Forest Monitoring & Carbon Accounting

Merang REDD Pilot Project (MRPP)

Measuring and monitoring carbon stock in the Merang Peat Swamp Forest

In South Sumatra, the Merang peat swamp forest area is a promising location for a REDD pilot project due to the still relatively intact forest cover and the large below ground carbon storage in the peat soil. In close proximity to the protected areas of Sembilang National Park in South Sumatra province, and Berbak National Park in Jambi province, the Merang peat swamp forest stores around 3.1 billion m^3 of peat soil within a 134 thousand hectare area. Drillings and calculations revealed an average peat depth of 2.48 meters.

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Long-tailed Macaque *(Macaca fascicularis)*

Merang Peat Swamp Forest & REDD+

The Merang Peat Swamp Forest (MPSF) is the last peat swamp forest in South Sumatra province and is situated over a large peat dome that stores a considerable amount of carbon. Illegal logging and forest fires are the main threats and the deforestation and degradation they cause result in large carbon emissions. Conversion to intensive plantation forest is an ongoing process that is reducing the area of natural peat swamp forest. We believe that a REDD+ mechanism could address these issues and significantly reduce the amount of deforestation and degradation, thus increasing carbon sequestration.

REDD+ mechanism requires an internationally accepted carbon monitoring system. The higher the precision level of carbon measurement, the more convenient it will be for validation and verification, as well as for carbon trading negotiations. A carbon measurement system with accepted accuracy and precision is needed. Emission data calculations require two main datasets, activity data and emission factors.

Forest monitoring is one of the most important aspects for a sustainable forest management program. Actual information on existing forest areas can be used for carbon stock assessment and the dataset incorporated with other remote sensing data to produce baseline emission calculations.

This document has been prepared as a description of how to monitor the forest and measure forest carbon in the MPSF within the framework of REDD+ mechanism, and is promoted by the Merang REDD Pilot Project (MRPP). Forest monitoring has been conducted to collect information related to forest coverage, deforestation and degradation agents as well as on biodiversity in the MPSF. The forest carbon measurement methodology implemented in this project was developed alongside accepted forest sampling techniques, and uses scientific-based and international standards on biomass / carbon measurements.

Forest Mapping and Monitoring

Forest monitoring should be conducted regularly to assess not only forest coverage but also other parameters associated with the forest ecosystem, such as soil characteristics, plant and wildlife diversity, and threats to the ecosystem. Forest monitoring uses both remote sensing technology and field surveys. Remote sensing technologies are useful to capture vast areas of forest and land for forest and vegetation mapping, as well as fire and hotspot monitoring. Moreover, it is possible to use remote sensing to assess deforestation rates and calculate historical emissions. Terrestrial surveys collect detailed and comprehensive information on forest composition. A combination of these two methodologies can give accurate and comprehensive forest information.

Land Cover Mapping

Vegetation and land cover mapping for the MRPP project area was conducted using remote sensing data. Available spectral signatures were used with knowledge of vegetation types in the field to define land cover classes. We differentiated degradation levels of peat swamp forest since they store different values of carbon stock. 9 land cover classes were used for image classification in the MPSF; 2 classes of logged-over peat swamp forest (dense and medium); 2 vegetation classes of secondary forest (mahang and gelam forest); 1 re-growth class and 4 deforestation classes (shrubs, grasslands, open/burnt land, and recently logged forest).

Land cover types classified from Landsat imagery, 2008

No	Classes	Size (ha)	%
1	Logged over peat swamp forest – dense canopy	3054	13
2	Logged over peat swamp forest – medium canopy	5950	25.3
3	Forest re-growth	4393	18.7
4	Mahang and gelam-dominated forest	139	0.6
5	Shrubs	1308	5.6
6	Grasslands	1305	5.6
7	Open lands	3534	15
8	Recently logged/burnt forest	3802	16.2

We used these land cover classes for stratification of carbon stock assessment. Stratification is needed to improve accuracy during biomass sampling. For the purpose of stratification we simply further divided the classes into 8 sub-classes. Gelam forest was merged into the same class as Mahang forest due to the small area it has in the MPSF.

Based on interpretation of Landsat images from 2008, more than 38% of the MRPP project area is covered by natural logged-over peat swamp forest. Other forest classes, including forest re-growth and secondary forest dominated by

