Submission by Indonesia

NATIONAL FOREST REFERENCE EMISSIONS LEVEL FOR REDD+
In the Context of Decision 1/CP.16 Paragraph 70 UNFCCC

Republic of Indonesia
2015

Published by the Directorate General of Climate Change (DG-PPI)
The Ministry of Environment and Forestry, 2015

Citation:
MoEF, 2015, National Forest Reference Emission Level for REDD+ In the Context of Decision 1/CP.16 Paragraph 70, Directorate General of Climate Change. The Ministry of Environment and Forestry. Indonesia

DG-Climate Change MoEF office:
Manggala Wanabhakti Building, block VII 12th floor
Jl. Gatot Subroto, Senayan, Jakarta, 10270, INDONESIA

Ph. 62-21 57902966 ext. 822; 62-21-5720 194; Fax. 62-21 5730 242
http://www.dephut.go.id
http://ditjenppi.menlhk.go.id (launched end of November 2015)
Printed in Indonesia

ISBN: 978-602-73066-1-5

Executive in charge

Director General of Climate Change and Director General of Forestry Planning and Environmental Governance

Authors

(in alphabetical order) Dr. Arief Dharmawan, Arif Budiman, Dr. Arief Wijaya, Dr. Belinda Arunarwati Margono, Budiharto, Delon Martinus, Dida Migfar Ridha, Prof. Fahmuddin Agus, Dr. Haruni Krisnawati, Dr. I Wayan Susi Dharmawan, Judin Purwanto, Dr. Kirsfianti Ginoga, Kustiyo, Dr. Muhammad Ardiansyah, Solichin Manuri, Dr. Teddy Rusolono.

Internal reviewer

Prof. Rizaldi Boer.

Contributors

(in alphabetical order) Anak Agung Putra Agung, Ardi Chandra, Ari Wibowo, Dianovita, Dr. Hadi Daryanto, Hari Wibowo, Haryo Pambudi, Hendra Nurrofiq, Iwan Wibisono, Muhammad Farid, Dr. Ruandha Agung Sugardiman, Roosi Tjandrakirana, Vinna Priscylla, Wahyudi Wardojo, Dr. Wawan Gunawan, Yenny Safrina, Yuyu Rahayu.

Foreword

The Conference of Party (COP) under the United Nations Framework Convention on Climate Change (UNFCCC) invites developing countries aiming to undertake Reducing Emissions from Deforestation and Degradation (REDD+) activities to provide a number of strategic documents. Indonesia accepts the invitation to voluntarily submit proposed national forest reference emission level (FREL) for deforestation and forest degradation in the context of results-based payments for activities relating to REDD+. The FREL in this submission revises the previous FRELs, which developed under three initiatives, namely Second National Communication (SNC), REDD+ Agency (RA) and Ministry of Forestry (MoFor). This submission fulfils the COP requirements by following the guidance for technical assessment and adopting principals on transparency, accuracy, completeness and consistency.

Experts representing cross-ministerial agencies and organizations were commissioned to facilitate the construction process through a transparent and scientific-based participatory mechanism. Stepwise approach of FREL calculation was implemented and allowed Indonesia to improve the FREL by incorporating better data, improved methodologies and, where appropriate, additional pools, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71.

Definitions of forest, deforestation, forest degradation and peat land used in the document were defined and clarified for consistency with data that used. The scope of the area for FREL calculation is Indonesia's land area that was covered by natural forest in year 2000, accounted for 113.2 million ha or 60% of the country's land area. This includes primary and secondary forests, regardless forest status under national forest area defined by MoFor (2014). Peatland outside this area was excluded but will be included in Biennial Update Report (BUR). Two activities were included in FREL construction, namely: deforestation and forest degradation. Above ground biomass (AGB) and soil in peat land, and CO_2 were defined and selected as pools and gas included in this FREL document.

Table of Contents

1. Introduction

1.1. Relevance

Conference of Parties (COP)-16 in Cancun, in its Decision 1/CP.16 Paragraph 70 encouraged developing country Parties to contribute to mitigation actions in the forest sector, in accordance with their respective capabilities and national circumstances, by undertaking the following activities: (a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forests; and (e) Enhancement of forest carbon stocks (UNFCCC, 2011).

Beginning with the G-20 Pittsburgh meeting in 2009, where the President of Indonesia pledged to reduce emissions of 26 % by 2020 from Business as Usual (BAU) with domestic resources and up to 41 % if supported by international communities, Indonesia has submitted to UNFCCC Secretariat a pledge of voluntary contribution to reduce emissions up to 26 % through four sectors including land use and forestry, known as Presidential Regulation (PERPRES) No. 61/2011 on National Action Plan on GHG reduction or *Rencana Aksi Nasional Penurunan Emisi* GRK (RAN-GRK). Referring to Dec 1/CP. 16, RAN-GRK can be categorized as Unilateral Nationally Appropriate Mitigation Actions (NAMAs), and thus subject to domestic *Measuring, Reporting, and Verifying* (MRV). Likewise, the pledge can be categorized as supported NAMAs, and in the case of land use sector in Indonesia, contribution to the 41 % emissions reduction target may be achieved through several schemes, including REDD+ and supported NAMAs (REDD+ Task Force, 2012).

In the specific case of REDD+ in Indonesia, there have been several result-based finance arrangements, including: bilateral (Letter of Intent/LoI Indonesia-Norway, German-Indonesia Early Mover) and multilateral (Forest Investment Programmes/FIP, FCPF-Carbon Fund) schemes, with different focus and approach of interventions. COP through decision 9/CP.19 also encourages entities (can be bilateral and/or multilateral) providing results-based finance, to apply the methodological guidance consistent with decisions 4/CP.15, 1/CP.16, 2/CP.17, 12/CP.17, 9/CP.19, 11/CP.19 to 15/CP.19 in order to improve the effectiveness and coordination of results-based finance.

Paragraph 71 of decision 1/CP.16 requested developing countries aiming to undertake REDD+ activities under the convention, in the context of the provision of adequate and predictable support, including financial resources and technical and technological support, to develop a number of elements as follows:

1. REDD+ National Strategy or Action Plan
2. Forest Reference Emission Level/Forest Reference Level (FREL/FRL)
3. A robust and transparent National Forest Monitoring System

4. Safeguards Information System

Dec. 12/CP.17 provides guidance for developing country party aiming to undertake REDD+ to include in its FREL/FRL submission transparent, complete, consistent with guidance agreed by the COP, and accurate information for the purpose of allowing a technical assessment of the data, methodologies and procedures used in the construction of FREL/FRL. The information provided should be guided by the most recent Intergovernmental Panel on Climate Change guidance and guidelines, as adopted or encouraged by the COP.

Indonesia accepts the invitation as in Dec. 12/CP.17 to voluntarily submit proposed national FREL for deforestation and forest degradation in the context of results-based payments for activities relating to "reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+)" under the United Nations Framework Convention on Climate Change (UNFCCC), herein explained.

Dec. 13/CP.17 clearly stated a complete set of guidance for participating countries to move forward with REDD+ readiness. Those are including decisions guideline and procedures for the technical assessment of submission from parties on proposed forest reference emission levels and/or forest reference levels (UNFCCC, 2012).

1.2. General Approach

Climate change is an issue that based on science, which is not saying about right or wrong, but possibilities and improvements. This FREL submission employed the same concept. The establishment of FREL does not merely apply principles of "transparency, accuracy, completeness, and consistency", but also considering "practicality and cost effectiveness". These, mean that all data and information employed in this submission were based on existing operational day-by-day system with at hand-national budget, which allows for technical assessment and verification of the data, methodologies, and procedures used. This is important, in particular when the FREL would get into the need of establishing Measurement, Reporting and Verification (MRV). Moreover, the established FREL aims to maintain consistency data for Biennial Update Report (BUR) and Intended Nationally Determined Contribution (INDC).

Decision 12/CP.17 allows stepwise approach in submission of forest reference emission level and/or forest reference level (FREL/FRL), enabling Parties to improve the FREL/FRL by incorporating better data, improved methodologies and, where appropriate, additional pools, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71.

Development in data availability and clarity, human resources and institutional capacities, facilitates the understanding and transparency of the existing FREL and allows future reviews and revisits. The FREL in this submission improves the previous FRELs by being consistent with COP-guidance for FREL/FRL construction (Dec. 12/CP.17) and technical assessment (Dec. 13/CP.19), as well as taking into account relevant COP decisions especially on modalities for MRV (Decision 14/CP.19). Modalities for MRV include national policies and plans. This FREL was constructed using improved activity data and updated emissions factors. Activity data were developed with more consistent and confident data on land cover and land cover changes, over longer time period than the previous FRELs, (in this case 1990-2012). The updated emission factors reflect more diversity of forest types and conditions than the previous FRELs. Furthermore, the data used have been thoroughly scrutinized in terms of clarity, comprehensiveness, consistency, and comparability; the step that was not done in the previous FREL.

There have been a number of initiatives on REL/RL construction in Indonesia that generated in various levels of interest (projects, districts, provinces). The national FREL has been initially developed by three different initiatives. Firstly, collaboration of REDD+ Agency of Indonesia and the Ministry of Forestry (now Ministry of Environment and Forestry) developed national FRELs using land cover data of the Ministry of Forestry under reference year 2000-2012. Secondly, Indonesia SNC also established emission projection for Land Use, Land Use Change and Forestry (LULUCF) up to 2020 using land-cover data from the Ministry of Forestry under reference period from 2000 to 2006 (Boer et al., 2010). Thirdly, MoFor updated and issued as Minister of Forestry Decree No. 633/2014. It was developed using the same land cover data with reference period 2000-2006. Due to data limitation, those three initiatives employed stock difference approach using historical deforestation rate.

This FREL covered an area of 113.2 million ha of natural forests in 1990, which accounted for approximately 78.6 % of the total designated forest areas. The forest areas equals to 60% of the total country land area. Two REDD+ activities under decision 1/CP.16 paragraph 70 were included in FREL construction, namely: deforestation and forest degradation. CO_2 emissions from tree above ground biomass and degraded peat land were included in this submission. The rationales of area, activities, pools and gases covered in the FREL construction are explained in the following chapters.

1.3. The Objectives of this Submission

The first objective is to present a national FREL figure for REDD+ implementation including step-by-step analysis that has been exercised for establishing FREL for Indonesia.

The second objective is to provide broader audience and stakeholders with clear, transparent, accurate, complete and consistent estimates of emissions projection as a basis for further discussion with other agencies who have expressed an interest in supporting Indonesia in this undertaking.

A final objective is to share with many other countries interested in the REDD+ mechanism, the process that Indonesia has followed in approaching the entrance of full REDD+ implementation on the basis of result-based payment.

1.4. Process on FREL establishment

The national FREL in this submission was developed by a group of expert representing cross-ministerial agencies and organizations through a "transparent scientific-based participatory process".

The FREL was completed by team that based on Minister of Environment and Forestry Decree No. 134/2015. The team consists of two groups focusing on policy and technical aspects. The policy team addressed key issues significant for FREL development, including policy consideration and substantial national circumstances. The technical team focused on translating policy implication into quantitative calculation and qualitative explanation, including setting and approving assumptions and important adjustment, as well as establishing the document. In addition, the role of technical team was to assure scientific background on this submission.

FREL employed historical land cover data for baseline. Four options of method were considered to establish Indonesia's National FREL using historical land cover data: (a) Historical Emission Method, (b) Adjustment Historical Method (Historical Adjusted Method), (c) Forward Looking Non-Parametric Method, and (d) Forward Looking Parametric Method. Each option has its advantages and disadvantages, thus the chosen option was based on comprehensive consideration.

This submission complied with IPCC guidelines. The Forward Looking Non-Parametric Method would be an ideal target for improvement when all spatial data and related policy time-frame were available. However, with the current existing spatial data and information, empirical model fitted the requirement for developing FREL. Thus the Historical Emission Method was utilized in this FREL.

Five scenarios on baseline period were exercised for Indonesia's FREL. Those baseline period scenarios are of (a) 1990 – 2000, (b) 1990 – 2006, (c) 1990 – 2012, (d) 2000 – 2006, and (e) 2000 – 2012. The longest time interval, which is 1990 – 2012, was selected. This longest period of historical data best illustrates and captures temporal variations of land-based management practices and associated policy interventions, perturbations, and its impacts. Thus it provides most reliable estimate of future carbon emissions.

2. Definitions Used

For the purpose of FREL construction, the following definitions were established or adopted:

2.1. Forest

The definition of forest usually refers to the objective of the data generated and its method. For FREL there are two definitions that used because of the formal right and technical in the development, or it called “working definition”. The formal right definition used as guidance principal definition and mostly based on forest ecology, while the working definition is referring to limitation of method and data that used to generate the Indonesia forest definition.

As a formal right, forest in this document is defined as “Land spanning more than 0.25 hectares with trees higher than 5 meters at maturity and a canopy cover of more than 30 percent, or trees able to reach these thresholds in situ”. This is the definition of forest stated in the Minister of Forestry Decree No 14/2004 on A/R CDM (MoFor, 2004). The definition of forest used in the MoFor decree was established to meet the requirement of climate change mitigation scheme under CDM and thus relevant to be used in FREL construction. This definition was used by the Ministry of Forestry for the purpose of ground-truthing in order to support satellite image classification.

Global Forest Resource Assessment of the Food and Agriculture Organization used different definition with minimum area of 0.5 ha and canopy cover of more than 10 percent and trees higher than 5 meters at maturity. For this submission, Indonesia adjusted the FAO forest definition to the country natural tropical forest ecosystem, excluding other tree covers and wood land areas.

In this document, the term “working definition” of forest was used to produce land-cover maps through visual interpretation of satellite images in a scale that minimum area for polygon delineation is 0.25 cm^2 at 1: 50,000 of scale which equals to 6.25 ha. The term “working definition” was used within the Indonesian National Standard (SNI) 8033:2014 on “Method for calculating forest cover change based on results of visual interpretation of optical satellite remote sensing image”. The SNI defined forest based on satellite data feature including colour, texture and brightness. Forests were classified into seven classes based on forest types and degradation or succession level. Six of the seven forest classes were classified as natural forests (*see* Table 1).

Table 1. *Land cover classes used in Forest Reference Emission Level*

No	Land-cover class	Abbreviation	Category	IPCC
1.	Primary dryland forest	PF	Natural forest	Forest
2.	Secondary dryland forest	SF	Natural forest	Forest

No	Land-cover class	Abbreviation	Category	IPCC
3.	Primary mangrove forest	PMF	Natural forest	Forest
4.	Secondary mangrove forest	SMF	Natural forest	Forest
5.	Primary swamp forest	PSF	Natural forest	Forest
6.	Secondary swamp forest	SSF	Natural forest	Forest
7.	Plantation forest	TP	Plantation forest	Forest
8.	Estate crop	EP	Non-forest	Crop land
9.	Pure dry agriculture	AUA	Non-forest	Crop land
10.	Mixed dry agriculture	MxUA	Non-forest	Crop land
11.	Dry shrub	Sr	Non-forest	Grassland
12.	Wet shrub	SSr	Non-forest	Grassland
13.	Savanna and Grasses	Sv	Non-forest	Grassland
14.	Paddy Field	Rc	Non-forest	Crop land
15.	Open swamp	Sw	Non-forest	Wetland
16.	Fish pond/aquaculture	Po	Non-forest	Wetland
17.	Transmigration areas	Tr	Non-forest	Settlement
18.	Settlement areas	Se	Non-forest	Settlement
19.	Port and harbor	Ai	Non-forest	Other land
20.	Mining areas	Mn	Non-forest	Other land
21.	Bare ground	Br	Non-forest	Other land
22.	Open water	WB	Non-forest	Wetland
23.	Clouds and no-data	Ot	Non-forest	No data

2.2. Deforestation

In this submission, deforestation was defined as a conversion of natural forest cover into other land-cover categories that has only occurred one time in particular areas. The practical definition emphasises on land cover instead of land use. Consequently it is different from the definition of deforestation by FAO, which employed terminology of land use. This practical definition referred to The Minister of Forestry No. 30/2009 that stated deforestation as the permanent alteration from forested area into a non-forested area as a result of human activities (MoFor, 2009).

Since the definitions of the forest are still debatable, especially for Indonesia that has high dynamical condition on climate, region and ecology. There are also so many definition of deforestation used in Indonesia, referring to ecological and technical aspects. The definition of deforestation used in this document is mostly for the shake of practicality, simplicity and clarity during the identification and classification processes. Some expert said this method is “gross deforestation” (IFCA, 2008). This approach also used in many REDD+ programs to avoid confused with land cover changes of afforestation and reforestation covered under the CDM.

2.3. Forest Degradation

In this document, forest degradation is defined as a change of primary forest classes, which include primary dryland, primary mangrove and primary peat swamp forests, to secondary forest classes. The definition is a narrow definition of forest degradation that is a reduction in the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes (e.g. Thompson *et al.*, 2013). Whereas, ITTO (2002), defined degraded forest as natural forest which has been fragmented or subjected to forest utilization including for wood and or non-wood forest product harvesting that alters the canopy cover and overall forest structure. According to The Minister of Forestry No. 30/2009, forest degradation is a deterioration of forest cover quantity and carbon stock during a certain period of time as a result of human activities.

The main causes of forest degradation include unsustainable logging, agriculture (shifting cultivations), fires, fuel wood collection, and livestock grazing, which have various impacts of degradation level. However, for the time being there is no general approach to identify a degraded forest because perceptions on forest degradation vary depending on the causes, particular goods or services of interest, temporal and spatial scales as well as bio-geophysical condition that influences the forest appearances. With such a complex and unique Indonesia's conditions, defining the degree of forest degradation is not a simple task. So the definition of forest degradation used here is the general one.

2.4. Peat land

Peat land is defined as an area with an accumulation of partly decomposed organic matter, water saturated with carbon content of at least 12% (usually 40-60% C content) and the thickness of the carbon rich layer of at least 50 cm (Agus *et al.* 2011; SNI, 2013b). The comprehensive Indonesia's peat land maps were developed from period of 2002 – 2004 (Wahyunto *et al.* 2003, 2004 and 2006). The map estimated the peat land area to be about 20.6 million ha. Ritung *et al*. (2011) refined the maps by using soil survey data, collected in the last decade. The updated map came up with the new estimate of 14.9 million ha peat land area. The main source of the previous maps' overestimation was the lack of ground measurement data in Papua region, thus they relied highly on the use of Landsat TM imageries.

Peat land is an important land resource not only as a carbon storage, but also for human livelihood, from which various agricultural crops are produced. However, the conversion into suitable croplands requires peat drainages which lead to a high rate of CO_2 emissions. Drained peat also creates fire-prone condition during the long dry season which entails high GHG emissions (Hiraishi *et al*., 2014).

2.5. FREL

In this submission, FREL is a benchmark for assessing Indonesia's performance in implementing REDD+, expressed in tons of carbon dioxide equivalent per year. Technical definition of FREL adopted in this submission is a projection of CO_2 gross emissions that is used as a reference to compare against actual emissions in a given point of time in the future. In accordance with the decision 12/CP.17 the FREL will be updated periodically as appropriate, taking into account new knowledge, new trends and any modification of scope and methodologies.

In UNFCCC COP decisions the term forest reference emission levels and/or forest reference levels (FREL/FRLs) are used. Though the UNFCCC does not explicitly specify the difference between a FREL and a FRL, the most common understanding is that a FREL includes only gross emissions i.e. from deforestation and forest degradation, where as a FRL includes both emissions by sources and removals by sinks, thus it includes also conservation of forest carbon stocks, sustainable management of forest, and enhancement of forest carbon stocks.

This FREL was developed based on historical forest dynamics and serves as a benchmark for future performance evaluation on REDD+ activities. FREL was established by taking into account the trends, starting dates, availability and reliability of historical data, and the length of the reference period that sufficient to capture policy dynamics and impacts during that period.

3. Area and Activities Covered

3.1. Area Covered

As stated in Chapter One, the scope of the area for FREL calculation is Indonesia's land that was covered by natural forest in year 1990, accounted for 113.2 million ha or 60% of the country's land. This includes primary and secondary forests, regardless forest status under national forestland use defined by MoFor (2014).

Indonesia is home for 14.9 million ha of peat land (Ritung *et al.*, 2011), which 11.1 million ha of those peat land was covered by natural forest in 1990 (MoFor, 2001). This figure was used in FREL construction. The non-natural-forested peat land was excluded from this FREL, in the context of decision 1/CP. 16 paragraph 70 for this submission, yet will be included in the Biennial Update Report (BUR). In the future, the non-natural-forested peat land need to be included under the FRL construction, especially when the data that allow the inclusion of other REDD+ activities under decision 1/CP.16 paragraph 70 (conservation of forest carbon stocks, sustainable management of forest, and enhancement of forest carbon stocks) become available.

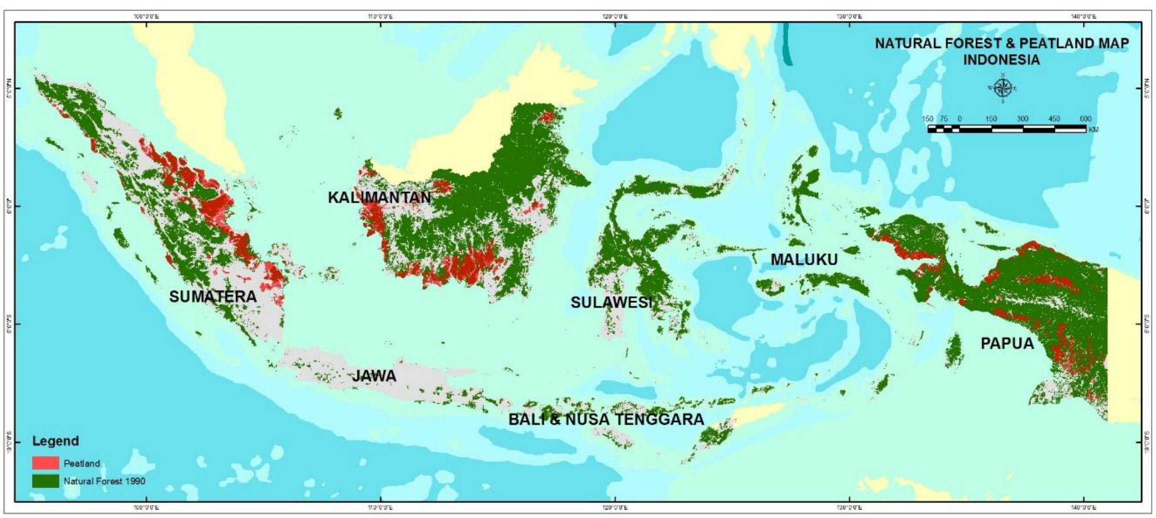

Figure 1. *Area for FREL calculation in 1990 (113.2 million ha). Overall land area of Indonesia is approximately 187 million ha.*

3.2. Activities Covered

Activities included in the FREL are deforestation and forest degradation, both on mineral and peat soil. The two activities were selected for FREL calculation due to the following reasons: (1) major contribution to the total emission from land use, land use change and forestry (LULUCF) and (2) availability and quality of the data in the context of reliability/accuracy, completeness, comprehensiveness, and consistency. According to Indonesia's Second National Communication (SNC), emissions from LULUCF, which include deforestation and forest degradation, accounted for 37.7 % from total national emission in 2005.

The data of deforestation and forest degradation from available monitoring system are methodologically consistent, which is important in the FREL development process. However, a wall-to-wall monitoring system for various levels of forest degradation on current categories for land-cover is remaining problematic. Especially with the very wide range of bioregion over natural Indonesia's forest. Wallace and Webber lines divided the Indonesia into three distinctive eco-zones that represent different vegetation and faunal characteristics (Kartawinata, 2005; Mayr, 1944).

Despite the availability of long time-series of activity data at national level, data on carbon sequestration is very limited and scarce. Therefore, other REDD+ activities i.e. forest degradation at more detail level, conservation of forest carbon stocks, sustainable management of forests, enhancement of forest carbon stocks, were excluded from the current FREL construction. Referring to the agreement under Decision 12/CP.17, the FREL could be improved along with the availability of better data, more complete data, improved methodologies, and additional pools, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71. Chapter 6 provides information regarding opportunity for improvement based on existing activities to address emission estimates associated with REDD+ activities, including deforestation, forest degradation, sustainable management of forests, and enhancement of forest carbon stocks.

3.3. Pools and Gases

In this FREL, two carbon pools i.e. aboveground biomass (AGB) and soil carbon in the peat land experiencing deforestation and forest degradation since 1990 were included in the emission calculation.

CO_2 is the dominant constituent element of the GHG emissions from LULUCF, contributing to more than 99.9% of the total GHGs. In addition to CO_2, other greenhouse gases (GHGs) are methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbon (HFC), perfluorocarbon (PFC), and others (Indonesia's Second National Communication, 2011). Carbon dioxide (CO_2) is the gas reported in this submission.

AGB is an important carbon pool of LULUCF emission. AGB and organic soil are the dominant element to the other four carbon pools (i.e. below ground biomass, debris, litter and mineral soil). Moreover, the current record in Indonesia regarding other carbon pool is very limited. Review on carbon pools proportion which was conducted by Krisnawati et al. (2014) found that the biomass proportion of understory vegetation and seedlings was generally small. Similarly, litter is accounted for about 2% only from total forest biomass. An additional analysis using compiled data sets from Sumatra and Kalimantan shows a similar trend (*see* Annex 3). Tree AGB, below ground biomass and necromass have a significant proportions of biomass with 71.2%, 13.6% and 14.5%, respectively. Yet the proportions measured only in the part of Indomalaya ecozones (western side of Wallace line), which may significantly different from the middle and eastern part of Indonesia.

Without neglecting the importance of soil carbon on peat, some underlying reasons to focus only on aboveground biomass carbon pools are as follows:

1. Emissions from deforestation and forest degradation are primarily originated from AGB pool. AGB is the most studied carbon pool across forest ecosystem types in Indonesia, which allows further calculation of carbon emissions more accurately using Tier 2 or Tier 3 and comparable throughout national scope. AGB data are widely available and can be estimated using allometric equations. Many studies on allometric equations for estimating aboveground tree biomass in Indonesia are available (e.g. Yamakura *et al.*, 1986; Ketterings *et al.*, 2001; Chave *et al.*, 2005; Basuki *et al.*, 2009; Krisnawati *et al.*, 2012; Manuri *et al.*, 2014).
2. Indonesia almost completes the estimation of AGB values, managed by the Ministry of Forestry (now is the Ministry of Environment and Forestry). It is based on forest inventory results from the National Forest Inventory (NFI) Field Data System that covers the entire forests across Indonesia measured since 1990s.
3. Forest Research and Development Agency (FORDA) within the Ministry of Environment and Forestry collaborated with Forest Carbon Partnership Facility (FCPF) has established an online carbon monitoring system in 13 Provinces (http://puspijak.org/karbon/). The system estimates AGB based on permanent sample plots established at various vegetation types.
4. In the next re-measurement, the measurement of the AGB is simpler and easily done from the national to the sub-national level.

