Center for Climate Change and Policy Research and Development
Forestry Research and Development Agency
Ministry of Forestry, Indonesia
In Cooperation with
International Tropical Timber Organization (ITTO)

Enhanced Approaches to Estimate Net Emission Reductions from Deforestation and Degradation of Undrained Peat Swamp Forests in Central Kalimantan, Indonesia

March 2013

経済産業省
Ministry of Economy, Trade and Industry

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Jointly Developed by:

MAZARS STARLING RESOURCES

J-spacesystems

Marubeni CORPORATION

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ENHANCED APPROACES TO ESTIMATES NET EMISSIO REDUCTIONS FROM DEFORESTATION AND DEGRADATION OF UNDRAINED PEAT SWAMP FORESTS IN CENTRAL KALIMANTAN, INDONESIA

Report for Activity 1,2, AND 3 ITTO Project REDD+ Feasibility Study for the Bilateral Offset Scheme FY 2012 in Central Kalimantan, Indonesia

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Foreword

The protection of forests, especially in the tropics and sub-tropics, is an essential part of the international effort to reduce global GHG emissions andstabilize the global climate system. Previous research suggests that approximately 20% of global GHG emissions are attributed to the forestry sector, and a 50% reduction in deforestation is needed by 2030 if the forestry sector is to effectively support collective efforts to halt global temperature rise at below 2 degrees Celsius[1]. Given this background, reducing emissions from deforestation and forest degradation (REDD+) has gained momentum in global climate change dialogues, as it provides a framework to incentivize both public and private sectors to reduce GHG emissions, enhance carbon stocks and promote sustainable forest management in developing countries such as Indonesia.

The 26-41% GHG emission reduction commitment announced by President Susilo Bambang Yudhoyono in 2009 and abatement potentials of Indonesia's land-use, land-use change and forestry and peatland sectors have triggered a number of multi-stakeholder initiatives and REDD+ financing outside the United Nations Framework Convention on Climate Change (UNFCCC) framework. These include private sector investment and bilateral cooperation programs between the Governments of Indonesia and developed countries including Japan, Norway, Australia, Germany, the UK and the USA. Furthermore, REDD+ was mainstreamed into the national policy as a part of low carbon development strategies backed by the President Regulation No. 61/2011, collectively known as the National and Regional GHG Emission Reduction Action Plans (RAN-GRK and RAD-GRK).

In response to Japan's pledge to cut GHG emissions (specific target is yet to be determined), the Japanese government has been scoping bilateral mechanisms as an alternative approach to the UNFCCC framework in effectively reducing greenhouse gas (GHG) emissions from activities implemented in developing countries.

[1] Copenhagen Accord, United Nations Framework Convention on Climate Change (UNFCCC), 2009.

In order to design and establish a credible bilateral offset credit mechanism, collectively known as Joint Credit Mechanism (JCM) to be adopted as a cooperation framework, the Ministry of Economy, Trade and Industry (METI) as well as the Ministry of the Environment (MOE) have been undertaking various feasibility studies (FS) on GHG emission reduction projects and accumulating experience and expertise from each case study. Indonesia is one of the key nations, with which the Japanese government aims to develop and implement JCM.

Followed by two feasibility study projects undertaken by the METI in 2010 and 2011, Marubeni Corporation implemented the third feasibility study in 2012 with an aim of testing and verifying key approaches to carbon measurement, reporting and verification (MRV) as well as social safeguards as defined in the Methodology Design Document (MDD 2012). The REDD+ FS 2012 was jointly implemented from October 2012 to February 2013 by a consortium of institutions – namely, the Ministry of Forestry Indonesia, Mazars Starling Resources, Yayasan Puter Indonesia, Verified Carbon Standard (VCS), Japan Space Systems and Hokkaido University, in cooperation with Marubeni Corporation, PT. Rimba Makmur Utama and International Tropical Timber Organization.

Summary

Implications for a joint commitment to reduce GHG emissions

The protection of forests, especially in the tropics and sub-tropics, is an essential part of the international effort to reduce global GHG emissions andstabilize the global climate system. Previous research suggests that approximately 20% of global GHG emissions are attributed to the forestry sector. Given this background, reducing emissions from deforestation and forest degradation (REDD+) has gained momentum in global climate change dialogues, as it provides a framework to incentivize both public and private sectors to reduce GHG emissions, enhance carbon stocks and promote sustainable forest management in developing countries such as Indonesia.

The 26-41% GHG emission reduction commitment announced by President Susilo Bambang Yudhoyono in 2009 and abatement potentials of Indonesia's land-use, land-use change and forestry and peatland sectors have triggered a number of multi-stakeholder initiatives and REDD+ financing outside the United Nations Framework Convention on Climate Change (UNFCCC) framework. These include private sector investment and bilateral cooperation programs between the Governments of Indonesia and developed countries.

One of the bilateral initiatives in the pipeline is the development of a REDD+ mechanism under the Joint Credit Mechanism (JCM) between the Governments of Indonesia and Japan. In order to establish a cooperation framework, the Japanese Ministry of Economy, Trade and Industry (METI) as well as the Ministry of the Environment (MOE) have been undertaking various feasibility studieson GHG emission reduction projects and accumulating experience and expertise from each case study. The Katingan Peatland Restoration and Conservation Project (Katingan Project), located on a tropical peat swamp forest in Central Kalimantan, Indonesia, has been one of the case studies used to develop REDD+ instruments under the JCM since 2010.

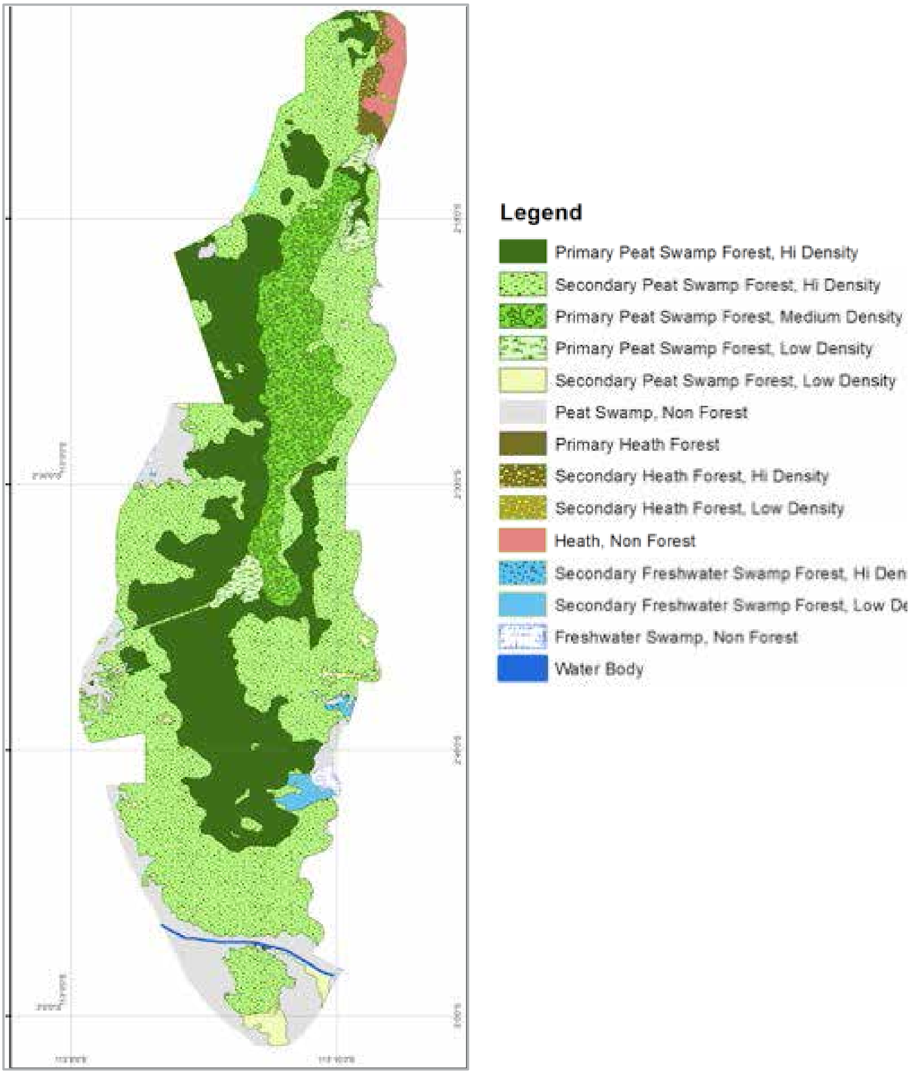
Key studies conducted during the REDD+ feasibility study 2012

The REDD+ feasibility study 2012 consisted of two key components – the application of carbon MRV and the implementation of social safeguard programs. This report provides key findings and results from the studiesconducted for the former component. A new detailed land cover and forest stratification of the Katingan Project site was developed, followed by the comprehensive and scientifically rigorous analysis of carbon stocks and the estimation of net emission reductions from the project site.

Key findings from the analysis of land cover and forest stratification

This study developed a new forest stratification system for the Katingan Project site. The area occurs on distinctive ecosystems consisting of peatland (96%), heath (2.8%), and freshwater swamps (1.2%). Within each ecosystem, forest strata were determined based on vegetation density by using a combination of optical satellite imagery (RapidEye, Landsat and Alos Aster) and radar image data (Alos Palsar).

In summary, approximately 40% of the Katingan Project site consist of primary peat swamp forest, 48% secondary peat swamp forest, 9% non-forested peat land, and the rest are heath and freshwater swamp forest and non-forest areas. The following map shows the detailed stratification of land cover inside the Katingan Project site.



Key findings from the analysis of full carbon stocks

Average total carbon stocks for all five carbon pools (i.e., aboveground biomass, belowground biomass, peat/soil biomass, understory vegetation and necromass)were estimated per land cover stratum asshown in the table below.

Total carbon stocks per hectar on each land cover stratum

No	Stratum	AGB+BGB (ton C/ha)	Peat (ton C/ha)	Understorey Litter Necromass (ton C/ha)	Total C stock (ton C/ha)
1	Primary Peat Swamp Forest, High Density	100.65	4,863.75	9.42	4,973.81
2	Primary Peat Swamp Forest, Medium Density	64.39	2,994.65	7.24	3,066.28
3	Primary Peat Swamp Forest, Low Density	56.54	3,081.51	7.68	3,145.73
4	Secondary Peat Swamp Forest, High Density	67.47	3,747.83	9.65	3,824.95
5	Secondary Peat Swamp Forest, Low Density	37.51	*No data*	*9*	46.51
6	Peat Swamp, Non Forest	12.53	*No data*	*9*	21.53
7	Secondary Fresh Water Swamp Forest, High Density	60.63	654.25	9.00	723.88
8	Secondary Fresh Water Swamp Forest, Low Density	46.23	*No data*	*9*	55.23
9	Fresh Water Swamp, Non Forest	2.95	596.78	14.61	614.35
10	Primary Heath Forest, High Density	64.86	*No data*	*9*	73.86
11	Secondary Heath Forest, High Density	59.08	572.24	6.33	637.65
12	Secondary Heath Forest, Low Density	37.51	*No data*	*9*	46.51
13	Heath, Non Forest	4.62	1,872.88	8.07	1,885.58
14	Water Body	N/A	N/A	N/A	N/A

The total carbon stock from the study site wasestimated by multiplying the average C stock/ha from each stratum by the area of each stratum. Estimated total 722,210,242.68 t C/ha or 0.722 Gt C/ha of carbon is potentially stored at the project site as of 2012.

Total Carbon Stocks from the study site

No.	Stratum	Total C stock (ton C/ha)	Area (ha)	Total C stock (ton C)
1	Primary peat swamp forest, high density	4,973.81	56,253.70	279,795,454.71
2	Primary peat swamp forest, medium density	3,066.28	21,725.50	66,616,458.90
3	Primary peat swamp forest, low density	3,145.73	3,301.05	10,384,208.65
4	Secondary peat swamp forest, high density	3,824.95	94,090.72	359,892,211.77
5	Secondary peat swamp forest, low density	46.51	2,744.03	127,626.58
6	Peat swamp, non forest	21.53	17,944.01	386,278.99
7	Secondary fresh water swamp forest, high density	723.88	287.50	208,115.96
8	Secondary fresh water swamp forest, low density	55.23	1,245.46	68,791.41
9	Fresh water swamp, non forest	614.35	868.55	533,598.15
10	Primary heath forest, high density	73.86	758.82	56,046.62
11	Secondary heath forest, high density	637.65	1,246.22	794,655.61
12	Secondary heath forest, low density	46.51	116.46	5,416.77
13	Heath, non forest	1,885.58	1,772.07	3,341,378.57
14	Water body	N/A	N/A	N/A
TOTAL				**722,210,242.68**

From this study, the total carbon stock of the Katingan Project sitewas estimated to be 0.722 Gt C over the area of 203,570 ha, where the most carbon storage was found in the soil/peat carbon pool. This amount equals to approximately 11.46% of the total peat carbon stock found in the island of Borneo, which amounted to 6,351 million tons C or 6.35 Gt C (56.34%).

Key findings from the analysis of emission factors and total net emission reductions

Baseline deforestation rates

The estimation of emission factors and total net emission reductions was based on time series analyses for landcover changes in theKatingan Project sitefrom 1994 to 2012. For the baseline analysis, the average deforestation rate published by the Ministry of Forestry was used for estimating the likely business-as-usual scenario by logging activities and peat drainage. As a maximum case, an annual deforestation rate of **0.84%** was used. Similarly, the average deforestation rate of **5.92%** was used to estimate emissions from areas deforested due to peat combustion and forest fires.

Emission factors

Following tables present emission factors due to a change in carbon stock potency (ton/ha) as a result of land cover changes. Emission factors from land cover changes from forest classes B to A are quantified.

Matrix of emission factors for Peat Swamp Ecosystem: from primary PSF to secondary PSF

Land cover change (B to A)	B			
A	Primary peat swamp forest, high density (tonC/ha)	Primary peat swamp forest, medium density (tonC/ha)	Primary peat swamp forest, low density (tonC/ha)	Secondary peat swamp forest, high density (tonC/ha)
Primary peat swamp forest, high density	na	nc	nc	nc
Primary peat swamp forest, medium density	-34.94	na	nc	nc
Primary peat swamp forest, low density	-42.50	-7.56	na	nc

Land cover change (B to A)	B			
A	Primary peat swamp forest, high density (tonC/ha)	Primary peat swamp forest, medium density (tonC/ha)	Primary peat swamp forest, low density (tonC/ha)	Secondary peat swamp forest, high density (tonC/ha)
Secondary peat swamp forest, high density	-30.86	+4.08	+11.64	na
Secondary peat swamp forest, low density	-60.84	-25.90	-18.34	-29.98

Remarks: (-) : emission;
(+): positive emission (removal);
nc : no change
na : not applicable

Matrix of emission factors for Peat Swamp Ecosystem: peat swamp forest to peat swamp, non forest

Land cover change (B to A)	B				
A	Primary peat swamp forest, high density (tonC/ha)	Primary peat swamp forest, medium density (tonC/ha)	Primary peat swamp forest, low density (tonC/ha)	Secondary peat swamp forest, high density (tonC/ha)	Secondary peat swamp forest, low density (tonC/ha)
Bareland	-96.98	-62.05	-54.48	-66.12	-36.15
Shrub	-82.27	-47.34	-39.77	-51.41	-21.44
Swamp shrub	-82.27	-47.34	-39.77	-51.41	-21.44
Agriculture	-90.19	-55.25	-47.69	-59.33	-29.35

Remarks: (-) : emission

Matrix of emission factors for Heath Ecosystem: from primary heath to secondary heath forest

Land cover change (B to A)	B	
A	Primary heat forest, high density (tonC/ha)	Secondary heath forest, high density (tonC/ha)
Secondary heath forest, high density	-5,57	na
Secondary heath forest, low density	-26,35	-20,78

Remarks: (-) : emission;
na : not applicable

Matrix of emission factors for Heath Ecosystem: heath forest to heath, non forest area

Land cover change (B to A)	B		
A	Primary heat forest, high density (tonC/ha)	Secondary heath forest, high density (tonC/ha)	Secondary heath forest, low density (tonC/ha)
Bareland	-62,50	-56,93	-36,15
Shrub	-58,04	-52,47	-31,69
Swamp shrub	-58,04	-52,47	-31,69

Remarks: (-) : emission

Matrix of emission factors for Freshwater Samp Ecosystem: primary freshwater swamp forest to secondary fresh water swamp forest

Land cover change (B to A)	B			
A	Primary fresh water swamp forest, high density (tonC/ha)	Secondary fresh water swamp forest, high density (tonC/ha)	Young secondary fresh water swamp forest, low density (tonC/ha)	Old secondary fresh water swamp forest, low density (tonC/ha)
Primary fresh water swamp forest, high density	0	nc	nc	nc
Secondary fresh water swamp forest, high density	-38.56	0	nc	nc
Young secondary fresh water swamp forest, low density	-52.43	-13.87	0	+8.86
Old secondary fresh water swamp forest, low density	-61.29	-22.73	-8.86	0

Remarks: (-) : emission;
nc : no change

Matrix of emission factors for Freshwater Swamp Ecosystem: freshwater swamp forest to freshwater swamp, non forest area

Land cover change (B to A)	B		
A	Primary freshwater swamp forest, high density (tonC/ha)	Secondary freshwater swamp forest, high density (tonC/ha)	Secondary freshwater swamp forest, low density (tonC/ha)
Bareland	-96,98	-58,42	-35,69
Shrub	-96,12	-57,56	-34,83
Swamp shrub	-96,12	-57,56	-34,83
Agriculture	-90,19	-51,63	-28,90

Remarks: (-) : emission

Total net emission reductions from the Katingan Project site

Total NERs under both maxium and minimum drainage cases were estimated as follows.

1. Total net emission reductions in year 1 (from maximum peat drainage)

   = net emission reductions from aboveground biomass + peat emission

   = 603,250.87 ton CO_2 + 170,503 ton CO_2

   = 773,753.62 ton CO_2

2. Total net emission reductions in year 1 (from minimum peat drainage)

   = net emission reductions from aboveground biomass + peat emission

   = 603,250.87 ton CO_2 + 116,043 ton CO_2

   = 719,293.71 ton CO_2

3. Total net emission reductions in year 30 (from maximum peat drainage)

   = net emission reductions from above ground biomass + peat emission

   = 603,250.87 ton CO_2 + 4,457,275 ton CO_2

   = 5,060,526.32 ton CO_2

4. Total net emission reductions in year 30 (from minimum peat drainage)

   = net emission reductions from above ground biomass + peat emission

   = 603,250,87 ton CO_2 + 2,823,478 ton CO_2

   = 3,426,729.10 ton CO_2

5. Accumulated total net emission reductions for the period of 30 years (from maximum peat drainage)

   = ∑ [total net emission reductions in year 1, 2, 3, ... 30 (max peat drainage)]

   = 87,514,199.11 ton CO_2

6. Accumulated total net emission reductions for the period of 30 years (from minimum peat drainage)

   = ∑ [total net emission reductions in year 1, 2, 3, ... 30 (min peat drainage)]

   = 62,190,342.20 ton CO_2

The following tablepresents the summary ofestimated total netemission reduction amountsfrom the Katingan Project site for the period of30 years.

Net emission reductions from the Katingan Project site from year 1 to 30

Period	Emission (tCO_2/year)	
	Max-case drainage depth	Min-case drainage depth
	(Drainage 0.95 m)	(Drainage 0.60 m)
Year 1	773,753.62	719,293.71
Year 2	921,573.37	812,653.55
Year 3	1,069,393.11	906,013.39
Year 4	1,217,212.86	999,373.23
Year 5	1,365,032.61	1,092,733.07
Year 6	1,512,852.36	1,186,092.92
Year 7	1,660,672.11	1,279,452.76
Year 8	1,808,491.86	1,372,812.60
Year 9	1,956,311.61	1,466,172.44

Period	Emission (tCO_2/year)	
	Max-case drainage depth	Min-case drainage depth
	(Drainage 0.95 m)	(Drainage 0.60 m)
Year 10	2,104,131.35	1,559,532.28
Year 11	2,251,951.10	1,652,892.12
Year 12	2,399,770.85	1,746,251.96
Year 13	2,547,590.60	1,839,611.80
Year 14	2,695,410.35	1,932,971.65
Year 15	2,843,230.10	2,026,331.49
Year 16	2,991,049.84	2,119,691.33
Year 17	3,138,869.59	2,213,051.17
Year 18	3,286,689.34	2,306,411.01
Year 19	3,434,509.09	2,399,770.85
Year 20	3,582,328.84	2,493,130.69
Year 21	3,730,148.59	2,586,490.53
Year 22	3,877,968.34	2,679,850.37
Year 23	4,025,788.08	2,773,210.22
Year 24	4,173,607.83	2,866,570.06
Year 25	4,321,427.58	2,959,929.90
Year 26	4,469,247.33	3,053,289.74
Year 27	4,617,067.08	3,146,649.58
Year 28	4,764,886.83	3,240,009.42
Year 29	4,912,706.57	3,333,369.26
Year 30	5,060,526.32	3,426,729.10
Accumulated Total	**87,514,199.11**	**62,190,342.20**

Acronyms

AFOLU	:	Agriculture, Forestry, and Other Land Use
ANR	:	Assisted Natural Regeneration
BAU	:	Business-As-Usual
BOCM	:	Bilateral Offset Credit Mechanism
C	:	Carbon
Co	:	Alluvial sediment
CO_2	:	Carbon dioxide
DBH	:	Diameter at breast height (1.3 meter)
DF	:	Deforestation
DG	:	Forest Degradation
DM	:	Dry Matter
DNPI	:	National Council on Climate Change (Dewan Nasional Perubahan Iklim)
EF	:	Emission Factor
ERC	:	Ecosystem Restoration Concession
FAO	:	Food and Agriculture Organization
FS	:	Feasibility Study
GHG	:	Greenhouse Gas
GIS	:	Geographic Information System
GoI	:	Government of Indonesia
GPS	:	Global Positioning System
GWP	:	Global Warming Potential
Ha	:	Hectare
HCV	:	High Conservation Value
IPCC	:	Intergovernmental Panel on Climate Change
ITTO	:	International Tropical Timber Organization
JCM	:	Joint Credit Mechanism

LULC	:	Land Use and Land Cover
LULUCF	:	Land Use, Land-Use Change and Forestry
METI	:	Ministry of Economy, Trade and Industry Japan
MDD	:	Methodology Design Document
MOE	:	Ministry of Environment Japan
MoF	:	Ministry of Forestry Indonesia
MRV	:	Monitoring, Reporting and Verification
MT	:	Metric Tonne
tCO_2e	:	Metric tonneof Carbon Dioxide equivalent
NER	:	Net Greenhouse Gas Emission Reduction
RAN-GRK	:	National GHG Emission Reduction Action Plan
RAD-GRK	:	Regional GHG Emission Reduction Action Plan
NER	:	Net Greenhouse Gas Emission Reduction
REDD+	:	Reducing Emissions from Deforestation and Degradation Plus sustainable forest management and carbon stock enhancement
RePPProt	:	Regional Physical Planning Program for Transmigration
SOC	:	Soil Organic Carbon
SOP	:	Standard Operation Procedure
TM	:	Landsat Thematic Mapper
TOd	:	Dahor formation
UNFCCC	:	United Nations Framework Convention on Climate Change
VCS	:	Verified Carbon Standard

INTRODUCTION 1

1.1 Background

Peatland is one of the most important and rare ecosystems in the world. It is a wetland characterised by decomposed organic matterswhich have accumulated over thousands of years in an anaerobic condition. Thus,peatlands stock a huge amount of carbon dioxide (CO_2) and serve as a carbon sinker (Jaenicke *et al.*, 2008; Parish *et al.*, 2008).

In 2005, as much as 85% of the total greenhouse gas(GHG) emissions in Indonesia resulted from land use, land-use change and forestry (LULUCF) and peatland, among which emissions from carbon-rich peatlands amounted to 41% (DNPI, 2010). Indonesia has a projected abatement potential of 1,770 million tons of CO_2 equivalent ($MtCO_2e$) from the LULUCF sector and peatlands when compared with its business-as-usual (BAU) emissions of 3,260 $MtCO_2e$ in 2030 (DNPI, 2010).

Therefore, peatswamp forests have important roles in regulatingboth global and local climate. Furthermore, peat swamp forests regulate hydrological cycle by reducingthe downstream maximum water height of a flood (i.e., flood peaks), and also by maintaining base flows in rivers during dry periods. They play an important role in natural water management by preventing loss of life and damage to infrastructure and agriculture by reducing the risk of floods and droughts.

Peat swamp forests contain a high variety of flora and fauna, which are often unique and endemic to the ecosystem. They also play a crucial role in meeting basic needs of local communities and their livelihoods. Such basic needs include: i) nutrient intake; ii) clean water for drinking, cooking, bathing and washing; iii) building materials; iv) firewood; v) medicines; vi) livestock; and vii) timber and non-timber products.

Despite these socio-ecological benefits, peatswamp forests are facing pressingthreat from land-use changes including industrial agriculture, mining, logging, pulp and paper production, and urbanization.

The high demand of land acquisition for plantation forests, agriculture, and infrastructure development has led to the conversion of peatswamp forests in Indonesia (Jaenicke et al., 2008). Once thedrainage system is disturbed, peat organic matters would be exposed to the air, subject to oxidation and peat decomposition, leading toCO2 emissions.

Land cover and land use represent key elements to be integrated in natural resource use planning and management. Land cover changes occur both naturally and due to human activities, affecting global climatic systems. Land use is characterized by human activities on particular land cover types for both socio-economic and ecological purposes.It is a direct relationship between land cover and the behavior of people in an environment.Therefore, land cover is often used as a geographic parameter, which plays an important role as a reference baseline for many applications, such as forest planning and management, monitoring, statistics, investment, biodiversity conservation and climate change mitigation and adaptation.

Because peatland characteristics such as vegetation types, peat depths, water table levels and soil organic carbon contents are highly variable from location to location, the variability of carbon stocks and CO_2 emissions is also considered high. In order to minimize uncertainty and geostatistical errors as a result of high variability, it was deemed necessary to estimate emission factors based on detailed land cover and forest stratification in several research locations.Furthermore, the quantification ofemission factor and carbon stock values derived from land-use change and vegetation growthon eachland cover stratum was necessary in order to accurately estimatenet emission reduction (NER) amounts from the study site.

Land cover classification is an abstract representation of the situation in the field based on diagnostic criteria defined as a classifier. Sokal *et al.* (1995) defines land cover classification as: "the order or arrangement of objects into groups or sets on the basis of their relationship. A classification describes a systematic framework with the names of the classes and the criteria used to distinguish them, and the relationships between the classes."The Forestry Planning Agency of the Ministry of Forestry, Indonesia defines 23 land cover classes as the official delineation of different land covers and land uses throughout the archipelago (Table 1).

