National Forest Reference Emission Level for Deforestation and Forest Degradation in the Context of the Activities Referred to in Decision 1/CP.16, Paragraph 70 (REDD+) Under the UNFCCC:

A Reference for Decision Makers

BADAN PENGELOLA REDD+ REPUBLIK INDONESIA

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EXECUTIVE SUMMARY

The Conference of the Parties (COP) under the United Nations Framework Convention on Climate Change (UNFCCC) invites developing countries aiming to undertake REDD+ activities to provide a number of strategic documents. Indonesia accepts the invitation to 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 publication attempts to improve the previous FRELs, which was developed under three initiatives (Second National Communication/SNC, REDD+ Agency/RA, and Ministry of Forestry/MoFor) and fulfill 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 thus allowed Indonesia to improve the FREL by incorporating better data, improved methodologies and, where appropriate, additional pools, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71.

Definitions of forest, deforestation, forest degradation and peat land used in the document were defined and clarified for consistency with data that was 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 99.3 million ha or 52% of the country's land area and 80 % of national forest area. This includes primary and secondary forests, regardless forest status under national forest area defined by MoFor (2013). Peat land 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 CO2 were defined and selected as pools and gas included in this FREL document.

The data used to construct FREL-REDD+ for this publication have been thoroughly scrutinized in terms of clarity, comprehensiveness, consistency, and comparability. Improved activity data and emission factors were used to construct the FREL, which is more consistent in data acquisition and processing of land cover and land cover changes, as well as over longer period (2000 – 2012) than the previous FRELs. Moreover, the emission factors used for the calculation were improved from national forest inventory (NFI) data that better reflect diversity of forest types and represent wide range of Indonesian region. As such, the calculated emissions from deforestation and forest degradation represent more temporal and spatial variability.

Improved peat land map that combined several peat land maps and verified in the field was selected to be integrated into the calculation. Credible studies on peat emissions due to decomposition were added to reduce uncertainties of emission calculation. Both were compiled to update emissions calculation from peat decomposition in deforested areas and degraded forests.

The annual rate of deforestation in Indonesia from 2000 to 2012 was 671,420 ha, which released emissions of 213 MtCO2e annually. In the same period, the annual rate of forest degradation was 425,296 hectares annually and emitted 56.4 MtCO2e annually. Additional emission from peat decomposition as an impact of forest degradation activity as well as the remaining secondary forest that started from 97 MtCO2e yr-1 in 2000 – 2001 to 75 MtCO2e yr-1 in 2011 – 2012. In total, the emission from deforestation, forest degradation and the associated emission from peat decomposition for 2013 was 0.410 GtCO2e and will be projected to be 0.441 GtCO2e in 2020.

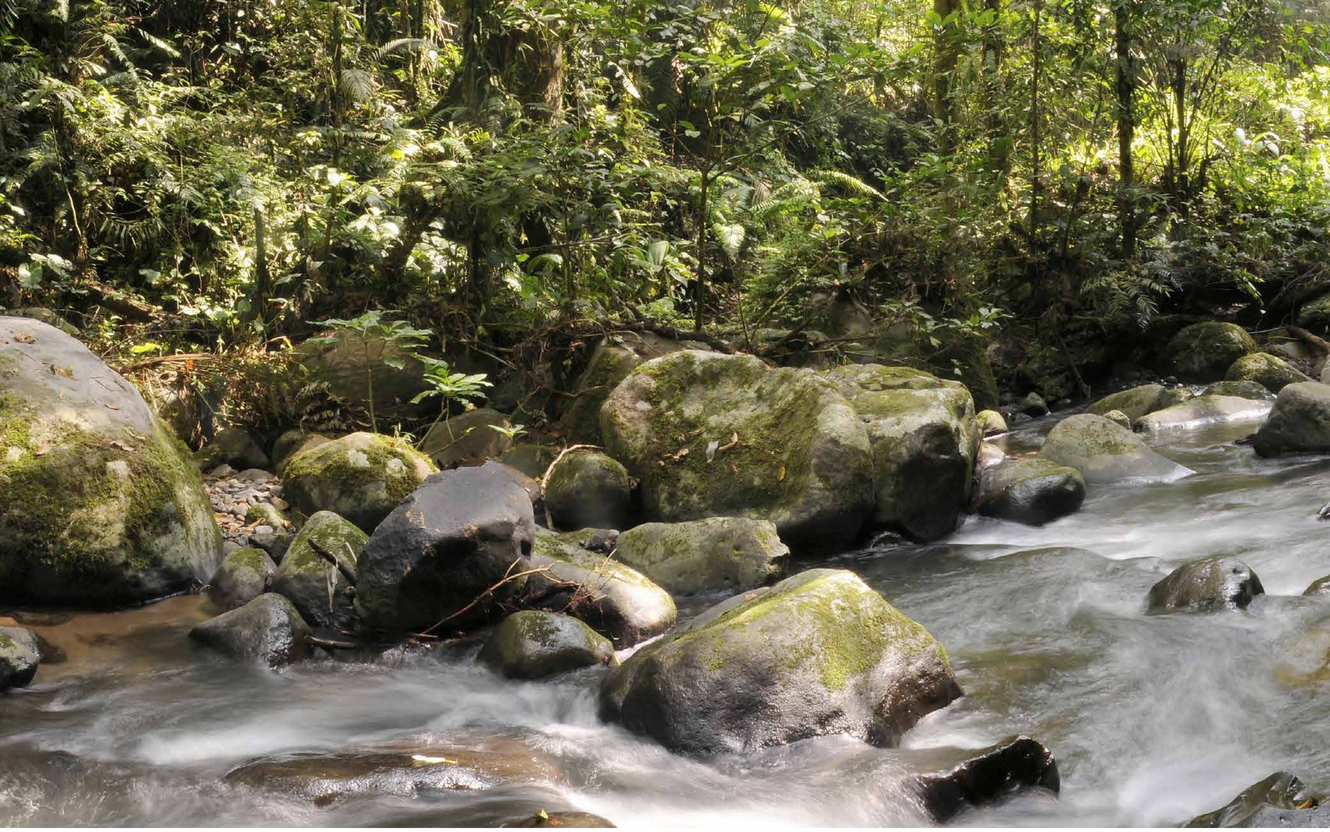
The new government has declared a new road map for the sovereignty, self-reliance and integrity of Indonesia. This important agenda will consequently affects the future characteristic of land-based emission in Indonesia. However, due to the absence of adequate basis for making assumption for FREL construction, this publication did not differentiate planned and unplanned deforestation. This will directly implies the national plan on converting 14.72 million ha of natural forests into other land uses (planned deforestation). Therefore, this need to be taken into account in the FREL construction.

This document also acknowledged several limitations in data accuracy, completeness and consistency, and thus suggested potential improvement. Utilization of advance technology in remote sensing (e.g. high resolution optical satellites or LiDAR) will be explored for improving wall-to-wall monitoring of deforestation and forest degradation. Advanced methods for cloud-free image mosaicking, digital and hybrid classification as well as object-oriented classification, will be explored for more accurate and reliable data.

Future improvement should include the establishment of new plots in mangrove forest classes and the development of new forest-types specific allometric equations for accurate estimation of above ground biomass. Utilizing advance information technology to connect ground measurement and server can be used to support database management, data processing and real time data collection. Research network should be developed to allow research institutions to have better coordination on research for certain forest types.

Scientific research on peat land emission factor that covers wide range of peat land characteristics and land use/land cover was required for more reliable and valid data. This should be done through continuous monitoring of water level and associated peat emission in relevant land cover types. Most importantly, huge emissions from peat fires were factored out of the calculation due to high uncertainty. Exploration of more accurate and reliable methods for burnt area mapping and the depth of burnt peat are therefore needed.