The carbon pool and type of activities used for FREL calculation has also been consistent with the national standard for calculation and monitoring of emission reduction, emission prevention or enhancement of forest carbon stocks. Several Indonesian National Standard (Standard Nasional Indonesia-SNI) for measuring and monitoring forest carbon have been issued by Ministry of Forestry that follow IPCC 2006 Guideline, namely:

- SNI 7725-2011 on Development of allometric equations for estimating forest carbon stocks based on field measurement (*ground based forest carbon accounting*)
- SNI 7724-2011 on Measurement and Carbon Stock Accounting-Field Measurement to measure forest carbon stock, and

- SNI 7848-2013 on Demonstration Activities for REDD+ Demonstration activity which used COP guidance as one of the main references

Specific to peat land, emissions from peat decomposition are calculated in the area where deforestation and forest degradation has occurred. Peat emissions are calculated not only at the time deforestation occurred, but it continues over longer periods until organic contents/organic peats are fully decomposed. This current analysis only deals with emissions related to drainage (emissions from peat decomposition). Although drainage and burning are the major sources of GHG emissions in peat land, emission from peat fires are excluded since the generation of the activity data for the latter is complicated and highly uncertain (Agus *et al.,* 2013). Various studies have been attempted to develop calculation methods for peat fire emission estimates, for example, a simple approach for estimating emission from burned peat (peat fire) as shown in Annex 4. Because the process of refining data on peat fire emission is ongoing, the estimate on this emission was not included in recent FREL submission.

Although peat fire was excluded in this FREL submission, the emissions from peat fires were not totally excluded in the calculation. Emission from the loss of above ground biomass due to the fires was taken into account when deforestation and forest degradation were calculated.

4. Data, Methodology and Procedures

4.1. Data

Data support is highly required when estimating GHG emission. Both data used, activity data and emission factor, should be selected based on the principle of transparent, accurate, complete and consistent. In addition, to ensure concept of practicability and cost effectiveness, continuous data collection that based on applicable system is crucial. So, required process can be repeated in the future to determine the performance of REDD+ through MRV (Measuring, Reporting and Verification). The data sets used in this submission were generated by credible national institutions and consistent with the National GHG Inventory, BUR (Biennial Update Report) and INDC (Intended Nationally Determined Contribution).

4.1.1. Land-cover data

Land cover data used for generating activity data in this submission were land cover map produced by the Ministry of Environment and Forestry (MoEF). The wall-to-wall land-cover maps were produced using Landsat satellite images. They were digitized manually by visual interpretation technique. The classification was carried out using 23 land cover classes, including six natural forest classes. Detail explanation of land cover data establishment elaborated in Annex 1.

The land-cover data is part of National Forest Monitoring System (NFMS) and has been stored in NFMS website (http://nfms.dephut.go.id) and linking to the One Map Web GIS, at http://tanahair.indonesia.go.id (Geospatial Agency Republic of Indonesia, 2010). These official data describes land cover classes and forest cover change over years, which have been developed and updated regularly since 2000. In addition, data 1990s were added to the NFMS. For this FREL submission, the data set of 1990, 1996, 2000, 2003, 2006, 2009, 2011 and 2012 were used to capture historical land cover data.

The Ministry of Forestry data sets were thoroughly scrutinized by checking and comparing the consistency to other available data, e.g. forest and non-forest data from LAPAN (Aeronautics and Space Agency of Indonesia); as well as to other similar products that have been published in peer review international journals (e.g. Margono *et al*., 2014; Hansen *et al*., 2013).

Hansen *et al*. (2013) concluded that rate of forest lost in Indonesia was increasing. However, the data used was based on tree cover at global scale derived from Landsat images 2000 – 2012, and did not distinguish natural forest from other tree cover. Furthermore, Margono *et al*. (2014) enhanced the global gross forest cover loss of Hansen *et al*. (2013), by disaggregating total forest cover loss from natural and non-natural forests. This is relevant to the Indonesian context, because for FREL submission took into account "natural forest and gross forest cover loss". Natural forest in Margono was defined as mature natural forests of 5 ha or more in extent that retain their natural composition and structure, and have not been completely cleared and re-planted. As for above reason, this submission used the improved data set of Margono *et al*. (2014) instead of Hansen *et al*. (2013) data. Detail comparison of NFMS and LCCA LAPAN and Margono's elaborated in Annex 1.1.

4.1.2. National peat land data

Various peatlands data in Indonesia were available from many different sources Daryono (2010). The variation of the data exists because of the difference in the definition of peat (see section 2.4 for the definition used in this submission).

The peat land spatial data used in this FREL provided by the Ministry of Agriculture (MoA), based on several related maps, field survey and accompanied ground check verification, and published in Ritung *et al*. (2011). The latest was used in the Indicative Map of Moratorium of New Permit in primary forests and peat (PIPIB). The main peat areas corrected/removed were peat land that rarely observed, particularly in southeast and south of Papua. Many of these areas were previously identified as peat land. Field verification found that the soil carbon contents were less than 12% or with peat depth of less than 50 cm (Ritung *et al.*, 2011). By definition these were categorized as mineral soil.

Data update were carried out mainly in three major islands where major peat land occurred, namely Sumatra, Kalimantan and Papua. Several related thematic maps were used for identifying and delineating peat distribution, including revised peat maps for major islands, Land Resources Evaluation and Planning (LREP) Maps, Soil Map, Peat land Map of the Mega Rice Project (PLG) and Agro-Ecological zone map, as well as topography Maps (base-map) and Geology Maps. Additionally, satellite images of Landsat were deployed to improve the quality of peat ecosystem distribution. The detail methodology and description available in Ritung *et al*. (2011) (see Annex 2). The map has a 1:250.000 scale, which is sufficient for the national level FREL analysis. The map is published in the One Map Web GIS, at http://tanahair.indonesia.go.id.

4.1.3. Emission factors for deforestation and forest degradation

The primary source of data used to derive emission factors was the National Forest Inventory (NFI) Plots - a national program initiated by the Ministry of Forestry in 1989 and supported by the Food and Agriculture Organization of the United Nations (FAO) and the World Bank through the NFI Project. From 1989 until 2013, more than 3,900 cluster of sample plots, have been developed and distributed on a 20x20 km, 10x10 km and 5x5 km grids across the country (Ditjen Planologi Kehutanan, 2014). Each cluster consists of 1ha size permanent sample plot (PSP) and surrounding by 8 temporary sample plots (TSP).

The majority of the plots were established in areas below 1000 m altitude. Individual trees within the 1-ha PSP were measured within 16 recording unit (RU) numbered 25x25m sub-plots. All trees with a minimum diameter of 5 cm were measured for DBH, and a sub-set measured for total tree height. Trees were also classified by local species name, crown characteristics, damage, and infestation. Site information, including observations on disturbance and regeneration, and non-tree data (bamboo, rattan, etc) was also recorded. The plots are classified under a range of types/conditions which include land system, altitude in 100 m class, land use, forest type, stand condition and plantation status, terrain, slope, and aspect. The protocols used in field sampling and system design for plot data processing for the NFI in Indonesia are described in Revilla (1992).

A total of 4,450 measurements of PSPs from NFI (1990-2013) across the country were available for data processing and analysis. All individual trees in the plot were examined and plots' information was checked for each plot to ensure correct information, as part of the quality assurance process. The data validation included: (i) checking the location of the plots overlaid with MoFor land cover map, (ii) checking the number of recording units (sub-plots) in each plot, (iii) checking measurement data through abnormality filtering of DBH and species name of individual trees in the plots, (iv) checking information on basal area, stand density, etc. Detailed description of the process of analysis was documented in Annex 3.

Of the 4,450 measurement data available from NFI PSPs, 80% was located in forested lands while the remaining data were located in shrubs or other lands. From PSPs located in the forestland, the data validation process reduced the usable number of measurement data to 2,622 (74.1%) for analysis (Table 2). These PSPs were located in dryland forest and swamp forest. Additional forest research data especially for mangrove forests in Indonesia were included since there was no PSP record has been found in this forest type.

The AGB of individual trees in the plots were estimated using allometric models developed for pan tropical forest (Chave *et al.*, 2005), which used diameter at breast height (DBH) and wood density (WD) of the species as the key parameters. Several other allometric models were also tested, including some local allometric models as compiled in Krisnawati *et al.* (2012). However, the availability of local allometric models specific for six forest types were not all represented in seven main islands of Indonesia so this generalized allometric model of Chave *et al.* (2005) was selected, instead. This model has been found to perform equally well as local models in the Indonesian tropical forests (Rutishauser *et al.*, 2013; Manuri *et al.*, 2014).

The total AGB for each plot (per hectare) was then quantified by summing AGB estimates for all trees on the plots in dry weight (expressed in tons (t)) (Equation 1).

$$M_p = \sum_1^n \frac{M_T}{A_P} M_p = \sum_1^n \frac{M_T}{A_P} \quad \text{(Equation 1)}$$

where MP = AGB of plot expressed as (t ha-1), MT = AGB of measured tree (t), AP = plot area (ha), n = number of trees per plot.

The total AGB per hectare for each forest type in the main island were derived by averaging the AGB of the total plots (Equation 2).

$$M_j = \sum_{1=1}^{n} \frac{MP_i}{n} M_j = \sum_{1=1}^{n} \frac{MP_i}{n} \qquad \text{(Equation 2)}$$

where M_j = mean AGB (t ha^{-1}) of forest type-*j*, MP_i = AGB of plot-*i*, *n*= plot number

Table 2 provides a summary of AGB estimates for six forest types (primary dryland forest, secondary dryland forest, primary swamp forest, secondary swamp forest, primary mangrove forest, and secondary mangrove forest) in some main islands of Indonesia that were used as basis for determining emission factor.

Table 2*. The estimates of AGB stocks in each forest type in Indonesia*

Forest type	Main island	Mean AGB (t ha^{-1})	95% Confidence Interval (t ha^{-1}) *)		N of plot measurement
Primary Dryland Forest	Bali Nusa Tenggara	274.4	247.4	301.3	52
	Jawa	Nd	Nd	nd	nd
	Kalimantan	269.4	258.2	280.6	333
	Maluku	301.4	220.3	382.5	14
	Papua	239.1	227.5	250.6	162
	Sulawesi	275.2	262.4	288.1	221
	Sumatera	268.6	247.1	290.1	92
	Indonesia	266.0	259.5	272.5	874
Secondary Dryland Forest	Bali Nusa Tenggara	162.7	140.6	184.9	69
	Jawa	170.5	Na	na	1
	Kalimantan	203.3	196.3	210.3	608
	Maluku	222.1	204.5	239.8	99
	Papua	180.4	158.5	202.4	60
	Sulawesi	206.5	194.3	218.7	197
	Sumatera	182.2	172.1	192.4	265
	Indonesia	197.7	192.9	202.5	1299
Primary Swamp Forest	Bali Nusa Tenggara	Na	Na	na	na
	Jawa	Na	Na	na	na
	Kalimantan	275.5	269.2	281.9	3
	Maluku	Na	Na	na	na
	Papua	178.8	160.0	197.5	67
	Sulawesi	214.4	-256.4	685.2	3
	Sumatera	220.8	174.7	266.9	22
	Indonesia	192.7	174.6	210.8	95
Secondary Swamp	Bali Nusa Tenggara	Na	Na	na	na

Forest type	Main island	Mean AGB (t ha^{-1})	95% Confidence Interval (t ha^{-1}) *)		N of plot measurement
Forest	Jawa	Na	Na	na	na
	Kalimantan	170.5	158.6	182.5	166
	Maluku	Na	Na	na	na
	Papua	145.7	106.7	184.7	16
	Sulawesi	128.3	74.5	182.1	12
	Sumatera	151.4	140.2	162.6	160
	Indonesia	159.3	151.4	167.3	354
Primary Mangrove Forest[a,b,c]	Kalimantan	263.9	209.0	318.8	8
Secondary Mangrove Forest[b,c]	Kalimantan dan Sulawesi	201.7	134.5	244.0	12

Notes:
- [a] Murdiyarso *et al.* (2009);
- [b] Krisnawati *et al.* (2014);
- [c] Donato *et al.* (2011)
- nd = no data
- na = not applicable
- *) 95% confidence interval merely from field statistical data (timber volume estimation) and does not include uncertainty of Chave's allometric equation

To estimate the amount of carbon (C) in each forest type, information on carbon fraction is needed. The carbon fraction of biomass (dry weight) was assumed to be 47% (1 tons biomass = 0.47 tons C) following IPCC 2006 Guideline. Conversion of C-stock into carbon dioxide equivalent (CO_2e) was then obtained by multiplying C-stock with a factor of 3.67 (44/12) (Paciornik and Rypdal, 2006).

4.1.4. Peat emission factor

Contributions of peatland to the emission are mainly from forest fire, oxidation process and peat compaction that results in peat subsidence. Van Noordwijk *et al.*, (2014) described the mechanisms involved in peatland ecosystems can not be separated each other. Peatland emission assessment must be seen in a whole entity, as it has interconnections. The process that occurs in the peat will be influenced by land management activity, such as land clearing, drainage, spacing and depth of drainage. Due to comprehensive process in peatland ecosystem and mutual relationship with land cover, calculating of emissions from peat decomposition should preferably be cumulative from the first year to subsequent years based on the average of peat decomposition in every land cover.

The emission factor figures for peat decomposition presented in the '2013 Supplement to the 2006 IPCC Guidelines for National GHG Inventory: Wetlands' (Hiraishi *et al*., 2014) were used as Tier 2 emission factors. As these figures originated almost exclusively from research based on data from Indonesia, they conform by definition to the IPCC Tier 2 classification. Hiraishi *et al*. (2014)

categorized emission factors into IPCC land-cover classes under the assumption that certain peat land drainage will occur within particular land-cover class. For this publication, land use classes have been disaggregated to suit land-cover classes used in this document (*see* Table 3).

Various emission factors have been used in the past (e.g. Agus *et al.*, 2013; Hergoualc'h & Verchot, 2013; Hiraishi et al., 2014; Agus *et al.,* 2014). Agus *et al.* (2014) and the Roundtable for Sustainable Palm Oil used modified Hooijer *et al.* (2006) and Hooijer *et al.* (2010) equations in which water table depth (regulated by the drainage depth) is the determining factor for peat emission. Similar to Hiraishi *et al*. (2014), Hergoualc'h and Verchot (2013) also used land cover class as the basis for determining peat emission factor. However, in the latter, the measured CO_2 emissions (usually from chamber measurement) were subtracted with the annual rate of litter inputs on the surface of the soil and the litter from dead roots. Due to relatively high uncertainty among the sources, Hiraishi *et al*. (2014) default values are used in this publication.

Table 3. *Emission factors of peat decomposition from various land cover and land use types*

No.	Land cover	Emission ($t\ CO_2\ ha^{-1}\ th^{-1}$)	95% confidence interval		Remarks
1.	Primary forest	0	0	0	Paciornik and Rypdal (2006)
2.	Secondary forest	19	-3	35	Hiraishi *et al*. (2014)
3.	Plantation forest	73	59	88	Hiraishi *et al*. (2014)
4.	Estate crop	40	21	62	Hiraishi *et al*. (2014)
5.	Pure dry agriculture	51	24	95	Hiraishi *et al*. (2014)
6.	Mixed dry agriculture	51	24	95	Hiraishi *et al*. (2014)
7.	Dry shrub	19	-3	35	Hiraishi *et al*. (2014)
8.	Wet shrub	19	-3	35	Hiraishi *et al*. (2014)
9.	Savanna and Grasses	35	-1	73	Hiraishi *et al*. (2014)
10.	Paddy Field	35	-1	73	Hiraishi *et al*. (2014)
11.	Open swamp	0	0	0	Waterlogged condition, assumed zero CO_2 emission
12.	Fish pond/aquaculture	0	0	0	Waterlogged condition, assumed zero CO_2 emission
13.	Transmigration areas	51	24	95	Assumed similar to mixed upland agriculture
14.	Settlement areas	35	-1	73	Assumed similar to grassland
15.	Port and harbor	0	0	0	Assumed zero as most surface is sealed with concrete.
16.	Mining areas	51	24	95	Assumed similar to bare land

No.	Land cover	Emission ($t\ CO_2\ ha^{-1}\ th^{-1}$)	95% confidence interval		Remarks
17.	Bare ground	51	24	95	Hiraishi *et al*. (2014)
18.	Open water	0	0	0	Waterlogged condition, assumed zero CO_2 emission
19.	Clouds and no-data	nd	Nd	Nd	

4.2. Methodology and Procedure

The principal guideline for establishing FREL shall refer to the annex of FCCC/CP/2013/10/Add.1 (Guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels and/or forest reference levels). Methodology and procedure for determining FREL need to be carefully selected from of variety of methodology that available (Angelsen, et al. 2011), taking into account the national circumstances. Step-by-step information regarding methodological approach used in this document is described subsequently.

4.2.1. Reference period

A period span from 1990 to 2012 was used for FREL reference period. The period selection has considered the following aspects: (1) availability of land-cover data that transparent, accurate, complete and consistent, (2) reflect the general condition of the forest transition in Indonesia, and (3) the length of time that could reflect the national circumstances, policy dynamics and impacts (biophysical, social, economic growth, political and spatial planning), as well as associated carbon emission.

The land cover maps during the period of 1990 – 2000 were produced only twice for epochal data of 1990 and 1996; for 2000 – 2009 were produced every 3 years, and since 2011 the maps were generated annually. So that emission calculation from deforestation, forest degradation and peat decomposition, were based on the periods of 1990 - 1996; 1996 – 2000; 2000 – 2003; 2003 – 2006; 2006 – 2009; 2009 – 2011 and 2011-2012.

4.2.2. Reference emission calculation

Reference emission was calculated by using average annual emission from 1990 to 2012, i.e. from historical emission from deforestation and forest degradation. The advantage of this approach is the simplicity in capturing highly dynamic activities in the past.

Historical emission from peat decomposition was calculated from the same base period as deforestation and forest degradation. Once deforestation or forest degradation occurs in particular peat land areas, GHGs will be emitted and calculated on annual basis, and continue to emit GHG subsequently as inherited emission. The emission was reported in average of the total period of calculation.

4.2.3. Emission calculation from deforestation and forest degradation

Emissions from deforestation and forest degradation occurred at definite period were calculated by aggregating CO_2 emissions resulted from a newly identified deforested areas and degraded forests within the period. Deforestation and forest degradation activities were monitored in the area that was forested (natural forest) in 1990 and counted only once for deforestation that occurs at one particular area.

Emissions from deforestation were derived from the total loss of forest biomass regardless biomass gain, or **gross deforestation**. Forest degradation is the change from primary forests to secondary forests or logged-over forests. From 1990-2012, the 6-years, 4-years and 3-year land cover data sets were averaged to attain annual rate of deforestation and forest degradation. Overall processes of data analysis for deriving activity data of deforestation and forest degradation is depicted in Figure 2.

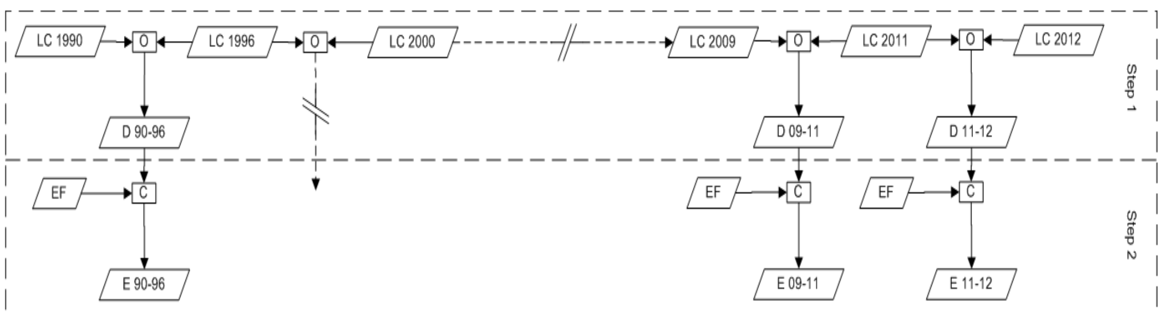

Figure 2. *Flow chart of emission calculation from deforestation and forest degradation. "LC" is Land Cover, "EF" is Emission Factor, "D" is deforestation and forest degradation, and "E" is emission, "O" is Overlay, "C" is Calculate.*

Procedures for emissions calculation from deforestation and forest degradation, as depicted by flow chart in Figure 2, as follow:

Step 1: Generate deforestation and forest degradation for each interval period, i.e. 1990 – 1996, 1996 – 2000, 2000 – 2003, 2003 – 2006, 2006 – 2009, 2009 – 2011 and 2011 -2012. For example, forest cover map of 2000 and 2003 were overlaid to create deforestation degradation areas.

Step 2: The generated deforestation and forest degradation polygons were multiplied by associated emission factors to calculate emissions from deforestation and forest degradation for each interval period. Later the result was divided by number of years for each interval period, to generate annual emissions from deforestation and forest degradation.

CO_2 emissions (GE_{ij}) from a deforested or degraded forest area-i (A_{ij}), was calculated by multiplying the area (in ha) with emission factor of the associated forest cover change type-j (EF_j). A conversion factor from C to CO_2 was further multiplied to derived emissions in tCO_2 equivalent (equation 3).

$$GE_{ij} = A_{ij} \times EF_j \times (44/12) \qquad \text{(Equation 3)}$$

where GE_{ij} = CO_2 emissions from deforested or forest degradation area-i at forest change class-j, in tCO_2e. A_{ij} = deforested or forest degradation area-i in forest change class j, in hectare (ha). EF_j = Emission Factor from the loss of carbon stock from change of forest class-j, due to deforestation or forest degradation; in tons carbon per ha ($tC\ ha^{-1}$). (44/12) is conversion factor from tC to tCO_2e.

Emission from gross deforestation and forest degradation at period t (GE_t), was estimated using equation 4:

$$GE_t \sum_{i=1}^{N} \sum_{j=1}^{P} GE_{ij} \qquad \text{(Equation 4)}$$

where, GE_t is in tCO2, GE_{ij} is emission from deforested or degraded forest area-i in forest classes j, expressed in tCO2. N is number of deforested or degraded forest area unit at period t (from t_0 to t_1), expressed without unit. P is number of forest classes which meet natural forest criterion.

Mean emissions from deforestation and forest degradation from all period P (MGE_P) were calculated using equation 5.

$$MGE_P = \frac{1}{T} \sum_{t=1}^{P} GE_t \qquad \text{(Equation 5)}$$

Where, MGE_P is expressed in tCO_2yr^{-1}. GE_t is total emissions from gross deforestation and forest degradation at year t and expressed in tCO_2. T is number of years in period P.

4.2.4. Emission calculation from peat decomposition

Land emission from peat decomposition is calculated by multiplying the transition matrix of land cover change in forested peat land and the transition matrix of emission factor within the subsequent land cover (*see* Annex 7). The calculation is used is Equation 6.

$$PDE_{ijt} = A_{ijt}\ x\ EF_j \qquad \text{(Equation 6)}$$

Where *PDE* is CO_2 emission ($tCO2\ yr^{-1}$) from peat decomposition in peat forest area-i changed into land cover type-j within time period-t. *A* is area-i of peat forest changed into land cover type-j within time period-t. *EF* is the emission factor from peat decomposition of peat forest changed into land cover class-j ($tCO_2\ ha^{-1}\ yr^{-1}$)

The inherited emission from previous activities occurs within subsequent land cover (e.g. Agus *et al.*, 2011), so that the total emission from peat decomposition is the accumulation of peat emissions from 1990 onward. Emissions from peat decomposition are from deforestation and forest degradation. The peat decomposition from degraded forest was calculated not only from forest which degraded since 1990 but also from degraded forest which already exist in 1990. The detail calculation process is in the following Figure 3.

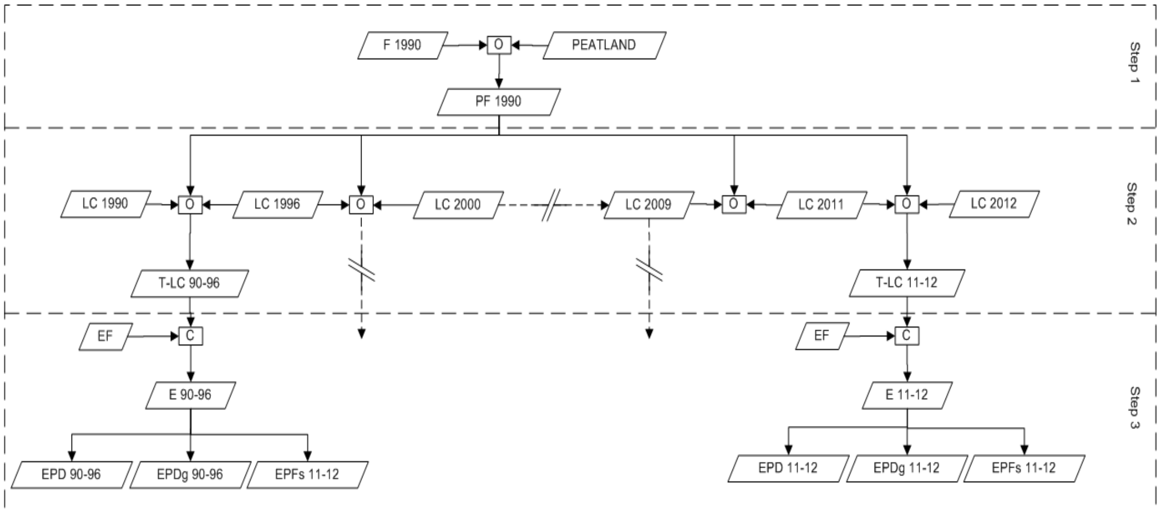

***Figure 3**. Flow chart of Calculation flow chart of peat decomposition emission calculation from peat decomposition in deforested peat forests from forested peatland of 1990. "LC" is land cover, "EF" is Emission Factor for peat decomposition, "E" is emission, "T-LC"is transition area matrix, "EPD"is Emission Peat from Deforestation, "EPDg" is Emission Peat from from Forest Degradation, "EPFs" is Emission Peat from Secondary Forest, "O" is Overlay, "C" is Calculate. "LC Annual" is the annual rate of deforestation within one interval (e.g. 1990 – 1996)the proportion of annual deforestation derived from annual loss of primary forest data (Margono et al., 2014), "Dp" is deforested areas and degraded forest occurred in peat forests.*

Procedures for annual peat emissions calculation from deforestation and forest degradation as depicted by flow chart in Figure 3 were as follows:

Step 1: Define natural forest 1990 over peat land.

Step 2: Generate land cover change from each interval year to define transition area matrix for the associated year of interval.

Step 3: Calculate total annual emmision by multyplying transition matrix of both areas and associated emission factors. Emission factor from the areas of change is half of total emission factor, because of time averaged. For example, emission factor of secondary forest is 19 tCO_2 ha^{-1} y^{-1} and emission factor of bare ground is 51 tCO_2 ha^{-1} y^{-1}, so that emission factor of the change from secondary forest to bare ground is 35 tCO_2 ha^{-1} y^{-1} (*see* Annex 6).