Table 1. *Land cover classification in Indonesia*

No	Land cover classification
1.	Primary dry land forest
2.	Secondary dry land forest
3.	Primary swamp forest
4.	Secondary swamp forest
5.	Primary mangrove forest
6.	Secondary mangrove forest
7.	Plantation forest
8.	Shrub
9.	Swamp shrub
10.	Grassland
11.	Crops
12.	Dry land agriculture
13.	Dry land agriculture and shrub
14.	Transmigration
15.	Rice field
16.	Pond
17.	Bareland
18.	Mining
19.	Settlement
20.	Swamp
21.	Airport
23.	Cloud

Source: Forestry Planning Agency, the Ministry of Forestry Indonesia

This land cover classification, however, does not grasp the complex characteristics of tropical peat swamp ecosystems. In order to estimate carbon stocks and NERs from peat swamp forest accurately, an ecosystem-based land cover and forest stratification with different levels of vegetation density was deemed invaluable. Thus, this study developed a new detailed land cover and forest stratification of the Katingan Peatland Restoration and Conservation Project (Katingan Project) site, based on which the analyses of carbon stocks and NERs were conducted.

This report sets out to present key approaches to and findings from the carbon-related studies conducted under the METI REDD+ FS 2012 at Katingan Project site in Central Kalimantan, Indonesia. It is organized into three sub-categories – land cover and forest stratification, full carbon stock analysis, and the estimation of net emission reductions.

1.2 Study site

1.2.1 Project location

The REDD+ FS2012was conducted at the Katingan Peatland Restoration and Conservation Project ("Katingan Project") site,located in the districts of Kotawaringin Timur and Katingan in Central Kalimantan Province, Indonesia with southern latitudes 2 32' 36.8" – 3 01' 43.6" and eastern longitudes 113 00' 29.7" – 113 18' 57.4" (see Figure 1 – the area inside the red box indicates the study site).Covering a total area of 203,570 ha, the area is home to some of the world's endangered species, including the Bornean orangutan (*Pongo pygmaeus*) and proboscis monkeys (*Nasalis larvatus*). Approximately 90% of the total area is identified as forest land.

1.2.2 Basic physical parameters of the study site

1.2.2.1 Soils

Two formations make up the geological characteristic of the Katingan Project area i.e.,: Alluvial sediment (Co) and Dahor formation (TQd). Most of the soils in the area are considered Organosol glei humus. The soil is characterized as peat, which is naturally acidic at pH levels between 3.0 and 5.0, and is composed of the high accumulation of organic matter substances such as partly decomposed leaves and tree stems. The formation of peat soil in the proposed concession area is a result of constant conditions of water logging above mineral soil and a lack of oxygen, in which a large amount of organic residues are decomposed, forming a peat layer.

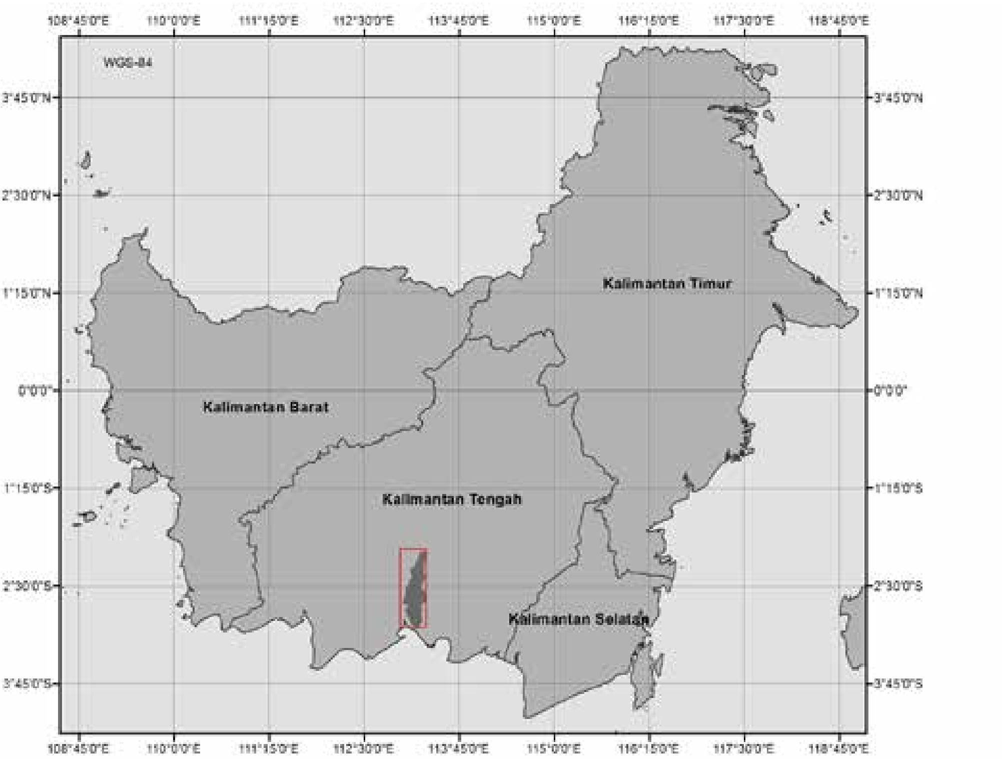


Figure 1. *The location of the Katingan Project site*[2]

1.2.2.2 Land systems

The Katingan Project area is mostly a peatland, a large part of which is still covered with peat swamp forest. It is characterized by flat terrain with a slope angle of 0-8%, at an altitude of 0-30 meters above sea level. According to a study conducted by the Regional Physical Planning Program for Transmigration[3] (RePPProt), there are threeforest ecosystem proxies within the proposed concession area – peat forest, heath forest and fresh water swamp forest.

[2] The figure was taken from the VCS project description of the Katingan Project prepared by Mazars Starling Resources and Terra Global Capital, LLC.

[3] RePPProt is a land classification database system developed by the Government of Indonesia for its transmigration program during the 1980s through 1990s. It is the only system, coordinated by the National Land Agency and the Coordinating Agency for Surveys and Mapping, which has been used by all sectors for land-use planning, management and baseline setting until today.

1.2.2.3 Rainfall

Average monthly rainfall in the proposed concession is estimated at 240 mm per month with total annual rainfall equal to 2,881 mm per year. Rainfall is relatively evenly distributed throughout the year with all months reportedly receiving more than 200 mm of rain.

June through October are generally the driest months, while the wettest months occur in November through May with the average monthly rainfall rises up to 303 mm per month.

1.2.2.4 Hydrology

The total area of the Katingan Project area is 203,570 ha, which falls between the Mentaya and Katingan Rivers. The flood plains of the two major rivers extend only a short distance from the river banks into forests. Thus, the entire project area receives little nutrient influx from these river floodplains and therefore can be classified as an “ombrogenous” peat swamp. In ombrogenous peat swamps, the only source of nutrient influx is from aerial precipitation (i.e., rain and dust), with small amounts of nutrient influx through microbial nitrogen fixation and faunal migration/animal faeces (Sulistiyanto, 2004).

1.2.3 Definitions

The definitions applied in this study are consistent with or complement the definitions suggested by the Ministry of Forestry Forest Planning Agency as well as the VCS AFOLU requirements. More details are provided in the Methodology Design Document (2012).

1. **Peat** is organic soil with at least 30% organic matter and a minimum thickness of 30 cm.
2. **Forest** is an area with trees with a minimum canopy cover of 30%.
3. **Deforestation** is the change of land cover from forest to non-forest classes such as shrub land, bare land and crop land.
4. **Degradation**is a forest cover changefrom its original status to another forest status with greater disturbancy (i.e., from primary forest to secondary forest).

5. **Forest strata** are forest land use and land cover (LULC) classes devided according to the carbon stock density, native forest type, past and future management, landscape position, biophysical properties, and/or the degree of past disturbance. The minimum mapping unit set forward in the forest definition must also be applied to forest strata.
6. **Forest stratification** is the process of sub-dividing the broad forest LULC class into more narrow forest strata.
7. L**and transition** is a change from one LULC class or forest stratum into another within one geographical area.
8. **Forest regeneration (RG)** is the persistent increase of canopy cover and/or carbon stocks in an existing forest due to natural succession or human intervention, and falls under the IPCC 2003 Good Practice Guidance land category of forest remaining forest.
9. **Increased forest cover** is the transition of non-forest land into forest land, and encompasses both reforestation and natural succession.
10. **Reforestation (RF)** is the human-induced increase in forest cover (e.g., from cropland to forest, or grassland to forest).
11. **Natural succession** is a natural increase in forest cover without any human intervention. Natural succession is included in the baseline and project scenarios. Natural succession and increase in forest cover are likely results of decrease in deforestation rate due to project activities.

METHODS 2

2.1 Land cover and forest stratification

Forest and land cover stratification analysis was conducted by using the combination of a Synthetic Aperture Radar (SAR) data and medium-to-high resolution optical satellite sensors to reduce data gaps and improve interpretation. Geographical information system (GIS) based data processing allowed for the integration of multiple data sources, and distinguished different interpretations between PALSAR and other optical satellite images. Nevertheless, the calibration of spatial data was mostly based on imageries obtained from medium to high resolution optical satellite sensors. SAR data, which provided interpretation on structural characteristics of different forest and land covers, were reviewed to enhance the level of interpretation of spatial analysis. Table 2 presents a list of satellite sensors used for this study.

Table 2. *Satellite sensors capability used for the study*

Satellite sensor	Data capability	Date	Number of scenes acquired	Spatial resolution
ALOS PALSAR	SAR active microwave sensor	4/28/2010 and 5/15/2010 (polarimetry); and 7/5/2010 (FBD)	4 scenes for full polarimetry mode HH+HV+VH+VV; and 4 scenes for fine beam double polarization mode HH+HV/VV+VH	25 m for full polarimetry mode; and 12.5m for FBD; L-band (1270 MHz) frequency
RapidEye	High resolution optical sensor	2/24/2010	2 scenes	6.5 m for all spectral bands
ALOS ASTER	Medium resolution optical sensor	9/10/2012	2 scenes	15 m for multispectral bands 1-4
Landsat TM5 and 7	Medium resolution optical sensor	1990, 1994, 1997, 2000, 2003, 2006, 2010, 2012	2 scenes for 2010, and multiple imageries from past years	30 m for multispectral bands 1-7

2.1.1 Stratification methods using radar sensor

ALOS PALSAR polarimetric and fine beam double polarization (FBD) data were used to interpret complex forest structures such as the size and shape of tree trunks, tree height, moisture content of vegetation and soil, and volume of biomass. PALSAR is an active microwave sensor for all-weather observation regardless of day or night, and is free from obstructions of clouds and rain. It provides detailed information of the area of interest with its characteristic scatter measurement of inner forest, in contrast to observation by optical satellite sensors such as RapidEye and Landsat. Backscattering coefficient analysis, interferometry processing and polarimetric data processing were conducted to obtain a combination of HH, HV, HV and VV vector information. PALSAR data calibration was performed at different off-nadir angles of 20.5, 21.5, and 23.1 for the full polarimetry mode. Red (HH), Green (HV) and Blue (VV) were specified for each polarization image, and superimposed to indicate a synthetic color image (see Figure 2). Bi-dimensional classification was conducted by using entropy (H) and alpha angle (α) as an input to classifier. These parameters, estimated based on H/α relationships, were used to understand various characterization of vegetation and land cover classes.

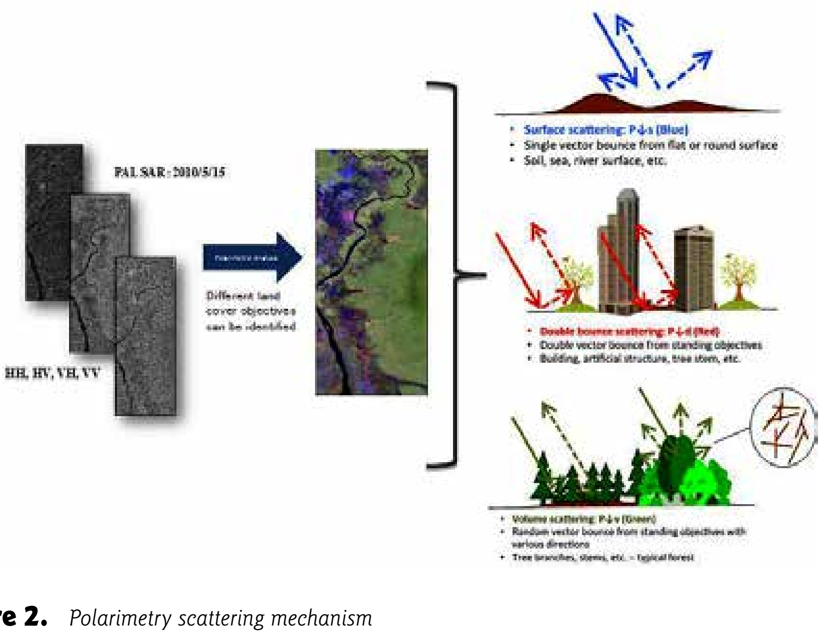


Figure 2. *Polarimetry scattering mechanism*

The full polarimetry mode of PALSAR was proven to also provide high classification accuracy for each representative stratum. The performance of polarimetry and FBD was also compared to test their interpretation capabilities and the level of accuracy. Both polarimetry and FBD datasets presented similar interpretation results. However, FBD showed some classification bias due to limited information on polarimetric waves. Therefore, polarimetry was considered as a more reliable and accurate method for forest and land cover stratification. PALSAR polarimetric data (level 4.1 product) were then analyzed with optical satellite sensors – ASTER, RapidEye and Landsat TM5 – by overlaying image layers on a GIS platformin order to conduct a more detailed forest and land cover stratification analysis.

2.1.2 Stratification methods using the combination of optical sensors and SAR

Several sample images from different optical satellite sensors in time-series were examined before the acquisition of data in order to identify the finest satellite images for the area. For example, RapidEye images captured in different months in 2010 were reviewed and compared to identify scenes with minimal cloud cover. While Landsat was useful for the time-series analysis of past land use in the study site, RapidEye and ASTER became invaluable where Landsat imagery could not provide clear interpretation because of its image resolution and data availability. Due to the nature of the tropical climate in Central Kalimantan, almost all available images contained clouds and haze cover at least over some parts of the project area. In order to reduce data gaps and improve image interpretation, a combination of three different optical satellite sensors was used.

RapidEye, ASTER and Landsat TM5 imagery were used to analyze surface cover information such as forest canopy and vegetation cover. With visible, near infrared and short-wave infrared sensors, which detect solar radiation reflected or scattered from the earth, images similar to photographs were obtained. These image files were further overlaid with other geographical vector data such as the project boundary, land ecosystems (i.e., peat, heath/kerangas and freshwater swamp), existing watersheds and rivers, and jurisdiction. A GIS platform was used to integrate all geographical data to digitally create and manipulate spatial areas over the Katingan Project area (Figure 3).

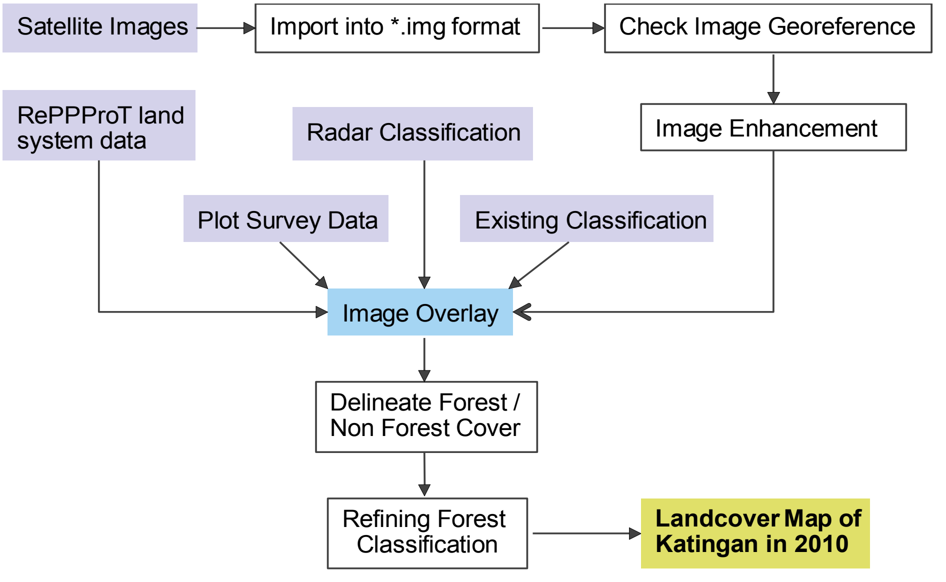


Figure 3. *Digital integration process of optical satellite imagery and vector data*

Forest and land-cover stratification was conducted by visually interpreting optical satellite imagery (see Figure 4). Each RapidEye, ASTER and Landsat TM5 image was compared and analyzed to obtain the maximal surface cover information without data gaps and uncertainties. While the current land cover map is mostly based on optical satellite imageries from 2010, additional time-series images were also obtained and examined. This was necessary to learn about the past land-use in the Katingan Project site.

In particular, the delineation of secondary forest, where there are traces of past or current logging tracks, was conducted by reviewing Landsat imageries from 1990, 1994, 1997, 2000, 2003, 2006 and 2010 in order to identify areas with the history of human disturbances. Land cover changes caused by selective logging activities was determined by interpreting satellite imagery and by identifing areas of degradation. Land cover changes by logging activities was assumed where traces of past or current logging tracks existed. For example, it was considered as degradation when primary forest was visually degraded to secondary forest class on satellite imagery, and likewise, high density secondary forest changing into low density secondary forest.

The land classification system of 1987 by RePPProT was used to overlay information on different ecosystems, and it was adjusted based on ground truthing results. For example, some areas identified as fresh water swamps by RePPProT were found to be peat during the field survey. These areas were corrected and reclassified in the final stratification map.

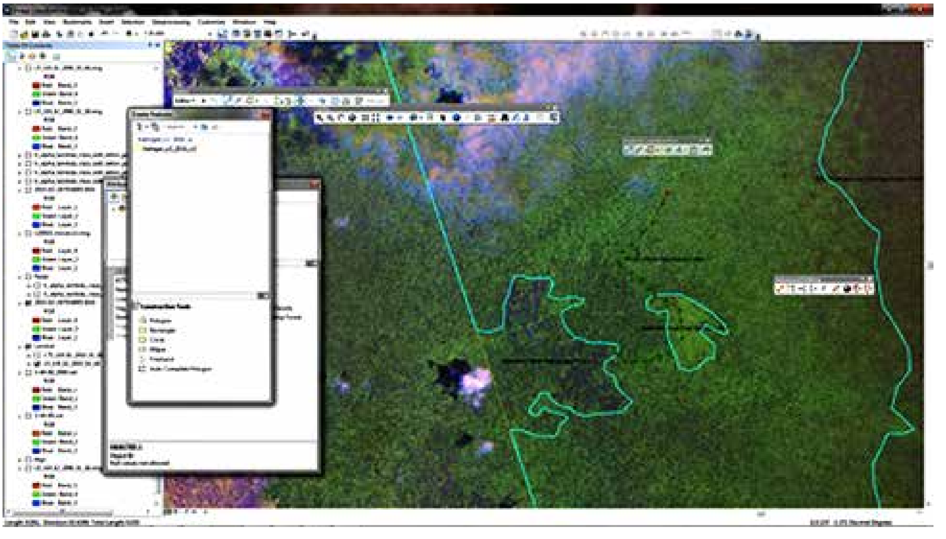


Figure 4. *Visual interpretation of forest stratification on GIS (the red arrow showing the digital manipulation process of forest strata on the Rapid Eye imagery)*

The visual interpretation of satellite images was then calibrated to ancillary vector data, vegetation density and field measurement data (i.e., peat depth, aboveground biomass and water table levels). It was also overlaid with SAR classification results to generate a new stratification map based on the land and forest cover from 2010, as well as fire hot spot data to identify fire-prone areas, where recurring peat fires have been a problem (Annex 1). Image classification was ground truthed and re-classified where appropriate to validate the landcover and forest stratification map based on the real condition in the field. This was done by surveying purposive sampling points (i.e., areas which needed field clarification), and conducting interviews with local communities to clarify the past and current land use. After ground trothing, stratification map was re-interpreted.

2.2 Full carbon stock analysis

2.2.1 Selection of sampling plot location

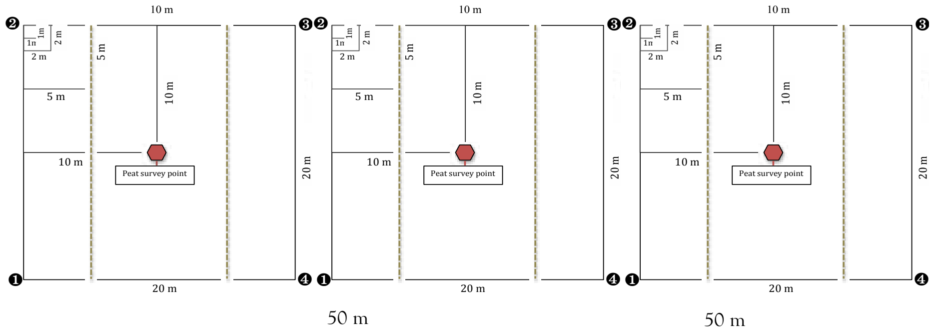
Full carbon stock analysis was conducted based on data collected from field surveys and geospatial data obtained from both radar and optical satellite imagery. The location of permanent and temporary sampling plots was determined based on the result of land cover and forest stratification analysis. During the REDD+ FS 2012, six permanent sampling plots and 12 temporary sampling plots were established.

These new data points were then added to existing sampling database developed by PT. Mazars Starling Resources from 2008 to 2011, as well as database created during the previous REDD+ FS in 2010 and 2011. In total, over 100 sampling plot data were used to estimate the full carbon stock for each land cover and forest stratum in the study area. To conduct the analysis, all sampling plots were re-stratified based on the new land cover and forest stratification result obtained during this study.

2.2.2 Plot establishment and survey in the field

Sampling plots were established in the field, using the nested square plot methodas defined by the standard operation procedure (SOP) developed during the REDD+ FS 2011 (see Figure 5). While details may be different, this SOP is consistent with the Indonesian National Standard 7724-2011: Measurement and calculation of carbon stocks – field measurement for estimating forest carbon stocks.

Inside the plots, peat depth was measured at the center of a 20m x 20m plot. An *Eijilkamp* peat auger was used to measure the depth of peat layers in 50 cm segments until reaching mineral soils or clay layers. Further to validate the depth, additional measurements were taken nearby the center of the plots. Peat samples were taken for the length of 30 cm from each 50 cm segment, weighed on site using the digital balance and placed into labeled plastic bags. Field observations of peat soils described structure, color, decomposition level and visible organic elements. Hand squeezing method was used to determine peat maturity. Conducting both field and laboratory classification was deemed crucial for peat survey as peat characteristics and chemical properties may changeduring sample transportation and storage (Wust, et. al., 2003).



Plot measurements:

1m x 1m	:	litter, understory vegetation
2m x 2m	:	seedlings (DBH < 2.5 cm)
5m x 5m	:	saplings (DBH 2.5 – 9.9 cm)
10m x 10m	:	poles (DBH 10.0 – 19.9 cm)
20m x 20m	:	trees (DBH ≥ 20.0 cm)
	:	canopy closure and peat measurement
----	:	dead wood (necromass) measurement

Figure 5. *Nested sampling plots*

Aboveground biomass was also measured using direct sampling method. Fresh weight of organic matters (litter, understory vegetation and necromass) was also measured at sampling plots in the field. 250 grams of fresh biomass were collected as samples to estimate dry weight of litter, understory vegetation and necromass in the laboratory. Local names of each tree species were identified, trees tagged with plastic labels, the diameter at breast height measured (DBH or 1.3 m), and the height of all trees inside the subplots larger than or equal to 2 m x 2 m recorded. The canopy cover was measured, using a spherical densitometer.

2.2.3 Biomass and carbon stock estimation

Biomass and carbon stock estimation was conducted by analyzing five carbon pools – aboveground biomass, soil/peat, litter, belowground biomass such as roots, and necromass. Geostatistical analysis wasconducted for each land cover stratum by upscaling remote sensing information and field measurement data from sampling plots to interpolate the volume of biomass and carbon stock for the entire project site.

2.2.3.1 Above- and belowground biomass estimation

Above- and belowground biomass was estimated using a local allometric equation, which was developed for the peatswamp forest of the Katingan Project site during the previous REDD+ FS 2011. The equation is:

$$Y = 0.1032\, X^{2.4695} \quad \text{with } R^2 = 0.9643$$

Where:

Y = Biomass (kg)
X = Diameter at breast height (cm)

2.2.3.2 Peat/soil carbon estimation

Laboratorial analysis was conducted to examine physical and chemical parameters, especially bulk density and organic carbon contents. Peat carbon contents were estimated using the following equation:

$$Cs = Pd \times \rho \times \%\, C\ \text{organic}$$

Where:
Cs = Soil carbon (g/cm2);
Pd = Peat depth (cm)
ρ = Bulk density (g/cm3);
%C organic = Percentage of carbon content (%)

2.2.3.3 Litter and understory biomass estimation

Biomass of litter, understory vegetation and necromass with diameter at breast height smaller than 2.5 cm was estimated using the following equation:

$$Wo = \frac{Wd \times Wft}{Wfs}$$

Where:

Wo = Weight of organic matter (litter, understorey, necromass) (kg)
Wd = Weight of dry organic matter (kg)
Wft = Total fresh weight of organic matter (kg)
Wfs = Fresh weight of organic sample (kg)

2.2.3.4 Total biomass estimation

Based on the land cover and forest stratification of the Katingan Project site, the total volume of biomass in eachexisting stratum was estimated. The analysis was conducted by overlaying sampling locations with stratified land cover data. The total sampling number (N)was obtained for each stratum. Calculation of average biomass was based on the number of N samples in each land cover stratification. The volume oftotal biomass was obtained by multiplying the average biomass volume with the size ofeach stratification area.

Calculation of average biomass and total biomass in each stratification is based on the following formulas (Center for Standardization and Environment, 2011):

<u>Biomass average in each stratification</u>

$$B = Tn / n$$

Where:

B = biomass average in each land cover stratification
Tn = biomass total in sample location plots
n = sample number

<u>Total biomass in each stratification</u>

$$TB = B \times L$$

Where:

TB = total biomass in each land cover stratification
B = biomass average in each land cover stratification
L = land cover stratification area

2.3 Estimation of Net Emission Reductions

2.3.1 Land cover and land cover change analysis

Land cover and land cover change analysis was conducted using a combination of different satellite sensors – ALOS PALSAR, RapidEye, ALOS ASTER and Landsat TM5 and 7 (see Table 2).