INTRODUCTION

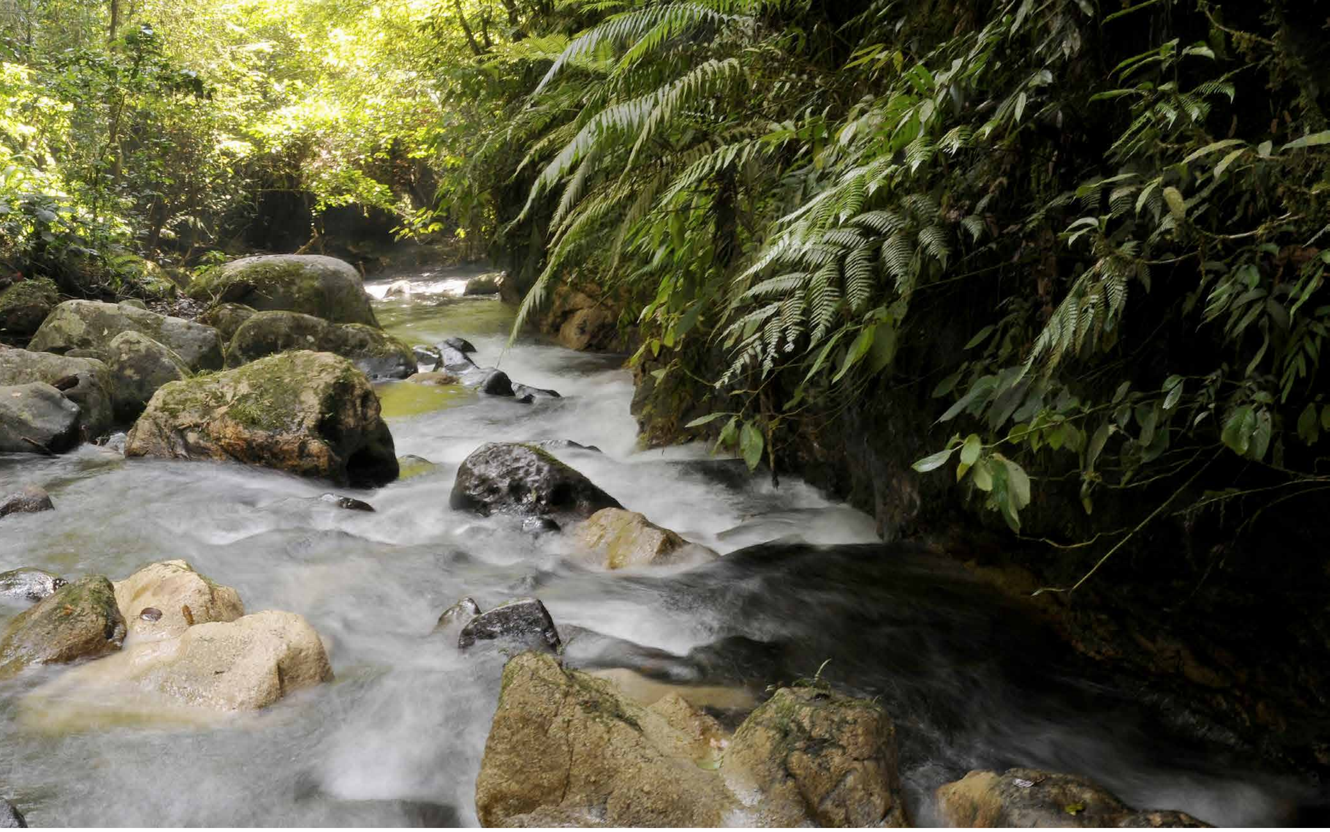


1.1. Relevance

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

During the G-20 Pittsburgh meeting in 2009, the President of Indonesia pledged to reduce emissions of 26 % by 2020 from Business as Usual (BAU) with domestic resources and up to 41 % if supported by international communities. After COP15 in Copenhagen, 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. Through Presidential Regulation (PERPRES) No. 61/2011, Indonesia set a target to reduce 26 % of emissions from BAU by 2020, known as Rencana Aksi Nasional Penurunan Emisi GRK (RAN-GRK). Referring to Dec 1/CP. 16, RAN-GRK can be categorized as Unilateral Nationally Appropriate Mitigation Actions (NAMAs), and thus subject to domestic Measuring, Reporting, and Verifying (MRV). Likewise, the pledge to reduce emissions up to 41 % by 2020 can be categorized as supported NAMAs, and in the case of land use sector in Indonesia, contribution to the 41 % emissions reduction target may be achieved through several schemes, including REDD+ and supported NAMAs.

In the specific case of REDD+ in Indonesia, there have been several result-based finance arrangements, including: bilateral (LoI Indonesia-Norway, German-



Indonesia Early Mover) and multilateral (Forest Investment Programmes/FIP, FCPF-Carbon Fund) schemes, with different focus and approach of interventions. COP through decision 9/CP.19 also encourages entities (can be bilateral and/or multilateral) providing results-based finance, to apply the methodological guidance consistent with decisions 4/CP.15, 1/CP.16, 2/CP.17, 12/CP.17, 9/CP.19 and 11/CP.19 to 15/CP.19, in order to improve the effectiveness and coordination of results-based finance.

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

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

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

Indonesia accepts the invitation as in Dec. 12/CP.17 to voluntarily submit proposed national forest reference emission level (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).

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

There have been a number of REDD+ initiatives that include FREL/FRL construction at different levels in Indonesia (projects, districts, provinces). At the provincial level, as part of REDD+ Provincial Strategy, FRELs/FRLs were developed in 11 Provinces under the bilateral Norway-Indonesia cooperation. Similar processes were used to develop BAU-baseline for Provincial Emissions Reduction Action Plans under PERPRES No. 61/2011 known as RAD-GRK in all provinces (33 provinces). However, they are not readily used for FREL construction at the national level, and will take considerable time to assess clarity, consistency, completeness, and accuracy of the data, as well as the methodology used both in Provincial FREL/FRL and BAU baseline in RAD-GRK.

At the national level, both REDD+ Agency and the Ministry of Forestry (now Ministry of Environment and Forestry) have developed national FREL. Earlier than these two initiatives, Indonesia through the Second National Communication (SNC) has established FREL using land cover data from the Ministry of Forestry with reference period of 2000-2006. The national FREL developed by the REDD+ Agency (FREL-RA) used land cover data from the Ministry of Forestry and Indonesia National Carbon Accounting System (INCAS) with reference period from 2000-2009. Both FREL-SNC and FREL value of the Ministry of Forestry (Ministerial Decree No. 633/2014 : FREL-MoFor) were developed using the same land cover data with the same reference period. The three initiatives used historical approach with historical deforestation rate and stock difference to construct FREL values. In terms of GHGs pools, both FREL-RA and FREL-MoFor included only above ground biomass, while FREL-SNC also included below ground biomass from relevant studies.

Development in data availability and clarity, human resources and institutional capacities, has opened the opportunity to revisit the existing FREL values, developed under the three initiatives (FREL-SNC, FREL-RA, FREL-MoFor). Consistent with COP-guidance for FREL/FRL construction (Dec. 12/CP.17) and technical assessment (Dec. 13/CP.19), taking into account relevant COP decisions especially Decision 14/CP.19 (modalities for MRV), as well as national policies and plans, the FREL in this publication improves the previous FRELs. FREL-REDD+ in this publication was constructed using improved activity data (more consistent data on land cover and land cover changes over longer period than the previous FRELs, in this case 2000-2012) and emission factors (better reflect diversity of forest types and conditions than the previous FRELs). Furthermore, the data used to construct FREL-REDD+ for this publication have been thoroughly scrutinized in terms of clarity, comprehensiveness, consistency, and comparability; the step that was not done in the FREL construction under the three initiatives.

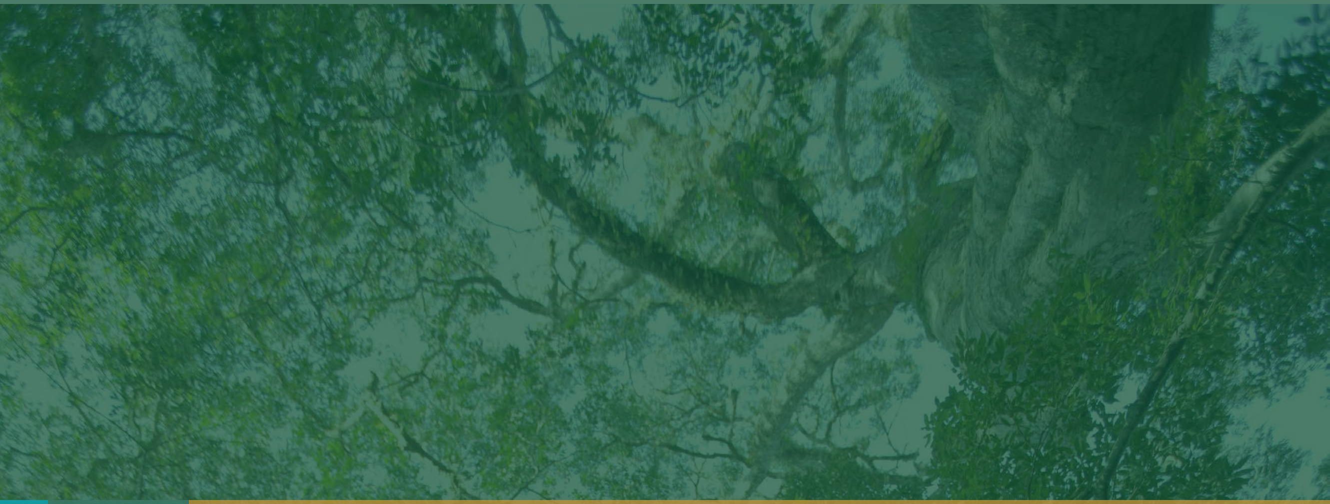
The national FREL in this publication was developed by experts representing cross-ministerial agencies and organizations through a "transparent scientific-based participatory process". The FREL construction covered area of 99.3 million ha natural forests in 2000 or approximately 80 % of the total territory of forest areas and 52% of the total country land area. Two activities under decision 1/CP.16 paragraph 70 were included in FREL construction, namely: deforestation and forest degradation. Above ground biomass (AGB) and soil in peat land, and CO2 were the pools and gas included in FREL construction. The rationales of area, activities, pools and gases covered in the FREL construction are explained in the following chapters.