<u>4.2.5. Uncertainty calculation</u>

Uncertainty (U) was calculated following the IPCC 2006 Guidelines, volume 1. Chapter 3. If EA is uncertainty from Activity Data and EE is uncertainty from emission factor from *i* forest cover class and activity *j*, the combined uncertainty is calculated using equation 7.

$$Uij = \sqrt{EAij^2 + EEij^2} \qquad \text{(Equation 7)}$$

Uncertainties from activity data of forest degradation and deforestation were derived from the overall accuracy assessment of land cover map against ground truth points. The assessment was conducted for all 23 classes and concluded that the overall accuracy is 88% (MoFor, 2012, Margono *et al*. 2012). The uncertainties of emission factor were generated from standard error of carbon stock values from every forest types/classes in each major island/group of island. The carbon stock was estimated from the NFI plots that established in seven major island/group of island. For peat decomposition, uncertainty of activity data derived from the overall accuracy of peat land mapping (80%) (Ritung *et al*. 2011), while for uncertainty values of emission factors were derived from IPCC guideline 2013 default values (Hiraishi *et al*., 2014). Since the AGB emissions calculation using Tier 2 accuracy, the uncertainty level for forest degradation and deforestation is lower than that of peat emissions. Detail table for calculating uncertainty is in Annex 7.

A proportion of accuracy contribution (C_{ij}) was calculated from activity j that occurs in forest cover class i, by involving the uncertainty (U_{ij}), total emissions occurred in the corresponding forest cover classes and activities (E_{ij}) and total emission from the corresponding year (E).

$$C_{ij} = (E_{ij} * U_{ij})^2 / E \qquad \text{(Equation 8)}$$

$$TU = \sqrt{\sum C_{ij}} \qquad \text{(Equation 9)}$$

Total uncertainty of each year (TU), was derived from a square root of sum C_{ij}.

5. Results of the Construction of Forest Reference Emission Level (FREL)

5.1. Estimates of Deforestation and Forest Degradation Area

5.1.1. Deforestation

The annual rate of deforestation in Indonesia in the period of 1990 to 2012 was 918,678 ha (*see* Figure 4 for the dynamic rate of deforestation). This figure accounted for 723,628 ha deforestation from mineral soil and 195,050 ha deforestation from peat (organic) soil. The highest rate of deforestation was during the period of 1996 – 2000 accounted for more than 2,2 million ha yr^{-1}, and drastically decreased to the lowest rate in the period 2000-2003 which was about 444 thousand ha yr^{-1}. In the latest period (2011-2012), the deforestation rate was about 786 thousands ha yr^{-1}. Most of deforestation during these periods occurred in secondary dryland forests and secondary swamp forests accounted for about 503 thousand ha yr^{-1} and 229 thousand ha yr^{-1}, respectively (*see* Annex 5).

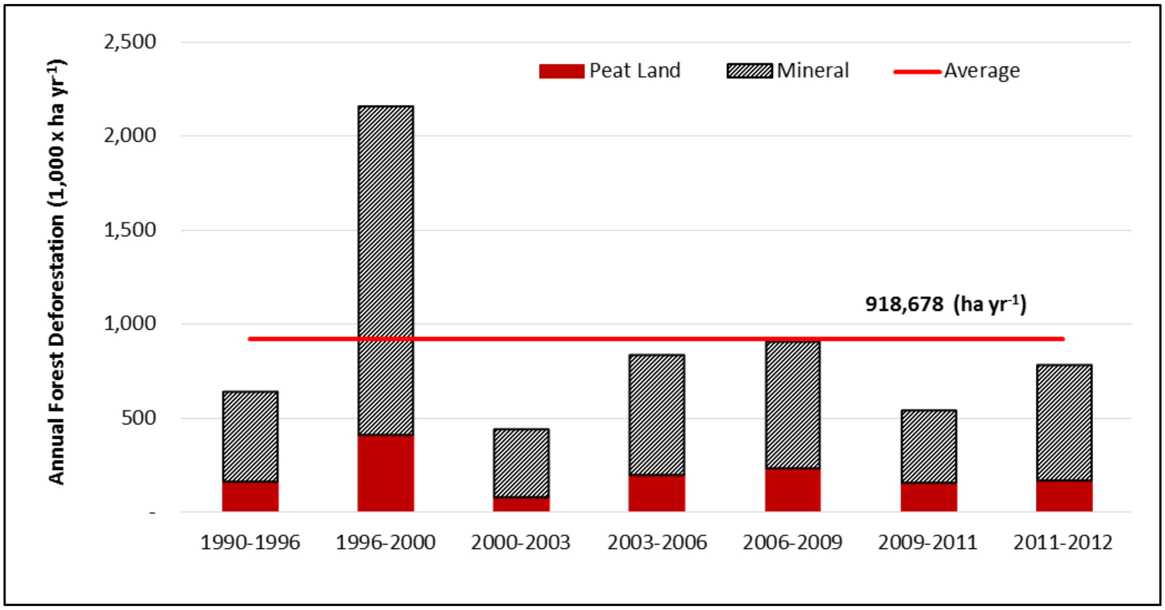

Figure 4. *Annual deforestation from period of 1990 to 2012in hectares. The bars indicate dynamic rate of deforestation per associated interval period, and black red-line depicts average annual deforestation from 2000 1990 – 2012.*

Approximately 78% of deforestation occurred in Sumatra and Kalimantan, while Sulawesi and Papua only contributed to about 8% each. As expected, the least forested regions, Maluku, Java, and Bali Nusa Tenggara experienced very low deforestation, from which contributed only 6% of total deforestation in Indonesia (Figure 5).

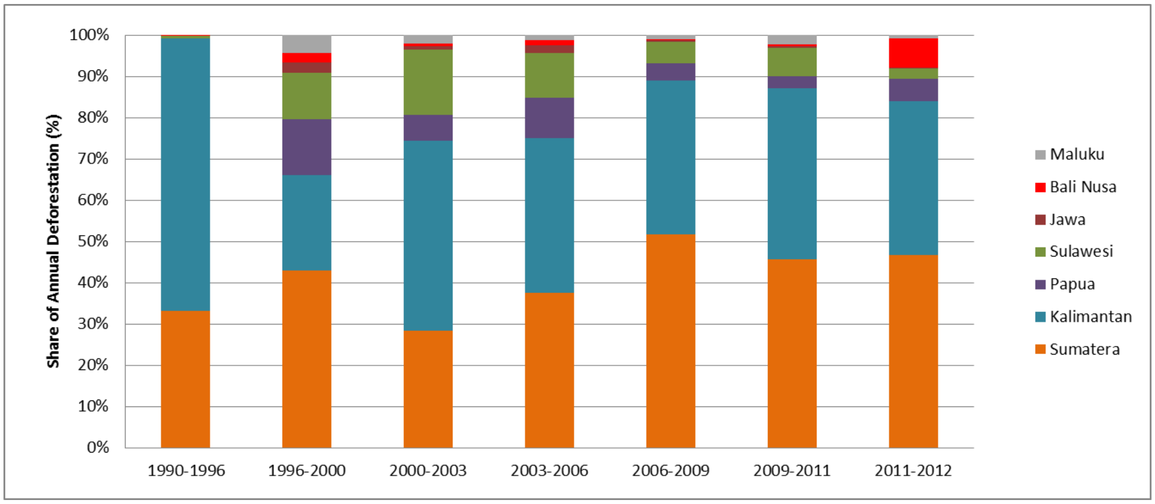

Figure 5*. Share of aAnnual deforestation (in %) in Indonesia for 7 major islands/ or island groups of island in Indonesia.*

The high rate of deforestation in the period of 1996 -2000 was likely caused by large fire events due to prolonged El Nino in 1997/1998 (Siegert, et al. 2001), Cochrane 2003), as well as illegal logging, expansion of industrial timber plantations and rapid expansion of palm oil (Pagiola, 2000, Margono *et al*. 2012). The low deforestation rate in the period of 2000-2003 was mainly due to the implementation of the National Strategic Plan of the Ministry of Forestry, renowned as soft landing policy. The policy aimed to reduce Annual Allowable Cut (AAC) for timber extraction from more than about 200 m^3 y-1 to 70 m^3 y-1 (MoFor, 2002). In addition during that period, the government sets policies to encourage efforts for forest rehabilitation, including one man one tree (OMOT) movement.

5.1.2. Forest degradation

Annual rate of forest degradation in Indonesia during 1990 to 2012 was about 507,486 hectares. This figure accounted for 490,329 ha of forest degradation on mineral soil, and 17,157 ha of forest degradation on peat soil. The forest degradation rate was very high in the period of 1996 to 2000, which was 1.3 million ha, and reduced gradually to only 44 thousands hectares in year 2012, which was much lower than the annual rate (9% lower than the annual rate), see Figure 6.

Although at national level, trend of forest degradation was decreasing sharply (Figure 6), the proportion of forest degradation at island level varied dynamically (Figure 7).

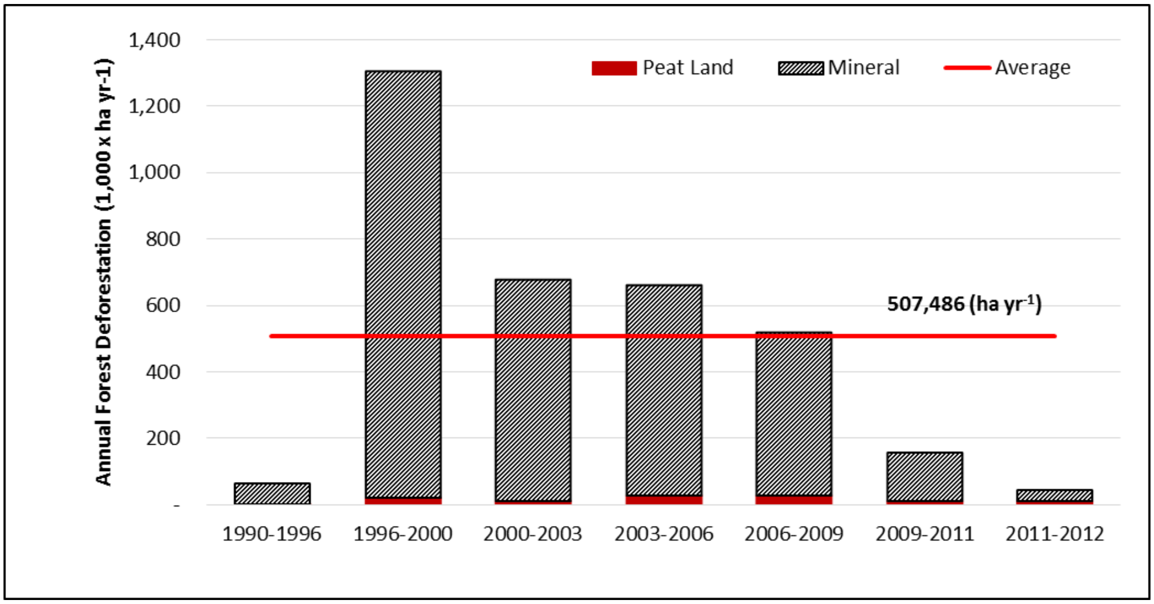

Figure 6. *Annual forest degradation from period of 1990 to 2012. The bars indicate dynamic rate of deforestation per associated interval period, and red-line depicts average deforestation from 1990 – 2012.*

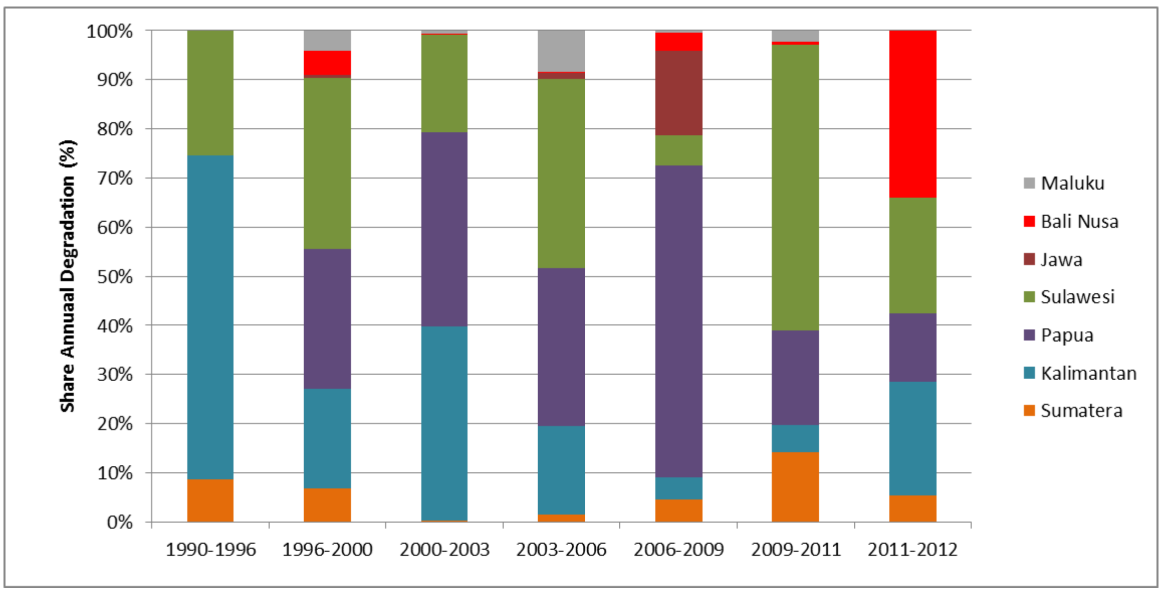

Figure 7. *Proportion of annual forest degradation (in %) for 7 major islands/group of island in Indonesia.*

The largest proportion of degradation in Sulawesi during period 1996 - 2000 was due to forest encroachment mostly for planting cocoa and cloves. In the period of 2000 -2003, forest degradation in Sulawesi, Kalimantan and Sumatra, in particular within conservation forests was likely caused by illegal logging and encroachment activities, insufficient incentives for maintaining protected areas, and low capacity of responsible institutions in managing protected areas (IFCA, 2008). While forest degradation in Papua mostly caused by subsystem local community activity.

5.2. Emissions from Deforestation, Forest Degradation, and Peat Decomposition

5.2.1. Emissions from deforestation

The average of historical emission from AGB due to deforestation in period 1990 – 2012 accounted for approximately 293 $MtCO_2e\ yr^{-1}$ (*see* Figure 8). This figure accounts for about 238 $MtCO_2e\ yr^{-1}$ of emission on mineral soil and about 55 $MtCO_2e\ yr^{-1}$ of emission on peat soil.

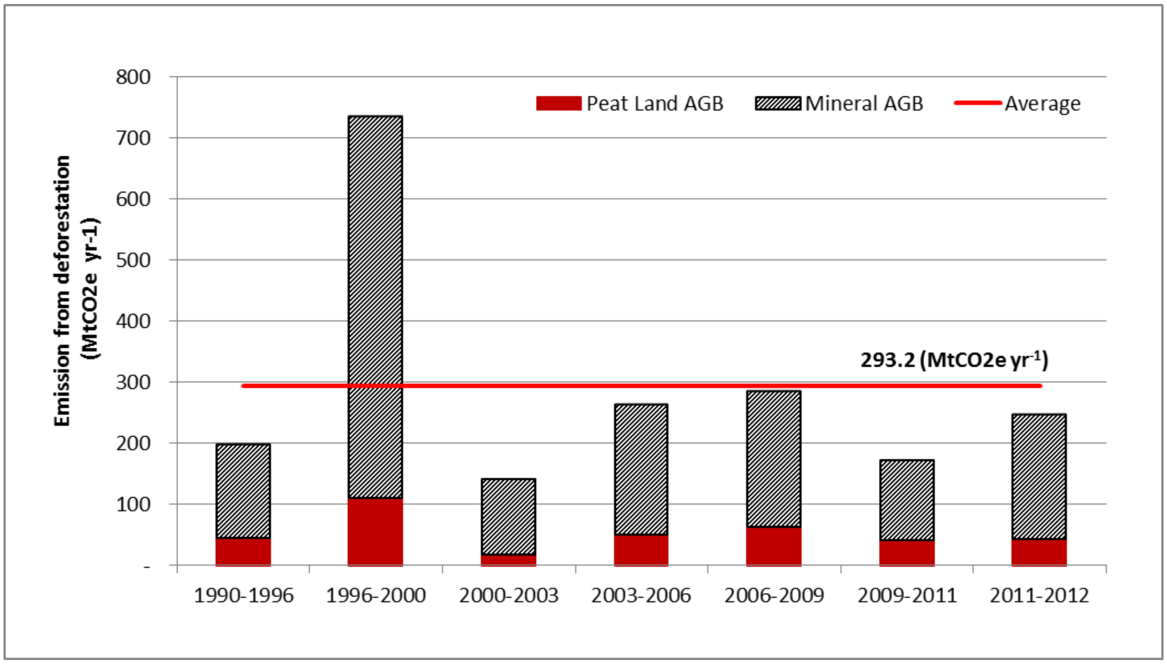

Figure 8*. Annual historical emissions from deforestation expressed in millions* tCO_2e.

5.2.2. Emissions from forest degradation

The average of historical emission from AGB due to forest degradation in period 1990 – 2012 accounts approximately 58 $MtCO_2e\ yr^{-1}$ (*see* Figure 9). This figure accounts for 56 $MtCO_2e\ yr^{-1}$ of emissions on mineral soil, and 2 $MtCO_2e\ yr^{-1}$ of emissions on peat soil.

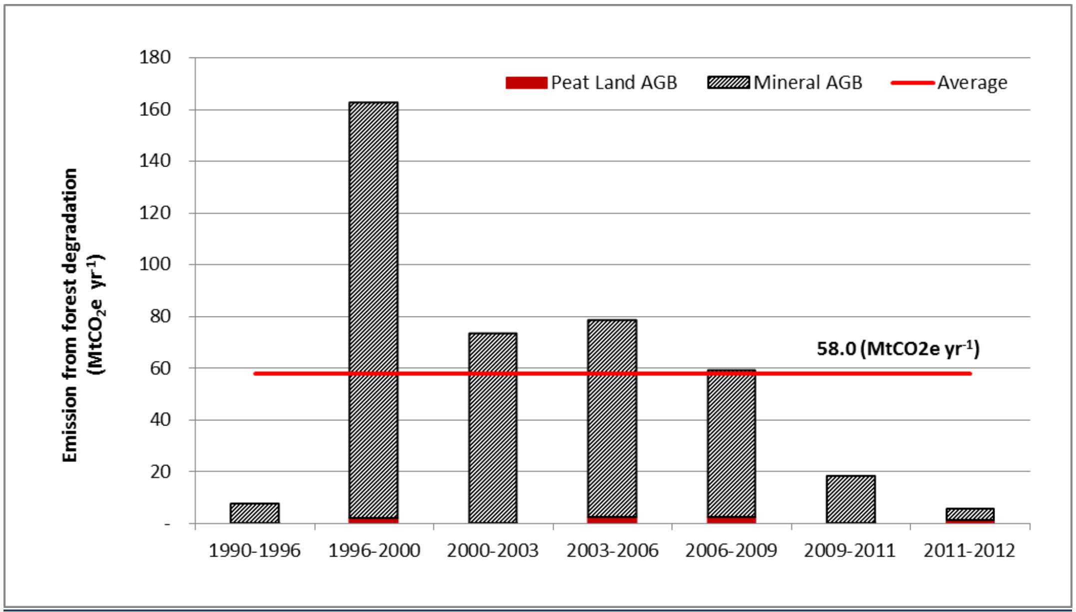

Figure 9. *Annual historical emissions from forest degradation expressed in millions t*CO_2*e.*

5.2.3. Emissions from peat decomposition.

In the period of 1990 to 2012, CO_2 emissions from peat were occurred due to conversions of forest to non-forest, and transitions of primary forest to secondary forest. CO_2 emission from peat degradation was increasing time to time from about 151.7 MtCO_2e yr^{-1} in the initial period (1990-1991) to about 226.1 MtCO_2e yr-1 in the end of analysis period (2011-2012). The increasing of emission was due to the expansion of drained peatland area which progressively emits CO_2 within the timeframe of this analysis.

As stated in previous Chapter, emission from peat fire actually has been partly estimated in the FREL calculation. The emission due to loss of AGB from fires has been captured in emission from deforestation and forest degradation, while the long-term emission captured by emission from peat decomposition. What that could not be captured in the FREL calculation is the immediate emission from occurring fires at the time of fires.

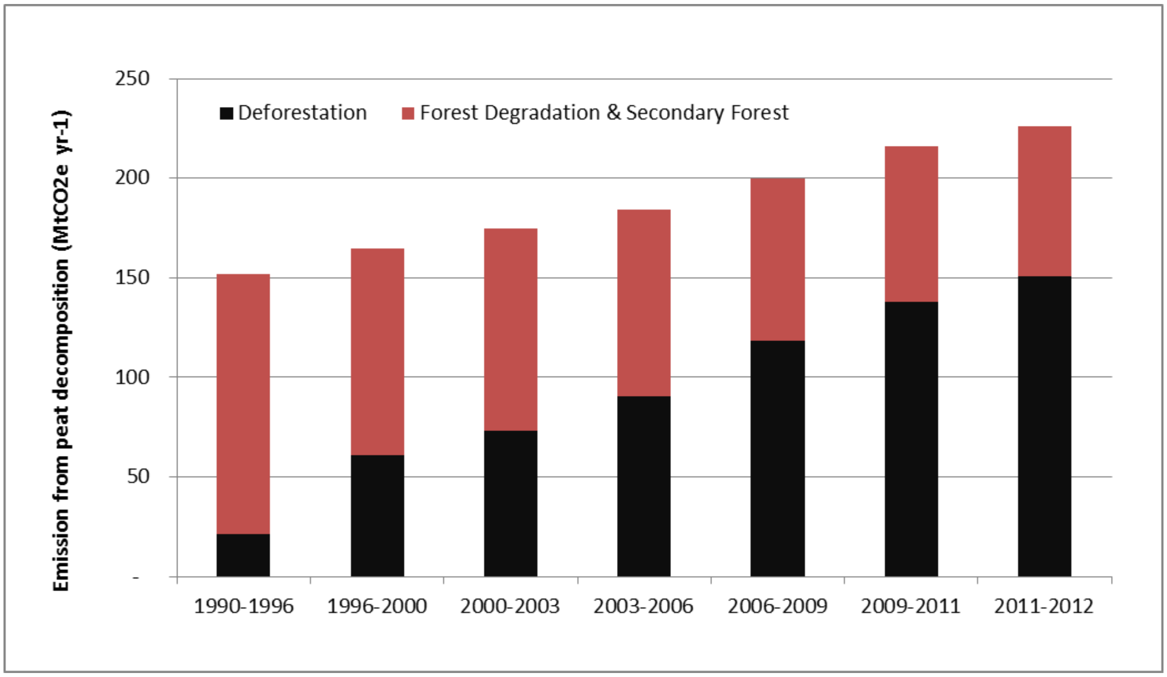

Figure 10. *Annual historical emissions fromfor forest degradation and peat decomposition coming from deforestation, forest degradation and secondary forest, expressed in millions tCO2e.*

5.3. Uncertainty Analysis

As mentioned in the chapter 4.2.5, the accuracy assessment for parameter "activity data" (land cover) is 88%, while for peat land is 80%. So that, the accuracy assessment for "emission factor" is varied from 50-97% depends on specific island/group of island and land cover types. The accuracy of emission factor from peat decomposition is 50% as it is taken from IPCC. By using equations explained in chapter 4.2.5, the uncertainty result is described in the following table. The uncertainty for overall emission calculation is 15.95%.

Table 4. *Uncertainty analysis in calculating emission*

Emission's Source	Emission in each Period (CO2e)						
	1990-1996	1996-2000	2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
Deforestation	198,912,693	737,006,187	142,951,619	264,363,082	286,400,629	173,891,040	248,937,119
Forest Degradation	7,676,560	162,396,173	73,690,805	78,596,482	59,226,954	18,511,560	5,920,802
Peat decomposition	151,712,921	164,773,548	174,711,277	184,188,644	200,067,598	215,742,080	226,109,789
Total	358,302,174	1,064,175,908	391,353,701	527,148,209	545,695,181	408,144,680	480,967,710
% Uncertainty	**16.2%**	**7.2%**	**16.4%**	**13.1%**	**21.3%**	**19.7%**	**17.8%**
Average uncertainty	15.95%						

5.4. Constructed National Forest Reference Emissions Level

The annual historical emission from deforestation, forest degradation and the associated peat decomposition (in $MtCO_2$) from 1990 to 2012 is depicted in Figure 10. In general, the emissions from deforestation still dominant with 51% of total emission, followed by peat decomposition contribute about 39%, while the rest 10% was the emission from forest degradation.

Using reference period of 1990 – 2012, forest reference emission level from deforestation and degradation was set at 0.351 $GtCO_2e\ yr^{-1}$ (AGB). To this figure, the additional emission of 0.217 $GtCO_2e\ yr^{-1}$ from peat decomposition was added with annual linear increment as much as 1.6% (with R^2 93%) because of inherited emission. This FREL will be used as the benchmark against actual emission starting from 2013 to 2020, depicted in Table 5.

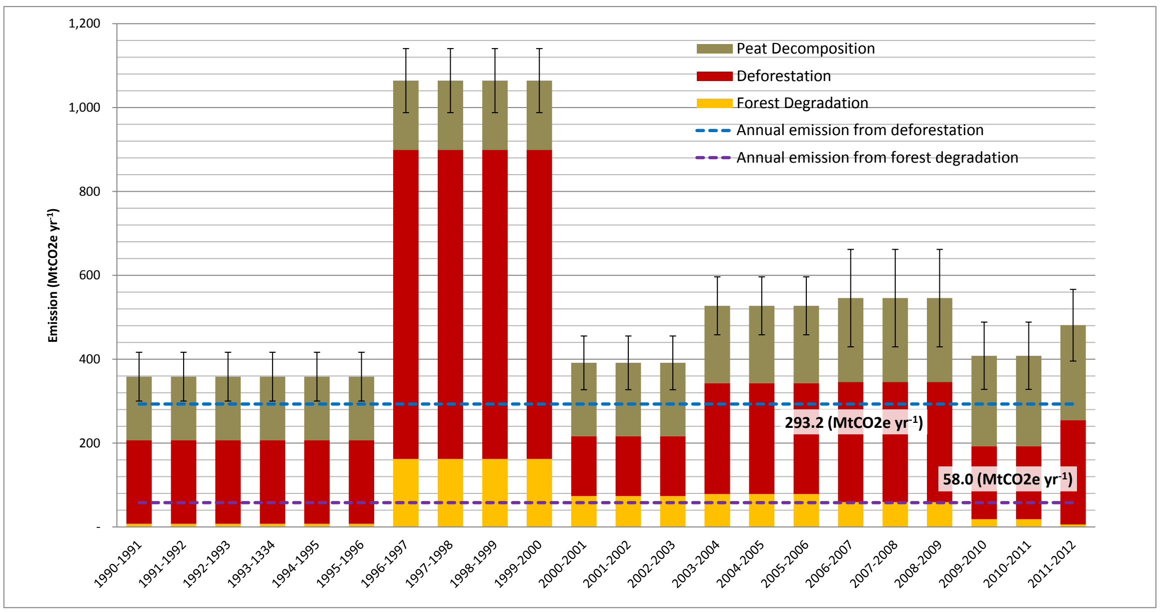

Figure 11. *Annual and the average historical emissions from deforestation, forest degradation and the associated peat decomposition (in MtCO2) in Indonesia from 1990 to 2012.*

Based on the historical emission from 1990-2012, the emission from deforestation, forest degradation and the associated emission from peat decomposition for 2013 is projected to be 0.57 $GtCO_2e$. In 2020, the emission figure will increase to 0.59 $GtCO_2e$ (*see* Table 4). For monitoring purposes, table 4 should be used as benchmark for evaluating emission reduction activities during the implementation period (up to 2020). Indonesia will re-establish/re-adjust the FREL for beyond 2020 to match to the Intended Nationally Determined Contribution (INDC).