Map of vegetation cover derived from Landsat TM 2008
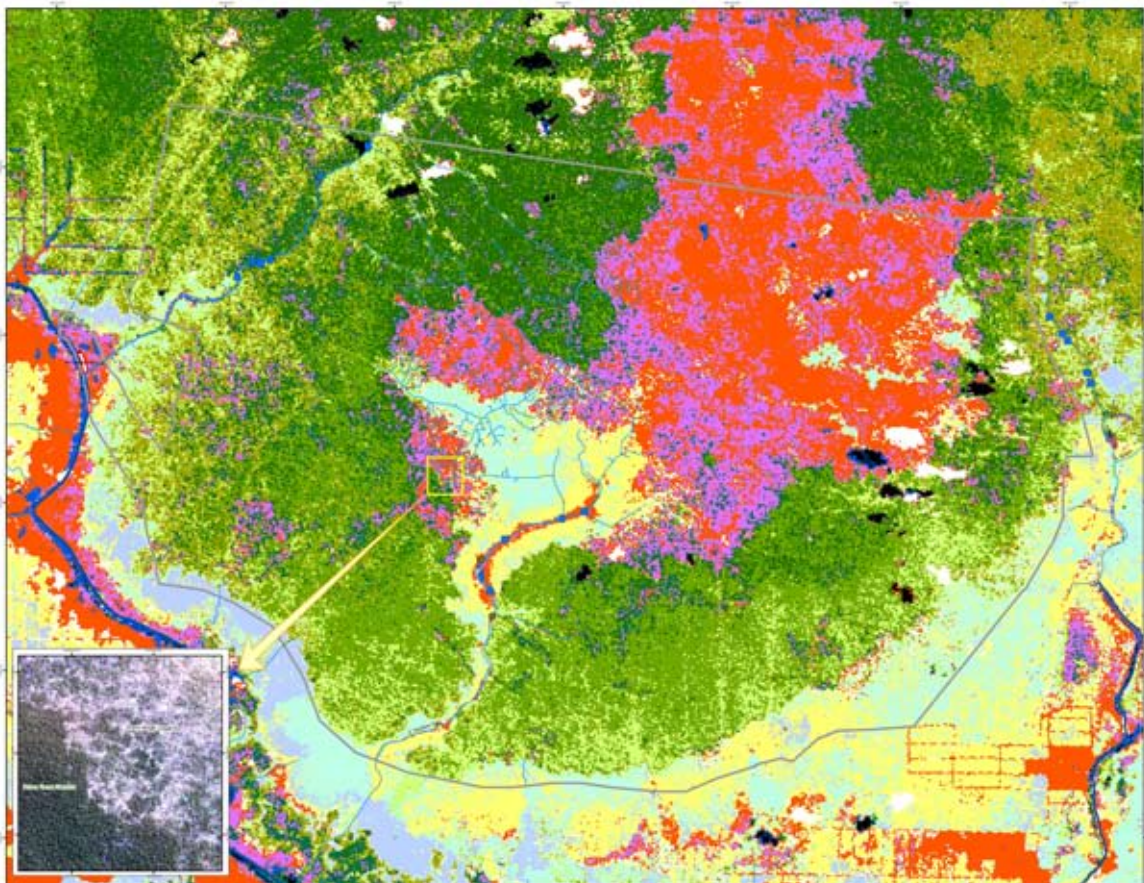
Mahang, contribute to 19% of the area. More than 41% of the project area is deforested due to the logging and peat fires of 2004 and 2006. These areas need human intervention for rehabilitation, mainly through enrichment planting and canal blocking.

Canal mapping

Canals dug by illegal loggers destroy the existing hydrological system by directing water into existing rivers and draining the peat land, leaving the area severely prone to fires during the dry season. A canal survey was conducted to identify locations, width, estimated length of the canals and the names of each canal owner. However to get the exact spatial patterns of the canals is time consuming field work so more detailed mapping was conducted using QuickBird images. Apart from those hidden below the dense forest canopy, most of the small canals are easily detected and can be digitized through the 0.6 meter resolution.
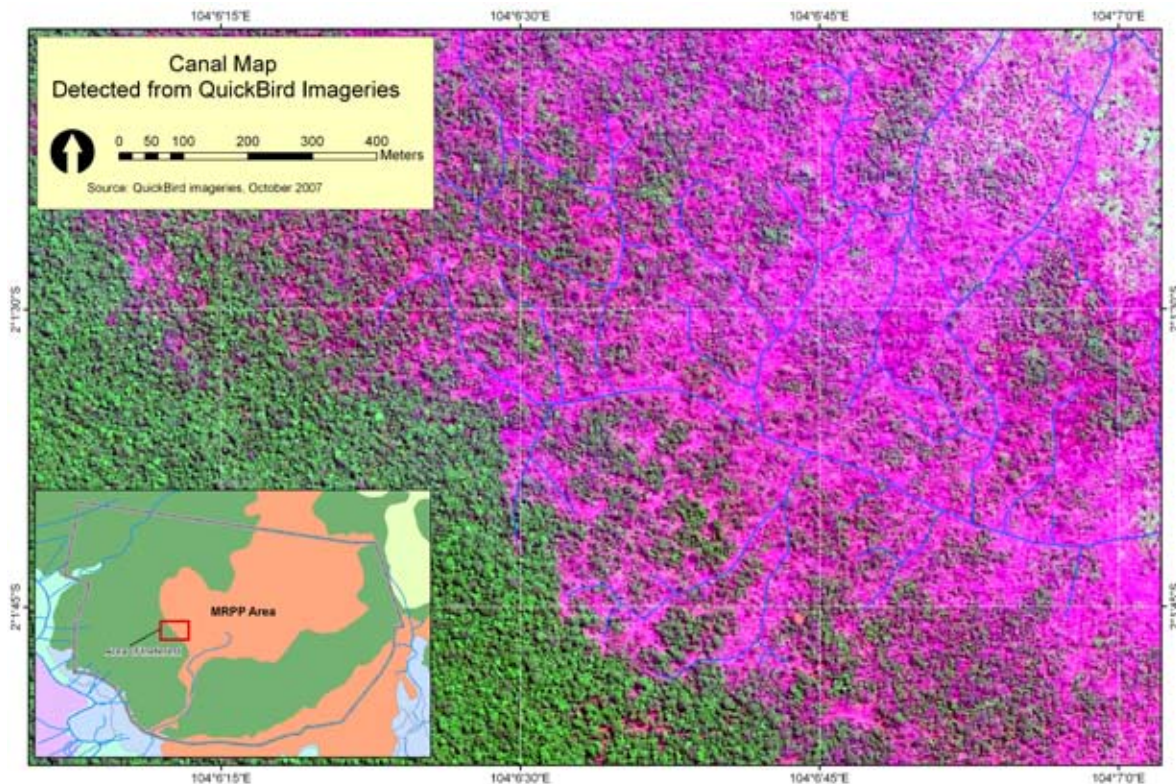
Peat Dome Updating

Organic or peat soils dominate the MRPP project area. Peat soils are considered the largest carbon pools in this area, more than 10 times higher than carbon stock from the living biomass or above ground biomass pools. Assessment of this peat soil pool is crucial for the carbon emission project. Updating a 3D model developed by Siegert and Bachteler (2005), Mott and Siegert (2006) and Ballhorn and Siegert (2007) was conducted using additional peat depth drilling information. A peat survey was made in the MRPP area in 2009 to get information on the peat depth using 125 drilling points. However, in the centre of the dome the extension rods where shorter than the depth of the dome at some drilling points so another peat survey was conducted in 2010 to get a more accurate depth assessment (using 13 additional drilling points).