1.2. The objectives and structure of this publication

This publication brings together the findings of the FREL working groups under BP-REDD+ coordination, plus feedback obtained from internal focus group meetings, national workshops. Experts representing cross-ministerial agencies (Bappenas, MoA, MoFor, MoE, BIG, LAPAN, BP-REDD+, IPB) and organizations (CIFOR, UNORCID, TNC, WWF) were commissioned to facilitate the construction process through a transparent and scientific-based participatory mechanism.

The first objective of this report is to present a proposed national FREL figure for REDD+ implementation including step-by-step analysis that has been exercised for establishing FREL for Indonesia. The second objective is to provide the public, particularly REDD+ related stakeholders a clear, transparent, accurate, complete and consistent basis for discussion with the many agencies who have expressed an interest in supporting Indonesia in this undertaking. A final objective is to share with the many other countries that have expressed an interest in the REDD scheme, the process Indonesia has followed in approaching an entrance of implementation of full REDD+ mechanism.

Following an Introductory section which sets out the international and national context of FREL, the publication is presented in a further six substantive sections which reflect the step-by-step processes of FREL establishment. Section 2 is concerned with the key information required to understand definition used for FREL. It provides an overview of the legal and working definitions of forest, deforestation, forest degradation, peat land as well as basic definition of FREL. Section 3 is concerned on the Area and Activities covered by the FREL as well as pool and gases that is taken into consideration. Section 4 is concerned with the data, methodology and procedures that need to be taken for establishing FREL. On this chapter, explanations about data and methodological approach used in this analysis were clearly explained, which is also explained more detail in the annex. Section 5 deals with the issue of governance, policies and plans and their implications to the constructed FREL. Section 6 deals with the results of the construction of FREL, and the last, Section 7 discuss options for the opportunity of improvement for FREL.



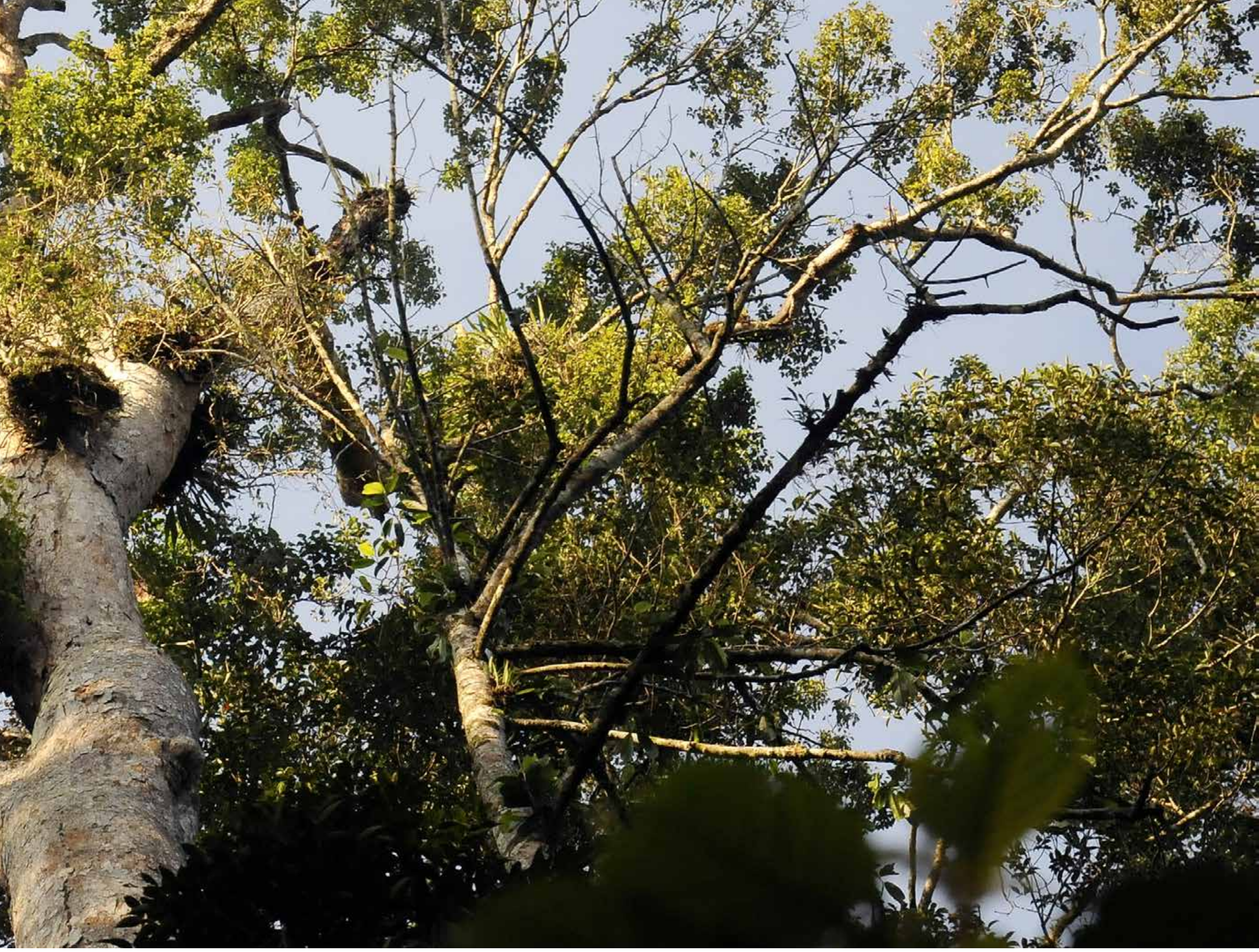
DEFINITIONS USED

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

2.1. Forest

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

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



A different definition was used for the submission to the Food and Agriculture Organization for Global Forest Resource Assessment in 2010 (FAO, 2010). It used minimum area of 0.5 ha and canopy cover of more than 10% and trees higher than 5 meters at maturity. The definition was generated to comply with the FAO definition for global forest resource assessment, hence was not used in this document.

In this document, the term "working definition" of forest was used to produce land-cover maps through visual interpretation of satellite images in a scale that minimum area for polygon delineation is 0.25 cm2 at 1: 50,000 of scale which equals to 6.25 ha. The term "working definition" was used within the Indonesian National Standard (SNI) 8033:2014 on "Method for calculating forest cover change based on results of visual interpretation of optical satellite remote sensing image". The SNI defined forest based on satellite data feature including colour, texture and brightness. Forests were classified into seven classes based on forest types and degradation or succession level. Six of the seven forest classes were classified as natural forests (see Table 1).

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

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

2.2. Deforestation

Since the definitions of the forest are still debatable especially for Indonesia which have high dynamical in the climate, region and ecology, there are also so many definitions of deforestation used in Indonesia, both on ecologically and technically. The definition of deforestation used in this document is mostly for the practically and "technically simple and clear" on the identification purposes. Some of the experts said that this method is "gross deforestation" (IFCA, 2008). This approach is also used in many REDD+ programs to avoid confusion with land cover changes of afforestation and reforestation covered under the CDM.

The definition of deforestation was defined as a conversion of natural forest categories into other land-cover categories that has only occurred one time in particular areas. This is different with the definition of deforestation used by FAO, which employed land use terminology to define deforestation.

2.3. Forest degradation

In this document, forest degradation is defined as a change of primary forest classes, which include primary dryland, primary mangrove and primary peat swamp forests, to secondary forest classes. The definition is a narrow definition of forest degradation that is a reduction in the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes (e.g. Thompson et al., 2013). Whereas, according to ITTO (2002), degraded forest is defined as natural forest, which has been fragmented or subjected to forest utilization including wood and or non-wood forest product harvesting that alters the canopy cover and overall forest structure.

The main causes of forest degradation include unsustainable logging, agriculture (shifting cultivations), fires, fuel wood collection, and livestock grazing, which have various impacts of degradation level. However, there is no general approach to identify a degraded forest because perceptions on forest degradation vary depending on the causes, particular goods or services of interest, and temporal and spatial scales considered.

2.4. Peat land

There is limited data of Indonesia peat land, since there are not many researches on the Indonesia peat land. Indonesia or tropical peat land is just recently explored, mostly started about 20 years ago, when peat land fire became a phenomenon in 1997. One of the comprehensive Indonesia peat land maps was developed in 2002 – 2004 by Wetland International Indonesia collaboration with Ministry of Agriculture. The recent data of the peat land map is made by Ministry Agriculture, the map is updated from the compiled old data and combined with field verified data.

