Submission by Indonesia

NATIONAL FOREST REFERENCE EMISSION LEVEL FOR DEFORESTATION AND FOREST DEGRADATION

In the Context of Decision 1/CP.16 para 70 UNFCCC
(Encourages developing country Parties to contribute to mitigation actions in the forest sector)

Republic of Indonesia
2016

The proposed Forest Reference Emission level document was submitted in January 2016; and reviewed by UNFCCC secretariat from February to November 2016.

Published by the Directorate General of Climate Change (DG-PPI)
The Ministry of Environment and Forestry, 2016

Citation:
MoEF, 2016, National Forest Reference Emission Level for Deforestation and Forest Degradation: In the Context of Decision 1/CP.16 para 70 UNFCCC (Encourages developing country Parties to contribute to mitigation actions in the forest sector), Directorate General of Climate Change. The Ministry of Environment and Forestry. Indonesia

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Printed in Indonesia

ISBN: 978-602-73066-1-5

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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 forest 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 had been 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 the data 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 of 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.

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1. Introduction

1.1. Relevance

In its Decision 1/CP.16 Paragraph 70, encouraged the Conference of Parties (COP)-16 in Cancun 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 by 26 % by 2020 compared to 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 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 results-based finance arrangements, including: bilateral (Letter of Intent/LoI Indonesia-Norway, assessment of the potential for results-based payments within a German-Indonesian REDD Early Mover Programme) 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+ activities, 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 based on science, which is not about right or wrong, but about 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". This means that all data and information employed in this submission were based on existing day-by-day systems operated with at-hand national budget, which allow for technical assessment and verification of the data, methodologies, and procedures used. This is important, in particular when the FREL will get into the need of establishing Measurement, Reporting and Verification (MRV), especially MRV for Land-Based sectors. Moreover, the established FREL aims to maintain consistency with data used for National Communications (NatCom), Biennial Update Reports (BUR) and Intended Nationally Determined Contributions (INDC), as well as Nationally Determined Contributions (NDC). The data and methods used for this FREL construction and national reporting on GHG Inventory complies with the 2006 IPCC Guidelines for National GHG Inventory (IPCC, 2006).

Decision 12/CP.17 allows a stepwise approach in submissions 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.

Developments in data availability and clarity as well as in human and institutional capacities facilitate the understanding and transparency of the existing FREL and allow future reviews and revisits. The FREL in this submission is 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.

The scope of area of this submitted FREL covers an area of 113.2 million ha of natural forests as of 1990, which accounted for approximately 78.6 % of the total designated forest areas. The forest areas equal 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. Historical background

This submission was constructed using refined activity data and updated emissions factors (see Annex 1 and 3 for details). Activity data were developed with more consistent and more accurate data on land cover and land cover changes, and over a time period longer than in the initial FREL initiative (now 1990-2012, see below). The updated emission factors better reflect the diversity of forest types and conditions. Furthermore, the data used in this submission have been thoroughly scrutinized in terms of clarity, comprehensiveness, consistency, and comparability – a step that was not done in the previously proposed FREL.

Prior to this FREL submission, there have already been a number of initiatives to calculate a reference emission level for Indonesia. Those were generated at various levels of interest such as national, project, district, and province level. At the national level, FRELs had been initially developed by three different initiatives: Firstly, by a collaboration of the REDD+ Agency of Indonesia and the Ministry of Forestry/MoFor (now Ministry of Environment and Forestry/MoEF). Secondly, by the Indonesia Second National Communication (SNC) that established emission projections for Land Use, Land Use Change and Forestry (LULUCF) up to 2020 (Ministry of Environment, 2010). And thirdly, by the Minister of Forestry Decree No. 633/2014 updated and issued by MoFor.

The first initiative (collaboration of the REDD+ Agency and MoFor, 2014) was for the construction of a national FREL for REDD+ consisting of deforestation and forest degradation activities; the second (under the SNC, 2010) was to develop an emission baseline from LULUCF for the period 2007-2020; and the third initiative (MoFor Decree No. 633/2014) was for a reference level of only deforestation up to 2020. The differences between the three initiatives are (a) the reference period, (b) the activities covered (deforestation/forest degradation), (c) the activity data used (deforestation data), and (d) the emission factors employed.

Table **1** gives an overview on the different parameters used in each initiative. All three initiatives employed the stock difference approach using historical deforestation rate. The submitted FREL (2015 and updated 2016) is an updated version of the first initiative using an extended reference period (see section 1.5 for details).

Table 1. *Comparison of three national initiatives to develop a FREL*

	1. Collaboration REDD+ Agency and MoFor	**2. SNC**	**3. MoFor Decree No. 633/2014**
Reference period	2000-2012	2000-2006	2000-2006
Activities covered	Deforestation and forest degradation	Deforestation	Deforestation
Activity data	Refined LU data MoFor[a]	LU data MoFor (not refined)	LU data MoFor (not refined)
Emission factors	NFI 1990-2013 with complementary research data for mangrove forests[b]	National average data based of different publications [c]	NFI 1990-2013 with complementary research data for mangrove forests[b]

[a] see Annex 1
[b] see Annex 3
[c] see SNC 2010

1.4. The Objectives of this Submission

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

The second objective is to provide a broader audience and stakeholders with clear, transparent, accurate, complete and consistent estimates of emissions projection as a basis for further discussion with organizations 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 results-based payment.

1.5. Process of FREL establishment

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

The FREL was completed by a team 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 considerations and substantial national circumstances. The technical team focused on translating policy implication into quantitative calculation and qualitative explanations, including setting and approving of assumptions and important adjustment, as well as establishing the document. In addition, the role of the technical team was to assure scientific soundness of this submission.

The FREL employed historical land cover data as basis. Four different methods were considered to establish Indonesia's National FREL using historical land cover data: (a) Historical Emissions Method, (b) Adjusted Historical Emissions Method, (c) Forward-Looking Non-Parametric Method, and (d) Forward-Looking Parametric Method. Each option has its advantages and disadvantages; thus comprehensive considerations preceded the choice of the method.

This submission complies with the IPCC guidelines (2006) for National Greenhouse Gas Inventories and the 2013 Wetland supplement to the IPCC guideline 2006. 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, considering that the other methods involved too many and too general assumptions about future policies and developments with a relatively high degree of uncertainty as well as considering the currently available spatial data and information, an empirical model matched best with the requirements for developing the FREL. Thus, the Historical Emissions Method was utilized in this FREL.

Five scenarios for a baseline period were exercised for Indonesia's FREL. Those baseline period scenarios are (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. Chapter 4.2.2 will elaborate further on the reasons for this decision.

2. Definitions Used

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

2.1. Forest

"Forest" has been defined in many ways. In the most common way, the definition reflects the diversity of forests and type of forest ecosystems. In the case of Indonesia, the forest definition also refers to the objective of data establishment (e.g. monitoring purposes), as well as the method used. For this FREL, there are two definitions introduced: "formal right" and "working definition". The formal right definition is a principal definition, mostly based on qualitative forest ecology, and likely based on a law. The working definition refers to practicality, such as limitations of methods and data used. Related forest definitions are explained in Box 1.

Box 1: Forest Definitions

Global Forest Resource Assessment of the Food and Agriculture Organization, as "common/general" reference, defined forest as a land area of more than 0.5 ha with tree canopy cover of more than 10 percent and trees higher than 5 meters at maturity (GFRA FAO, 2010).

Forest is defined as unity of ecosystem in the form of landscape in natural resources dominated by tree communities in the natural world, in which one and the other cannot be separated (National Forestry Law 41/1999).

The Decree of Minister of Forestry of Indonesia, No. 14/2004 on A/R CDM, as "formal right", defined forest 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" (MoFor, 2004).

In a tropical country like Indonesia, a 10 percent canopy cover represents more vegetation types, including other trees and wood lands. In this submission, Indonesia adjusts the FAO forest canopy cover threshold to 30 percent, highlighting the country's natural tropical forest ecosystems, excluding other tree cover and wood lands.

The definition under National Forestry Law is rather qualitative, general and likely complicated for implementation. The GFRA-FAO definition is widely recognized and globally accepted, but does not match Indonesia's intention to emphasize on the country's natural forest ecosystems. Hence, the MoFor Decree under CDM was integrated in the working definition, in particular for the threshold for defining forest (30% canopy cover instead of 10%). Since in this submitted FREL the considered forest is merely natural forest, the criteria employed should only cover natural forest. In case of an area covered by trees which is not natural (i.e. plantation forest), the area is excluded.

Forest in this document, which refers to the "working definition", is defined as "a land area of more than 6.25 ha with trees higher than 5 meters at maturity and a canopy cover of more than 30 percent". The area span is based on the production of land-cover maps through visual interpretation of satellite images at a scale of 1:50.000 where the minimum area for polygon delineation is 0.25 cm^2 which equals to 6.25 ha (minimum mapping unit).

The "formal right definition" is the legal basis, which gives an illustration that would match with the work implemented. Referring to section 1.2., this FREL considers the concept of "practicality". Practicality means that the definition employed needs to relate to operational processes (quantitative), which depend on data availability and reliability. The definition that fits to the implementation needs to refer to the so-called "working definition".

In this document, the term "working definition" of forest was used to attribute the production of land-cover maps. Since the approach involves visual interpretation of satellite images at a scale of 1: 50,000 where the minimum area of polygon delineation is 0.25 cm^2 (minimum mapping unit), which equals to 6.25 ha; thus, 6.25 ha was selected for the working definition instead of 0.25 ha. The term "working definition" introduced follows 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", and SNI 7645:2010 on "Land Cover Classification". Those SNIs define forest based on satellite data features employed for interpretation, including color, texture and brightness. Forests are classified into seven classes based on types and disturbances or succession level, of which only six classes are classified as natural forests (*see* Table 2).

Table 2. *Land cover classes used in the 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
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

Forests considered in the National Communications and BUR include natural forests (primary and secondary forests) as well as plantation forest (i.e. all seven forest classes). In contrast in this submitted FREL, natural forests (primary and secondary forests) are the main concern, while plantation forest is excluded from the calculation.

2.2. Deforestation

In this submission, deforestation is defined as conversion of natural forest cover to other land-cover categories that occurred once in an area. This means that deforested areas that might regenerate and meet again the forest definition were not taken into account a second time in the emission calculation from deforestation. Concerning the working definition, deforestation refers to the one-time conversion of natural forest cover into plantation forest or non-forested lands (see Table 2 and Table Annex 1.1).

The practical definition emphasizes on land cover instead of land use. Even though the naming of some classes in the Indonesian land cover classification system suggest that it is a land *use* classification, the underlying definitions applied during the satellite imagery interpretation relate purely to land cover. Indonesia concentrates on practical implementation, so the selected deforestation definition is different from the definition of deforestation by FAO, which employs the terminology of land use (See Box 2). The approach used by Indonesia is also used in many REDD+ programs to avoid confusion with land cover changes of afforestation and reforestation covered under the CDM scheme.

Box 2: Deforestation

Deforestation is the conversion of forest to another land use or the long-term reduction of tree canopy cover below the 10 percent threshold (FAO, 2000). The term "long-term" is debatable, and a complicated fact for Indonesia, a country with a fast vegetation regrowth.

The Decree of Minister of Forestry of Indonesia No. 30/2009 states deforestation as the "permanent alteration from forested area into a non-forested area as a result of human activities" (MoFor, 2009). Permanent alteration exhibits the importance of natural forest. Using that definition, areas with temporary unstocking followed by regeneration would not count as deforestation. The definition is based on the facts that in most cases in Indonesia, the natural forest cover that has been changed (cleared) to become non-forested lands, rarely grows back into natural forest. The area would likely be utilized, and/or forest regeneration following succession stages would be interrupted by other anthropogenic activities.

The definition of deforestation in this document as one-time conversion of natural forest cover into other other land cover categories was selected for the sake of practicality, simplicity and clarity on the land cover class identification and classification processes. The term was introduced in IFCA document (2008), and the common sense of this definition is "gross deforestation".

"Gross deforestation" is a deforestation counting only what has been lost (natural forest cleared) and does not consider forest regrowth (both natural and human intervention), nor carbon sequestration that is taken up by forest regrowth. This definition is different from "Net deforestation" that allows re-growing secondary forests and plantations to be counted.

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 swamp forests, to secondary forest classes. For Indonesia, the classes of secondary forests (see Table 2) are classes representing forests that were subject to selective logging or other external influences. Emissions from forest degradation are estimated roughly from the change of primary to secondary forest.

The main drivers of forest degradation include logging, agriculture (shifting cultivations), fires, fuel wood collection, and livestock grazing, which result in various degrees of degradation. However, for the time being there is no general approach to identify the level of degradation 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 conditions influencing the forest appearance. Particularly with the complex and unique Indonesian conditions, identifying the degree of forest degradation is not a simple task, especially not on a routine basis with the currently used medium-resolution satellite imagery (Landsat).

Therefore, emissions from further degradation of secondary forest is not included in the construction of FREL, as at present Indonesia has no capacity and data available to assess different levels of degradation occurring within secondary forests. This is one of the fields with intention to improve, as elaborated in section 7.1. Hence for the time being, the current FREL submission only considers emissions from degradation of natural forests in the sense of loss of carbon stock through conversion of primary to secondary forest.

Box 3: Forest Degradation

Forest degradation is a reduction of the canopy cover or stocking within a forest (FAO, 2000).

Forest degradation 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).

Besides referring to the process of forest degradation, degraded forest is a 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 (ITTO, 2002).

According to The Minister of Forestry Decree 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.

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). A comprehensive peat land map of Indonesia was developed in the period 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 map by using soil survey data, collected in the last decade. The updated map came up with a new estimate of 14.9 million ha peat land area. The main source of the previous map's overestimation was the lack of ground measurement data in Papua region, thus they relied highly on the use of Landsat TM imageries.

Peatland is an important land resource not only as carbon storage, but also for human livelihood, from which various agricultural crops are produced. However, the conversion into suitable croplands requires peat drainage which leads to a high rate of CO_2 emissions. Drained peat is also fire-prone, especially during the dry season, which entails high GHG emissions (IPCC, 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. The 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 at a given point of time in the future. In accordance with 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 FREL and FRL, the most common understanding is that a FREL includes only gross emissions i.e. from deforestation and forest degradation, whereas 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 of REDD+ activities. FREL was established by taking into account the trends, availability and reliability of historical data, and by choosing a length of the reference period that suffices to capture significant policy dynamics and other impacts.

3. Area, Activities and Pools Covered

3.1. Area Covered

As stated in Chapter 1, the scope of the area for FREL calculation is Indonesia's land that was covered by natural forest in the year 1990, accounting for 113.2 million ha or 60% of the country's land. This includes primary and secondary forests, regardless of forest status under national forest land use defined by MoFor (2014).

Peat land in Indonesia amounts to 14.9 million ha (Ritung *et al.*, 2011), of which 11.1 million ha (74.5%) were covered by natural forest in 1990. This figure was used in the FREL construction: Emissions from naturally forested peatland that was degraded or deforested since 1990 were included, since all inherited emission from peat soil of peat land since 1990 have to be calculated. Likewise, peatland that was already covered with degraded (secondary) forest in 1990 was included in the emission calculation, based on the assumption that secondary forest existing in 1990 is a disturbed natural forest and hence, the inherited emissions need to be included.

On the other hand, peatland that was unforested or covered by non-natural forest in 1990 was excluded from this FREL submission, in the context of decision 1/CP. 16 paragraph 70; yet it will be included in the Biennial Update Report (BUR). In the future, non-natural forested peat land needs to be included under a 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.

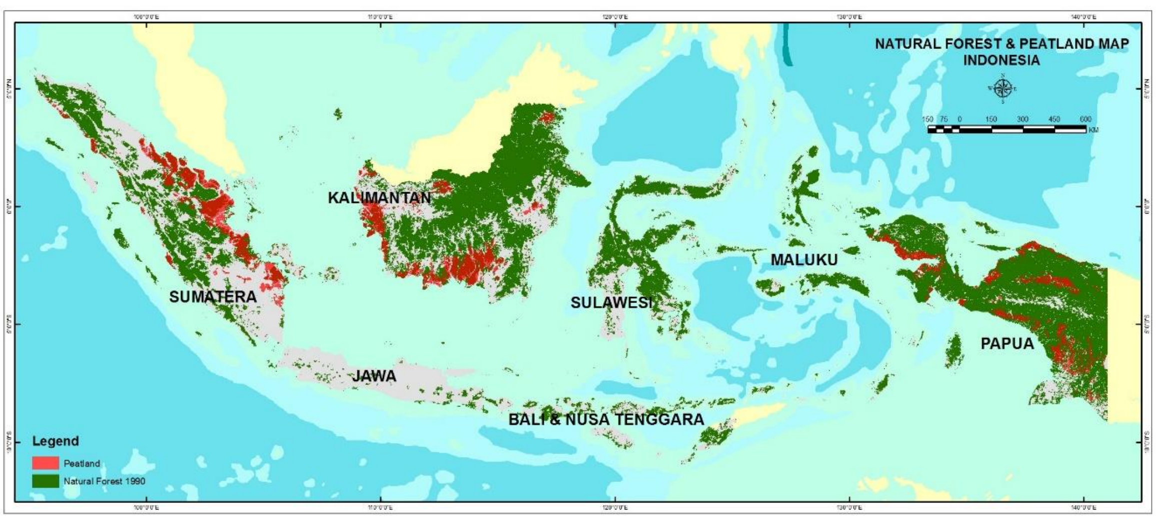

Figure 1. *Scope of the area for the FREL calculation in 1990 (113.2 million ha). Overall land area of Indonesia is approximately 187 million ha.*

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 transparency, reliability/accuracy, completeness, 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 used for this FREL submission, generated from the available national forest monitoring system, are methodologically consistent: the FREL employs the nation-wide land cover data set which was generated using the same methods/approaches since the establishments of the system in 2000, and then also applied backwards in time to the 1990s (see Annex 1). The activity data for deforestation and forest degradation are part of the national forest monitoring, and have been used in the national communications, though some data adjustment has been done to match the data availability and current technology, explained in Annex 1. The same data is also used to report national forest inventory in the most recent national communication document. However, a wall-to-wall monitoring system for various forest degradation degrees on current categories for land-cover remains problematic, especially considering the very wide range of eco-zones across Indonesia's natural forests. The Wallace and Weber lines divide 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 7 provides information regarding the opportunities 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 namely aboveground biomass (AGB) and soil carbon in peatland 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 elements compared to the other four carbon pools (i.e. belowground biomass, necromass, litter and mineral soil). Moreover, the current records in Indonesia regarding the other carbon pools are very limited. Review on the proportion of carbon pools (see Annex 3) showed that the biomass proportion of understory vegetation and seedlings is generally small. Similarly, litter is accounted for only about 2% from the total forest biomass. An additional analysis using compiled data sets from Sumatra and Kalimantan shows a similar trend. In contrast, tree AGB, belowground biomass and necromass have significant proportions of the total biomass with 71.2%, 13.6% and 14.5%, respectively (see Table Annex 3.2). Yet the proportions were measured only in the part of Indomalaya ecozones (west of the Wallace line), which may significantly differ from the middle and eastern part of Indonesia. The proportions of belowground biomass and necromass can be quite significant particularly in secondary forests, and may need to be included in the FREL once more complete data become available. This will be a field for improvement, as elaborated in section 7.5.