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Comparison between previous 3D model by Ballhorn *et al.*, 2007, and updated model

	Ballhorn 2007	MRPP 2010
Interpolation method	Kriging	Kriging
Point numbers	61	167
Area (m^2)	1,415,240,100	1,251,288,948
Volume (m^3)	1,794,015,772	3,102,107,950
Average depth (m)	1.27	2.48

Using an additional 167 peat drilling points from the MRPP field survey area, and areas within the MPSF from other researches, we updated a 3D model of the peat dome using Kriging interpolation. Results show that the whole MPSF area stores around 3.1 billion m^3 of peat soil within a 134 thousand hectare area. The drillings and calculations revealed an average depth of 2.48 meters. Compared to the previous model, the updated model has a 1 meter higher depth average. Updating on a smaller scale for the dome boundary will take place after validation with remote sensing data. The MRPP area covers 24 thousand hectares with more than 1 billion m^3 volume in peat soils. The MRPP area is located in the deepest area of the peat dome with an average depth of 4.4 meters. The deepest peat soils are 8 meters in depth and are located in the centre of the project area.

Illegal Logging Monitoring

Deforestation and degradation in the MPSF area result from logging (legal logging in the past and illegal logging at present) and peat fires. Previous legal logging was conducted by timber concessions and resulted mostly in forest degradation as they only cut large trees. Many timber concessions stopped their selective logging operations in the MPSF at the end of 1999. This led to unmanaged forest areas and areas without sufficient protection, a situation that was exploited by illegal loggers. The illegal logging that is conducted by communities, with support from rich businessmen, extracts most of the (smaller diameter) commercial trees.[1] Non-commercial trees are also harvested to support the wood extraction process, either for making skidding tracks or floating the timber in the canals and rivers. This exploitation system has lead to excessive damage to the forest stands.

Monitoring of illegal logging activities was - and continues to be - of utmost importance, hence the need for field surveys and remote sensing. In 2009, a survey on illegal logging activities was implemented in cooperation with the University of Muhammadiyah Palembang. The survey revealed that loggers operate in small groups of 3-5 persons. Each group can extract around 70 – 100 m^3 timber per month.[2] It is estimated, that around 75 illegal logging groups are operating near Merang and Kepahiang rivers. Annually around 57,000 m^3 of timber are potentially extracted by the loggers from the area. This data does not include the timber used for facilitating the logging and transport, or the damage caused.

MRPP is working together with local communities that are situated near the MRPP block to monitoring illegal logging. Canals and rivers are the only access for illegal timber extraction so it is possible (and also very effective) to record illegal logging traffic at major river points. Two Community Forest Ranger (CFR) field stations are situated at the river mouth of the Merang and Kepahiang rivers – a

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[1] Lubis *et al.*, 2004

[2] Yuningsih *et al.*, 2009

place where all rafts of illegal logs and timbers have to pass. The field station in the Merang river is very suitable for regular monitoring since it is located in the village where the CFR crews live.

Recorded data of log rafts from illegal logging on the Merang river

Month	Illegal raft numbers		Total	Number of days rafts passed
	Timber	Log		
Mei 2009	484	334	818	3
June 2009	2030	2457	4487	11
July 2009	1766	1293	3059	9
December 2009	–	1154	1154	8
January 2010	–	729	729	3
March 2010	–	2837	2837	10
April 2010	–	1704	1704	–

The above survey was conducted over a 1-year period but due to the irregular presence of the CFR crew for daily monitoring (either working in nearby plantations or in the forest), the recording of illegal log rafts was incomplete, especially in May 2009 and January 2010. Loggers often raft their logs at night and this may result in miscounting and underestimation. 2009 was an El-Nino year with a prolonged dry season and low water levels in the MPSF during August to November. This might be one of the reasons why no rafts were recorded from the field station during these months. June 2009 was the busiest month when 4,487 rafts were counted over 11 days.

Using this dataset we estimate more than 2,500 m^3 of logs and timber are extracted along the Merang river during the wet months. Illegal logs could annually reach 20,000 - 30,000 m^3, solely from the Merang river. The number of rafts that are pulled by a tugboat vary from 50 to 686 rafts. These rafts can stretch from 0.5 to 1.5 km along the river. Rafts may be aligned next to each other to shorten the total length in the main rivers but not in the narrow canals. Each raft usually contains from 2 to 5 pieces of timber or logs, with a length of 4 meters and around 1 to 1.5 m^3 volume.

The remains of an illegal sawmill near the centre of the peat dome. Many reconnaissance field surveys have been conducted by MRPP staff during field visits to the project area and locations of places such as logger camps, sawmills or new canals are recorded using GPS. This information has been send to the authorities for law enforcement. Some law enforcement operations are quite successful, though some leaks have occurred during other operations.

## Monitoring system for Fire Early Warning and fire occurrences

Years identified as El-Nino years or the years with a prolonged dry season were 1987, 1992, 1997, 2002, 2004, 2006 and 2009. During these years most degraded peat swamp areas in Sumatra and Kalimantan experienced large fires. Although the largest fire seasons were in 1987 and 1997, large fires hit the MRPP area only after 2000 when major forest degradation and deforestation started to take place.

Fire early warning and fire occurrence monitoring has been conducted regularly for the Merang peat swamp areas. This has been developed as part of a fire management plan to reduce the impact of forest fires. The Fire Early Warning System (FEWS) involves weather monitoring since most weather parameters (especially rainfall intensity) contribute to the fire danger rating. An Automatic Weather System (AWS) was installed at MRPP Field Office in mid 2009. It monitors daily weather parameters including rainfall, temperature, humidity and wind speed. These parameters are used to develop the fire danger rating system. We use the Keetch-Byram Drought Index (KBDI) to represent the fire danger and this is disseminated on a daily basis to the 2 CFR field stations located on the Merang and Kepahyang rivers. The up-date of the fire danger status board is conducted by CFRs when there is a change in the fire danger status and provides information to whoever passes the CFR field station.