Table 5. *Projected annual REL from deforestation, forest degradation and the associated peat decomposition in 2013-2020 (in tCO_2), calculated using linear projection based on conservative historical data of 1990-2012.*

Year	Deforestation	Forest Degradation	Peat Decomposition	Total annual emission
2013	293,208,910	58,002,762	217,648,209	568,859,881
2014	293,208,910	58,002,762	221,143,831	572,355,503
2015	293,208,910	58,002,762	224,639,453	575,851,125
2016	293,208,910	58,002,762	228,135,075	579,346,747
2017	293,208,910	58,002,762	231,630,697	582,842,369
2018	293,208,910	58,002,762	235,126,319	586,337,991
2019	293,208,910	58,002,762	238,621,941	589,833,613
2020	293,208,910	58,002,762	242,117,562	593,329,235

Quality control and quality assurance (QC/QA) for the data and calculation processes for FREL was made by the data custodian as well as the process of expert consultation. This calculation has been made so far to reach the guidance/standard made by COP decision including transparency, accuracy, completeness and consistency of data as well as the calculation process as describes in annexes.

6. Description of policies and plans and their implications to the constructed Forest Reference Emission Level (FREL)

6.1. Forest Governance in Indonesia

Indonesia once possessed the world's third largest area of tropical forests. Forests support the livelihood of 48.8 million people (Ministry of Forestry, 2010), of which 60% is directly dependent on shifting cultivation, fishing, hunting, gathering, logging, and selling wood and non-wood forest products (Nandika 2005). Back to the earlier periods, timber was a major source of export earning for Indonesia, second only to oil, where much of the exported timber came from Kalimantan. The large-scale timber cuts began in 1967 when all Indonesian forests were declared as the state forests. The enactment of Basic Forestry Law (UU No.5/1967), Foreign Capital Investment Law in 1967 and the Domestic Capital Investment Law in 1968, coupled with the issuance of various forestry regulations and incentives, had stimulated investments in timber industries.

In the 1980s, a national forest map called Forest Land Use by Consensus (*Tata Guna Hutan Kesepakatan*/TGHK) was developed to administer state forest lands in outer Islands. The 1980s TGHK was the first forest use plan applied in Indonesia. It was simply established by scoring three main geo-physical characteristics, i.e., soil type (sensitivity to soil-erosion), slope, and rainfall. It was produced at national scale (1:500.000). The TGHK became a basic reference for natural forest utilization with a definite planning prepared by the MoFor. With the absence of land cover and other important information, TGHK could not keep up with the rapid development. Therefore, in 1999/2000 a synchronization of TGHK to the provincial spatial planning was carried out.

Synchronization between TGHK and Provincial Spatial Planning was carried out between 1999 and 2000, resulted in maps of Provincial Forest Area that were legalized by Forestry Ministerial Decree. These maps defined forest areas into three broad categories based on function namely Protection Forest, Conservation Forest and Production Forest that was legalized under the Forestry Act No. 41/1999. All lands that were not designated as a forest were entitled to non-forest area (*areal penggunaan lain*-APL).

Conservation Forest is a forest area with a particular characteristic, which has principal function of preserving the diversity of flora and fauna and the ecosystem. Conservation forest is divided into: (1) Sanctuary Reserve area consists of Strict Nature Reserve and Wildlife Sanctuary; (2) Nature conservation area consists of National Park (TN), Grand Forest Park (THR), Nature Recreation Park (TWA); and (3) Game Hunting Park (TB).

Protection Forest (*Hutan Lindung*/HL) is a forest area that has principal function as protection of life support systems to manage water, prevent flooding, control erosion, prevent intrusion of sea water, and to maintain soil fertility.

Production forest is forest area that has principal function of producing forest products, particularly timber. Production forest consisted of Permanent Production Forest (*Hutan Produksi*/HP), Limited Production Forest (*Hutan Produksi Terbatas*/HPT) and Production Forest that can be Converted (*Hutan Produksi yang dapat di konversi*/HPK).

As the new Forestry Law (UU 41/1999) enacted, the Map of Forest Area Designation was published by MoFor through compilation of the Maps of Provincial Forest Area.

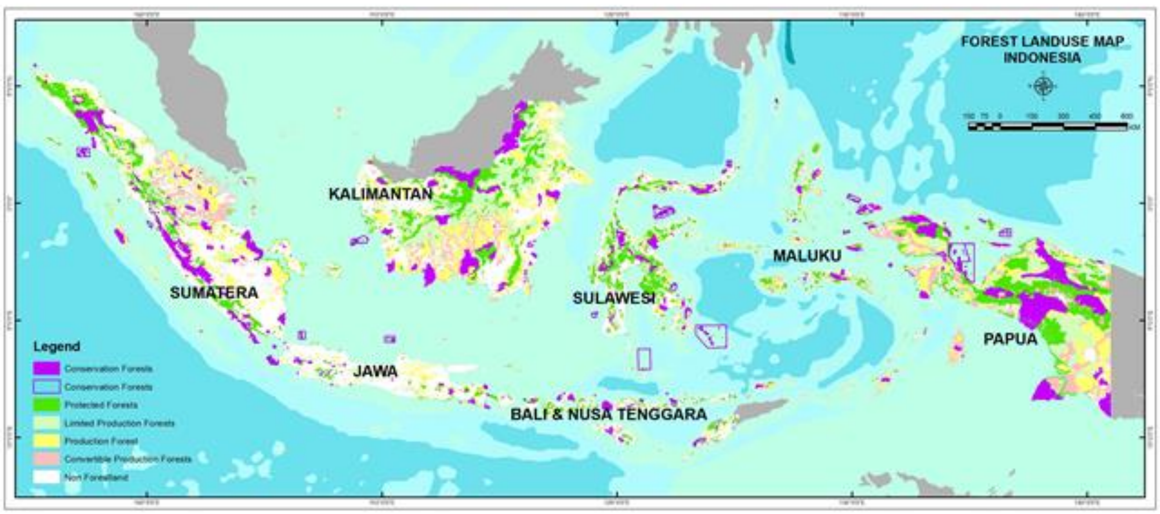

Figure 12. *Map of Forest Area Designation – Forestland Use Map (MoFor, 2014)*

6.2. Trend of Development in the Land Based Sector

Indonesia is currently endeavoring to achieve national security in food and energy and improved human resources qualities. The BPS-Statistic Indonesia (2013) stated that the Indonesian annual population growth is projected to reach 1.19 percent (from 238.5 million of population in 2010 to 305.6 million of population in 2035). This increasing trend of population growth will also bring consequences on the increasing demand for agricultural products as well as for settlement and other infrastructure development.

The new government has declared a new agenda for development so called *NAWA CITA (road of change for the sovereignty, self-reliance and integrity of Indonesia)* that emphasizes on debottlenecking actions in three main areas, namely: human resources, energy sovereignty and food sovereignty. *NAWA CITA* consists of nine priority agenda, including food security, based on community agribusiness and energy security, for the sake of national interest. This important agenda for *NAWA CITA* will consequently affects the future characteristic of forest and land use in Indonesia. It is expected that agricultural production for rice, corn, soybean, palm oil and livestock will increase within the next five years. With 27.7 million tons of crude palm oil (CPO) in 2013 increase 7.7 percent annually from 21.9 million tons in 2010, Indonesia is the highest palm oil production in the world. Ministry of Agriculture (MoA) recorded annual increase on rubber production of 4.09 percent, while the annual increase on productions of coffee, clove and cacao were 1.03 percent, 3.38 percent and -0.23 percent, respectively. Increasing trend of agricultural production (e.g. palm oil, rubber, coffee, cacao, pepper) is also influenced by the increasing of global demands on agricultural products. Similarly, increasing trend take place for mining and forest products. Increasing demands for natural resources will lead to increasing demand for additional lands, hence pressures to forests will increase.

The Ministry of Forestry has allocated approximately 15.2 million ha of national forest area for conversion to other land uses (HPK) whenever needed for development in the future (see Map of Designated Forest Area of MoFor, 2014). In the 15.2 million ha of HPK, the total remaining natural forest in 2012 were 7.24 million ha, distributed across seven major/groups of islands (Figure 12). Other than the above forested area, there are also 7,48 million ha of natural forest of 2012 which is located in the APL (other landuses/non forest land). Hence, the total area of natural forests that can be converted from HPK and APL is 14.72 million ha (Figure 13).

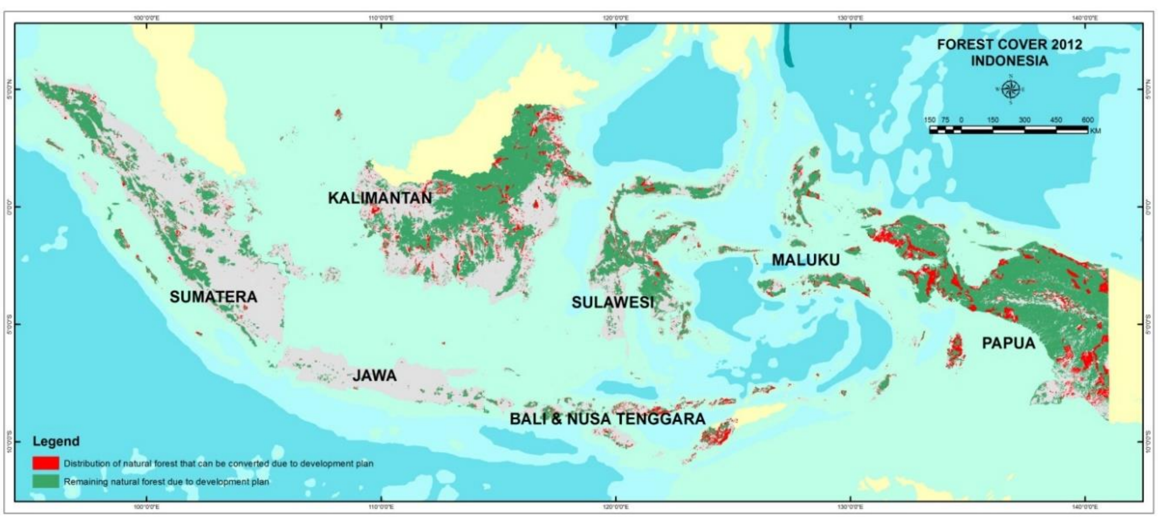

***Figure 13**. Distribution of natural forests that allowed to be converted (MoFor, 2014)*

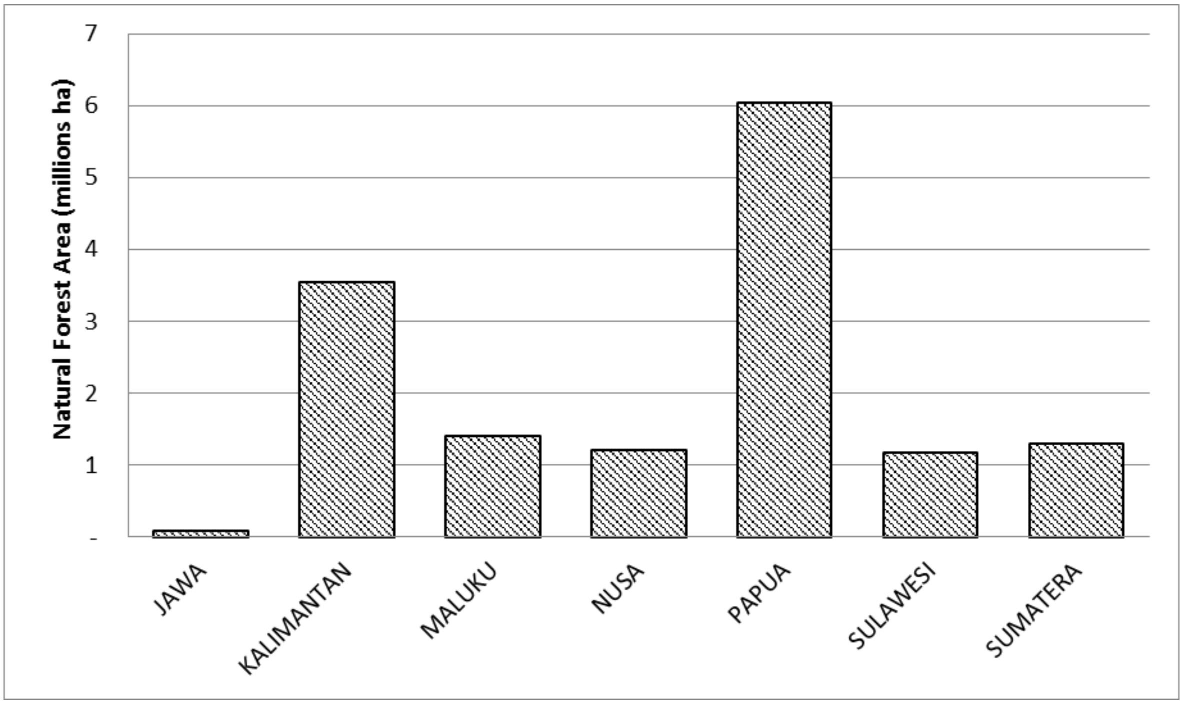

Figure 14. *Area covered by natural forest that allowed to be converted to other land uses*

6.3. The policy intervention to reduce forest conversion

Natural forest area of 15.44 million ha in HPK and APL (MoFor, 2014) is by law allowed to be converted to other land uses, and so, this need to be taken into account in the FREL construction. Since forest area allocation for conversion is indicative in nature and is only allowed to be converted if needed for development purposes, there have not been specific planning on area and timing for the conversion of these forests. Hence, assumption needs to be made to enable estimation of the associated emissions. However, in the absent of adequate basis for making assumption for FREL construction, the FREL construction for this submission did not differentiate between planned and unplanned deforestation.

For reducing forest conversion, government of Indonesia has enacted policy on moratorium of new permit/concession. The moratorium at first declared under Presidential Instruction No.10/2010, and renewed every two years (Presidential Instruction 6/2013, 8/2015).

Government of Indonesia has also carried out significant effort to reduce unplanned deforestation particularly in areas that have no on-site agencies responsible for managing the areas, mostly areas where concession permits have been terminated. The Ministry of Forestry (now Ministry of Environment and Forestry/MoEF) plans to establish 600 Forest Management Unit (FMU) in all forest areas by 2019. During the period of 2009-2013, 120 units of FMU model were established. The establishment of FMU will therefore need to be prioritized in regions with high deforestation risk.

Geospatial data and information is a major foundation in establishing integrated development. Concerning about a decade experiences in solving problem of spatial data disintegration, Indonesia has declared the one map policy in 2011. The one map policy is a movement towards development of one reference, one standard, one database and one geoportal, which aims to improve access to reliable geospatial data and integrated spatial information among government ministries and agencies.

7. Opportunity for Improvement

The FREL was constructed based on the current available data and knowledge under national circumstances, capacity and capability. Limitation on the analysis was mostly related to the data in the context of availability, clarity, accuracy, completeness and comprehensiveness. Further improvement may be carried out to the current estimates (i.e. more detail estimates on deforestation and forest degradation) as well as the inclusion of other REDD+ activities (i.e. conservation of forest carbon stock, sustainable management of forest and enhancement of forest carbon stock), when more and better data and better methodology become available, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71.

Towards further improvement in the future, there have been a number of on-going initiatives, including for example improvement of activity data, improvement of forest emission factor (carbon stock), and improvement of emission factor from peat land and mangrove ecosystems, in which the results have not been fully used in the FREL construction for this submission. For other approach of improvements, Indonesian National Carbon Accounting System (INCAS) was initiated to establish specific platform for GHG accounting system in Indonesia. The system employs developed Tier 3 and uses a systematic approach in quantifying GHG emissions and removals. The initiative was proposed to cover estimation of GHG emissions from five REDD+ scoping activities. However the system needs to be further tested for compatibility and deeply elaborated with many other available monitoring system in Indonesia.

7.1. Improvement of Activity Data

The future improvement of activity data will be focused on reducing uncertainty of the emission estimates associated with deforestation, forest degradation and peat decomposition (see Table 4 on uncertainty). The effort for improving activity data may cover two major aspects pertaining to utilization of the latest technology and methodology enhancements.

Utilization of advance technology in remote sensing will be explored for improving wall-to-wall monitoring of deforestation and forest degradation. By using current land-cover data derived from historical Landsat images (TM, ETM, OLI), it is possible to detect deforestation with good accuracy, but it is still problematic to monitor various forest degradation level with the same level of uncertainty.

To help resolve inconsistency resulting from the use of different data and maps, One Map Policy as mandated in the law of geospatial information to the Agency of Geospatial Information (BIG) is implemented (Ina-Geoportal, 2015). Through One Map Policy, the national standard of land cover/use for land cover mapping has been developed. Currently, BIG is cooperating with the related Ministries/Agencies to develope standardized map for the national land cover.

The potential use of high-resolution image data such as SPOT image for filling the gaps will be further explored in coordination with Indonesia's Aeronautics and Space Agency (LAPAN) under the One-Gate Policy for high-resolution satellite image provision. Furthermore, the increasing use of LiDAR technology will be further explored for validating biomass values in remote areas. As such, accuracy of biomass estimates from degraded forests could be increased and the level of forest degradation can be quantified.

On the methodological aspect, producing annual cloud-free image is increasingly possible by utilizing current pixel selection methodology (e.g. Potapov *et al.*, 2012, Hansen *et al.*, 2012). Referring to this result, the possibility for mapping annual wall-to-wall land-cover for the next monitoring period will be high.

The historical land-cover data used for this FREL submission were generated using visual interpretation, which is time-consuming and required trained operators (Margono *et al*., 2015). Apart from this, early stage of digital classification method has been utilized for producing wall-to-wall forest (tree) and non-forest (non-tree) maps by LAPAN (LAPAN, 2014). It is expected that future improvement by using hybrid approach involving manual and digital classification will be deployed to generate annual land cover maps for Indonesia (e.g. Margono *et al.*, 2014). Optionally, object-oriented classification method deserves similar attention to be explored. The method has been exercised by the ICRAF ALLREDDI Project (Ekadinata *et al.*, 2011) and GIZ Forclime (Navratil *et al*., 2013) for land cover mapping with detailed classification.

7.2. Improvement of Forest Emission Factor (Carbon Stock)

Current forest emission factor (carbon stock) for land-cover change was derived from 4.450 National Forest Inventory (NFI) permanent sample plots (PSPs) data. Out of 7 forest classes, only mangrove forests are not represented by the PSP. Consequently, future improvement should include the establishment of new plots in these forest classes. In addition, research on this particular ecosystem is currently progressing (e.g. Donato, *et.al*, 2011). Similar to peat lands, mangrove forests are important carbon sink, especially due to its organic-rich soils. Additional plots will be essential to represent forest classes in each region.

In addition to NFI data, FORDA established 263 research permanent plots since 2011 in 13 provinces. These can be utilized to improve the available field data. More pools that significantly contribute to total forest biomass need to be measured and included in the next plan to improve NFI system, i.e. necromass and below ground biomass. Several forest carbon inventory methods have been developed to include all carbon pools in a practical and robust way (SNI, 2011; Kaufman and Donato, 2010; Ravindranath and Oswald, 2008; Pearson *et al.*, 2005).

Improvement of NFI can be carried out through validating existing plots and ensuring accurate measurement in future measurements. Capacity building will be crucial to support this improvement plan, as it requires skillful and well-trained field operators. Utilizing current advance information technology to connect ground measurement and server can be used to support database management, data processing and real-time data collection. As such, errors can be identified faster, and makes it easier to be fixed or checked in the field. Moreover, data processing and reporting can be done in transparent way.

7.3. Improvement of Peatland Emission Factor

For future emission calculation from Indonesian peat land, emission factors can be updated with research findings and adapted to suit each land-cover class in Indonesia. Monitoring annual peat land emission through distributed permanent research stations is needed to enhance the data reliability and validity. Robust methodology should be applied according to the peat land characteristics in Indonesia through fostering research activities on peat issues. In parallel, continuous monitoring of water table levels throughout seasons at representative sampling plots for each relevant land cover strata should be conducted in the future in order to establish an improved peat land GHG emission model. Scientifically credible estimation of peat land emission factors requires a large number of samples.

Peatland characteristics such as vegetation types, peat depths, water table levels and soil organic carbon contents are highly variable among sites that lead to large variability of carbon stocks and CO_2 emissions. 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 types of peatland condition.

7.4. Estimating Peat land Fire Emission

Various researches used optical images for burnt area mapping, namely Landsat (Phua *et al.*, 2007) and SAR images (Siegert and Ruecker, 2000). Cloud cover persistence after fire season is the biggest challenge to acquire cloud-free optical images. In addition to that, vegetation growth after fire is tremendously fast in tropical region, leading to a narrow window for image acquisition that depicts the burnt area. In East Kalimantan, Siegert and Hoffman (1999) undertook burn scar mapping after fire episode of 1997/1998, which compare SAR images before and after the fire. At global level, NASA and Maryland University developed an algorithm to generate burnt scar maps from MODIS data (Li *et al.*, 2004). However the product has not been validated for Indonesia.

Another initiative utilizes low-resolution input. This was a research project conducted and tested in Central Kalimantan (MRI, 2013). The study used hotspot data to estimate burn scar areas by filtering annual fire hotspots using 1x1 km grid. This method is easy to apply, but the uncertainty was unknown. Due to the high uncertainty of the relationship between the hotspot and the burn scar area, the calculation of peat fire emission is excluded in this document. Annex 4 explain the uncertainties associated with the determination of activity data of burn scars as proposed by MRI (2013).

The opportunity to improve this approach is mostly to provide annual data (wall-to-wall) on burn scar maps. LAPAN has had necessary infrastructure and multi-sensor image data that is needed for this purpose, so improvements can be done in a step-wise method. For the emission factor, more in-depth research on refining emission factor from peat fire emission is still needed.

In addition to the identification of burn scar area, it is also important to accurately estimate the burn peat depth for calculating emissions from peat fires. Airborne lidar has been used for calculating burn peat depth with high accuracy (Ballhorn, et al. 2009). However to implement it at large scale will be challenging and costly. Reducing the lidar density could be a solution for larger landscape. Improvement should also be done in mapping the peatland. This effort would include validation of peatland boundaries and improvement of peat attributes, such as peat category and depth.

7.5. Inclusion of other REDD+ Activities

Indonesia started REDD+ readiness process since 2007 (prior to COP-13 in Bali). Most of required REDD+ frameworks have been tested and developed. However due to diversity of persepsions and expectation across actors, improvement is still required before full implementation. Following the progress of REDD+ infrastructure development in many areas including database development, stakeholders engagement as well as policy making may broader other REDD+ activities in future submissions, including the role of conservation, sustainable management of forests and enhancement of forest carbon stocks as well as reducing emission from peat fires. Existing REDD+ demonstration activities provide lessons learn for the improvements (see Figure 15).

Figure 15. *Distribution of REDD+ Demonstration Activity*

This FREL submission covers only two activities: deforestation and forest degradation, so that other REDD+ activities such as are not yet covered. The decision to include other three REDD+ activities need to consider the implication of data requirements and methodology selection. For example, if Indonesia wants to include forest carbon enhancement, the non-forested areas (i.e. shrubs, bareland, etc), in which the activity will be carried out, should be included for baseline emission calculation. Old regrowth and highly degraded logged-over area within forest area were assigned as non-forested area. This is because the minimum crown cover in the definition of forest used in this submission was different from the one used by FAO. Instead of minimum of 10 percent crown cover, we used 30 percent (MoFor, 2004).

In addition, enhancement of carbon stock will be eminent in plantation forests. Given the wide variation of site characteristics and tree species, a more comprehensive and detail research on AGB stocks and their annual increments will be required. Role of conservation and sustainable management (SFM) of forest are potential activities to be included in the future FREL future. Programmes on improved approaches and techniques have been initiated since decades to improve SFM and the role of conservation in Indonesia. However, the inclusion of those two activities do not merely imply on involvement of the technical aspects, but also in strengthening the role of local community and institutions (including private company, civil society, and government) in maintaining, preserving, and scaling up the role of natural forest conservation with regards to the emission reduction.

References

Agus, F., Hairiah, K., Mulyani, A. (2011). *Measuring Carbon Stock in Peat Soil. Practical Guidelines.* (pp. 1–60). World Agroforestry Centre (ICRAF) and Indonesian Soil Research Institute Bogor: Retrieved from http://balittanah.litbang.deptan.go.id

Agus, F., Henson, I. E., Sahardjo, B. H., Harris, N., Noordwijk, V., & Killeen, T. J. (2013). *Historical CO2 Emissions from Land Use and Land Use Change from The Oil Palm Industry in Indonesia, Malaysia and Papua New Guine*. Roundtable on Sustainable Palm Oil, 7–28: From http://www.rspo.org/file/GHGWG2

Agus, F., Santosa, I., Dewi, S., Setyanto, P., Thamrin, S., Wulan, Y.C., Suryaningrum, (Eds.) (2014). *Pedoman Teknis Penghitungan Baseline Emisi dan Serapan Gas Rumah Kaca dari Sektor Berbasis Lahan*. (p. 102): Badan Perencanaan Pembangunan Nasional, Jakarta.

Angelsen, A., Boucher, D., Brown, S., Merckx, V., Streck, C., & Zarin, D. (2011). Guidelines for REDD+ reference levels: Principles and recommendations. Meridian Institute.

Ballhorn, U., Siegert, F., Mason, M. and Limin, S. 2009 Derivation of burn scar depths and estimation of carbon emissions with LIDAR in Indonesian peatlands. *Proceedings of the National Academy of Sciences of the United States of America*, 106 (50), 21213-21218.

Basuki, T.M., van Laake, P.E., Skidmore, A.K., Hussin, Y.A., (2009). *Allometric Equations for Estimating the Above-Ground Biomass in Tropical Lowland Dipterocarp Forests*: For. Ecol. Manage. 257, (p. 1684–1694).