In this document, peat land is defined as an area with an accumulation of partly decomposed organic matter, with carbon content of at least 12% (usually 40-60% C content) and thickness of the carbon rich layer is at least 50 cm (Wahyunto, et al. 2004). Peat land has special interlinked condition with forest since most of the peat land area is covered by forest i.e. peat swamp forest. Deforestation and forest degradation activities on peat land will increase drainage from this area and accelerate peat decomposition. Drained peat land areas are assumed to emit CO2 from soil microbial activities (IPCC, 2013).

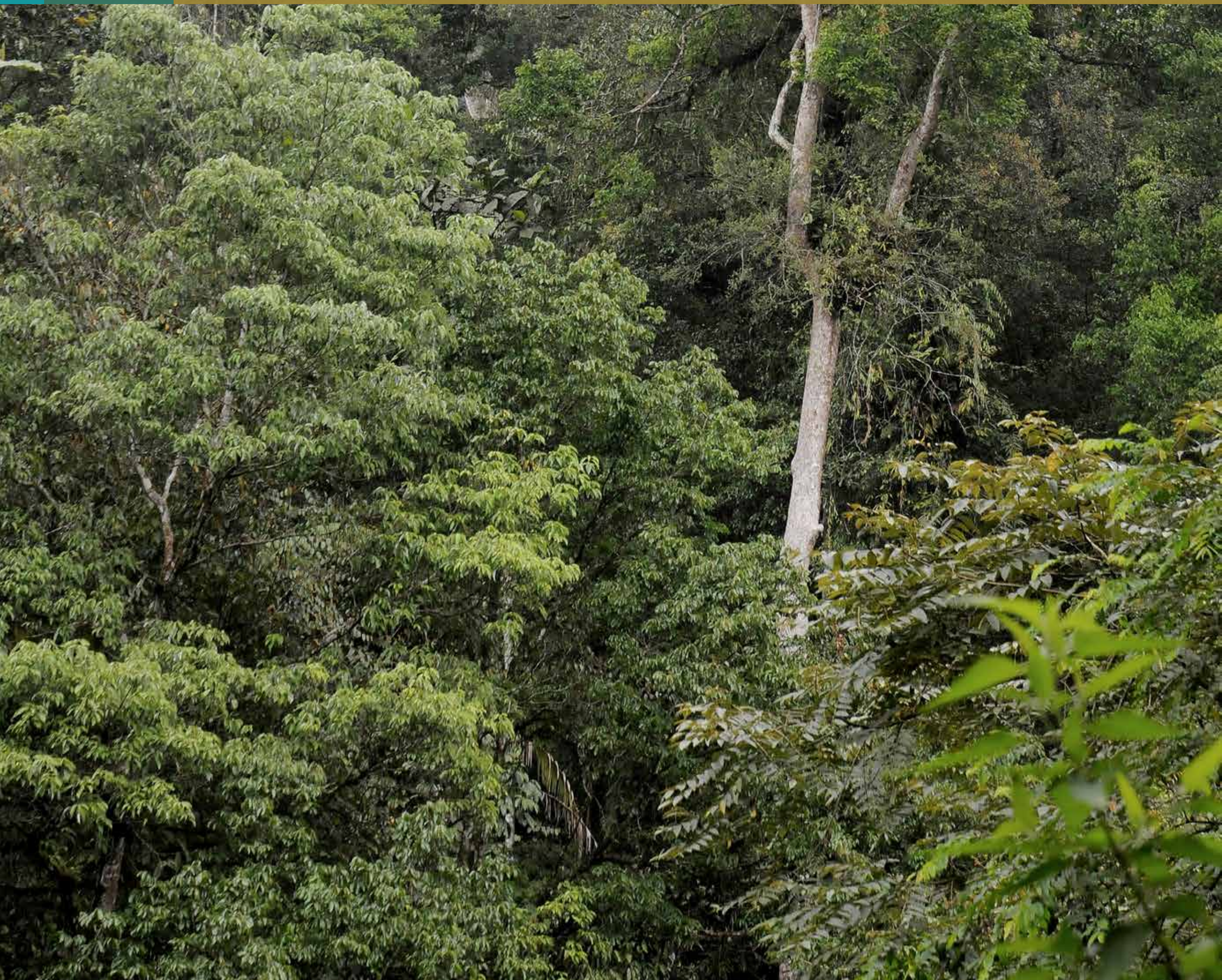
2.5. FREL

In this document, FREL is a benchmark for assessing Indonesia's performance in implementing REDD+, expressed in tons of carbon dioxide equivalent per year. Technical definition of FREL adopted in this document is a projection of CO2 gross emissions that is used as a reference to compare against actual emissions in a given point of time in the future. In accordance with the decision 12/CP.17 the FREL will be updated periodically as appropriate, taking into account new knowledge, new trends and any modification of scope and methodologies.

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

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

AREA AND ACTIVITIES COVERED



3.1. Area covered

The scope of the area for FREL calculation is Indonesia's land area that was covered by natural forest in year 2000, accounted for 99.3 million ha or 52% of the country's land area. This includes primary and secondary forests, regardless forest status under national forest area defined by MoFor (2013).

Indonesia is a home for 14.9 million ha of peat land and 8.5 million ha of the area was covered by natural forest in 2000 (MoFor, 2000; MoA, 2011). The latter was used in FREL construction. Other peat land area was excluded from FREL construction in the context of decision 1/CP. 16 paragraph 70 for this publication, but will be included in Biennial Update Report (BUR). The remaining peat land area which was excluded from FREL construction for this publication could be part of specific bilateral/multilateral arrangements of result-based payments or supported Nationally Appropriate Mitigation Actions (NAMAs). It could also be included under the FRL construction in the future when the data that allow the inclusion of other REDD+ activities under decision 1/CP.16 paragraph 70 (conservation of forest carbon stocks, sustainable management of forest, and enhancement of forest carbon stocks) become available.

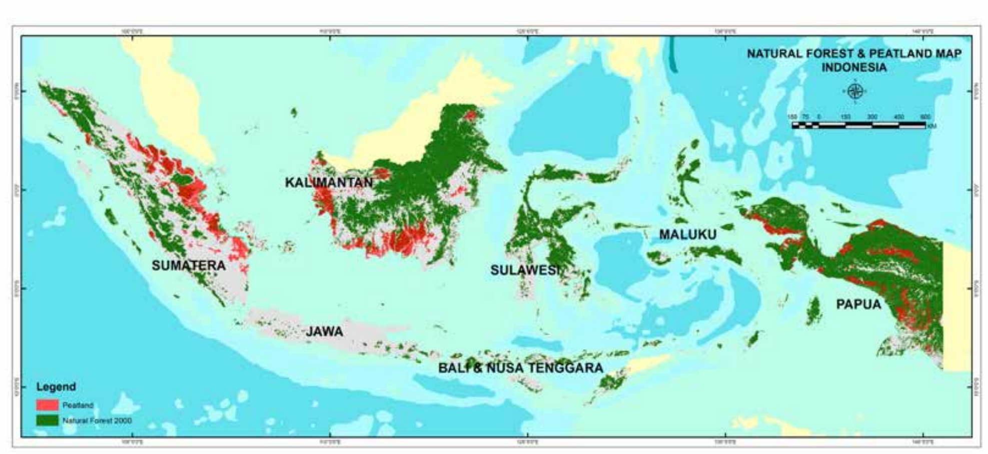
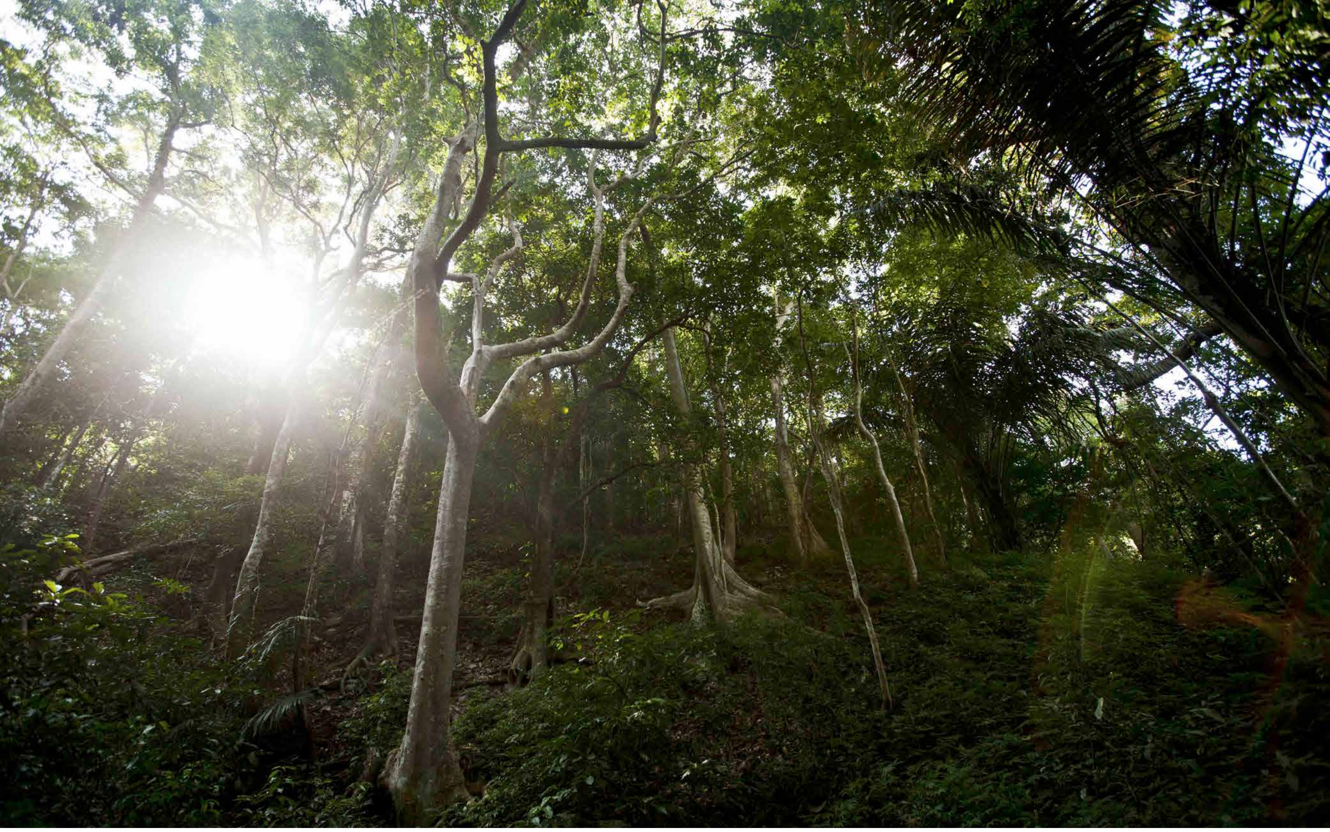