A fire monitoring system based on the National Oceanic and Atmospheric Administration (NOAA) satellite imagery was introduced to South Sumatra at the start of the European Union funded fire project in 1995. Since then, Japanese, UK and German supported projects have installed more NOAA ground-based satellite receivers. These additional NOAA ground-based stations contributed to more diverse sources of hotspot information. However, there is still a debate over which threshold algorithm is the most accurate for hotspot detection.

As part of NASA's Earth Observing System, the Moderate Resolution Imaging Spectro-radiometer (MODIS) satellite began in February 2000 to collect land surface information. The MODIS fire product is an output generated by the

MODIS Fire Team, which includes developing an algorithm for fire detection on a global scale.[3] The product is becoming well known to Indonesian stakeholders and is a system that supports and will eventually replace the present fire monitoring system. One example of this is FireWatch Indonesia, a collaboration project among Indonesian stakeholders (Ministry of Forestry, National Aeronautic and Space Agency; and Ministry of Environment) and the Australian government that is developing a reliable fire monitoring system covering the Indonesian archipelago. This system provides near-real time hotspot information derived from MODIS fire products and is disseminated through a web-based Geographic Information System.
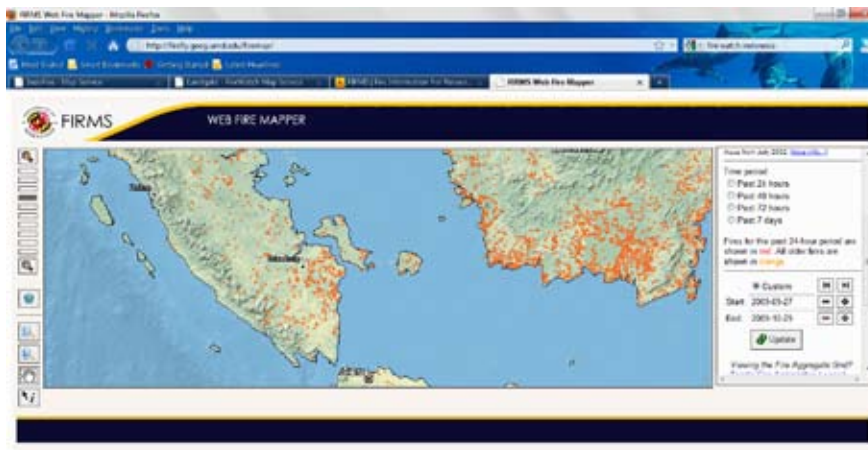
A web-based fire monitoring system, depicting distribution and coordinates of MODIS hotspots detected in the project area (http://maps.geog.umd.edu/firms/)

A compilation of hotspot information providers has been made by the European Union funded Fire Management Project in South Sumatra.[4] Most of these providers give access to real-time dissemination of hotspot information using web GIS and an email alert system. The MODIS fire products will therefore be suitable for fire monitoring, using remote sensing, in the MRPP project area.

Community Forest Rangers(CFRs), trained in initial fire suppression. At present, hotspot information derived from providers is conveyed to a project field officer who will send CFRs out for ground truthing and fire patroling. These first steps give us detailed information on what happens in the field as there are some false alarms or, in the worst case scenario, some fire events that are not detected by MODIS that could be suppressed at an earlier stage.

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[3] Justice *et al.*, 2002

[4] Solichin *et al.*, 2007

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Biodiversity Assessment

The MPSF is an important peat swamp ecosystem for biodiversity conservation as it provides habitat and migration corridors for many threatened species. Biodiversity surveys have been conducted in the MPSF by Wetland International (WI) and the South Sumatra Forest Fire Management Project (SSFFMP)[5], and provide an important baseline for biodiversity in the area. Most surveys have focused on birds and large mammals, though some reptiles were recorded, particularly those specific to peat swamp forest such as the False Gharial *(Tomistoma schlegelii)*.

A total of 122 bird species were recorded in the MPSF, including 25 near threatened species, 2 vulnerable species and 2 endangered bird species.[6] The last four species (Lesser Adjutant Stork, Wallace's Hawk Eagle, White-winged Duck and Storm's Stork) are a priority for monitoring. Hornbills are also important key species for peat swamp forest ecosystems and are relatively easily observed due to their size and calls.

The surveys conducted by WI and SSFFMP also assessed large mammals and most of the large mammals recorded in the 2003 survey were confirmed and found again in the 2008 survey.

In 2009, MRPP conducted a multi-purpose inventory, focusing on biomass measurement in 45 plots, distributed randomly throughout the project area. The inventory leader recorded any indication of wildlife, either through direct observation or indirect evidence such as calls, tracks, feces, and other signs. GPS points were recorded for each observation. Some remarkable observations were made during the survey, including Tiger *(Panthera tigris)*, Tapir *(Tapirus indicus)* and Sun Bear *(Helarctos malayanus)* footprints. Two teams who worked separately (one team in Buring river and the other in Kepahyang river) spotted fresh tiger tracks 6 times along a transect. This indicates that at least 2 individual tigers are using the project area and this is substantiated by the relatively good quality of remaining forest and available food - Wild Boar *(Sus scrofa)*, Sambar Deer *(Cervus unicolor)*, Barking Deer *(Muntiacus muntjak)* and Mouse Deer *(Tragulus napu)* are all present.

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[5] Goenner, 2001; Lubis, 2003; and Waltert, 2008

[6] Waltert, 2008

Many project field activities can be done in parallel with wildlife surveillance. One such observation was made in July 2009 during a survey for biomass allometric development near a timber company on the Buring River. A company worker who often went hunting in the forest at night using an air rifle brought home two dead Greater Mouse Deer *(Tragulus napu)* and the next day a Lesser Mouse Deer *(Tragulus javanicus)*. These species had not been recorded by previous surveys. Footprints belonging to at least 3 individual tigers were also observed on the riverbank during the same survey.