Without neglecting the importance of belowground biomass, 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 more accurate calculation of carbon emissions using Tier 2 or Tier 3 and which is comparable throughout the national scope. AGB data are widely available and can be estimated from forest inventory or sample plot data 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 has an almost completed estimation of AGB values, managed by the Ministry of Forestry (now 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. The Forest Research and Development Agency (FORDA) within the Ministry of Environment and Forestry in collaboration with the 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.

The carbon pool and type of activities used for the FREL calculation is also consistent with the national standard for calculation and monitoring of emission reduction, emission prevention or enhancement of forest carbon stocks. Several Indonesian National Standards (Standard Nasional Indonesia-SNI) for measuring and monitoring forest carbon have been issued by the National Standardization Agency of Indonesia (BSN) in collaboration with MoFor that follow the 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 peatland, emissions from peat decomposition are calculated in the area where forest degradation and/or deforestation have occurred. Peat emissions are calculated not only at the time deforestation/degradation 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 peatland, emission from peat fires are excluded since the historical activity data for the latter are not available in Indonesia and the development of emission factors is complicated and afflicted with high uncertainties (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 this FREL submission.

Although peat fires per se were excluded in this FREL submission, not all emissions resulting from peat fires were excluded from the calculation. Emissions from the loss of AGB due to fires are taken into account through the calculation of deforestation and forest degradation.

Meanwhile, soil carbon in mineral soil is not included in the emission calculation, since the changes of carbon in mineral soil that indicate emissions and sequestration is relatively low, as shown in IPCC (2006). IPCC (2006) provides emission factors for mineral soil based on treatment/management level (e.g. no tillage and organic matter addition to the mineral soil that lead to the increase of carbon in mineral soil). We have limited data and information on the mineral soil treatment/management for the activity data. In addition to that, emissions or sequestration in mineral soil related to land use change are very small. Therefore, we concluded to neglect soil carbon in mineral soil in the FREL calculation.

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 principles of transparency, accuracy, completeness and consistency. In addition, to ensure a concept of practicability and cost effectiveness, continuous data collection based on applicable systems is crucial, so that required processes 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 maps that serve as activity data were produced by the Ministry of Environment and Forestry (MoEF). The land-cover data is part of the National Forest Monitoring System (NFMS) which is accessible via the NFMS website (http://nfms.dephut.go.id or http://nfms.klhk.go.id) and links to the One Map Web GIS, at http://tanahair.indonesia.go.id (Geospatial Information Agency Republic of Indonesia, 2010).

The wall-to-wall land-cover maps were derived from Landsat satellite images. The series of land cover maps were digitized manually for each selected year by using visual interpretation technique. Indonesia has generated the land cover data since 2000. At first due to data source (Landsat) limitations, the monitoring system produced land cover data every three years (triennially): 2000, 2003, 2006, and 2009. Upon public release of Landsat data by USGS in 2008, MoEF has collected more Landsat scenes, and taking advantage of the data abundance, created more frequent land cover data sets in 2011, 2012 and onward (yearly). The free Landsat data access marked a new era of national land cover maps production. Interdependent satellite data interpretation with consideration of the interpretation from previous years was adopted to reduce biases of the MoEF GIS analyses and to ensure consistency of the annual land cover products. This time series land cover product is stored as one feature class in a consolidated geodatabase.

The time series data is an official data set and describes land cover classes as well as forest cover changes over the available intervals. The NFMS has been established and updated regularly since 2000. In addition, by taking advantage of the free Landsat data archive at USGS, land cover data for the 1990s were added to the NFMS. For this FREL submission, the data sets of 1990, 1996, 2000, 2003, 2006, 2009, 2011 and 2012 were used to capture historical land cover changes.

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) presented in Land Cover Change Analysis (LCCA); as well as to other similar products that have been published in peer reviewed international journals (Margono *et al*., 2014; Hansen *et al*., 2013).

Hansen *et al*. (2013) concluded that the rate of forest loss 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 the FREL submission we 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) for comparison instead of Hansen *et al*. (2013) data. A detailed comparison of NFMS, LCCA LAPAN and Margono's data is elaborated in Annex 1.

4.1.2. National peat land data

Peat land data for Indonesia is available from many different sources (Daryono 2010) which vary greatly. The variation of the data exists because of differences 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 was 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) (see Annex 2). The main peat areas corrected/removed in comparison to previous peatland maps were peatlands particularly in southeastern and southern Papua which were previously identified as peat land but 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.

The MoA peatland map has a 1:250.000 scale, which is sufficient for the national level FREL analysis. The map is published in the One Map webGIS, at http://tanahair.indonesia.go.id.

4.1.3. Emission factors for deforestation and forest degradation

For the emission factors for deforestation and forest degradation, mainly Tier-2 EFs were used in the analysis. The primary data source used to derive emission factors was the National Forest Inventory (NFI) - 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 clusters of sample plots have been developed which are distributed on 20x20 km, 10x10 km and 5x5 km grids across the country (Ditjen Planologi Kehutanan, 2014). Each cluster consists of a permanent sample plot (PSP) with a size of 1ha surrounded 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 units (RU) as numbered 25x25m sub-plots. All trees with a minimum diameter of 5 cm DBH were measured, and for a sub-set of trees the total tree height was measured. 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 the plot 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 by overlaying it with the 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 is documented in Annex 3.

Of the 4,450 measurements available from NFI PSPs, 80% were located in forested lands while the remaining data were located in shrubs or other lands. From PSPs located in 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 had to be used since the amount of PSP records for this forest type was statistically not sufficient.

The AGB of individual trees in the plots were estimated using allometric model 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. The WD values were taken from the database of the Ministry of Environment and Forestry through the Research, Development and Innovation Agency/FORDA (FORDA, 2012), which is a compendium of WD data for Indonesian tree species compiled from various sources (e.g. Hanum and Maesen, 1997; Oey, 1951; Lemmens and Wulijarni-Soetjipto, 1992; Lemmens et al., 1995; Soerinegara and Lemmens, 1994; Sosef et al., 1995; Suzuki, 1999; Verheij and Coronel, 1992). The database provides information on WD by species, genus, and family. 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 was not given for all seven main islands of Indonesia so the 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).

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

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 for the main islands were derived by averaging the AGB of the total plots (Equation 2).

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

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 the emission factors.

Table **3** below is to be regarded in combination with tables annex 7.1 and 7.2, which explain the emission factors, and its uncertainty as elaborated further in Annex 8.

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 ton 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).

__Table 3__. The estimates of AGB stocks in each forest type in Indonesia

Forest Type	Main Island	Mean AGB (Mg ha-1)	95% Confidence Interval (Mg ha^{-1})		N of plot measurements	SE (%)
Primary Dryland Forest	Bali Nusa Tenggara	274,4	247,4	301,3	52	10%
	Jawa					
	Kalimantan	269,4	258,2	280,6	333	4%
	Maluku	301,4	220,3	382,5	14	27%
	Papua	239,1	227,5	250,6	162	5%
	Sulawesi	275,2	262,4	288,1	221	5%
	Sumatera	268,6	247,1	290,1	92	8%
	Indonesia (Average)	266,0	259,5	272,5	874,0	2%
Secondary Dryland Forest	Bali Nusa Tenggara	162,7	140,6	184,9	69	14%
	Jawa	170,5			1	
	Kalimantan	203,3	196,3	210,3	608	3%
	Maluku	222,1	204,5	239,8	99	8%
	Papua	180,4	158,5	202,4	60	12%
	Sulawesi	206,5	194,3	218,7	197	6%
	Sumatera	182,2	172,1	192,4	265	6%
	Indonesia (Average)	197,7	192,9	202,5	1299	2%
Primary Swamp Forest	Bali Nusa Tenggara					
	Jawa					
	Kalimantan	275,5	269,2	281,9	3	2%
	Maluku					
	Papua	178,8	160	197,5	67	10%
	Sulawesi	214,4	-256,4	685,2	3	
	Sumatera	220,8	174,7	266,9	22	21%
	Indonesia (Average)	192,7	174,6	210,8	95	9%
Secondary Swamp Forest	Bali Nusa Tenggara					
	Jawa					
	Kalimantan	170,5	158,6	182,5	166	7%
	Maluku					
	Papua	145,7	106,7	184,7	16	27%
	Sulawesi	128,3	74,5	182,1	12	42%
	Sumatera	151,4	140,2	162,6	160	7%
	Indonesia (Average)	159,3	151,4	167,3	354	5%
Primary Mangrove Forest[a,b,c]	Kalimantan	263,9	209,0	318,8	8	21%
	Indonesia (Average)	263,9	209,0	318,8	8	21%
Secondary Mangrove Forest[,b,c]	Kalimantan, Sulawesi	201,7	134,5	244,0	12	21%
	Indonesia (Average)	201,7	134,5	244,0	12	21%

Notes:

- [a] Murdiyarso *et al.* (2009);
- [b] Krisnawati *et al.* (2014);
- [c] Donato *et al.* (2011)
- *) 95% confidence interval is from field statistical data (timber volume estimation) and does not include uncertainty of Chave's allometric equation

4.1.4. Peat emission factor

Contributions of peatland to the emission originate mainly from forest fire, oxidation processes and peat compaction resulting in peat subsidence. Van Noordwijk *et al.*, (2014) described the mechanisms involved in peatland ecosystems cannot be separated from each other. Peatland emission assessment must be seen as an entity, as the processes interconnect. A process that occurs in peat will be influenced by land management activities, such as land clearing, drainage, spacing and depth of drainage. Nevertheless, due to the complex processes in peatland ecosystems, their mutual relationship with land cover and limited data availability, this FREL submission is limited to the inclusion of emissions from peat decomposition. This should preferably be done cumulative from the first year of disturbance to subsequent years based on the average of peat decomposition in every land cover.

The emission factors presented in Table 44 are taken from the '2013 Supplement to the 2006 IPCC Guidelines for National GHG Inventory: Wetlands (2014)" – for drained organic soils emission factors. In the case of Indonesia, most of forested peat were converted to croplands (estate crops, mixed dry agriculture) and plantation forests. Those peatlands are considerably drained as such cultivation activities would affect peat water table in order to optimally grow crops/trees.

Table 4. *Emission factors of peat decomposition from various land cover and land use types*

No.	Land cover	Land use category	Emission factor (tCO_2e $ha^{-1}yr^{-1}$)*	95% confidence interval		Remarks
				Min	Max	
1.	Primary forest		0	0	0	Paciornik and Rypdal (2006)
2.	Secondary forest	Forestland and cleared Forestland, drained	5.3	-0.7	9.5	IPCC (2014)
3.	Plantation forest	Plantations, drained, short rotations, e.g. acacia	20	16	24	IPCC (2014)
4.	Estate crop	Plantations, drained, oil palm	11	5.6	17	IPCC (2014)
5.	Pure dry agriculture	Cropland and fallow, drained	14	6.6	26	IPCC (2014)
6.	Mixed dry agriculture	Cropland and fallow, drained	14	6.6	26	IPCC (2014)
7.	Dry shrub	Forestland and cleared Forestland, drained	5.3	-0.7	9.5	IPCC (2014)
8.	Wet shrub	Forestland and cleared Forestland, drained	5.3	-0.7	9.5	IPCC (2014)

No.	Land cover	Land use category	Emission factor (tCO_2e $ha^{-1}yr^{-1}$)*	95% confidence interval Min	Max	Remarks
9.	Savanna and Grasses	Cropland, drained, paddy rice	9.4	-0.2	20	IPCC (2014)
10.	Paddy Field	Cropland, drained, paddy rice	9.4	-0.2	20	IPCC (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	Cropland and fallow, drained	14	6.6	26	Assumed similar to mixed upland agriculture
14.	Settlement areas	Cropland, drained, paddy rice	9.4	-0.2	20	Assumed similar to grassland
15.	Port and harbor		0	0	0	Assumed zero as most surface is sealed with concrete.
16.	Mining areas	Cropland and fallow, drained	14	6.6	26	Assumed similar to bare land
17.	Bare ground	Cropland and fallow, drained	14	6.6	26	IPCC (2014)
18.	Open water		0	0	0	Waterlogged condition, assumed zero CO_2 emission
19.	Clouds and no-data		nd	nd	nd	

Notes:
- nd: no data
- *) For the calculation purpose presented in Table Annex 6.1, the values in column 4 were converted with a factor 44/12 to get the estimate of CO_2 equivalent (1 t CO_2-C = (44/12)*1 t CO_2 =3.67 t CO_2).

The emission factor figures for peat decomposition presented in the '2013 Supplement to the 2006 IPCC Guidelines for National GHG Inventory: Wetlands' (IPCC, 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. The IPCC Wetland Supplementary 2013 (IPCC, 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 44).

Various emission factors have been developed in the past (e.g. Agus *et al.*, 2013; Hergoualc'h & Verchot, 2013; IPCC, 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 IPCC (2014), Hergoualc'h and Verchot (2013) also used land cover classes as basis for determining peat emission factors. 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, IPCC (2014) default values are used in this publication.

Large areas of deforested peatland have been converted to oil palm and timber plantations but there are also extensive areas of peatlands with degraded forests. Most peatlands are located in the provinces Central, East and South Kalimantan, Riau and Jambi (Hooijer et al., 2006). When primary peat forest is converted into other land uses, most likely it will be drained to keep the surface dry and then the plants can grow well. In another common case, the drainage system is usually being used for transporting harvested timber. The 1 Mha mega rice project area in Central Kalimantan is a good example of drainage areas, when peatlands were affected by drainage systems (Page *et al*., 2008).

It is impossible to differentiate between drained and undrained secondary peat forest due to the data used (Landsat). Prior to 2000, a few concession holders used rails for logging, but the majority used drainage. After 2000, the rail system became less popular and the drainage system was used. It is impossible to trace back the drained and the negligibly small areas of undrained secondary peat forest and therefore, it is justifiable to consider all of the secondary forest as drained forests. Additionally, there is also natural drainage through the surrounding peat in secondary forests (Beekman 2006).

For peatland converted to transmigration, settlement and mining areas, the emission factors utilized have been assumed to be similar to those of mixed dryland agriculture, grassland and bare land respectively. This assumption was adopted considering the similarity of the field conditions among those land cover types. Development of emission factors for these type of covers and improvement of the emission factors presented in the IPCC 2014 Supplementary guideline, with more area representation, are significantly required to reduce uncertainty of emission estimates from peatland.

4.2. Methodology and Procedures

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 a variety of methodologies that are available (Angelsen, et al. 2011), taking into account the national circumstances. The general reference for measuring emissions is the IPCC Guideline (2006). Step-by-step information regarding the methodological approach used in this document is described subsequently.

4.2.1. Land cover change analysis

Indonesia's land cover classification consists of 23 land cover categories including six natural forest classes. Details on land cover data, including step-by-step explanations to demonstrate the methodology for classification are explained in Annex 1 and Margono *et al* (2015). In general, land cover change analysis was conducted by comparing land cover categories of two subsequent periods. So that, referring to the working definition, deforestation is the change of natural forests into non-forested classes that occurred one time at any given location across the entire observation period (1990-2012).

Forest degradation is the change of primary forests to secondary forests classes in the subsequent year. As elaborated in Annex 1 and Margono *et al* (2015), the land cover (LC) data set is a series (T_1 to T_{1+n}) of data, and the degraded forest was generated by comparing the LC of T_n (class of primary forests in the first observation period) to the LC of T_{n+1} (becoming class of secondary forests in the consecutive observation period). The assumption we made for this method is that a change from primary forests to secondary forest usually occurs because of subtle to excessive disturbances to the primary forest due to logging operation (legal and illegal) and other activities, without causing deforestation.

4.2.2. Reference period

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

This longest period of historical data best illustrates and captures the dynamics of policy and social aspects, which provides opportunity to appropriately describe national circumstances affecting land use policy. As a background, Indonesia established an intensive forest plantation development in 1990s. Capturing the decade is important, as the country initiated a massive forest-based industry, such as wood-fiber industry and forest estates (plantations). This time period also covers the economic crisis in 1998 when almost all sectors collapsed, including the forestry sector, resulting in increased illegal logging activities and forest encroachments on the ground. Besides, the period also includes the years 1997 to 1998 when extensive fire disasters occurred in Indonesia due to a prolonged drought.

The trend of forest land use changes and the cycle of prolonged droughts due to El Nino events are ongoing, and are relevant to predict deforestation and forest degradation in the future. Considering these external factors may provide more realistic estimates of future carbon emissions.

4.2.3. Reference emission calculation

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

Historical emissions from peat decomposition were calculated for 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 emissions are reported as average of the total period of calculation.

4.2.4. Emission calculation from deforestation and forest degradation

Emission from deforestation and forest degradation occurred at a certain time period were calculated by aggregating CO_2 emissions resulted from newly identified deforested areas or degraded forests in that 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 (gross deforestation). Forest degradation is the change from primary to secondary forests or logged-over forests. From 1990-2012, the 6-year, 4-year and 3-year land cover data sets were averaged to attain annual rates of deforestation and forest degradation. The overall processes of data analysis for deriving activity data of deforestation and forest degradation are depicted in Figure 2.

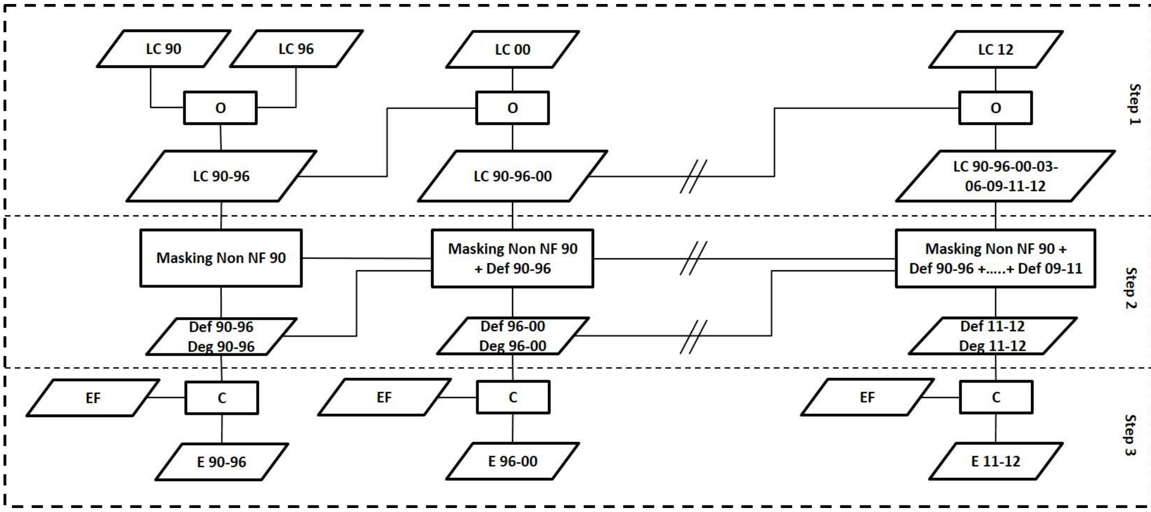

Figure 2. *Flow chart of emission calculation from deforestation and forest degradation. "LC" is Land Cover, "Non NF" is Non Natural Forest, "EF" is Emission Factor, "Def." is for deforestation and "Deg." is for forest degradation, and "E" is emission, "O" is Overlay, "C" is Calculate.*

The processing steps for emissions calculation from deforestation and forest degradation, as depicted in Figure 2, are as follows:

Step 1: Overlay land cover data for each interval period, and create a sequential land cover change data set from 1990 to 2012.