Figure 1. Area for FREL calculation (99.3 million ha). Overall land area of Indonesia is approximately 192 million ha, with about 124 million ha of national forest area (MoFor, 2013)

3.2. Activities covered

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

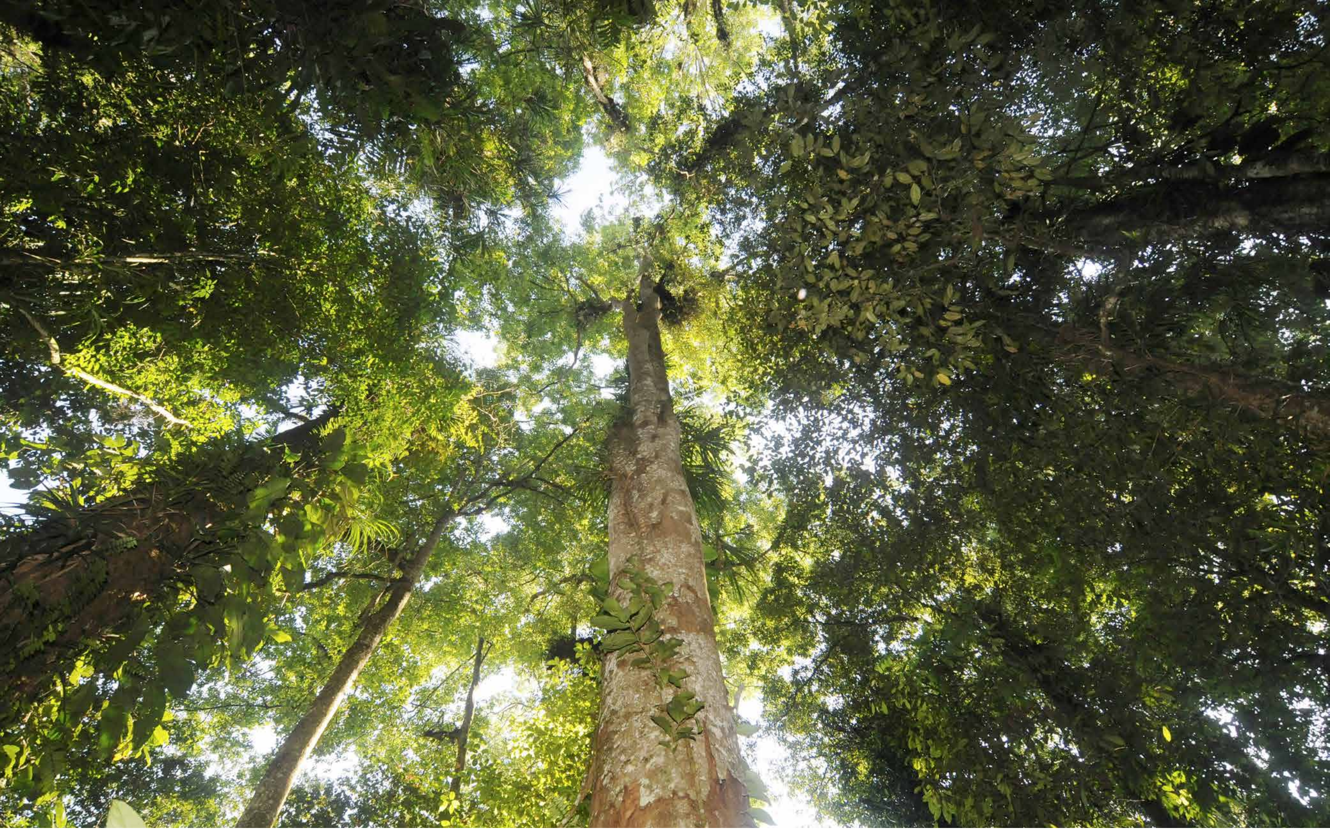


The deforestation and forest degradation estimates in this publication allow possibilities for monitoring and are included in the FREL calculation. However, wall-to-wall monitoring for various levels of forest degradation using current categories for land-cover is still problematic, which has led to high uncertainty in the estimates.

Similarly, there are limited reliable data related to carbon sequestration. Therefore, other 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 in the current FREL construction. And so, there is an opportunity to continue improving the estimates of emissions associated with REDD+ activities. Referring to the agreement under Decision 12/CP.17, the FREL could be improved along with the availability of better data, improved methodologies, and additional pools, noting the importance of adequate and predictable support as referenced by decision 1/CP.16, paragraph 71. Chapter 6 provides information regarding opportunity for improvement based on existing activities to address emission estimates associated with REDD+ activities, including deforestation, forest degradation, sustainable management of forests, and enhancement of forest carbon stocks.

3.3. Pools and Gases

In this FREL, two carbon pools i.e. aboveground biomass (AGB) and soil carbon in the peat land experiencing deforestation and forest degradation since 2000, and carbon dioxide (CO2) gas were included in the emission calculation. CO2 is the dominant constituent element of the GHG emissions from LULUCF, contributing to more than 99.9% of the total GHGs. In addition to CO2, other greenhouse gases are methane (CH4), nitrous oxide (N2O), hydro fluorocarbon



(HFC), perfluorocarbon (PFC), and others (Indonesia's Second National Communication, 2011). AGB is the most important carbon pool of LULUCF emission, since AGB is the dominant element to the other four carbon pools (i.e. below ground biomass, debris, litter and soil except for organic soil). Moreover, the current record (data) in Indonesia regarding other carbon pool is very limited. Review on carbon pools proportion which was conducted by Krisnawati et al. (2014) found that the biomass proportion of understory vegetation and seedlings was generally small. Similarly, litter is accounted for about 2% only from total forest biomass. An additional analysis using compiled data sets from Sumatra and Kalimantan shows a similar trend (see Annex 3). Tree AGB, below ground biomass and necromass have a significant proportions of biomass with 71.2%, 13.6% and 14.5%, respectively.