Boer, R., Sulistyowati, Las I, Zed, F., Masripatin, N., Kartakusuma, D.A., Hilman, D., Mulyanto, S.M. (2010) *Indonesia's Second National Communication Under The United National Framework Convention on Climate Change (UNFCCC):* Ministry of Environment, Republic of Indonesia.

Chave, J., Kira, T., Lescure, J.P., Nelson, B.W., Ogawa, H., Puig, H., Riéra, B., Yamakura, T., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Fölster, H., Fromard, F., Higuchi, N. (2005). *Tree Allometry And Improved Estimation Of Carbon Stocks And Balance In Tropical Forests*: Oecologia 145, 87–99.

Cochrane, Mark. A. (2003) *Forest Fire, Deforestation and Landcover Change in the Brazilian Amazon.* Contribute. Paper from the Mapping Session: Wood Hole Research Center, PO Box 296, Woods Hole, MA 02543 USA.

Daryono, H. (2010). Rencana Penelitian Integratif: *Pengelolaan Hutan Rawa Gambut:* Pusat Penelitian dan Pengembangan Hutan dan Konservasi Alam, Bogor.

Direktorat Jenderal Planologi Kehutanan (2014). *Potensi Sumber Daya Hutan dari Plot Inventarisasi Hutan Nasional*: Ministry Of Environmental and Forestry Indonesia.

Donato, Daniel C., Kauffman, J. Boone ., Mardiarso, D., Kurnianto, S., Stidham, M., Kanninen, M., (2011). *Mangroves Among the Most Carbon Rich Forest In The Tropics*. Nature Geoscience Letter.

Ekadinata, A., Hairah, K., Dewi, S., Agus, F., Velarde, S.J., Rahayu, S., Noordwijk, M. (2011). *Measuring Carbon Stocks across Land Use Systems*: World Agroforestry Centre-ICRAF, South East Asia Regional Office, Bogor.

FAO (2010). *Global Forest Resources Assessment 2010*: Food and Agriculture Organization of The United Nations Forestry Paper 163, (p. 209)Rome.

Geospatial Agency Republic of Indonesia (2010). *One Map webGIS* : From http://tanahair.indonesia.go.id

Hansen, M.C., Loveland, T.R., (2012). *A Review of Large Area Monitoring of Land Cover Change Using Landsat Data*. (p. 66 - 74): Remote Sensing of Environment. Volume 122.

Hansen, M. C. et al. (2013) *High-resolution global maps of 21st-century forest cover change. Science.* 342**,** 850_853.

Hergoualc'h, K., & Verchot, L. V. (2013). *Greenhouse Gas Emission Factors For Land Use And Land-Use Change In Southeast Asian Peat Lands.* Mitigation and Adaptation Strategies for Global Change: Springer Netherlands.

Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (2014). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: *Wetlands* (p. 354). Intergovermental Panel on Climate Change: (IPPC), Switzerland.

Hooijer, A., Silvius, M., W¨osten, H., and Page, S. (2006). *PEAT-CO2, Assessment Of CO2 Emissions From Drained Peat Lands In SE Asia:* Delft Hydraulics Report Q3943

Hooijer A., Page S., Canadell J. G., Silvius M., Kwadijk J., Wosten H., Jauhiainen J. (2010). *Current and future CO2 emissions from drained peat lands in Southeast Asia*. (p. 1505–1514): Biogeosciences.

IFCA (2008). *Reducing Emissions from Deforestation and Forest Degradation In Indonesia*, Consolidation Report, FORDA: Ministry of Forestry of the Republic of Indonesia.

Ina-Geoportal (2015). *Galeri Data Geospasial Indonesia,* One Map Web GIS: From http://tanahair.indonesia.go.id

ITTO (2002). ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary Tropical Forests. ITTO Policy Development Series No. 13, International Tropical Timber Organization.

Kartawinata, K. (2005). Six decades of natural vegetation studies in Indonesia. *Naturindo Publication, Bogor, Indonesia*.

Kauffmann, J.B and Donato, D. (2010) *Protocols for the Measurement, Monitoring and Reporting of Structure, Biomass, and Carbon Stocks in Mangrove Forests,* Working Paper 86, CIFOR, Bogor, Indonesia.

Ketterings, Q.M., Coe, R., van Noordwijk, M., Ambagau', Y., Palm, C.A. (2001) *Reducing Uncertainty In The Use Of Allometric Biomass Equations for Predicting Above-Ground Tree Biomass in Mixed Secondary Forests.* For. Ecol. Manage. 146, 199–209.

Krisnawati, H., Adinugroho, C. & Imanuddin, R. (2012). Monograph: *Allometric Models for Estimating Aboveground Tree Biomass ate Various Forest Ecosystem Types in Indonesia.* Research and Development Center for Conservation and Rehabilitation: Forestry Research and Development Agency, Bogor.

Krisnawati, H., Adinugroho, W. C., Imanuddin, R., & Hutabarat, S. (2014). Estimation of forest biomass for quantifying CO2 emissions in Central Kalimantan: A comprehensive approach in determining forest carbon emissions factors. *Research and Development Center for Conservation and Rehabilitation, Forestry Research and Development Agency, Bogor, Indonesia*.

LAPAN (2014). *The Remote Sensing Monitoring Program of Indonesia's National Carbon Accounting System*. Methodology and Products. Jakarta.

Li, R.-R., Y. J. Kaufman, W. M. Hao, J. M. Salmon, and B. C. Gao, (2004). *A Technique for Detecting Burn Scars Using MODIS Data*. IEEE Transactions on Geoscience and Remote Sensing, 42, 6, (p. 1300-1308).

Manuri, S., Brack, C., Nugroho, N.P., Hergoualc'h, K., Novita, N., Dotzauer, H., Verchot, L., Putra, C.A.S., & Widyasari, E. (2014). *Tree Biomass Equations for Tropical Peat Swamp Forest Ecosystems In Indonesia* (p. 241-253): For. Ecol. Manage. 334.

Margono, B. A., Turubanova S., Zhuravleva I., Potapov P.V., Tyukavina A., Baccini A., Goetz S., and Hansen M.C. (2012). *Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010.* Environ. Res. Lett. **7,** 034010.

Margono B. A., Potapov P. V., Turubanova S., Fred Stolle F., Matthew Hansen C. M. (2014). *Primary Forest Cover Loss In Indonesia Over 2000–2012*. Nature Climate Change 4, 730–735.

Margono, B.A.; Usman, A.B.; Budiharto; Sugardiman, R.A. (2015). *Indonesia's forest resources monitoring*. 31p. Submitted for publication to Indonesian Journal of Geography, UGM (in review).

Mayr, E. (1944). Wallace's line in the light of recent zoogeographic studies. *The Quarterly Review of Biology, 19*(1), 1-14.

MoFor (2001). Rekalkulasi penutupan lahan Indonesia tahun 2000. Direktorat Inventarisasi dan Pemantauan Sumber Daya Hutan. DitJend Planologi Kehutanan. Kementrian Kehutanan.

MoFor (2002). Kebijakan rehabilitasi dan konservasi sumber daya hutan. Ministry of Forestry. Jakarta

MoFor (2003). Rekalkulasi penutupan lahan Indonesia tahun 2002. Direktorat Inventarisasi dan Pemantauan Sumber Daya Hutan. DitJend Planologi Kehutanan. Kementrian Kehutanan.

MoFor (2004). *Peraturan Menteri Kehutanan Nomor : P.14/Menhut-II/2004 Tentang Tata Cara Aforestasi dan Reforestasi Dalam Kerangka Mekanisme Pembangunan Bersih*. (p. 1. article 1). Ministry of Foresty. Jakarta.

MoFor (2009). Decree No. P30/Menhut-II/2009, *Implementation Procedures of REDD*. Ministry of Foresty. Jakarta.

MoFor (2012). Rekalkulasi penutupan lahan Indonesia tahun 2011. Direktorat Inventarisasi dan Pemantauan Sumber Daya Hutan. DitJend Planologi Kehutanan. Kementrian Kehutanan.

MoFor (2014). Rekalkulasi penutupan lahan Indonesia tahun 2013. Direktorat Inventarisasi dan Pemantauan Sumber Daya Hutan. DitJend Planologi Kehutanan. Kementrian Kehutanan.

MRI (2013). *Green House Gas Reduction Project through Forest Conservation in Peat land in Central Kalimantan*: Mitsubisi Rerearch Intititute, Inc.

Murdiyarso, D., Donato, D., Kauffmann, J.B., Kurnianto, S., Stidham, M. and Kanninen, M. (2009). *Carbon Storage in Mangrove And Peat Land Ecosystems:* A

Preliminary Accounts From Plots in Indonesia. Working Paper 48: CIFOR. Bogor - Indonesia

Nandika, D. (2005). *Hutan Bagi Ketahanan Nasional*: Universitas Muhammadiyah Surakarta.

Navratil, P. (2013). *Land Cover Situation And Land Use Change In The Districts of West Kalimantan And East Kalimantan, Indonesia.* Assessment of District And Forest Management Unit Wide Historical Emission Levels: GIZ Forclime.

Noor, Y.R. dan Heyde,J. (2007). *Pengelolaan Lahan Gambut Berbasis Masyarakat di Indonesia:* Wetlands International Indonesia.

Paciornik, N., Rypdal, K. (2006). 2006 *International Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories.* Chapter 4. Forest Land: IPCC, Switzerland.

Pagiola. S. (2000). *Land Use Change in Indonesia*: Environment Department, World Bank.

Pearson, T., Walker, S., Brown, S., (2005). *Sourcebook for Land Use, Land-Use Change and Forestry Projects:* Winrock International and the BioCarbon Fund of the World Bank 57.

Phua, M., S. Tsuyuki, J. Lee, and H. Sasakawa (2007), *Detection Of Burned Peat Swamp Forest In A Heterogeneous Tropical Landscape*: A case study of the Klias Peninsula, Sabah, Malaysia, Landscape Urban Plann. (p. 82, 103 – 116).

Potapov, PV; Turubanova, SA; Hansen, MC; Adusei, B; Broich, M; Altstatt, A; Mane, L; Justice, CO (2012). *Quantifying Forest Cover Loss in Democratic Republic Of The Congo, 2000-2010, With Landsat ETM Plus Data. REMOTE SENSING OF ENVIRONMENT*, 122, 106-116: From http://modis.gsfc.nasa.gov/

Ravindranath N. H. and M. Ostwald. (2008). Carbon Inventory Methods. *Handbook For Greehouse Gas Inventory, Carbon Mitigation And Roundwood Production Projects*: Springer.

REDD+ Task Force (2012). *REDD+ National Strategy*: (p. 9): From www.satgasreddplus.org

Revilla, J.A.V. (1992). *Step-by-Step Field Sampling Procedures for the NFI Project. Indonesia UTF/INS/066/ INS National Forest Inventory Working Document No. 3*: Food and Agriculture Organisation of the United Nations. Jakarta.

Ritung S., Wahyunto, Nugroho K., Sukarman, Hikmatullah, Suparto, C. T. (2011). *Peta Lahan Gambut Indonesia Skala 1:250.000* (p. 11): Indonesia Ministry of Agriculture , Jakarta - Indonesia.

Rutishauser, E., Noor'an, F., Laumonier, Y., Halperin, J., Rufi'ie, Hergoualc'h, K., & Verchot, L. (2013). *Generic Allometric Models Including Height Best Estimate Forest Biomass and Carbon Stocks in Indonesia*: For. Ecol. Manage. 307, 219-225.

Siegert F. and Hoffmann A. A. (2000). T*he 1998 Forest Fires in East Kalimantan (Indonesia). A Quantitative Evaluation Using High Resolution, Multitemporal ERS-2 SAR Images and NOAA-AVHRR Hotspot Data (p. 64–77*): Remote Sensing Environment 72.

Siegert, F., Ruecker, G., Hinrichs, A. and Hoffmann, A. (2001). Increased damage from fires in logged forests during droughts caused by El Nino. *Nature*, **414** (6862), 437-440.

Siegert F. and Ruecker G. (2000). *Use Of Multitemporal ERS-2 SAR Images For Identication of Burned Scars in Southeast Asian Tropical Rainforest*. (p. 831–837): International Journal Remote Sensing, vol. 21, no. 4.

SNI (2010). Standar Nasional Indonesia 9645: Klasifikasi Penutupan Lahan. Badan Standar Nasional Indonesia. Jakarta – Indonesia.

SNI (2011). Standar Nasional Indonesia 7725: *Development of Allometric Equations For Estimating Forest Carbon Stocks Based On Field Measurement (Ground Based Forest Carbon Accounting)*. Jakarta – Indonesia.

SNI (2011). Standar Nasional Indonesia 7724: *Measurement and Carbon Stock Accounting-Field Measurement to Measure Forest Carbon Stock*. Jakarta – Indonesia.

SNI (2011b). Standar Nasional Indonesia 7725: *Development of Allometric Equations For Estimating Forest Carbon Stocks Based On Field Measurement (Ground Based Forest Carbon Accounting)*. Jakarta – Indonesia.

SNI (2013). Standar Nasional Indonesia 7848. P*enyelenggaraan Demonstration Activity (DA) REDD+.* Badan Standar Nasional Indonesia. Jakarta-Indonesia.

SNI (2013b). Standar Nasional Indonesia 7925: *Pemetaan Lahan Gambut skala 1:50.000 berbasis Citra Penginderaan Jauh*. Jakarta – Indonesia.

SNI (2014). Standar Nasional Indonesia 8033: *Metode Penghitungan Perubahan Tutupan Hutan Berdasarkan Hasil Penafsiran Citra Penginderaan Jauh Optik Secara Visual*. Jakarta – Indonesia.

Statistic Indonesia (2013). *Proyeksi Penduduk Indonesia 2010 - 2035:* Statistik Indonesia.

Thompson, I. D., M. R. Guariguata, K. Okabe, C. Bahamondez, R. Nasi, V. Heymell, and C. Sabogal (2013). *An Operational Framework for Defining and Monitoring Forest Degradation:* Ecology and Society 18 (2): 20.

UNFCCC (2011). COP 16; *Report Of The Conference Of The Parties On Its Sixteenth Session, Held In Cancun From 29 November to 10 December 2010*. (p. 12): UN.

UNFCCC (2012). COP 17; *Report of the Conference of the Parties on its seventeenth session, held in Durban from 28 November to 11 December 2011.* Part Two; Action taken by the Conference of the Parties at its seventeenth session. (p. 16 - 19): UN.

Van Noordwijk M, Matthews R,Agus F,Farmer J,Verchot L,Hergoualc'h K,Persch S,Tata HL,Lusiana B, Widayati A, Dewi S. (2014). *Mud, Muddle And Models In The Knowledge Value-Chainto Action On Tropical Peatland Conservation (p.* 887–905): Mitig Adapt Strateg Glob Change 19.

Wahyunto, S. Ritung dan H. Subagjo (2003). *Maps of Area of Peat land Distribution and Carbon Content in Sumatera, 1990 – 2002*: Wetlands International - Indonesia Programme & Wildlife Habitat Canada (WHC).

Wahyunto, S. Ritung dan H. Subagjo (2004). *Map of Peat land Distribution Area and Carbon Content in Kalimantan, 2000 – 2002*. Wetlands International - Indonesia Programme & Wildlife Habitat Canada (WHC).

Wahyunto, Bambang Heryanto, Hasyim Bekti dan Fitri Widiastuti (2006). *Maps of Peat land Distribution, Area and Carbon Content in Papua, 2000 - 2001*. Wetlands International – Indonesia Programme & Wildlife Habitat Canada (WHC).

Yamakura, T., Hagihara, A., Sukardjo, S., & Ogawa, H. (1986). *Aboveground Biomass of Tropical Rain Forest Standsin Indonesian Borneo.* (p. 71–82). Plan Ecol. 68.

Annexes

Annex 1. Documentation and specification of the land-cover data

Land-cover map of the Ministry of Forestry (MoFor) of Indonesia

The Directorate General of Forestry Planning of The Ministry of Forestry (MoFor), has used satellite data since 1990s, particularly Landsat, for land cover mapping of Indonesia. The mapping system was first established in 2000 and could only be updated every three years based on data availability, due to problems of clouds and haze. In total, ± 217 Landsat TM/ETM+ scenes are required to cover the entire land area of Indonesia, excluding additional scenes to minimize/remove clouds and the presence of haze. Up to around 2006, other data sets such as SPOT Vegetation 1000 meters and MODIS 250 meters were used for alternative, especially when the purchased Landsat data of MoFor were not yet ready for processing and classification processes.

More consistent data was available at around 2009; following the change in Landsat data policy of the United States Geological Survey (USGS) in 2008 that has made Landsat data available free of charge over the internet. The new Landsat data policy, automatically benefits Indonesia by increasing the number of data available for supporting the mapping system. In 2013, MoFor started to use the newly launched Landsat 8 OLI to monitor Indonesian land cover condition and placed the Landsat 7 ETM+ as a substitution for cloud elimination. More data available through free-download has opened opportunities for Indonesia to change the three interval year into annual basis. Up to now, land-cover data is available for the years of 2000, 2003, 2006, 2009, 2011, 2012, and 2013. In the last five years, the updating work for land cover data of 1900s has been carried out, to renew the information made during the era of NFI. However, USGS and LAPAN have not enough Landsat archive available, so that annual 1990s data was not possible, and two 1990s sets of data were established: 1990 and 1996.

To maintain product continuity and the work improvement, a collaboration between LAPAN for Landsat data preparation and the MoFor for classification process become significant key for future works. Those two institutions have a Memorandum of Understanding for the work since 2004 which was recently updated. The existing system is known as the National Forest Monitoring System (NFMS) named Simontana (*Sistem Monitoring Hutan Nasional*) (MoFor, 2014). It is available online at http://nfms.dephut.go.id/ipsdh/, which coupled with webGIS at http://webgis.dephut.go.id/ for display and viewing. The two website is part of geospatial portal under the one map policy.

Variation of sensors and methods employed post 2000 is a significant contributor in better illustrating national land-cover, compared to before 2000 when land-cover map in the ear of NFI was mostly derived from various data formats (hardcopy, softcopy, analog, digital). The historical condition and ongoing improvements is illustrated in figure Annex 1.1.

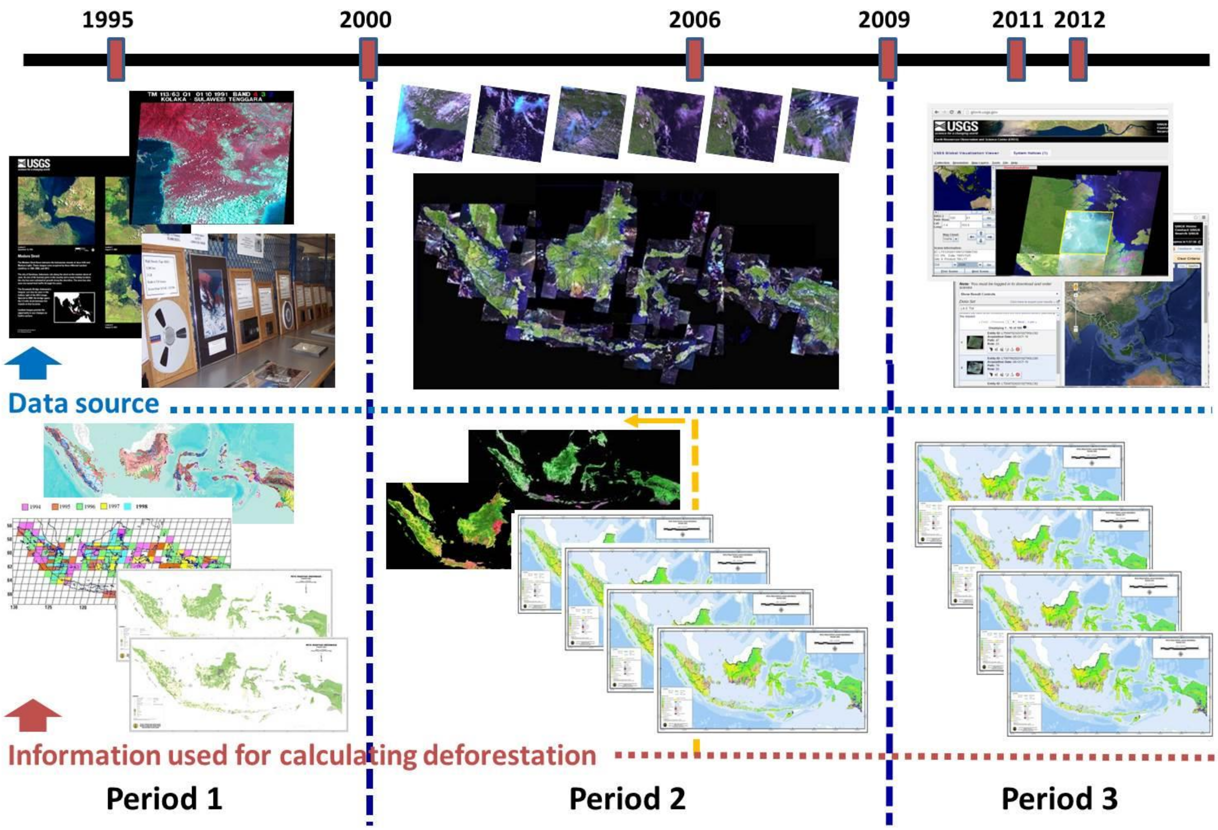

***Figure Annex 1.1**. Historical condition and improvement in establishing the land-cover map of Indonesia that consists of three significant periods (1990s: NFI period; 2000-2009: period of limited Landsat data used; >2009: period of free download Landsat data).*

Within Period 1 (prior 2000), all available data including analog data, and Landsat hard copy that was delineated manually and digitized, were used. For Landsat, most scenes either use softcopy in CCT format or the hard copy were not having same year interval, but during that Period 1, that data was the only available data for generating land cover. Products of Period 1 were generated under the National Forest Inventory (NFI) activity and later published on Holmes (2000, 2002). Period 2 (2000-2009) is the period of using merely digital data. However the manual classification method employed is time consuming and delayed the product delivery, especially when work experiences in wall-to-wall mapping are limited. Alternative approach by using SPOT Vegetation 1000 meters and MODIS 250 meters was done for immediate reporting. Within period 3 (2009 onward), data availability is no longer a constraint, and only Landsat data has been used as a data source. Here, overcoming the time consuming manual classification process is becoming a concern. Significant improvements were carried out at the previous period (2006) and becoming a major concern at the beginning of the Period 3 (2009); that improvement intended to migrate every single layer of time-sequential land cover data (2000, 2003, 2006, and 2009) into a single geodatabase. A geodatabase is a solution to improve interdependency among layers.

The land cover map of Indonesia presents in 23 classes, including 6 classes of natural forests, 1 class of plantation forest, 15 classes of non-forested, and 1 class of clouds-no data. Name of the 23 classes and description are in table annex 1.1 (SNI 7645-2010, Margono *et al*. 2015 in review); with the series of monogram for those 23 classes is described in Annex 6.

Table Annex 1.1. *The 23 land cover classes of Indonesia and their description*

No	Classes	Description
	Forest	
1	Primary dryland forest	Natural tropical forests grow on non-wet habitat including lowland, upland, and montane forests with no signs of logging activities. The forest includes heath forest and forest on ultramafic and lime-stone, as well as coniferous, deciduous and mist or cloud forest, which is not (or low) influenced by human activities or logging.
2	Secondary dryland forest	Natural tropical forest grows on non-wet habitat including lowland, upland, and montane forests that exhibit signs of logging activities indicated by patterns and spotting of logging (appearance road and patches of logged-over). The forest is including heath forest and forest on ultramafic and lime-stone, as well as coniferous, deciduous and mist or cloud forest.
3	Primary swamp forest	Natural tropical forest that grow on the wet habitat in swamp form, including, brackish swamp, marshes, sago and peat swamp, which is not or low influenced by human activities or logging.
4	Secondary swamp forest	Natural tropical forest grows on wet habitat in swamp form, including brackish swamp, marshes, sago and peat swamp that exhibit signs of logging activities indicated by patterns and spotting of logging (appearance road and patches of logged-over).
5	Primary mangrove forest	Wetland forests in coastal areas such as plains that are still influenced by the tides, muddy and brackish water and dominated by species of mangrove and Nipa (*Nipa frutescens*), which is not or low influenced by human activities or logging.
6	Secondary mangrove forest	Wetland forests in coastal areas such as plains that are still influenced by the tides, muddy and brackish water

		and dominated by species of mangrove and Nipa (*Nipa frutescens*), and exhibit signs of logging activities, indicated by patterns and spotting of logging activities.
7	Plantation forest	The appearance of the structural composition of the forest vegetation in large areas, dominated by homogeneous trees species, and planted for specific purposes. Planted forest including areas of reforestation, industrial plantation forest and community plantation forest
	Non-Forest	
8	Dry shrub	Highly degraded log over areas on non-wet habitat that are ongoing process of succession but not yet reach stable forest ecosystem, having natural scattered trees or shrubs
9	Wet shrub	Highly degraded log over areas on wet habitat that are ongoing process of succession but not yet reach stable forest ecosystem, having natural scattered trees or shrubs
10	Savanna and Grasses	Areas with grasses and scattered natural trees and shrubs. This is typical of natural ecosystem and appearance on Sulawesi Tenggara, Nusa Tenggara Timur, and south part of Papua island. This type of cover could be on wet or non-wet habitat
11	Pure dry agriculture	All land covers associated to agriculture activities on dry/non-wet land, such as tegalan (moor), mixed garden and ladang (agriculture fields)
12	Mixed dry agriculture	All land covers associated to agriculture activities on dry/non-wet land that mixed with shrubs, thickets, and log over forest. This cover type often results of shifting cultivation and its rotation, including on karts
13	Estate crop	Estate areas that has been planted, mostly with perennials crops or other agriculture trees commodities
14	Paddy field	Agriculture areas on wet habitat, especially for paddy, that typically exhibit dyke patterns (pola pematang). This cover type includes rainfed, seasonal paddy field, and irrigated paddy fields
15	Transmigration areas	Kind of unique settlement areas that exhibit association of houses and agroforestry and/or garden at surrounding
16	Fish pond/aquaculture	Areas exhibit aquaculture activities including fish ponds, shrimp ponds or salt ponds
17	Bare ground	Bare grounds and areas with no vegetation cover yet,

		including open exposure areas, craters, sandbanks, sediments, and areas post fire that has not yet exhibit regrowth
18	Mining areas	Mining areas exhibit open mining activities such as open-pit mining including tailing ground
19	Settlement areas	Settlement areas including rural, urban, industrial and other settlements with typical appearance
20	Port and harbor	Sighting of port and harbor that big enough to independently delineated as independent object
21	Open water	Sighting of open water including ocean, rivers, lakes, and ponds
22	Open swamps	Sighting of open swamp with few vegetation
23	Clouds and no-data	Sighting of clouds and clouds shadow with size more than 4 cm^2 at 100.000 scales display

The 23 land cover classes are based on physiognomy or biophysical appearance that are sensed by remote sensing data used (Landsat at 30 meter spatial resolution). The name of land cover classes (Table Annex 1.1) correspondingly feature land uses, such as class of forest plantation or estate crops. However, the object identification is based purely on existing appearance on imagery. Manual-visual classification through on-screen digitizing technique based on key elements of image/photo-interpretation was selected for classification. Several ancillary data sets (including concession boundaries both logging and plantation, forestland-use boundary) were utilized during the process of delineation, to catch additional information valuable for classification.