Step 2: Masking the 1990 Non Natural Forest areas in the sequential land cover change data sets to create layers of only Natural Forest of 1990; and derive the areas of deforestation and forest degradation for each interval period, using logical approach as follows:

- For generating deforestation:
  - Deforestation period 1990 – 1996: using the layers of Natural Forest 1990 and Non Forest 1996;
  - Deforestation period 1996 – 2000: using Natural Forest 1990 and Non Forest 1996 and 2000;
  - Deforestation period 2000 – 2003: Natural Forest 1990 and Non Forest 1996 and 2000 and 2003; and so on.
- For generating degradation: Overlaying the Primary Forest layer with the layer of Secondary Forest in the consecutive year.

Step 3: 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 the emission factor of the associated forest cover change type-j (EF_j) (see table annex 7.1). 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 ton 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 units 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.

4.2.5. Emission calculation from peat decomposition

Emissions from peat decomposition are 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 6). The emission factors were taken from the document "2013 supplement to the IPCC 2006 Guidelines for National GHG Inventory: Wetlands (2014)". These emission factors are applied to all utilized peat lands, with or without drainage, as a differentiation is impossible with the data currently used. The calculation used Equation 6.

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

Where *PDE* is CO_2 emission (tCO_2 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}).

Box 4: Peat Decomposition

Peat decomposition: Changing process of peat form as a result of a decline in water levels caused by deforestation and degradation activities, and land utilization.

Inherited emissions: Emission of peat decomposition will continuously occur after peatland is drained due to peat forest land conversions or land utilizations. The emissions will only stop when the peatland is completely decomposed or completely rewetted. Thus, emissions are inherited from one to to another after the initial disturbance and the total emission from peat decomposition is the accumulation of peat emissions from 1990 onwards.

Emission factor for peat decomposition emission calculation: The emission factors used in the calculation are derived from the document “2013 supplement to the IPCC 2006 Guidelines for National GHG Inventory: Wetlands (2014)”.

These emission factors are used with the assumption that all utilized areas are drained. For instance, if there is a transition from primary swamp forest to secondary swamp forest, we will use the mean emission factor of the two land cover types, (0+19)/2 = 9.5 t CO2 $ha^{-1}yr^{-1}$. Because it was assumed that the transition occurs gradually within the transition period, rather than abruptly in the first or the last year of the period.

There are activities needed to be seriously and continuously done for reducing the emission from peat decomposition. Those mitigation action include peat land rewetting, establishing water management systems for peat land, reducing deforestation and degradation and preventing fires on peat land.

The peat decomposition on peat land covered with degraded forest was calculated not only for areas which degraded after 1990 but also on areas where degraded forests already existed in 1990. The detailed calculation process is shown in the following Figure 3.

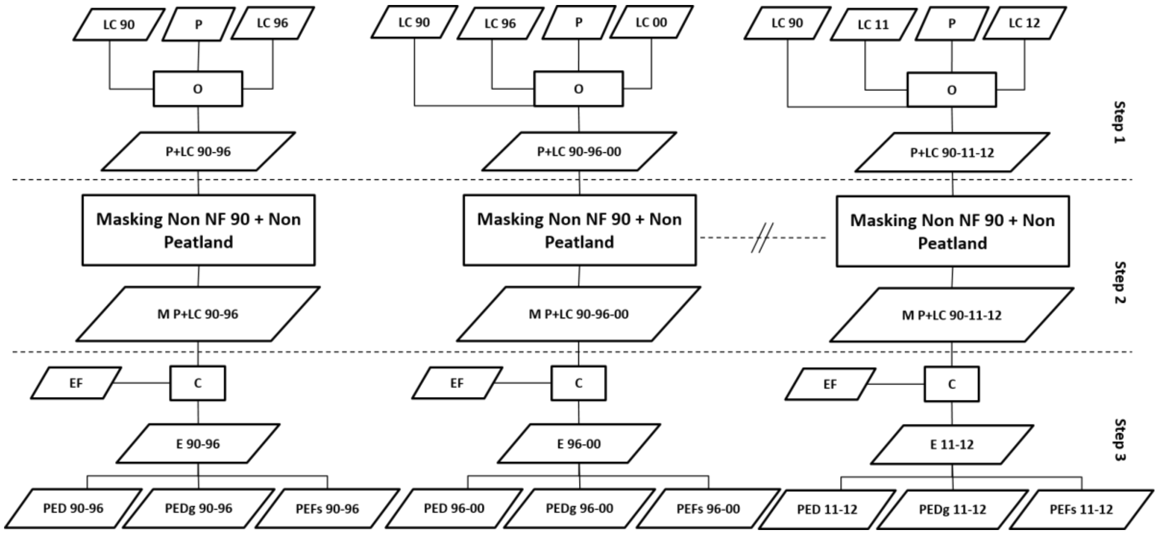

***Figure 3**. Flow chart of Calculation flow chart of peat decomposition emission calculation from peat decomposition in deforested peat forests from forested peatland of 1990. "LC" is land cover, "EF" is Emission Factor for peat decomposition, "M" is the result of masking process, "E" is emission, "P" is Peat/Peatland, "PED" is Peat Emission from Deforestation, "PEDg" is Peat Emission from Forest Degradation, "PEFs" is Peat Emission from Secondary (degraded) Forests existing already in 1990, "O" is Overlay, "C" is Calculate. "LC Annual" is the annual rate of deforestation within one interval (e.g. 1990 – 1996) by averaging the emissions.*

The processing steps for annual peat emissions calculation from deforestation and forest degradation as depicted in Figure 3 are as follows:

Step 1: Define the areas to be included in the calculation of peat emissions by overlaying land cover and peat land.

Step 2: Masking of non-natural forest in 1990 and non-peat land and generate land cover change map from each interval year to define transition area matrix for the associated years of the interval.

Step 3: Calculate the total annual emission by multiplying the transition matrix of both areas with the associated emission factors. Emission factor for an area of change is an average of the emission factors of the respective land cover before and after. This reflects the assumption that conversion of land cover on peatland between two time periods gradually effects the peat water table implying a gradual peat decomposition emission. For example, the emission factor of secondary forest is 19 tCO_2 ha^{-1} y^{-1} and the emission factor of bare ground is 51 tCO_2 ha^{-1} y^{-1}, so that the average emission factor for an area changing from secondary forest to bare ground is 35 tCO_2 ha^{-1} y^{-1} (*see* Annex 6).

The emission from peat decomposition is not indefinite as it may cease when the peat has completely decomposed or reached the natural water level. This may result in a change of the emission profile from peat decomposition in the future. As the scope of this FREL is only up to 2020, the peat will not be completely decomposed within this period. On average the rate of loss of peat due to decomposition after drainage is about 5.6 cm per year in secondary forest (Maswar and Agus, 2014) and constant at around 5 cm per year with an average water table depths of 0.7 m after 5-year drainage in *Acacia* and oil palm plantations (Hooijer *et al*, 2012). With an average peat depth of more than 2 m (Hooijer et al. 2012; Maswar and Agus 2014), it will take about 40 years to decompose all this 2 m peat depth. The peat depth of deforested areas and degraded forests in Indonesia is generally more than 2 m (Ritung *et al*. 2011; see Annex 2). The development of the peat depth map was based on a limited number of samplings, especially in Sumatera and Kalimantan. A refinement of the peat depth map particularly in deforested areas and degraded forests is required for the development of the next FREL beyond 2020.

4.2.6. Uncertainty calculation

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 181 ground truth points. The land cover assessment was conducted for all 23 classes of the 2011 land cover map and the results found an overall accuracy of 88% of the map (MoFor, 2012, Margono *et al*. 2012). Additional work to assess the accuracy of change analysis data is already planned and it will be expedited in the near future. The existing contingency table is shown in Table Annex 1.2.

The uncertainties of emission factor were generated from the standard error of carbon stock values from every forest type/class in each major island/group of islands. The carbon stock was estimated from the NFI plots that have been established in seven major island/group of islands. For peat decomposition, uncertainty of activity data was derived from the overall accuracy of the peat land mapping (80%) (Ritung *et al*. 2011), while the IPCC guideline 2013 default values (Hiraishi *et al*., 2014) were adopted as uncertainty values of emission factors. Since the AGB emissions calculation is using Tier 2 accuracy, the uncertainty level for forest degradation and deforestation is lower than that of peat emissions. Detailed tables on calculating the uncertainties can be found in Annex 8.

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 the 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

This FREL is mainly made for deforestation and forest degradation. Yet when deforestation and forest degradation occur on peat soil, emissions from peat decomposition contribute considerably.

5.1.1. Deforestation

The average 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). 79% of this figure (723,628 ha) is accounted for by deforestation on mineral soil and 21% (195,050 ha) by deforestation on peat (organic) soil. The highest rate of deforestation occurred during the period 1996 – 2000 accounting for more than 2.2 million ha yr^{-1}, and drastically decreased to the lowest rate in the subsequent period 2000-2003 of about 444 thousand ha yr^{-1}. In the latest period (2011-2012), the deforestation rate was about 786 thousands ha yr^{-1} (*see* Annex 5 for details).

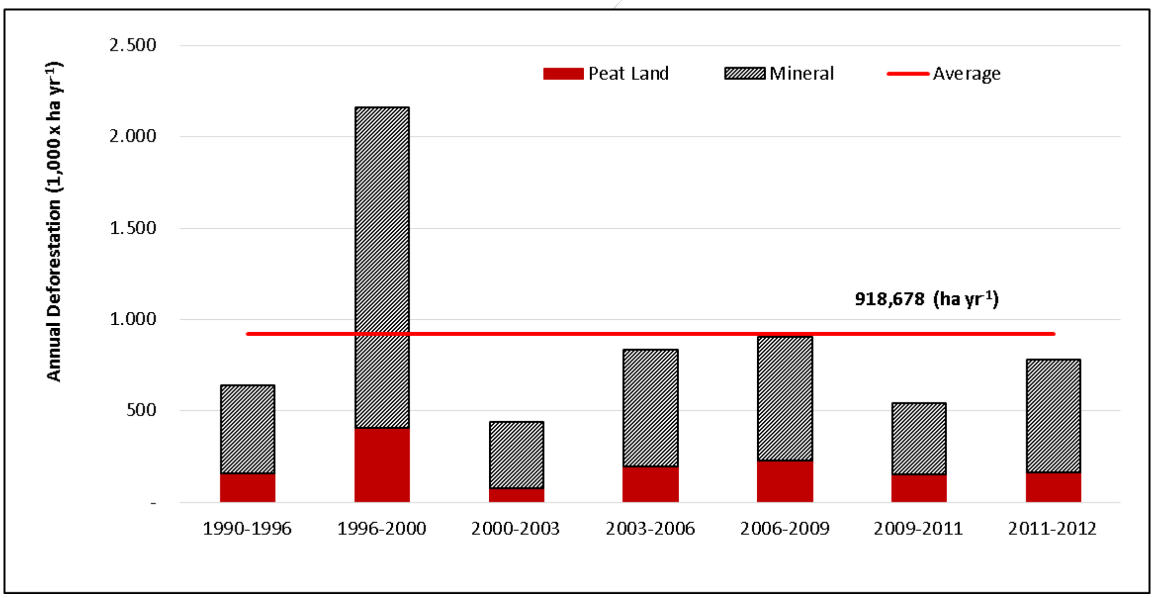

Figure 4. *Annual deforestation rates in the period 1990 to 2012 in hectares. The bars indicate the dynamic rates of deforestation per associated interval period, and the red line depicts the average annual deforestation from 1990 – 2012.*

Regarding the whole reference period, 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 represent only a small proportion of the national deforestation, contributing to only 6% of the total deforestation in Indonesia (Figure 5).

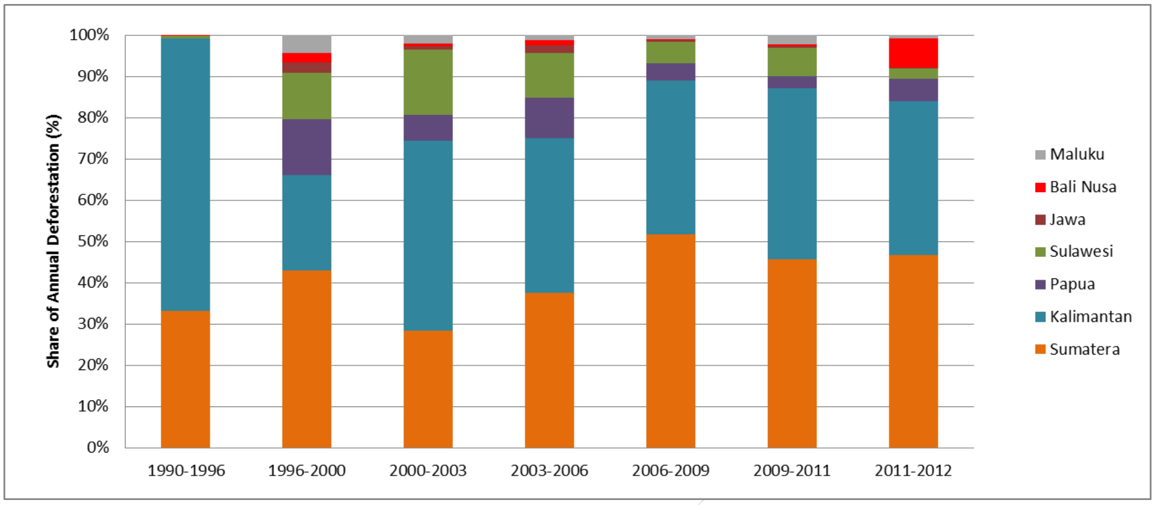

Figure 5. *Proportion of annual deforestation (in %) for 7 major islands/groups of islands in Indonesia.*

The high rate of deforestation in the period 1996 -2000 was likely caused by large fire events due to a prolonged El Nino in 1997/1998 (Siegert *et al*. 2001, Cochrane 2003, Tacconi 2003), as well as illegal logging, expansion of industrial timber plantations and rapid expansion of palm oil (Pagiola, 2000, Margono *et al*. 2012). Expansion of industrial timber plantations and rapid expansion of palm oil have also been essential reasons of the second highest rate of deforestation in the period 2006-2009 (Margono *et al*. 2012). The low deforestation rate in the period 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 the Annual Allowable Cut (AAC) for timber extraction from more than about 200 m^3y^{-1} to 70 m^3y^{-1} (MoFor, 2002).

5.1.2. Forest degradation

The average annual rate of forest degradation in Indonesia from 1990 to 2012 was about 507,486 hectares. This figure is accounted for by 490,329 ha (97%) of forest degradation on mineral soil, and 17,157 ha (3%) of forest degradation on peat soil. The forest degradation rate was very high in the period 1996 to 2000 (1.3 million ha), and decreased gradually to only 44 thousands ha in year the period 2011-2012 (see Figure 6.

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

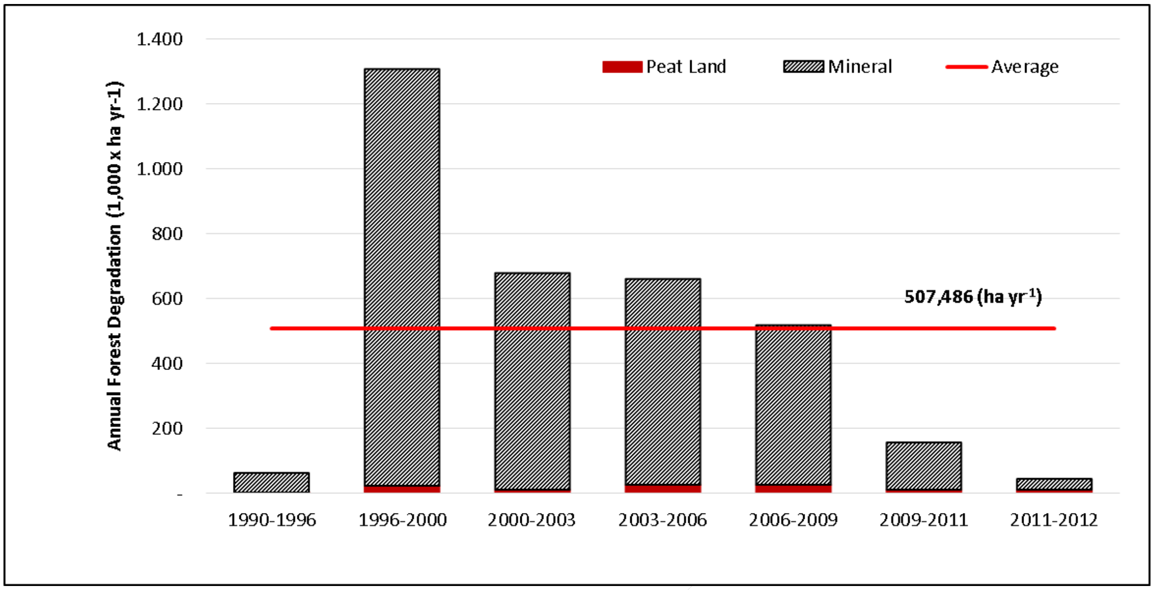

Figure 6. *Annual forest degradation rates in the period 1990 to 2012 in hectares. The bars indicate the dynamic rates of degradation per associated interval period, and the red line depicts the average annual degradation from 1990 – 2012.*

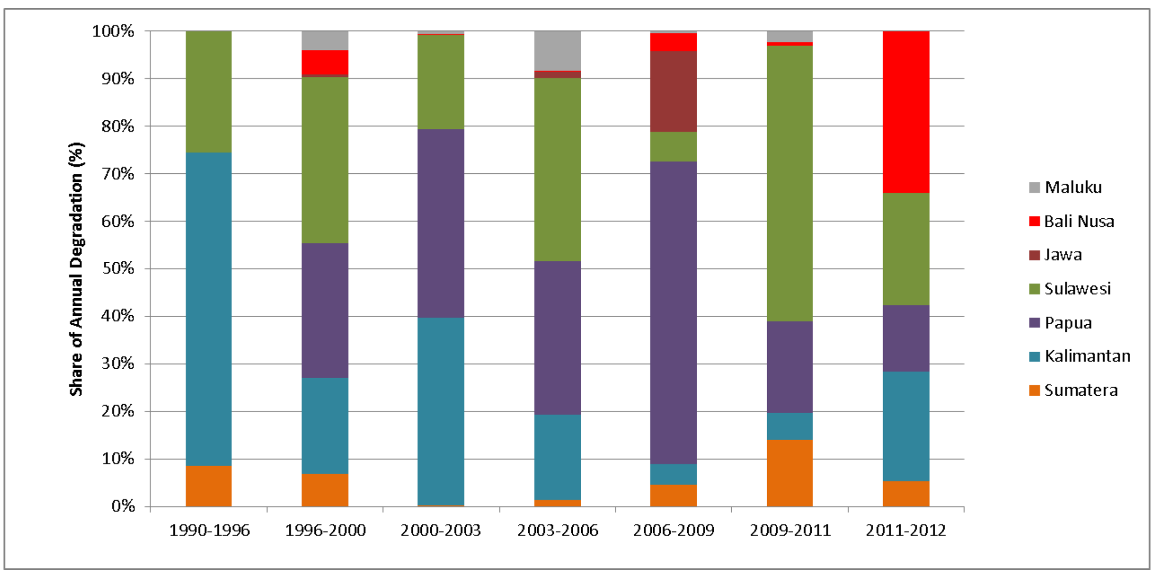

Figure 7. *Proportion of annual forest degradation (in %) for 7 major islands/groups of islands in Indonesia.*

The largest proportion of degradation in Sulawesi during the period 2009-2011 was due to forest encroachment mostly for planting cocoa. 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). Forest degradation in Papua is mostly caused by subsystem (sub-farming system) local community activity, which is intended to fulfill the community primary needs (foods and housing materials).

