= 310 for the first commitment period); t CO_2-e (t N_2O)$^{-1}$
GWP_{CH4}	= Global Warming Potential for CH_4 (= 21 for the first commitment period); t CO_2-e (t CH_4)$^{-1}$

Total CO_2e emissions from biomass burning are **557,304 yr^{-1}** and **3,912,438 t CO_2e total** for the first 10 years and the same accumulative total for the 30 year life of the project, as detailed in the table below.

Table 19. Annual CO2e emissions from biomass burning (t CO2e yr-1)

Year of Project	Area burned yr-1	Total CO_2 emissions (t CO_2e)	Cumulative CO2 emission (t CO_2e)
1	5,600	557,304	557,304
2	11,200	932,655	1,489,960
3	11,200	932,655	2,422,615
4	9,286	749,749	3,172,364
5	6,977	517,836	3,690,199
6	2,974	222,239	3,912,438
7	0	0	3,912,438
8	0	0	3,912,438
9	0	0	3,912,438
10	0	0	3,912,438
11	0	0	3,912,438
12	0	0	3,912,438
13	0	0	3,912,438
14	0	0	3,912,438
15	0	0	3,912,438
16	0	0	3,912,438
17	0	0	3,912,438
18	0	0	3,912,438
19	0	0	3,912,438
20	0	0	3,912,438
21	0	0	3,912,438
22	0	0	3,912,438
23	0	0	3,912,438
24	0	0	3,912,438
25	0	0	3,912,438
26	0	0	3,912,438
27	0	0	3,912,438
28	0	0	3,912,438
29	0	0	3,912,438
30	0	0	3,912,438
Total	**47,237**		**3,912,438**

9.9 GHG removals from oil palm sequestration

In the baseline scenario, a new land use (palm oil plantation) is established after merchantable trees are harvested and the remaining biomass is cleared with fire. To remain conservative, the baseline calculations must account for the removal of CO_2 that occurs due to biomass growth of living trees on the future land use, as per the methodology section 8.1.3. This biomass growth is estimated as:

$$R_{B,growth,it} = R_{ARB,it} \cdot A_{it}^{planted} \cdot \frac{44}{12} \tag{40}$$

To estimate $R_{ARB,it}$, growth curves for palm oil were constructed from literature data. Equations 43-46 from the approved methodology were used to estimate the accumulation of biomass carbon on the future plantation sites. Biomass data used to formulate a non-linear growth curve are cited in Cannell (1982) but reported originally in Ng et al. (1968). In Malaysia, one or two palms of average size were sampled from each high-yielding, fertilized stand on marine clay with fine sandy loams. Stand values were obtained by multiplying mean values by the number of palms per hectare (palms ha-1 = 148 at all age classes).

Dry biomass values for stem wood and bark were combined with values for branches, fruit and foliage to compute a total aboveground biomass value. The use of these data is conservative because oil palm would likely have lower growth rates on peat soils than on high-yielding, fertilized stands on mineral soils. Equation 44 of the proposed methodology requires the use of four parameters to calibrate the non-linear growth function. The modeled growth curve and data points used to fit the curve are shown in Figure 27.

A 90% CI was constructed for the regression model (95%CI shown in Figure 24) and used to calculate uncertainty across palm oil cohorts and years in the baseline scenario. Uncertainty is low overall in the palm oil growth parameter (<4% over the 30-year project life) but exceeds the 10% precision target in years 3-8. Baseline palm oil carbon accumulation associated with these years is low, especially compared to other carbon pools such that the project meets the allowable uncertainty under this methodology of +/- 10% CREDD, at the 90% confidence level. (methodology p.98). However, in order to build in conservativeness, estimated carbon accumulation associated with palm oil growth has been increased in years 3-8 to account for the maximum expected uncertainty.

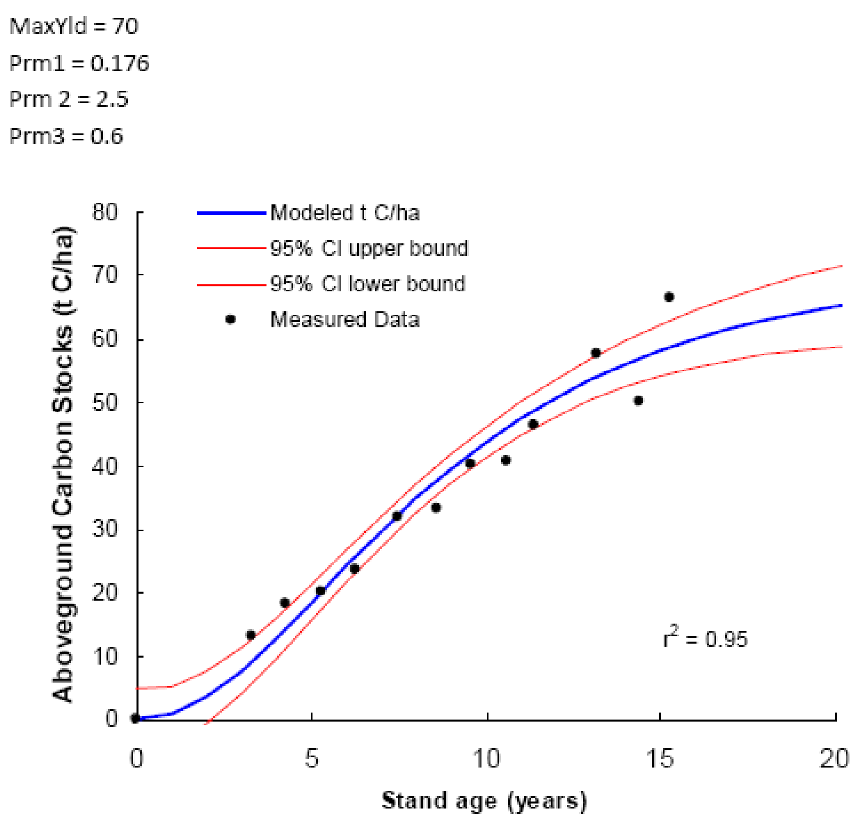


Figure 27. Modeled growth curve for oil palm (source: Ng et al. 1968).

To estimate $A^{planted}$, it is assumed that the concession areas would have been drained, cleared and burned one year prior to planting. Based on satellite image analysis of palm oil conversion rate by PT. BEST, the agent of deforestation, planting was assumed to occur at 2,800 ha yr^{-1}, for a total of six age "cohorts" of trees across the four concessions.

GHG removals from the palm oil sequestration are calculated as **-4,230,884** **t CO_2e** over the first ten years and **-12,083,770** **t CO_2e** for the 30 year life of the project.

Table 20. Annual carbon sequestration in (t CO2e yr-1) from oil palm growth

Year of project	TOTAL		
	Total C accumulation (t C yr-1)	Total CO2 accumulation (t CO2 yr-1)	Cumulative total CO2 accumulation (t CO2 yr-1)
1	0	0	0
2	0	0	0
3	17,813	65,314	65,314
4	44,108	161,729	227,043
5	82,281	301,696	528,739
6	127,532	467,616	996,355
7	173,214	635,119	1,631,474
8	211,649	776,046	2,407,520
9	242,367	888,679	3,296,199
10	254,914	934,685	4,230,884
11	253,246	928,570	5,159,454
12	241,845	886,764	6,046,218
13	224,497	823,155	6,869,374
14	204,061	748,225	7,617,599
15	182,553	669,362	8,286,961
16	161,311	591,475	8,878,437
17	141,169	517,618	9,396,055
18	122,595	449,513	9,845,568
19	105,809	387,968	10,233,536
20	90,868	333,183	10,566,719
21	77,720	284,974	10,851,693
22	66,254	242,933	11,094,626
23	56,326	206,529	11,301,155
24	47,778	175,186	11,476,341
25	40,452	148,324	11,624,665
26	34,196	125,387	11,750,051
27	28,871	105,861	11,855,913
28	24,349	89,281	11,945,194
29	20,518	75,231	12,020,425
30	17,276	63,345	12,083,770
Total	**3,295,574**	**12,083,770**	

9.10 GHG emissions from Peat

In addition to aboveground changes in carbon stocks, baseline emissions also include emissions from peat and are estimated as:

$$E_{B,p,it} = E_{B,Drainageit} + E_{B,PeatBurn,it} \quad (56)$$

9.11 Peat drainage

GHG emissions from peat drainage resulting from baseline land clearing are estimated as:

$$E_{B,drainageit} = A_{B,drainit} \cdot ME_{B,dd,it} \quad (57)$$

and:

$$ME_{B,dd,it} = f(D_{B,drainit}) \quad (58)$$

where:

$E_{B,drainage,it}$	= CO_2 emissions from peat drainage under the baseline scenario in stratum *i* at time *t*, t CO_2-e
$A_{B,drain,it}$	= area of drainage impact under the baseline scenario in stratum *i*, time *t*, ha
$ME_{B,dd,it}$	= mean CO_2 emissions from drained peat in stratum *i*, time *t*, t CO_2 ha^{-1}
$D_{B,,drain,it}$	= average depth of peat drainage or average depth to water table under the baseline scenario in stratum *i*, time *t*, cm

9.11.1 Depth of peat drainage ($D_{B, drain,it}$)

To be conservative, it is assumed that areas outside the proposed plantation boundaries would be unaffected by drainage under the baseline scenario. For this analysis, it is assumed that all peat areas within the project area are undrained and that palm oil plantations maintain a constant drainage depth **restricted to 100 cm** below the surface (conservative value required by the methodology). This is based on data from Hooijer et al. (2006)[18] who derived a minimum estimate of 0.80 m, a likely estimate of 0.95 m and a maximum estimate of 1.1 m based on peat depths more shallow than those found in the project site.

9.11.2 Tome dimension of peat drainage

Equation 58 from the methodology (shown above), relating CO2 emissions to drainage depth is assumed to be applicable throughout the life of the project as long as there is a peat supply available to undergo oxidation. Because peat depth in the project exceeds 1.5 meters in depth, the time dimension of peat

[18] Hooijer, A., M. Silvius, H. Wösten, S. Page. 2006. PEAT-CO2, Assessment of CO2 emissions from drained peatlands in SE Asia. Delft Hydraulics report Q3943 (2006).

drainage can be disregarded as per the methodology (section 8.2.1.2) since emissions from drainage would continue for more than 30 years.

9.11.3 Area of peat drainage ***($A_{B, drain,it}$)***

It is widely recognized that forests are not homogenous and coastal Bornean peatlands may include mosaic patches of non-peat soils in close proximity to or mixed with peat. This variation in soil type is often reflected in tree species composition, such as patches of kerangas forest, which are mixed with peat swamp forest species in Rimba Raya. Therefore, to be conservative, all areas that may not meet the peat requirement based on land cover classification, were excluded from belowground biomass estimation in the baseline accounting.

Within the peat areas accounted, the annual area drained was estimated to be 2,800 ha/year based on the land conversion rate assessment presented in section 4.2.2. As per the methodology, once drained, emissions continue in subsequent years for the life of the project in the case of Rimba Raya, such that emissions are cumulative as new areas are cleared over time.

Mean CO2 emissions from drained peat ($ME_{B,dd,it}$)

Drainage depth is linked to CO2 emissions (in t CO2 ha-1 yr-1) using a regression relationship derived primarily from long-term monitoring of peat subsidence in drained peatlands combined with peat carbon content and bulk density analysis[19]. This method filters the contribution of peat compaction from the total subsidence rate, and the remainder is attributed to CO2 emission[20][21]. Long-term monitoring of peat subsidence produces the most accurate and reliable data, but yields only few measurement points. For lack of a large enough population of observations, a linear relation between drainage depth and CO2 emission was fitted through the data, though the actual relation is known to be non-linear. Based on data from Couwenberg et al. (2009), mean CO2 emissions from drained peat were applied as:

$$ME_{B,DD,it} = 1.33 * D_{B,drain,it}$$

In the drainage depth range most common in southeast Asian peatlands, the relation is supported by results from numerous gas emission monitoring studies in peatlands. The mean CO2 emissions factor used in this analysis is considered conservative with ranges cited in Couwenberg et al. (2009), from 0.90 g CO2/cm to 5.0 g CO2cm.

Methane (CH4) fluxes from peat were not accounted for because research to date indicates that CH4 fluxes in tropical peatlands are negligible compared to CO2 fluxes[22].

[19] relation provided in Hooijer et al. (2006).

[20] Furukawa, Y., K. Inubushi, M. Ali, A.M. Itang, H. Tsuruta. 2005. Effect of changing groundwater levels caused by land use changes on greenhouse gas fluxes from tropical peat lands. Nutrient Cycling in Agroecosystems 71: 81-91.

[21] Hadi, A, K. Inubushi, Y. Furukawa, E. Purnorno, M. Rasmadi, H. Tsuruta. 2005. Greenhouse gas emissions from tropical peatlands of Kalimantan, Indonesia. Nutrient Cycling in Agroecosystems 71: 73-80.

[22] Jauhiainen, J., A. Jaya, T. Inoue, J. Heikkinen, P. J. Martikainen and H. Vasander. 2005. Carbon fluxes from a tropical peat swamp forest floor. Global Change Biology 11, 1788-1797.

Baseline drainage emissions from the palm oil concessions are **582,096 t CO2e** in year one, **38,169,542 t CO2e** over the first ten years and **136,469,842 t CO2e** for the 30 year life of the project.

Table 21. Annual emissions from peat drainage (t CO2e yr^{-1})

Year of Project	Area Drained (per year)		Cumulative
	Area of Peat	CO_2e emissions	CO_2e emissions
1	5,238	582,096	582,096
2	13,939	1,708,385	2,290,481
3	22,639	2,785,138	5,075,619
4	29,624	3,939,956	9,015,575
5	34,428	4,578,892	13,594,467
6	36,955	4,915,015	18,509,482
7	36,955	4,915,015	23,424,497
8	36,955	4,915,015	28,339,512
9	36,955	4,915,015	33,254,527
10	36,955	4,915,015	**38,169,542**
11	36,955	4,915,015	43,084,557
12	36,955	4,915,015	47,999,572
13	36,955	4,915,015	52,914,587
14	36,955	4,915,015	57,829,602
15	36,955	4,915,015	62,744,617
16	36,955	4,915,015	67,659,632
17	36,955	4,915,015	72,574,647
18	36,955	4,915,015	77,489,662
19	36,955	4,915,015	82,404,677
20	36,955	4,915,015	87,319,692
21	36,955	4,915,015	92,234,707
22	36,955	4,915,015	97,149,722
23	36,955	4,915,015	102,064,737
24	36,955	4,915,015	106,979,752
25	36,955	4,915,015	111,894,767
26	36,955	4,915,015	116,809,782
27	36,955	4,915,015	121,724,797
28	36,955	4,915,015	126,639,812
29	36,955	4,915,015	131,554,827
30	36,955	4,915,015	136,469,842
Total	**36,955**	**136,469,842**	

9.12 Peat burning

After peat drainage occurs, the upper layer of peat is assumed to be intentionally burned along with aboveground biomass when the land is cleared with fire to prepare the site for new land use. GHG emissions from peat burning are estimated as:

$$E_{B,PeatBurn,it} = E_{B,PeatBurn,CO2,it} + E_{B,PeatBurn,CH4,it} \quad (60)$$

and:

$$E_{B,PeatBurn,CO2,it} = \frac{M_{B,p,it} * EF_{CO_2}}{10^6} \quad (61)$$

In accordance with the methodology, and as presented in Couwenberg et al. (2009), it was conservatively assumed that the average depth of peat burned for initial land clearing **is 0.34m**. The area of peat burned in the baseline scenario is **2,800 ha/yr** as described in the conversion rate analysis.

The default value for peat bulk density **0.14 g/cm^3** was used in baseline calculations.

Note that peat bulk density was surveyed and assessed to be 0.1505 g/cm^3 based on test results from the University of Palangkaraya survey of the project area (see Peat Survey Report). This survey was conducted for the single belowground strata defined for the project and met the uncertainty requirements of the methodology (n=48, sd = 0.0584, uncertainty = 9.234%). However, an additional survey of peat bulk density will be carried out to better represent potential variation in above-ground strata.

Emission factors for peat combustion at lower temperatures (480 °C) taken from Muraleedharan (2000) were assumed for ex ante baseline estimates as required by the methodology, as this results in lower overall GHG emissions and thus a conservative baseline. These were **185,000** g CO2 per ton of peat and **5,785** g CH4 per ton of peat.[23]

Total emissions from peat burned for initial land clearing over the first ten years of the project are estimated at **764,128 t CO_2e yr^{-1}**, and **5,391,249 t CO_2e total** over the first ten years and the same accumulative total for the 30 year life of the project.