A tiger occupancy survey was conducted using camera traps in cooperation with the Zoological Society of London. Unfortunately the first attempt was not a great success due to the limited number of cameras used. A further survey focusing on the areas where tigers are reported to be present will be conducted using new traps and more cameras.

Gibbon *(Hylobates agilis)*, Banded Langur *(Presbytis melalophos)*, Silvered Langur *(Presbytis cristata)*, Pig-tailed Macaque *(Macaca nemestrina)*, and Long-tailed Macaque *(Macaca fascicularis)* were recorded during a carbon inventory and other field surveys. The Long-tailed Macaque is still common and the most frequent mammal to be seen in the Merang river area. A specific survey to assess the gibbon population in the project area will be conducted soon. The Pig-tailed Macaque and Banded Langur should also be monitored regularly, since they are susceptible to forest degradation and deforestation.

Poaching and hunting is a very serious and ongoing threat to wildlife diversity. Poachers use wire traps and sometimes specific devices using electric shocks to catch deer and wild boar. At least 1 tiger has been caught in this way.

Male Greater Leafbird *(Chloropsis sonnerati)* attached to a stick and used to attract and trap other birds. One poacher estimated that if he was lucky, in a week he could catch about 80 Leafbirds in this way. Sold in the Jambi bird market, the male is priced at Rp. 200.000,- to Rp. 300.000,- or 10 times more than the female.

Forest Carbon Measurement

The Intergovernmental Panel on Climate Change (IPCC) has published general guidelines for carbon stock and emission measurements and the default values derived from global research data provided in the guidelines can be used to calculate carbon stock. This is considered as Tier 1. Tier 2 should use data compiled from the national level. Data sets for this method are available from many different carbon studies in Indonesia. Nevertheless, it will be more suitable for the Merang REDD Pilot Project to measure carbon stock and emissions in MPSF using the Tier 3 method to achieve higher accuracy and precision.

Approaches and Tiers introduced by IPCC to define levels of accuracy

Approaches for Activity Data	Tiers for Emission Factors
Approach 1. Non-spatial country statistics (e.g. FAO) – generally gives net change in forest area	**Tier 1.** IPCC default values at a continental scale
Approach 2. Based on maps, surveys, and other national statistical data	**Tier 2.** Country specific data for key factors
Approach 3. Spatially specific data from interpretation of remote sensing data	**Tier 3.** National inventory of key carbon stocks, repeated measurements or modeling

Tree-based biomass quantification

Some allometric equations have been developed to accommodate carbon measurement in tropical countries.[7] However, it is more appropriate to estimate tree biomass based on a local allometric equation developed from similar forest types. The nearest forest type to the MPSF that has been studied for an allometric equation, is a Jambi lowland secondary forest.[8] However most of the study site is located on mineral soil, hence it will differ to forest on peat land.

MRPP Project is actively implementing a study for an allometric equation in the peat swamp forest at Merang to get a higher level of precision and accuracy in carbon calculations. In cooperation with the adjacent timber plantation PT Rimba Hutani Mas, we are using the harvesting method to develop 2 allometric equations, one for logged over forest and one for burnt forest.

For logged over forest we used data from 30 dominant trees with a diameter at breast height (DBH) of 5 cm to 64 cm. For burnt forest we used only 20 trees with DBH of 5 cm to 30 cm. After felling each tree was fractioned into 4 sections, stem, large branches, branches, twigs and leaves. All sections were weighted in the field using calibrated scales. We took samples of all sections for biomass and carbon analysis.

Below are the allometric equations developed for logged over forest and burnt forest.

Logged over Forest : $\quad W = 0.206284\, D^{2.4511}\quad$ (Novita, 2010)

Burnt Forest : $\quad W = 0.153108\, D^{2.4}\quad$ (Widyasari, 2010)

The equations have been developed in collaboration with students from Bogor Agricultural University for their master thesis. An updating of the equations is in progress. Additional data from large trees will be used to increase accuracy of the carbon accounting for the whole project area.

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[7] Brown, 1997; Kettering *et al.*, 2001; Chave *et al.*, 2005

[8] Kettering *et al.*, 2001

Forest carbon inventory

Stratification can increase the homogeneity of a population and reduce the number of plots to be used for a forest carbon inventory. A land cover map derived from satellite imageries (see pages 2 and 3), should be used for stratification. Additionally, peat depth information gives more information on stratification for carbon stock. Unfortunately, we had limited information of peat depth, when we developed the sampling plot design for the carbon inventory in the project area. Therefore this information was not utilized for stratification. Collecting peat depth information became a priority objective when designing the terrestrial carbon inventory.

Plot numbers for biomass inventory were calculated and distributed at each stratum, according to the size of the stratum, potential carbon stock, as well as variation among plots within a stratum.

Plot numbers distributed in each stratum

Strata	Plot Number
Logged over peat swamp forest – dense canopy	9
Logged over peat swamp forest – medium canopy	12
Forest re-growth	9
Mahang dominated	1
Shrubs	3
Grasslands	1
Open lands	2
Recently logged/burnt	8

We measured most of the carbon pools in the field, above ground biomass, dead organic matter and organic or peat soil. It was not possible to measure below ground biomass during the inventory. To estimate carbon stock from below ground and above ground biomass, we used allometric equations.

Detailed information on the carbon inventory methodology is described in a project manual[9] and has also been adopted as an appendix in the Directorate General Forest Utilization Regulation No 3/2010 of the Ministry of Forestry. (http://www.dephut.go.id/files/PerdirjenBPK_3_2010.pdf).

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[9] Solichin, 2009

The Important Value Index (IVI) is calculated on the density of a species within a plot, frequency of a species to be found, and dominancy (basal area). Based on results from the field inventory, Rengas burung *(Melanorrhoea walicchii)* is the species with the highest IVI in the project area, followed by Punak *(Tetramerista glabra)* and Ramin *(Gonystylus bancanus)*. Although Rengas burung is a commercial species, it is not a favourite of illegal loggers due to its toxic sap that can severely irritate the skin.