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

5.2.1. Emissions from deforestation

The average annual historical emission from AGB due to deforestation in the period 1990 – 2012 is approximately 293 $MtCO_2e$ yr^{-1} (*see* Figure 8). 81% (238 $MtCO_2e$ yr^{-1}) of this figure is accounted for by emissions on mineral soil and about 19% (55 $MtCO_2e$ yr^{-1}) by emission on peat soil.

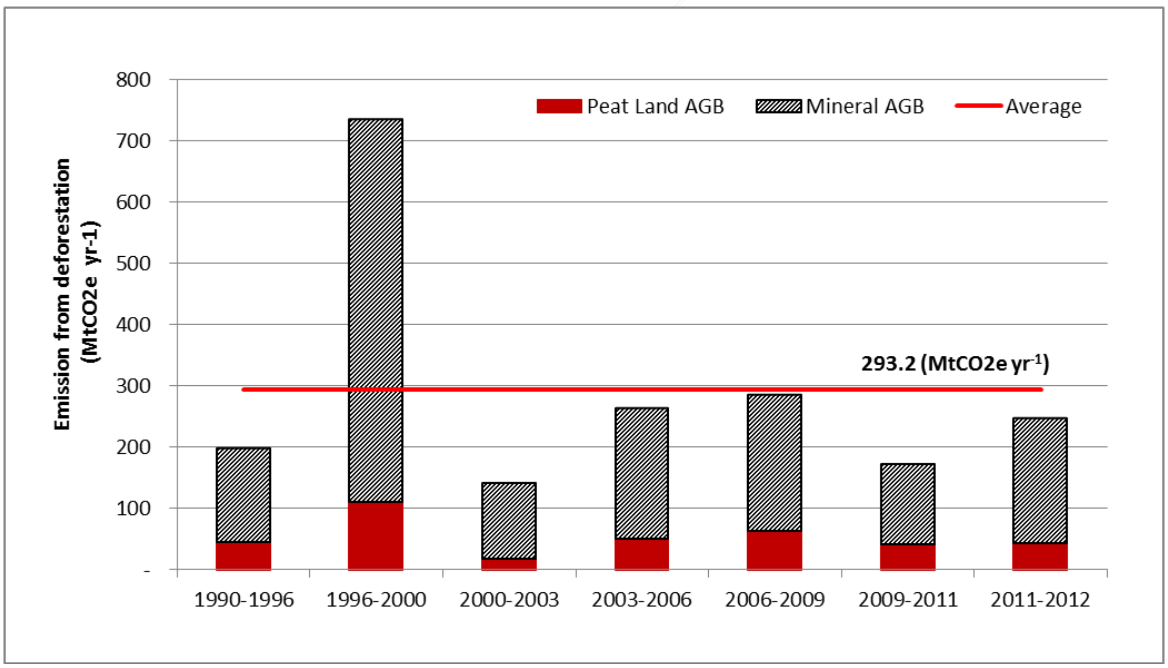

Figure 8. *Average annual historical emissions from deforestation expressed in millions tCO_2e.*

5.2.2. Emissions from forest degradation

The average annual historical emission from AGB due to forest degradation in the period 1990 – 2012 amount to approximately 58 $MtCO_2e\ yr^{-1}$ (*see* Figure 9). 97% (56 $MtCO_2e\ yr^{-1}$) of this figure is accounted for by emissions on mineral soil, and 3% (2 $MtCO_2e\ yr^{-1}$) by emissions on peat soil.

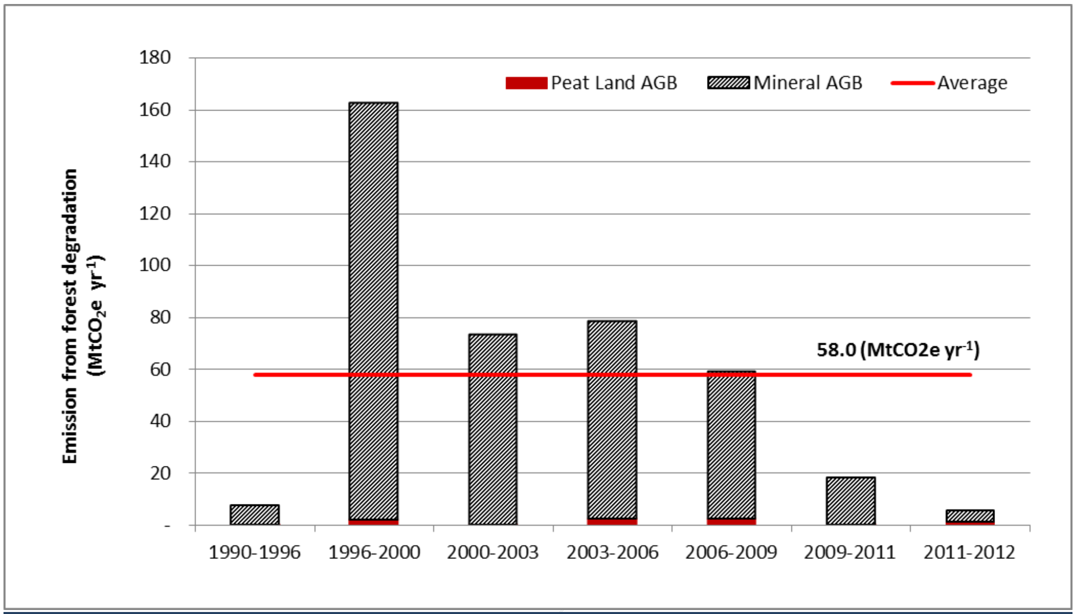

Figure 9*. Average annual historical emissions from forest degradation expressed in millions* tCO_2e.

5.2.3. Emissions from peat decomposition

Emissions from peat decomposition were calculated based on the cumulative process of decomposition due to conversions of peatland forest and land utilizations from 1990 to 2012.

The method to estimate emission from peat decomposition is explained in chapter 4.2.3. The results show that emission from peat decomposition increase over time from about 151.7 $MtCO_2e\ yr^{-1}$ in the initial period (1990) to about 226.1 $MtCO_2e\ yr^{-1}$ in the end of analysis period (2012) (see Figure 10). The increase of annual emissions is partly due to the expansion of drained peatland which progressively emits CO_2 within the time frame of this analysis, and also because the occurrence of inherited emissions (see Box 4). Figure 11 shows the linear regression of the emissions from peat decomposition. This linear model is used to predict the emissions for the projection period (see Table 6).

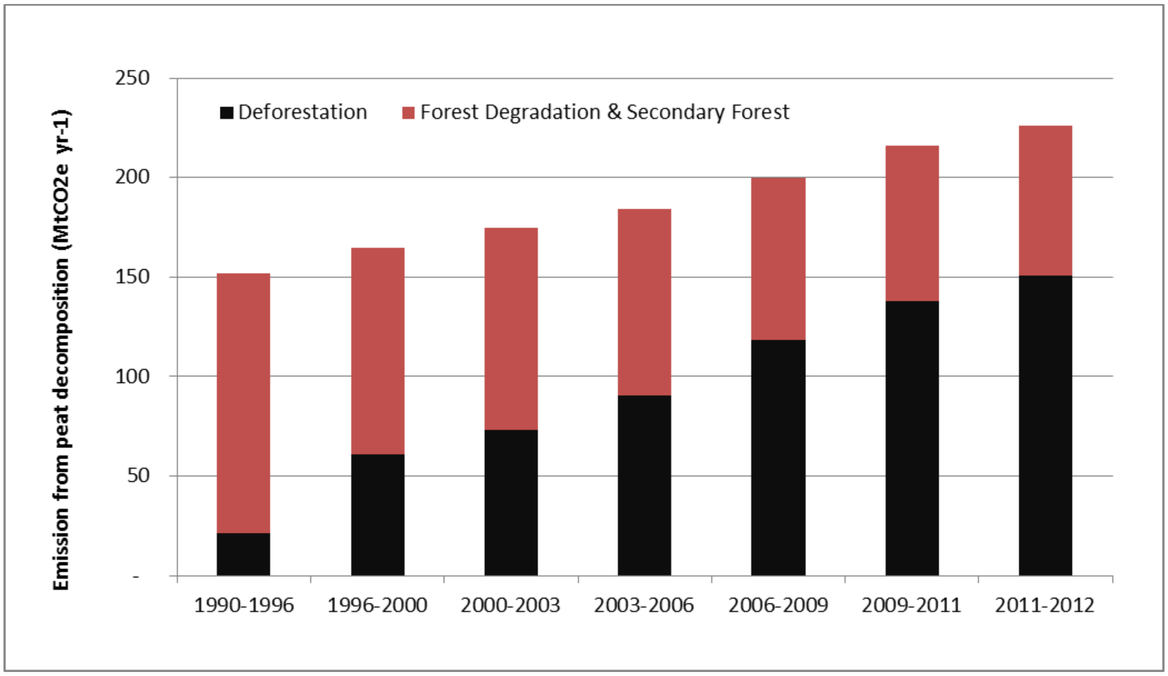

Figure 10. *Annual historical emissions from peat decomposition due to deforestation, forest degradation and secondary forest (degraded forest existing in 1990), expressed in millions tCO2e.*

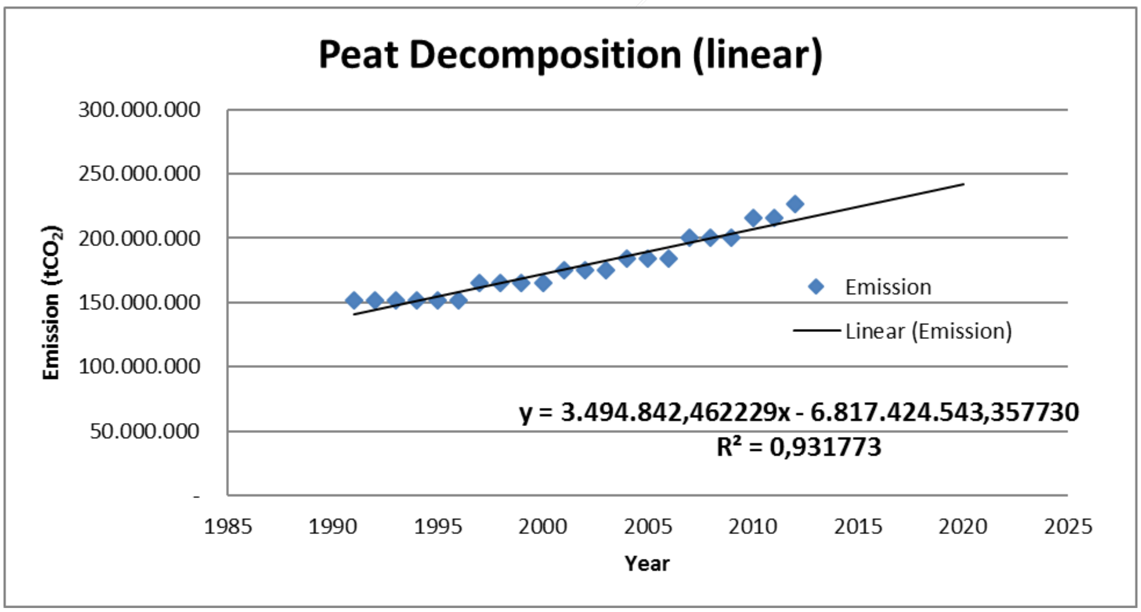

Figure 11. *Annual historical emissions from peat decomposition (in tCO_2) and linear regression.*

5.3. Uncertainty Analysis

As mentioned in chapter 4.2.6, the accuracy for the parameter “activity data” (land cover) is 88% (table annex 1.2), while for peat land it is 80% (Ritung *et al*. 2011). While the accuracy for the parameter “emission factor” varies from 50-97% depending on island/group of islands and land cover types. The accuracy of emission factor for peat decomposition is 50% as it is taken from IPCC (2014). Applying equations 7-9 as described in chapter 4.2.6, the average uncertainty for all emissions is 16.1% (see Table 5 and

Annex 8. Uncertainty analysis for the details).

Table 5. 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	151,782,943	164,815,980	174,757,024	184,235,616	200,118,642	215,799,004	226,167,756
Total	358,372,196	1,064,218,341	391,339,448	527,194,180	545,746,225	408,201,603	481,025,677
% Uncertainty	**16.3. %**	**7.6%**	**16.5%**	**13.3%**	**21.5%**	**19.7%**	**17.8%**
Average uncertainty	**16.1%**						

5.4. Constructed National Forest Reference Emissions Level

The annual historical emissions from deforestation, forest degradation and the associated peat decomposition (in $MtCO_2$) from 1990 to 2012 are depicted in Figure 12. In total, the emissions from deforestation are dominant with a contribution of 51% to the total emissions, followed by emissions from peat decomposition contributing to 39%, while the remaining 10% are emissions from forest degradation.

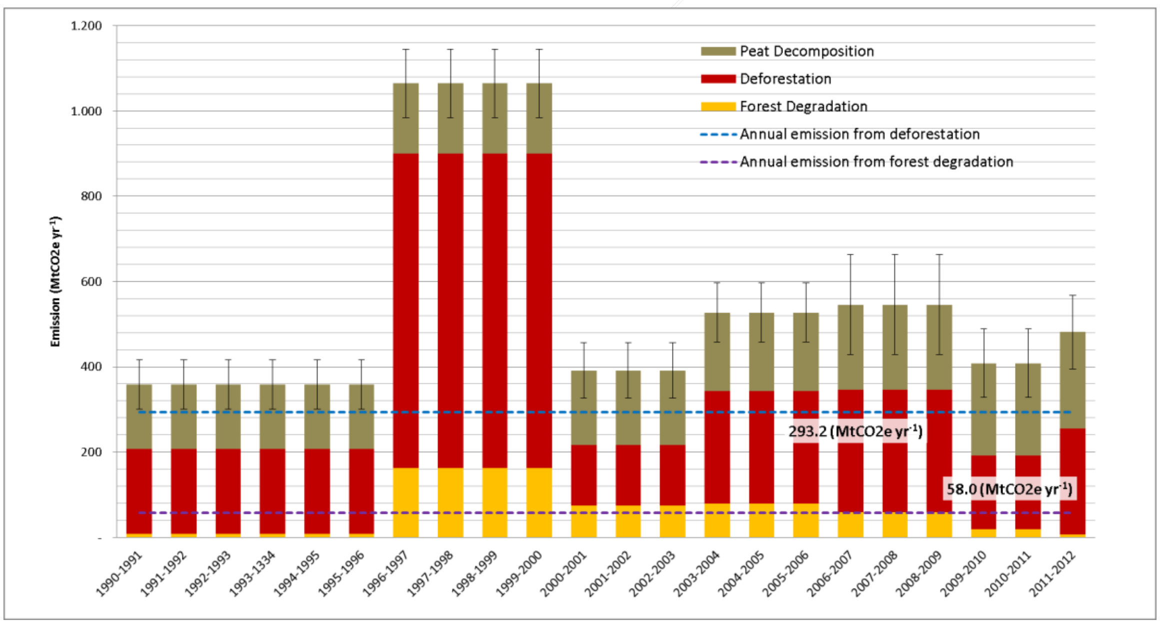

Figure 12. *Annual and average annual historical emissions from deforestation, forest degradation and the associated peat decomposition (in MtCO2) in Indonesia from 1990 to 2012.*

Following Figure 12, the forest reference emission level from deforestation and degradation was set at 0.351 $GtCO_2e\ yr^{-1}$ (AGB) for the reference period 1990-2012. To this figure, the emission of 0.217 $GtCO_2e\ yr^{-1}$ from peat decomposition (see

Table **6**) was added with an annual linear increment of 1.6% (with R^2 93%), due to inherited emissions (see Figure 11).

However, referring to Figure 4and Figure 6, only about 21% of deforestation and 3% of forest degradation occurred on peat. Meaning, the proportion of deforestation and forest degradation on peatland is low compared to what happens on mineral soil. The emissions from deforestation and forest degradation on peat account only for about 19% and 3% respectively, as seen in Figure 8 and Figure 9. So, if Indonesia needs to disaggregate the emissions from only deforestation and forest degradation of the peat decomposition, the result is depicted in Figure 12a.

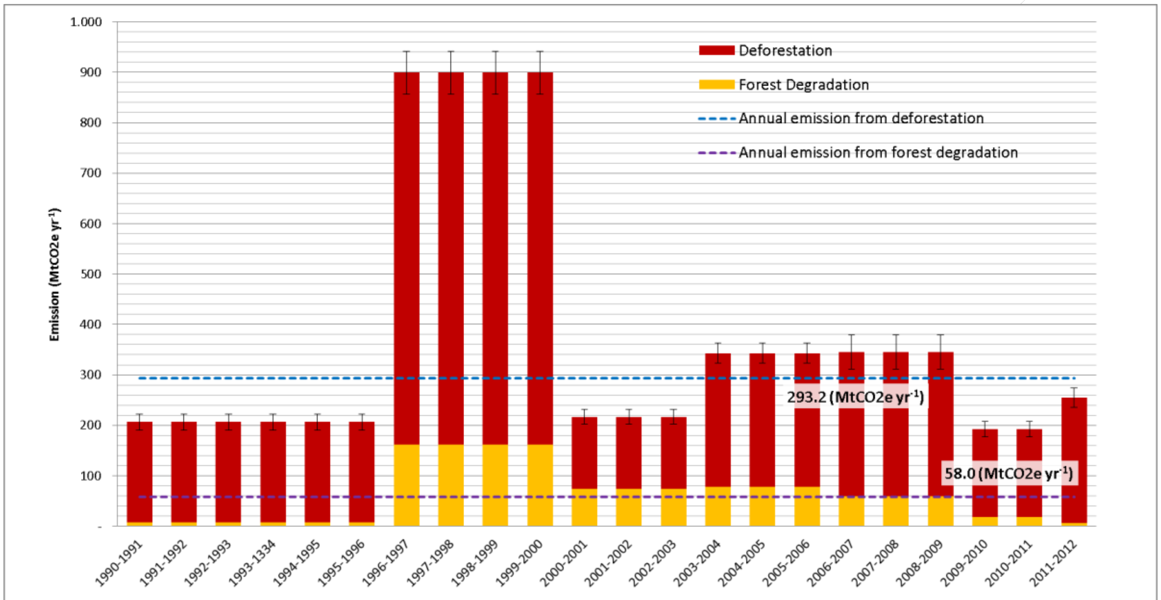

Figure 12a. *Annual and average annual historical emissions from deforestation and forest degradation in Indonesia from 1990 to 2012.*

The logic behind considering disaggregation is that mitigation actions for suppressing deforestation and forest degradation are more accountable rather than mitigation action specific for preventing peat decomposition. Indonesia is aware that emissions from peat decomposition will continue to occur, once peat lands were drained for forest conversions or land utilizations. Those emissions will only cease when the peat is completely decomposed, or the peat lands completely re-wetted. The annual increment of inherited peat decomposition emissions of 1.6% is so large that and it would superimpose all mitigation actions taken with regard to deforestation and forest degradation.