Manual classification is time-consuming and labor intensive (Margono *et al.*, 2012, Margono *et al,*. 2014), involving the MoFor staffs from district and provincial levels to manually interpret and digitize the satellite images, to capture local knowledge in the same time. Prior to 1989, visual interpretation on aerial photos was started, and later within NFI, continuously employed on Landsat data. Digital classification was at first generated in the early 1990s but was constrained with conversion of raster format into vector format for further analysis. Visual classification technique was then selected for operational method. In contrast, the SPOT Vegetation and MODIS used for alternatives were classified using digital classification.

Data validation to assure the classification results were carried out by comparing land cover map to the post classification field data. Stratified random sampling is a selected approach to verify the classification map to the field reality. Compilation of several field visit data within a specific year interval was exercised for accuracy assessment. Comparison results performed on table of accuracy (contingency table), yielding an overall accuracy of 88%for all 23 classes, and 98%for aggregated classes of forest and non-forest (MoFor, 2012, Margono *et al.*, 2012).

Following the latest development on data availability, the MoFor has been refining the national land cover classification map, trace-back from 1990s to 2013, and plan to update deforestation data over more than two decades using the refined land cover data set. The MoFor has been collecting and archiving more than 10,000 scenes of Landsat images from the entire country dating back from the early 1990s onwards. Although targeting the observation period of the 1990s to 2013, the first version of refinement (up-to July 2014) focused on data 2009 onward. In addition, the deforestation rate from 2000 to 2003 that was generated using alternative data of SPOT Vegetation (2000-2005) has been replaced with deforestation rates of Landsat. Data used in this report are the one that based on first refinement and additional replacement.

<u>Other data-set introduced in this report</u>

There are two independent studies used for comparison to illustrate the reliability of the MoFor data used in this report, as well as to give scientific background to the presented results. Those are the study of Margono *et al.* (2014) and study of LCCA-LAPAN.

Land Cover map of Margono et al. (2014)

Study of Margono *et al.* (2014) has been published in journal of Nature Climate Change, available online since June 2014. The study is part of global mapping system of Hansen *et al* (2013) that modified specific for national scale (Indonesia). The study generates three main land cover classes: primary forest, consisting of primary intact and primary degraded classes; and non-primary forest (other land cover). Referring to the supplementary material of the NCC submission, primary forests was defined as all mature forests of 5 ha or more in extent that retain their natural composition and structure and have not been completely cleared in recent history (at least 30 years in age). The primary forest is disaggregated into two types: intact (undisturbed type), and degraded (disturbed type). Intact primary forest has a minimum area unit of 500 km^2 with the absence of detectable signs of human-caused alteration or fragmentation, and is based on the Intact Forest Landscape definition of Potapov *et al.* (2008). The degraded primary forest class is a primary forest that has been fragmented or subjected to forest utilization, e.g. by selective logging or other human disturbances that have led to partial canopy loss and altered forest composition and structure.

Pointing to the descriptions, primary forest of Margono *et al*. (2014) stands for natural forest, excluding all other tree covers (forest plantation, oil palm and other man-made forests); with term of primary intact forest refers to primary forest (*hutan primer*) of the MoFor (Table Annex 1.1), and primary degraded forest refers to secondary forest (*hutan sekunder*) of the MoFor (Table Annex 1.1). The primary forest of Margono *et al*. (2014) that equaled primary intact forest plus primary degraded type forests were compared with that of the MoFor, for the years 2000 up to 2012 with three years interval (Graph Annex 1.2). For MoFor, it equaled primary plus secondary forest categories. This was performed to assess the primary forest reference mask. The primary forests class of Margono *et al*. (2014) and that of MoFor yielded a 90 percent agreement with an 80 percent Kappa and balanced omission and commission errors (Table Annex 1.2).

Detail of Margono study available in
http://www.nature.com/nclimate/journal/v4/n8/full/nclimate2277.html and the produced data available in
http://glad.geog.umd.edu/indonesia/data2014/index.html.

Table Annex 1.2. *Product comparison of Margono et al. (2014) to the data of The Ministry of Forestry of Indonesia for primary forests (intact and degraded forms) for 2000 (starting date) and 2012 (ending date) of the analysis*

Assessment for agreement	**Primary forest (intact and degraded)**	
	2000	**2012**
Overall agreement	90.7	90.9
Producer's agreement	92.1	90.7
User's agreement	90.1	90.6
Kappa statistic	81.0	81.0

Land cover map of LAPAN (National Institute of Aeronautics and Space of Indonesia)

This data is a result of The Land Cover Change Analysis program (LCCA), the remote sensing monitoring component of Indonesia's National Carbon Accounting System (INCAS). The LCCA provides a wall-to-wall spatially detailed monitoring of Indonesia's forest changes over time using satellite remote sensing imagery. The primary objective of the LCCA is to produce annual forest extent and change products, and initial objective is to map the extent of forested land and the annual changes for the 13-year period from 2000-2012, to provide inputs for carbon accounting activities. The LCCA was conducted in LAPAN and assisted by CSIRO Australia.

Forest is defined as a collection of trees with height greater than 5 meters and having greater than 30% canopy cover. For this activity, Landsat 5 (LS-5) and Landsat 7 (LS-7) were chosen as the only feasible data source in providing such monitoring Information. Samples derived from high-resolution satellite imagery were use as reference to accurately interpret the land cover classes. Such image resolution could estimate tree density and indications of tree height from shadow.

This work has not yet been published in an academic journal, but simple key activities are outlined in the following paragraph. There are a number of steps to produce the annual forest extent and change maps of LCCA-LAPAN, including image preparation, forest extent and change mapping, as well as review of the product. The outputs from previous steps are automatically used as the input for the next step. Image preparation is intended to produce a free-cloud mosaic. At first the images in scenes (path/row) are selected and geographically corrected, if necessary, as those scenes should be aligned to each other and to other maps used as reference. Corrections to normalize every pixel value to be more consistent through time are subsequently executed. Contaminating data, such as clouds and shadows, haze, smoke and image noise that obscures the ground cover are masked. The individual selected-corrected images are then consolidated into mosaic tiles, to simplify the following process.

There are three steps taken into consideration to make the annual forest extent and change products. First, ground-truth information; expert knowledge and high-resolution images were used to capture relationships between image signals and the forest/not forest cover, to create a forest base for every single year. A semi-automated matching process was subsequently used to 'match' the adjacent years to the base. At last, knowledge of temporal growth patterns in forest and non-forest cover types were used in a mathematical model to refine the single-date for more reliable change detection. The final step is to review the products, both to collect feedback on accuracy and to understand the strengths and limitations of the particular works. The review will constitute input suggestion for strategies to improve the products in the future. Details on methodology are provided in document entitled "The Remote Sensing Monitoring Program of Indonesia's National Carbon Accounting System: Methodology and Products". The forest of LCCA-LAPAN was later compared to the MoFor for the year 2000 and 2012.

Table Annex 1.3. *Product comparison of the LCCA LAPAN result (that refer to tree cover) to The Ministry of Forestry of Indonesia data for forest in 2000 (starting date) and 2012 (ending date of analysis)*

Assessment for agreement	**Tree cover**	
	2000	**2012**
Overall agreement	78.7	78.1
Producer's agreement	75.6	73.6
User's agreement	89.7	88.7
Kappa statistic	56.0	56.0

Graph for comparing the MoFor data used in this report to the other two independent studies are presented in figure Annex 1.2.

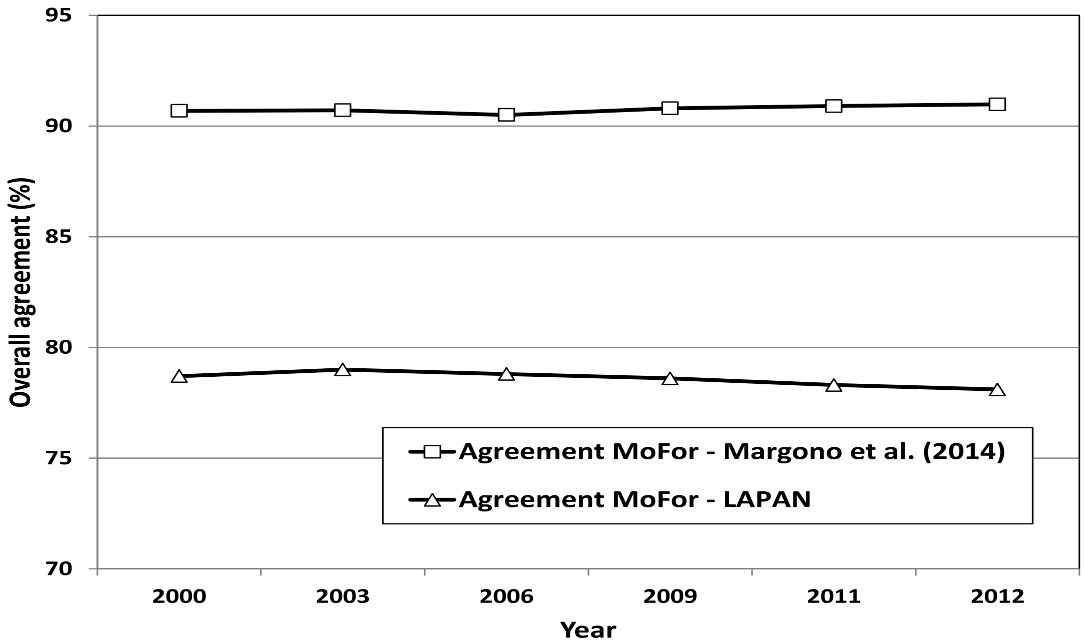

Figure Annex 1.2. *Graph comparison, shows agreement of the land cover data MoFor used in this analysis to the other two independent studies (Margono and LAPAN/LCCA-LAPAN).*

References

Margono, B. A., Turubanova S., Zhuravleva I., Potapov P.V., Tyukavina A., Baccini A., Goetz S., and Hansen M.C. (2012). *Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010.* Environ. Res. Lett. **7,** 034010.

Margono B. A., Potapov P. V., Turubanova S., Fred Stolle F., Matthew Hansen C. M. (2014). *Primary Forest Cover Loss In Indonesia Over 2000–2012*. Nature Climate Change 4, 730–735.

MoFor (2006). "*Petunjuk Pelaksanaan Penafsiran Citra Dengan Digitasi On-Screen Dalam Rangka Pemantauan Sumber Daya Hutan"*. Ministry of Foresty. Jakarta.

MoFor (2008). "*Petunjuk Teknis Pembuatan, Petunjuk Pelaksanaan Pencermatan, Penyempurnaan Dan Kompilasi Citra Satelit Landsat Indonesia Dalam Rangka Pemantauan Sumber Daya Hutan Dengan Citra Resolusi Sedang"*. Ministry of Foresty. Jakarta.

MoFor (2014). *National Forest Monitoring System (NFMS).* Ministry of Foresty. Jakarta. http://nfms.dephut.go.id

Annex 2. Documentation and specification of the peat land data

Activities on peat land mapping in Indonesia are closely related to soil mapping projects for agricultural development programs, which was conducted by the Ministry of Agriculture. Indonesia has developed procedure for peatland mapping based on remote sensing at the scale 1:50.000 (SNI 7925:2013). The map of Indonesia's peat land has been updated and released several times due to the dynamics of data availability. For this FREL submission, the peat map exercised is the latest Peat land Map 2011 edition at the scale of 1:250.000 (national scale). This map was generated based on the 1989 - 2011 data and information, from the Land/Soil Resources Mapping project, under the Agricultural Research and Development Agency of the Ministry of Agriculture. Under this project, the map of peat land was made from series of available data in Indonesia, which was a result of soil mapping carried out in various levels and scales, accompanied by appropriate ground truth.

The method of preparing Peat map of Indonesia can be described as follows:

Data Input:

The data input for preparing the Peat land map are listed as follows:

- Indicative soil maps with the scale of 1:250.000, 1:100.000, and 1:50.000.
- Sumatera: Maps of LREP I (Land Resource Evaluation and Planning I).
- Kalimantan: Reconnaissance soil Maps of West Kalimantan, South Kalimantan, East Kalimantan, Maps of Peat land Megarice Project (PLG) of Central Kalimantan, other map of Kalimantan Tengah.
- Papua and West Papua: Agro-Ecological Zone Maps.
- Digital data of Landsat 7 ETM+ covering all area of Indonesia (with different date of acquisition).
- Digital map of Rupabumi Indonesia (RBI) 1:250.000 from Bakosurtanal (BIG).
- 1:250.000 scale map of Geology from the Center for Research and Development of Geology, Bandung.

Method:

The method of preparing peat land map of Indonesia is using a comparative method. All data collected from any sources were compared spatially by using spatial data analysis tools and combined by literature review. In order to increase the accuracy of the results of the comparative method, validation was conducted by ground truth surveys. Soil Classification System used in this map refers to the Presidential Instruction (Inpres) No. 10/2011 (Moratorium New License) and the Minister of Agriculture Regulation (Permentan) No. 4/2009.

Currently, the combination of remote sensing techniques and physiography/landform analysis (supported by topography and geology data) were used to increase the accuracy. Remote sensing Indicators used for detecting peat land area are: wetness (surface drainage), topography, and land cover. Ground truths were conducted to verify the remote sensing analysis results. Level of error of using this method to produce peat land map was 20-30%. The reliability of the map depends on the following factors.

- The density of sample points in ground truth activity
- The variety of soil types
- The quality of the remotely sensed data
- The accuracy of the delineation of the map soil and land unit map.
- The competency of the surveyors.

The detail documentation of peat land map of Indonesia can be found in the document entitled "Peta Lahan Gambut Indonesia Skala 1:250.000 Edisi Desember 2011" (in Indonesian "*Indonesian Peat land Map Scale 1:250,000 Edition 2011*") published in 2011 by the Agricultural Research and Development Agency, Ministry of Agriculture of Indonesia (Figure Annex 2.1)

Figure Annex 2.1. *The cover of the documentation and specification of Indonesian peat land map 2011 edition (in Indonesian).*

Annex 3. Documentation and specification of the forest carbon stock data

Background information

NFI was initially a Word Bank and United Nations supported project to assist MoF of Indonesia for conducting forest resource enumeration during the period of 1989 to 1996. The implementation was carried out through technical assistance from FAO-UN. The goal of NFI project was to support the development of a forest resource information system and institution, including for the purpose of establishing a Forest Resource Assessment (FRA). The implementing agency of NFI project was the Directorate General of Forest Planning or DG of Planology (DGFP) of the Ministry of Forestry.

NFI was designed to encompass all components related to forest inventory at a national scale. This includes Field Data System (FDS), Digital Image Analysis (DIAS), Geographic Information System (GIS) and National Forest Inventory Information Service (NFIIS). Through this project, a number of forest inventory plots, both permanent sample plots (PSPs) and temporary sample plots (TSPs), have been established and measured throughout the country. The plots are distributed with systematic sampling throughout the country for every 20 km x 20 km grid. All plots were distributed in lowland area below 1000 m above sea level. In addition to that, land and forest cover map were digitized at scale of 1:250,000 based on satellite images covering national area.

In 1996, NFI project published the first statistic report on Indonesian forest resources. This is the first and complete report made available by the Indonesian Government describing complete and detail information on forest resources, forest and land cover and timber stocks from each forest function in Indonesia, except Java. Up to now, NFI system has been implemented as part of regular program from the DGFP. Activities related to NFI that is being implemented by DGFP include re-enumeration or re-measurement of the established PSPs that still exist, establishing new PSP/TSP in new area for filling the gaps and additional plots in mountainous region and conservation areas.

NFI sampling design

The purpose of the plots established by NFI project was to conduct forest resource assessment at national scale. The NFI plots are actually a group of 9 square plots (1 PSP and 8 TSPs), or so called a cluster. The plot size is 100 m x 100 m and systematically placed in 3 x 3 sub-plot/tract with 500 m distance between sub-plots. The sub-plot/tract in the middle (no 5) is measured as PSP and TSP. The other 8 tracts are TSP. PSP is divided into 16 recording unit (RU) areas (25 m x 25 m). The numbering of plots and recording units is depicted in Figure Annex 3.1.

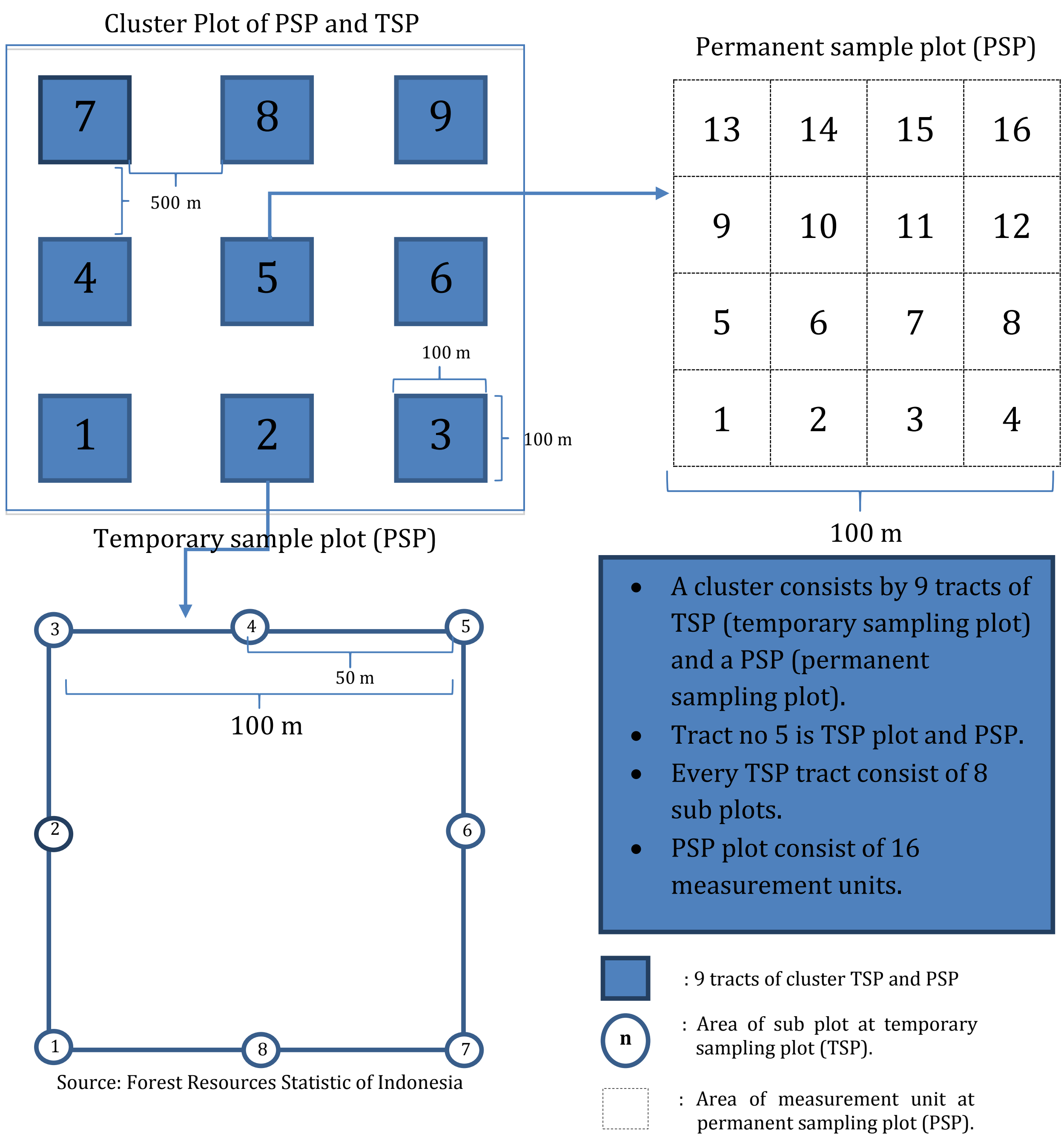

Figure Annex 3.1. *Plot cluster layout.*

<u>NFI Cluster distribution</u>

NFI clusters were systematically distributed at 20 km x 20 km covering all forest and land cover types within the forest area of Indonesia. Most of the clusters are located in the area with altitude below 1000 m above sea level (ASL). Along with the improvement, several clusters of PSP were established between the 20 km x 20 km grid (i.e. become 10 km x 10 km) in production forests and at altitude above 1000 m ASL. None of the clusters are located outside forestland, even though it is forested.

Since the commencement of the NFI program in 1989, PSP/TSP that have been established and measured until 2014 totalling 3,928 clusters distributed in 7 major islands/regions. Sumatra and Kalimantan have the largest plot allocation, with 23.5% and 32.5% respectively. Some clusters are no longer maintained due to conversion into other land use.

Table Annex 3.1. *Cluster distribution of NFI's PSP/TSP*

Islands	N Clusters	%
Jawa	92	2.3
Kalimantan	1277	32.5
Maluku	225	5.7
Nusa Tenggara	307	7.8
Papua	540	13.7
Sulawesi	565	14.4
Sumatera	922	23.5
Total	3928	100.0

Parameter being measured

Since the main purpose of NFI was to monitor forest resources, data to generate timber volume or stocks were strongly required. These includes species name (local name), tree diameter at breast height or above buttress, tree height and bole height and buttress height. The quality of the trees was also recorded for both stem and crown quality. Inside the plots, it was not only trees to be measured but also bamboo, rattan and other palms. At cluster level, general information such as, ecosystem type, forest type, land system, altitude, aspect, slope, terrain and logging history was also recorded. All trees measured in sub plots according to the size class:

- Sub plot circle with radius = 1 m for measuring seedlings (height less than 1.5 m).
- Sub plot circle with radius = 2 m for measuring saplings (dbh less than 5 cm and height from 1.5 m or more).
- Sub plot circle with radius = 5 m for measuring poles (dbh between 5 cm – 19.9 cm).
- For PSP, all trees inside the recording unit with DBH = 20 cm or more are measured. While for TSP, use BAF = 4 for basal area and volume estimation.

Post stratification

For FREL calculation, land-cover categories for each plot were assigned from land-cover map from the year NFI data that was measured. The information from this post stratification is more relevant to the need for FREL, since the land use types and forest types recorded in the NFI data were different or not adjusted to current land-cover categories used for FREL.

NFI data calculation

For the purpose of FREL, only PSPs data were used for calculation (Tract No. 5). Moreover, only those that fall into natural forest classes were incorporated. A total of 4,450 measurements of PSPs from NFI (1990-2013) across the country were available for data processing and analysis. All individual trees in the plot were examined and plots' information was checked for each plot to ensure correct information, as part of the quality assurance process. The data validation included: (a) checking the location of the plots overlaid with MoFor land cover map, (b) checking the number of recording units (sub-plots) in each plot, (c) checking measurement data through abnormality filtering of DBH and species name of individual trees in the plots, (d) checking information on basal area, stand density, etc.

Of the 4,450 measurement data available from NFI PSPs, 80% was located in forested areas while the remaining located in shrubs or other covers.

From the total PSPs measured, the data validation process reduced the usable number of measurement data to 2,622 (74.1%) for further analysis. These selected PSPs were dominantly located in dryland forest and swamp forest. The mangrove forest were excluded in this FREL submission since there was not enough PSP record has been found in the type.

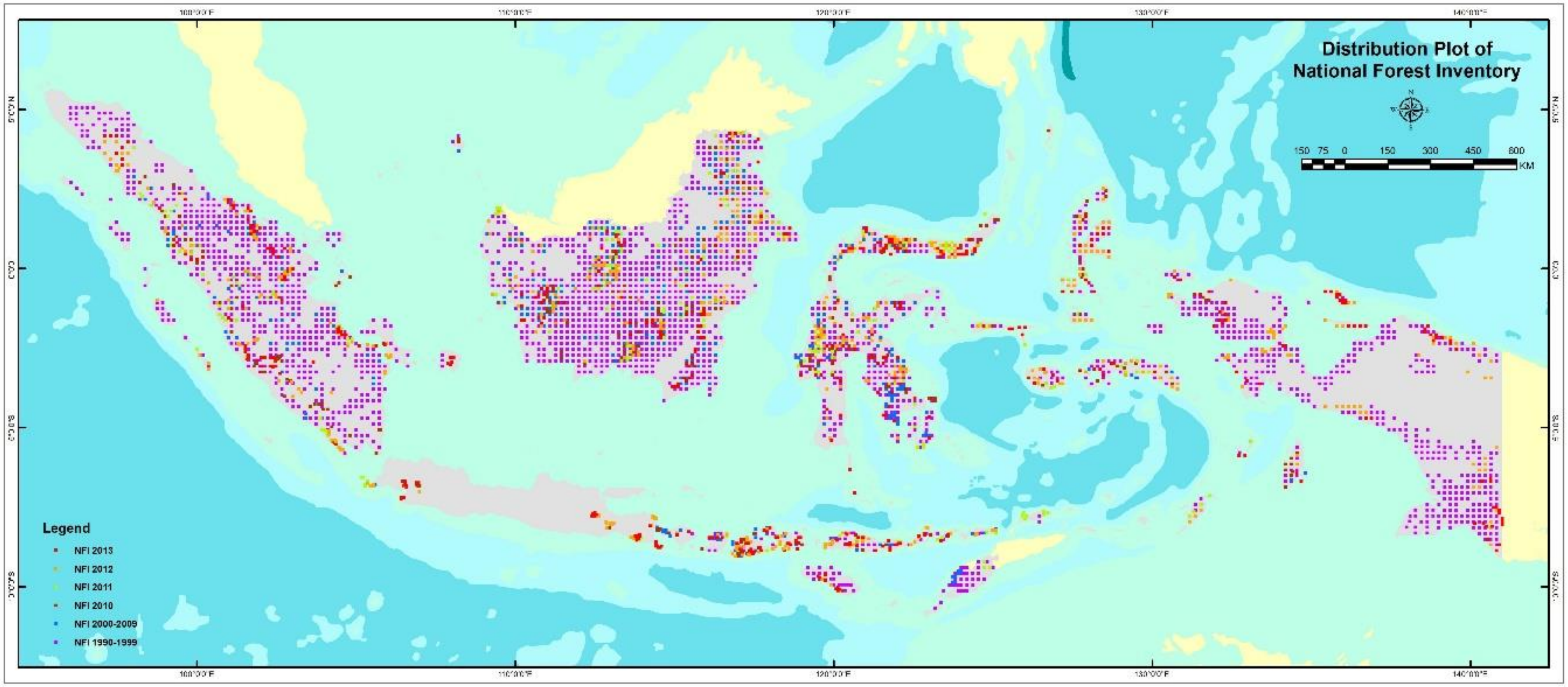

Figure Annex 3.2. NFI's PSP/TSP distribution map.