Table 22. Annual emissions from peat burning (t CO_2e yr^{-1})

Year of Project	Area Burned (ha)	Total emissions from peat burning (t CO_2e)	Cumulative emissions from peat burning (t CO_2e)
1	5238	764,128	764,128
2	8701	1,269,325	2,033,453

[23] Muraleedharan, T.R., M. Radojevic, A. Waugh, A. Caruana. 2000. Emissions from the combustion of peat: an experimental study. Atmospheric Environment 34: 3033-3035.

3	8701	1,269,325	3,302,778
4	6984	1,018,935	4,321,713
5	4804	700,845	5,022,557
6	2527	368,692	5,391,249
7	0	0	5,391,249
8	0	0	5,391,249
9	0	0	5,391,249
10	0	0	5,391,249
11	0	0	5,391,249
12	0	0	5,391,249
13	0	0	5,391,249
14	0	0	5,391,249
15	0	0	5,391,249
16	0	0	5,391,249
17	0	0	5,391,249
18	0	0	5,391,249
19	0	0	5,391,249
20	0	0	5,391,249
21	0	0	5,391,249
22	0	0	5,391,249
23	0	0	5,391,249
24	0	0	5,391,249
25	0	0	5,391,249
26	0	0	5,391,249
27	0	0	5,391,249
28	0	0	5,391,249
29	0	0	5,391,249
30	0	0	5,391,249
Total	**36,955**	**5,391,249**	

9.13 Ex Post Actual Net GHG Emissions Avoided

GHG emissions from the baseline scenario that are not prevented within the project boundary in the project case (C_{PRJ}), such as logging, fire, or other land use changes that lead to an increase in emissions must be subtracted from the baseline scenario in annual carbon accounting. The calculations are performed annually according to the monitoring plan.

$$C_{ACTUAL} = C_{BSL} - C_{PRJ} \tag{88}$$

where:

C_{ACTUAL} = actual net greenhouse gas emissions avoided; t CO_2-e.

C_{BSL} = sum of peat emissions and carbon stock changes in aboveground biomass under the baseline scenario; t CO_2-e

C_{PRJ} = sum of emissions that occur within the project boundary ; t CO_2-

9.14 Market Leakage

A deduction against the biomass of timber extracted under the baseline scenario must be estimated for Market Leakage by implementing steps outlined in Section 10.1 in the methodology:

Section 10.1 of the Methodology

When REDD project activities result in reductions in wood harvest, it is likely that production could shift to other areas of the country to compensate for the reduction. Therefore, in cases where the project area would be harvested for commercial timber before clearing the site for a new land use, market effects leakage must be estimated as the baseline emissions from logging multiplied by a leakage factor:

$$LK_{MarketEffects} = \sum_{t=1}^{t*} \sum_{i=1}^{m_{LK}} LK_{ME,it} \quad \textbf{(66)}$$

$$LK_{ME,it} = LF_{ME,i} * C_{B,XBT,it} \quad \textbf{(67)}$$

The amount of leakage is determined by where harvesting would likely be displaced to. If in the forests to which displacement would occur a lower proportion of biomass in commercial species is in merchantable material than in the project area, then more trees will need to be cut to supply the same volume and thus higher emissions should be expected. In contrast, if a higher proportion of biomass of commercial species is merchantable in the displacement forest than in the project forest, then a smaller area would need to be harvested and lower emissions would result.

Each project thus shall calculate within each stratum the proportion of total biomass in commercial species that is merchantable (*PMPi*). Merchantable biomass per stratum is conservatively defined as the total volume (converted to biomass) of all commercially valuable trees within a stratum that are above the minimum size class sold in the local timber market (see Applicability Condition J). *PMPi*is therefore equal to the merchantable biomass as a proportion of total aboveground tree biomass for stratum *I* within the project boundaries. *PMPi*shall then be compared to the mean proportion of total biomass that is merchantable for each forest type (*PMLFT*) to which displacement is likely to occur.

The following deduction factors ($LF_{ME,i}$) shall be used:

PML_{FT} is equal (±0.15) to PMP_i	$LF_{ME,i}$	=	0.4
PML_{FT} is > 0.15 less than PMP_i	$LF_{ME,i}$	=	0.7
PML_{FT} is >0.15 greater than PMP_i	$LF_{ME,i}$	=	0.2

Where:

PML_{FT} = Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type; dimensionless

PMP_i = Merchantable biomass as a proportion of total aboveground tree biomass for stratum i within the project boundaries; dimensionless

$LF_{ME,i}$ = Leakage factor for stratum i market-effects calculations; dimensionless

Instead of applying the default market leakage discounts, project proponents may opt to estimate the project's market leakage effects across the entire country and/or use analysis(es) from other similar projects to justify a different market leakage value. A description of the market leakage assessment, including steps for determining where leakage is likely to occur (i.e., to which forest types leakage is likely to occur) and what the carbon stocks of those lands are, shall be outlined in the PDD. The outcome of this assessment conducted at first VCU issuance (whether using default discounts or project specific analysis(es)) shall be subject to the VCS double approval process. Market leakage assessments conducted at validation stage and at verification other than the first VCU issuance are not required to undergo the double approval process.

The next step is to estimate the emissions associated with the displaced logging activity – this is based on the total volume that would have been logged in the project area in the baseline scenario. The emission due to the displaced logging has two components: the biomass carbon of the extracted timber and the biomass carbon in the forest damaged in the process of timber extraction:

$$C_{B,XBT,it} = \left(\left[V_{B,it} * \phi_i * CF\right] + \left[V_{B,it} * LDF\right]\right) * \frac{44}{12} \quad \textbf{(68)}$$

Where:

$C_{B,XBT,it}$ = Carbon emission due to displaced timber harvests in the baseline scenario in stratum i at time t; t CO_2-e

$V_{B,it}$ = Volume to be extracted under the baseline scenario in stratum i at time t; m^3

ϕ_i = volume-weighted average wood density; t d.m. m^{-3} merchantable volume

CF = carbon fraction of dry matter (0.5 t C / t biomass); dimensionless

LDF = Logging damage factor; t C m^{-3} (default 0.37 t C m^{-3})

i = 1, 2, 3, ..., m_{BL} baseline strata

t = 1, 2, 3, ..., t^* years elapsed since the projected start of the REDD project activity

The total volume to be extracted under the baseline scenario in stratum i at time t (VB,it) can be estimated by multiplying the plot-level volume per stratum (MVB,it see Eq. 34) by the area cleared or logged in stratum I at time t (A cleared ,it or A logged B,it).

The logging damage factor (*LDF*) is a representation of the quantity of emissions that will ultimately arise per unit of extracted timber (m3). These emissions arise from the non-commercial portion of the felled tree (the branches and stump) and trees incidentally killed during tree felling. The default value given here comes from the slope of the regression equation between carbon damaged and volume extracted based on 534 logging gaps measured by Winrock International in Bolivia, Belize, Mexico, the Republic of Congo, Brazil, and Indonesia.

Though project proponents have made a defensible econometrics argument that neither Activity Shifting nor Market Leakage can occur with a finite non-renewable resource (peat lands) in the PD, both have been accounted for in Baseline calculations in accordance with the methodology.

In order to demonstrate the conservativeness of the methodology and these calculations, the econometrics argument against the existence of both Activity Shifting and Market Leakage is annexed herein as Annex 5 although it was not used in the calculations.

Leakage from Market Effects was taken as a one-time deduction[24] of **-4,836,855 t CO2e** as detailed in the section below.

Table 23. Annual CO2e emissions deductions from market leakage (t CO2e yr-1)

Year of Project	Area logged yr-1	Total CO_2 emissions (t CO_2e)	Cumulative CO2 emission (t CO_2e)
1	0	0	0
2	5,600	(1,198,394)	(1,198,394)
3	11,200	(2,021,067)	(3,219,461)
4	8,104	(1,484,087)	(4,703,548)
5	668	(133,306)	(4,836,855)
6	0	0	(4,836,855)
7	0	0	(4,836,855)
8	0	0	(4,836,855)
9	0	0	(4,836,855)
10	0	0	(4,836,855)
11	0	0	(4,836,855)
12	0	0	(4,836,855)
13	0	0	(4,836,855)
14	0	0	(4,836,855)
15	0	0	(4,836,855)
16	0	0	(4,836,855)
17	0	0	(4,836,855)
18	0	0	(4,836,855)
19	0	0	(4,836,855)
20	0	0	(4,836,855)
21	0	0	(4,836,855)
22	0	0	(4,836,855)
23	0	0	(4,836,855)

[24] Note that the "one-time" market leakage deduction refers to this deduction being taken "up-front" since market leakage is not monitored, but over a five-year period (year 2-6) in accordance with the estimated land clearing rate.