However, the inclusion of peat in the calculation of emissions is very important as it is a significant carbon pool. The management of peatland (particularly water management) is very important to reduce the rate of peat decomposition. Indonesia as set up a plan to stop the conversion of naturally forested peatland for development, to restore peatlands and also to improve the water management of managed peat land (palm oil, timber plantations, etc.). With this plan we expect to reduce the emission from peat decomposition significantly within the result phase. Of course, the challenge is to implement a reliable monitoring system for peat emissions. This is also one of the fields for future improvement.

The emission factor used for the calculation of peat decomposition from the IPCC is a general EF. This emission factor may vary depending on the water management. Implementation of better water management will change emissions in the result phase. Although computing peat decomposition seems to be less favorable with respect to mitigation actions to reduce the emissions (refer to Figure 12a and its below explanation), the FREL with the associated peat decomposition will be used as benchmark against the actual emissions starting from 2013 up to 2020, as depicted in

Table **6.**

The constructed FREL is projected for the period up to 2020. During the projection period (2013-2020) it is assumed that the utilized peatland areas are kept drained and continue to release emissions, i.e. emissions during the projection period include the inherited emissions since 1990. We realize that the emissions from peat decomposition are not indefinite, but due to a lack of accurate information on peat thickness the assumption remains that all utilized peatlands will continue to emit and not reach the end stage of peat decomposition emissions. However, the projected emissions from peat decompositions only include these inherited emissions but not additional emissions that may occur due to degradation or deforestation after 2012.

Based on the historical emissions 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 **6**). For monitoring purposes,

Table **6** 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).

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

Table 6. *Historical (1990-2012) and projected (2013-2020) annual REL from deforestation, forest degradation and the associated peat decomposition (in tCO_2e), calculated using linear projection (R^2=0.931) based on conservative historical data of 1990-2012.*

Year	Deforestation	Forest Degradation	Peat Decomposition	Total annual emission	
1991	198.912.693	7.676.560	151.782.943		Historical
1992	198.912.693	7.676.560	151.782.943		
1993	198.912.693	7.676.560	151.782.943		
1994	198.912.693	7.676.560	151.782.943		
1995	198.912.693	7.676.560	151.782.943		
1996	198.912.693	7.676.560	151.782.943		
1997	737.006.187	162.396.173	164.815.980		
1998	737.006.187	162.396.173	164.815.980		
1999	737.006.187	162.396.173	164.815.980		
2000	737.006.187	162.396.173	164.815.980		
2001	142.951.619	73.690.805	174.757.024		
2002	142.951.619	73.690.805	174.757.024		
2003	142.951.619	73.690.805	174.757.024		
2004	264.363.082	78.596.482	184.234.616		
2005	264.363.082	78.596.482	184.234.616		
2006	264.363.082	78.596.482	184.234.616		
2007	286.400.629	59.226.954	200.118.642		
2008	286.400.629	59.226.954	200.118.642		
2009	286.400.629	59.226.954	200.118.642		
2010	173.891.040	18.511.560	215.799.004		
2011	173.891.040	18.511.560	215.799.004		
2012	248.937.119	5.920.802	226.167.756		
2013	293.208.910	58.002.762	217.648.209	568.859.881	Projection
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	

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% are 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 state forests. The enactment of the Basic Forestry Law (UU No.5/1967), the 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, resulting 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 forest area were entitled non-forest area (*areal penggunaan lain*-APL).

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

Protection Forest (*Hutan Lindung*/HL) is a forest area that has the 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 consists 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) was enacted, the Map of Forest Area Designation was published by MoFor through compilation of the Maps of Provincial Forest Area (see Figure 13).

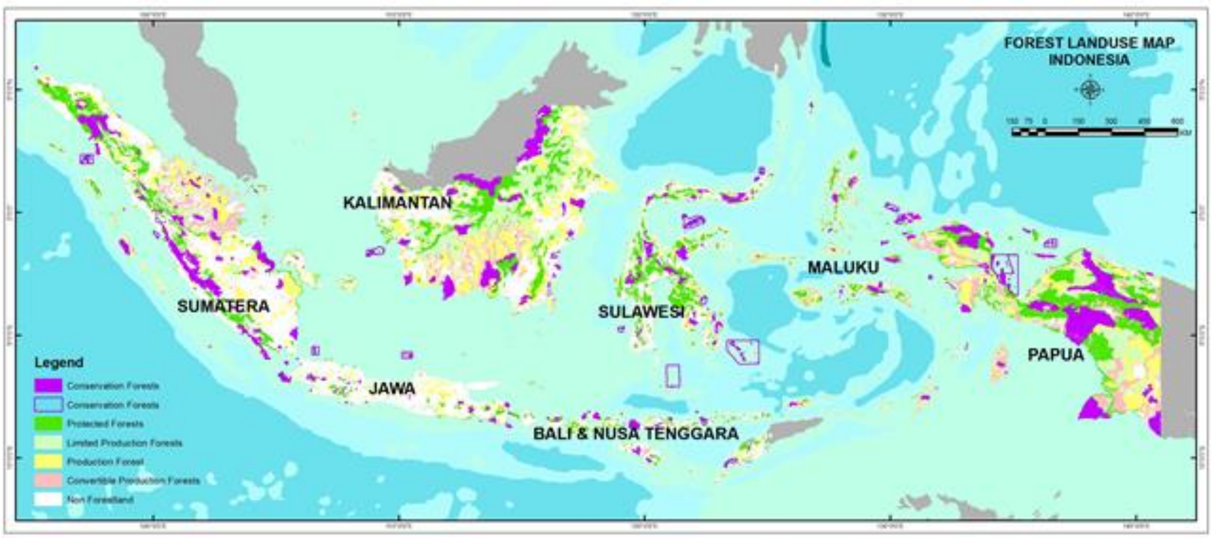

Figure 13. *Map of Forest Area Designation – Forestland Use Map (MoFor, 2014)*

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, the 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 agendas, including food security, based on community agribusiness and energy security, for the sake of national interest. This important agenda for *NAWA CITA* will consequently affect the future characteristics 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. Target of oil production in 2015 amounted to 30,798,320 tons, and increased to 36,419,870 tons in 2019 (MoAg, 2015). , Indonesia is the largest palm oil producer in the world. Ministry of Agriculture (MoA) recorded an annual growth in the period 2015-2019 of rubber production of 3.09 percent, while the annual increase of the production of coffee 2,6 percent, clove 1,9 percent and cacao 6,3 percent (MoAg, 2015). The trend of increasing agricultural production (e.g. palm oil, rubber, coffee, cacao, pepper) is also influenced by the increasing global demand of agricultural products. Similarly, upward trends 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). Of the 15.2 million ha of HPK, 7.24 million ha were still natural forest in 2012, distributed across the seven major islands/groups of islands (Figure 13). Apart from these forested areas, there are also 7.48 million ha of natural forest (as of 2012) which are located on APL (other land uses/non forest land). Hence, the total area of natural forests that can be converted is 14.72 million ha (Figure 14). The distribution of these convertible areas across the major islands/groups of islands are shown in Figure 15**Error! Reference source not found.**.

Figure 14. *Distribution of natural forests that can be converted (MoFor, 2014)*

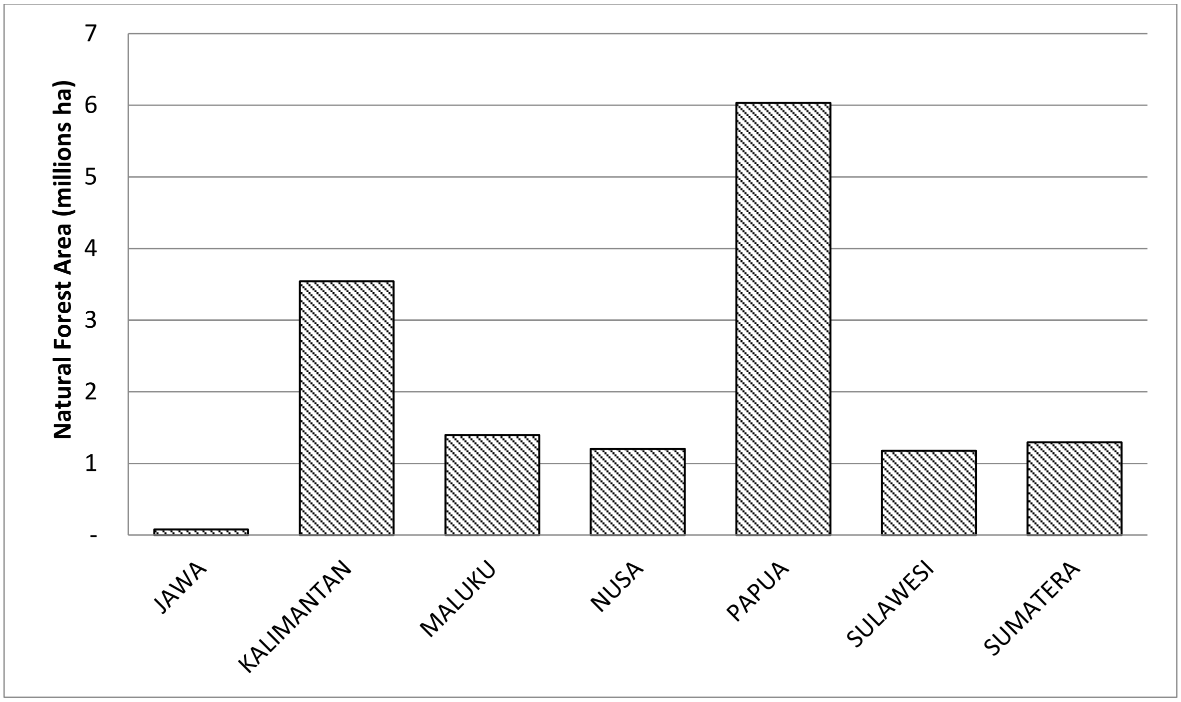

Figure 15. *Area covered by natural forest that can be converted to other land uses per major island/group of islands*

6.3. Policy intervention to reduce emissions

Natural forest area of 14.72 million ha in HPK and APL (MoFor, 2012) is by law allowed to be deforested, and this needs to be taken into account in the FREL construction. Since forest area allocation for conversion is indicative in nature and these areas are only allowed to be converted if needed for development purposes, there is no specific planning on these areas or timing for the conversion of these forests. Hence, assumptions would need to be made to enable an estimation of the associated emissions. However, due to a lack of an adequate basis for making such assumptions for the FREL construction, this submission did not differentiate between planned and unplanned deforestation.

For reducing forest conversion, the Government of Indonesia has enacted a policy on moratorium of new permits/concessions on primary forests and peatland. The moratorium was at first declared under Presidential Instruction No.10/2011, and was since then renewed every two years (Presidential Instruction 6/2013, 8/2015). Stopping deforestation and minimizing forest degradation of natural peat forest means that there will be a minimum or no additional increase of emissions from peat decomposition in the future. For example, supposedly if Indonesia were to stop deforestation on natural peat forest in 2016, the emission from peat decomposition in 2016 would be same as that of 2015. In addition, efforts to push the implementation of sustainable peat management by concessionaires (palm oil, and timber plantation companies), such as improvement of water management will also play significance role in reducing the rate of peat decomposition.

The Government of Indonesia has also carried out significant efforts 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.

In early 2016, a special agency for peat restoration (Peat Restoration Agency/*Badan Restorasi Gambut*) has been established. The agency has a special mandate for restoring degraded peatlands (Presidential Regulation No 1/2016) with different approaches, such as rewetting in priority areas, as well as canal blocking development. With these policies and plans, Indonesia expects that emissions from peat decomposition from now up to 2020 will be reduced significantly.

The emission factors used for the peat decomposition calculation in this FREL are from the 2013 Supplementary IPCC guideline, representing the average condition of EF for each particular land cover. These emission factors are expected to be lower with an improvement of water management, and may be back to zero if rewetting of peatlands took place as part of mitigation programs. With the implementation of these mitigation programs, the rate of emission from peat decomposition will decrease from the FREL. We understand that the challenge is to have a reliable monitoring system for peat emissions, and Indonesia is in the process of developing a peat monitoring system. This is one of the areas that need further support from international organizations. With the inclusion of peat in the FREL, Indonesia aims to evaluate the impact of implementation of the peat management policies in the future.

Geospatial data and information is a major foundation in establishing integrated development. In 2011, Indonesia has declared the so-called One Map Policy. The One Map Policy is a movement towards the development of one reference, one standard, one database and one geoportal, which aims to improve the access to reliable geospatial data and integrated spatial information among government institutions and agencies. Using One Map data will help to solve problems resulting from inconsistencies and contradictions in geospatial data, like overlapping of concession permits with other themes (e.g. protected areas).

7. Opportunities for Improvement

The FREL was constructed based on the currently available data and knowledge under national circumstances, capacities and capabilities. Limitation of 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. As another approach of improvements, the Indonesian National Carbon Accounting System (INCAS) was initiated to establish a specific platform for GHG accounting in Indonesia (see Krisnawati et al. 2015a; 2015b). The system employs Tier 3 and uses a systematic approach in quantifying GHG emissions and removals. The initiative was proposed to cover estimations of GHG emissions from five REDD+ scoping activities. However, the system needs to be further tested and deeply elaborated for compatibility with the other available monitoring systems in Indonesia.

7.1. Improvement of Activity Data

The future improvement of activity data will be focused on reducing the uncertainty of the emission estimates associated with deforestation, forest degradation and peat decomposition (see Table 5 on uncertainty). The efforts for improving activity data may cover two major aspects pertaining to utilization of the latest technology and methodology enhancements.

Utilization of advanced 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 different degrees of forest degradation with the same level of confidence. Furthermore, the transformation from the existing (visual-manual) system to a semi-automatic land cover classification system, which is expected to be fully operational and not in a development stage, needs a complex modification throughout the system. This includes a lot of efforts on technology exchange and transfer, hardware-software, capacity building, as well as improving quality management. The complexity particularly high when an operational system needs to provide consistent information on the 23 land cover categories across the country, instead of less classes.

In order to resolve inconsistencies resulting from the use of different data and maps, the One Map Policy as mandated in the law of geospatial information to the Geospatial Information Agency (BIG) is implemented (Ina-Geoportal, 2015). Through the One Map Policy, the national standard of land cover/use for land cover mapping has been developed. Currently, BIG is coordinating with the related ministries/agencies to develop a standardized map for the national land cover.

The potential use of high-resolution image data such as SPOT imagery, especially for determining the degree of forest degradation, 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 could be better quantified.

On the methodological aspect, producing an annual cloud-free image mosaic is increasingly possible by utilizing up-to-date pixel selection methodology (e.g. Potapov *et al.*, 2012, Hansen *et al.*, 2012). Hence, the possibility for annual wall-to-wall land-cover mapping for the coming monitoring periods will be high.

The historical land-cover data used for this FREL submission were generated using visual interpretation, which is time-consuming and requires trained operators (Margono *et al*., 2015). Apart from this, an early stage 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 in the future improvement by using a hybrid approach involving manual and digital classification can 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 Factors (Carbon Stock)

Current forest emission factors (carbon stock) for land-cover change were 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; Murdiyarso *et al*, 2015). Similar to peat lands, mangrove forests are an important carbon sink, especially due to its organic-rich soils. Additional plots will be essential to represent all forest classes in each region.

In addition to NFI data, FORDA established 263 permanent research plots since 2011 in 13 provinces. These can be utilized to improve the available field data. More pools that significantly contribute to the 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 up-to-date advanced information technology to connect ground measurements and server can be used to support database management, data processing and real-time data collection. As such, errors can be identified faster, and are 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 Factors

For future emission calculations 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. A 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.

7.4. Estimating Peatland Fire Emissions

Various researches used satellite images for burnt area mapping, like Landsat (Phua *et al.*, 2007) and SAR images (Siegert and Ruecker, 2000). Cloud cover persistence during and after a 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 regions, 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 the fire episode of 1997/1998, comparing 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 emissions is excluded in this document. Annex 4. **Measuring emissions from peat fires** explains 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 the 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 burnt peat depth for calculating emissions from peat fires. Airborne LiDAR has been used for calculating burnt peat depth with high accuracy (Ballhorn, et al. 2009, Konecny et al. 2016). However, to implement it at large scale will be challenging and costly. Reducing the LiDAR point density could be a solution for a 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 its REDD+ readiness process in 2007 (prior to COP-13 in Bali). Most of the required REDD+ frameworks have been developed and tested. However due to diversity of perceptions and expectations among stakeholders, improvement is still required before a full implementation is possible. 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 learnt for future improvements (see Figure 16).

Figure 16. Distribution of REDD+ Demonstration Activities in Indonesia

The decision to include other REDD+ activities (conservation, sustainable forest management, carbon stock enhancement) needs to consider the implications for data requirements and methodology selection. For example, if Indonesia wanted to include forest carbon stock enhancement, non-forested areas (i.e. shrubs, bare land, etc.), in which the activity were to be carried out, should be included in the baseline emission calculation. This is currently not the case as old regrowth and highly degraded logged-over areas within forest areas were assigned as non-forested areas. 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 a minimum of 10 percent crown cover, we used 30 percent (MoFor, 2004)).

In addition, enhancement of carbon stock will be dominant in plantation forests. Given the wide variation of site characteristics and tree species, more comprehensive and detailed research on AGB stocks and their annual increments in plantation forests will be required. The role of conservation and sustainable forest management (SFM) are other potential activities to be included in a future FREL. Programs 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 the involvement of the technical aspects, but also in strengthening the role of local communities and institutions (including private companies, civil society, and government) in maintaining, preserving, and scaling up the role of natural forest conservation with regards to emission reduction.

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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 was initially be updated every three years based on data availability, due to problems of clouds and haze, and cost-effectiveness. In total, 217 Landsat 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 2006, other data sets such as SPOT Vegetation 1000 meters and MODIS 250 meters were used as alternatives, especially when the purchased Landsat data of MoFor were not yet ready for processing and classification processes.