Based on the land cover and forest stratification result, a land use change matrix was generated in order to estimate emission factors from land cover and land cover change, and also to estimate net emission reduction potentials from the Katingan Project site. Figure 6 illustrates steps taken to conduct land cover and land cover change analysis. Instruments used for data analysis is computer software including Erdas Imagine 9.1, Er Mapper 7.0, and ArcView 3.2. A handheld GPS was used for ground truthing activities in the study site.

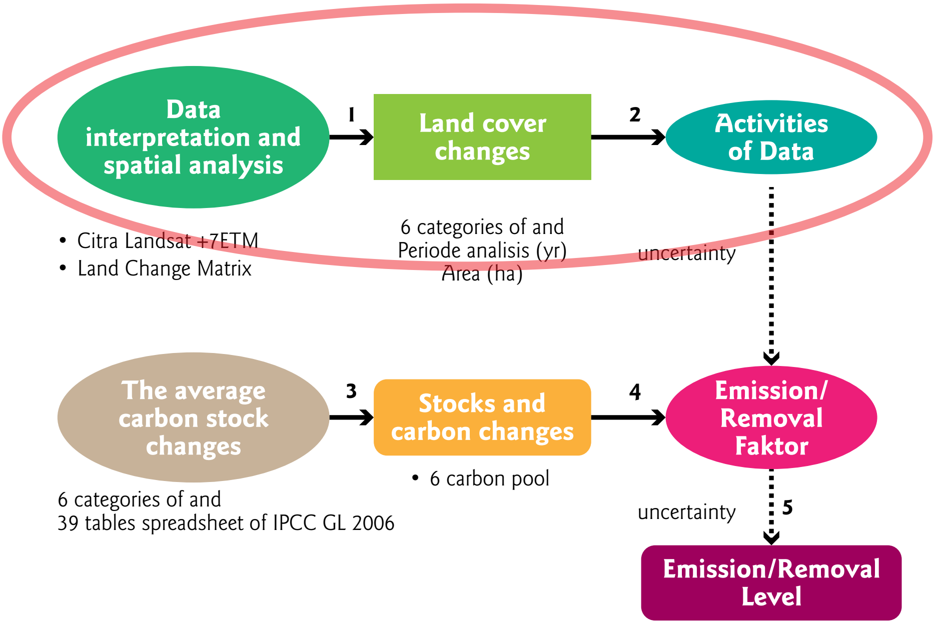


Figure 6. *Land cover and land cover change analysis steps*

Information on land cover changes were obtained through the interpretation ofmultiple satellite image data. Landsat TM 5 and 7 were used as the primary satellite imagery data source. The interpretation process consisted of object identification in satellite imagery, delineation and labeling. Initial data processing (pre-processing) with radiometric and geometric correction was conducted before data interpretation. In order to enhance the visual interpretation of satellite imagery,the Landsat composite image color of RGB 543 and RGB 453 was selected.Rapid eye,Alos Aster and Alos Palsar data were also used as complementary data sources toclarify and validateuncertain delineation and cloud-covered areas on Landsat imagery.

Although classes used for land cover and land cover change analysis was primarily based on the stratification result obtained in this study,additional classifications defined by theForest Planning Agency, the Ministry of Forestry Indonesia, were also considerd in order to capture all possible patterns of land cover change in the study site. For example, peatland non-forest stratum was further divided into smaller sub-classes – bare land, agriculture, shrub land and swamp shrub. These additional classifications weredeemed necessary for the purpose of emission factor estimation because the volume of potential GHG emissions vary across these classes. Emission factors from these sub-classes were then integrated into the primary land cover and forest stratification result for overall estimation of NER. Figure 7 shows procedures for land cover change analysis.

2.3.2 Estimation of Emission Factors

Emission factors from land cover changes was estimated based on theland cover and forest stratification for the Katingan Project site. Emission factors were accounted in each stratum using the results of aboveground carbon stock estimation (carbon stocks from peat are not included in this study).The conversion to CO_2 from C, was based on the ratio of molecular weights (44/12). The negative stock change (-) indicates an increase in CO_2 emissions to the atmosphere, whereas the positive stock change (+) indicates a removal factor (i.e., sequestrationof CO_2 emissions). Emissions and removals of CO_2 within the AFOLU Sector are generally estimated on the basis of changes in ecosystem carbon stocks. These consist of above- and below-ground biomass, dead organic matter (i.e., necromass and litter), and soil organic matter (i.e., peat). In this study, however, peat was excluded from the estimation of emission factors.

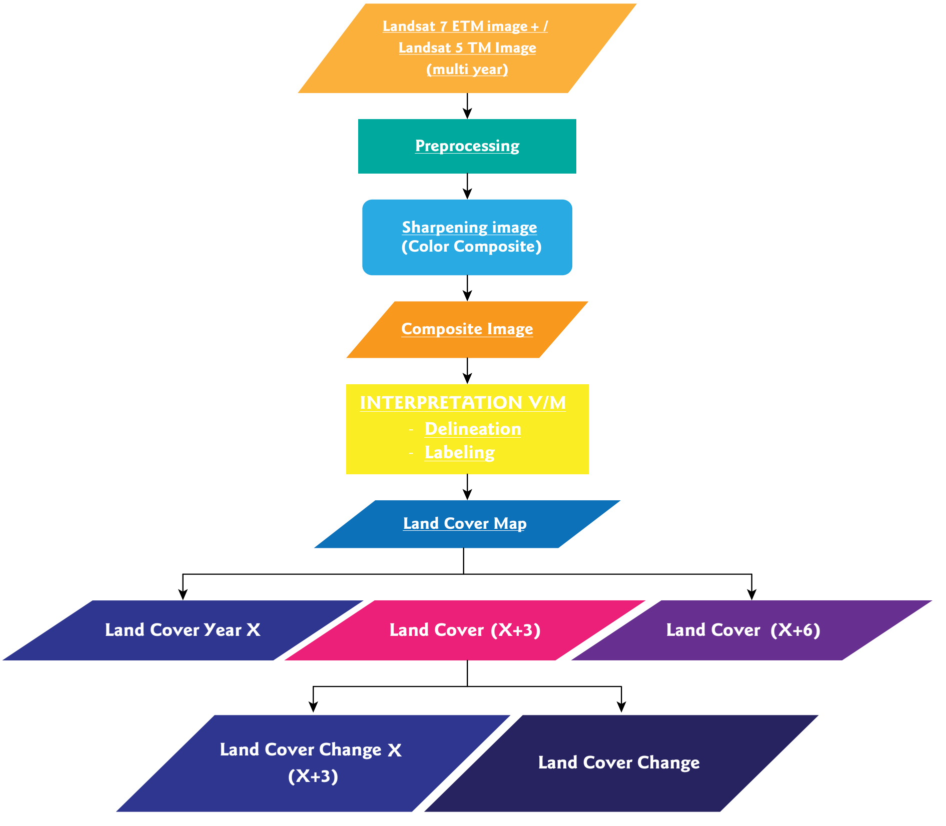


Figure 7. *Precedures for land cover change analysis*

A stock-difference method was used to estimate emission factors from stock changes in five carbon pools (i.e., aboveground biomass, belowground biomass, soil/peat, litter and necromass).These parameters were used to estimate CO_2 emissions to the atmosphere, and net gains in total carbon stocks were used to estimate removal of CO2 from the atmosphere. The Stock-Difference method, as defined in the IPCC Guidelines (IPCC, 2006),requires that "biomass and carbon stock inventories for a given land area, at least two points in time. Annual biomass change is the difference between the biomass stock at time t_2 and time t_1, divided by the number of years between the inventories. In some cases, primary data on biomass may be in the form of wood volume data, for example, from forest surveys, in which case factors are provided to convert wood volume to carbon mass units." The stock difference of these five carbon pools were estimated by usingthe following formula:

$$\Delta C_B = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

Where:

ΔC_B = annual change in carbon stocks in biomass (the sum of above-ground and below-ground biomass) in land remaining in the same category (e.g., *Forest Land Remaining Forest Land*), tonnes C yr-1

$C\ t_2$ = total carbon in biomass for each land sub-category at time t_2, tonnes C

$C\ t_1$ = total carbon in biomass for each land sub-category at time t_1, tonnes C

Note: the carbon stock values for some pools may be in tC/ha, in which case the difference in carbon stocks will need to be multiplied by an area.

2.3.3 Estimation of CO_2 emissions

CO_2 emissions from aboveground biomass and peat were estimated based on two scenarios – peat drainage and fires. Following formulas were applied.

2.3.3.1 CO_2 emissions from aboveground biomass

1. Total carbon stock of extracted trees

   = ∑ [logged timber biomass x carbon stock in each forest stratification]

   = ∑ [(area of each stratification (ha) x rate of deforestation 0.84%) x (carbon stock in each forest stratification tC/ha)]

2. Carbon stock turning into long-lived wood products

   = Total carbon stock from timber extraction x percent of harvested roundwood turning into long-lived wood products

3. CO_2 emisson from timber extraction

   = (Total carbon stock of extracted trees - carbon stock turning into long-lived wood products) x 44/12

4. CO_2 emission from biomass burning

   = [((area cleared due to biomass burning x avarage carbon stock in above-ground living biomass) - Total carbon stock of extractedtrees)) x average proportion of carbon stock burnt x average biomass combustion efficiency x carbon stock (DBH < 10cm) x 44/12]

5. N_2O emission from biomass burning

   = CO_2 emission from biomass burning x 12/44 x nitrogen/carbon ratio x emission ratio for N2O x 44/28 x GWP N2O

6. CH_4 emission from biomass burning

   = CO_2 emission from biomass burning x 12/44 x emission ratio for CH_4 x 16/12 x GWP CH_4

7. Total emission from biomass burnt

   = CO_2 emission from biomass burning + N_2O emission from biomass burning + CH_4 emission from biomass burning

2.3.3.2 CO_2 emissions from peat

1. Area of peat drainage in year 1

   = total area 203,558.0 ha x deforestation rate 0.84%

2. Total CO_2 from maximum/minium peat drainage in year 1

   = relationship between CO_2 and drainage depth x maximum / minimum drainage x area of peat drainage in year 1

3. Mass of peat burning

   = [area of peat burning x depth of burnt peat x scaling factor from m^3 to ha x peat bulk density]

4. Total CO_2 from peat burning

   = mass of burnt peat x emission factor of CO_2 from peat combustion

5. Total CH_4 from peat burning

   = [(Mass of burnt peat x (Emission factor of CH_4 from peat combusion)) x GWP CH_4]

2.3.4 Analysis of baseline deforestation rate

The Methodology Design Document (2012) defines three options for determining a project baseline deforestation rate, which is to be used for the estimation of net emission reduction potentials. They are:

a. Legally approved conversion rate
b. Historical conversion analysis in a reference region
c. Conservative Estimate of a conversion rate based on literature review

In this study, the option b) was used for the project baseline analysis. Since the rate of deforestation is highly variable across different time periods and also depends on drivers. Therefore, two deforestation drivers were considered – forest fires and logging.

Fires cause drastic changes in each type of land cover. As a result of fires, forest drastically loses biomass, and forest becomes non-forested land such as shrub land, bushes swamps, and bareland. This type of land cover change, from forest stata to non-forest strata, is defined as deforestation in this study.Similary, degradation occurs when forest cover changes its status from primary to secondary forest classification. Deforestation in this study was assumed to be caused by forest fires, logging and land encroachment, which resulted in forest changing into non-forest areas (e.g., shrubs, bushes, swamps, and bareland).

2.3.4.1 Baseline deforestation rate from forest fires

Land cover change caused by forest fires was determined mostly by interpreting satellite imagery. Land cover change by forest fires was assumed when forested areas indicated a drastic change into non-forest areas within a short time period. Spatial querying was generated to define any land cover of primary and high density secondary forests turning into non-forest area (i.e., bareland, bush and shrub)as an forest fire damaged area.

Possibilities of land conversion in the study area were disregarded, because there have been no concessionaires converting the Katingan Project site's forest into plantations or mining excavations. Thus, the baseline deforestation rate due to forest and peat fires was obtained from the spatial analysis of land cover changes.

2.3.4.2 Baseline deforestation rate from logging

The annual deforestation rate of Central Kalimantan Province was used as the baseline deforestation rate from logging for the Katingan Project site. The data published by the Ministry of Forestry, Forest Planning Agency, contain areas of deforestation (ha) which were observed from 1985 to 2010. The provincial deforestation rate was calculated based on the total deforested area on forest land for a given time period.

2.3.5 Estimation of Net Emission Reductions

Potential net emission reduction volume was estimated by using the formula as defined by the Methodology Design Document(MDD, 2012):

Net Emission Reduc-tions (NERs)	=	GHG benefits related to avoided deforestation	❶
		+ GHG benefits related to avoided peat emissions	❷
		+ Net GHG benefits related to assisted natural regeneration (ANR) in forests	❸
		+ GHG emissions from deforestation due to the displacement of planned conversion activities (values are negative)	❹
		+ GHG emissions from deforestation due to the displacement of forest good extraction and forest services (values are negative)	❺
		+ Emissions from methane, nitrous oxide, and fuel due to project activities and assisted natural regeneration.	❻
		+ Changed in the carbon stored in long-lived wood products	❼

Where:

$$❶ = \sum_{i=1}^{nrFNFTransitions} \left(\left(\mu_{classification} \cdot \begin{pmatrix} -\Delta_{project\ area\ without\ ANR, baseline\ scenario}(t,i) \\ -\Delta_{project\ area\ without\ harvest, baseline\ scenario}(t,i) \end{pmatrix} \cdot \mu_{inventory}(t) \cdot EF(i) \right) \right) \quad \begin{matrix}\text{Project Scenario} \\ \text{Baseline Scenario}\end{matrix} \quad [EQ1]$$

$$❷ = E_{peat}(t) \quad [EQ2]$$

$$❸ = \frac{44}{} \sum_{i=1}^{nrstrata} \Delta C(t,i) . \mu_{inventory.ANR}(t,i)$$

$$\left\{ \begin{matrix} + \frac{44}{12} \mathrm{CF} - \sum_{\mathrm{i=t}}^{nrstrata} NAI(t)\ area_{project\ area\ with\ ANR\ baseline\ scenario\ (t.i)} \cdot (2 - \mu_{inventory\ (i)} \\ + \sum_{\mathrm{i=t}}^{nrFNFTransitions} \mu_{classification} \cdot \Delta area_{project\ area\ wuith\ ANF\ baseline\ scenario}(t,i) . \mu_{inventory}(i) . EF(i) \end{matrix} \right\} \quad [EQ3]$$

In case [EQ4]

$$\sum_{\mathrm{t=i}}^{\text{crediting period}} \left(\frac{44}{12} \sum_{\mathrm{i=1}}^{\mathrm{nrstrata}} \mathrm{area}_{\text{project area with harvest,project scenario (t,i)}} - \mathrm{C(t,i)} \right)$$

$$\geq \sum_{\mathrm{t=i}}^{\text{crediting period}} \left(\frac{44}{12} \sum_{\mathrm{i=1}}^{\mathrm{nrstrata}} \mathrm{area}_{\text{project area with harvest,project scenario(t,i)}} - \mathrm{LTAC}_{\mathrm{harvest}} \right)$$

❹ = 0

In case the inequality above does not hold (4) shall be:

$$❹ = \sum_{\mathrm{t=i}}^{\text{crediting period}} \left(\frac{44}{12} \sum_{\mathrm{i=1}}^{\mathrm{nrstrata}} \mathrm{area}_{\text{project area with harvest,project scenario (t,i)}} - \mathrm{C(t,i)} \right) \quad [EQ5]$$

$$\sum_{\mathrm{i=1}}^{\mathrm{nrFNFTransition}} \left(\mu_{classification} \cdot \Delta area_{project\ area\ with\ ANF\ baseline\ scenario}(t,i) - \mu_{inventory}(i) . EF(i) \right)$$

$$❺ = \sum_{i=1}^{nrFNFTransitions} \left(\mu_{classification} \cdot \begin{pmatrix} 0 \\ -\Delta area_{leakage\ planned\ (t,i)} \end{pmatrix} - \mu_{inventory}(i) . EF(i) \right) \quad [EQ6]$$

$$❻ = E_{sources,project\ Area}(t) - E_{sources,leakage\ Prevention}(t) - E_{sources,ANR}(t) - E_{harvest,timber}(t) - E_{harvest,fossil-fuel}(t) \quad [EQ7]$$

RESULTS AND DISCUSSIONS 3

3.1 Land cover and forest stratification

This study developed a new forest stratification system for the Katingan Project site. The area occurs on distinctive ecosystems consisting of peatland, heath (kerangas), and freshwater swamps. Within each ecosystem, forest strata were determined based on vegetation density, and each stratum was defined according to literatures and inputs from Forest Planning Agency of the Ministry of Forestry Indonesia (see Table 3).

Table 3. *Proposed forest stratification and definitions*[4]

Ecosystem	Forest stratum	Definition
Peatland	Primary peat swamp forest, high density	A high density intact mixed swamp forest which occurs on peat land with no traces of logging tracks or history of forest fires. It is a tall forest with uneven canopy, and consists of mixed plant species.
	Primary peat swamp forest, medium density	A low diversity, low pole primary forest which accurs on constantly inundated deep peat. Trees in this forest type are characterized with short structure and low diversity. They are typically small with the average DBH of 10 cm
	Primary peat swamp forest, low density	A low diversity and low density primary forest which occurs on constantly inundated deep peat. Trees in this forest type are thinnly distributed and markedly small and short.
	Secondary peat swamp forest, high density	Also known as logged-over forest, it is a disturbed high density, old mixed swamp forest which occurs on peat land with traces of past or current logging tracks. Few in this forest type are smaller and sparsely distributed.
	Secondary peat swamp forest, low density	Also known as logged-over forest, it is a disturbed low density, young mixed swamp forest which occurs on peat land with traces of past or current logging tracks. Trees in this forest type are smaller and sparsely distributed.
	Peat non-forest	An open area with canopy cover less than 30%, which occurs on peatland. This stratum includes grassland, cropland, wetlands, sttlements and other-land (based on Forest Planning Agency - MoF classes). Some areas have been fire damaged, and are prone to peat fires during the dry season. It is typically occupied with ferns, kelakai grasses and other shurbs. Some areas may have sparsely distributed trees such as Melaleuca sp. and Combretocarpus.
Heath (Kerangas)	Primary heath forest	An intact forest characterized by trees with short structure, low diversity and slender trucks, which occurs on nutrient-poor white sands and has no traces of logging tracks or history of forest fires.

[4] Definitions were adopted from Miyamoto, et al. (2007) *Forest structure and primary productivity in a Bornean heath forest*; Page, et al. (1999) *Peat and vegetation interdependence*; and Anderson (1964) *The structure and development of peat swamp forest of Sarawak and Brunei.* These definitions were then reviewed by the Ministry of Forestry agencies including Forestry Planning Agency and Forestry Research and Development Agency in December 2012.

Ecosystem	Forest stratum	Definition
	Secondary heath forest, high density	Mosaic of disturbed old forest which occurs over nutrient-poor white sand with traces of past or current logging tracks. Trees in this forest type are densely distributed with short structure and low diversity, and understory vegetation is abundant.
	Secondary heath forest, low density	Mosaic of highly disturbed young forest which occurs over nutrient-poor white sand with traces of past or current logging tracks. Trees in this forest type are sparsely distributed with short structure and low diversity, and understory vegetation and ferns are abundant.
	Heath non-forest	Open scrubby vegetation occurs on nutrient-poor white sands. It is an open mosaic, with small and short trees scattered with canopy cover less than 30% and shrubs and saplings grown in clumps.
Freshwater swamps	Primary freshwater swamp forest	An intact forest which occurs on permanently or seasonally inundated freshwater swamps.
	Secondary freshwater swamp forest	A disturbed forest with traces of logging trails, which occurs on permanently or seasonally inundated freshwater swamps.
	Non-forest	An open area with canopy cover less than 30%, which occurs on permanently or seasonally inundated freshwater swamps.
Water body		This class contains open water (including rivers, lakes, and canals).

Peatland, consisting of approximately 96% of the study site, can be classified into primary forest, secondary forest and non-forest areas with different density levels. Within the primay peat swamp forest (PSF) category, high density mixed swamp forest, medium density (low pole) forest, and low density (very low pole) forest were recognized based on the level of forest density and structures. Secondary PSF are disturbed forest areas with traces of logging tracks observed by remote sensing images. Non-forest peatlands mostly consist of scrubland, but some croplands were found in the south part of the project area. Other than peatland, heath (kerangas) open scrub and secondary forest as well as freshwater swamp forest and non-forest areas also occupy small parts of the Katingan Project site.

The combination of PALSAR, RapidEye, ASTER and Landsat TM5 satellite sensors provided comprehensive and detailed information about different forest and land cover classes for the Katingan Project area. RapidEye provided high resolution multispectral imaging capabilities, and was proven to be very reliable in surface cover discrimination. However, similar to other optical satellite data, cloud and haze remained to be an issue. In order to reduce data gaps, multiple satellite image data were used simultaneously to achieve the optimal interpretation.

Figure 8 shows the stratification map[5] obtained from the spatial analysis using the combination of optical satellite sensors.

It was overlaid with three different land systems (peatland, heath/kerangas, and fresh water swamp) based on RePPProT's data as well as SAR (ALOS PALSAR) classification data. Table 4 provides the size of each stratum and the ratio of the total area.

In summary, approximately 40% of the Katingan Project site consist of primary peat swamp forest, 48% secondary peat swamp forest, 9% non-forested peat land, and the rest are heath and freshwater swamp forest and non-forest areas.

To validate the stratification result obtained through the remote sensing analysis (as shown in Figure 8), structural classification was also conducted by using ALOS PALSAR. The structural information obtained from PALSAR indicated similar classification information of forest canopy and surface cover obtained from optical satellite imageries (see Figure 9). The polarimetry scattering analysis of bi-dimensional classification based on entrophy (H) and alpha angle (α) identified that zones Z2, Z5 and Z6 are the dominant classes for the Katingan Project area. Within the Z2 class are further classified into medium and high intensity entropy vegetation scattering. These intensity differences are indicated with light green (low density forest) and dark green (high density forest).

Table 4. *The size of each stratification class*

No	Landcover	Area (Ha)	% of total area
1	Primary Peat Swamp Forest, Hi Density	56,236.60	27.63%
2	Primary Peat Swamp Forest, Medium Density	21,725.50	10.67%
3	Primary Peat Swamp Forest, Low Density	3,301.05	1.62%
4	Secondary Peat Swamp Forest, Hi Density	94,126.47	46.24%
5	Secondary Peat Swamp Forest, Low Density	2,754.36	1.35%
6	Peat Swamp, Non Forest	18,440.99	9.06%
7	Primary Heath Forest	758.82	0.37%
8	Secondary Heath Forest, Hi Density	1,246.22	0.61%
9	Secondary Heath Forest, Low Density	116.46	0.07%

5] While the stratification result was groundtruthed during the field survey conducted during this study, additional points (particularly freshswamp and heath ecosystems) should be surveyed to validate the land cover.

No	Landcover	Area (Ha)	% of total area
10	Heath, Non Forest	2,295.75	1.13%
11	Secondary Freshwater Swamp Forest, Hi Density	287.50	0.14%
12	Secondary Freshwater Swamp Forest, Low Density	1,245.46	0.61%
13	Freshwater Swamp, Non Forest	946.23	0.46%
14	Water Body	88.57	0.04%
Total		**203,570.00**	100.00%

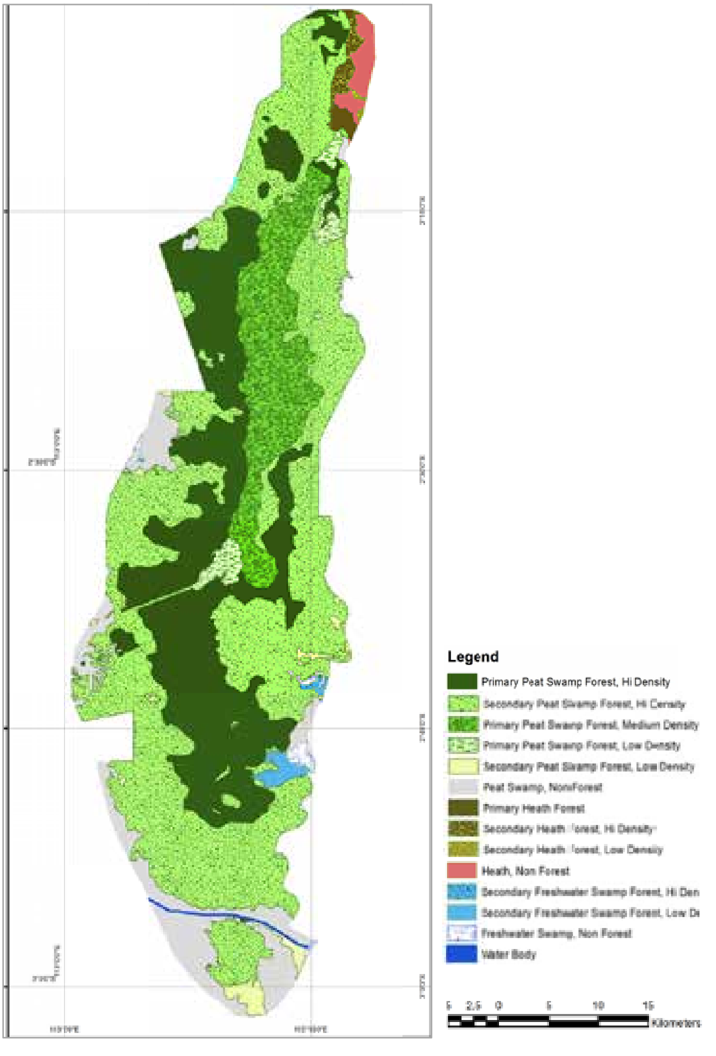
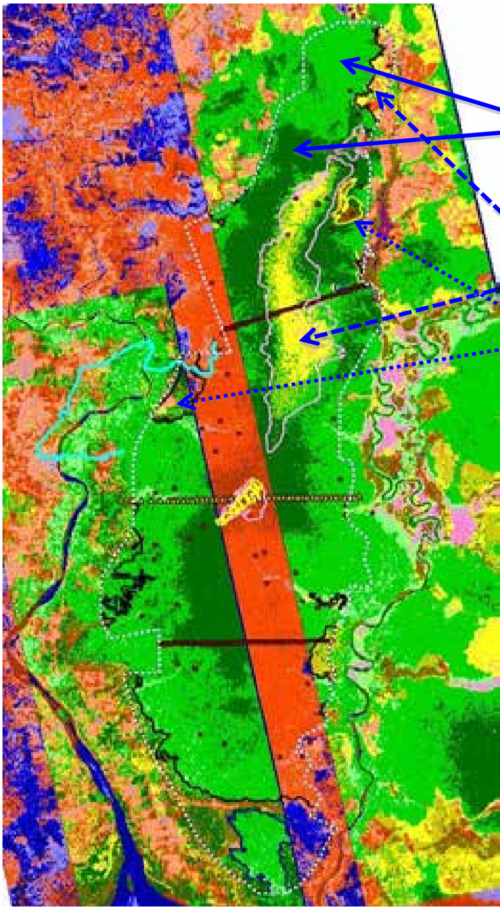


Figure 8. *Stratification map based on a combination of available satellite sensors*



Zone	Target	Example
Z1	High entropy multiple scattering	High density forest, large tree stems and well-developed crown structure, etc.
Z2	High entropy vegetation scattering	Scattered forest canopy, etc.
Z3	None	–
Z4	Medium entropy multiple scattering	Low biomass forest, etc.
Z5	Medium entropy vegetation scattering	Thin vegetation and forest, etc.
Z6	Medium entropy surface scattering	Rough surface, short vegetation, etc..
Z7	Low entropy multiple scattering	Scattering 2 dimensional objects
Z8	Low entropy dipole scattering	Scattering vegetation with strong directional characteristics
Z9	Low entropy surface scattering	Sea and ground surface, etc.