24	0	0	(4,836,855)
25	0	0	(4,836,855)
26	0	0	(4,836,855)
27	0	0	(4,836,855)
28	0	0	(4,836,855)
29	0	0	(4,836,855)
30	0	0	(4,836,855)
Total	**25,572**		**(4,836,855)**

9.15 Quantifying GHG emission reductions and removal enhancements for the project

9.15.1 Total gross baseline emissions

The table below summarizes the gross GHG emissions avoided by preventing the establishment of palm oil plantations in the project area. This summary table is broken down by component and shows that peat drainage is overwhelmingly the most significant source of GHG emissions associated with palm oil development.

Under the VCS, the baseline must be reassessed after ten years. Therefore, the baseline emissions in the first ten years should be the focus of attention; estimates beyond the 10-year window are subject to change as new policy measures are instituted and new data become available.

*Total Gross Baseline emissions after leakage deductions are **2,462,212 t CO_2e** in year one, **40,660,403 t CO_2e** over the first ten years and **131,107,818 t CO_2e** for the 30 year life of the project.*

Table 24. Total gross GHG emissions avoided due to project activities (after leakage deductions).

Yr of Project	Em. from timber (t CO_2e)	Em. from biomass burning (t CO_2e)	Growth of oil palm (t CO_2e)	Em. from peat burning (t CO_2e)	Em. from peat drainage (t CO_2e)	Total Gross CO2e Baseline emissions (t CO_2e)	Market Leakage Deductions (t CO_2e)	Total Gross Emissions after Market Leakage Deduction (t CO_2e)	Total Gross Cumulative CO2e emissions (t CO_2e)
1	558,684	557,304	0.00	764,128	582,096	2,462,212	0	2,462,212	2,462,212
2	942,209	932,655	0.00	1,269,325	1,708,385	4,852,575	(1,198,394)	3,654,181	6,116,393
3	691,873	932,655	(65,314)	1,269,325	2,785,138	5,613,677	(2,021,067)	3,592,611	9,709,003
4	62,147	749,749	(161,729)	1,018,935	3,939,956	5,609,057	(1,484,087)	4,124,970	13,833,973
5	0	517,836	(301,696)	700,845	4,578,892	5,495,876	(133,306)	5,362,569	19,196,543
6	0	222,239	(467,616)	368,692	4,915,015	5,038,330	0	5,038,330	24,234,873
7	0	0	(635,119)	0	4,915,015	4,279,896	0	4,279,896	28,514,769
8	0	0	(776,046)	0	4,915,015	4,138,969	0	4,138,969	32,653,738
9	0	0	(888,679)	0	4,915,015	4,026,336	0	4,026,336	36,680,074
10	0	0	(934,685)	0	4,915,015	3,980,330	**0**	**3,980,330**	**40,660,403**
11	0	0	(928,570)	0	4,915,015	3,986,445	0	3,986,445	44,646,849

12	0	0	(886,764)	0	4,915,015	4,028,251	0	4,028,251	48,675,099
13	0	0	(823,155)	0	4,915,015	4,091,860	0	4,091,860	52,766,959
14	0	0	(748,225)	0	4,915,015	4,166,790	0	4,166,790	56,933,749
15	0	0	(669,362)	0	4,915,015	4,245,653	0	4,245,653	61,179,402
16	0	0	(591,475)	0	4,915,015	4,323,540	0	4,323,540	65,502,941
17	0	0	(517,618)	0	4,915,015	4,397,397	0	4,397,397	69,900,338
18	0	0	(449,513)	0	4,915,015	4,465,502	0	4,465,502	74,365,840
19	0	0	(387,968)	0	4,915,015	4,527,047	0	4,527,047	78,892,887
20	0	0	(333,183)	0	4,915,015	4,581,832	0	4,581,832	83,474,719
21	0	0	(284,974)	0	4,915,015	4,630,041	0	4,630,041	88,104,760
22	0	0	(242,933)	0	4,915,015	4,672,082	0	4,672,082	92,776,842
23	0	0	(206,529)	0	4,915,015	4,708,486	0	4,708,486	97,485,328
24	0	0	(175,186)	0	4,915,015	4,739,829	0	4,739,829	102,225,157
25	0	0	(148,324)	0	4,915,015	4,766,691	0	4,766,691	106,991,848
26	0	0	(125,387)	0	4,915,015	4,789,628	0	4,789,628	111,781,476
27	0	0	(105,861)	0	4,915,015	4,809,154	0	4,809,154	116,590,630
28	0	0	(89,281)	0	4,915,015	4,825,734	0	4,825,734	121,416,364
29	0	0	(75,231)	0	4,915,015	4,839,784	0	4,839,784	126,256,148
30	0	0	(63,345)	0	4,915,015	4,851,670	0	4,851,670	**131,107,818**
Totals	**2,254,913**	**3,912,438**	**(12,083,770)**	**5,391,249**	**136,469,842**	**135,944,672**	**(4,836,855)**		

9.15.2 Total net baseline emissions

In accordance with the methodology, an uncertainty assessment was conducted for all parameters where required and is specified for all parameters in section 10 of this document. Typically the uncertainty confidence deduction was zero (default value used or uncertainty quantified to be <10%). In rare cases, where uncertainty could not be calculated or exceeded 10%, parameter estimates were adjusted to conservatively include this uncertainty. This built-in confidence deduction was developed by parameter so that carbon pool estimates were conservative and further confidence deductions were not warranted in calculated summary emissions.

Section 24.3 of the methodology

The allowable uncertainty under this methodology is +/- 10% of CREDD,t at the 90% confidence level. Where this precision level is met, then no deduction should result for uncertainty. Where uncertainty exceeds 10% of CREDD,t at the 90% confidence level then the deduction shall be equal to the amount that the uncertainty exceeds the allowable level.

The adjusted value for CREDD,t to account for uncertainty shall be calculated as:

$$Adjusted\_C_{REDD,t} = C_{REDD,t} * \frac{(100 \quad C_{REDD\_ERROR,t} \quad 10)}{100} \qquad \textbf{(131)}$$

Where:

$C_{REDD,t}$	Net anthropogenic greenhouse emission reductions at time *t*; t CO_2-e
$C_{REDD\_ERROR,t}$	Total uncertainty for REDD project activity; %
$Adjusted\_C_{REDD,t}$	Adjusted value for $C_{REDD,t}$ to account for uncertainty; t CO_2-e

9.15.3 Non-Permanence Risk Assessment & Deduction and Summary Emissions

Per the VCA standard, a Non-Permenence Risk Assessment has been conducted using the *"VCS_Program Update_Tool For Non-Permanence Risk Analysis And Buffer Determination_090810"* (see Annex 6).

The assessment of a **20% Risk Buffer** (See Annex 6) resulted in a total deduction of **-26,221,564 t CO_2e.** The resulting net baseline emissions are therefore calculated as **1,969,770 t CO_2e** for year one, **32,528,323 t CO_2e** for the first ten years and **104,886,254 t CO_2e** for the 30 year life of the project.

Table 25. Total Buffers deducted from Baseline Emissions

Risk Buffers			Cumulative CO_2e After All Buffers (Final Baseline)
Non-Permanance Risk Buffer	Overall Project Uncertainty Deduction	Total Annual Buffers	
-20%	0%	0	
(492,442)	0	(492,442)	1,969,770
(730,836)	0	(730,836)	4,893,114
(718,522)	0	(718,522)	7,767,203
(824,994)	0	(824,994)	11,067,179
(1,072,514)	0	(1,072,514)	15,357,234
(1,007,666)	0	(1,007,666)	19,387,898
(855,979)	0	(855,979)	22,811,815
(827,794)	0	(827,794)	26,122,990
(805,267)	0	(805,267)	29,344,059
(796,066)	0	(796,066)	**32,528,323**
(797,289)	0	(797,289)	35,717,479
(805,650)	0	(805,650)	38,940,080
(818,372)	0	(818,372)	42,213,567
(833,358)	0	(833,358)	45,546,999
(849,131)	0	(849,131)	48,943,521
(864,708)	0	(864,708)	52,402,353
(879,479)	0	(879,479)	55,920,270
(893,100)	0	(893,100)	59,492,672
(905,409)	0	(905,409)	63,114,309
(916,366)	0	(916,366)	66,779,775

(926,008)	0	(926,008)	70,483,808
(934,416)	0	(934,416)	74,221,474
(941,697)	0	(941,697)	77,988,262
(947,966)	0	(947,966)	81,780,125
(953,338)	0	(953,338)	85,593,479
(957,926)	0	(957,926)	89,425,181
(961,831)	0	(961,831)	93,272,504
(965,147)	0	(965,147)	97,133,091
(967,957)	0	(967,957)	101,004,918
(970,334)	0	(970,334)	**104,886,254**
(26,221,564)		**(26,221,564)**	

10. METHODOLOGICAL PATHWAYS, DATA AND PARAMETERS USED IN BASELINE CALCULATIONS

Methodological pathways for baseline calculations (Figure 28) are taken from the conceptual diagram in the methodology p. 39.