More complete data became available around 2009; following the change in the 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 scenes 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. The abundant data availability through the free download has opened opportunities for Indonesia to change the three-year mapping interval into annual. Up to now, land-cover data is available for the years of 2000, 2003, 2006, 2009, 2011, 2012, 2013, 2014 and 2015. During the last five years, efforts for updating land cover data of 1990s have been carried out, to renew the information made during the era of NFI. However, USGS and LAPAN have not enough Landsat scenes archived, so that annual 1990s mapping was not possible; thus only two 1990s sets of data were established: 1990 and 1996.

To maintain product continuity and further improve the work, a collaboration between LAPAN for Landsat data preparation and MoFor/MoEF for the classification process is a 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) or Simontana (*Sistem Monitoring Hutan Nasional*) (MoFor, 2014). It is available online at http://nfms.dephut.go.id/ipsdh/, coupled with a webGIS at http://webgis.dephut.go.id/ for display and viewing or the updated web version at http://webgis.dephut.go.id:8080/klhk/home/mapview. The website is part of the geospatial portal under the One Map Policy.

The historical development of land cover mapping Indonesia can be divided in three periods. Within Period 1, representing the time prior to 2000, all available data including analog data and hard copies of Landsat scenes, were delineated manually and digitized. For Landsat, most scenes that were available as either softcopy in CCT format or hard copy did not have the same year interval. So that, during the 1st period, the data used for generating land cover maps came in various conditions and formats. Products in the 1st period 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 data were classified manually which is a time-consuming process and delayed the product delivery, especially as work experiences in wall-to-wall mapping were still limited. Problems of permanent cloud cover in some of Indonesia's areas and thus data unavailability for these areas slowed down the process as well. An alternative approach by using SPOT Vegetation 1000 meters and MODIS 250 meters was applied for immediate reporting. In Period 3 (2009 onwards), data availability is no longer a constraint, and Landsat imagery is now the only source of data. Significant improvements were carried out during the 2nd period (2006) and became a major concern at the beginning of Period 3 (2009); the improvements included the migration of every layer of the time-sequential land cover data into a single geodatabase. Geodatabase is a solution to improve interdependency and consistency among the different layers. Now, efforts to overcome the time-consuming manual classification process are the main concern.

The land cover map of Indonesia consists of 23 classes, including 6 classes of natural forest, 1 class of plantation forest, 15 classes of non-forest, and 1 class of clouds-no data. The 23 classes are described in Table Annex 1.1 (refer to SNI 7645-2010, Margono *et al*. 2016); with the series of monogram for those 23 classes is described in (MoF, 2003). A monogram is a detailed explanation or class description completed by example image subsets in different band combinations and field pictures.

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

No	Class	Description
	Forest	
1	Primary dryland forest	Natural tropical forests growing on non-wet habitat including lowland, upland, and montane forests. The class 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 growing on non-wet habitat including lowland, upland, and montane forests that exhibit signs of logging activities indicated by patterns and spotting of logging (appearance of roads and logged-over patches). The class includes 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 growing on 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 growing 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 of roads and logged-over patches).
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 include areas of reforestation, industrial plantation forest and community plantation forest
	Non-Forest	
8	Dry shrub	Highly degraded logged-over areas on non-wet habitat that are in an ongoing process of succession but have not yet reached a stable forest ecosystem, with naturally scattered trees or shrubs
9	Wet shrub	Highly degraded logged-over areas on wet habitat that are in an ongoing process of succession but have not yet reached a stable forest ecosystem, with naturally 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 agricultural 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 agricultural activities on dry/non-wet land mixed with shrubs, thickets, and logged-over forest. This cover type often results of shifting cultivation and its rotation, including on karst
13	Estate crop	Estate areas that have been planted, mostly with perennials crops or other agricultural trees commodities
14	Paddy field	Agriculture areas on wet habitat, especially for paddy, that typically exhibit dyke patterns (pola pematang). This cover type includes rain fed, 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, including open exposure areas, craters, sandbanks, sediments, and areas post fire that do 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 include rural, urban, industrial and other built-up areas with typical appearance
20	Port and harbor	Sighting of port and harbor that is big enough to be delineated as independent object
21	Open water	Water bodies including ocean, rivers, lakes, and ponds
22	Open swamps	Wetland area with few vegetation
23	Clouds and no-data	Clouds, cloud shadows or data gaps with a size of more than 4 cm^2 at a 100.000 scale 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 class names (**Error! Reference source not found.**) correspondingly feature land uses, such as class of forest plantation or estate crops. However, the object identification is purely based on the existing appearance in the imagery. Manual-visual classification through on-screen digitizing technique based on key elements of image/photo-interpretation was applied as classification method. Several ancillary data sets (including concession boundaries of logging and plantation, forest area boundaries) were utilized during the process of delineation, to integrate additional information valuable for classification.

Manual classification is time-consuming and labor intensive (Margono *et al.*, 2012, Margono *et al*., 2014). It involves also MoFor/MoEF staff from district and provincial levels to manually interpret and digitize the satellite images, to exploit their local knowledge. 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 by the conversion of raster format into vector format for further analysis. Visual classification technique was then selected as the 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 the land cover maps to field data collected afterwards. 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 a table of accuracy (contingency matrix, see Table Annex 1.2), 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).

Table Annex 1.2. *Contingency Matrix of field verification (Land Cover Map of Indonesia 2011)*

Contingency Matrix of field verification (Land Cover Map of Indonesia 2011)

Land Cover		Classified Map																							Total	Error of Comission	User Accuracy
		PF	SF	PMF	SMF	PSF	SSF	TP	MxUA	AUA	EP	Se	Rc	Sr	SSr	Sv	Mn	WB	Sw	Po	Tr	Br	Ai	Ot			
Ground Check	PF	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0,00%	100,00%
	SF	0	119	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	121	1,65%	98,35%
	PMF	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	25,00%	75,00%
	SMF	0	0	0	4	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	7	0,00%	57,14%
	PSF	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0,00%	100,00%
	SSF	0	0	0	1	0	24	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	28	14,29%	85,71%
	TP	0	1	0	0	0	0	20	0	0	1	0	0	2	3	0	0	0	1	1	0	3	0	0	32	37,50%	62,50%
	MxUA	0	0	0	0	0	0	0	174	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	177	1,69%	98,31%
	AUA	0	0	0	0	0	0	0	0	22	5	2	0	4	0	1	1	0	2	2	0	0	0	0	39	43,59%	56,41%
	EP	0	0	0	0	0	0	0	2	1	70	1	0	3	1	0	0	0	0	1	0	3	0	0	82	14,63%	85,37%
	Se	0	0	0	0	0	0	1	0	0	1	51	0	4	0	0	0	0	1	1	0	3	0	0	62	17,74%	82,26%
	Rc	0	0	0	0	0	0	0	0	0	0	2	28	0	2	0	1	0	0	1	0	0	0	0	34	17,65%	82,35%
	Sr	0	1	0	0	0	0	1	0	0	1	0	0	78	0	0	0	0	0	0	0	2	0	0	83	6,02%	93,98%
	SSr	0	0	0	0	0	1	0	1	0	0	1	0	3	34	0	0	0	2	0	0	1	0	0	43	20,93%	79,07%
	Sv	0	0	0	0	0	0	0	1	0	0	0	0	0	0	13	0	0	0	0	0	1	0	0	15	13,33%	86,67%
	Mn	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3	33,33%	66,67%
	WB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	1	0	0	0	0	28	3,57%	96,43%
	Sw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	11	0,00%	100,00%
	Po	0	1	0	0	0	0	1	0	0	0	2	0	2	0	0	0	0	0	20	0	1	0	0	27	25,93%	74,07%
	Tr	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	9	0	0	0	11	18,18%	81,82%
	Br	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	2	0	25	0	0	31	19,35%	80,65%
	Ai	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	9	0	11	18,18%	81,82%
	Ot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total		7	123	3	5	1	26	23	182	23	79	62	28	99	44	14	4	27	19	29	9	41	9	0	857		
Error of Comission		0,00%	3,25%	0,00%	0,00%	0,00%	7,69%	13,04%	4,40%	4,35%	11,39%	17,74%	0,00%	21,21%	22,73%	7,14%	50,00%	0,00%	42,11%	31,03%	0,00%	39,02%	0,00%				
Producer Accuracy		100,00%	96,75%	100,00%	80,00%	100,00%	92,31%	86,96%	95,60%	95,65%	88,61%	82,26%	100,00%	78,79%	77,27%	92,86%	50,00%	100,00%	57,89%	68,97%	100,00%	60,98%	100,00%				

Total (Forest)	:	181
Overall Accuracy	:	**87,63%**
Overall Accuracy (Forest)	:	**98,34%**

Following the latest developments on data availability, MoFor has been refining the national land cover classification maps, from 1990s to 2013, and plans to update deforestation data over more than two decades using the refined land cover data set. MoFor has collected and archived more than 10,000 Landsat scenes from the entire country dating back from the early 1990s onwards. Although targeting the whole observation period from 1990 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 the alternative data of SPOT Vegetation (2000-2005) has been replaced with deforestation rates derived from Landsat. Land cover data used in this submission are those based on the first refinement.

Other data sets introduced in this report

There are two independent studies used for comparison to illustrate the reliability of the MoFor data used in this FREL submission, 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)

The study of Margono *et al.* (2014) has been published in the Journal of Nature Climate Change, available online since June 2014. The study is part of the global mapping system of Hansen *et al.* (2013) with specific modifications for national scale (Indonesia). The study generates three main land cover classes: primary intact forest, primary degraded forest, 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 (Figure Annex 1.1). 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 1.3).

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

Table Annex 1.3. *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

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 more 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 one steps are automatically used as the input for the next step. Image preparation is intended to produce a cloud free 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 then compared to the MoFor for the year 2000 and 2012 (see Table Annex 1.4 and Figure Annex 1.1).

Table Annex 1.4. *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

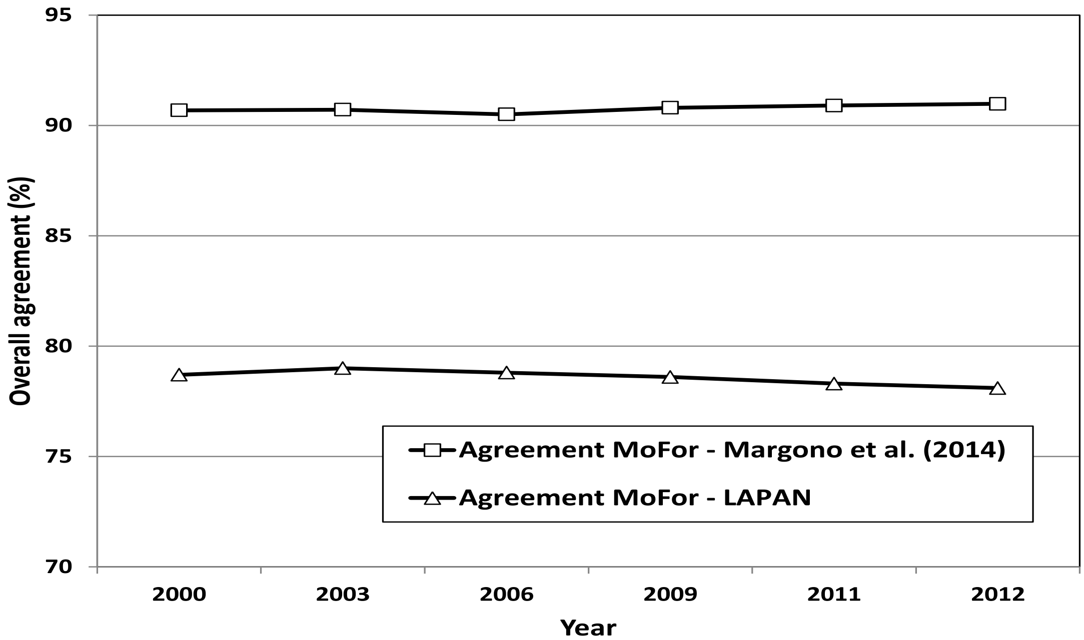

Figure Annex 1.1. *Agreement of the MoFor land cover data used in this analysis to the other two independent studies (Margono and LAPAN/LCCA-LAPAN).*

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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, conducted by the Ministry of Agriculture. Indonesia has developed a procedure for peatland mapping based on remote sensing at a scale of 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 used peat map is the latest Peatland Map edition 2011 at a scale of 1:250.000 (national scale). This map was generated based on 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 peatland map was created from a series of available data in Indonesia, resulting from soil mapping carried out at various levels and scales, accompanied by appropriate ground measurements.

The method to prepare the peat map of Indonesia is as follows:

Data Input:

- Indicative soil maps with scales 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, Mapsof 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 varying acquisition dates).
- Digital map of Rupabumi Indonesia (RBI) 1:250.000 from Bakosurtanal (BIG).
- 1:250.000 scale geological map from the Center for Research and Development of Geology, Bandung.

Method:

A comparative method was used. All data collected from any sources were compared spatially by using spatial data analysis tools and combined with literature review. In order to increase the accuracy of the results of the comparative method, validation was conducted by ground truth surveys. The soil classification system used in this map refers to the Presidential Instruction (Inpres) No. 10/2011 (forest moratorium) and the Minister of Agriculture Regulation (Permentan) No. 4/2009.

A 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. Field measurements 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 detailed 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 Peatland Map Scale 1:250.000 Edition December 2011*”) published in 2011 by the Agricultural Research and Development Agency, Ministry of Agriculture of Indonesia.

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 MoFor in conducting forest resource enumeration during the period of 1989 to 1996. The implementation was carried out through technical assistance from FAO. The goal of the 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 on a 20 km x 20 km grid. All plots were distributed in lowland area below 1000 m above sea level. In addition to that, a land and forest cover map was produced 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 areas for filling the gaps and additional plots in mountainous region and conservation areas.

NFI sampling design

The purpose of the plots established by the 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.

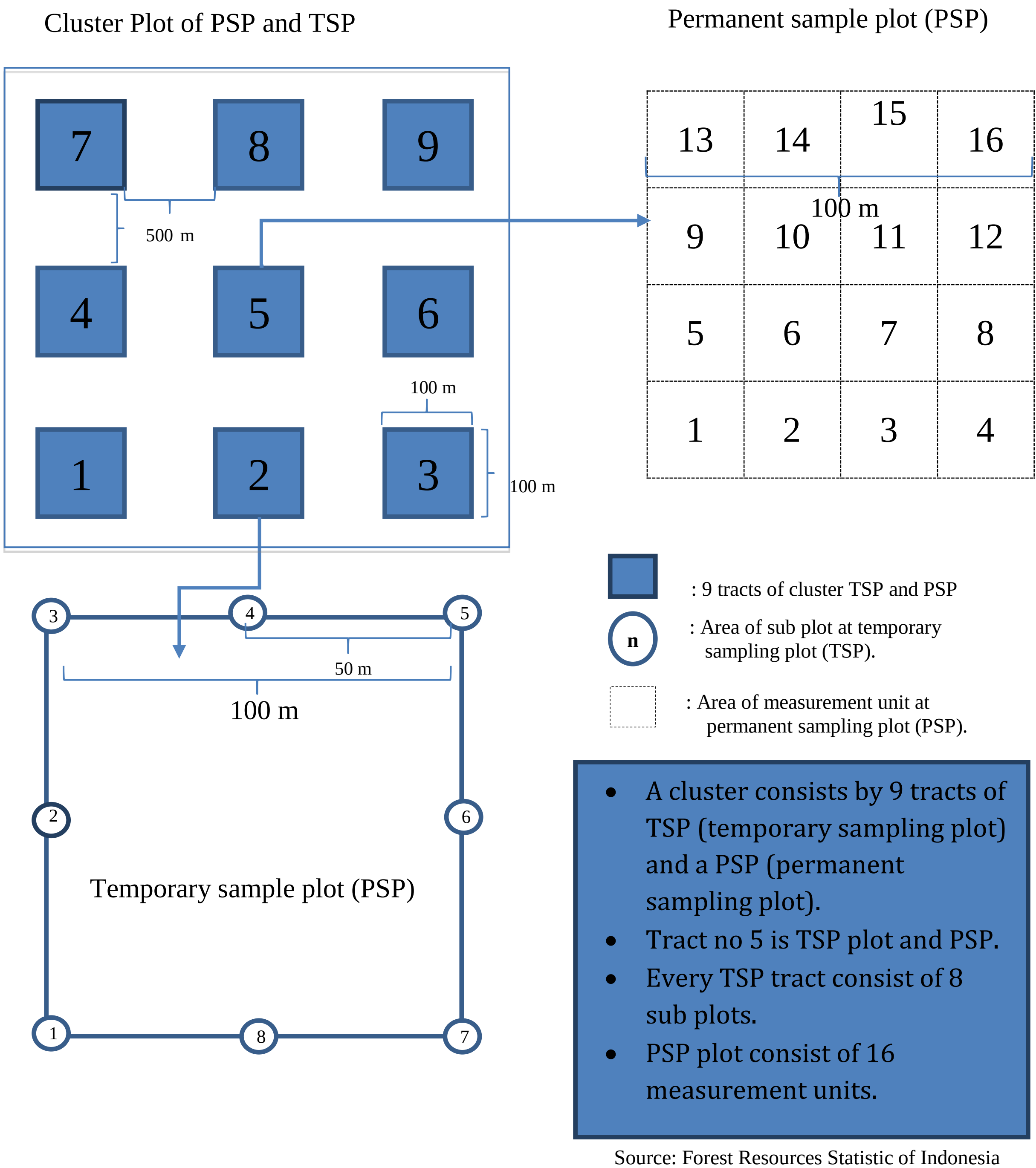

Figure Annex 3.1. *Plot cluster layout.*

NFI Cluster distribution

NFI clusters were systematically distributed at 20 km x 20 km covering all land cover types within the forest area of Indonesia (see Figure Annex 3.2). Most of the clusters are located in the area with altitudes 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 totaling 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 the plot's 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 the 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% were located in forested areas while the remaining were 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 and swamp forest. The PSPs located in mangrove forest were excluded since there were not enough PSP records available in this forest type.