Important Value Index (IVI) of peat swamp forest species in the MRPP project area

Name	Scientific Name	Density %	Frequency %	Dominancy %	IVI
Rengas Burung	*Melanorrhoea walicchii*	11.02	5.49	19.39	35.91
Punak	*Tetramerista glabra*	8.98	8.79	10.97	28.74
Ramin	*Gonystylus bancanus*	6.94	4.95	5.53	17.42
Makai	*Hydnocarpus woodii*	6.12	6.04	4.83	17
Balam Cabe	*Palaquium* sp.	4.08	4.95	3.97	12.99
Jelutung Rawa	*Dyera lowii*	3.67	3.85	2.69	10.21
Rengas Lempuing	-	2.86	1.65	5.57	10.08
Rengas	-	2.45	1.1	5.91	9.45
Kelat	*Syzygium racemosum*	2.86	3.85	1.74	8.45
Durian Payo	*Durio* sp.	2.45	3.3	2.09	7.8

Previously natural peat swamp forests in the project area were dominated by dipterocarp species. As logging (both illegal and legal) cut these commercial species only non-commercial species or very hard timber like Rengas burung and Punak were left. Generally, large and heavy trees with a diameter exceeding 100cm were not felled by timber companies during logging operations due to difficulties in extraction.[10] However, illegal loggers have developed a system that is able to cut and process the hard, large trees into timber. Cut timber is easier to transport. Illegal portable sawmills are now used in the forest to process the felled trees into transportable timber near felling sites. This has become common practice.

Two inventory groups were deployed to collect data in 45 plots within the MRPP project area. Each group consisted of 8 persons: 1 team leader, 1 tree identifier, 3 cruisers and plot makers, 2 peat drillers and 1 cook. It took around one and a half months to finish all plots.

[10] Muhdi, 2002

Peat carbon calculation

Volume estimation of the Merang Peat Dome has been conducted and updated using 3D analysis (see pages 4 and 5). Based on the updated results we can estimate with higher accuracy how much organic matter and carbon is contained in the dome. To calculate carbon and CO_2 stock in the peat dome, we use the following equation:

$$C = V * BD * CF$$

$$CO_2 = C * \left(\frac{44}{12}\right)$$

C: Carbon stock of peat dome (ton)
V :   Volume of the dome (m^3)
BD: Bulk Density of peat soil (ton/m^3)
CF : Carbon fraction of peat soil

Total carbon stock contained at the Merang peat dome

	Merang dome Ballhorn *et al.*, 2007	Merang dome (this study)
Bulk Density	0.1	0.1
Carbon content	0.57 (Neuzil, 1997)	0.42 (SSFFMP, 2005)
Area (m^2)	1,415,240,100	1,251,288,948
Volume (m^3)	1,794,015,772	3,102,107,950
Organic matters (ton)	179,401,577	446,703,545
C- stock (ton)	102,258,899	130,288,533
CO_2 eq (ton)	374,949,296	477,724,624
CO_2 eq ton/ha	2,649	3,817

The volume of the Merang peat dome is around 3 billion m^3 or roughly 125,000 m^3 per hectare. A laboratory analysis is needed to measure the bulk density and carbon fraction of peat soils when calculating carbon stock. The South Sumatra Forest Fire Management Project with Sriwijaya University made a peat survey in Merang and used a laboratory analysis for the carbon content. Hence, we use our own data with 0.42 as mean value of carbon content from all samples which ranged between 0.32 – 0.47. We used the same value of bulk density from the previous study. Therefore, by using our own data we estimate that the Merang peat dome contains C stock of around 130 million tons or 477 million tons CO_2 equivalents. The dome potentially stores 3,817 ton of CO_2 per hectare. It is almost 70% bigger than the estimation from Ballhorn *et al.*, (2007) with the lower average peat depth.

Defining Baseline Emissions
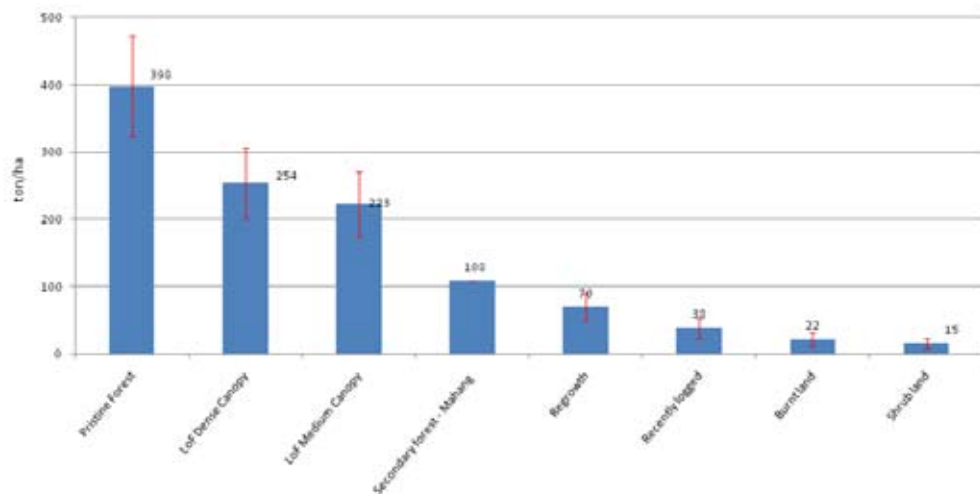
Carbon stock calculation

Biomass and peat soil are the largest carbon pools in the peat swamp forest. Due to the variation in historical forest use and threats, different amounts of carbon stock will occur at different vegetation types across the landscape. It is important to have landscape-scale land cover assessment using remote sensing technique. The technique also allows us to do land cover change assessment using a time series of remotely sensed imageries. Historical as well as actual Landsat satellite imageries are available and suitable for such assessment.

Actual land cover classification has been made based on Landsat TM 2008 (pages 2-3). The land cover map also has been utilized for defining stratification of the area during the planning design of the carbon inventory (pages 13-14). The same dataset can be used for landscape-based carbon calculations.