There were deviations in the Aerial Image Method (AIM) steps of the baseline calculations, which are detailed in Figure 26. Briefly, equations 23, 24 and 25 reflect a deviation in tree height and crown area field measurements, neither of which was used in direct biomass estimation. Tree biomass was estimated using the Broadbent et al. (2009) regression equation (deviation in eq. 28 and 30) using tree crown areas digitized in virtual plots. This model performed better than the allometric model using site-specific data. Biomass estimates were then adjusted downward to match ground-based biomass estimates, which are lower than IPCC default values for tropical moist forest.

The deviation in AIM steps had a negligible effect on baseline calculations since methods used are consistent with prescribed methods. The method used produced lower biomass estimates than the IPCC defaults for moist tropical forest, so any effect may be considered conservative. Further, all aboveground biomass contributes <3% to total carbon stocks in Rimba Raya's peat-dominated area.

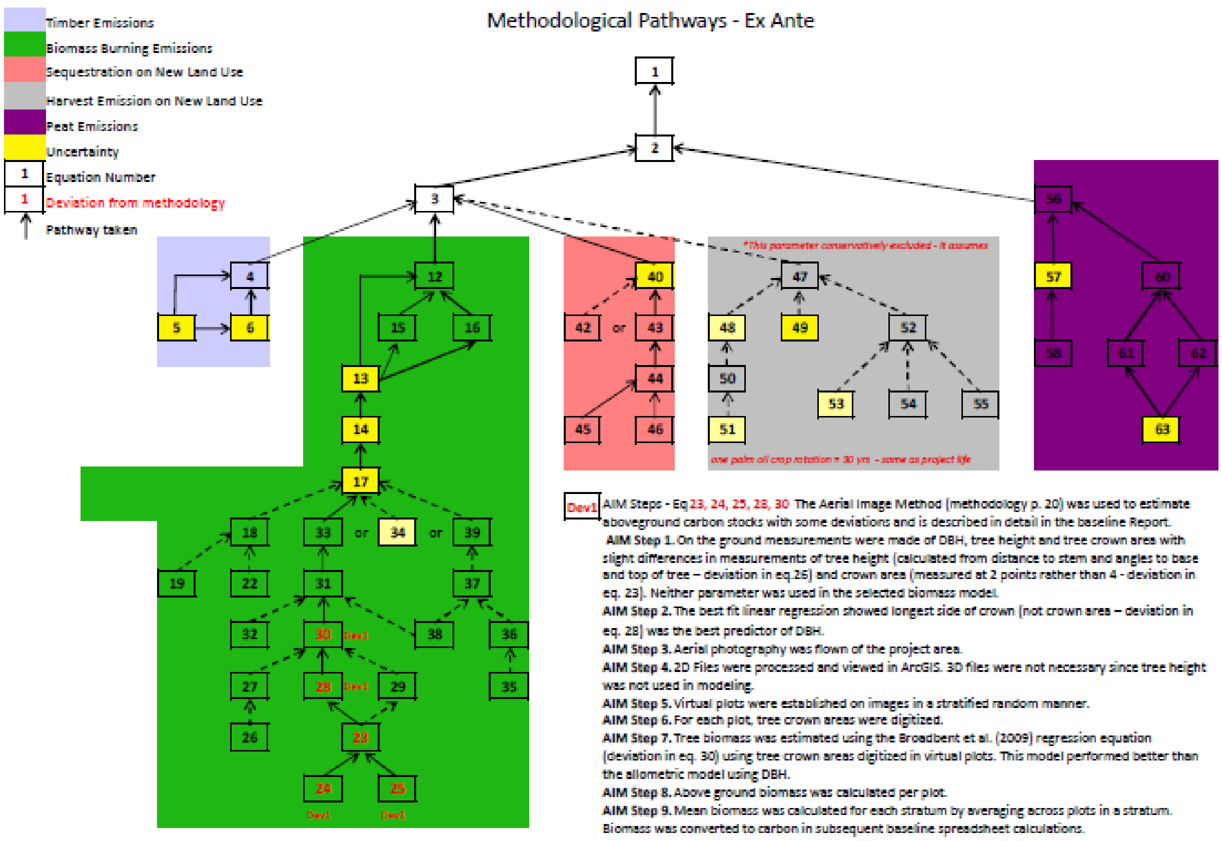


Figure 28. Conceptual diagram of baseline equations and methodological pathways used to calculate Ex-Ante GHG emissions

Specific data collected for ex ante actual net avoided GHG emissions are summarized in Table 26. These data/parameter tables expand on those in the methodology to include value used, assumptions and decisions, uncertainty estimate and deviation information.

Uncertainty estimation was conducted in accordance with the methodology and is presented in the parameter table below. Note that since this methodology is only applicable to projects where deforestation is planned and projected to occur within 10 years of the project start date (Applicability Condition D), **uncertainty in deforestation rate is assumed to be zero** (methodology p. 53). To demonstrate the most likely deforestation rate scenario, an analysis of recent palm oil conversion by the agent of deforestation was conducted. These GIS-based calculations are estimated to be > 90% accurate. GIS-based parameters for ex ante calculations fall into one of two cases, which are referenced in the parameter table:

- Case 1 Area cleared, logged or planted (2,800 ha/yr): These parameters are based on the actual rate of clearing by the deforestation agent, determined from analysis of Landsat data. Landsat is the primary tool for mapping tropical deforestation (Defries et al. 2005) and has been validated against high resolution imagery to be 92-97.5% accurate (NASA accessed January 15, 2011 http://www.glcf.umd.edu/data/paraguay/description.shtml).

- Case 2 Area drained: Drainage area is based on stratification of peat/non-peat which derives from landcover stratification where non-peat types (Kerangas Forest and Open Kerangas Scrub) were differentiated from all other types with 92% producer's accuracy and 98.5% user's accuracy.

Table 26. Data/Parameters Needed for Estimation of Ex Ante GHG Emissions

Data/parameter 1:	CF
Data unit:	Dimensionless
Used in equations:	5, 30, 34, 36, 67
Description:	Carbon fraction of dry matter
Source of data and reference:	IPCC default value = 0.50
Measurement procedures: (if any)	n/a
Value used:	0.50
Comment:	used in multiple spreadsheets in biomass => carbon calculations
Assumptions and Decisions:	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 2:	$A_{B,it}^{logged}$
Data unit:	Ha
Used in equations:	5
Description:	Area of land logged under the baseline scenario for stratum i, in time t
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation
Measurement procedures: (if any)	n/a
Value used:	Rate 2,800 ha/yr (stratum i, time t)
Comment:	Used in Timber Extraction spreadsheet
Assumptions and Decisions	The area logged was assumed to be the area cleared in all landcover types classified as forest. The expected annual rate of conversion was determined by analyzing historical rate of conversion by the baseline agent.
Uncertainty estimate:	Required. Zero. Case 1 described above.
Deviation from Methodology:	None

Data/parameter 3:	P
Data unit:	Dimensionless
Used in equations:	6, 49
Description:	percent of harvest industrial roundwood going into long term wood products
Source of data and reference:	Industry standard value: FAO 1995. FAO Yearbook: Forest products. FAO For. Serv. No. 28, FAO, Rome, 422 p.
Measurement procedures: (if any)	n/a
Value used:	0.25
Comment:	Used in Timber Extraction spreadsheet