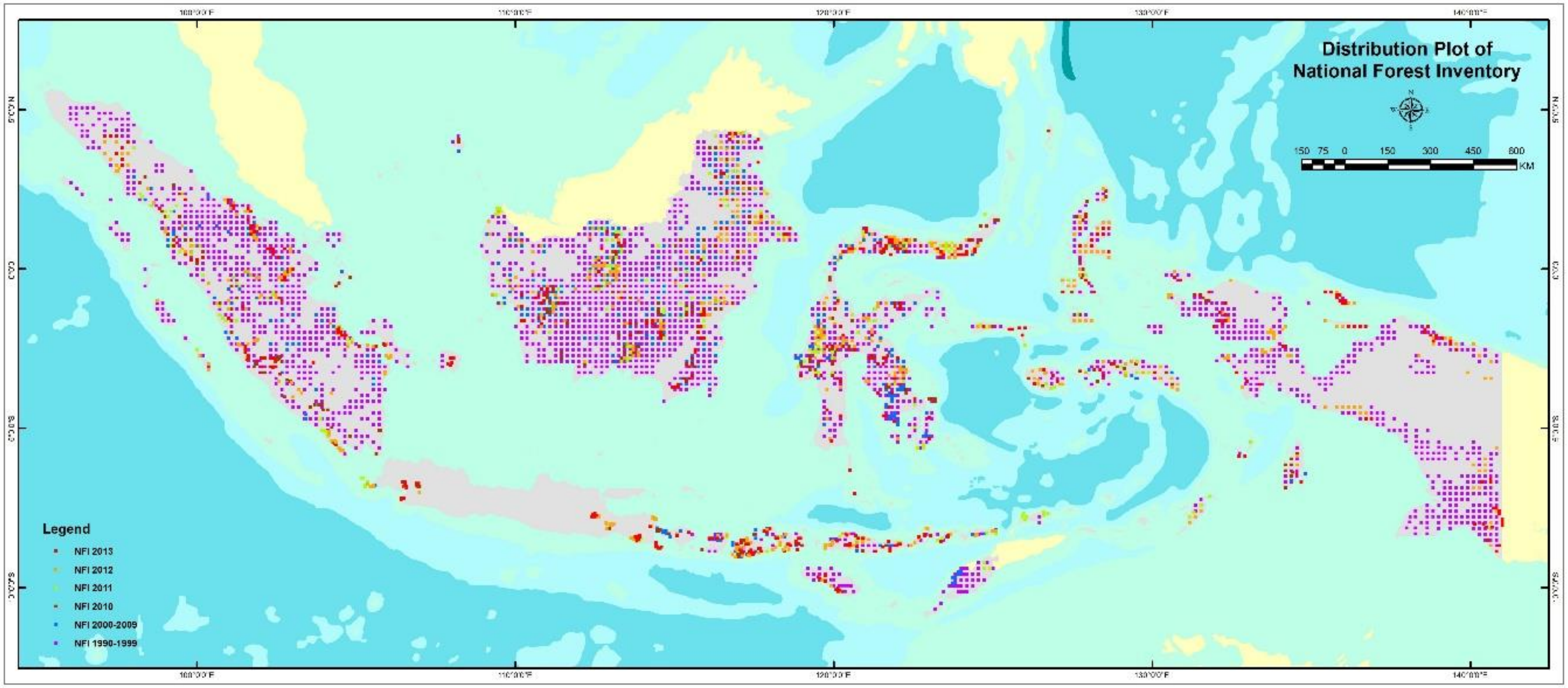

***Figure Annex 3.2**. NFI's PSP/TSP distribution map.*

In order to estimate total tree biomass, an allometric equation was applied using field measurement data (DBH and tree species). Local allometric models specific for the six forest types were not available for all seven main islands of Indonesia so the 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).

Forest Biomass Proportion

An analysis was conducted to assess the proportion of biomass pools to total forest biomass (excluding 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. Central Kalimantan study covering six forest types for the whole province (Krisnawati *et al*., 2014).
3. KPH Kapuas Hulu, West Kalimantan (Manuri *et al.*, 2014)
4. UNPAR Forest research area, Katingan, Central Kalimantan (Dharmawan, Saharjo, Supriyanto, HS, & Siregar, 2013)

Table Annex 3.2 concludes that AGB accounts for more than 70% of the 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 pools assessed in 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%**		

Notes:
[1] Manuri, *et al*. 2011
[2] Krisnawati *et al*., 2014
[3] Manuri *et al*., 2014
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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} 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 5 of burned areas (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 are 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% are selected. As MODIS hotspots are not available for the period before 2000, NOAA hotspot might be used for to fill the gap. However, comparability and 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) is generated and overlaid on top of the hotspot data. Pixels without hotspots are considered as not burned and excluded from the activity data. Each 1km ×1 km pixel with at least one hotspot is considered as burned but with the assumption that the burned area is 75% of the pixel area (7,500 ha). This rule applies for each pixel regardless the number of hotspots within a particular pixel (Figure Annex 4.1). Then, these burned areas were overlaid with the peat land map (produced by MoA) to estimate the burned peat land for each year.

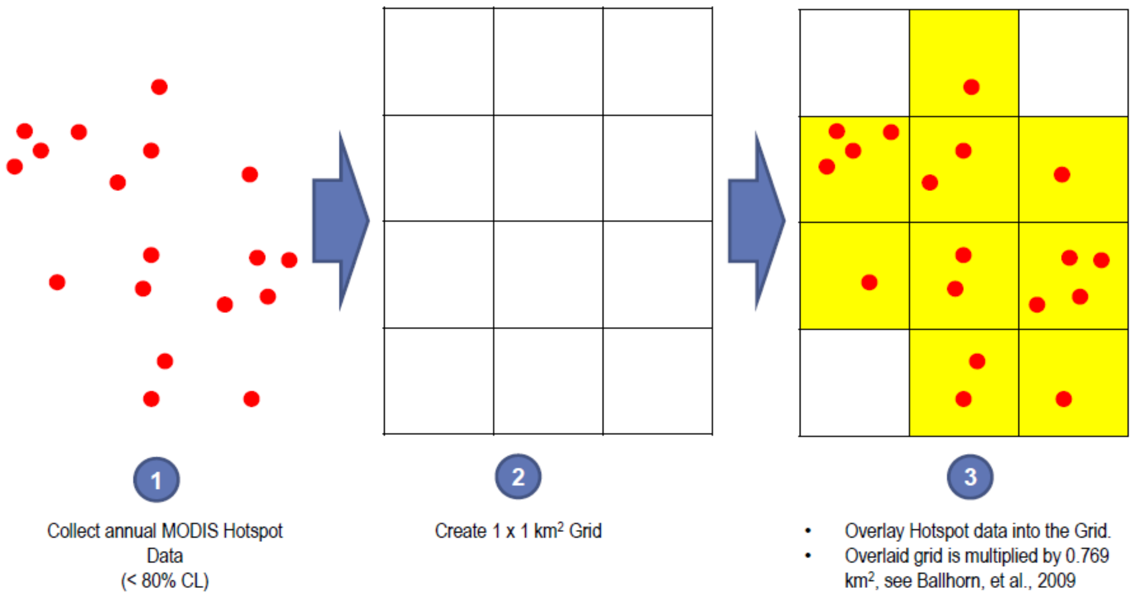

Figure Annex 4.1. *Methodology to derive burned area (activity data)*

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 M_s is mass of soil solids, which is equal to accumulation mass of ash (M_{ash}) and mass of organic matters. Ratio of M_{ash} and M_s 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} 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, the value would be 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. Emissions from peatlands that suffer more than one fire event are assumed to be reduced by half compared to that of the first burning, e.g. the first burning of 1 ha peat emits 923.1 tCO_2 (UKP4 and UNORCID, 2013), while the subsequent burning of exactly the same area will release 462 tCO_2. The third burning of the same area will release again a lower amount of emissions than the second burning but further research is necessary to determine the amount of reduction. The above assumption is from a manuscript that resulted from Peat Emission Workshop held by UKP4 and UNORCID (6 November 2013) in Jakarta.

<u>Historical emission from peat fire</u>

Due to the unavailability of MODIS hotspot data prior to 2000, historical emissions from peat fire have only been calculated for the period 2000-2012. Scope of area were naturally forested areas as of 2000.

It was found that the annual estimated burned peat areas varied greatly from 2001 to 2012 (Figure Annex 4.2). The highest rate occurred in 2006 accounting for 95,147 ha of burned peatland, while the lowest rate occurred in 2007 accounting for 3,446 ha of burned peat area. Using this historical data set, the average value used as activity data for proposed REL from burned peat accounts for 29,379 ha.

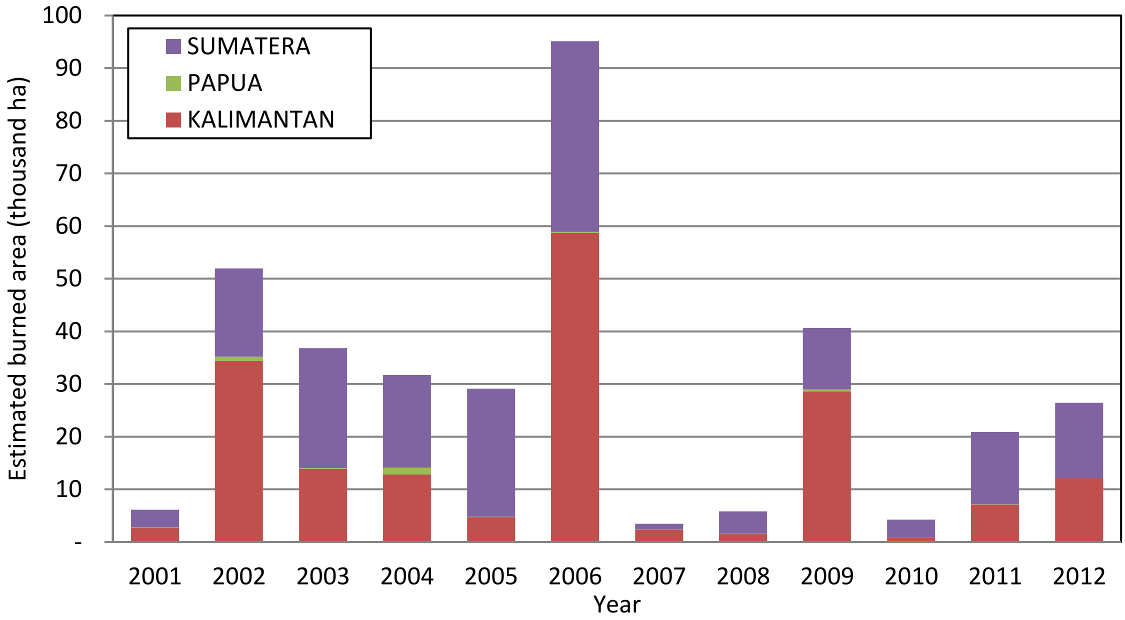

Figure Annex 4.2. *Estimated burned peat area (in the natural forest of 2000)*

The results of the calculation of emissions from burned peat are shown in Figure Annex 4.3. Average emission from peat fire from 2000 – 2012 is 27.1 $MtCO_2e\ yr^{-1}$. The derivation of the burned areas has not been verified using ground truthing or high-resolution satellite data. Therefore, the uncertainty level cannot be estimated.

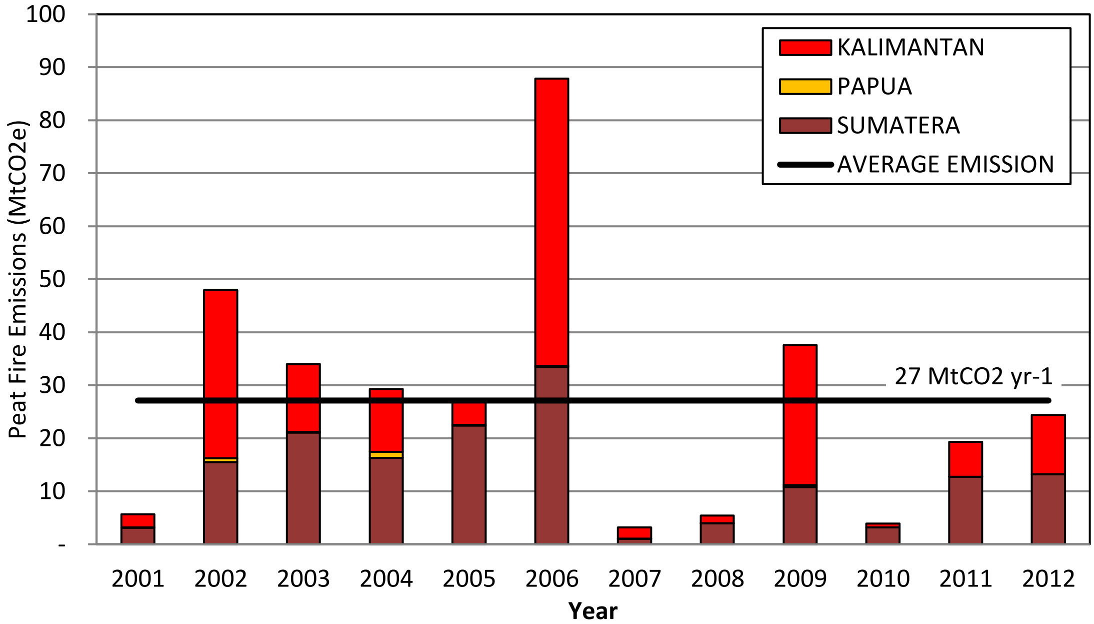

Figure Annex 4.3. *Estimated historical emission from burned peat (in natural forested areas as of 2000)*

Constraints in measuring emissions from peat fires

Some critical issues on the accuracy of the burn scar lies in 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 is possible as a thermal anomaly can originate from other heat sources than fires. Selection of hotspot with high confidence level can reduce such error. However, smoke coverage is very common during fire season, which reduces the sensor's capability to detect fires covered by smokes. This can result in underestimation of the burned areas. In contrast, assuming that the burned area is 75% for each pixel with hotspot might lead to a severe overestimate of the burned area, especially in the border area between burned and unburned.

A further challenge lies in determining the peat depth consumed by fires. Relationship analyses between hotspot parameters (fire intensity, frequency etc.) with burned peat depth need to be carried out to better estimate the burned peat depth of the burned peatland and thus estimate the actual emissions from peat fires. Ballhorn *et al*. (2009) used airborne LIDAR for estimating burned peat depth with accuracy of less than 20 cm. Konecny *et al.* (2016) found that carbon loss varies significantly for recurrent fires in drained tropical peatlands. According to their research the relative burned area depth decreases over the first four fire events and is then constant for further successive fires. They estimate values for the dry mass of peat fuel consumed to be only 58–7% of the current IPCC Tier 1 default value for all fires. This indicates that accurate estimation of emissions from peat fires should also consider the frequency of fires in an area and employ accordingly adjusted emission factors.

With above conditions and high level of uncertainties of all involved parameters (hotspot detection, size of burned area estimation, fire frequency, burned peat depth, mass of fuel available for combustion), this FREL document did not include emissions from peat fires. Advancing technology in remote sensing to improve burned scar and peat depth mapping will increase the accuracy of peat fire emission calculation which can then be included as improvement in a future FREL.

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Annex 5. Detailed Activity Data for calculation of emissions 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

Island/Soil/ Land Cover	Deforestation (ha)						
	1990-1996	1996-2000	2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
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
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. Emission Factor Matrix for peat decomposition calculation

The calculation of emission from peat decomposition was performed by employing transition matrix of emission factor (Table Annex 6.1). The emission factors were multiplied by the extent of land cover change (activity data) within a change period (e.g. 1990 to 1996, 1996 to 2000, and so forth) to obtain emissions from peat decomposition as provided in Table Annex 6.2.

Table Annexes 6.1 and 6.2 actually present the emissions from peat decomposition, not the emissions from land-use transition. This issue appears due to the use of two independent data sets, in this case:

a) land cover data as elaborated in Table Annex 1.1, analyzed based solely on Landsat imageries, without reference to the actual soil types
b) peatland map as elaborated in section 2.4 and Annex 2 based on soil survey data.

The available land cover data (AD) has an uneven year interval (e.g. 1990-1996, and 1996-2000) in its nature. We considered the importance of re-evaluating the land cover change for each time interval (1990-1996, 1996-2000, etc.) by averaging the EF based on the land cover types of each time interval, to capture all changes of water level variation during the time interval. In particular, we did not handle changes as immediate but as gradual or subtle changes within each mapping interval.

For generating the land cover transition matrix, the peatland map was used as the base map, overlaid with the classification of forests including dryland forest. In cases where *dryland forest* occurs in peatland area, it is reclassified as *(primary/secondary) swamp forest*. This kind of confusion in the delineation is called *sliver* areas, resulting due to the use of two independent data sets as described above. These sliver areas might be recognized as dryland within peat lands. In the future, with the One Map Policy initiatives, this issue is expected to be resolved. For the calculation of emissions from peat decomposition, however, we used the right emission factor, i.e. the emission factor for *primary swamp forest* for the misclassified *primary dryland forest*. As such, there is no error in the calculation.

The emission factors for each land cover type (diagonal; for land remaining the same land cover) and each land cover undergoing transition to other land cover (off-diagonal) are shown in Table Annex 6.1. Table Annex 6.1. (23 x 23 matrix) was generated from Table 44. It includes all 23 land cover classes, including the four non-peat forest classes PF, SF, PMF and SMF which might occur on peat due to the above explained sliver phenomenon. All standard deviations in Table Annex 6.1., have been analyzed for each land cover change, but are not shown in order to maintain readability of the table. For example, emission factor for agriculture crop (AUA) is 51 $tCO_2e\ ha^{-1}y^{-1}$. The above or below cells (white cells) from the diagonal cells represent emission factors for the areas that change during a change period to that land cover. Assuming that a change occurs gradually, the associated emission factors were calculated as the average of peat emission factor of land cover before (T_0) and after (T_1) the change. For example, an area changing from secondary dryland forest (SF) into agriculture crop (AUA) will have an emission factor of 35 $tCO_2e\ ha^{-1}y^{-1}$, which is the average emission factor between secondary dry-land forest (19 $tCO_2e\ ha^{-1}y^{-1}$) and agriculture crop (51 $tCO_2e\ ha^{-1}\ y^{-1}$).