In order to estimate total tree biomass, field measurement data (DBH, species and tree height) were converted using allometric equation. The availability of local allometric models specific for six forest types were not all represented in seven main islands of Indonesia so this generalized allometric model of Chave *et al*. (2005) was selected, instead.

$$AGB = Exp(-1.499 + 2.148(lnDBH) + 0.207(lnDBH)^3 - 0.0281(lnDBH)^3) * WD$$

Where, AGB is aboveground biomass of individual tree. DBH is diameter at breast height and WD is the wood density.

This model has been found to perform equally well as local models in the Indonesian tropical forests (Rutishauser *et al*., 2013; Manuri *et al*., 2014).

<u>Forest Biomass Proportion</u>

An analysis was conducted to assess the proportion of biomass pools to total forest biomass (exclude soil carbon). A compiled dataset from 4 independent researches carried out in Sumatra and Kalimantan was used for this analysis, these are:

1. Merang peat swamp forest, South Sumatra (Manuri, *et al*. 2011)). A forest biomass inventory was implemented through field measurement of 45 plots randomly distributed across project area of 24 thousand hectares. A nested square and rectangle plots were established for biomass and necromass measurements
2. Former Mega Rice Project area, Central Kalimantan (Krisnawati *et al*., 2014).
3. KPH Kapuas Hulu, West Kalimantan (Manuri *et al*., 2012)
4. UNPAR Forest research area, Katingan, Central Kalimantan (Dharmawan, Saharjo, Supriyanto, HS, & Siregar, 2013)

Table Annex 3.2. Concluded that AGB contributes to more than 70% from total forest biomass, excluding soil. Biomass from understory and seedlings as well as litter play an insignificant role in contributing to total forest biomass, with only 1.9% and 1%, respectively. However, below ground biomass (BGB) and necromass share 14.3% and 13.6% respectively. As they share more than 10% contribution, BGB and necromass should be included in the next submissions.

Table Annex 3.2. *Biomass pool on various research projects in Sumatera and Kalimantan*

Forest types	Understorey and seedlings		AGB		BGB		Necromass		Litter		Total	Sites
	ton Biomass	%	ton Biomass	%	ton Biomass	%	ton Biomass	%	ton Biomass	%	ton Biomass	
Dense peat swamp logged over forest	-	-	254	86.8%	23.7	8.1%	15	5.1%	0.11	0.0%	292.7	South Sumatra[1]
Medium peat swamp logged over forest	-	-	223	88.4%	21.1	8.4%	8.18	3.2%	0.16	0.1%	252.3	South Sumatra[1]
Secondary peat swamp forest-mahang	-	-	108	90.6%	11.2	9.4%	0	0.0%	0.1	0.1%	119.2	South Sumatra[1]
Average Peat swamp South Sumatra								**2.8%**		**0.1%**		
Primary forest	1.9	0.4%	296.8	68.2%	86.5	19.9%	49.9	11.5%	9	2.1%	435.1	Central Kalimantan[2]
Secondary forest	8.2	2.4%	201	59.3%	63.3	18.7%	66.3	19.6%	7.4	2.2%	338.8	Central Kalimantan[2]
Primary swamp forest	5.1	1.6%	216.2	69.7%	48.7	15.7%	40	12.9%	3.5	1.1%	310.0	Central Kalimantan[2]
Secondary swamp	7	2.5%	183.1	66.4%	41.8	15.2%	43.8	15.9%	4.3	1.6%	275.7	Central Kalimantan[2]
Average Central Kalimantan		**1.8%**						**15.0%**		**1.7%**		
Heath Forest	-	-	303.9	59.2%	60.8	11.8%	148.9	29.0%	-	-	513.6	West Kalimantan[3]
Hill - Sub Forest	-	-	243.6	74.5%	48.7	14.9%	34.6	10.6%	-	-	327.0	West Kalimantan[3]
Lowland Forest	-	-	328.7	73.9%	65.7	14.8%	50.1	11.3%	-	-	444.5	West Kalimantan[3]
Peat Forest	-	-	331.0	69.8%	66.2	14.0%	76.8	16.2%	-	-	474.0	West Kalimantan[3]
Secondary Heath Forest	-	-	240.9	45.4%	48.2	9.1%	240.9	45.5%	-	-	530.0	West Kalimantan[3]
Secondary Low Forest	-	-	98.2	75.2%	19.6	15.0%	12.8	9.8%	-	-	130.6	West Kalimantan[3]
Secondary Peat Swamp Forest	-	-	312.7	72.8%	62.5	14.6%	54.3	12.6%	-	-	429.6	West Kalimantan[3]
Average West Kalimantan								**19.3%**				
Primary peat forest	5.0	2.4%	141.2	68.2%	29.7	14.3%	28.9	13.9%	2.3	1.1%	207.0	Central Kalimantan[4]
Average all		**1.9%**		**71.2%**		**13.6%**		**14.5%**		**1.0%**		

Reference:

Dharmawan, I. W. S., Saharjo, B. H., Supriyanto, Arifin, H. S. and Siregar, C. A. (2013). *Allometric Equation And Vegetation Carbon Stock At Primary And Burnt Peat Forest.*: Forest Research and Nature Conservation Journal Vol. 10 No. 2(p. 175-191).

Annex 4. Measuring emissions from peat fires

According to the IPCC Supplement for Wetland (Hiraishi *et al.*, 2014), emissions from organic soil fires are calculated with the following formula:

$$L_{fire} = A \times MB \times CF \times G_{ef}$$

Where, $L_{fire}L_{fire}$is emission from peat fires, A is burned peat area, MB is mass of fuel available for combustion, CF is combustion factor (default factor = 1.0) and G_{ef} is emissions factor.

Tier 1 estimation of peat fire emission requires data on burn scar area. The currently available methods for determining burned scar area are based on low resolution MODIS images or hotspots analysis (MRI, 2013). However, the MODIS collection of 5 burned area (MCD45A1) data had no observation over SE Asia regions, especially for major Islands of Indonesia.

The following is the method adapted from MRI (2013) to generate burn scar map in peatland based on hotspot analysis. The method was developed from a REDD+ demonstration activity project in Central Kalimantan. First, hotspots data were compiled annually from the baseline years (e.g. 1990, 1991, 1992, 1993, etc). To improve certainty, only hotspots with confidence level of more than 80% were selected. As MODIS hotspots were not available for the period before 2000, NOAA hotspot might be used for to fill the gap. However, assessment of the comparability and the accuracy of NOAA hotspots need to be assessed, as they do not have the information on the confidence level. Second, a raster map with 1×1 km grid (pixel size) were generated and overlaid on top of the hotspot data. Pixels without hotspots were considered as areas that were not burned and excluded from the activity data. Each 1km ×1 km pixel with at least one hotspot is considered to be burned with the burned area of 7,500 ha (75% of the pixel area). This rule applies for each pixel regardless the number of the hotspots within a particular pixel (Figure Annex 4.1). Then, these area were overlaid to the peat land map (i.e. produced by MoA) to estimate the peat land burned area for one consecutive year.

Some critical issues on the accuracy of the burn scar, lies on the assumptions used to estimate the size and intensity of the fires. Hotspots are just an indication of active fire existence through thermal differentiation with neighboring pixels. Thus, false detection are possible to occur. Selection of hotspot with high confidence level could reduce such error. However smoke coverage is very common during fire season, thus reducing capability of the sensor to detect fires covered by smokes. This could result in underestimation of the burned areas. In addition, assuming that the burned area is 75% for each pixel with hotspot will lead to a severe overestimate of the area, especially in the border area between burned and unburned. Further challenge lies in providing information on peat depth consumed by fires. Relationship analysis between hotspot parameters (fire intensity, frequency etc) with burned peat depth need to be carried out to better estimate the peat depth of the burned peatland. Ballhorn *et al.* (2009) used airborne LIDAR for estimating burned peat depth with accuracy of less than 20 cm. More similar research need to be carried out at various fire intensities and frequencies.

With above conditions and high level of uncertainty, this FREL document did not include emission from peat fires. Advance technology in remote sensing to improve burned scar and peat depth mapping, will increase the accuracy of peat fire emission improvement in the future FREL.

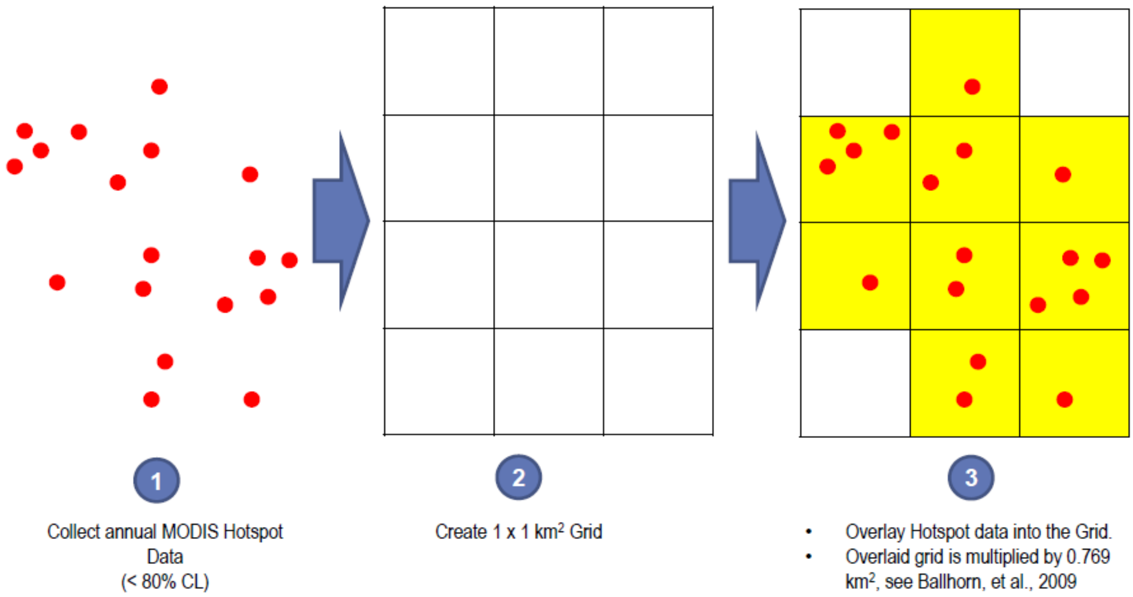

Figure Annex 4.1. *Methodology to derive burned area (activity data)*

Mass of fuel available for combustion

Mass of fuel available for combustion, MB, is estimated from multiplication of mean depth of burned peat (D) and bulk density (BD), assuming average peat depth burned by fire is 0.33 m (Ballhorn *et al.*, 2009) and bulk density is 0.153 ton/m^3 (Mulyani *et al.*, 2012). Resulted mass available for combustion is 0.05049 ton/m2 or 504.9 ton/ha.

Emission factor

CO_2 emission factor (G_{ef}) can be indirectly estimated from organic carbon content (C_{org}, % of weight), which is equal to:

$$G_{ef} = C_{org} \times 3.67$$

C_{org} can be estimated by the following equation :

$$C_{org} = \frac{(1 - {M_{ash}}/{M_s})}{1.724} \times 3.67$$

Where Ms is mass of soil solids, which is equal to accumulation mass of ash (Mash) and mass of organic matters. Ratio of Mash and Ms is 14.04%, which is the mean ash contents of three peat types; namely, Sapric (4.98%), Hemic (21.28%) and Fibric (15.85%) (*see* Mulyani *et al.*, 2012).

Adjustment factor of 1/1.724 is used to convert organic matter estimate to organic carbon content. Estimated C_{org} C_{org} is 49.86% (or kg/kg), which is equal to 498.6 C g/kg dry matter burnt.

If the value is converted to CO_2e estimate, the value would be C_{org} C_{org} x 3.67 = 1,828.2 CO_2 g/kg dry matter burnt or 1,828.2 CO_2 kg/ton. Assuming of 1 ha peat burning, CO_2 emissions released to the atmosphere is:

$$L_{fire} = A \times MB \times CF \times G_{ef}$$

= 1 ha × 504.9 t/ha × 1,828.2 kg/t
= 923,058.18 kg/ha
= 923.1 tCO_2e/ha

This result is used as emission factor of burned peat, considering peat lands suffer more than one fire event release half of CO_2 compared to that of the previous burning, e.g. first burning of 1 ha peat emits 923.1 tCO_2, while the subsequent burning of exactly the same area will release 462 tCO_2.

Historical emission from peat fire

Similar to the area of calculation for FREL submission i.e. in the natural forest of 2000, it was found that the annual estimated burned peat areas were varied from 2001 to 2012 (Figure Annex 4.2). The highest occurrence was found in 2006 that accounts for 95,147 ha of burned peat area, while the lowest occurrence was found in 2007 that accounts for 3,446 ha of burned peat area. Using this historical data set, the average value was used as the activity data for proposed REL from burned peat that accounts for 29,379 ha.

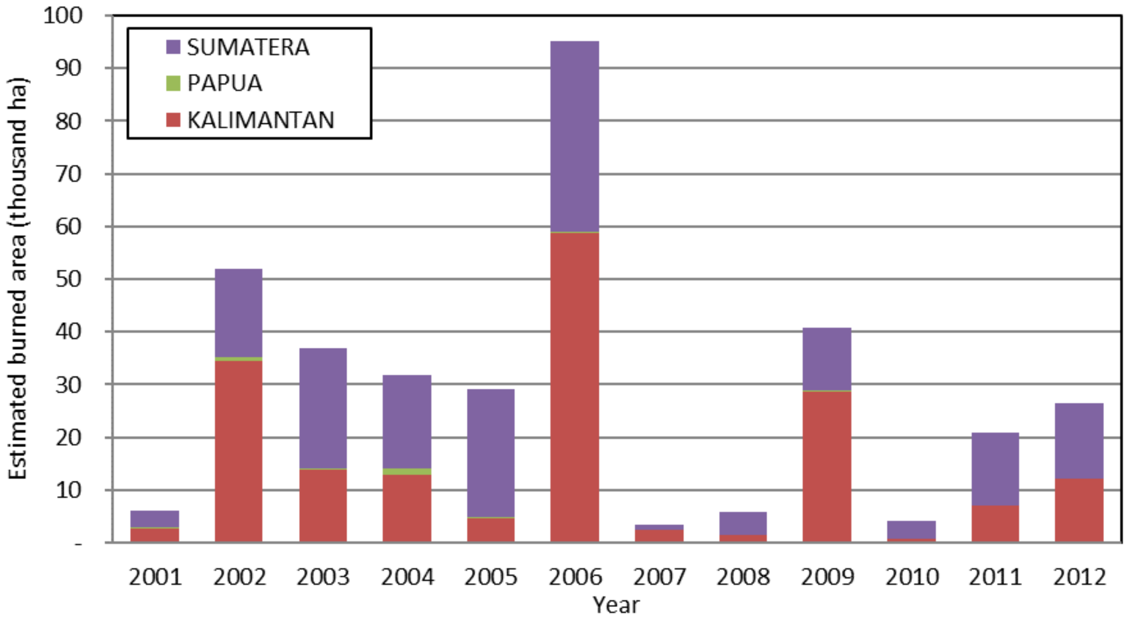

Figure Annex 4.2. *Estimated burned peat area (in the natural forest of 2000)*

Emission from burned peat was calculated historically as described in Figure Annex 4.3. Average emission from peat fire from 2000 – 2012 was 27.1 $MtCO_2e$ yr^{-1}. The method used for burned area mapping has not been verified using ground thruthing or other high-resolution data. Therefore uncertainty level cannot be estimated.

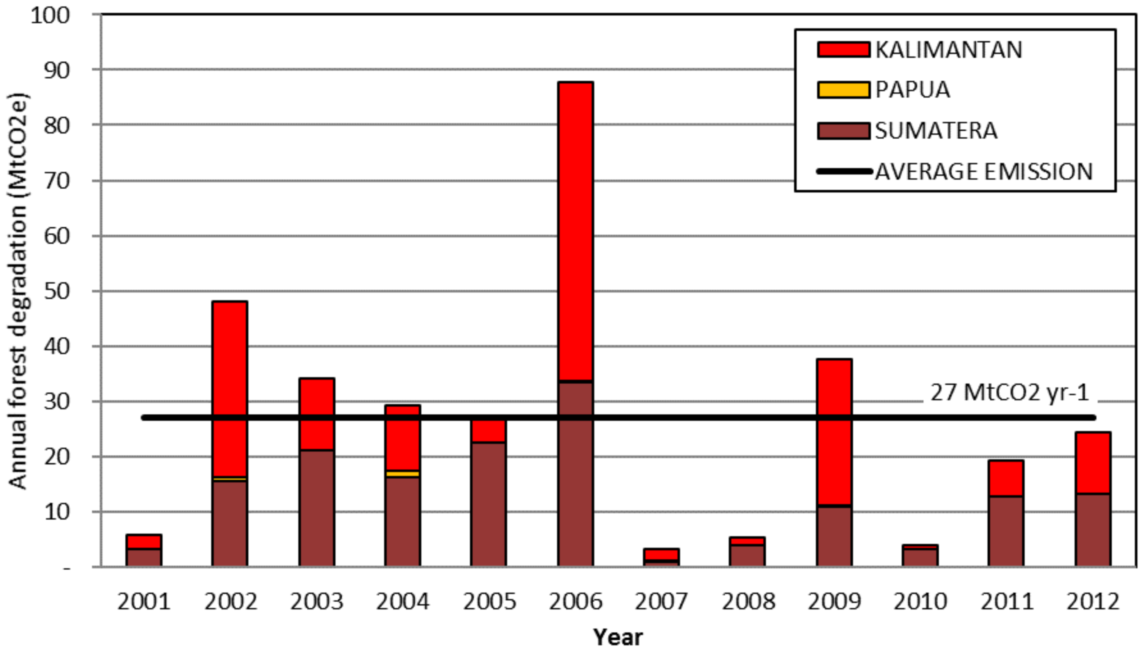

Figure Annex 4.3. *Estimated historical emission from burned peat (in the natural forest of 2000)*

References

Ballhorn, U., Siegert, F., Mason, M. and Limin, S. 2009 Derivation of burn scar depths and estimation of carbon emissions with LIDAR in Indonesian peatlands. *Proceedings of the National Academy of Sciences of the United States of America*, **106** (50), 21213-21218.

Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (2014). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: *Wetlands* (p. 354). Intergovermental Panel on Climate Change: (IPPC), Switzerland.

MRI (2013). *Green House Gas Reduction Project through Forest Conservation in Peat land in Central Kalimantan*: Mitsubisi Rerearch Intititute, Inc.

Mulyani, et al. (2012). *Basis Data Karakteristik Tanah Gambut Di Indonesia*. Prosiding Seminar Nasional Pengelolaan Lahan Gambut Berkelanjutan 4 Mei 2012: From http://balittanah.litbang.deptan.go.id

Annex 5. Detail calculation on emission from deforestation, forest degradation and the associated peat decomposition

Table Annex 5.1. *Deforestation*

Island/Soil/ Land Cover	Deforestation (ha)						
	1990-1996	1996-2000	2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
SUMATERA	**1,269,347**	**3,868,484**	**379,847**	**951,138**	**1,420,549**	**502,062**	**367,706**
PEAT	**346,189**	**1,200,950**	**128,343**	**413,308**	**433,076**	**204,652**	**108,510**
Primary Dryland Forest	85	1,031					
Secondary Dryland Forest	17,243	80,591	5,794	5,470	14,920	2,708	3,691
Primary Mangrove Forest		6			0		
Secondary Mangrove Forest	833	377	1,194	1,177	751	1,087	547
Primary Swamp Forest	9,517	70,447		3,507	37,901	10,757	5,678
Secondary Swamp Forest	318,510	1,048,498	121,355	403,154	379,503	190,100	98,595
MINERAL	**923,158**	**2,667,534**	**251,504**	**537,830**	**987,473**	**297,410**	**259,195**
Primary Dryland Forest	133	11,396	862	4,504	8,063	7,871	7,300
Secondary Dryland Forest	410,691	2,052,701	156,207	281,236	752,153	181,813	202,431
Primary Mangrove Forest	198	2,680		256	1,043	110	715
Secondary Mangrove Forest	6,976	54,771	9,730	9,142	24,441	2,906	5,485
Primary Swamp Forest	389	59,020	16	299	5,001	236	134
Secondary Swamp Forest	504,770	486,967	84,689	242,392	196,772	104,473	43,130
KALIMANTAN	**2,530,446**	**2,091,536**	**612,710**	**948,730**	**1,021,058**	**458,046**	**292,796**
PEAT	**598,304**	**271,908**	**76,738**	**149,012**	**234,606**	**99,684**	**52,164**
Primary Dryland Forest	3,323	3,037					
Secondary Dryland Forest	116,729	4,000	2,710	5,554	5,580	1,407	2,054
Primary Mangrove Forest		983	1			213	
Secondary Mangrove Forest	24,434		24	4,796	341	19	66
Primary Swamp Forest	15,463	5,262		478	3,837	2,058	339
Secondary Swamp Forest	438,355	258,624	74,003	138,183	224,847	95,987	49,704
MINERAL	**1,932,142**	**1,819,628**	**535,971**	**799,718**	**786,452**	**358,362**	**240,632**
Primary Dryland Forest	35,567	137,109	465	5,496	2,968	362	6,968
Secondary Dryland Forest	1,054,274	1,436,262	358,519	548,310	584,102	273,274	194,914
Primary Mangrove Forest	11	17,102	2,727	1,379	493	133	164
Secondary Mangrove Forest	41,786	8,461	51,918	80,470	22,061	3,608	8,768
Primary Swamp Forest	22,087	29,984	14	370	3,237	7	600
Secondary Swamp Forest	778,417	190,709	122,329	163,693	173,591	80,977	29,219
PAPUA	**477**	**1,219,820**	**83,711**	**247,777**	**115,232**	**31,876**	**43,003**
PEAT	**21**	**137,504**	**12,319**	**12,394**	**11,987**	**1,729**	**1,039**
Primary Dryland Forest		20,888	594	668	48	229	590
Secondary Dryland Forest		9,796	1,569	2,459	1,848	1,359	298
Primary Mangrove Forest	21	1,802			52		37
Secondary Mangrove Forest		335	258	204	212	10	49
Primary Swamp Forest		68,036	454	2,561	4,911	105	66
Secondary Swamp Forest		36,647	9,445	6,502	4,916	25	
MINERAL	**456**	**1,082,316**	**71,392**	**235,383**	**103,246**	**30,147**	**41,964**
Primary Dryland Forest	263	280,696	1,951	31,647	17,442	14,118	9,116
Secondary Dryland Forest		328,598	32,501	156,181	69,499	9,952	22,597
Primary Mangrove Forest	193	36,700		33	49	88	173
Secondary Mangrove Forest		34,420	2,408	8,035	372	339	238
Primary Swamp Forest		118,297	136	936	8,403	4,974	1,532
Secondary Swamp Forest		283,604	34,396	38,552	7,481	677	8,308
SULAWESI	**27,116**	**1,029,932**	**211,295**	**274,363**	**140,533**	**74,658**	**19,448**
MINERAL	**27,116**	**1,029,932**	**211,295**	**274,363**	**140,533**	**74,658**	**19,448**
Primary Dryland Forest	849	187,185	5,391	12,887	4,327	18,996	1,892
Secondary Dryland Forest	21,682	779,181	202,273	253,483	121,052	54,885	17,268
Primary Mangrove Forest	10	8,905	59	75	193	116	
Secondary Mangrove Forest	851	17,298	3,171	6,109	3,722	556	223
Primary Swamp Forest		6,150					
Secondary Swamp Forest	3,724	31,213	401	1,809	11,239	105	65
JAWA	**35**	**208,685**	**11,414**	**43,541**	**13,244**	**6,100**	**1,294**
MINERAL	**35**	**208,685**	**11,414**	**43,541**	**13,244**	**6,100**	**1,294**
Primary Dryland Forest		44,478	58	2,872	84	150	
Secondary Dryland Forest	35	161,600	11,128	40,099	6,377	5,943	1,294
Primary Mangrove Forest		1,498		6			
Secondary Mangrove Forest		1,078	228	564	6,783	7	
Primary Swamp Forest		30					
Secondary Swamp Forest							
BALI NUSA	**1,552**	**215,758**	**8,011**	**33,787**	**4,877**	**3,612**	**55,092**
MINERAL	**1,552**	**215,758**	**8,011**	**33,787**	**4,877**	**3,612**	**55,092**
Primary Dryland Forest		34,272	3,838	1,097	190	146	1,409
Secondary Dryland Forest	1,552	179,579	4,156	32,530	4,687	3,194	52,111
Primary Mangrove Forest		579				157	1,569
Secondary Mangrove Forest		1,104	17	39		115	3
Primary Swamp Forest				118			
Secondary Swamp Forest		224		3			
MALUKU		**386,569**	**26,098**	**28,573**	**25,965**	**24,687**	**6,713**
MINERAL		**386,569**	**26,098**	**28,573**	**25,965**	**24,687**	**6,713**
Primary Dryland Forest		41,696	38	36	309	1,732	10
Secondary Dryland Forest		323,170	26,019	28,343	25,371	21,911	6,590

Island/Soil/ Land Cover	Deforestation (ha)						
	1990-1996	1996-2000	2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
Primary Mangrove Forest		224	18	13	188	1	112
Secondary Mangrove Forest		561	23	180	48	22	
Primary Swamp Forest		2,499					
Secondary Swamp Forest		18,418			50	1,021	
Grand Total	**3,828,973**	**9,020,783**	**1,333,085**	**2,527,909**	**2,741,459**	**1,101,040**	**786,052**
Annual Rate	**638,162**	**2,255,196**	**444,362**	**842,636**	**913,820**	**550,520**	**786,052**

Table Annex 5.2. *Forest Degradation*

Island/Soil/ Land Cover	Forest Degradation (ha)						
	1990-1996	1996-2000	2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
SUMATERA	**33,212**	**372,550**	**3,835**	**30,554**	**70,409**	**45,463**	**2,346**
PEAT	**20,504**	**1,807**	**3,406**	**17,210**	**33,571**	**15,421**	**2,228**
Primary Dryland Forest		597					
Primary Mangrove Forest		313			258		
Primary Swamp Forest	20,504	897	3,406	17,210	33,313	15,421	2,228
MINERAL	**12,708**	**370,743**	**429**	**13,344**	**36,838**	**30,042**	**118**
Primary Dryland Forest	796	361,474	147	10,520	3,595	24,480	26
Primary Mangrove Forest	10,836	9,176	181	503	28,134	2,939	
Primary Swamp Forest	1,076	93	100	2,321	5,109	2,624	93
KALIMANTAN	**255,059**	**1,098,826**	**810,510**	**388,703**	**70,608**	**18,019**	**10,210**
PEAT	**14,317**	**2,053**	**2,678**	**3,011**	**740**	**166**	**10,210**
Primary Dryland Forest	1,582	1,524	12	93			10,210
Primary Mangrove Forest							
Primary Swamp Forest	12,735	529	2,667	2,918	740	166	
MINERAL	**240,742**	**1,096,774**	**807,832**	**385,692**	**69,868**	**17,853**	
Primary Dryland Forest	231,352	1,095,810	802,093	373,133	67,975	17,713	
Primary Mangrove Forest	72	12	5,546	8,347	1,887		
Primary Swamp Forest	9,318	951	193	4,212	7	140	
PAPUA		**1,545,144**	**809,285**	**696,516**	**992,217**	**62,177**	**6,165**
PEAT		**87,999**	**31,391**	**62,525**	**47,726**	**5,941**	**710**
Primary Dryland Forest		87,598	16,072	31,354	14,533	535	
Primary Mangrove Forest			824	446	3,205	255	
Primary Swamp Forest		400	14,496	30,725	29,988	5,151	710
MINERAL		**1,457,145**	**777,894**	**633,991**	**944,491**	**56,236**	**5,455**
Primary Dryland Forest		1,455,390	682,923	492,231	817,699	37,989	1,009
Primary Mangrove Forest		94	7,823	13,135	5,547	53	
Primary Swamp Forest		1,661	87,148	128,625	121,244	18,194	4,445
SULAWESI	**98,457**	**1,899,278**	**406,494**	**832,039**	**97,610**	**186,799**	**10,462**
MINERAL	**98,457**	**1,899,278**	**406,494**	**832,039**	**97,610**	**186,799**	**10,462**
Primary Dryland Forest	97,951	1,898,849	403,503	829,162	95,666	186,707	10,462
Primary Mangrove Forest	507	430	2,991	2,877	1,944	92	
Primary Swamp Forest							
JAWA		**28,641**	**785**	**28,283**	**267,460**		
MINERAL		**28,641**	**785**	**28,283**	**267,460**		
Primary Dryland Forest		28,641	710	28,283	266,518		
Primary Mangrove Forest			75		942		
Primary Swamp Forest							
BALI NUSA		**275,015**	**3,558**	**3,369**	**59,491**	**2,107**	**15,010**
MINERAL		**275,015**	**3,558**	**3,369**	**59,491**	**2,107**	**15,010**
Primary Dryland Forest		275,015	3,295	3,369	59,457	2,107	14,387
Primary Mangrove Forest			263		33		624
Primary Swamp Forest							
MALUKU		**219,216**	**11,843**	**180,393**	**5,266**	**7,460**	
MINERAL		**219,216**	**11,843**	**180,393**	**5,266**	**7,460**	
Primary Dryland Forest		219,144	11,843	10,359	56	7,375	
Primary Mangrove Forest		72		170,034	5,210	85	
Primary Swamp Forest							
Grand Total	**386,729**	**5,438,670**	**2,046,309**	**2,159,856**	**1,563,061**	**322,024**	**44,193**
Annual Rate	**64,455**	**1,359,667**	**682,103**	**719,952**	**521,020**	**161,012**	**44,193**

Annex 6. Matrix for peat decomposition calculation

Transition matrix of peat decomposition emission was created using data of emission factor (Table 3). The emission factors were adjusted into dimension of activity data and provided in matrix of 23 x 23 cell following the 23 class of land cover class. The diagonal cells (blue and red) are the emission factor for areas that remain in the same land cover class. For example, emission factor for agriculture crop is 38 ton CO_2e ha-1 y-1. The above or below cells (white) from the diagonal cells represent emission factors for the areas that change during. Having assumption that area of change occurred gradually, the associated emission factors were calculated as an average of land cover before and after the change. For example, the area that change from dry-lowland forest into agriculture crop will have an emission factor of 29.5 CO_2e ha-1 y-1, which is the average emission factor between dry-lowland forest (40 CO_2e ha-1 y-1) and agriculture crop (19 CO_2e ha-1 y-1).