Assumptions and Decisions	In the project region, the proportion of harvested wood that goes into long-term wood products was obtained using FAO data for Indonesia cited in Winjum et al. (1998)
Uncertainty estimate:	Required. Zero. Conservative Value. Industry standard dataset (FAO 1995) and report (Winjum et al. (1998) calculated with 90% Confidence Interval.
Deviation from Methodology:	None

Data/parameter 4:	*AP*
Data unit:	m^2
Used in equations:	32, 38
Description:	Plot Area
Source of data and reference:	Aerial plot measurement
Measurement procedures: (if any)	Digitized on aerial photographs using GIS measure tool
Value used:	10,000
Comment:	parameter created but not used
Assumptions and Decisions	eq 38 not used since allometric method not selected as allowed by the methodology p. 20; eq 32 not used because different AIM Step calculations were made.
Uncertainty estimate:	Not required.
Deviation from Methodology:	Deviation AIM Steps

Data/parameter 5:	*BEF*
Data unit:	Dimensionless
Used in equations:	8, 34
Description:	Biomass expansion factor for conversion of biomass of merchantable volume to above-ground biomass
Source of data and reference:	Literature Values
Measurement procedures: (if any)	n/a
Value used:	
Comment:	Parameter not used
Assumptions and Decisions	eq 34 not used (since BEF method not selected as allowed by the methodology p. 20; eq 8 not used because different AIM Step calculations were made.
Uncertainty estimate:	n/a
Deviation from Methodology:	Deviation AIM Steps

Data/parameter 6:	**Φ**
Data unit:	g cm^3
Used in equations:	8, 34, 51, 68
Description:	Volume-weighted average wood density
Source of data and reference:	Literature Value: Reyes, Brown, Chapman and Lugo (1992) mean wood density for tropical Asia

	represented by 428 species, SE = 0.007
Measurement procedures: (if any)	n/a
Value used:	0.57 (SD = 0.145)
Comment:	Used in Biomass Burning Spreadsheet
Assumptions and Decisions	eq 68 used for leakage calculation; eq 34 not used (since BEF method not selected as allowed by the methodology p. 20; eq 8 not used because different AIM Step calculations were made.
Uncertainty estimate:	90%CI/mean* 100 = 2.03%
Deviation from Methodology:	None

Data/parameter 7:	$PBB_{B,it}$
Data unit:	Dimensionless
Used in equations:	13
Description:	average proportion of *CB,AC,it* burnt under the baseline scenario in stratum *i*, time *t*
Source of data and reference:	methodology p. 16
Measurement procedures: (if any)	n/a
Value used:	1
Comment:	Used in Biomass Burning -BL E51
Assumptions and Decisions	As per the methodology p. 16 “because the land is being cleared for another land use in the baseline scenario, all of the biomass that is not extracted as timber is assumed to be burned and therefore this methodology the proportion burned in the baseline $PBB_{B,it}$ is assumed to be equal to 1.”
Uncertainty estimate:	n/a
Deviation from Methodology:	none

Data/parameter 8:	*CE*
Data unit:	Dimensionless
Used in equations:	13, 53
Description:	Average biomass combustion efficiency
Source of data and reference:	IPCC default =0.50
Measurement procedures: (if any)	n/a
Value used:	0.50
Comment:	Used in Biomass Burning spreadsheet
Assumptions and Decisions	
Uncertainty estimate:	Required. Zero. Default value used.
Deviation from methodology:	None.

Data/parameter 9:	$A^{cleared}_{B\,it}$
Data unit:	Ha
Used in equations:	14, 72, 74, 76

Description:	Area cleared under the baseline scenario for stratum *i,* in time *t*
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation
Measurement procedures: (if any)	GIS overlay analysis
Value used:	Rate 2,800 ha/yr (stratum i, time t)
Comment:	Used in Timber Extraction spreadsheet
Assumptions and Decisions	The expected annual rate of conversion was determined by analyzing historical rate of conversion by the baseline agent.
Uncertainty estimate:	Required. Zero. Case 1 described above.
Deviation from Methodology:	None

Data/parameter 10:	*N/C ratio*
Data unit:	Dimensionless
Used in equations:	15, 54
Description:	Nitrogen-carbon ratio
Source of data and reference:	IPCC default =0.01
Measurement procedures: (if any)	n/a
Value used:	0.01
Comment:	used in Biomass Burning spreadsheet
Assumptions and Decisions	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 11:	ER_{N2O}
Data unit:	t CO2-e (t C)-1
Used in equations:	16, 55
Description:	Emission ratio for N2O
Source of data and reference:	IPCC default value =0.007
Measurement procedures: (if any)	n/a
Value used:	0.007
Comment:	see Biomass Burning spreadsheet
Assumptions and Decisions	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 12:	ER_{CH4}
Data unit:	t CO2-e (t C)-1
Used in equations:	16, 55
Description:	Emission ratio for CH4
Source of data and reference:	IPCC default value = 0.012
Measurement procedures: (if any)	n/a

Value used:	0.012
Comment:	see Biomass Burning spreadsheet
Assumptions and Decisions	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 13:	GWP_{N2O}
Data unit:	t CO2-e (t N2O)-1
Used in equations:	15, 54
Description:	Global Warming Potential for N2O
Source of data and reference:	Methodology =310 for the first commitment period
Measurement procedures: (if any)	n/a
Value used:	310
Comment:	see Biomass Burning spreadsheet
Assumptions and Decisions	Used in eq 15. Eq 54 not calculated – as palm oil plantations operate on a 25-30 year timeframe, emissions from harvest rotations were not considered in baseline estimation. This is conservative.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 14:	GWP_{CH4}
Data unit:	t CO2-e (t CH4)-1
Used in equations:	16, 55
Description:	Global Warming Potential for CH4
Source of data and reference:	Methodology =21 for the first commitment period
Measurement procedures: (if any)	n/a
Value used:	21
Any comment:	see Biomass Burning spreadsheet
Assumptions and Decisions	Used in eq 16. Eq 55 not calculated – as palm oil plantations operate on a 25-30 year timeframe, emissions from harvest rotations were not considered in baseline estimation. This is conservative.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 15:	$A_{sampleframe}$
Data unit:	m^2
Used in equations:	20
Description:	Area of one sampling frame
Source of data and reference:	Field Measurement
Measurement procedures: (if any)	n/a
Value used:	

Comment:	Parameter not used
Assumptions and Decisions	non-tree biomass accounts for < 0.5% of total GHG emissions and was conservatively excluded from biomass estimation.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None.

Data/parameter 16:	*CFnon-tree*
Data unit:	Dimensionless
Used in equations:	19
Description:	Carbon fraction of dominant non-tree vegetation species
Source of data and reference:	Field measurement or literature values
Measurement procedures: (if any)	n/a
Value used:	
Comment:	Parameter not used
Assumptions and Decisions	non-tree biomass accounts for < 0.5% of total GHG emissions and was conservatively excluded from biomass estimation.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None.

Data/parameter 17:	*MCAG,nontree_sample,sf,,it*
Data unit:	Kg. d.m.
Used in equations:	19
Description:	Carbon stock in above ground non-tree vegetation in sample plot *sf* in stratum *i* at time *t* from sampling frame method
Source of data and reference:	Field measurement.
Measurement procedures: (if any)	n/a
Value used:	
Comment:	Parameter not used
Assumptions and Decisions	non-tree biomass accounts for < 0.5% of total GHG emissions and was conservatively excluded from biomass estimation.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None.

Data/parameter 18:	*CFq*
Data unit:	t C t-1 d.m.
Used in equations:	21
Description:	Carbon fraction of biomass for species q
Source of data and reference:	Field measurement or literature values
Measurement procedures: (if any)	n/a
Value used:	

Comment:	Parameter not used
Assumptions and Decisions	non-tree biomass accounts for < 0.5% of total GHG emissions and was conservatively excluded from biomass estimation.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None.

Data/parameter 19:	*fq(vegetation parameters)*
Data unit:	t. d.m. individual-1
Used in equations:	21
Description:	Allometric equation for species *q* linking parameters such as stem count, diameter of crown, height, or others to above-ground biomass of an individual
Source of data and reference:	Field measurement or literature values
Measurement procedures: (if any)	n/a
Value used:	
Comment:	Parameter not used
Assumptions and Decisions	non-tree biomass accounts for < 0.5% of total GHG emissions and was conservatively excluded from biomass estimation.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None.