Some underlying reasons to focus on aboveground biomass carbon pools are as follows:

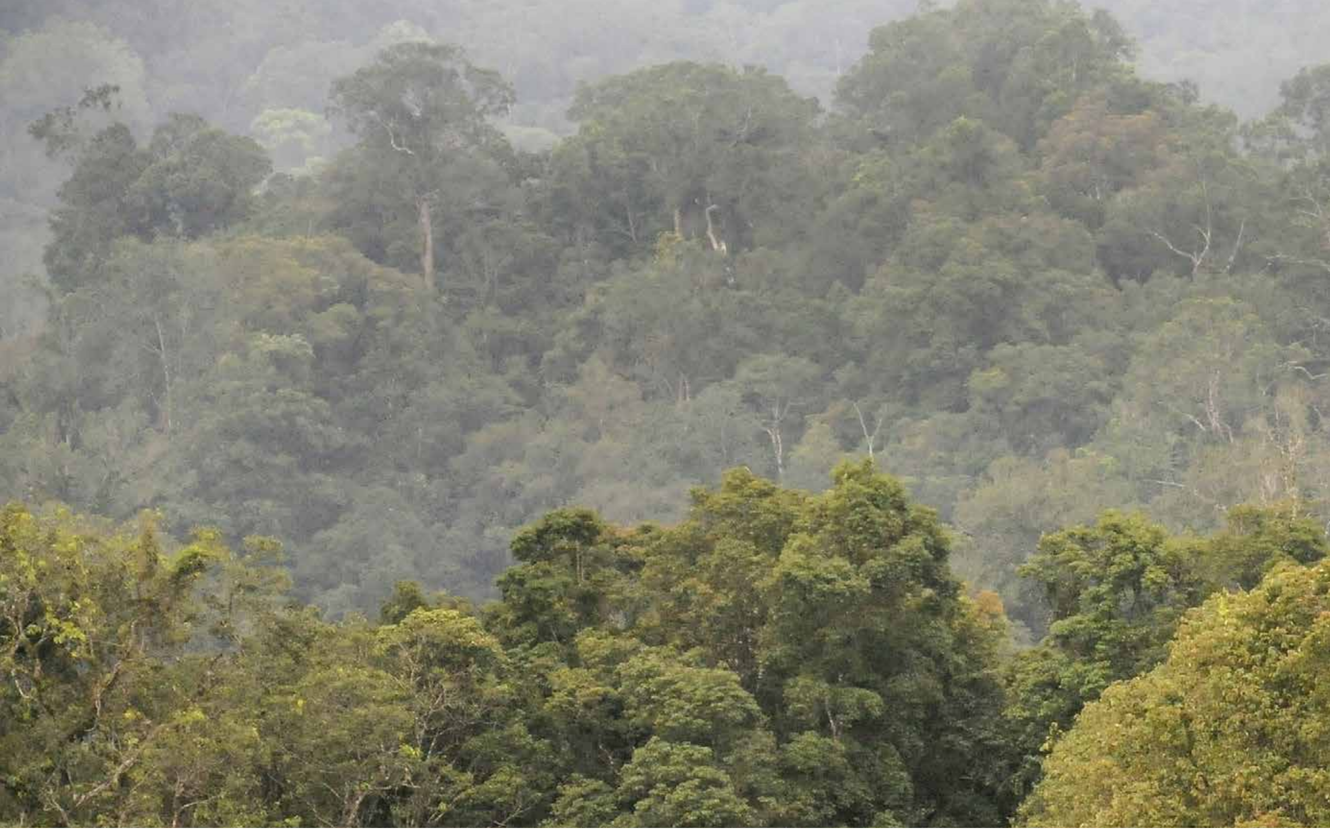
1. Emissions from deforestation and forest degradation are primarily originated from AGB pool. AGB is the most studied carbon pool across forest ecosystem types in Indonesia, which allows further calculation of carbon emissions more accurately using Tier 2 or Tier 3 and comparable throughout national scope. AGB data are widely available and can be estimated easily 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 quite complete data for AGB, managed by the Ministry of Forestry since the 1990s. The data is based on forest inventory results from the National Forest Inventory (NFI) System Plots covering the whole area of forests across Indonesia.
3. In the next re-measurement, the measurement of the aboveground biomass is more easily done from the national to the sub-national level.

The carbon pool and type of activities used for FREL calculation have been consistent with the national standard for calculation and monitoring of emission reduction, emission prevention or enhancement of forest carbon stocks (SNI 7848:2013 on Demonstration activity which used COP guidance as one of the main references).

Specific to peat land, emissions from peat decomposition are calculated in the area where deforestation and forest degradation have occurred. Peat emissions are calculated not only at the time deforestation occurred, but it continues to the future for a certain period of time. This current analysis only deals with emissions related to drainage (emissions from peat decomposition). Although drainage and burning are the major sources of GHG emissions in peat land, emission from peat fires are excluded since the generation of the activity data for the latter is complicated and highly uncertain (Agus et al., 2013). Various studies have been attempted to develop calculation methods for peat fire emission estimates, for example, a simple approach for estimating emission from burned peat (peat fire) as shown in Annex 4. However, they are inapplicable of being integrated in the FREL construction for this publication due to high uncertainty in mapping.

DATA, METHODOLOGY AND PROCEDURES



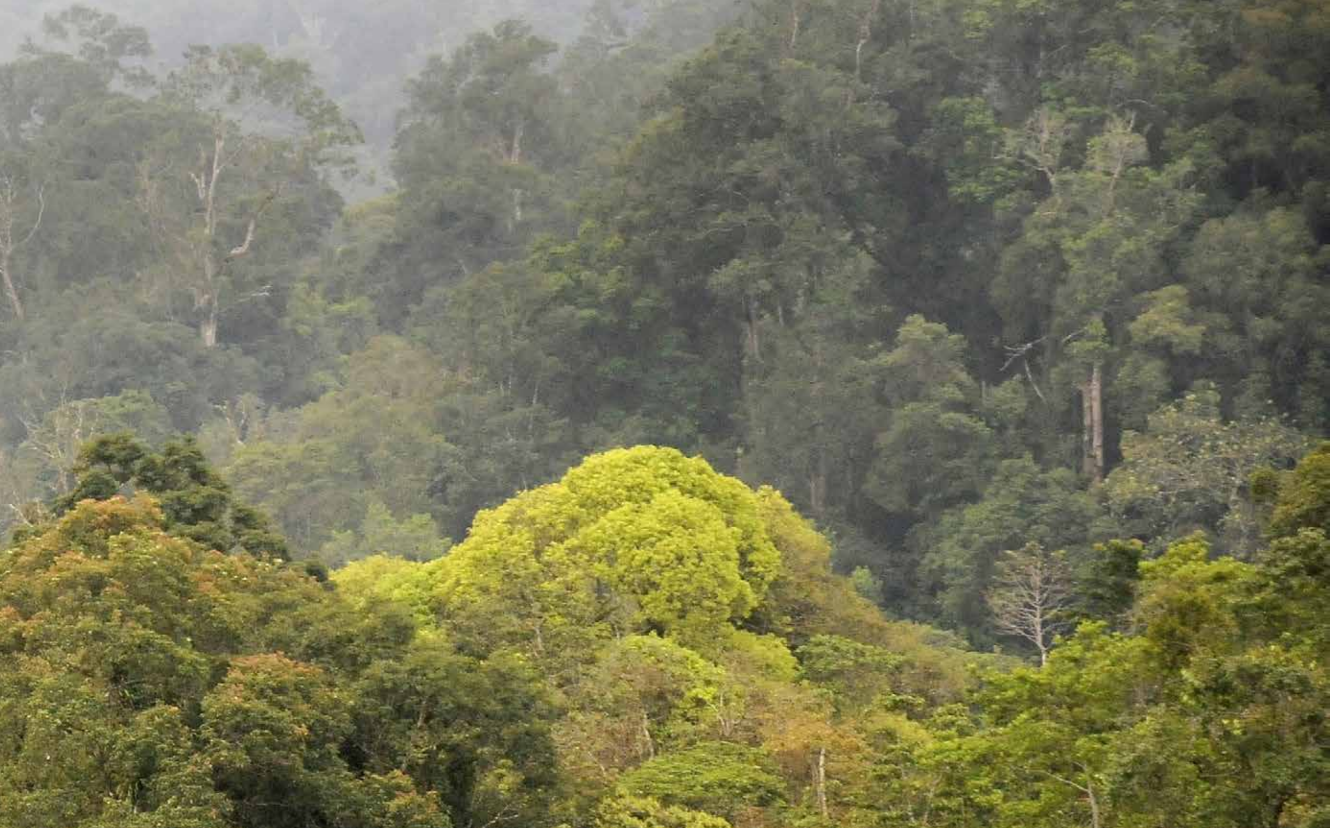
4.1. Data

Data support is needed when estimating GHG emission. The data used shall be selected based on the principle of transparent, accurate, complete and consistent that is available at the national level. In addition, the continuous availability of data is also taken into consideration, so that it can be repeated in the future calculation to determine the performance of REDD+ through MRV activity.

4.1.1 Land-cover data

There are several wall-to-wall land cover data sets available for Indonesia. Through several steps to assess the available data, the land-cover data produced by the Ministry of Forestry was used as the basis for generating activity data for the FREL construction.