Entrophy (H) and alpha angle (α)

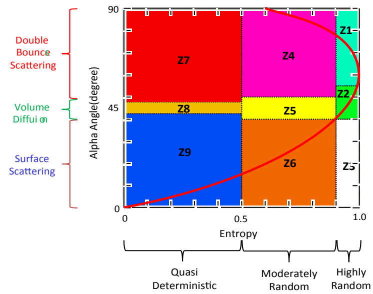


Figure 9. ALOS PALSAR 2010 classification by color code

The low density forest area indicated with light green color by PALSAR generally matched the area identified as secondary high density and low density peat swamp forest by the optical satellite imagery analysis. Similarly, the dark green area identified as high density forest by PALSAR overlapped with many areas indicated as primary high density forest.

Although the analysis of remote sensing imageries and PALSAR polarimetric data largely resulted in similar interpretations, they returned slightly different classification information in some areas within the study site.

This is partly because of the difference in applicable parameters obtained from satellite sensors. While PALSAR reads information on forest structures, remote sensing imageries provide information based on surface cover. This simply implies that these satellite sensors have different capabilities in data processing and interpretation. PALSAR may identify certain areas as one class where forest structures resemble. On the other hand, remote sensing data may classify such areas differently based on ecosystems and canopy cover characteristics.

One of the most distinctive examples of this interpretation gap was that some areas, which were classified into different strata by the remote sensing analysis, appeared to be a single stratum under Zone 5 (medium entropy vegetation scattering). Indicated in yellow in Figure 9, all of these areas have the characteristic of thin vegetation and immature forest structures. In order to verify the interpretation result obtained from PALSAR data, optical satellite imageries and field survey data were carefully examined and compared. Yellow parcels along the concession boundary were found to consist of highly degraded forest or shrub lands. On the other hand, vertically long areas in the center of the concession area were identified as primary peat swamp forest situated on top of a peat dome. While the structure of this type of forest is similar to that of degraded forest, this is a typical forest structure found on thick peat, where trees are naturally small and short (low canopy) with lower density and diversity. Such interpretation would not have been possible by PALSAR data alone without referring to optical satellite images and field data.

3.2 Full carbon stock analysis[6]

3.2.1 Biomass and carbon stock estimation

3.2.1.1 Aboveground and belowground biomass and carbon stocks

Above- and belowground (roots) biomass was estimated by using the allometric equation (see Section 2.2.3.1). Based on the floral data

[6] The results of full carbon stock analysis presented in this report are subject to review and discussions by the Joint Committee, consisting of international experts and committee members, under Joint Credit Mechanism between Indonesia and Japan. Additional field data points, which were collected by PT. RMU and PT. Mazars Starling Resources from 2008 through 2011, will also be included in the final carbon stock assessment by the Joint Committee, in order to increase the sampling number and statistical accuracy.

collected at the study site during the REDD+ FS 2010 through 2012, forest structure and the composition of tree species were identified for eight strata[7].

It is important to identify dominant species for different types of forest strata because tree growth rate varies depending on trees species. Allometric equation used in this study was developed based on locally common species.

1. Primary peat swamp forest, high density

   In high density primary PSF, *Syzygium sp.* is the dominant species, followed by *Palaquium pseudrostratum, H.J.L.*and *Litsea spp.*The growth stage of tree species, on the other hand, showed different results. The species with the DBH between 25cm and 40cm was dominated by *Combretocarpus rotundatus (Miq.) Danser*. The canopy of this forest type typically reaches a maximum height of 16 - 16.5m.

2. Primary peat swamp forest, medium density

   Syzygium sp. is the dominant species in medium density primary PSF, followed by *Tristaniophsis sp.* and *Callophylum hosei.*Even though *Syzygium sp.*is the most abandunt species in this stratum, the tree growth stage with the highest diameter range was*Dactylocladus stenostachys* and *Combretocarpus rotundatus (Miq.) Danser*. This type of forest has DBH ranging from 20.4 to 51.3 cm, with canopy closure of 75% - 90%.. The upper canopy reaches a maximum height of 16 meters and the minimum height of 8 meters.

3. Primary peat swamp forest, low density

   Syzygium sp. is the dominant species which occupies low density primary PSF. *Tristaniophsis* sp., *Combretocarpus rotundatus* (Miq.) Danser and *Litsea spp.* are also abundant after *Syzygium* sp. This type of forest is dominated with trees with DBH ranging from 21-32 cm with the height of 5 – 16 meters. Canopy closure in this forest type ranges from 79% - 91%.

[7] Non-forest areas were omitted from the floral assessment. Also, due to limited field sampling data availability, the assessment was conducted in eight stratification classes only.

4. Secondary peat swamp forest, high density

   20 species were identified as most abundant in high density secondary PSF, with*Diospyros korthalsiana* Hiern as the dominant species. Other species commonly identified in sampling plots include *Syzygium* sp., *Campnosperma corieaceum*, sagagulang., and *Shorea* sp.

   Relatively rarer tree species identified in this type of forest include *Tectratomia tretrandra*, gumala, *Dyera costulata*, *Blumeodendron tokbrai* (Bl.) Kurz., Shorea sp., Ketiau, Perawas (*Litsea spp)*, *Nephelium Maingayi, and Diospyros cf. evena.* The diameter of tree species identified in sampling plotsranges from 22.2 cm and 54.1 cm with the height of 9 to 26 meters. The canopy closure ranges from 88% to 90%.

5. Secondary freshwater swamp forest, high density

   The dominant species in high density secondary freshwater swamp forest is ubar (*Syzygium* sp.), followed by mahang (*Macaranga diepenhorstii* Muell. Arg.) and sagagulang. The largest tree found in temporary sampling plots is Bintan, with DBH ranging from 20.2 to 44.1 cm.

6. Secondary heath forest, high density

   *Syzygium sp.*is the species with the highest number found in the area followed by *Callophylum hosei.* The largest tree species identified in sampling plots is *Syzygium leucoxylon* with DBH ranging between 25 cm and 33.5 cm,with the maximum canopy heightof 22 m. The size of typical trees in this type of forest ranges from 20 cm to 52.2 cm with the height of 14 mand 27 m. The canopy closure in this forest type ranges between 75% to 88%.

7. Heath, non forest

   The dominant species in heath non forest areas is *Cratoxylon arborescens* (Vahl), followed by *Syzygium sp.* and Papar bubu. There are few trees above DBH 20 cm that grow on this stratum. Tree canopy cover is less than 30%, and most vegetation are shrubs, seedlings and saplings.

8. Freshwater swamp, non forest

   Within this stratum, punak (*Tetrameristra glabra)* is the dominant species, followed by ubar (*Syzygium* sp.) and Jambul burung (*Polyalthia cauliflora*).Trees are rarely found in this stratum, and most abundant vegetation is grass, ferns, shrubs, and saplings with the height of less than 10m.

Above- and belowground biomass and C stockspresented in this report summarized biomass data from previous surveys conducted in 2009, 2011, 2012 and 2013 (data compiled from over 100 samplings – see Figure 10). Above- and belowground (roots)biomass was estimated for the13 land cover strata delineated in this study (see Table 5).

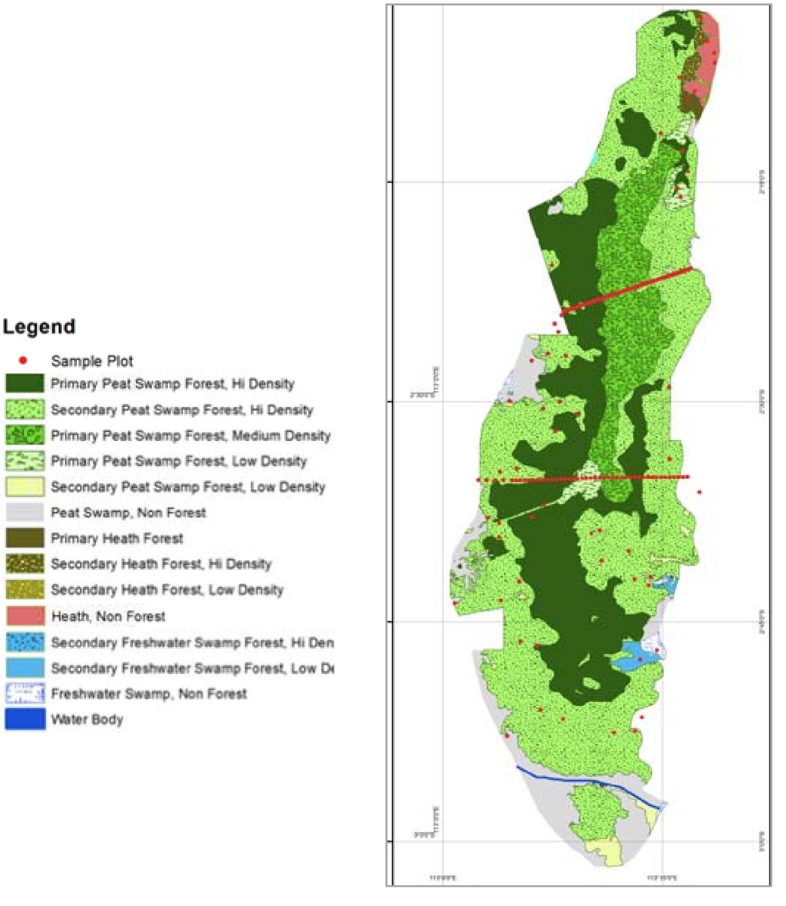


Figure 10. *Location of sampling plots inside 14 land cover strata*

Table 5. *Above and Belowground Biomass and C stock of Each Stratum*

No.	Land cover stratum	Total Biomass (AGB + BGB) (ton/ha)	C stock AGB+BGB (tonC/ha)
1	Primary Peat Swamp Forest, High Density	214.14	100.65
2	Primary Peat Swamp Forest, Medium Density	137.00	64.39
3	Primary Peat Swamp Forest, Low Density	120.30	56.54
4	Secondary Peat Swamp Forest, High Density	143.56	67.47
5	Secondary Peat Swamp Forest, Low Density	79.81	37.51
6	Peat Swamp, Non Forest	26.65	12.53
7	Secondary Fresh Water Swamp Forest, High Density	129.00	60.63
8	Secondary Fresh Water Swamp Forest, Low Density	98.37	46.23
9	Fresh Water Swamp, Non Forest	6.27	2.95
10	Primary Heath Forest, High Density	138.00	64.86
11	Secondary Heath Forest, High Density	125.70	59.08
12	Secondary Heath Forest, Low Density	79.81	37.51
13	Heath, Non Forest	9.84	4.62
14	Water Body	N/A	N/A
Total		1,308.45	614.97

Table 5 shows that high density primary PSF has the largest volume of above- and belowground biomass and C stock (214.14 tonnes/ha or 100.65 tC/ha), followed by high density secondary PSF (143.56 tonnes/ha or 67.47 t C/ha). Total carbon stocks in the primary PSF are exceptionally high relative to other forest types. This is because the large amount of carbon is stored in intact tree biomass(2.5 cm – 51.3 cm DBH).

Primary forests typically sustain the same amount of biomass with no observable changes from year to year, since the primary forest is positioned at the top of the succession patterns.Secondary forests, on the other hand,contain a variable amount of biomass from year to year, since they undergo succession processes until reaching the optimal point. A primary PSF transformed into a secondary PSF would also change the condition and physical parameters of the peat due to peat decomposition as a result of oxidation and changes in groundwater levels.

In a disturbed PSF due to forest fires and/or logging activities, the annual growth of aboveground biomass is found to be approximately 15 ton/ha (Dharmawan, 2012).By taking this assumption into consideration, in the period of 7-10 years, in the Katingan Project site, the volume of the secondary PSF biomass is likely to reach the amount similar to that of the primary PSF. However, in reality, this succession pattern varies based on forest conditions and the level of light intensity, which affect the speed of natural regeneration.

3.2.1.2 Peat / soil carbon stock

Peatland is characterized with its large carbon pool stored in the peat layer. The peat C stock of every stratum was estimated according to Table 6.

Table 6. *Peat C-stock in each stratum*

No.	Land cover stratum	Total Peat C stock (ton C)	Average Peat C stock (ton C/ha)
1	Primary Peat Swamp Forest, High Density	273,604,014.5	4,863.75
2	Primary Peat Swamp Forest, Medium Density	65,060,261.33	2,994.65
3	Primary Peat Swamp Forest, Low Density	10,172,211.72	3,081.51
4	Secondary Peat Swamp Forest, High Density	352,635,905.7	3,747.83
5	Secondary Peat Swamp Forest, Low Density	*No data*	*No data*
6	Peat Swamp, Non Forest	*No data*	*No data*
7	Secondary Fresh Water Swamp Forest, High Density	188,097.46	654.25
8	Secondary Fresh Water Swamp Forest, Low Density	*No data*	*No data*
9	Fresh Water Swamp, Non Forest	564,708.41	596.80
10	Primary Heath Forest, High Density	*No data*	*No data*
11	Secondary Heath Forest, High Density	713,138.39	572.24
12	Secondary Heath Forest, Low Density	*No data*	*No data*
13	Heath, Non Forest	4,299,670.79	1,872.88
14	Water Body	*N/A*	*N/A*
Total		**88,404,751.03**	**2,297.99**

Table 6 shows that the large volume of peat / soil C stock was found primarily in peat swamp forest, with the largest in the high density primary PSF (4,863.75 ton C/ha), followed by the high density secondary PSF (3,747.83 tonC/ha), the low density primary PSF (3,081.51 ton C/ ha) and the medium density primary PSF (2,994.65 ton C/ha). In this study, the value of organic carbon was found to range from 9.6 % (in heath non forest areas) up to 51.61% in the low density primary peat swamp forest. Carbon content in peatland is determined by the type of peat deposits (Parish, *et al.*, 2008). Moreover almost all lowland peatlands in Southeast Asia (including Indonesia) are covered with forest vegetation, thus, holding a high wood content.

The deepest peat was found in the high density primary PSF (10.25 m) and the lowest peat depth in the high density secondary PSF (3.3 m) (see Figure 10). This finding is consistent with the study carried out by Jaenicke *et al.* (2008) in Sebangau, Central Kalimantan.Their study developed a model to estimate peat depth.Peat thickness within their study area was identified to range between 0.5 m and 10.6 m, with the average peat depth of approximately 4.83 m. Another research conducted by Hooijer *et al.* (2006) profiled peat thickness in Indonesia (i.e., Sumatera, Kalimantan and Papua). Their study showed that peat thickness in these three regions ranged from less than one meter to over 12 m. Central Kalimantan is found to encompass a large area of peat soil with a thickness of deeper than 8 m (Wahyunto *et. al.*,2010).

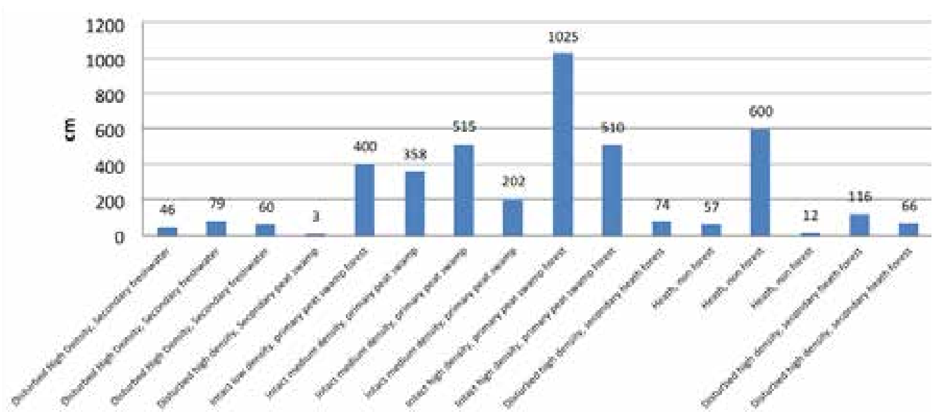


Figure 11. *Average peat depth of each sampling plot (unit in cm)*

Table 7 shows physical properties of peat at the study site, which is the result of laboratory examination to analyze bulk density, ash content and C organic. From this analysis,it was observed that the bulk density increasedaccording to the level of peat decomposition (from fibric, hemic to sapric), while the ash content and C organic tended to be steady for each decomposition level. For peaty soil and mineral soil (clay),on the other hand the bulk density and ash content were found to bequite high exceeding those of fibric, hemic and sapricpeat, with low C organic content in comparison to peat layers.

Table 7. *Physical properties of peat in the study site*

Decomposition Level	Bulk Density (g/cc)	Ash content (%)	C-organic (%)
Fibric	0.05 - 0.11	0.25 - 9.30	47 - 52
Hemic	0.07 - 0.17	0.26 - 5.72	49 - 52
Sapric	0.11 - 0.24	0.28 - 9.60	47 - 52
Peaty Soil	0.10 - 0.46	7.75 - 54.43	24 - 48
Mineral Soil (clay)	0.43 - 1.12	51.38 - 89.68	5.5 - 25.5

Types of land use and land cover and other environmental factors influence the degree of bulk density and carbon density (Wahyunto *et. al.*,2010). Unsustainable management of peatland and drainage could significantly change the level of bulk density and carbon organic content of peat. In this regard, the study by Wahunto *et. al. (2010)* found higher bulk density and carbon content in secondary peat swamp forest, then in shrubs/bushes, paddy fields and oilpalm plantations. Our study results showed a lower value of bulk density and higher C organic content compared to the results obtained by Wahunto *et. al. (2010)*. This is because most of the study site is still intact with fewer human disturbances and a limited occurance of peat oxidation and fires,while maintaining its C organic content at a high level.

3.2.1.3 Carbon stock of seedlings, understory, litter and necromass

The carbon stock of seedlings, understorey vegetation, litter and necromass were estimatedby applying the local allometric equation. The result of the analysis is shown in Table 8.

Table 8. *Biomass and Carbon Stock of Seedlings, Understorey, Litter and Necromass in each Stratum*

No	Stratum	Understorey		Litter		Necromass		Seedling		Total	
		Biomass (t/ha)	Carbon (t/ha)	Biomass (t/ha)	Carbon (t/ha)	Biomass (t/ha)	Carbon (t/ha)	Biomass (t/ha)	Carbon (t/ha)	Biomass (t/ha)	Carbon (t/ha)
1.	Primary peat swamp forest, high density	4.69	2.30	7.66	3.64	2.82	1.32	4.40	2.16	19.56	9.42
2.	Primary peat swamp forest, medium density	6.23	3.11	3.65	1.83	2.01	1.01	2.59	1.29	14.48	7.24
3.	Primary peat swamp forest, low density	6.24	3.12	4.54	2.27	2.88	1.44	1.7	0.85	15.36	7.68
4.	Secondary peat swamp forest, high density	4.03	1.86	9.93	4.61	5.9	2.72	1.04	0.46	20.9	9.65
5.	Secondary peat swamp forest, low density	No data									
6.	Peat swamp, no forest	No data									
7.	Secondary freshwater swamp forest, high density	5.23	2.50	5.86	2.77	5.64	2.70	2.16	1.042	18.89	9.00
8.	Secondary freshwater swamp forest, low density	No data									
9.	Freshwater swamp, non forest	9.18	3.96	7.91	3.35	13.50	6.22	2.52	1.08	33.11	14.61
10	Primary heath forest, high density	No data									
11	Secondary heath forest, high density	1.85	0.93	4.92	2.47	3.41	1.70	2.48	1.24	12.66	6.33
12	Secondary heath forest, low density	No data									
13	Heath, non forest	4.37	2.19	2.4	1.21	8.93	4.46	0.42	0.21	16.12	8.07

Table 8 shows that the highest biomass and C stock values were found in freshwater non forest areas (33.11 ton/ha and 14.61 ton C/ha respectively), followed by high density secondary PSF (20.9 ton/ha and 9.65 ton C/ha). This result indicates that seedlings, understory vegetation, litter and necromass are abundant in non forest areas as well as secondary forest, where canopy cover is lower. Lower canopy cover would increase the penetration of the sunlight to the forest floor and enhance the growth of seedlings, understorey and litter, entailing larger carbon stocks of this vegetation group.

3.2.1.4 Average total carbon stocks

Average total carbon stocks for all five carbon pools are shown in Table 9 below.

Table 9. *Average total carbon stocks for all carbon pools*[8]

No	Stratum	AGB+BGB (ton C/ha)	Peat (ton C/ha)	Understo-rey Litter Necromass (ton C/ha)	Total C stock (ton C/ha)
1	Primary Peat Swamp Forest, High Density	100.65	4,863.75	9.42	4,973.81
2	Primary Peat Swamp Forest, Medium Density	64.39	2,994.65	7.24	3,066.28
3	Primary Peat Swamp Forest, Low Density	56.54	3,081.51	7.68	3,145.73
4	Secondary Peat Swamp Forest, High Density	67.47	3,747.83	9.65	3,824.95
5	Secondary Peat Swamp Forest, Low Density	37.51	*No data*	*9*	46.51
6	Peat Swamp, Non Forest	12.53	*No data*	*9*	21.53
7	Secondary Fresh Water Swamp Forest, High Density	60.63	654.25	9.00	723.88
8	Secondary Fresh Water Swamp Forest, Low Density	46.23	*No data*	*9*	55.23
9	Fresh Water Swamp, Non Forest	2.95	596.78	14.61	614.35
10	Primary Heath Forest, High Density	64.86	*No data*	*9*	73.86
11	Secondary Heath Forest, High Density	59.08	572.24	6.33	637.65
12	Secondary Heath Forest, Low Density	37.51	*No data*	*9*	46.51
13	Heath, Non Forest	4.62	1,872.88	8.07	1,885.58
14	Water Body	N/A	N/A	N/A	N/A

8] The estimation of total carbon stocks is subject to further verification in the field as well as by experts appointed by the Join Committee under the JCM between Indonesia and Japan. Additional groundtruthing activities will be necessary to validate the land cover and peat survey.

The estimation of average total carbon stocks from five carbon pools showed that the high density primary PSF had the largest volume of C stocks (4973.81 tC/ha) compared to other strata. The second largest C stocks were found in the high density secondary PSF (3824.95 tC/ha), followed by the low density primary PSF (3145.73 tC/ha) and the medium primary PSF (3066.28 tC/ha). This indicate that the primary peat swamp forest contain larger amount of C stocks compared to the secondary peat forest or other land cover strata (see Figure 12). In peatland forests, aboveground C mass varies widely depending on the tree stand composition and history, but peat composes the largest portion of ecosystem C storage (Kauffman, 2011).

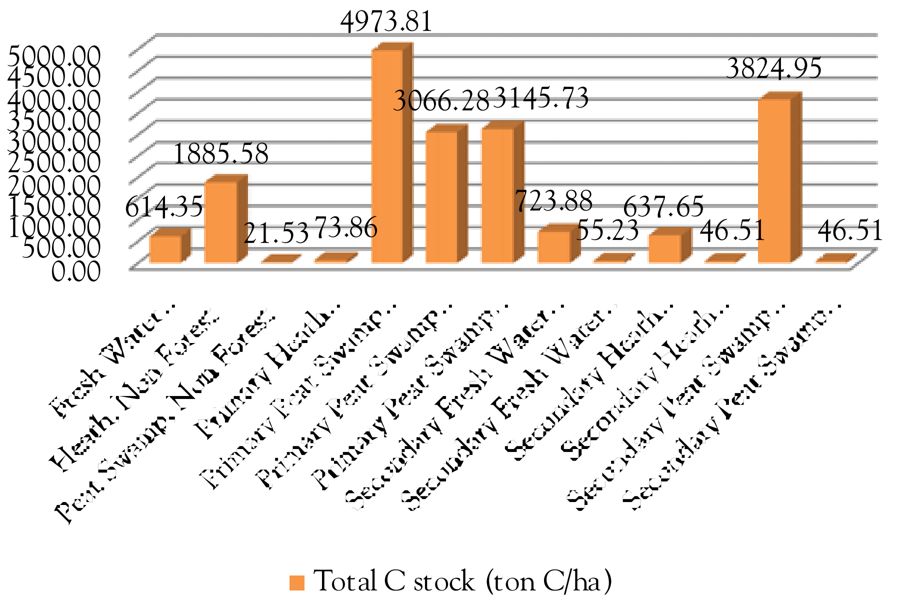


Figure 12. *Total Carbon Stock (ton C/ha) of Each Stratum*

The proportion of peat C to total C stocks ranged between 89 and 99.3% from the lowest at the high density secondary heath forest to the highest at the heath non forest area. At the secondary heath forest, C vegetation was relatively high (59.08 t C/ha), while the peat depth was non existent or shallow (66-116 cm).

3.2.1.5 Total carbon stocks from the Katingan Project site

The total carbon stock from the study site was estimated by multiplying the average C stock/ha from each stratum by the area of each stratum (see Table 10). Estimated total 722,210,242.68 t C/ha or 0.722 Gt C/ha of carbon is potentially stored at the project site as of 2012.