Data/parameter 20:	Ar_i
Data unit:	Ha.
Used in equations:	22
Description:	Total area of all non-tree allometric method sample plots in stratum *i*
Source of data and reference:	Field Measurement
Measurement procedures: (if any)	n/a
Value used:	
Comment:	Parameter not used
Assumptions and Decisions	non-tree biomass accounts for < 0.5% of total GHG emissions and was conservatively excluded from biomass estimation.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None.

Data/parameter 21:	$MC_{AG\_nontree\_allometric,i,r,t}$
Data unit:	t C
Used in equations:	22
Description:	Aboveground biomass carbon stock in nontree vegetation in sample plot *r* of stratum *i* at time *t* from non-tree allometric sample plots
Source of data and reference:	Field measurement.
Measurement procedures: (if any)	n/a

Value used:	
Comment:	Parameter not used
Assumptions and Decisions	non-tree biomass accounts for < 0.5% of total GHG emissions and was conservatively excluded from biomass estimation.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None.

Data/parameter 22:	*angle*
Data unit:	Degrees
Used in equations:	24, 25, 26
Description:	angle formed between observer's eye and end of farthest observable canopy branch facing each of eight compass directions or one of two vantage points (24, 25). Angle formed between observer's eye and top of tree (26)
Source of data and reference:	Field Measurement.
Measurement procedures: (if any)	Clinometer used to position observer directly below canopy edge (angle = 90 and cos angle = 1) for crown dimension measurement (see Field SOP) (similar to 24, 25) and to top and bottom of tree (similar to 26)
Value used:	See Carbon Survey Report data
Comment:	Parameter not used
Assumptions and Decisions	tree height tested but not used in allometric equation as allowed by the methodology AIM Step 2
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 23:	*Dist*
Data unit:	Cm
Used in equations:	24, 25
Description:	distance from observer to end of first canopy branch facing each of eight compass directions or from one of two vantage points
Source of data and reference:	Field Measurement.
Measurement procedures: (if any)	Laser distance measurer used to measure tree distance from single vantage point to the tree stem (see Field SOP)
Value used:	See Carbon Survey Report data
Comment:	Parameter not used
Assumptions and Decisions	tree height tested but not used in allometric equation as allowed by the methodology AIM Step 2
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 24:	*Dbh*
Data unit:	Cm
Used in equations:	24, 25
Description:	diameter at breast height of tree
Source of data and reference:	Field Measurement.
Measurement procedures: (if any)	measured using DBH tape and standard forest survey procedures (see Field SOP)
Value used:	See Carbon Survey Report data
Comment:	
Assumptions and Decisions	Not used in eq 24,25. DBH was used in allometric equation by Chave et al. (2005) to estimate aboveground biomass from survey plots to test/validate biomass estimation equations.
Uncertainty estimate:	Not required.
Deviation from Methodology:	Deviation AIM Step 1.

Data/parameter 25:	H_{eye}
Data unit:	Meters
Used in equations:	26
Description:	height from ground to observer's eye
Source of data and reference:	Field Measurement.
Measurement procedures: (if any)	Clinometer used to measure angle to top and bottom of tree rather than H_{eye} (see Field SOP)
Value used:	See Carbon Survey Report data
Comment:	Parameter not used
Assumptions and Decisions	Note: tree height tested but not used in allometric equation as allowed by the methodology AIM Step 2
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 26:	H_{tree}
Data unit:	Meters
Used in equations:	26, 27, 29
Description:	height of tree
Source of data and reference:	Calculation from field data.
Measurement procedures: (if any)	n/a
Value used:	See Carbon Survey Report data
Comment:	Parameter not used
Assumptions and Decisions	Note: tree height tested but not used in allometric equation as allowed by the methodology AIM Step 2
Uncertainty estimate:	Not required
Deviation from Methodology:	None

Data/parameter 27:	$MV_{B,AG\_timber,it}$
Data unit:	m3 ha-1
Used in equations:	34, 76
Description:	Mean merchantable volume under the baseline scenario in stratum i at time *t*
Source of data and reference:	Field Measurement.
Measurement procedures: (if any)	
Value used:	n/a
Comment:	Parameter not used
Assumptions and Decisions	eq 34 not used since BEF method not selected as allowed by the methodology p. 20; Parameter B_{logged} used in place of $MV_{B,AG_tree,it}$in eq 76 leakage
Uncertainty estimate:	n/a
Deviation from Methodology:	None

Data/parameter 28:	$A_{it}^{planted}$
Data unit:	Ha
Used in equations:	40
Description:	area of biomass growth on future land use in the baseline scenario in stratum *i* at time *t*
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation
Measurement procedures: (if any)	GIS analysis
Value used:	Rate 2,800 ha/yr
Comment:	Based on historical rate of plantation conversion by the baseline agent. See discussion Baseline Report. For values see oil palm regrowth worksheet. Annual area of planting cohorts A-F shown in columns E, I, M, Q, U, Y.
Assumptions and Decisions	Strata based on concession boundaries. Time based on staggered concession development and planting north to south.
Uncertainty estimate:	Required. Zero. Case 1 described above.
Deviation from Methodology:	None

Data/parameter 29:	*Slp*
Data unit:	t C ha-1 yr-1
Used in equations:	42
Description:	slope of regression line of biomass accumulation function
Source of data and reference:	Calculated based on field measurements
Measurement procedures: (if any)	
Value used:	

Comment:	Parameter not used
Assumptions and Decisions	Non-linear function used to fit data on palm oil growth, therefore Slp parameter and eq 42 not used as allowed by the methodology p.28
Uncertainty estimate:	Not required
Deviation from Methodology:	None

Data/parameter 30:	*B*
Data unit:	t C ha-1
Used in equations:	41
Description:	intercept of regression line
Source of data and reference:	Calculated based on field measurements
Measurement procedures: (if any)	
Comment:	
Value used:	Parameter not used
Assumptions and Decisions	Non-linear function used to fit data on palm oil growth, therefore Slp parameter and eq 42 not used as allowed by the methodology p.28
Uncertainty estimate:	Not required
Deviation from Methodology:	None

Data/parameter 31:	age_{peak}
Data unit:	Years
Used in equations:	45
Description:	age of stand at peak production
Source of data and reference:	literature values : Data reported in Cannell M.G. R. 1982. World Forest Biomass and Primary Production Data. Academic Press. London. 391 pp.
Measurement procedures: (if any)	n/a
Value used:	14
Comment:	See discussion Baseline Report Oil Palm Growth Model Data
Assumptions and Decisions	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 32:	$A^{cleared}_{BH\,it}$
Data unit:	Ha
Used in equations:	48, 53
Description:	Area cleared at harvest *H* under the baseline scenario for stratum *i*, in time *t*
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation

Measurement procedures: (if any)	
Value used:	Parameter not used
Comment:	
Assumptions and Decisions	Eq 48 not calculated – as palm oil plantations operate on a 25-30 year timeframe, emissions from harvest rotations $E_{harvest}$ were not considered in baseline estimation. This is conservative.
Uncertainty estimate:	n/a
Deviation from Methodology:	None

Data/parameter 33:	*PBH*
Data unit:	Dimensionless
Used in equations:	48
Description:	average proportion of aboveground carbon stock removed during harvest *H* under the baseline scenario for stratum *i*, time t
Source of data and reference:	Field measurements or literature data
Measurement procedures: (if any)	
Value used:	Parameter not used
Comment:	
Assumptions and Decisions	Eq 48 not calculated – as palm oil plantations operate on a 25-30 year timeframe, emissions from harvest rotations $E_{harvest}$ were not considered in baseline estimation. This is conservative.
Uncertainty estimate:	n/a
Deviation from Methodology:	None

Data/parameter 34:	$PBB_{BH,it}$
Data unit:	Dimensionless
Used in equations:	53
Description:	average proportion of remaining aboveground carbon stocks burnt at harvest H under the baseline scenario in stratum *i*, time *t*
Source of data and reference:	
Measurement procedures: (if any)	
Value used:	
Comment:	Parameter not used
Assumptions and Decisions	Eq 48 not calculated – as palm oil plantations operate on a 25-30 year timeframe, emissions from harvest rotations $E_{harvest}$ were not considered in baseline estimation. This is conservative.
Uncertainty estimate:	n/a
Deviation from Methodology:	None