Table Annex 6.1. *Transition Emission Factor Matrix.*

	LC	T1																						
		PF	SF	PMF	SMF	PSF	SSF	TP	Sr	EP	SSr	AUA	MxUA	Rc	Sv	Po	Sw	Se	Ai	Tr	Br	Mn	WB	Ot
	PF	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-
	SF	9.5	19.0	9.5	19.0	9.5	19.0	46.0	19.0	29.5	19.0	35.0	35.0	27.0	27.0	9.5	9.5	27.0	9.5	35.0	35.0	35.0	9.5	9.5
	PMF	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-
	SMF	9.5	19.0	9.5	19.0	9.5	19.0	46.0	19.0	29.5	19.0	35.0	35.0	27.0	27.0	9.5	9.5	27.0	9.5	35.0	35.0	35.0	9.5	9.5
	PSF	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-
	SSF	9.5	19.0	9.5	19.0	9.5	19.0	46.0	19.0	29.5	19.0	35.0	35.0	27.0	27.0	9.5	9.5	27.0	9.5	35.0	35.0	35.0	9.5	9.5
	TP	36.5	46.0	36.5	46.0	36.5	46.0	73.0	46.0	56.5	46.0	62.0	62.0	54.0	54.0	36.5	36.5	54.0	36.5	62.0	62.0	62.0	36.5	36.5
	Sr	9.5	19.0	9.5	19.0	9.5	19.0	46.0	19.0	29.5	19.0	35.0	35.0	27.0	27.0	9.5	9.5	27.0	9.5	35.0	35.0	35.0	9.5	9.5
	EP	20.0	29.5	20.0	29.5	20.0	29.5	56.5	29.5	40.0	29.5	45.5	45.5	37.5	37.5	20.0	20.0	37.5	20.0	45.5	45.5	45.5	20.0	20.0
	SSr	9.5	19.0	9.5	19.0	9.5	19.0	46.0	19.0	29.5	19.0	35.0	35.0	27.0	27.0	9.5	9.5	27.0	9.5	35.0	35.0	35.0	9.5	9.5
	AUA	25.5	35.0	25.5	35.0	25.5	35.0	62.0	35.0	45.5	35.0	51.0	51.0	43.0	43.0	25.5	25.5	43.0	25.5	51.0	51.0	51.0	25.5	25.5
T0	MxUA	25.5	35.0	25.5	35.0	25.5	35.0	62.0	35.0	45.5	35.0	51.0	51.0	43.0	43.0	25.5	25.5	43.0	25.5	51.0	51.0	51.0	25.5	25.5
	Rc	17.5	27.0	17.5	27.0	17.5	27.0	54.0	27.0	37.5	27.0	43.0	43.0	35.0	35.0	17.5	17.5	35.0	17.5	43.0	43.0	43.0	17.5	17.5
	Sv	17.5	27.0	17.5	27.0	17.5	27.0	54.0	27.0	37.5	27.0	43.0	43.0	35.0	35.0	17.5	17.5	35.0	17.5	43.0	43.0	43.0	17.5	17.5
	Po	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-
	Sw	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-
	Se	17.5	27.0	17.5	27.0	17.5	27.0	54.0	27.0	37.5	27.0	43.0	43.0	35.0	35.0	17.5	17.5	35.0	17.5	43.0	43.0	43.0	17.5	17.5
	Ai	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-
	Tr	25.5	35.0	25.5	35.0	25.5	35.0	62.0	35.0	45.5	35.0	51.0	51.0	43.0	43.0	25.5	25.5	43.0	25.5	51.0	51.0	51.0	25.5	25.5
	Br	25.5	35.0	25.5	35.0	25.5	35.0	62.0	35.0	45.5	35.0	51.0	51.0	43.0	43.0	25.5	25.5	43.0	25.5	51.0	51.0	51.0	25.5	25.5
	Mn	25.5	35.0	25.5	35.0	25.5	35.0	62.0	35.0	45.5	35.0	51.0	51.0	43.0	43.0	25.5	25.5	43.0	25.5	51.0	51.0	51.0	25.5	25.5
	WB	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-
	Ot	-	9.5	-	9.5	-	9.5	36.5	9.5	20.0	9.5	25.5	25.5	17.5	17.5	-	-	17.5	-	25.5	25.5	25.5	-	-

Note: Refer to Table 2 for explanation of the abbreviations of land cover types

Table Annex 6.2. *Transition Area Matrix of Land Cover. "Yellow" is total emission, "red" is emission from secondary forest existing in 1990, "green" is emission from forest degradation, emission from deforestation = yellow-red-green.*

	LC	T1 (1996)																							Total
		PF	SF	PMF	SMF	PSF	SSF	TP	Sr	EP	SSr	AUA	MxUA	Rc	Sv	Po	Sw	Se	Ai	Tr	Br	Mn	WB	Ot	
T0 (1990)	PF																								
	SF																								
	PMF																								
	SMF																								
	PSF																								
	SSF																								
	TP																								
	Sr																								
	EP																								
	SSr																								
	AUA																								
	MxUA																								
	Rc																								
	Sv																								
	Po																								
	Sw																								
	Se																								
	Ai																								
	Tr																								
	Br																								
	Mn																								
	WB																								
	Ot																								
Total																									

Note: Refer to Table 2 for explanation of the abbreviations of land cover types

Annex 7. The estimates of AGB stocks and emission factors in each forest type in Indonesia (by main Islands)

Table Annex 7.1. *The estimates of AGB stocks in each forest type in Indonesia (by Main Island)*

Main Island	Forest Type	Mean AGB (Mg ha-1)	95% Confidence Interval (Mg ha^{-1})		N of plot measurements	SE(%)
Bali Nusa Tenggara	Primary dryland	274,4	247,4	301,3	52	10%
	Secondary dryland	162,7	140,6	184,9	69	14%
	Primary swamp					
	Secondary swamp					
	Primary mangrove					
	Secondary mangrove					
Jawa	Primary dryland					
	Secondary dryland	170,5			1	
	Primary swamp					
	Secondary swamp					
	Primary mangrove					
	Secondary mangrove					
Kalimantan	Primary dryland	269,4	258,2	280,6	333	4%
	Secondary dryland	203,3	196,3	210,3	608	3%
	Primary swamp	274,8	269,2	281,9	3	2%
	Secondary swamp	170,5	158,6	182,5	166	7%
	Primary mangrove	263,9	209,0	318,8	8	21%
	Secondary mangrove	201,7	134,5	244,0	12	21%
Maluku	Primary dryland	301,4	220,3	382,5	14	27%
	Secondary dryland	222,1	204,5	239,8	99	8%
	Primary swamp					
	Secondary swamp					
	Primary mangrove					
	Secondary mangrove					
Papua	Primary dryland	239,1	227,5	250,6	162	5%
	Secondary dryland	180,4	158,5	202,4	60	12%
	Primary swamp	178,8	160	197,5	67	10%
	Secondary swamp	145,7	106,7	184,7	16	27%
	Primary mangrove					
	Secondary mangrove					
Sulawesi	Primary dryland	275,2	262,4	288,1	221	5%
	Secondary dryland	206,5	194,3	218,7	197	6%
	Primary swamp	214,4	-256,4	685,2	3	
	Secondary swamp	128,3	74,5	182,1	12	42%
	Primary mangrove					
	Secondary mangrove					

Sumatera	Primary dryland	268,6	247,1	290,1	92	8%
	Secondary dryland	182,2	172,1	192,4	265	6%
	Primary swamp	220,8	174,7	266,9	22	21%
	Secondary swamp	151,4	140,2	162,6	160	7%
	Primary mangrove					
	Secondary mangrove					

Table Annex 7.1. *The estimates of Emission Factor in each forest type in Indonesia (by Main Island)*

Main Island	Forest Type	Deforestation		Forest Degradation	
		($t\ CO_2\ ha^{-1}$)	SE (%)	($t\ CO_2\ ha^{-1}$)	SE (%)
Bali Nusa Tenggara	Primary dryland	473,3	10%	192,7	17%
	Secondary dryland	280,6	14%		
	Primary swamp				
	Secondary swamp				
	Primary mangrove				
	Secondary mangrove				
Jawa	Primary dryland				
	Secondary dryland				
	Primary swamp				
	Secondary swamp				
	Primary mangrove				
	Secondary mangrove				
Kalimantan	Primary dryland	464,7	4%	114,0	5%
	Secondary dryland	350,7	3%		
	Primary swamp	474,0	2%	179,9	7%
	Secondary swamp	294,1	7%		
	Primary mangrove	455,2	21%	107,3	30%
	Secondary mangrove	348,0	21%		
Maluku	Primary dryland	519,9	27%	136,8	28%
	Secondary dryland	383,1	8%		
	Primary swamp				
	Secondary swamp				
	Primary mangrove				
	Secondary mangrove				
Papua	Primary dryland	412,4	5%	101,3	13%
	Secondary dryland	311,2	12%		
	Primary swamp	308,4	10%		29%
	Secondary swamp	251,3	27%		
	Primary mangrove				
	Secondary mangrove				

Sulawesi	Primary dryland	474,7	5%	118,5	8%
	Secondary dryland	356,2	6%		
	Primary swamp	369,8		148,5	42%
	Secondary swamp	221,3	42%		
	Primary mangrove				
	Secondary mangrove				
Sumatera	Primary dryland	463,3	8%	149,0	10%
	Secondary dryland	314,3	6%		
	Primary swamp	380,9	21%	119,7	22%
	Secondary swamp	261,1	7%		
	Primary mangrove				
	Secondary mangrove				

Annex 8. Uncertainty analysis

Using the equations 7 to 9 in chapter 4.2.6, the detailed results of the uncertainty analysis for each assessment period are shown in the tables below.

Table Annex 8.1. *Uncertainty analysis for period 1990-1996*

Island	Emissions Source	Gas	Base year emissions or removals	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	8	14,42	0,00
	Forest Degradation	CO_2	0	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	137.900.425	12	5	13,00	25,02
	Forest Degradation	CO_2	5.088.902	12	10	15,62	0,05
	Peat Decomposition	CO_2	72.446.712	20	50	53,85	118,51
Maluku	Deforestation	CO_2	0	12	14	18,44	0,00
	Forest Degradation	CO_2	0	12	28	30,46	0,00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	72.607	12	8	14,42	0,00
	Forest Degradation	CO_2	0	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	34.320	12	8	14,42	0,00
	Forest Degradation	CO_2	0	12	16	20,00	0,00
	Peat Decomposition	CO_2	7.346.737	20	50	53,85	1,22
Sulawesi	Deforestation	CO_2	1.541.804	12	14	18,44	0,01
	Forest Degradation	CO_2	1.943.597	12	21	24,19	0,02
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	59.361.825	12	6	13,42	4,94
	Forest Degradation	CO_2	644.061	12	12	16,97	0,00
	Peat Decomposition	CO_2	71.989.494	20	50	53,85	117,02
		...					
	Total		358.372.196			∑H	266,8
					Percentage uncertainty in total inventory:		16,33

Table Annex 8.2. *Uncertainty analysis for period 1996-2000*

Island	Emissions Source	Gas	Base year emissions or removals	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	8	14,42	0,05
	Forest Degradation	CO_2	1.179.499	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	182.553.904	12	5	13,00	4,97
	Forest Degradation	CO_2	31.345.277	12	10	15,62	0,21
	Peat Decomposition	CO_2	73.014.959	20	50	53,85	13,65
Maluku	Deforestation	CO_2	37.918.245	12	14	18,44	0,43
	Forest Degradation	CO_2	7.495.807	12	28	30,46	0,05
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	16.831.945	12	8	14,42	0,05
	Forest Degradation	CO_2	13.246.856	12	17	20,81	0,07
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	99.312.923	12	8	14,42	1,81
	Forest Degradation	CO_2	39.089.457	12	16	20,00	0,54
	Peat Decomposition	CO_2	8.807.612	20	50	53,85	0,20
Sulawesi	Deforestation	CO_2	96.411.996	12	14	18,44	2,79
	Forest Degradation	CO_2	56.265.214	12	21	24,19	1,64
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	286.727.007	12	6	13,42	13,07
	Forest Degradation	CO_2	13.774.064	12	12	16,97	0,05
	Peat Decomposition	CO_2	82.993.410	20	50	53,85	17,64
		...					
	Total		1.064.218.341			$\sum H$	57,2
					Percentage uncertainty in total inventory:		7,56

__Table Annex 8.3.__ Uncertainty analysis for period 2000-2003

Island	Emissions Source	Gas	Base year emissions or removals	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	8	14,42	0,00
	Forest Degradation	CO_2	41.666	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	67.983.716	12	5	13,00	5,10
	Forest Degradation	CO_2	30.854.004	12	10	15,62	1,52
	Peat Decomposition	CO_2	73.794.979	20	50	53,85	103,09
Maluku	Deforestation	CO_2	3.334.564	12	14	18,44	0,02
	Forest Degradation	CO_2	539.975	12	28	30,46	0,00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	996.253	12	8	14,42	0,00
	Forest Degradation	CO_2	221.015	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	7.926.226	12	8	14,42	0,09
	Forest Degradation	CO_2	25.835.048	12	16	20,00	1,74
	Peat Decomposition	CO_2	10.574.063	20	50	53,85	2,12
Sulawesi	Deforestation	CO_2	25.275.290	12	14	18,44	1,42
	Forest Degradation	CO_2	16.045.387	12	21	24,19	0,98
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	36.309.394	12	6	13,42	1,55
	Forest Degradation	CO_2	153.709	12	12	16,97	0,00
	Peat Decomposition	CO_2	90.387.982	20	50	53,85	154,66
		...					
	Total		391.399.448			ΣH	272,3
					Percentage uncertainty in total inventory:		16,50

Table Annex 8.4. *Uncertainty analysis for period 2003-2006*

Island	Emissions Source	Gas	Base year emissions or removals	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	8	14,42	0,01
	Forest Degradation	CO_2	1.552.986	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	105.419.288	12	5	13,00	6,76
	Forest Degradation	CO_2	14.910.612	12	10	15,62	0,20
	Peat Decomposition	CO_2	75.194.404	20	50	53,85	59,00
Maluku	Deforestation	CO_2	3.648.628	12	14	18,44	0,02
	Forest Degradation	CO_2	6.552.141	12	28	30,46	0,14
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	3.234.024	12	8	14,42	0,01
	Forest Degradation	CO_2	216.345	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	25.991.493	12	8	14,42	0,51
	Forest Degradation	CO_2	21.189.526	12	16	20,00	0,65
	Peat Decomposition	CO_2	11.510.175	20	50	53,85	1,38
Sulawesi	Deforestation	CO_2	32.988.728	12	14	18,44	1,33
	Forest Degradation	CO_2	32.854.953	12	21	24,19	2,27
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	88.644.298	12	6	13,42	5,09
	Forest Degradation	CO_2	1.319.919	12	12	16,97	0,00
	Peat Decomposition	CO_2	97.530.037	20	50	53,85	99,25
		...					
	Total		527.194.180			ΣH	176,6
					Percentage uncertainty in total inventory:		13,29

Table Annex 8.5. *Uncertainty analysis for period 2006-2009*

Island	Emissions Source	Gas	Base year emissions or removals	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	8	14,42	0,00
	Forest Degradation	CO_2	14.668.010	12	17	20,81	0,73
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	112.238.515	12	5	13,00	16,58
	Forest Degradation	CO_2	2.695.646	12	10	15,62	0,01
	Peat Decomposition	CO_2	77.735.081	20	50	53,85	136,45
Maluku	Deforestation	CO_2	3.331.973	12	14	18,44	0,03
	Forest Degradation	CO_2	188.842	12	28	30,46	0,00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	468.501	12	8	14,42	0,00
	Forest Degradation	CO_2	3.819.775	12	17	20,81	0,05
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	12.295.066	12	8	14,42	0,24
	Forest Degradation	CO_2	31.279.395	12	16	20,00	3,05
	Peat Decomposition	CO_2	12.602.007	20	50	53,85	3,59
Sulawesi	Deforestation	CO_2	16.347.358	12	14	18,44	0,71
	Forest Degradation	CO_2	3.848.351	12	21	24,19	0,07
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	140.294.426	12	6	13,42	27,59
	Forest Degradation	CO_2	2.726.935	12	12	16,97	0,02
	Peat Decomposition	CO_2	109.781.554	20	50	53,85	272,14
		…					
	Total		545.746.225			$\sum H$	461,2
					Percentage uncertainty in total inventory:		21,48

Table Annex 8.6. *Uncertainty analysis for period 2009-2011*

Island	Emissions Source	Gas	Base year emissions or removals	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	8	14,42	0,00
	Forest Degradation	CO_2	0	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	75.467.060	12	5	13,00	5,78
	Forest Degradation	CO_2	1.037.268	12	10	15,62	0,00
	Peat Decomposition	CO_2	80.448.505	20	50	53,85	112,64
Maluku	Deforestation	CO_2	4.791.500	12	14	18,44	0,05
	Forest Degradation	CO_2	508.941	12	28	30,46	0,00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	538.484	12	8	14,42	0,00
	Forest Degradation	CO_2	202.939	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	5.670.503	12	8	14,42	0,04
	Forest Degradation	CO_2	2.633.248	12	16	20,00	0,02
	Peat Decomposition	CO_2	13.136.046	20	50	53,85	3,00
Sulawesi	Deforestation	CO_2	14.418.131	12	14	18,44	0,42
	Forest Degradation	CO_2	11.067.388	12	21	24,19	0,43
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	72.095.845	12	6	13,42	5,61
	Forest Degradation	CO_2	3.061.776	12	12	16,97	0,02
	Peat Decomposition	CO_2	122.214.452	20	50	53,85	259,95
	Keep Blank!	...					
	Total		408.201.603			ΣH	388,0
					Percentage uncertainty in total inventory:		19,70

Table Annex 8.7. *Uncertainty analysis for period 2011-2012*

Island	Emissions Source	Gas	Base year emissions or removals	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	8	14,42	0,00
	Forest Degradation	CO_2	0	12	17	20,81	0,00
	Peat Decomposition	CO_2					
Kalimantan	Deforestation	CO_2	99.113.621	12	5	13,00	7,17
	Forest Degradation	CO_2	1.164.151	12	10	15,62	0,00
	Peat Decomposition	CO_2	82.193.776	20	50	53,85	84,67
Maluku	Deforestation	CO_2	2.581.187	12	14	18,44	0,01
	Forest Degradation	CO_2	0	12	28	30,46	0,00
	Peat Decomposition	CO_2					
Nusa	Deforestation	CO_2	16.006.653	12	8	14,42	0,23
	Forest Degradation	CO_2	2.838.799	12	17	20,81	0,02
	Peat Decomposition	CO_2					
Papua	Deforestation	CO_2	13.903.308	12	8	14,42	0,17
	Forest Degradation	CO_2	396.533	12	16	20,00	0,00
	Peat Decomposition	CO_2	13.248.513	20	50	53,85	2,20
Sulawesi	Deforestation	CO_2	7.141.031	12	14	18,44	0,07
	Forest Degradation	CO_2	1.239.767	12	21	24,19	0,00
	Peat Decomposition	CO_2					
Sumatera	Deforestation	CO_2	109.810.804	12	6	13,42	9,38
	Forest Degradation	CO_2	281.552	12	12	16,97	0,00
	Peat Decomposition	CO_2	130.725.467	20	50	53,85	214,18
		...					
	Total		481.025.677			ΣH	318,1
					Percentage uncertainty in total inventory:		17,84

Annex 9. Sustainable forest management

Sustainable forest management (SFM) is one of important activities linked to REDD+ program. SFM involves selective cutting, appropriate cutting cycles, sustainable annual cut as well as reduced impact logging (RIL). In Indonesia more than 56 million hectares or 52% of the total forest area are allocated as production forests. Out of these, 39 million hectares were still forested in 2013 (MoFor, 2014). In 2014, about 276 forest concessions (including ecosystem restoration program) were granted licenses to operate in 21 million hectares of 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 will be gained through the implementation of RIL instead of conventional logging and longer cutting cycles (Sasaki *et al.*, 2012). A study in East Kalimantan found that RIL could reduce the total stand damage by 20% compared to conventional logging (Bertault and Sist 1997). Furthermore, Sasaki, *et al*. (2012) concluded that about 41% of CO2 emissions could be avoided by replacing conventional logging with RIL with longer cutting cycles. However, Griscom, et al. (2013) found that regarding carbon emissions, certified and non-certified timber concessions are not easily distinguishable due to a high variability of biophysical aspects as well as the history of forest management and investments. 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 improved estimates on emission reductions from implementing SFM.

Monitoring of forest degradation and selective logging at large scale is still problematic. Medium resolution satellite imagery is not able to accurately detect small disturbances 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 imagery are still required to map logging roads and canopy gaps detection. However, Pithon, *et al*. (2013) found that automatic detection of logging roads using high resolution optical imagery is still problematic.
The use of airborne LiDAR has been intensified since the last decade. Research on monitoring forest degradation in selectively logged tropical forests 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 of forest degradation and selective logging using reliable and cost effective methods need to be explored.

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