Table 10. *Total Carbon Stocks from the study site*

No.	Stratum	Total C stock (ton C/ha)	Area (ha)	Total C stock (ton C)
1	Primary peat swamp forest, high density	4,973.81	56,253.70	279,795,454.71
2	Primary peat swamp forest, medium density	3,066.28	21,725.50	66,616,458.90
3	Primary peat swamp forest, low density	3,145.73	3,301.05	10,384,208.65
4	Secondary peat swamp forest, high density	3,824.95	94,090.72	359,892,211.77
5	Secondary peat swamp forest, low density	46.51	2,744.03	127,626.58
6	Peat swamp, non forest	21.53	17,944.01	386,278.99
7	Secondary fresh water swamp forest, high density	723.88	287.50	208,115.96
8	Secondary fresh water swamp forest, low density	55.23	1,245.46	68,791.41
9	Fresh water swamp, non forest	614.35	868.55	533,598.15
10	Primary heath forest, high density	73.86	758.82	56,046.62
11	Secondary heath forest, high density	637.65	1,246.22	794,655.61
12	Secondary heath forest, low density	46.51	116.46	5,416.77
13	Heath, non forest	1,885.58	1,772.07	3,341,378.57
14	Water body	N/A	N/A	N/A
TOTAL				**722,210,242.68**

Table 10 indicates that the largest total C stock of the entire project area was found in the high density secondary PSF (359,892,211.77 t C), which is the largest area among other strata in the project area (see Figure 13). The high density primary PSF indicated the second largest amount of total C stock (279,795,454.71 t C). This implies that the management of high density secondary PSF is the key to sustaining and enhancing C stocks stored in the stratum, because this forest area could serve as potential carbon sinker within the project site.The result of this study is consistent with the study conducted by Jaenicke *et al.* (2008), which estimated a total carbon storage in peat domes in the Block B within the Ex-Mega Rice Project site, Central Kalimantan. Their study identified an estimated 0.8 Gt C over the area of 2,838 km^2,whereas in the Katingan Project site, an estimated 0.72 Gt C over the area of 2,035 km^2. The amount of carbon sequestered in peat depends on the carbon content and bulk density. Both values vary from different peat types.

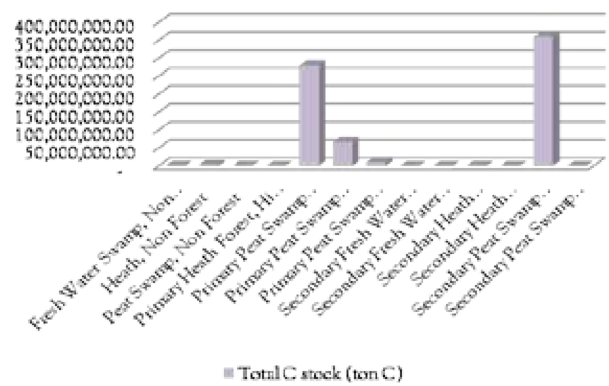


Figure 13. *Total Carbon Stocks of Each Stratum from the Project Area*

From this study, we estimated the total carbon stock of the Katingan Project siteto be 0.722 Gt C over the area of 203,570 ha, where the most carbon storage was found in the soil/peat carbon pool. This amount equals to approximately 11.46% of the total peat carbon stock found in the island of Borneo, which amounted to 6,351 million tons C or 6.35 Gt C (56.34%). In order to maintain the ecological functions and values of peatlands,they must be conserved and protected as a carbon reservoir by applying peatland best management practices.

3.3 Estimation of net emission reductions[9]

3.3.1 Land cover and land cover changes

Time series analyses for landcover change in theKatingan Project site observed distinct changes from 1994 to 1997 (see Annex 2) as well as from 2000 to 2010 in the southern part of the study site(see Annexes 3, 4, 5 and 6). Land cover change from 2010 to 2012 are presented in Annex 7.

The estimation of the biomass content in the study area for 1994, 1997, 2000, 2003, 2006, 2010 and 2012 was based on the assumption that if land cover classes remained unchanged, each land cover class contained the same relative amount of aboveground biomass per hectare as measured in 2010.For example, the same volume of biomass measured in field surveys since 2010 was applied to estimate the amount of biomass for the area which was classified as a medium density PSF for both 1994 and 2010.

In general, the Katingan Project site is dominated by the primary peat swamp forests and high density secondary peat swamp forest.The primary PSF area decreased considerably during the period of 1994 to 2003,but became relatively stable after 2006. The loss of primary PSF during this period was primarily due to selective logging by concessions (HPH), local communities and illegal operations. A large amount of trees were extracted from 1997 to 2000 (mostly by concessions) and again from 2000 to 2003 (mostly by communities and illegal operators). As much as 19,563.58 ha and 22,080.85 ha of primary PSF were deforested during these periods respectively.

Table 11 presents the summary of land cover changes observed in the study site from 1994 to 2012. 10 extra land cover classes were added to the original stratification (13 strata plus water body – see Table 3) for the land cover change analysis[10]. This was necessary to capture past land cover patterns, which do not appear in the current land cover

[9] The results of net emission reduction analysis presented in this report are subject to review and discussions by the Joint Committee, consisting of international experts and committee members, under Joint Credit Mechanism between Indonesia and Japan.

[10] This table only presents land cover changes from 23 key land cover strata, which were used to estimate emission factors. A full land cover change analysis conducted in this study examined total 35 land cover classes. Codes of land cover classes and results are presented in Annex 8.

stratification map. For example, primary freshwater swamp forest, which existed in the study site until 1997, was added as one of the classes for the analysis of land cover changes. Similarly, non forest areas were divided into sub-classes in order to make more accurate estimation of land cover changes. More details are provided in Annex 10.

Table 11. *Time series land cover changes in the Katingan Project site*

No	Land cover stratum	1994 (ha)	1997 (ha)	2000 (ha)	2003 (ha)	2006 (ha)	2010 (ha)	2012 (ha)
1	Primary peat swamp forest, high density	105,104	99,151	80,392	58,730	56,482	56,254	56,254
2	Primary peat swamp forest, medium density	21,726	21,726	21,726	21,726	21,726	21,726	21,726
3	Primary peat swamp forest, low density	3,301	3,301	3,347	3,301	3,301	3,301	3,301
4	Secondary peat swamp forest, high density	64,260	69,543	39,005	55,726	85,917	94,109	90,616
5	Secondary peat swamp forest, low density	485	734	38,623	43,487	10,721	2,733	2,744
6	Peat swamp, non forest (bareland)	63	49	278	481	2,328	359	397
7	Peat swamp, non forest (shrub)	1,099	1,506	12,444	11,857	15,014	16,879	16,885
8	Peat Swamp, Non Forest (Swamp shrub)	546	573	765	1,271	696	712	689
9	Peat swamp, non forest (agriculture)					271	357	371
10.	Primary freshwater swamp forest, high density	351	198					
11.	Secondary freshwater swamp forest, high density	771	1,961	272	272	1,454	287	287
12.	Secondary freshwater swamp forest, low density (young secondary)	68	196	1,340	1,282	79	1,245	79
13	Secondary freshwater swamp forest, low density (old secondary)[11]	1,166		79	79			1,166

[11] Freshwater swamp forest low density forests were classified into two sub-classes, young and old secondary forests, determined by the succession level.

No	Land cover stratum	1994 (ha)	1997 (ha)	2000 (ha)	2003 (ha)	2006 (ha)	2010 (ha)	2012 (ha)
14	Freshwater swamp, non forest (bareland)	12	3	26	95	518	10	10
15	Freshwater swamp, non forest (shrub)	38	38	541	541	278	705	705
16	Freshwater swamp, non forest (swamp shrub)	72	72	195	195	67	147	147
17	Freshwater swamp, non forest (agriculture)					16	16	16
18	Primary heath forest, high density	1,171	787	759	759	759	759	759
19	Secondary heath forest, high density	2,660	2,911	2,911	2,911	1,246	1,246	1,246
20	Secondary heath forest, low density	122	137	145	140	112	116	116
21	Heath, non forest (bareland)	54	78		5	394	394	524
22	Heath, non forest (shrub)	33		24	24	1,515	1,510	1,380
23	Heath, Non Forest (Swamp shrub)	378	378	453	453	392	392	392

3.3.2 Baseline deforestation rate[12]

The Methodology Design Document (2012) defines three options for determining a project baseline deforestation rate, which is to be used for the estimation of net emission reduction potentials. They are:

a. Legally approved conversion rate
b. Historical conversion analysis in a reference region
c. Conservative Estimate of a conversion rate based on literature review

In this study, the option b) was used for the project baseline analysis.

[12] The baseline deforestation rate used in this study is subject to review and discussions by the Joint Committee, consisting of international experts and committee members, under Joint Credit Mechanism between Indonesia and Japan.

Central Kalimantan province encompasses 15,395,931.55 ha of land, of which 52.5% fall under forest land and 47.5% non-forest land as of 2010 (Ministry of Forestry, 2011). The provincial deforestation rate was calculated based on the total deforested area on forest land for a given time period (see Table 12).

Table 12. *Annual deforestation rate in Central Kalimantan Province 1985-2010 (source: Ministry of Forestry, Forest Planning Agency)*

Year	Deforestation (ha)	Kalteng Province (ha)	Deforestation Rate (%)
(1) 1985-1997	138208.00	15395931.55	0.075
(2) 2000-2003	126508.72	15395931.55	0.274
(3) 2003-2006	240612.58	15395931.55	0.521
(4) 2006-2009	386225.99	15395931.55	0.836
(5) 2009-2010	128648.10	15395931.55	0.279
AVERAGE	204040.68		0.397

Since the rate of deforestation is highly variable across different time periods, the average historical deforestation rate was not deemed representative of the real state of the Katingan Project site. Thus, the highest historical annual deforestation rate of **0.836% (0.84%)** was used as the maximum baseline conversion rate[13].

Deforestation rate due to forest and peat fires was obtained from the spatial analysis of land cover changes. **5.92%** was used as the baseline deforestation rate from forest and peat fires.

3.3.3 Estimation of emission factors

Two emission factors considered in this study are:

a. emission factor from annual carbon stock changes using stock-difference method on the remaining land within the same land cover stratum (tonC/year);

b. emission factor emission factors due to a change in carbon stock potency (ton/ha) as a result of land cover changes.

[13] This deforestation rate was not calculated based on the most likely land use scenario for the Katingan Project site – forest conversion by timber and oil palm plantations. If this scenario is taken into consideration, the baseline deforestation rate will be higher because the conversion rate of these land uses tend to be considerably higher.

The emission factor a) was quantified in order to analyze the amount of emissions from land cover changes on the remaining land within the same stratum. Table 13 shows various volume of emissions across different land cover strata for the period of 1994 to 2012[14]. The largest annual emissions observed from 1994 to 2012 occured in the high density primary peat swamp forest (-263,205.61 tC/year). This is because this forest stratum has suffered from the most significant land cover changes since 1994.Thus, emissions occured due to the decrease of the high density primary PSF area into other degraded land cover classes. Positive emission factor values indicate a gain in carbon stocks, implying an increase of the area within the same land cover class (e.g., 96,820.23 tC/year for the high density secondary PSF). This table explains which land cover classes have gained or lost the total areal cover over the past 18 years.

Table 13. *Estimation of emission factors from annual carbon stock changes on the remaining land within the same land cover stratum during 1994-2012*

No	Land cover stratum	Emission factor (tonC/year)
1	Primary peat swamp forest, high density	-263,205.61
2	Primary peat swamp forest, medium density	0,00
3	Primary peat swamp forest, low density	0,00
4	Secondary peat swamp forest, high density	+96,820.23
5	Secondary peat swamp forest, low density	+4,535.46
6	Peat swamp, non forest (Bareland)	0
7	Peat swamp, non forest (Shrub)	+12,900.21
8	Peat swamp, non forest (Swamp Shrub)	+116.55
9	Peat swamp, non forest (Agriculture)	+139.92
10	Primary fresh water swamp forest, high density	-1,890.89
11	Secondary freshwater swamp forest, high density	-1,570.91

[14] The calculation example of emission factors from annual carbon stock changes in the remaining landwithin the same land cover stratum (tonC/year) is as follows:
Land cover stratum: Primary heath forest, high density
Carbon stock of primary heath forest, high density in 1994 (1,171.37 ha) = 73,210.81 tonC
Carbon stock of primary heath forest, high density in 2012 (758.82 ha) = 47,426.54 tonC
Time period for the analysis: 1994 – 2012 = 18 years
Emission factor of primary heath forest, high density
= (47,426.54 tonC – 73,210.81 tonC) / 18 years
= -1,432.46 tonC/year

No	Land cover stratum	Emission factor (tonC/ year)
12	Secondary freshwater swamp forest, low density (young secondary forest)	+28.03
13	Secondary freshwater swamp forest, low density (old secondary forest)	+574.08
14	Freshwater swamp, non forest (Bareland)	0
15	Freshwater swamp, non forest (Shrub)	+31.91
16	Freshwater swamp, non forest (Swamp Shrub)	+3.59
17	Freshwater swamp, non forest (Agriculture)	+5.95
18	Primary heath forest, high density	-1,432.46
19	Secondary heath forest, high density	-4,470.26
20	Secondary heath forest, low density	-10.53
21	Heath, non forest (Bareland)	0
22	Heath, non forest (Shrub)	+333.64
23	Heath, non forest (Swamp Shrub)	+3.41

Remarks: (-) : emissionsdue to a decrease in areal cover within the same land cover stratum;
(+) : positive emissions (removal or no emissions) due to an increase in areal cover within the same land cover stratum;
(0) : no change

The emission factor b)quantified the amount of emissions due to a change of one land cover class to another at the same arearegardles of a time period[15]. Section 3.3.3.1 to 3.3.3.3.present emission factorsdue to a change in carbon stock potency (ton/ha) as a result of land cover changes.

3.3.3.1 Peat swamp forest classes

Emission factors from land cover changes from forest classes B to A are quantified in Table 14. Land cover changes from B to A area shift from the primary PSF to the secondary PSF, and considered as degradation.

[15] The calculation example of emission factors due to a change in carbon stock potency (ton/ha) as a result of land cover changes is as follows:
Strata of land cover change: high density primary heath to high density secondary heath forest
Carbon stock of primary heath forest, high density = 62.5 tonC/ha
Carbon stock of secondary heath forest, high density = 56.93 tonC/ha
Emission factor = (56.93 tonC/ha – 62.5 tonC/ha)
= -5.57 tonC/ha

Table 14. *Matrix of emission factorsdue to a change in carbon stock potency (ton/ha) as a result of land cover changes[16]: from primary PSF to secondary PSF*

Land cover change (B to A)	B			
A	Primary peat swamp forest, high density (tonC/ha)	Primary peat swamp forest, medium density (tonC/ha)	Primary peat swamp forest, low density (tonC/ha)	Secondary peat swamp forest, high density (tonC/ha)
Primary peat swamp forest, high density	na	nc	nc	nc
Primary peat swamp forest, medium density	-34.94	na	nc	nc
Primary peat swamp forest, low density	-42.50	-7.56	na	nc
Secondary peat swamp forest, high density	-30.86	+4.08	+11.64	na
Secondary peat swamp forest, low density	-60.84	-25.90	-18.34	-29.98

Remarks: (-) : emission;
(+) : positive emission (removal);
nc : no change
na : not applicable

Emission factors from land cover changes from land cover classes B to A are quantified in Table 15. Land cover changes from B to A are a shift from peat swamp forest to non forest peatland, and considered as deforestation.

[16] These values need to be reviewed and validated by experts and the Joint Committee members under the JCM, since some of the emission factors seem to have outliers – e.g., removal factors (sequestration) occur when medium and low density primary PSF are degraded to high density secondary PSF.

Table 15. *Matrix of emission factors: peat swamp forest to peat swamp, non forest*

Land cover change (B to A)	B				
A	Primary peat swamp forest, high density (tonC/ha)	Primary peat swamp forest, medium density (tonC/ha)	Primary peat swamp forest, low density (tonC/ha)	Secondary peat swamp forest, high density (tonC/ha)	Secondary peat swamp forest, low density (tonC/ha)
Bareland	-96.98	-62.05	-54.48	-66.12	-36.15
Shrub	-82.27	-47.34	-39.77	-51.41	-21.44
Swamp shrub	-82.27	-47.34	-39.77	-51.41	-21.44
Agriculture	-90.19	-55.25	-47.69	-59.33	-29.35

Remarks: (-) : emission

3.3.3.2 Heath forest classes

Emission factors from land cover changes from forest classes B to A are quantified in Table 16. Land cover changes from B to A are indication of degradation.

Table 16. *Matrix of emission factors: from primary heath forest to secondary heath forest*

Land cover change (B to A)	B	
A	Primary heat forest, high density (tonC/ha)	Secondary heath forest, high density (tonC/ha)
Secondary heath forest, high density	-5,57	na
Secondary heath forest, low density	-26,35	-20,78

Remarks: (-) : emission;
na : not applicable

Emission factors from land cover changes from land cover classes B to A are quantified in Table 17. Land cover changes from B to A are a shift from heath forest to heath non forest area, and considered as deforestation.

Table 17. *Matrix of emission factors: heath forest to heath, non forest area*

Land cover change (B to A)	B		
A	Primary heat forest, high density (tonC/ha)	Secondary heath forest, high density (tonC/ha)	Secondary heath forest, low density (tonC/ha)
Bareland	-62,50	-56,93	-36,15
Shrub	-58,04	-52,47	-31,69
Swamp shrub	-58,04	-52,47	-31,69

Remarks: (-) : emission

3.3.3.3 Freshwater swamp forest classes

Emission factors from land cover changes from forest classes B to A are quantified in Table 18. Land cover changes from B to A are indication of degradation.

Table 18. *Matrix of emission factors:primary freshwater swamp forest to secondary fresh water swamp forest*

Land cover change (B to A)	B			
A	Primary fresh water swamp forest, high density (tonC/ha)	Secondary fresh water swamp forest, high density (tonC/ha)	Young secondary fresh water swamp forest, low density (tonC/ha)	Old secondary fresh water swamp forest, low density (tonC/ha)
Primary fresh water swamp forest, high density	0	nc	nc	nc
Secondary fresh water swamp forest, high density	-38.56	0	nc	nc
Young secondary fresh water swamp forest, low density	-52.43	-13.87	0	+8.86
Old secondary fresh water swamp forest, low density	-61.29	-22.73	-8.86	0

Remarks: (-) : emission;
nc : no change

Emission factors from land cover changes from land cover classes B to A are quantified in Table 19. Land cover changes from B to A are a shift from heath forest to heath non forest area, and considered as deforestation.

Table 19. *Matrix of emission factors: freshwater swamp forest to freshwater swamp, non forest area*

Land cover change (B to A)	B		
A	Primary freshwater swamp forest, high density (tonC/ha)	Secondary freshwater swamp forest, high density (tonC/ha)	Secondary freshwater swamp forest, low density (tonC/ha)
Bareland	-96,98	-58,42	-35,69
Shrub	-96,12	-57,56	-34,83
Swamp shrub	-96,12	-57,56	-34,83
Agriculture	-90,19	-51,63	-28,90

Remarks: (-) : emission

Emission factors or removal factors are used as an indicator of GHG emissions or sequestration. There are two key components or basic inputs in estimating emissions and removals of greenhouse gases associated with land use changes, namely: *Activity Data* and *Emission* ***Factor*** (Mendoza, 2012; IPCC, 2006).These values indicate emissions or removals of greenhouse gases per unit “activity data” as determined by the forest carbon inventory.

If there is a land cover change from forest land to non forest land (e.g., from high density primary PSF to low density secondary PSF), an emission factor value applicable for this type of land cover change is applied for the estimation of emissions. Meanwhile, if there is a land cover change from non forest land to forest land (e.g., from shrub land to low density secondary PSF), this will be a removal (sequestration) factor, and an applicable emission factor value should be used to estimate GHG emissions.

Emission or sequestration factors are calculated by using the following formula[17]:

Emission or sequestration (tonC/ha) = AD x E or R factor

Where:

AD = Activity Data from the area of land cover changes (ha)
E/R factor = emission or removal factor

GHG emissions will be estimated based on activity data in the REL (Reference Emission Level) and MRV (Measurement, Reporting and Verification) systems to monitor total emissions from deforestation and degradation.Emission or removal factors based on land cover changes are very useful for a quick estimation of emission or sequestration volume in areas of land cover changes.

The calculation of emission factors was determined through the analysis of satellite imagery based on the land cover stratification and land cover changes. It was also determined by the carbon fraction value obtained from the previous feasibility studies. The average carbon fraction value used in this study was similar to the value, 45.29%, obtained by Dharmawan (2012).The mean annual change in carbon stocks as a result of the removal factor from the regeneration of secondary peat swamp forest and secondary fresh waters wamp forest amounted to be 3.70 ton C/ha or equivalent of 13.57 ton CO_2e/ha. These values are also consistent with the value obtained by Dharmawan(2012).

This indicates that the potential of peat land carbon up take is very high, and possibly exceeds the a mount of CO_2 emissions caused by peat drainage[18]. With the carbon removal value greater than the value of emission factor from peat drainage, there covery of the fire damaged PSF may have a surplus of carbon up take by as much as 4.57 ton CO_2e/ha annually.

[17] A calculation example of emissions using emission factor values is as follows:
Area of land cover change: from primary peat swamp forest, high density to shrub land
Total area of land cover change: 1,502.70 ha.
Emission factor value: 82.27 tonC/ha.
Total Emission from the land cover change
= 1,502.70 ha x 82.27 tonC/ha
= 123,627.13 tonC

[18] The annual emission factor frompeatdrainagewas 9tonCO2e/ha from peatsubsidence measured inevery 10 cm(VCS,2010).

This study also quantified removal factors based on the CO_2 sequestration from the regeneration of secondary PSF and fresh waters wamp forest. These are two forest classes with a high rate of natural regeneration process. The mean diameter increment of disturbed PSF stands in Riau was found to be equal to 0.54 cm per year (Istomo *etal.*,2009). The natural forest regeneration in Kalampangan PSF in Central Kaliantan, where forest fires swept a large tract of the forest in 1997, has shown a quick recovery with the total 3.15 m^2/ha of basal area with in the first 5 years after the fire. Considering the speed of recovery based on the estimated value of basal area, it was estimated that it would only take 5 to 7 years for disturbed secondary PSF to recover similar to the condition of the primary PSF (Simbolon, 2003). In the Katingan Project site, where the secondary PSF and fresh water swamp forest are very densely dispersed, the potential removal factor from natural regeneration of disturbed forests may be significantly large.

3.3.4 Estimation of net emission reductions from the Katingan Project site

3.3.4.1 Net emission reductions (NERs) from aboveground biomass

NERs from aboveground biomass were estimated by taking the following calculation steps:

1. Total carbon stock of extracted trees

   = ∑ [logged timber biomass x carbon stock in each forest stratification]

   = ∑ [(area of each stratification (ha) x rate of deforestation 0.84%) x (carbon stock in each forest stratification tC/ha)]

   = 112,427.75 tonC

2. Carbon stock turning into long-lived wood products

   = Total carbon stock from timber extraction x percent of harvested roundwood turning into long-lived wood products

   = 112,427.75 tonC x 30% = 33,728.32 tonC

3. CO_2 emisson from timber extraction

= (Total carbon stock of extracted trees - carbon stock turning into long-lived wood products) x 44/12

= (112,427.75 tonC – 33,728.32 tonC) x 44/12

= 288,565 tonCO_2

4. CO_2 emission from biomass burning

= [((area cleared due to biomass burning x avarage carbon stock in above-ground living biomass) - Total carbon stock of extractedtrees)) x average proportion of carbon stock burnt x average biomass combustion efficiency x carbon stock (DBH < 10cm) x 44/12]

= [((total area 203.558,0 ha x deforestation rate 0.84% x deforestation rate due to forest fire 5.92% x average carbon stock in above-ground living biomass 71.17 tonC/ha) - Total carbon stock of extracted trees 112,427.75 tonC)) x average proportion of carbon stock burnt 38% x average biomass combustion efficiency 0.5 x carbon stock (DBH < 10cm) 11.05 tonC x 44/12]

= [- 105,227 tonC x 38% x 0.5 x 11.05 tonC x 44/12]

= - 810,052 tonCO_2

5. N_2O emission from biomass burning

= CO_2 emission from biomass burning x 12/44 x nitrogen/carbon ratio x emission ratio for N2O x 44/28 x GWP N2O

= - 810,052 tonCO_2 x 12/44 x 0.01 x 0.007 x 44/28 x 310

= - 7,533 tonCO_2

6. CH_4 emission from biomass burning

= CO_2 emission from biomass burning x 12/44 x emission ratio for CH_4 x 16/12 x GWP CH_4

= - 810,052 tonCO_2 x 12/44 x 0.012 x 16/12 x 21

= - 74,230 tonCO_2

7. Total emission from biomass burnt

   = CO_2 emission from biomass burning + N_2O emission from biomass burning + CH_4 emission from biomass burning

   = - 810,052 tonCO_2 + - 7,533 tonCO_2 + - 74,230 tonCO_2

   = - 891,815 tonCO_2

8. **Total net emission reductions from aboveground biomass**

   = CO_2 emisson from timber extraction + Total emission from biomass burnt

   = 288,565 tonCO_2 + (- 891,815 tonCO_2)

   = **- 603,250.87 tonCO_2**

3.3.4.2 Net emission reductions from peat

NERs from peat were estimated by taking the following calculation steps:

1. Use of maximum peat drainage scenario with the drainage depth of 0.95 meter and minimum peat drainage scenario with the drainage depth of 0.60 meter (methodology VM0004[19])
2. Area of peat drainage in year 1 = total area 203,558.0 ha x deforestation rate 0.84%

   = 1,710 ha

   Area of peat drainage in year 30 = total area 203,558,0 ha x deforestation rate 0.84% + area of peat drainage in year 29

   = 51,297 ha
3. Total CO_2 from maximum peat drained depth in year 1 = relationship between CO_2 and drainage depth x maximum drainage x area of peat drainage in year 1

   = 0.91 tonCO_2/ha x 0.95 meter x 1,710 ha

[19] This value needs to be reviewed and validated for its applicability for the Katingan Project site by experts and Joint Committee members under the JCM as it was taken from a different methodology, VM0004.