Data/parameter 35:	$D_{B,,drain,it}$
Data unit:	Cm

Used in equations:	58
Description:	average depth of peat drainage or average depth to water table under the baseline scenario in stratum *i*, time *t*
Source of data and reference:	Methodology default value = 100 cm
Measurement procedures: (if any)	
Value used:	100
Comment:	See Peat Drainage spreadsheet
Assumptions and Decisions	Note that peat depth across the project area is greater than the peat depth lost via subsidence and burning in the baseline scenario over the project life, therefore the net peat drainage depth of no more than 1 meter is used - Condition F of the methodology.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 36:	$A_{B,drain,it}$
Data unit:	Ha
Used in equations:	57
Description:	area of drainage impact under the baseline scenario in stratum *i*, time *t*
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation
Measurement procedures: (if any)	
Value used:	See Peat Drainage spreadsheet
Comment:	
Assumptions and Decisions	Strata comprised of concession boundaries and land cover (all types except kerangas forest and kerangas scrub which overlay sandy soil). Note peat drainage emissions are cumulative, expanding to cover the full extent of concessions, then continuing over the life of the project.
Uncertainty estimate:	Required. Zero. Case 2 described above.
Deviation from Methodology:	None

Data/parameter 37:	D_{peat}
Data unit:	Meters
Used in equations:	59
Description:	average depth of peat in project area
Source of data and reference:	Field Measurements
Measurement procedures: (if any)	Measured using peat probe at 159 sample points on 8 transects across project site (see Field SOP).
Value used:	4.3

Comment:	See Carbon Survey Report
Assumptions and Decisions	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 38:	$D_{B,burn,it}$
Data unit:	cm
Used in equations:	63
Description:	depth of peat burned under the baseline scenario in stratum *i* at time *t*;
Source of data and reference:	Literature value: Couwenberg et al. (2009) cited in the methodology p. 36
Measurement procedures: (if any)	
Value used:	34cm
Comment:	
Assumptions and Decisions	According to the methodology p. 37 "The depth of peat burned shall be assumed to be equal to the drainage depth, minus a critical threshold of 40 cm above the drainage depth. If the difference between drainage depth and the critical threshold exceeds 34 cm, then the maximum burn depth of 34 cm shall be applied." Since drainage depth for the baseline is 100cm, a burn depth of 34 cm is used.
Uncertainty estimate:	Required. Zero. Default value used.
Deviation from Methodology:	None

Data/parameter 39:	$A_{B,burn,it}$
Data unit:	Ha
Used in equations:	63
Description:	area of peat burned under the baseline scenario in stratum *i* at time *t*;
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation
Measurement procedures: (if any)	
Value used:	See Peat Burning spreadsheet
Comment:	
Assumptions and Decisions	Strata comprised of concession boundaries and land cover (all types except kerangas forest and kerangas scrub which overlay sandy soil). Note burning is a one-time event occurring during years 1-8 of staggered concession development. Estimated rate of burning = rate of deforestation and clearing.
Uncertainty estimate:	Required. Zero. Case 1 described above.
Deviation from Methodology:	None

Data/parameter 40:	BD_i
Data unit:	g cm-3 = t m-3
Used in equations:	63
Description:	Bulk density of peat in stratum I (g cm3 = t m3)
Source of data and reference:	Default value
Measurement procedures: (if any)	
Value used:	0.14
Comment:	see Peat Burning spreadsheet
Assumptions and Decisions	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 41:	EF_{CO2}
Data unit:	g CO2 (t peat)-1
Used in equations:	61
Description:	CO2 emissions from the combustion of peat
Source of data and reference:	Literature value. Muraleedharan et al. (2000) cited in the methodology p. 38
Measurement procedures: (if any)	
Value used:	185,000
Comment:	Peat Burning spreadsheet
Assumptions and Decisions	As per the methodology, the emission factors for peat combustion at the lower temperatures were assumed in the ex ante baseline estimates, as this results in lower overall GHG emissions (CO2 + CH4 reported as CO2 equivalents) and thus a conservative baseline scenario.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 42:	EF_{CH4}
Data unit:	g CH4 (t peat)-1
Used in equations:	62
Description:	CH4 emissions from the combustion of peat
Source of data and reference:	Literature value
Measurement procedures: (if any)	
Value used:	5,785 g/ton peat
Comment:	Peat Burning – BL worksheet cell E6
Assumptions and Decisions	As per the methodology, the emission factors for peat combustion at the lower temperatures were assumed in the ex ante baseline estimates, as this results in lower overall GHG emissions (CO2 + CH4 reported as CO2 equivalents) and thus a

	conservative baseline scenario.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 43:	*LDF*
Data unit:	t C m-3
Used in equations:	68
Description:	Logging Damage Factor for calculating the biomass of dead wood created during logging operations per cubic meter extracted
Source of data and reference:	Default value of 0.37 t C m-3 from 534 logging gaps measured by Winrock International in Bolivia, Belize, Mexico, the Republic of Congo, Brazil and Indonesia may be used for tropical broadleaf forests.
Measurement procedures: (if any)	
Value used:	0.37
Comment:	
Assumptions and Decisions	
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 44:	PML_{FT}
Data unit:	%
Used in equations:	Unnumbered eq methodology page 41
Description:	Mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type to which displacement of logging activities is likely to occur.
Source of data and reference:	GIS data from landcover/forest maps published by Ministry of Forestry. All forest types in which commercial logging could take place within PT Best concessions were considered.
Measurement procedures: (if any)	
Value used:	< 0.20
Comment:	
Assumptions and Decisions:	There is minimal remaining forest in PT BEST concessions outside Rimba Raya, therefore a relative value of < 0.20 was sufficient for determining that PML_{FT} is > 0.15 less than PMP_i (methodology p. 41) and therefore the highest market leakage deduction factor is selected and applied. This results in the most conservative (largest) deduction from the baseline estimate for market leakage as a result of Rimba Raya's comparatively high timber volume being removed from PT BEST concession's timber potential.
Uncertainty estimate:	n/a

Deviation from Methodology:	None

Data/parameter 45:	$V_{B,it}$
Data unit:	m^3
Used in equations:	68
Description:	Volume of timber projected to be extracted from within the project boundary during the baseline in stratum *i* at time *t*
Source of data and reference:	Source of data same as biomass logged parameter.
Measurement procedures: (if any)	
Value used:	Embedded in equation 68, see biomass burning spreadsheet
Comment:	Note that this volume does not include logging slash left onsite. Extracted volumes reported are gross volumes removed.
Assumptions and Decisions:	Biomass logged was already derived for RR based on Mawas field data and is the same as the first term of the CB,XBT,it equation. By setting this term equal to Biomass logged, V B, it is derived and used directly in eq. 68.
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 46:	PMP_i
Data unit:	%
Used in equations:	Unnumbered eq. p. 41
Description:	Merchantable biomass as a proportion of total aboveground tree biomass for stratum *i* within the project boundaries
Source of data and reference:	unpublished data from Mawas, Winrock 2008
Measurement procedures: (if any)	
Value used:	Mean 0.36, SD 0.169
Comment:	Same as B logged (Biomass Extracted as Merchantable Timber >30cm in Timber Extraction spreadsheet)
Assumptions and Decisions:	Mawas data provides complete dataset applicable to Rimba Raya project site. Average proportion of merchantable timber across 93 logging gaps
Uncertainty estimate:	Not required.
Deviation from Methodology:	None

Data/parameter 47:	$HistHa_i$
Data unit:	Ha
Used in equations:	72
Description:	Average annual area of deforestation by the baseline agent of the planned deforestation in stratum *i* for the 5-10 years prior to project

	implementation
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation
Measurement procedures: (if any)	GIS analysis
Value used:	6113.7
Comment:	See discussion Baseline Report
Assumptions and Decisions:	
Uncertainty estimate:	Required. Zero. Case 1 described above.
Deviation from Methodology:	None

Data/parameter 48:	$A_{defLK,it}$
Data unit:	Ha
Used in equations:	73
Description:	The total area of deforestation by the baseline agent of the planned deforestation in stratum *i* at time *t*
Source of data and reference:	Analysis of remote sensing data and/or legal records and/or survey information for lands owned or controlled or previously owned or controlled by the baseline agent of deforestation
Measurement procedures: (if any)	GIS analysis of satellite imagery
Value used:	Not calculated as of year 1 (no leakage)
Comment:	Legal records will include government permits to deforest including concession licenses. Ex-ante, project proponents shall determine and justify the likelihood of leakage based on characteristics of the baseline agent. To be calculated if activity shifting leakage is detected. See Monitoring plan discussion.
Assumptions and Decisions	
Uncertainty estimate:	N/A year 1
Deviation from Methodology:	None

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