The Ministry of Forestry data set was 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) which were produced through INCAS Project (as described in Annex 1). The maps have also been carefully reviewed and compared with other similar products that have been published in peer review international journals (e.g. Margono et al., 2014; Hansen et al., 2012). Hansen et al. generated global tree cover map from Landsat images 2000 – 2012, concluded that there was increasing forest lost in Indonesia. However, the data did not distinguish between natural forest and other vegetation since the definition of forest was made based on tree cover at global scale. Margono et al. (2014) enhanced the global gross forest loss data of Hansen et al. (2012) with an extension in disaggregating total forest cover



loss by natural/non-natural categories and land form for all of Indonesia, which is relevant to the Indonesian context for this publication. Natural forest in this data set is 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. Therefore, we used the improved data set from Margono et al. (2014) instead of Hansen et al. (2012) data for consistency comparison purpose. It was found that the natural forest cover of MoFor is consistent (more than 90% agreement) with the primary forest maps generated by Margono et al. (2014). Whilst, the comparison of the natural forest cover from MoFor and the forest/non-forest data produced by LAPAN found a consistent 78% to 79% of agreement (see Annex 1). This is understandable since LAPAN used a general definition of forest, not only natural forest.

The land-cover data set is also used in the National GHG Inventory. The method to generate wall-to-wall mapping for forest-cover change used approach 2, which lead to spatially explicit comparison between both GHG inventory and FREL. In addition to that, by using similar remote sensing data set as the based data is an essential foundation to ensure consistency.

This data is part of National Forest Monitoring System (NFMS) and has been stored in NFMS website (http://nfms.dephut.go.id). This official data describes forest cover change, which has been developed and updated regularly since 1990s. For this FREL publication, the 2000, 2003, 2006, 2009, 2011 and 2012 data sets were used to refer to the reference period that will be described in the next chapter.

The land-cover map was produced by means of Landsat satellite images interpretation. The image interpretation process was conducted manually (visual interpretation) in a scale that minimum area for polygon delineation is 0.25 cm2 at 1: 50,000 of scale that equals to 6.25 ha. It means the minimum mapping unit of generated land-cover map is 6.25 ha. To reduce cloud cover and to fill the gaps of SLC-off images, the combination of multi-temporal Landsat satellite images were used.

The Landsat images were visually interpreted into 23-classes of land cover including 6 natural forest classes (see table 1) and validated by ground checking and high-resolution images (see Annex 1). In addition to forest types, in this FREL publication, seven major island groups were integrated for the stratification process, i.e. Sumatra, Java, Kalimantan, Sulawesi, Bali and Nusa Tenggara, Maluku and Papua. This is to ensure the consideration of the variation among regions in the calculation of emissions from deforestation.

4.1.2. National peat land data

The peat land spatial data used in this FREL calculation was produced by the Ministry of Agriculture (MoA), based on several related maps, field survey and verified by ground check (Ritung et al. 2011). This map is an update of the previous Indonesian peat land map by Wahyunto et al. (2003, 2004 and 2006). The new map of Ritung et al. (2011) estimated peat land area of around 14.9 million ha, which is significantly lower than the previous estimate of 20.6 million ha. The main areas corrected were the remote peat land, especially in Papua, as many areas which were previously identified as peat land were found that their soil carbon contents are less than 12% or less than 50 cm of depth.

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

4.1.3. Emission Factors for Deforestation and Forest Degradation

The primary source of data used to derive emission factors was the National Forest Inventory (NFI) Plots - a national program initiated by the Ministry of Forestry in 1989 and supported by the Food and Agriculture Organization of the United Nations (FAO) and the World Bank through the NFI Project. More than 2700 permanent sample plots (PSP) of 1 ha size have been distributed on a 20x20 km grid across the country. In addition to PSPs, a cluster of nine temporary plots surrounding each PSP (temporary sample plots – TSP) were established.

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

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

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

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

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

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

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 in the main island were derived by averaging the AGB of the total plots (Equation 2).

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

where Mj = mean AGB (t ha-1) of forest type-j, MPi = AGB of plot-i, n= plot number

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

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

FOREST TYPE	MAIN ISLAND	MEAN AGB (T HA^{-1})	95% CONFIDENCE INTERVAL (T HA^{-1})		N OF PLOT MEASUREMENT
Primary Dryland Forest	Bali Nusa Tenggara	274.4	247.4	301.3	52
	Jawa	Nd	nd	nd	nd
	Kalimantan	269.4	258.2	280.6	333
	Maluku	301.4	220.3	382.5	14
	Papua	239.1	227.5	250.6	162
	Sulawesi	275.2	262.4	288.1	221
	Sumatera	268.6	247.1	290.1	92
	Indonesia	266.0	259.5	272.5	874

FOREST TYPE	MAIN ISLAND	MEAN AGB (T HA^{-1})	95% CONFIDENCE INTERVAL (T HA^{-1})		N OF PLOT MEASUREMENT
Secondary Dryland Forest	Bali Nusa Tenggara	162.7	140.6	184.9	69
	Jawa	170.5	na	na	1
	Kalimantan	203.3	196.3	210.3	608
	Maluku	222.1	204.5	239.8	99
	Papua	180.4	158.5	202.4	60
	Sulawesi	206.5	194.3	218.7	197
	Sumatera	182.2	172.1	192.4	265
	Indonesia	197.7	192.9	202.5	1299
Primary Swamp Forest	Bali Nusa Tenggara	Na	na	na	na
	Jawa	Na	na	na	na
	Kalimantan	274.8	269.2	281.9	3
	Maluku	Na	na	na	na
	Papua	178.8	160.0	197.5	67
	Sulawesi	214.4	-256.4	685.2	3
	Sumatera	220.8	174.7	266.9	22
	Indonesia	192.7	174.6	210.8	95
Secondary Swamp Forest	Bali Nusa Tenggara	Na	na	na	na
	Jawa	Na	na	na	na
	Kalimantan	170.5	158.6	182.5	166
	Maluku	Na	na	na	na
	Papua	145.7	106.7	184.7	16
	Sulawesi	128.3	74.5	182.1	12
	Sumatera	151.4	140.2	162.6	160
	Indonesia	159.3	151.4	167.3	354
Primary Mangrove Forest[a,b,c]	Kalimantan	263.9	209.0	318.8	8
Secondary Mangrove Forest[b,c]	Kalimantan dan Sulawesi	201.7	134.5	244.0	12

Notes:
- a Murdiyarso et al. (2009);
- b Krisnawati et al. (2014);
- c Donato et al. (2011)
- nd = no data
- na = not applicable

To estimate the amount of carbon (C) in each forest type, information on carbon fraction is needed. The carbon fraction of biomass (dry weight) was assumed to be 47% (1 tons biomass = 0.47 tons C) following IPCC (2006) Guideline. Conversion of C-stock into carbon dioxide equivalent (CO2e) was then obtained by multiplying C-stock with a factor of 3.67 (44/12).

4.1.4. Peat Emission Factor

The emission factor figures for peat decomposition presented in the '2013 Supplement to the 2006 IPCC Guidelines for National GHG Inventory: Wetlands' (IPCC, 2013) were used as Tier 2 emission factors. As these figures were originated almost exclusively from research based on data from Indonesia, they conform by definition to the IPCC Tier 2 classification. IPCC (2013) 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, further allocation of IPCC default values was applied to suit land-cover classes used in this document (see Table 3).

Various emission factors have been identified (e.g. Agus et al., 2013; Hergoualc'h & Verchot, 2013; IPCC, 2013; Agus et al., 2014) (Table 3). Agus et al. (2014) and the Roundtable for Sustainable Palm Oil (Agus et al. 2013&b) used modified Hooijer et al. (2006; 2010) equations in which water table depth (regulated by the drainage depth) is the determining factor for peat emission. Each land cover was assigned an average drainage depth and therefore modification of drainage depth within the same land cover class will result in an increase or decrease in the amount of emission. Like the IPCC (2013), Hergoualc'h and Verchot (2013) also used land cover class as the basis for determining peat emission factor. However, in the latter, the measured CO2 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 default values were used instead.

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

NO.	LAND COVER	EMISSION (T CO2 HA-1 TH-1)	95% CONFIDENCE INTERVAL		REMARKS
1.	Primary forest	0	0	0	IPCC (2006)
2.	Secondary forest	19	-3	35	IPCC (2013)
3.	Plantation forest	73	59	88	IPCC (2013)
4.	Estate crop	40	21	62	IPCC (2013)
5.	Pure dry agriculture	51	24	95	IPCC (2013)
6.	Mixed dry agriculture	51	24	95	IPCC (2013)
7.	Dry shrub	19	-3	35	IPCC (2013)
8.	Wet shrub	19	-3	35	IPCC (2013)
9.	Savanna and Grasses	35	-1	73	IPCC (2013)
10.	Paddy Field	35	-1	73	IPCC (2013)
11.	Open swamp	0	0	0	Waterlogged condition, assumed zero CO2 emission
12.	Fish pond/aquaculture	0	0	0	Waterlogged condition, assumed zero CO2 emission
13.	Transmigration areas	51	24	95	Assumed similar to mixed upland agriculture
14.	Settlement areas	35	-1	73	Assumed similar to grassland
15.	Port and harbor	0	0	0	Assumed zero as most surface is sealed with concrete.
16.	Mining areas	51	24	95	Assumed similar to bare land
17.	Bare ground	51	24	95	IPCC (2013)
18.	Open water	0	0	0	Waterlogged condition, assumed zero CO2 emission
19.	Clouds and no-data	nd	nd	Nd	

4.2. Methodology and Procedure

The principal guideline for establishing FREL shall refer to the annex of FCCC/CP/2013/10/Add.1 (Guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels and/or forest reference levels). Methodology and procedure for determining FREL need to be carefully selected from of variety of methodology that is available (i.e. UNREDD Programme, 2014; Meridian Institute, 2011; SBSTA, 2009), taking into account the national circumstances. Step-by-step information regarding methodological approach used in this document is described subsequently.