= 147,820 tonCO_2

Total CO_2 from maximum peat drained depth in year 30 = relationship between CO_2 and drainage depth x maximum drainage x area of peat drainage in year 30

= 0.91 tonCO_2/ha x 0.95 meter x 51,297 ha

= 4,434,592 tonCO_2

Total CO_2 from minimum peat drained depth in year 1 = relationship between CO_2 and drainage depth x minimum drainage x area of peat drainage in year 1

= 0.91 tonCO_2/ha x 0.60 meter x 1,710 ha

= 93,360 tonCO_2

Total CO_2 from minimum peat drained depth in year 30 = relationship between CO_2 and drainage depth x minimum drainage x area of peat drainage in year 30

= 0.91 tonCO2/ha x 0.60 meter x 51,297 ha

= 2,800,795 tonCO_2

4. Mass of peat burning = [area of peat burning x depth of burnt peat x scaling factor from m^3 to ha x peat bulk density]

   = [(total area 203,558.0 ha x deforestation rate 0.84% x deforestation rate due to forest fire 5.92%) x 0.34 meter x 10,000 x 0.17 ton/m^3

   = 58,508 ton

5. Total CO_2 from peat burning = mass of burnt peat x emission factor of CO_2 from peat combusion

   $$= 58{,}508 \text{ ton x } \left(\frac{149{,}591 \text{ gCO2/ton peat}}{1{,}000{,}000}\right)$$

   = 8,752 tonCO_2

6. Total CH_4 from peat burning = [(mass of burntpeat x (emission factor of CH_4 from peat combusion)) x GWP CH_4]

   $$= [\ (58{,}508 \text{ ton x } (\frac{\underline{11{,}338 \text{ gCO2/ton peat}}}{1{,}000{,}000})) \text{ x } 21\ ]$$

   = 663 tonCH_4 x 21

   = 13,931 ton CO_2

7. **Total emission reduction from peat under the maximum peat drainage case in year 1 =**

   Total CO_2 from the pepth of maximum peat drainage in year 1 + Total CO_2 from peat burning + Total CH_4 from peat burning

   = 147,820 tonCO_2 + 8,752 tonCO_2 + 13,931 ton CO_2

   = **170,503 tonCO_2**

8. **Total emission reduction from peat under the minimum peat drainage case in year 1 =**

   Total CO_2 from the pepth of minimum peat drainage in year 1 + Total CO_2 from peat burning + Total CH_4 from peat burning

   = 93,360 ton CO_2 + 8,752 ton CO_2 + 13,931 ton CO_2

   = **116,043 ton CO_2**

9. **Total emission reduction from peat under the maximum peat drainage case in year 30 =**

   Total CO_2 from the pepth of maximum peat drainage in year 30 + Total CO_2 from peat burning + Total CH_4 from peat burning

   = 4,434,592 ton CO_2 + 8,752 ton $CO_2$2 + 13,931 ton CO_2

   = **4,457,275 ton CO_2**

10. **Total emission reduction from peat under the minimum peat drainage case in year 30 =**

   Total CO_2 from the pepth of minimum peat drainage in year 30 + Total CO_2 from peat burning + Total CH_4 from peat burning

= 2,800,795 ton CO_2 + 8,752 ton CO_2 + 13,931 ton CO_2

= **2,823,478 ton CO_2**

3.3.4.3 Total net emission reductions from the Katingan Project site

Total NERs under both maxium and minimum drainage cases were estimated by taking the following calculation steps:

1. Total net emission reductions in year 1 (from maximum peat drainage)

   = net emission reductions from aboveground biomass + peat emission

   = 603,250.87 ton CO_2 + 170,503 ton CO_2

   = **773,753.62 ton CO_2**

2. Total net emission reductions in year 1 (from minimum peat drainage)

   = net emission reductions from aboveground biomass + peat emission

   = 603,250.87 ton CO_2 + 116,043 ton CO_2

   = **719,293.71 ton CO_2**

3. Total net emission reductions in year 30 (from maximum peat drainage)

   = net emission reductions from above ground biomass + peat emission

   = 603,250.87 ton CO_2 + 4,457,275 ton CO_2

   = **5,060,526.32 ton CO_2**

4. Total net emission reductions in year 30 (from minimum peat drainage)

   = net emission reductions from above ground biomass + peat emission

   = 603,250,87 ton CO_2 + 2,823,478 ton CO_2

   = **3,426,729.10 ton CO_2**

5. Accumulated total net emission reductions for the period of 30 years (from maximum peat drainage)

   = ∑ [total net emission reductions in year 1, 2, 3, ... 30 (max peat drainage)]

   = **87,514,199.11 ton CO_2**

6. Accumulated total net emission reductions for the period of 30 years (from minimum peat drainage)

   = ∑ [total net emission reductions in year 1, 2, 3, ... 30 (min peat drainage)]

   = **62,190,342.20ton CO_2**

Figure 14 and Table 20 present the summary of estimated total net emission reduction amounts from the Katingan Project site for the period of 30 years. Detailed calculation of netemission from above ground biomass and emissions from peat soil are presented in Annexes 12 and 13 as separate spreadsheets.

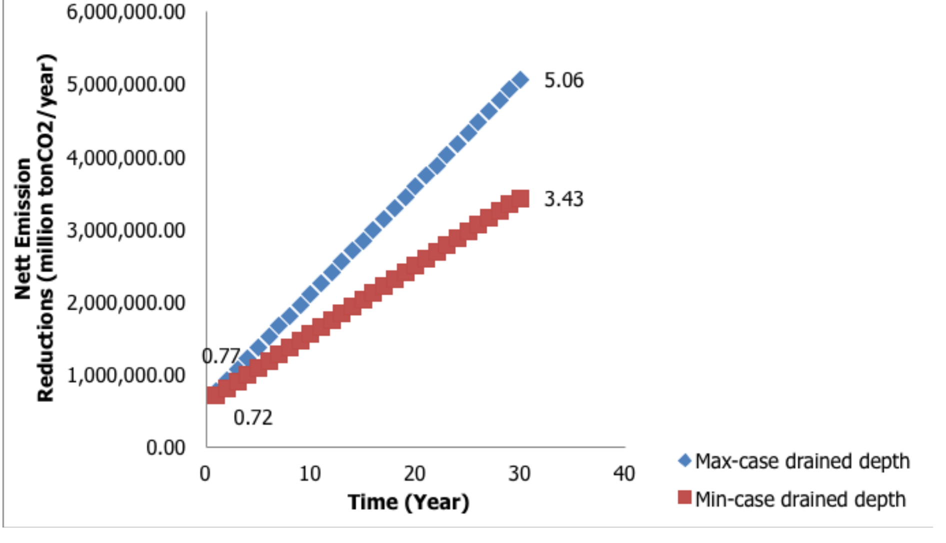


Figure 14. *Net emission reduction trends from the Katingan Project site from year 1 to 30*

Table 20. *Net emission reductions from the Katingan Project site from year 1 to 30*

Period	Emission (tCO_2/year)	
	Max-case drainage depth (Drainage 0.95 m)	Min-case drainage depth (Drainage 0.60 m)
Year 1	773,753.62	719,293.71
Year 2	921,573.37	812,653.55
Year 3	1,069,393.11	906,013.39
Year 4	1,217,212.86	999,373.23
Year 5	1,365,032.61	1,092,733.07
Year 6	1,512,852.36	1,186,092.92
Year 7	1,660,672.11	1,279,452.76
Year 8	1,808,491.86	1,372,812.60
Year 9	1,956,311.61	1,466,172.44
Year 10	2,104,131.35	1,559,532.28
Year 11	2,251,951.10	1,652,892.12
Year 12	2,399,770.85	1,746,251.96
Year 13	2,547,590.60	1,839,611.80
Year 14	2,695,410.35	1,932,971.65
Year 15	2,843,230.10	2,026,331.49
Year 16	2,991,049.84	2,119,691.33
Year 17	3,138,869.59	2,213,051.17
Year 18	3,286,689.34	2,306,411.01
Year 19	3,434,509.09	2,399,770.85
Year 20	3,582,328.84	2,493,130.69
Year 21	3,730,148.59	2,586,490.53
Year 22	3,877,968.34	2,679,850.37
Year 23	4,025,788.08	2,773,210.22
Year 24	4,173,607.83	2,866,570.06
Year 25	4,321,427.58	2,959,929.90
Year 26	4,469,247.33	3,053,289.74
Year 27	4,617,067.08	3,146,649.58
Year 28	4,764,886.83	3,240,009.42
Year 29	4,912,706.57	3,333,369.26
Year 30	5,060,526.32	3,426,729.10
Accumulated Total	**87,514,199.11**	**62,190,342.20**

CONCLUSION 4

This study had important implications for land cover stratification, the estimation of above- and below-ground biomass and carbon stocks, and potential net emission reductions for the Katingan Project site. The combined use of SAR imagery and different optical satellite images proved to be mutually beneficial to conduct these analyses. Areas which were difficult to be interpreted with optical satellite images, were compared with PALSAR data and clarified. Similarly, multiple optical satellite images were used to determine and verify PALSAR polarimetric classification results. Field survey data such as peat depth, soil bulk density and ash contents, and tree inventory were also reviewed and analyzed in order to verify the spatial analysis based results.

Another important implication is that total biomass, the summation of aboveground biomass and belowground peat, were be estimated per stratum in order to quantify the amount of carbon stored in the study area more accurately. The study found that the total carbon stock of the Katingan Project site is 0.722 GtC, covering the area of 203,570 ha, in which the most carbon storage was found in the soil/peat carbon pool. This amounts to beas much as 11.46% of the total peat carbon stock found across the island of Borneo. The study also found that the primary PSF contained the largest peat C stocks per hectare. This was probably because few human disturbances have occurred in the area, and the decomposition process of organic matter has been slow and stable throughout seasons. The secondary PSF, encompassing approximately 48% of the total area, was found to contain the largest total C stock among all land cover strata. This implies that the proper management of this type of forest is the key to preserving C stocks and enhancing sequestration.

Structural information obtained from PALSAR data could also provide an additional angle to be considered for the estimation of aboveground biomass in further research. By drawing a relationship between backscattering parameters and aboveground biomass, it is possible to estimate aboveground carbon stored in each structural type (i.e., zone 1 to 9 of Figure 8).

By adding field data of peat depth and water table levels, a PALSAR-based biomass analysis would enhance the interpretation level of carbon stock estimation.

This study also estimated potential NERs from the Katingan Project site over the period of 30 years. Cumulative potential net emission reductions were estimated to be approximately87,514,199.11ton CO_2 (max emission scenario with peat drainage depth = 95 cm) and 62,190,342.20tonCO_2 (min emission scenario with peat drainage depth = 60 cm). The baseline deforestation rate due to logging, 0.84%, was adopted from the forestry statistics of Central Kalimantan Province. Deforestation rate due to forest and peat fires, 5.92%, was computed through the spatial analysis of land cover changes. The comparative result of the NER analysis under maximum and minimum emission scenarios implies that the NERs could be reduced by 25,323,856.91 tonCO_2, if the drainage level is controlled down to 60 cm as in the case of minimum drainage scenario.

The high density primary PSF was found to be the greatest source of GHG emissions due to the past and present patterns of land uses. This forest type is facing a risk of the most pressing land cover changes, turning into secondary for estorn on forest land due to logging, encroachment and peat fires. Given that the primary PSF is still intact and has the greatest potential as a carbon reservoir, effective monitoring and protection of the area are important.

The secondary PSF was found to have the greatest potential for both emission mitigation and sequestration. The majority of the secondary PSF in the Katingan Project site are still in good condition, maintaining high water levels and deep peat layers. In this type of forest, natural regeneration of forest should be supported, and the integrity of hydrological functions be maintained. Water table levels in this type of areas, especially nearby canals, should be monitored carefully.

The Katingan Project area's peat swamp forest provides fundamental ecosystem services. It serves as a huge carbon reservoir, is home to a number of high conservation value (HCV) species, and provides important forest resources to the surrounding communities.

In order to mitigate potentially a huge amount of CO_2 emissions and maintain healthy ecosystem functions of peat swamp forest in the Katingan Project site, the protection, restoration and sustainable use of forest resources are necessary. Such an integrated peatland management approach will benefit all stakeholders in achieving carbon, community and biodiversity objectives.

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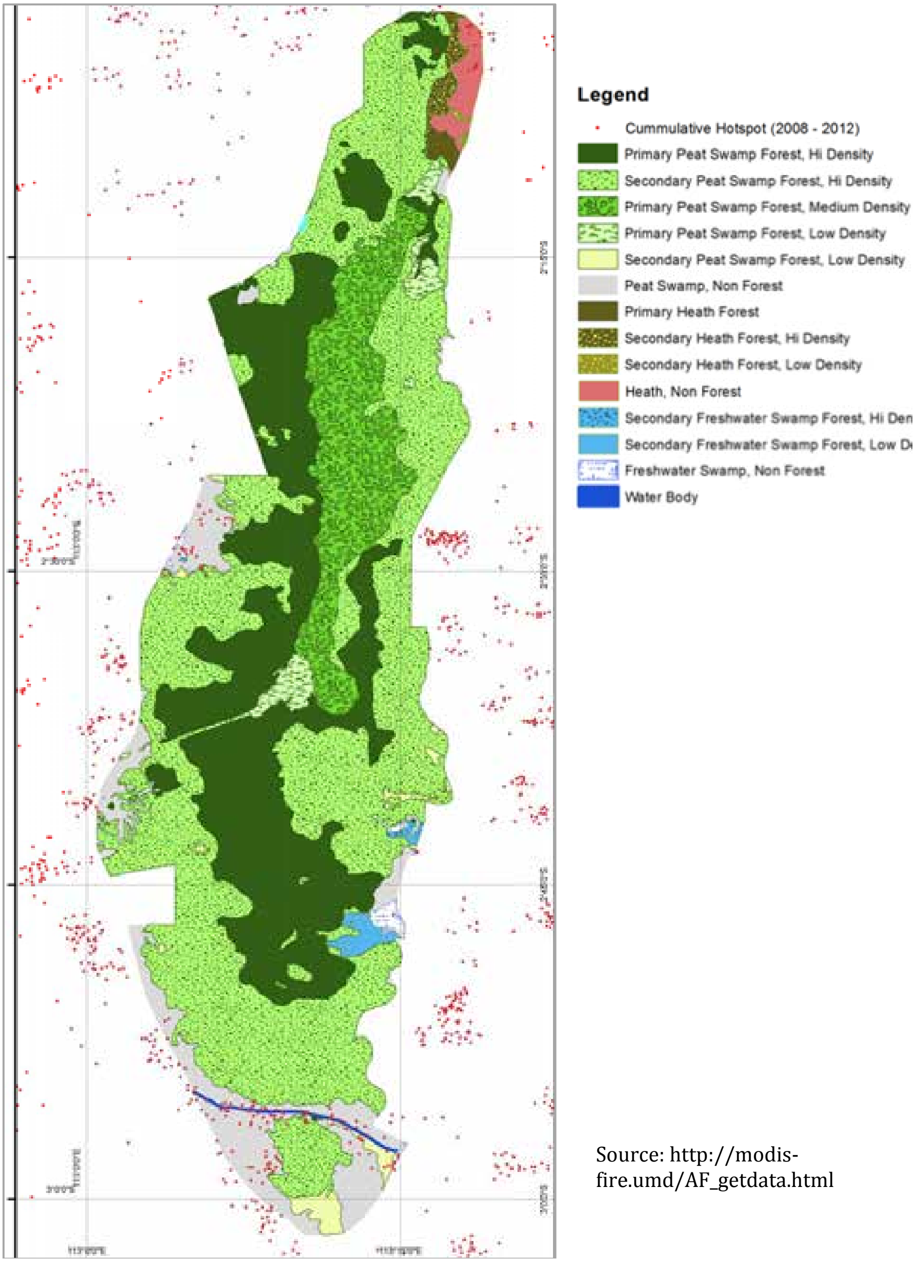
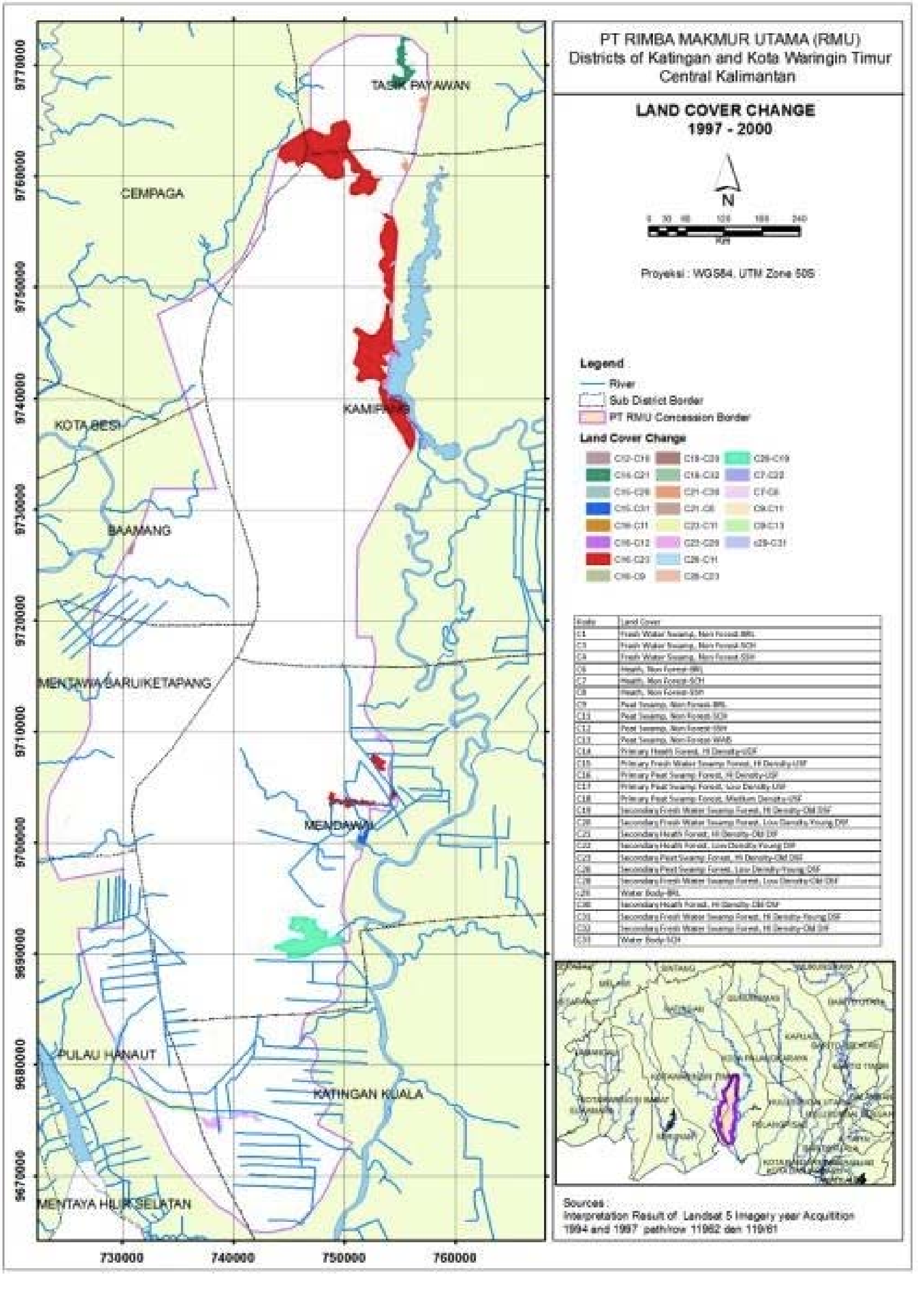
Annexes

Annex 1. **Map of Fire Hot Spots around the Katingan Project Site**

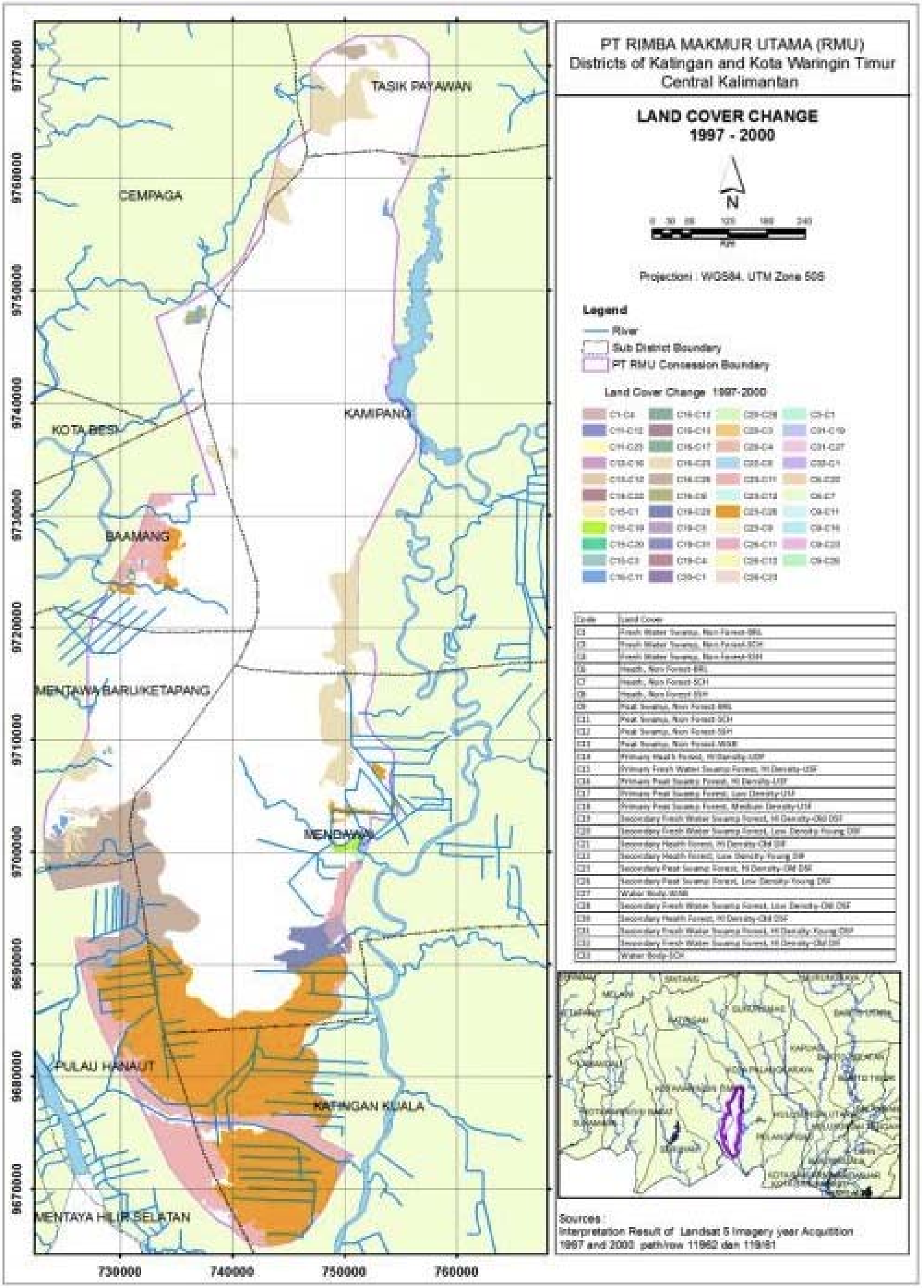


Source: http://modis-fire.umd/AF_getdata.html

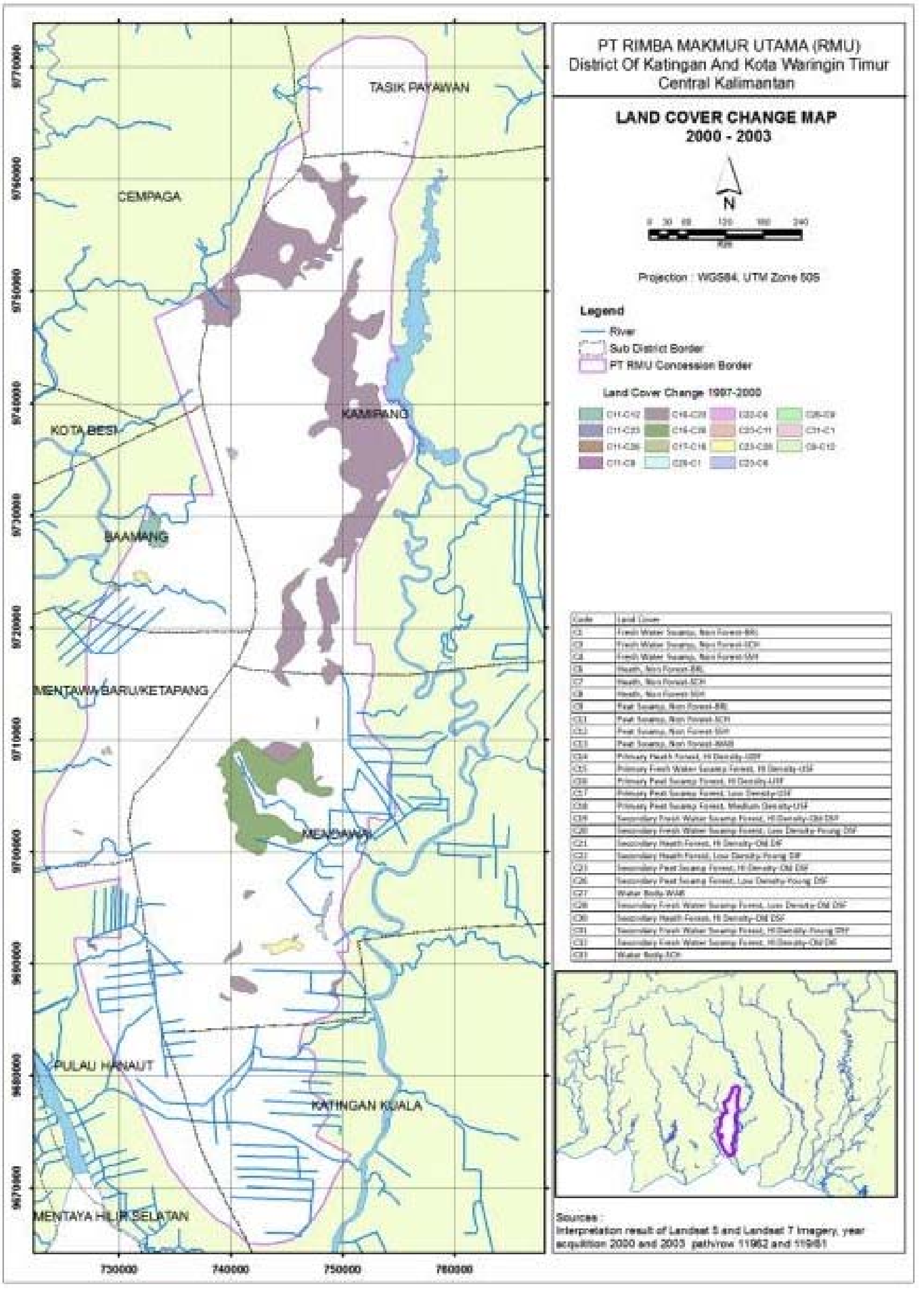
Annex 2. **Map of Land Cover Change in the Katingan Project Site from 1994 – 1997**