Total value of peat decomposition was generated from multiplication of value in a cell of emission factor with value from similar cell in activity data provided in table Annex 6.2.

Table Annex 6.1. *Transition Emission Matrix.*

	LC	T1																						
		PF	SF	PMF	SMF	PSF	SSF	TP	EP	AUA	MxUA	Sr	SSr	Sv	Rc	Sw	Po	Tr	Se	Ai	Mn	Br	WB	Ot
T0	PF	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0		25.5	25.5	0	0
	SF	9.5	19	9.5	19	9.5	19	46	19	29.5	19	35	35	26.5	27	9.5	9.5	27	9.5	35	35	35	9.5	9.5
	PMF	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0	25.5	25.5	25.5	0	0
	SMF	9.5	19	9.5	19	9.5	19	46	19	29.5	19	35	35	26.5	27	9.5	9.5	27	9.5	35	35	35	9.5	9.5
	PSF	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0	25.5	25.5	25.5	0	0
	SSF	9.5	19	9.5	19	9.5	19	46	19	29.5	19	35	35	26.5	27	9.5	9.5	27	9.5	35	35	35	9.5	9.5
	TP	36.5	46	36.5	46	36.5		73	46	56.5	46	62	62	53.5	54	36.5	36.5	54	36.5	62	62	62	36.5	36.5
	EP	9.5	19	9.5	19	9.5	19	46	19	29.5	19	35	35	26.5	27	9.5	9.5	27	9.5	35	35	35	9.5	9.5
	AUA	20	29.5	20	29.5	20	29.5	56.5	29.5	40	29.5	45.5	45.5	37	37.5	20	20	37.5	20	45.5	45.5	45.5	20	20
	MxUA	9.5	19	9.5	19	9.5	19	46	19	29.5	19	35	35	26.5	27	9.5	9.5	27	9.5	35	35	35	9.5	9.5
	Sr	25.5	35	25.5	35	25.5	35	62	35	45.5	35	51	51	42.5	43	25.5	25.5	43	25.5	51	51	51	25.5	25.5
	SSr	25.5	35	25.5	35	25.5	35	62	35	45.5	35	51	51	42.5	43	25.5	25.5	43	25.5	51	51	51	25.5	25.5
	Sv	17	26.5	17	26.5	17	26.5	53.5	26.5	37	26.5	42.5	42.5	34	34.5	17	17	34.5	17	42.5	42.5	42.5	17	17
	Rc	17.5	27	17.5	27	17.5	27	54	27	37.5	27	43	43	34.5	35	17.5	17.5	35	17.5	43	43	43	17.5	17.5
	Sw	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0	25.5	25.5	25.5	0	0
	Po	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0	25.5	25.5	25.5	0	0
	Tr	17.5	27	17.5	27	17.5	27	54	27	37.5	27	43	43	34.5	35	17.5	17.5	35	17.5	43	43	43	17.5	17.5
	Se	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0	25.5	25.5	25.5	0	0
	Ai	25.5	35	25.5	35	25.5	35	62	35	45.5	35	51	51	42.5	43	25.5	25.5	43	25.5	51	51	51	25.5	25.5
	Mn	25.5	35	25.5	35	25.5	35	62	35	45.5	35	51	51	42.5	43	25.5	25.5	43	25.5	51	51	51	25.5	25.5
	Br	25.5	35	25.5	35	25.5	35	62	35	45.5	35	51	51	42.5	43	25.5	25.5	43	25.5	51	51	51	25.5	25.5
	WB	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0	25.5	25.5	25.5	0	0
	Ot	0	9.5	0	9.5	0	9.5	36.5	9.5	20	9.5	25.5	25.5	17	17.5	0	0	17.5	0	25.5	25.5	25.5	0	0

Table Annex 6.2. *Transition Area Matrix of Land Cover. "Yellow" is total emission, "red" is emission from secondary forest, "green" is emission from forest degradation, emission from deforestation = yellow-red-green.*

LC		T1 (1996)																							Total
		PF	SF	PMF	SMF	PSF	SSF	TP	EP	AUA	MxUA	Sr	SSr	Sv	Rc	Sw	Po	Tr	Se	Ai	Mn	Br	WB	Ot	
T0 (1996)	PF	aPFPF	aPFSF		aPF SMF		aPFSSF			aPFAUA															
	SF	aSFPF	aSFSF							aSMF AUA															
	PMF		aPMFSF	aPMFPMF	aPMFSMF		aPMFSSF																		
	SMF				aSMFSMF																			aSMFOt	
	PSF		aPSFSF		aPSFSMF	aPSFPSF	aPSFSSF																		
	SSF						aSSFSSF															aPSFBr			
	TP															aSSFSw									
	EP																								
	AUA									aAUAAUA															
	MxUA																								
	Sr																								
	SSr																								
	Sv																								
	Rc																								
	Sw															aSwSw									
	Po																								
	Tr																								
	Se																								
	Ai																								
	Mn																								
	Br																								
	WB																								
	Ot									aOtAUA														aOtOt	
Total																									

Annex 7. Uncertainty analysis

Uncertainty analysis for overall emission was calculated following the IPCC 2006 Guidelines, volume 1. Chapter 3. The uncertainty from activity data and emission factors attributed to deforestation and forest degradation were combined using following equation.

$$Uij = \sqrt{EAij^2 + EEij^2}$$

U : Combined Uncertainty
EA : Uncertainty from Activity Data
EE : Uncertainty from emission factor
i : Forest cover class
j : Activity (Deforestation/Forest Degradation)

Uncertainties from activity data of forest degradation and deforestation were derived from the overall accuracy assessment of land cover map against ground truth points. The assessment was conducted for all 23 classes and concluded that the overall accuracy is 88% (MoFor, 2012, Margono *et al*. 2012).

The uncertainties of emission factor were generated from standard error of carbon stock values from every forest types/classes in each major island/group of island. The carbon stock was estimated from the NFI plots that provided in seven major island/group of island.

For peat decomposition, uncertainty of activity data derived from the overall accuracy of peat land mapping (80%) (Ritung *et al*. 2011), while for uncertainty values of peat emission factors were derived from Hiraishi et al., (2014) default values. Since the AGB emissions calculation using Tier 2 accuracy, the uncertainty level for forest degradation and deforestation is lower than that of peat emissions.

A proportion of accuracy contribution (C_{ij}) was calculated from activity j that occurs in forest cover class i, by involving the uncertainty (U_{ij}), total emissions occurred in the corresponding forest cover classes and activities (E_{ij}) and total emission from the corresponding year (E). Total uncertainty of each year (TU), was derived from a square root of sum C*ij*.

$$C_{ij} = (E_{ij} * U_{ij})^2 / E$$

$$TU = \sqrt{\sum C_{ij}}$$

Using the above equations, the detail of uncertainty analysis for each assessment periods is shown in the table below.

Table Annex 7.1. *Uncertainty analysis for period 1990-1996*

Island	Emissions Source	Gas	GHG Emissions	Activity data uncertainty	Emission factor/estimation parameter uncertainty	Combined uncertainty $\sqrt{E^2+F^2}$	Contribution to Variance by Category in Year *Base Year* $\frac{(G \bullet C)^2}{(\Sigma C)^2}$
			Gg CO_2 equivalent	%	%	%	
Jawa	Deforestation	CO_2	1,713	12	10	15.62	0.00
	Forest Degradation	CO_2	0	12	10	15.62	0.00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	137,900,425	12	3	12.37	22.66
	Forest Degradation	CO_2	5,088,902	12	3	12.37	0.03
	Peat Decomposition	CO_2	72,384,943	20	50	53.85	118.36
Maluku	Deforestation	CO_2	0	12	9	15.00	0.00
	Forest Degradation	CO_2	0	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	72,607	12	9	15.00	0.00
	Forest Degradation	CO_2	0	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	34,320	12	4	12.65	0.00
	Forest Degradation	CO_2	0	12	4	12.65	0.00
	Peat Decomposition	CO_2	7,346,737	20	50	53.85	1.22
Sulawesi	Deforestation	CO_2	1,541,804	12	4	12.65	0.00
	Forest Degradation	CO_2	1,943,597	12	4	12.65	0.00
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	59,361,825	12	4	12.65	4.39
	Forest Degradation	CO_2	644,061	12	4	12.65	0.00
	Peat Decomposition	CO_2	71,981,241	20	50	53.85	117.04
		...					
	Total		358,302,174			$\sum H$	263.7
					Percentage uncertainty in total inventory:		16.24

Table Annex 7.2. *Uncertainty analysis for period 1996-2000*

Island	Emissions Source	Gas	GHG Emissions	Activity data uncertainty	Emission factor/estimation parameter uncertainty	Combined uncertainty $\sqrt{E^2+F^2}$	Contribution to Variance by Category in Year *Base Year* $\frac{(G \bullet C)^2}{(\Sigma C)^2}$
			Gg CO_2 equivalent	%	%	%	
Jawa	Deforestation	CO_2	17,250,168	12	10	15.62	0.06
	Forest Degradation	CO_2	1,179,499	12	10	15.62	0.00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	182,553,904	12	3	12.37	4.50
	Forest Degradation	CO_2	31,345,277	12	3	12.37	0.13
	Peat Decomposition	CO_2	72,987,193	20	50	53.85	13.64
Maluku	Deforestation	CO_2	37,918,245	12	9	15.00	0.29
	Forest Degradation	CO_2	7,495,807	12	9	15.00	0.01
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	16,831,945	12	9	15.00	0.06
	Forest Degradation	CO_2	13,246,856	12	9	15.00	0.03
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	99,312,923	12	4	12.65	1.39
	Forest Degradation	CO_2	39,089,457	12	4	12.65	0.22
	Peat Decomposition	CO_2	8,807,612	20	50	53.85	0.20
Sulawesi	Deforestation	CO_2	96,411,996	12	4	12.65	1.31
	Forest Degradation	CO_2	56,265,214	12	4	12.65	0.45
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	286,727,007	12	4	12.65	11.62
	Forest Degradation	CO_2	13,774,064	12	4	12.65	0.03
	Peat Decomposition	CO_2	82,978,743	20	50	53.85	17.63
		...					
	Total		1,064,175,908			$\sum H$	51.6
					Percentage uncertainty in total inventory:		7.18

Table Annex 7.3. *Uncertainty analysis for period 2000-2003*

Island	**Emissions Source**	**Gas**	**GHG Emissions**	**Activity data uncertainty**	**Emission factor/estimation parameter uncertainty**	**Combined uncertainty** $\sqrt{E^2+F^2}$	**Contribution to Variance by Category in Year *Base Year*** $\frac{(G \bullet C)^2}{(\Sigma C)^2}$
			Gg CO_2 equivalent	**%**	**%**	**%**	
Jawa	Deforestation	CO_2	1,126,176	12	10	15.62	0.00
	Forest Degradation	CO_2	41,666	12	10	15.62	0.00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	67,983,716	12	3	12.37	4.62
	Forest Degradation	CO_2	30,854,004	12	3	12.37	0.95
	Peat Decomposition	CO_2	73,766,409	20	50	53.85	103.03
Maluku	Deforestation	CO_2	3,334,564	12	9	15.00	0.02
	Forest Degradation	CO_2	539,975	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	996,253	12	9	15.00	0.00
	Forest Degradation	CO_2	221,015	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	7,926,226	12	4	12.65	0.07
	Forest Degradation	CO_2	25,835,048	12	4	12.65	0.70
	Peat Decomposition	CO_2	10,574,063	20	50	53.85	2.12
Sulawesi	Deforestation	CO_2	25,275,290	12	4	12.65	0.67
	Forest Degradation	CO_2	16,045,387	12	4	12.65	0.27
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	36,309,394	12	4	12.65	1.38
	Forest Degradation	CO_2	153,709	12	4	12.65	0.00
	Peat Decomposition	CO_2	90,370,805	20	50	53.85	154.64
		...					
	Total		391,353,701			$\sum H$	268.5
					Percentage uncertainty in total inventory:		16.38

Table Annex 7.4. *Uncertainty analysis for period 2003-2006*

Island	Emissions Source	Gas	GHG Emissions	Activity data uncertainty	Emission factor/estimation parameter uncertainty	Combined uncertainty $\sqrt{E^2+F^2}$	Contribution to Variance by Category in Year *Base Year* $\frac{(G \bullet C)^2}{(\Sigma C)^2}$
			Gg CO_2 equivalent	%	%	%	
Jawa	Deforestation	CO_2	4,436,623	12	10	15.62	0.02
	Forest Degradation	CO_2	1,552,986	12	10	15.62	0.00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	105,419,288	12	3	12.37	6.12
	Forest Degradation	CO_2	14,910,612	12	3	12.37	0.12
	Peat Decomposition	CO_2	75,165,628	20	50	53.85	58.96
Maluku	Deforestation	CO_2	3,648,628	12	9	15.00	0.01
	Forest Degradation	CO_2	6,552,141	12	9	15.00	0.03
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	3,234,024	12	9	15.00	0.01
	Forest Degradation	CO_2	216,345	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	25,991,493	12	4	12.65	0.39
	Forest Degradation	CO_2	21,189,526	12	4	12.65	0.26
	Peat Decomposition	CO_2	11,510,175	20	50	53.85	1.38
Sulawesi	Deforestation	CO_2	32,988,728	12	4	12.65	0.63
	Forest Degradation	CO_2	32,854,953	12	4	12.65	0.62
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	88,644,298	12	4	12.65	4.52
	Forest Degradation	CO_2	1,319,919	12	4	12.65	0.00
	Peat Decomposition	CO_2	97,512,842	20	50	53.85	99.23
		…					
	Total		527,148,209			$\sum H$	172.3
					Percentage uncertainty in total inventory:		13.13

Table Annex 7.5. *Uncertainty analysis for period 2006-2009*

Island	Emissions Source	Gas	GHG Emissions	Activity data uncertainty	Emission factor/estimation parameter uncertainty	Combined uncertainty $\sqrt{E^2+F^2}$	Contribution to Variance by Category in Year *Base Year* $\frac{(G \bullet C)^2}{(\Sigma C)^2}$
			Gg CO_2 equivalent	%	%	%	
Jawa	Deforestation	CO_2	1,424,791	12	10	15.62	0.00
	Forest Degradation	CO_2	14,668,010	12	10	15.62	0.41
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	112,238,515	12	3	12.37	15.01
	Forest Degradation	CO_2	2,695,646	12	3	12.37	0.01
	Peat Decomposition	CO_2	77,701,513	20	50	53.85	136.38
Maluku	Deforestation	CO_2	3,331,973	12	9	15.00	0.02
	Forest Degradation	CO_2	188,842	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	468,501	12	9	15.00	0.00
	Forest Degradation	CO_2	3,819,775	12	9	15.00	0.03
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	12,295,066	12	4	12.65	0.19
	Forest Degradation	CO_2	31,279,395	12	4	12.65	1.22
	Peat Decomposition	CO_2	12,602,007	20	50	53.85	3.59
Sulawesi	Deforestation	CO_2	16,347,358	12	4	12.65	0.33
	Forest Degradation	CO_2	3,848,351	12	4	12.65	0.02
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	140,294,426	12	4	12.65	24.53
	Forest Degradation	CO_2	2,726,935	12	4	12.65	0.01
	Peat Decomposition	CO_2	109,764,078	20	50	53.85	272.16
		...					
	Total		545,695,181			$\sum H$	453.9
					Percentage uncertainty in total inventory:		21.31

Table Annex 7.6. *Uncertainty analysis for period 2009-2011*

Island	**Emissions Source**	**Gas**	**GHG Emissions**	**Activity data uncertainty**	**Emission factor/estimation parameter uncertainty**	**Combined uncertainty** $\sqrt{E^2+F^2}$	**Contribution to Variance by Category in Year *Base Year*** $\frac{(G \bullet C)^2}{(\Sigma C)^2}$
			Gg CO_2 equivalent	**%**	**%**	**%**	
Jawa	Deforestation	CO_2	909,516	12	10	15.62	0.00
	Forest Degradation	CO_2	0	12	10	15.62	0.00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	75,467,060	12	3	12.37	5.23
	Forest Degradation	CO_2	1,037,268	12	3	12.37	0.00
	Peat Decomposition	CO_2	80,409,848	20	50	53.85	112.56
Maluku	Deforestation	CO_2	4,791,500	12	9	15.00	0.03
	Forest Degradation	CO_2	508,941	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	538,484	12	9	15.00	0.00
	Forest Degradation	CO_2	202,939	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	5,670,503	12	4	12.65	0.03
	Forest Degradation	CO_2	2,633,248	12	4	12.65	0.01
	Peat Decomposition	CO_2	13,136,046	20	50	53.85	3.00
Sulawesi	Deforestation	CO_2	14,418,131	12	4	12.65	0.20
	Forest Degradation	CO_2	11,067,388	12	4	12.65	0.12
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	72,095,845	12	4	12.65	4.99
	Forest Degradation	CO_2	3,061,776	12	4	12.65	0.01
	Peat Decomposition	CO_2	122,196,186	20	50	53.85	259.95
		...					
	Total		408,144,680			$\sum H$	386.1
					Percentage uncertainty in total inventory:		19.65

Table Annex 7.7. *Uncertainty analysis for period 2011-2012*

Island	Emissions Source	Gas	GHG Emissions	Activity data uncertainty	Emission factor/estimation parameter uncertainty	Combined uncertainty $\sqrt{E^2+F^2}$	Contribution to Variance by Category in Year *Base Year* $\frac{(G \bullet C)^2}{(\Sigma C)^2}$
			Gg CO_2 equivalent	%	%	%	
Jawa	Deforestation	CO_2	380,515	12	10	15.62	0.00
	Forest Degradation	CO_2	0	12	10	15.62	0.00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	99,113,621	12	3	12.37	6.50
	Forest Degradation	CO_2	1,164,151	12	3	12.37	0.00
	Peat Decomposition	CO_2	82,154,765	20	50	53.85	84.61
Maluku	Deforestation	CO_2	2,581,187	12	9	15.00	0.01
	Forest Degradation	CO_2	0	12	9	15.00	0.00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	16,006,653	12	9	15.00	0.25
	Forest Degradation	CO_2	2,838,799	12	9	15.00	0.01
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	13,903,308	12	4	12.65	0.13
	Forest Degradation	CO_2	396,533	12	4	12.65	0.00
	Peat Decomposition	CO_2	13,248,513	20	50	53.85	2.20
Sulawesi	Deforestation	CO_2	7,141,031	12	4	12.65	0.04
	Forest Degradation	CO_2	1,239,767	12	4	12.65	0.00
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	109,810,804	12	4	12.65	8.34
	Forest Degradation	CO_2	281,552	12	4	12.65	0.00
	Peat Decomposition	CO_2	130,706,511	20	50	53.85	214.17
		…					
	Total		480,967,710			$\sum H$	316.3
					Percentage uncertainty in total inventory:		17.78

Annex 8. Sustainable management of forest

Sustainable management of forests (SMF) is one of important activities linked to REDD+ program. SMF involves selective cutting, appropriate cutting cycles, sustainable annual cut as well as reduced impact logging (RIL). In Indonesia more than 56 million hectares or corresponds to 52% of total forest area were allocated as production forests. Out of this, 39 million hectares were still forested in 2013 (MoFor, 2014). In 2014, about 276 forest concessions (including ecosystem restoration program) were granted licenses to operating in 21 million hectares production forests. This makes SFM a potential activity to be included in the next submission for Indonesian REDD+ program.

Additionality of emissions reduction from SFM activity will be gained from the implementation of RIL instead of conventional logging and longer period of cutting cycle (Sasaki *et al.*, 2012). A study in East Kalimantan found that RIL could reduce 20% of total stand damage from conventional logging (Bertault and Sist 1997). Furthermore, (Sasaki, *et al*. 2012) concluded that about 41% of CO2 emissions could be avoided from replacing conventional logging into RIL with longer cutting cycle. However (Griscom, et al. 2013) found that comparison between certified and non-certified timber concessions in relation to carbon emissions after RIL implementation was not easily distinctive due to high variability of biophysical aspects as well as history of forest management and investment. Further related research from various sites representing biophysical gradient and investment scales need to be carried out. In addition, research on carbon increment after logging can be done using permanent sample plots established by the timber concessions as well as NFI plots. This would provide improvement for better estimates on the emission reduction from implementing SMF.

Monitoring of forest degradation and selective logging at large scale is still problematic. Medium resolution satellite imageries were not able to accurately detect small disturbance due to selective logging (Asner, *et al*. 2002, Brown, *et al*. 2011). Although a proxy analysis using logging road density and NDVI from coarse resolution imageries explained biomass loss variation in selectively-logged forests (Neba, *et al*. 2014), high resolution imageries are still required for logging roads and gaps detection. However, Pithon, *et al*. (2013) found that automatic detection of logging roads using high resolution optical imageries was still problematic. The use of airborne LiDAR has been intensified since the last decade. A research on monitoring forest degradation in selectively-logged tropical forest using airborne LiDAR came out with a promising result (Andersen, *et al*. 2014). However, the cost associated with LiDAR data acquisition is currently comparable to direct ground measurement (Hummel, *et al*. 2011). Further improvement for more accurate wall-to-wall monitoring on forest degradation and selective logging using reliable and cost effective methods need to be explored.

References

Andersen, H.-E., Reutebuch, S.E., McGaughey, R.J., d'Oliveira, M.V. and Keller, M. 2014 Monitoring selective logging in western Amazonia with repeat lidar flights. Remote Sensing of Environment, 151, 157-165.

Asner, G.P., Keller, M., Pereira, R. and Zweede, J.C. 2002 Remote sensing of selective logging in Amazonia: Assessing limitations based on detailed field observations, Landsat ETM+, and textural analysis. Remote Sensing of Environment, 80 (3), 483-496.

Bertault, J.-G. and Sist, P. 1997 An experimental comparison of different harvesting intensities with reduced-impact and conventional logging in East Kalimantan, Indonesia. Forest Ecology and Management, 94 (1), 209-218.

Brown, S., Casarim, F., Grimland, S. and Pearson, T. 2011 Carbon Impacts from Selective Logging of Forests in Berau District, East Kalimantan, Indonesia.

Hummel, S., Hudak, A., Uebler, E., Falkowski, M. and Megown, K. 2011 A comparison of accuracy and cost of LiDAR versus stand exam data for landscape management on the Malheur National Forest. Journal of forestry, 109 (5), 267-273.

MoFor, 2014. Rekalkulasi penutupan lahan Indonesia tahun 2013. Direktorat Inventarisasi dan Pemantauan Sumber Daya Hutan. DitJend Planologi Kehutanan. Kementrian Kehutanan.

Neba, S.G., Kanninen, M., Atyi, R.E. and Sonwa, D.J. 2014 Assessment and prediction of above-ground biomass in selectively logged forest concessions using field measurements and remote sensing data: Case study in South East Cameroon. Forest Ecology and Management, 329, 177-185.

Pithon, S., Jubelin, G., Guitet, S. and Gond, V. 2013 A statistical method for detecting logging-related canopy gaps using high-resolution optical remote sensing. International Journal of Remote Sensing, 34 (2), 700-711.

Sasaki, N., Chheng, K. and Ty, S. 2012 Managing production forests for timber production and carbon emission reductions under the REDD+ scheme. Environmental Science & Policy, 23, 35-44.