The historical Landsat satellite images are available for the area from 1978, 1989, 1999 and 2008. However, so far we have only interpreted the imagery from 2008. For the degradation and deforestation trend analysis we used images from 1978 (pristine forest) as period T0 and 2008 (actual land cover) as period T1. The land cover change trend will be used as "activity data". The data will tell us how many hectares of pristine forest have changed into different land cover, and how much remains as pristine forest. This will allow us to estimate emissions released through deforestation and degradation.

The most challenging part at this stage is how to define carbon stock at T0. In the Merang case, the area has been logged since the early 80's and re-logged by illegal loggers beginning in 2000. These legal and illegal activities have changed the amount of carbon stock gradually over time. Due to difficulties in calculating carbon stock from forest degradation, we therefore estimate historical carbon stock of the project area when it still was covered by pristine forest or before 1980. Since there is no pristine peat swamp forest left in the Merang area, we use carbon stock data from the pristine peat swamp forest in Berbak National Park (Jambi Province), with the assumption that we share a similar ecosystem and thus, carbon stock value per hectare.

Above ground biomass from different strata in MPSF with standard deviation

Biomass and carbon stock estimations were calculated for each stratum based on field inventories conducted in the project area (see pages 13-14) and in the Berbak National Park (for pristine peat swamp forest). Pristine forest holds the largest portion of above ground biomass, followed by logged-over forest (LoF), and dense and medium canopy type forest with totals of 398 ton/ha, 254 ton/ha and 223 ton/ha respectively (see figure above).

Emergent Pulai rawa *(Alstonia pneumatophora)* are still commonly found in Berbak NP, which greatly contribute to total carbon stock. Secondary forest stratum, dominated by Mahang (*Macaranga* spp.) contains around 108 ton/ha of above ground biomass, higher than forest re-growth, which holds only 70 ton/ha. As a pioneer species, Mahang can grow faster than most primary forest species and thus sequester CO^2 more rapidly than that of forest re-growth. However, the species has shorter life cycle than primary forest species. Other stratum, shrub land, burnt land and recently logged contain above ground biomass of less than 50 ton/ha.

Emission from deforestation and degradation

IPCC Guidelines (2006) provide generic methods for estimating CO_2 emissions using the following equation:

E = A * EF

    E: Total Emission (ton CO_2 eq)

    A: Activity Data (ha)

    EF: Emission Factor (ton CO_2 eq/ha)

Activity data refers to the size of deforestation and degradation which took place in a project area over a period of time. We use data from land cover change from 1978 – 2008 as Activity Data. Emission Factor is data that refers to the amount of CO_2 emitted due to forest cover change. For the Emission Factor we use above ground biomass data from the carbon inventory for estimating the amount of CO_2 emissions from certain land cover changes.

CO_2 emission from deforestation and degradation in the MRPP project area

Land Cover Change 1978 – 2008	Activity Data (ha)	Emission factor (CO_2-eq t/ha)	CO_2 Emission (tCO_2 eq)
Pristine Forest to LoF dense canopy	3,142	248.68	781,307
Pristine Forest to LoF medium canopy	6,121	301.77	1,847,191
Pristine Forest to Forest re-growth	4,519	567.36	2,564,116
Pristine Forest to Mahang dominated	143	499.39	71,413
Pristine Forest to Shrub land	1,346	659.25	887,110
Pristine Forest to Grasslands	1,343	685.71	920,599
Pristine Forest to Open lands	3,636	648.55	2,357,892
Pristine Forest to Recently logged/burnt	3,911	619.43	2,422,834
Total CO_2 Emission in tons			11,852,462
Annual CO_2 Emission in tons			395,082

Major CO_2 emissions come from deforestation with around 685 ton CO_2 equivalent released per hectare. Once the forest is heavily logged it will increase the susceptibility to fire and most likely will be burnt during a prolonged dry season boosted by El Nino. During the fire season in 2006, more than 8 thousand hectares of degraded forest in the project area was burnt, and converted into open land and grassland. Together with previous logging activities, biomass burning in 2006 causing emissions of more than 5 million ton CO_2 equivalent. Based on these calculations, the average annual CO_2 emission (over the 30 year period) from the project area is equal to 395 thousand ton of CO_2 equivalent.

Conclusion

Climate change poses one of the greatest challenges to humankind. In order to mitigate emissions the forestry sector has to make a significant contribution. Indonesia, with one of the largest forested areas in the world is therefore a major player and will have to carry a large burden to reduce emissions. However before major plans are made and targets agreed it is necessary to have tools and methods available to calculate and monitor emissions and carbon. This brochure provides an appropriate set of tools and methodologies to enable stakeholders to do this in practice in the field.

Forest monitoring is one of the most important tools for collecting information for forest management and biodiversity conservation. Direct field survey and remote sensing methods and activities are an excellent combination to fill gaps of data and information. Forest inventories are not only capable of assessing timber and carbon stock, but also the species composition of the forest. The species composition can indicate the change of forest diversity and dynamics over time due to previous management. Multi-purpose inventories are cost and time effective compared to a separate field inventory, so the integration of carbon measurements into an existing forest inventory is attractive for forest managers. A sampling design will need to be developed according to field practicability and at the same time to meet certain accuracy requirements.

Wildlife biodiversity monitoring can be integrated as part of a field inventory, though it requires special staff who are capable of identifying species, especially

for avifauna. Identification of large mammals is possible in a multi-purpose forest inventory and inventory crews can record any signs of wildlife and plot their location with a GPS while transecting plots. Most of the forest carbon field measurement methodology is based on vegetation and forest inventory. A carbon inventory should measure at least 5 carbon pools instead of 1. This makes a huge difference and requires awareness and basic understanding of carbon stock from field crews. Some parameters to be measured or recorded are sometimes subjective and may be biased by different field crews, so intensive training for field crews is crucial.