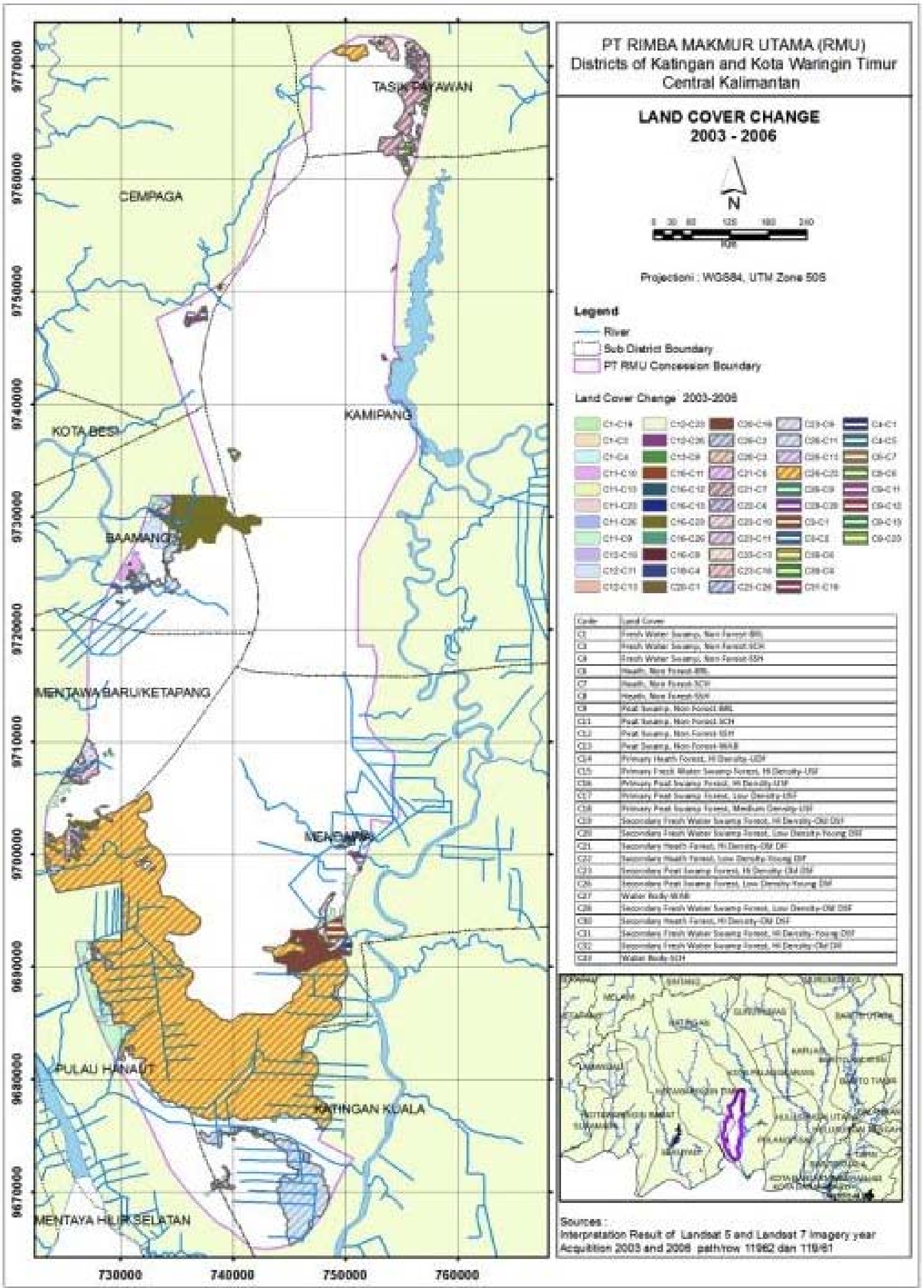
Annex 3. **Map of Land Cover Change in the Katingan Project Site from 1997 – 2000**



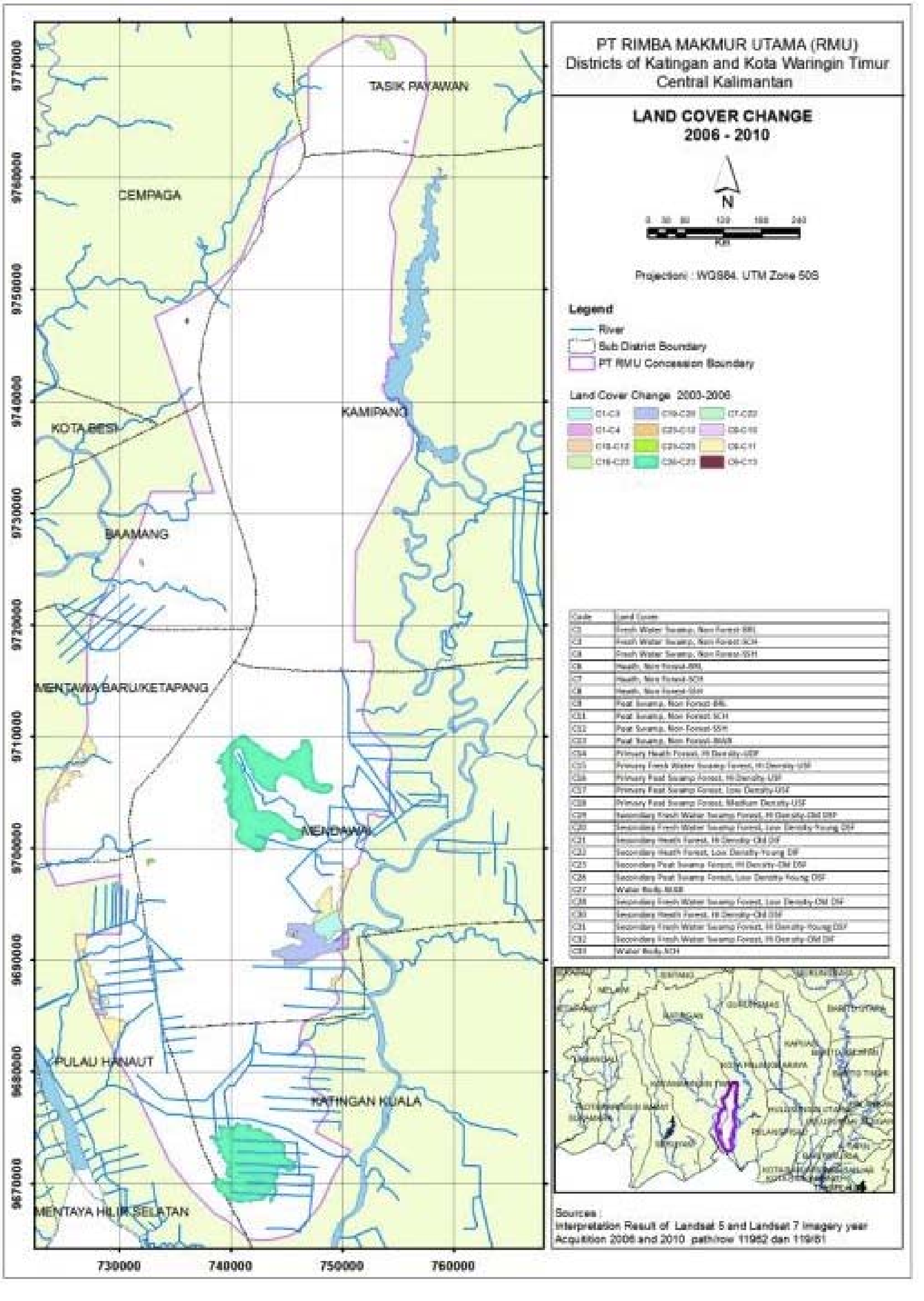
Annex 4. **Map of Land Cover Change in the Katingan Project Site from 2000 – 2003**



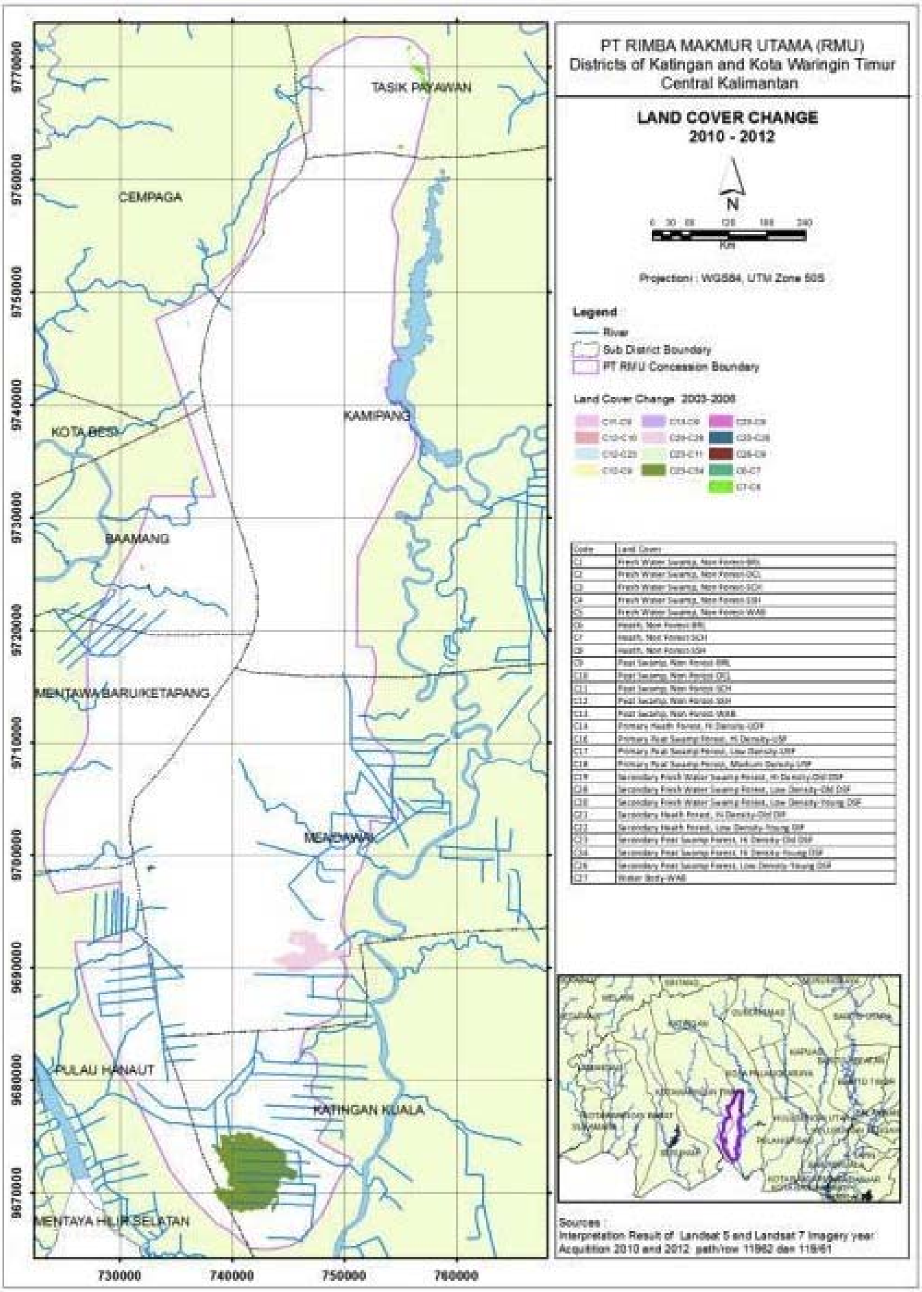
Annex 5. **Map of Land Cover Change in the Katingan Project Site from 2003 – 2006**



Annex 6. **Map of Land Cover Change in the Katingan Project Site from 2006 – 2010**



Annex 7. **Map of Land Cover Change in the Katingan Project Site from 2010 – 2012**



Annex 8. **Results of Land Cover Classification and Size**

No	Land cover strata	1994 (ha)	1997 (ha)	2000 (ha)	2003 (ha)	2006 (ha)	2010 (ha)	2012 (ha)
1.	Fresh water swamp, non forest (bareland)	12	3	26	95	518	10	10
2.	Fresh water swamp, non forest (agriculture)					16	16	16
3.	Fresh water swamp, non forest (shrub)	38	38	541	541	278	705	705
4.	Fresh Water Swamp, Non Forest (Swamp shrub)	72	72	195	195	67	147	147
5.	Fresh Water Swamp, Non Forest (Water body)					68	68	68
6.	Heath, non forest (bareland)	54	78		5	394	394	524
7.	Heath, non forest (shrub)	33		24	24	1,515	1,510	1,380
8.	Heath, Non Forest (Swamp shrub)	378	378	453	453	392	392	392
9.	Peat swamp, non forest (bareland)	63	49	278	481	2,328	359	397
10.	Peat swamp, non forest (agriculture)					271	357	371
11.	Peat swamp, non forest (shrub)	1,099	1,506	12,444	11,857	15,014	16,879	16,885
12.	Peat Swamp, Non Forest (Swamp shrub)	546	573	765	1,271	696	712	689
13.	Peat Swamp, Non Forest (Water body)	0	2	6	6	129	134	129
14.	Primary Heath Forest, High Density (Primary dry land forest)	1,171	787	759	759	759	759	759
15.	Primary fresh water swamp forest, high density	351	198					
16.	Primary peat swamp forest, high density	105,104	99,151	80,392	58,730	56,482	56,254	56,254
17.	Primary peat swamp forest, low density	3,301	3,301	3,347	3,301	3,301	3,301	3,301

No	Land cover strata	1994 (ha)	1997 (ha)	2000 (ha)	2003 (ha)	2006 (ha)	2010 (ha)	2012 (ha)
18.	Primary peat swamp forest, medium density	21,726	21,726	21,726	21,726	21,726	21,726	21,726
19.	Secondary Fresh Water Swamp Forest, High Density (Old secondary)	771	1,961	272	272	1,454	287	287
20.	Secondary Fresh Water Swamp Forest, Low Density (Young secondary)	68	196	1,340	1,282	79	1,245	79
21.	Secondary Heath Forest, High Density (Old secondary dry land forest)	2,660	2,911	2,911	2,911	1,246	1,246	1,246
22.	Secondary Heath Forest, Low Density (Young secondary dry land forest)	122	137	145	140	112	116	116
23.	Secondary Peat Swamp Forest, High Density (Old secondary)	64,260	69,543	39,005	55,726	85,917	94,109	90,616
24.	Secondary Peat Swamp Forest, Low Density (Old secondary)						21	
25.	Secondary Peat Swamp Forest, Low Density (Young secondary)	485	734	38,623	43,487	10,721	2,733	2,744
26.	Water body			77	77	77	77	77
27.	Secondary Fresh Water Swamp Forest, Low Density (Old secondary)	1,166		79	79			1,166
28.	Water body (bareland)	77						
29.	Secondary Heath Forest, High Density (Old secondary dry land forest)		126	126	126			
30.	Secondary Fresh Water Swamp Forest, highdensity (Young secondary)			26	15			

No	Land cover strata	1994 (ha)	1997 (ha)	2000 (ha)	2003 (ha)	2006 (ha)	2010 (ha)	2012 (ha)
31.	Secondary Fresh Water Swamp Forest, High Density (Old secondary)		11					
32.	Secondary Peat Swamp Forest, High Density (Young secondary)							3,475
33.	Water body (shrub)		77					
	Total	203,558	203,558	203,558	203,558	203,558	203,558	203,558

Annex 9. **Land Cover Classification Code Used for the Land Cover Change Analysis**

No	Land cover category	Code
1.	Fresh Water Swamp, Non Forest (Bareland)	C1
2.	Fresh Water Swamp, Non Forest (Agriculture)	C2
3.	Fresh Water Swamp, Non Forest (Grassland)	C3
4.	Fresh Water Swamp, Non Forest (Swamp grassland)	C4
5.	Fresh Water Swamp, Non Forest (Water body)	C5
6.	Heath, Non Forest (Braeland)	C6
7.	Heath, Non Forest (Grassland)	C7
8.	Heath, Non Forest (Swamp grassland)	C8
9.	Peat Swamp, Non Forest (Bareland)	C9
10.	Peat Swamp, Non Forest (Agriculture)	C10
11.	Peat Swamp, Non Forest (Grassland)	C11
12.	Peat Swamp, Non Forest (Swamp grassland)	C12
13.	Peat Swamp, Non Forest (Water body)	C13
14.	Primary Heath Forest, High Density (Primary dry land forest)	C14
15.	Primary Fresh Water Swamp Forest, High Density	C15
16.	Primary Peat Swamp Forest, High Density	C16
17.	Primary Peat Swamp Forest, Low Density	C17
18.	Primary Peat Swamp Forest, Medium Density	C18
19.	Secondary Fresh Water Swamp Forest, High Density (Old secondary)	C19, C31, C32
20.	Secondary Fresh Water Swamp Forest, Low Density (Young secondary)	C20
21.	Secondary Heath Forest, High Density (Old secondary dry land forest)	C21
22.	Secondary Heath Forest, High Density	C30
23.	Secondary Heath Forest, Low Density (Young secondary dry land forest)	C22
24.	Secondary Peat Swamp Forest, High Density (Old secondary)	C23
25.	Secondary Peat Swamp Forest, Low Density (Old secondary)	C25
26.	Secondary Peat Swamp Forest, Low Density (Young secondary)	C26
27.	Water Body	C27
28.	Secondary Fresh Water Swamp Forest, Low Density (Old secondary)	C28
29.	Primary Fresh Water Swamp Forest, High Density	C16
30.	Secondary Heath Forest, High Density	C30
31.	Secondary Peat Swamp Forest, High Density	C34
32.	Secondary Heat Forest, Low Density	C22
33.	Secondary Fresh Water Swamp Forest, Low Density	C20

Annex 10. **Land Cover Changes in the Katingan Project Site**

1. Land cover changes for the period of 1994 – 1997 in the Katingan Project Site (unit in ha)

	Land Cover	Land Ccover 1997																							Total
		C1	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C26	C3	C30	C31	C32	C4	C6	C8	C9	
Land Cover 1994	C1	3										10													12
	C11		1,099																						1,099
	C12			543				3																	546
	C13				0																				0
	C14					787							384												1,171
	C15						198					79							74						351
	C16		7	31				99,148							5,912									6	105,104
	C17								3,301																3,301
	C18									21,726															21,726
	C19										721	40								11					771
	C20											68													68
	C21												2,526					126				7			2,660
	C22													122											122
	C23		323												63,605	331									64,260
	C26		57												25	403									485
	C28										1,166														1,166
	c29																		77						77
	C3																38								38
	C4																				72				72
	C6																					54			54
	C7													16								17			33
	C8																						378		378
	C9		19		1																			43	63
	Total	3	1,506	573	2	787	198	99,151	3,301	21,726	1,887	196	2,911	137	69,543	734	38	126	151	11	72	78	378	49	203,558

2. Land cover changes for the period of 1997-2000 in Katingan Project Site(unit in ha)

	Land Cover	Land Cover 2000																							Total
		C1	C11	C12	C13	C14	C16	C17	C18	C19	C20	C21	C22	C23	C26	C27	C28	C3	C30	C31	C4	C7	C8	C9	
Land Cover 1997	C1																				3				3
	C11		1,397	14										94											1,506
	C12			556			17																		573
	C13			1	0																				2
	C14					759							28												787
	C15	2								169	14							12							198
	C16		427	118	5		80,373	46						8,732	9,286									163	99,151
	C17							3,301																	3,301
	C18								21,726																21,726
	C19									28	1,307							445		26	80				1,887
	C20	10									19						79	49			40				196
	C21											2,911													2,911
	C22												63										75		137
	C23		10,578	73										29,849	28,932									110	69,543
	C26		5	2										328	399										734
	C3	3																35							38
	C30																		126						126
	C31									74						77									151
	C32	11																							11
	C4																				72				72
	C6												54									24			78
	C8																						378		378
	C9		37				2							1	5									4	49
	Total	26	12,444	765	6	759	80,392	3,347	21,726	272	1,340	2,911	145	39,005	38,623	77	79	541	126	26	195	24	453	278	203,558

3. Land cover changes for the period of 2000-2003 in Katingan Project Site(unit in ha)

	Land Cover	Land Cover 2003																								Total
		C1	C11	C12	C13	C14	C16	C17	C18	C19	C20	C21	C22	C23	C26	C27	C28	C3	C30	C31	C4	C6	C7	C8	C9	
Land Cover 2000	C1	26																								26
	C11		11,853	488										45	8										50	12,444
	C12			765																						765
	C13				6																					6
	C14					759																				759
	C16						58,685							17,195	4,512											80,392
	C17						46	3,301																		3,347
	C18								21,726																	21,726
	C19									272																272
	C20	57									1,282															1,340
	C21											2,911														2,911
	C22												140									5				145
	C23		4											38,486	373										142	39,005
	C26														38,593										30	38,623
	C27															77										77
	C28																79									79
	C3																	541								541
	C30																		126							126
	C31	11																		15						26
	C4																				195					195
	C7																						24			24
	C8																							453		453
	C9			18																					259	278
	Total	95	11,857	1,271	6	759	58,730	3,301	21,726	272	1,282	2,911	140	55,726	43,487	77	79	541	126	15	195	5	24	453	481	203,558

4. Land cover changes period 2003-2006 in Katingan Project Site(unit in ha)

	Land Cover	Land Cover 2006																								Total
		C1	C10	C11	C12	C13	C14	C16	C17	C18	C19	C2	C20	C21	C22	C23	C26	C27	C3	C4	C5	C6	C7	C8	C9	
Land Cover 2003	C1	57									11								17	10						95
	C11		256	9,980		23										7	148								1,444	11,857
	C12		13	506	668	37										2	44									1,271
	C13					0																			5	6
	C14						759																			759
	C16			47	1	8		56,254								2,350	46								24	58,730
	C17								3,301																	3,301
	C18									21,726																21,726
	C19										261									10						272
	C20	71									1,166	11							34							1,282
	C21													1,246								179	1,486			2,911
	C22														112							28				140
	C23		2	849		15		229								53,950	33								649	55,726
	C26			3,351		42										29,549	10,450								95	43,487
	C27																	77								77
	C28												79													79
	C3	310										5							227							541
	C30																					53		74		126
	C31										15															15
	C4	80																		47	68					195
	C6																						5			5
	C7																						24			24
	C8																					134		318		453
	C9			281	27	3										59									111	481
	Total	518	271	15,014	696	129	759	56,482	3,301	21,726	1,454	16	79	1,246	112	85,917	10,721	77	278	67	68	394	1,515	392	2,328	203,558

5. Land cover changes period 2006-2010 in Katingan Project Site(unit in ha)

	Land Co-ver	Land Cover 2010																								Total
		C1	C10	C11	C12	C13	C14	C16	C17	C18	C19	C2	C20	C21	C22	C23	C25	C26	C27	C3	C4	C5	C6	C7	C8	C9	
Land Cover 2006	C1	10																		428	80						518
	C10		258		13																						271
	C11			15,014																							15,014
	C12				696																						696
	C13					129																					129
	C14						759																				759
	C16							56,254								229											56,482
	C17								3,301																		3,301
	C18									21,726																	21,726
	C19										287		1,166														1,454
	C2											16															16
	C20												79														79
	C21													1,246													1,246
	C22														112												112
	C23				2											85,894	21										85,917
	C26															7,987		2,733									10,721
	C27																		77								77
	C3																			278							278
	C4																				67						67
	C5																					68					68
	C6																						394				394
	C7														5									1,510			1,515
	C8																								392		392
	C9		99	1,865		5																				359	2,328
	Total	10	357	16,879	712	134	759	56,254	3,301	21,726	287	16	1,245	1,246	116	94,109	21	2,733	77	705	147	68	394	1,510	392	359	203,558

6. Land cover changes period 2010-2012 in Katingan Project Site(unit in ha)

	Land Co-ver	Land Cover 2012																										Total
		C1	C10	C11	C12	C13	C14	C16	C17	C18	C19	C2	C20	C21	C22	C23	C26	C27	C28	C3	C34	C4	C5	C6	C7	C8	C9	
Land Cover 2010	C1	10																										10
	C10		357																									357
	C11			16,866																							13	16,879
	C12		13		689											2											8	712
	C13					129																					5	134
	C14						759																					759
	C16							56,254																				56,254
	C17								3,301																			3,301
	C18									21,726																		21,726
	C19										287																	287
	C2											16																16
	C20												79						1,166									1,245
	C21													1,246														1,246
	C22														116													116
	C23			18												90,613					3,475						3	94,109
	C25																21											21
	C26																2,723										10	2,733
	C27																	77										77
	C3																			705								705
	C4																					147						147
	C5																						68					68
	C6																							389	4			394
	C7																							134	1,376			1,510
	C8																									392		392
	C9																										359	359
	Total	10	371	16,885	689	129	759	56,254	3,301	21,726	287	16	79	1,246	116	90,616	2,744	77	1,166	705	3,475	147	68	524	1,380	392	397	203,558

Annex 11. **Recommendations for Next Steps**

During the METI feasibility study for the fiscal year 2012, the consortium of partnering institutions have tested and implemented enhanced approached to the estimation of carbon stocks and emission reductions for tropical peat swamp forests of the Katingan Peatland Restoration and Conservation Project area.

Moving forward,with an aim of scaling up METI's engagement and contribution to global GHG emission reductions and climate change dialogues through REDD+ for the fiscal year 2013, the following activities are recommended. Since the goal of the Katingan project is to achieve an integrated sustainable peatland management atthe project site, our recommendations are cross-cutting among carbon, community and biodiversity objectives.

Recommended activities for the METI FS 2013

Component	Activity	Description
Carbon MRV	Peatland water management model development	This activity aims to develop an integrated peatland best management practice model based on sustainable hydrological management, and peatland agriculture. Monitoring of continuous water table levels throughout seasons at representative sampling plots in key land cover strata will be conducted in order to establish a GHG emission model with the water table level as a key emission factor.
	Estimation of above- and below-ground GHG emissions from agroforestry practices	There are considerable opportunities for promoting improved agroforestry practices integrated in smallholder carbon sequestration and emission reduction schemes. Since such schemes have not been established in Central Kalimantan, this activity will conduct a study on the feasibility and methodologies to estimate GHG emissions from smallholder agroforestry lands, and explore management mechanisms by linking to low emissions farming and/or agroforestry practices.
	Development of sampling plots (i.e., transect 4)	Scientifically credible GHG emission estimation requires a large number of samples. The Katingan Project has identified permanent 400 sampling plots inside the boundary, and approximately half of them have already been surveyed. The rest of permanent sampling plots, including the transect 4, will be surveyed through this activity.

Component	Activity	Description
Social Safeguard	Establishment of village-level microfinance scheme to support future REDD+ benefits-sharing	Fair and equitable benefits sharing is one of the key preconditions under REDD+. Though benefit sharing mechanisms rely much on the national and subnational arrangements, village-level arrangements are also necessary. To prepare and support future benefits-sharing among local communities, this activity will establish an efficient and equitable microfinance model, and test its applicability for benefits-sharing.
	Development of community maps with other project-zone villages	This activity is a continuation of thematic community map development from FS 2012, and will extend the number of villages to be involved.
	Monitoring and replication of sustainable agroforestry and land husbandry practices	During the FS 2012, a model of sustainable agroforestry development and land husbandry practices were developed through preparatory workshops, on-site training and implementation. However, this initial stage of the activity needs to be monitored for its effects. In FS 2013, this activity will implement the monitoring of agroforestry and land husbandry practices conducted in the model village in 2012. Furthermore, it will develop a market-based sustainable agroforestry model, which identifies value-added agroforestry crops and markets.
Biodiversity Safeguard	Development of ecosystem restoration strategies and plans (i.e., carbon sequestration on degraded lands)	During the REDD+ FS 2011, the FS team conducted a biodiversity safeguard survey based on a rapid assessment of the partial HCVF guidelines. Based on the land cover stratification result obtained during the FS 2012, this activity will re-stratify HCVF priorities and identify key restoration areas. Furthermore, it will identify native species for ecosystem restoration in order to enhance carbon sequestration potentials on degraded areas as well as biodiversity conservation efforts inside the Katingan Project's conceesion boundary.

Annex 12. **Estimation of GHG Emissions from Peat**

See the separate Excel-based model of the estimation of GHG emissions from peat.

	A	B	C	D	E	F	G	H	I	J
4	Rate of deforestation	0.84%	Max-case in Kalteng Province 1985-2010							
5	Rate of burning from forest fire	5.92%	Max-case in PT RMU Site 1994-2012							
6										
7										
8		Drainage								
9		Area of peat drainage	MAX-Case Drained depth (cm)	Min-Case Drained depth (cm)	Relationship between CO2 and drainage depth (tCO2/ha)	Max-Case Peat drainage total CO2 (t-CO2)	Min-Case Peat drainage total CO2 (t-CO2)	Area of peat burn	Peat depth of burned (m)	Scaling factor from m2 to ha
10		A b,drain,it	D b,drain,it (assumption in plantation, VM0004)	D b,drain,it (assumption in agriculture, VM0004)	dimensionless	E b,drainage,it	E b,drainage,it	A b,burn,it	D b,burn,it (assumption in VM0004)	dimensionless
11	Year1	1,710	95	60	0.91	147,820	93,360	101	0.34	10000
12	Year2	3,420	95	60	0.91	295,639	186,720	101	0.34	10000
13	Year3	5,130	95	60	0.91	443,459	280,080	101	0.34	10000
14	Year4	6,840	95	60	0.91	591,279	373,439	101	0.34	10000
15	Year5	8,549	95	60	0.91	739,099	466,799	101	0.34	10000
16	Year6	10,259	95	60	0.91	886,918	560,159	101	0.34	10000
17	Year7	11,969	95	60	0.91	1,034,738	653,519	101	0.34	10000
18	Year8	13,679	95	60	0.91	1,182,558	746,879	101	0.34	10000
19	Year9	15,389	95	60	0.91	1,330,378	840,239	101	0.34	10000
20	Year10	17,099	95	60	0.91	1,478,197	933,598	101	0.34	10000
21	Year11	18,809	95	60	0.91	1,626,017	1,026,958	101	0.34	10000
22	Year12	20,519	95	60	0.91	1,773,837	1,120,318	101	0.34	10000
23	Year13	22,229	95	60	0.91	1,921,657	1,213,678	101	0.34	10000
24	Year14	23,938	95	60	0.91	2,069,476	1,307,038	101	0.34	10000
25	Year15	25,648	95	60	0.91	2,217,296	1,400,398	101	0.34	10000
26	Year16	27,358	95	60	0.91	2,365,116	1,493,757	101	0.34	10000
27	Year17	29,068	95	60	0.91	2,512,936	1,587,117	101	0.34	[illegible]
28	Year18	30,778	95	60	0.91	2,660,755	1,680,477	101	0.34	10000
29	Year19	32,488	95	60	0.91	2,808,575	1,773,837	101	0.34	10000
30	Year20	34,198	95	60	0.91	2,956,395	1,867,197	101	0.34	10000
31	Year21	35,908	95	60	0.91	3,104,215	1,960,557	101	0.34	10000
32	Year22	37,618	95	60	0.91	3,252,034	2,053,917	101	0.34	10000
33	Year23	39,327	95	60	0.91	3,399,854	2,147,276	101	0.34	10000
34	Year24	41,037	95	60	0.91	3,547,674	2,240,636	101	0.34	10000
35	Year25	42,747	95	60	0.91	3,695,494	2,333,996	101	0.34	10000
36	Year26	44,457	95	60	0.91	3,843,313	2,427,356	101	0.34	10000
37	Year27	46,167	95	60	0.91	3,991,133	2,520,716	101	0.34	10000
38	Year28	47,877	95	60	0.91	4,138,953	2,614,076	101	0.34	10000
39	Year29	49,587	95	60	0.91	4,286,773	2,707,435	101	0.34	10000
40	Year30	51,297	95	60	0.91	4,434,592	2,800,795	101	0.34	10000
41	Accumulate Total					68,736,183	43,412,326	3036.75967		

Appendix 10 | Sheet3

K	L	M	N	O	P	Q	R	S	T
Peat burn								**Total**	
eat bulk ensity	Mass of peat burned (t)	EF(CO2) of peat combusion (gCO2/t-peat)	Peat burn total CO2 (t-CO2)	EF(CH4) of peat combusion (gCH4/t-peat)	Total CH4 (t-CH4)	GWP(CH4)	Peat burn total CH4 (t-CO2)	Max-Case drained depth Ground total (t-CO2)	Min-Case drained depth Ground total (t-CO2)
D (ground easurement)	M b,p,it	EF CO2 (default value VM0004)	E b,peatburn,CO2,it	EF CO2 (default value VM0004)	EF CH4	GWP CH4 (default value IPCC)	E b,peatburn,ch4,it	E b,peatburn,it	E b,peatburn,it
0.17	58,508	149,591	8,752	11,338	663	21	13,931	170,503	116,043
0.17	58,508	149,591	8,752	11,338	663	21	13,931	318,322	209,403
0.17	58,508	149,591	8,752	11,338	663	21	13,931	466,142	302,763
0.17	58,508	149,591	8,752	11,338	663	21	13,931	613,962	396,122
0.17	58,508	149,591	8,752	11,338	663	21	13,931	761,782	489,482
0.17	58,508	149,591	8,752	11,338	663	21	13,931	909,601	582,842
0.17	58,508	149,591	8,752	11,338	663	21	13,931	1,057,421	676,202
0.17	58,508	149,591	8,752	11,338	663	21	13,931	1,205,241	769,562
0.17	58,508	149,591	8,752	11,338	663	21	13,931	1,353,061	862,922
0.17	58,508	149,591	8,752	11,338	663	21	13,931	1,500,880	956,281
0.17	58,508	149,591	8,752	11,338	663	21	13,931	1,648,700	1,049,641
0.17	58,508	149,591	8,752	11,338	663	21	13,931	1,796,520	1,143,001
0.17	58,508	149,591	8,752	11,338	663	21	13,931	1,944,340	1,236,361
0.17	58,508	149,591	8,752	11,338	663	21	13,931	2,092,159	1,329,721
0.17	58,508	149,591	8,752	11,338	663	21	13,931	2,239,979	1,423,081
0.17	58,508	149,591	8,752	11,338	663	21	13,931	2,387,799	1,516,440
0.17	58,508	149,591	8,752	11,338	663	21	13,931	2,535,619	1,609,800
0.17	58,508	149,591	8,752	11,338	663	21	13,931	2,683,438	1,703,160
0.17	58,508	149,591	8,752	11,338	663	21	13,931	2,831,258	1,796,520
0.17	58,508	149,591	8,752	11,338	663	21	13,931	2,979,078	1,889,880
0.17	58,508	149,591	8,752	11,338	663	21	13,931	3,126,898	1,983,240
0.17	58,508	149,591	8,752	11,338	663	21	13,931	3,274,717	2,076,600
0.17	58,508	149,591	8,752	11,338	663	21	13,931	3,422,537	2,169,959
0.17	58,508	149,591	8,752	11,338	663	21	13,931	3,570,357	2,263,319
0.17	58,508	149,591	8,752	11,338	663	21	13,931	3,718,177	2,356,679
0.17	58,508	149,591	8,752	11,338	663	21	13,931	3,865,996	2,450,039
0.17	58,508	149,591	8,752	11,338	663	21	13,931	4,013,816	2,543,399
0.17	58,508	149,591	8,752	11,338	663	21	13,931	4,161,636	2,636,759
0.17	58,508	149,591	8,752	11,338	663	21	13,931	4,309,456	2,730,118
0.17	58,508	149,591	8,752	11,338	663	21	13,931	4,457,275	2,823,478
			262,569				417,921	69,416,673	44,092,816

Annex 13. **Net Emission**

Reductions from Natural Regeneration, Long-lived Wood Products, and Avoided GHG Emissions from Aboveground Biomass and Peat in the Katingan REDD+ Project Site.

Total area	203,558.00	ha
Fresh Water Swamp, Non Forest (Bareland)	10	ha
Fresh Water Swamp, Non Forest (Agriculture)	16	ha
Fresh Water Swamp, Non Forest (Shrub)	705	ha
Fresh Water Swamp, Non Forest (Swamp shrub)	147	ha
Fresh Water Swamp, Non Forest (Water body)	68	ha
Heath, Non Forest (Bareland)	524	ha
Heath, Non Forest (Shrub)	1,380	ha
Heath, Non Forest (Swamp shrub)	392	ha
Peat Swamp, Non Forest (Bareland)	397	ha
Peat Swamp, Non Forest (Agriculture)	371	ha
Peat Swamp, Non Forest (Shrub)	16,885	ha
Peat Swamp, Non Forest (Swamp shrub)	689	ha
Peat Swamp, Non Forest (Water body)	129	ha
Primary Heath Forest, High Density (Primary dry land forest)	759	ha
Primary Peat Swamp Forest, High Density	56,254	ha
Primary Peat Swamp Forest, Low Density	3,301	ha
Primary Peat Swamp Forest, Medium Density	21,726	ha
Secondary Fresh Water Swamp Forest, High Density (Old second	287	ha
Secondary Fresh Water Swamp Forest, Low Density (Young seco	79	ha
Secondary Heath Forest, High Density (Old secondary dry land f	1,246	ha
Secondary Heath Forest, Low Density (Young secondary dry land	116	ha
Secondary Peat Swamp Forest, High Density (Old secondary)	90,616	ha
Secondary Peat Swamp Forest, Low Density (Old secondary)	2,744	ha
Water Body	77	ha
Secondary Fresh Water Swamp Forest, Low Density (Old second	1,166	ha
Secondary Peat Swamp Forest,Low Density (Young secondary)	3,475	ha

Rate of deforestation	0.84%	Max-case in Kalteng Province 1985-2010
Rate of burning from forest fire	5.92%	Max-case in PT RMU Site 1994-2012

	Timber										
	timber logged										
	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)
	Fresh Water Swamp, Non Forest (Bareland)	Fresh Water Swamp, Non Forest (Agriculture)	Fresh Water Swamp, Non Forest (Shrub)	Fresh Water Swamp, Non Forest (Swamp shrub)	Fresh Water Swamp, Non Forest (Water body)	Heath, Non Forest (Bareland)	Heath, Non Forest (Shrub)	Heath, Non Forest (Swamp shrub)	Peat Swamp, Non Forest (Bareland)	Peat Swamp, Non Forest (Agriculture)	Peat Swamp, Non Forest (Shrub)
	A logged,b,it	A logged,b,it	A logged,b,it	A logged,b,it	A logged,b,it	A logged,b,it					
	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate
Year1	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year2	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year3	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year4	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year5	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year6	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year7	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year8	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year9	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year10	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year11	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year12	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year13	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year14	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year15	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year16	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year17	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year18	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year19	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year20	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year21	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year22	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year23	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year24	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year25	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year26	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year27	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year28	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year29	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Year30	0.085	0.132	5.925	1.238	0.567	4.399	11.596	3.290	3.336	3.114	141.830
Accumulat	2.564	3.971	177.762	37.142	17.011	131.967	347.867	98.695	100.083	93.427	4,254.894

	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)	Area of logged (ha)
	Peat Swamp, Non Forest (Water body)	Primary Heath Forest, High Density (Primary dry land forest)	Primary Peat Swamp Forest, High Density	Primary Peat Swamp Forest, Low Density	Primary Peat Swamp Forest, Medium Density	Secondary Fresh Water Swamp Forest, High Density (Old secondary)	Secondary Fresh Water Swamp Forest, Low Density (Young secondary)	Secondary Heath Forest, High Density (Old secondary dry land forest)	Secondary Heath Forest, Low Density (Young secondary dry land forest)	Secondary Peat Swamp Forest, High Density (Old secondary)	Secondary Peat Swamp Forest, Low Density	Water Body
	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate	= Total area × deforestation rate
Year1	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year2	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year3	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year4	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year5	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year6	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year7	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year8	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year9	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year10	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year11	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year12	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year13	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year14	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year15	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year16	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year17	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year18	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year19	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year20	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year21	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year22	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year23	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year24	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year25	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year26	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year27	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year28	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year29	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Year30	1.082	6.374	472.531	27.729	182.494	2.415	0.664	10.468	0.978	761.173	23.050	0.643
Accumulate To	32.464	191.223	14,175.934	831.865	5,474.826	72.450	19.910	314.048	29.349	22,835.195	691.495	19.291

Area of logged (ha)	Area of logged (ha)	Timber biomass logged (t/ha)	CF (carbon fraction) of dry matter	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)
Secondary Fresh Water Swamp Forest, Low Density (Old secondary)	Secondary Peat Swamp Forest, Low Density (Young secondary)			Fresh Water Swamp, Non Forest (Bareland)	Fresh Water Swamp, Non Forest (Agriculture)	Fresh Water Swamp, Non Forest (Shrub)	Fresh Water Swamp, Non Forest (Swamp shrub)	Fresh Water Swamp, Non Forest (Water body)	Heath, Non Forest (Bareland)	Heath, Non Forest (Shrub)	Heath, Non Forest (Swamp shrub)	Peat Swamp, Non Forest (Bareland)
		B logged	CF									
= Total area × deforestation rate	= Total area × deforestation rate	= ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
9.798	29.189	73.44	0.4529	0	6.79	0.86	0.86	0	0	4.46	4.46	0
293.945	875.666	2,203.200	13.587	0.000	203.700	25.800	25.800	0.000	0.000	133.800	133.800	0.000

Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)	Carbon Stock (t/ha)
Peat Swamp, Non Forest (Agriculture)	Peat Swamp, Non Forest (Shrub)	Peat Swamp, Non Forest (Swamp shrub)	Peat Swamp, Non Forest (Water body)	Primary Heath Forest, High Density (Primary dry land forest)	Primary Peat Swamp Forest, High Density	Primary Peat Swamp Forest, Low Density	Primary Peat Swamp Forest, Medium Density	Secondary Fresh Water Swamp Forest, High Density (Old secondary)	Secondary Fresh Water Swamp Forest, Low Density (Young secondary)	Secondary Heath Forest, High Density (Old secondary dry land forest)	Secondary Heath Forest, Low Density (Young secondary dry land forest)	Secondary Peat Swamp Forest, High Density (Old secondary)	Secondary Peat Swamp Forest, Low Density	Water Body	Secondary Fresh Water Swamp Forest, Low Density (Old secondary)	Secondary Peat Swamp Forest, Low Density (Young secondary)
= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement	= Ground measurement
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
6.79	14.71	14.71	0	62.5	96.98	54.48	62.05	58.42	44.55	56.93	36.15	66.12	36.15	0	35.69	36.15
203.700	441.300	441.300	0.000	1,875.000	2,909.400	1,634.400	1,861.500	1,752.600	1,336.500	1,707.900	1,084.500	1,983.600	1,084.500	0.000	1,070.700	1,084.500

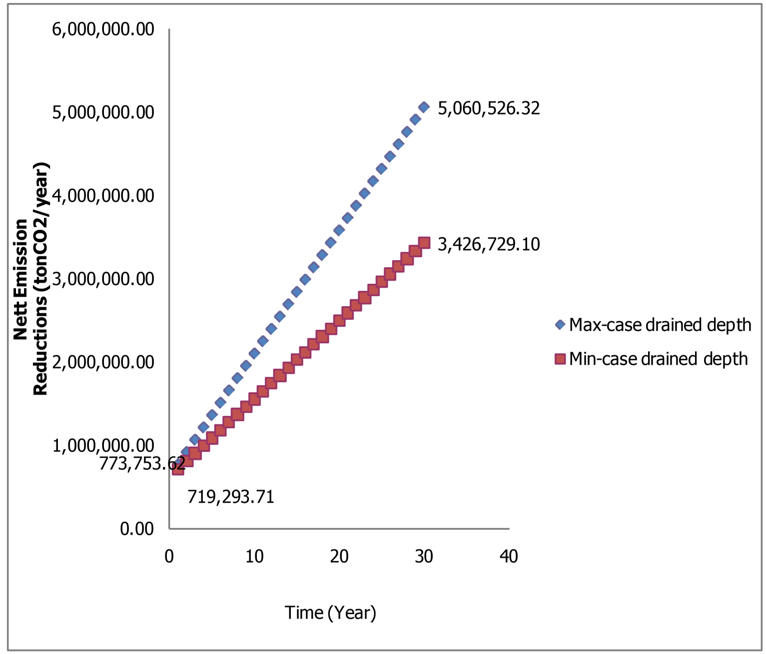
Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)
Fresh Water Swamp, Non Forest (Bareland)	Fresh Water Swamp, Non Forest (Agriculture)	Fresh Water Swamp, Non Forest (Shrub)	Fresh Water Swamp, Non Forest (Swamp shrub)	Fresh Water Swamp, Non Forest (Water body)	Heath, Non Forest (Bareland)	Heath, Non Forest (Shrub)	Heath, Non Forest (Swamp shrub)	Peat Swamp, Non Forest (Bareland)	Peat Swamp, Non Forest (Agriculture)	Peat Swamp, Non Forest (Shrub)	Peat Swamp, Non Forest (Swamp shrub)	Peat Swamp, Non Forest (Water body)
C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated
= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	0.899	5.096	1.065	0.000	0.000	51.716	14.673	0.000	21.146	2,086.316	#VALUE!	0.000
0.000	26.962	152.876	31.942	0.000	0.000	1,551.486	440.179	0.000	634.371	62,589.491	#VALUE!	0.000

Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)	Carbon stock from tree extracted (tC)
Primary Heath Forest, High Density (Primary dry land forest)	Primary Peat Swamp Forest, High Density	Primary Peat Swamp Forest, Low Density	Primary Peat Swamp Forest, Medium Density	Secondary Fresh Water Swamp Forest, High Density (Old secondary)	Secondary Fresh Water Swamp Forest, Low Density (Young secondary)	Secondary Heath Forest, High Density (Old secondary dry land forest)	Secondary Heath Forest, Low Density (Young secondary dry land forest)	Secondary Peat Swamp Forest, High Density (Old secondary)	Secondary Peat Swamp Forest, Low Density	Water Body	Secondary Fresh Water Swamp Forest, Low Density (Old secondary)	Secondary Peat Swamp Forest, Low Density (Young secondary)
C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated	C extrated
= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock	= A logged × Carbon stock
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
398.382	45,826.068	1,510.668	11,323.765	141.084	29.566	595.958	35.365	50,328.769	833.251	0.000	349.697	1,055.177
11,951.452	1,374,782.037	45,320.026	339,712.953	4,232.516	886.973	17,878.742	1,060.953	1,509,863.064	24,997.529	0.000	10,490.911	31,655.316

				BiomassBur									
	wood		Sub Total	CO2								N2O	
<Total> Carbon stock from tree extracted (tC)	Percent of harvest roundwood going into long term wood	Carbon stock moving into long-term wood products (tC)	CO2 emisson from timber extraction (t-CO2)	Area cleared (ha)	Mean carbon stock in above-ground living biomass (tC/ha)	Above-ground Carbon Stock (tC)	Average proportion of carbon stock burnt	Average biomass combustion efficiency	Carbon stock (DBH < 10cm) (tC)	CO2 emission from biomass burning (t-CO2)	Nitrogen-carbon ratio	Emission ratio for N2O
Total C extrated	ρ	C woodproduct	E timber,it	A cleared,b,it	MC b,ag,it	C b,ac,it	PBB b,it	CE	C sm	E BiomassBurn, CO2, it	N/Cratio	ER N2O
= ∑ [A logged × Carbon stock]	= assumption	= Total C extracted ×ρ	= (Total C extracted - C woodproduct) × 44/12	= Total area × deforestation rate X rate of burning from forest fire	= ground measurement	= (A cleared,b,it × MC b,ag,it) - Total C extracted	= assumption	= default value (IPCC)	= ground measurement	= (C b,ac,it× PBB b,it × CE X C sm) × 44/12	= (IPCC default 0.01);	= IPCC default value 0.007);
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
112,427.75	30%	33,728.32	288,565	101.23	71.14	(105,227)	38%	0.5	11.05	(810,052)	0.01	0.007
3,372,832.472	9.000	1,011,849.742	8,656,936.679	3,036.760	2,134.200	(3,156,797.390)	11.400	15.000	331.500	###########	0.300	0.210

		CH4			Sub Total	Total				
GWP(N2O)	N2O emission from biomass burning (t-CO2)	Emission ratio for CH4	GWP(CH4)	CH4 emission from biomass burning (t-CO2)	Emission from Biomass Burn	Total above ground emission (t-CO2)	Total peat emission (t-CO2)		Grand total emission (t-CO2)	
							Max-Case drained depth Ground total (t-CO2)	Min-Case drained depth Ground total (t-CO2)		
GWP N2O	E b,peatburn,ch4,it	ER CH4	GWP CH4	E b,peatburn,ch4,it	E b,biomassburn,it					
= UNFCCC default 310	= E biomassburnCO2 ×12/44×N/Cratio ×ER N2O×44/28×GWP	= IPCC default value 0.012);	= UNFCCC default 21	= E biomassburnCO2 ×12/44×ER CH4×16/12×GWP	= E CO2 + E N2O + E CH4				= total above ground emission + total peat emission max case drained depth	= total above ground emission + total peat emission min case drained depth
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	170,502.75	116,042.84	773,753.62	719,293.71
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	318,322.50	209,402.68	921,573.37	812,653.55
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	466,142.24	302,762.52	1,069,393.11	906,013.39
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	613,961.99	396,122.36	1,217,212.86	999,373.23
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	761,781.74	489,482.21	1,365,032.61	1,092,733.07
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	909,601.49	582,842.05	1,512,852.36	1,186,092.92
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	1,057,421.24	676,201.89	1,660,672.11	1,279,452.76
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	1,205,240.99	769,561.73	1,808,491.86	1,372,812.60
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	1,353,060.74	862,921.57	1,956,311.61	1,466,172.44
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	1,500,880.48	956,281.41	2,104,131.35	1,559,532.28
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	1,648,700.23	1,049,641.25	2,251,951.10	1,652,892.12
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	1,796,519.98	1,143,001.09	2,399,770.85	1,746,251.96
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	1,944,339.73	1,236,360.93	2,547,590.60	1,839,611.80
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	2,092,159.48	1,329,720.78	2,695,410.35	1,932,971.65
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	2,239,979.23	1,423,080.62	2,843,230.10	2,026,331.49
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	2,387,798.97	1,516,440.46	2,991,049.84	2,119,691.33
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	2,535,618.72	1,609,800.30	3,138,869.59	2,213,051.17
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	2,683,438.47	1,703,160.14	3,286,689.34	2,306,411.01
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	2,831,258.22	1,796,519.98	3,434,509.09	2,399,770.85
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	2,979,077.97	1,889,879.82	3,582,328.84	2,493,130.69
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	3,126,897.72	1,983,239.66	3,730,148.59	2,586,490.53
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	3,274,717.47	2,076,599.50	3,877,968.34	2,679,850.37
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	3,422,537.21	2,169,959.35	4,025,788.08	2,773,210.22
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	3,570,356.96	2,263,319.19	4,173,607.83	2,866,570.06
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	3,718,176.71	2,356,679.03	4,321,427.58	2,959,929.90
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	3,865,996.46	2,450,038.87	4,469,247.33	3,053,289.74
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	4,013,816.21	2,543,398.71	4,617,067.08	3,146,649.58
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	4,161,635.96	2,636,758.55	4,764,886.83	3,240,009.42
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	4,309,455.70	2,730,118.39	4,912,706.57	3,333,369.26
310	(7,533)	0.012	21	(74,230)	(891,815)	(603,250.87)	4,457,275.45	2,823,478.23	5,060,526.32	3,426,729.10
9,300.000	(226,004.438)	0.360	630.000	(2,226,905.896)	(26,754,462.772)	############	69,416,673.013	44,092,816.109	87,514,199.106	62,190,342.202

Period (Year)	Emission (tCO2)	
	Max-case drained depth (Drainaged 0.95 m)	Min-case drained depth (Drainaged 0.60 m)
Year 1	773,753.62	719,293.71
Year 2	921,573.37	812,653.55
Year 3	1,069,393.11	906,013.39
Year 4	1,217,212.86	999,373.23
Year 5	1,365,032.61	1,092,733.07
Year 6	1,512,852.36	1,186,092.92
Year 7	1,660,672.11	1,279,452.76
Year 8	1,808,491.86	1,372,812.60
Year 9	1,956,311.61	1,466,172.44
Year 10	2,104,131.35	1,559,532.28
Year 11	2,251,951.10	1,652,892.12
Year 12	2,399,770.85	1,746,251.96
Year 13	2,547,590.60	1,839,611.80
Year 14	2,695,410.35	1,932,971.65
Year 15	2,843,230.10	2,026,331.49
Year 16	2,991,049.84	2,119,691.33
Year 17	3,138,869.59	2,213,051.17
Year 18	3,286,689.34	2,306,411.01
Year 19	3,434,509.09	2,399,770.85
Year 20	3,582,328.84	2,493,130.69
Year 21	3,730,148.59	2,586,490.53
Year 22	3,877,968.34	2,679,850.37
Year 23	4,025,788.08	2,773,210.22
Year 24	4,173,607.83	2,866,570.06
Year 25	4,321,427.58	2,959,929.90
Year 26	4,469,247.33	3,053,289.74
Year 27	4,617,067.08	3,146,649.58
Year 28	4,764,886.83	3,240,009.42
Year 29	4,912,706.57	3,333,369.26
Year 30	5,060,526.32	3,426,729.10



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