Remote sensing is very useful for forest monitoring, carbon stock measurement and baseline emission calculations. Large areas can be covered in a systematic and consistent way. Historical and actual Landsat Satellite imageries are become freely available and have shown to be very useful for forest monitoring and carbon measurement (although one should not underestimate the difficulty to get cloud cover free images in tropical countries). The accuracy of the satellite imagery interpretation depends to a large degree on the knowledge of the interpreter and the accuracy of ground truthing. More field surveys on the ground and discussions with experienced people can assure higher accuracy of the image interpretation.

By using this methodology we have shown that there are still considerable amounts of carbon in the MPSF area. Yet this vast store of carbon is being jeopardized by deforestation and degretation. Unless steps are taken to implement a full REDD project, the loss of the Merang peat swamp forest will have global consequences.

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Glossary

Above ground biomass: Biomass above the soil surface, e.g., trees and other vegetation.

Allometry: The morphological evolution of species, based on the relation between an organism's size and the size of any part of the organism i.e., the change in proportion between size and shape as a consequence of growth.

Allometric equation: Scaling rule or equation that relates tree biomass, carbon or other similar properties to stem diameter and/or tree height.

Basal area: The area of a given section of land that is occupied by the cross-section of tree trunks and stems at their base

Biomass: Organic material both above-ground and below-ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc.

Carbon credit: The generic term for any tradable certificate or permit representing the right to emit one tonne of carbon or carbon dioxide equivalent (CO2-e).

Carbon stock: The quantity of carbon contained in a "pool", meaning a reservoir or system which has the capacity to accumulate or release carbon. In the context of forests it refers to the amount of carbon stored in the world's forest ecosystem, mainly in living biomass and soil, but to a lesser extent also in dead wood and litter.

Carbon sequestration: The process of removing carbon from the atmosphere and depositing it in a reservoir. Carbon dioxide is naturally captured from the atmosphere through biological, chemical or physical processes. Some sequestration techniques exploit these natural processes while others use artificial processes.

Carbon trading: An emissions trading approach where greenhouse gas emissions are capped and then markets are used to allocate the emissions among the group of regulated sources. The goal is to allow market mechanisms to drive industrial and commercial processes in the direction of low emissions or less carbon intensive approaches than those used when there is no cost to emitting carbon dioxide and other GHGs into the atmosphere. Since GHG mitigation projects generate credits, this approach can be used to finance carbon reduction schemes between trading partners and around the world.

Diameter at breast height: The standard method of expressing the diameter of the trunk or bole of a standing tree. Tree trunks are measured at the height of an adult's breast, which is defined differently in different countries and situations. In continental Europe, Australia, the UK, and Canada the diameter is measured at 1.3 metres above ground and in the US, New Zealand, Burma, India, Malaysia, and South Africa at 1.4 metres. In many cases the height makes little difference to the measured diameter.

Emissions: The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

Landsat: Satellite-based remote sensing technology for earth observation. Medium-resolution Landsat imageries are acquired from optical and multi-spectral sensors, which are highly capable of detecting forest and land cover changes. Due to their limitation to penetrate cloud and aerosols, cloud cover is the biggest problem that hinders monitoring in tropical areas.

QuickBird: High resolution satellite-based imageries derived from QuickBird satellite owned by DigitalGlobe. The satellite collects panchromatic and multi-spectral images with 60 cm and 2.4 m resolutions, respectively.

REDD+: Activities directed towards the local communities, indigenous people and forests which relate to reducing emission from deforestation and forest degradation. Includes enhancing existing forests and increasing forest cover, with policies to address enhancement of carbon stocks by providing funding and investments.

Remote sensing technologies: Imaging instruments using technologies for acquiring information (spectral, spatial, temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. Without direct contact, some means of transferring information through space must be utilised, such as satellites, space shuttle, aircraft, etc.

Spectral signatures: The specific combination of reflected and absorbed electromagnetic (EM) radiation at varying wavelengths that can uniquely identify an object e.g., the unique way in which a given type of land cover reflects and absorbs light.

Tier: Represents a level of methodological complexity. Tier 1 is the simplest method requiring minimal data. Tier 2 uses activity data and emission factors derived from national sources, and Tier 3 includes models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data.

Abbreviations

AWS	Automatic Weather System
BMU	German Federal Ministry of Environment, Nature Conservation and Nuclear Safety
CFR	Community Forest Ranger
DBH	Diameter at breast height
FEWS	Fire Early Warning System
GiZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IPCC	Intergovernmental Panel on Climate Change
KBDI	Keetch-Byram Drought Index
LoF	Logged-over Forest
MODIS	Moderate Resolution Imaging Spectro-radiometer
MPSF	Merang Peat Swamp Forest
MRPP	Merang REDD Pilot Project
MUBA	Musi Banyuasin District
NOAA	National Oceanic and Atmospheric Administration
PT	*Perseroan Terbatas* (Limited Company)
REDD	Reduction of Emissions from Deforestation and Forest Degradation
SSFFMP	South Sumatra Forest Fire Management Project

It is estimated that almost one fifth of global greenhouse gas emissions are produced by deforestation and forest degradation. Independent studies show that while Indonesia is among the world's largest emitters of greenhouse gases, it will also be strongly affected by climate change. Against this background Indonesia has made a strong commitment to reduce its CO^2 emissions by 26% by 2020. The forestry sector will have to provide the main proportion of this ambitious target and rehabilitation of peat swamp forests will play a pivotal role.

Funded by the German Ministry for Environment, Nature Conservation and Nuclear Safety, the Indonesian-German Merang REDD Pilot Project (MRPP) aims to protect and rehabilitate one of the last natural peat swamp forests in South Sumatra. The Project has developed a methodology for measuring and monitoring carbon stock that has since been adopted as a model approach by the Indonesian Ministry of Forestry.

This publication summarizes the role of forest monitoring in the Merang REDD Pilot Project. It is addressed to forest practitioners who are involved in sustainable forest management and REDD+ activities, and sets the standard for carbon-related forest monitoring in Indonesia.

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