UN-REDD Programme (2014) clustered the methodological approaches for the development of FREL of 10 REDD+ countries into : (1) using a historic average (Brazil, Mexico, Chile, Viet Nam, Ghana, Nepal); (2) using historic data with adjustments for national circumstances or projecting expected future emissions (DRC, Costa Rica, Republic of Congo); and (3) using other approach e.g. combined incentives (Guyana). A number of factors emerge from the analysis of those emerging approaches, including:

- Historical deforestation rate: countries with historically high deforestation tend to use historic averages. Countries with historically low deforestation rates tend to choose adjusted forest reference levels. Although this may reflect the current guidance provided by the FCPF Carbon Fund.
- Availability and robustness of data to predict future trends: An understanding of future trends in forest related emissions requires robust data, a good understanding of the specific drivers of deforestation and forest degradation, and potential modeling capacities. Simulations of future forest emissions by developed countries are generally based on various datasets and historical records (forest inventory, timber records, land-use change surveys, etc.), which most developing countries generally lack. Using a historical average is therefore the most feasible approach for many developing countries for the time being. Nonetheless, historically low deforestation countries are looking for sound ways to develop adjustments for national circumstances as allowed by UNFCCC decisions.
- Finding the balance between simplicity and accuracy. The use of future trend projections to construct forest reference levels may demand extensive data collection if complex modeling approaches are used. Starting with a high level of detail and complexity at the sub-national level may pose challenges when scaling up the approach to the national level. On the other hand some countries have proposed the use of a single emission factor to convert their activity data into emissions. This may result in the loss of detailed information on actual emissions, e.g. no distinction between the loss of highly degraded forest and the loss of primary forest.
- Variety of ecoregions or land uses in a single country. Multiple types of forests, land uses and activities may require the collection of specific data and methodologies to estimate carbon emissions and emission reductions. The level of effort across different land use types and/or activities may differ substantially. The Amazon Fund in Brazil has taken one approach that sets an eco-region wide forest reference level and then de-links payments into the Fund (based on a single forest reference emission level) from payments out of the fund (based on need and a set of defined objectives). On the other hand, some countries have developed multiple forest reference levels based on land use types, or tenure, in order to attribute performance and directly reward land users/managers for taking actions that reduce emissions from forests. An example of this more direct link between the forest reference level and results-based payment for specific activities is the emerging approach in the DRC.

4.2.1. Reference Period

A period span from 2000 to 2012 was used as the reference period for FREL. This period selection has considered the following aspects: (1) availability of land-cover data that is transparent, accurate, complete and consistent, (2) reflect the general condition of the forest transition in Indonesia, and (3) the length of time that could reflect the national circumstances, policy dynamics and impacts (biophysical, social, economic growth, political and spatial planning).

The land cover maps during the period of 2000 – 2009 were produced by the Ministry of Forestry every 3 years, and since 2011 the maps were generated annually. Therefore for emission calculation from deforestation, forest degradation and peat decomposition, were based on the following periods: 2000 – 2003; 2003 – 2006; 2006 – 2009; 2009 – 2011 and 2011-2012.

4.2.2. Reference emission calculation

Reference emission was calculated by using average annual emission from 2000 to 2012, i.e. historical emission from deforestation and forest degradation. The advantage of this approach is the simplicity in capturing highly dynamic activities in the past. This is preferable due to the unclear historical trend of deforestation and forest degradation in Indonesia.

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

4.2.3. Emission calculation from deforestation and forest degradation

Emissions from deforestation and forest degradation occurred at definite period were calculated by summing CO2 emissions resulted from a newly identified deforested areas and degraded forests within the period. Deforestation and forest degradation activities were monitored in the area that was still forested (natural forest) in 2000 and counted only once for deforestation that occurs at one particular area.

Emissions from deforestation were derived from the total loss of forest biomass regardless biomass gain, or in other word, gross deforestation. Forest degradation is the change from primary forests to secondary forests or logged-over forests. The 3-year land cover data sets were averaged to attain annual

rate of deforestation and forest degradation. Overall processes of data analysis for deriving activity data of deforestation and forest degradation is depicted in Figure 2

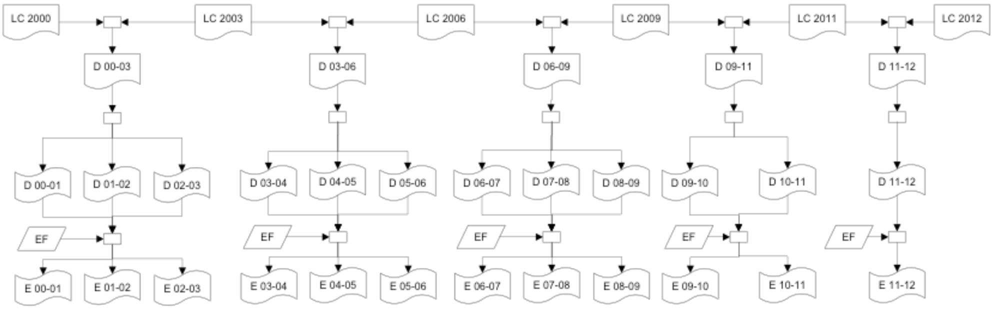


Figure 2. Flow chart of emission calculation from deforestation and forest degradation. "LC" is Land Cover, "EF" is Emission Factor, "D" is deforestation and forest degradation,"E" is emission.

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

Step 1: Generate deforestation and forest degradation map from each monitoring period, i.e. 2000 – 2003, 2003 – 2006, 2006 – 2009, 2009 – 2011 and 2011 -2012. For instance, forest cover map of 2000 and 2003 were analyzed for defining deforested area and degraded forests of 2000 – 2003.

Step 2: The defined deforested areas and degraded forests were integrated with associated emission factors to calculate emissions from deforestation and forest degradation from each monitoring period.

Step 3: Divide the calculated emissions by the number of year from each monitoring period, to derive annual emissions from deforestation and forest degradation.

CO2 emissions (GEij) from a deforested or degraded forest area-i (Aij), was calculated by multiplying the area (in ha) with emission factor of the associated

forest cover change type-j (EFj). A conversion factor from C to CO2 was further multiplied to derived emissions in tCO2 equivalent (equation 3).

$$GE_{ij} = A_{ij} \times EF_j \times 3.67 \qquad \text{(Equation 3)}$$

where GEij = CO2 emissions from deforested or forest degradation area-i at forest change class-j, in tCO2e. Aij = deforested or forest degradation area-i in forest change class j, in hectare (ha). EFj = Emission Factor from the loss of carbon stock from change of forest class-j, due to deforestation or forest degradation; in tons carbon per ha (tC ha-1). 3.67 is conversion factor from tC to tCO2e.

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

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

where, GEt is in tCO2, GEij is emission from deforested or degraded forest area-i in forest classes j, expressed in tCO2. N is number of deforested or degraded forest area unit at period t (from t0 to t1), 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 (MGEP) were calculated using equation 5.

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

Where, MGEP is expressed in tCO2yr-1. GEt is total emissions from gross deforestation and forest degradation at year t and expressed in tCO2. T is number of years in period P.

4.2.4. Emission calculation from peat decomposition

CO_2 emission from peat decomposition is calculated by multiplying the area of deforested and degraded peat forest with the emission factor of the subsequent land cover using 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 that deforested or degraded and changed into land cover type-j within time period-t. A is area-i of peat forest that deforested/degraded and changed into land cover type-j within time period-t. EF is the emission factor from peat decomposition of land cover class-j ($tCO_2\ ha^{-1}\ yr^{-1}$)

Since the inherited emission from previous activities occur in the subsequent land cover (e.g. Agus et al., 2011), total emission from peat decomposition is the accumulation of emissions since 2000. Emissions from peat decomposition sourced from deforested areas, degraded forests and remaining secondary forests. To approach the latter figure in annual basis, the annual loss of primary forest figure from Margono et al. (2014) was used as a reference proportion to the main data. The used of data from Margono et al. (2014) was based on the fine agreement results as previously stated. The detail calculation process was described in Figure 3.

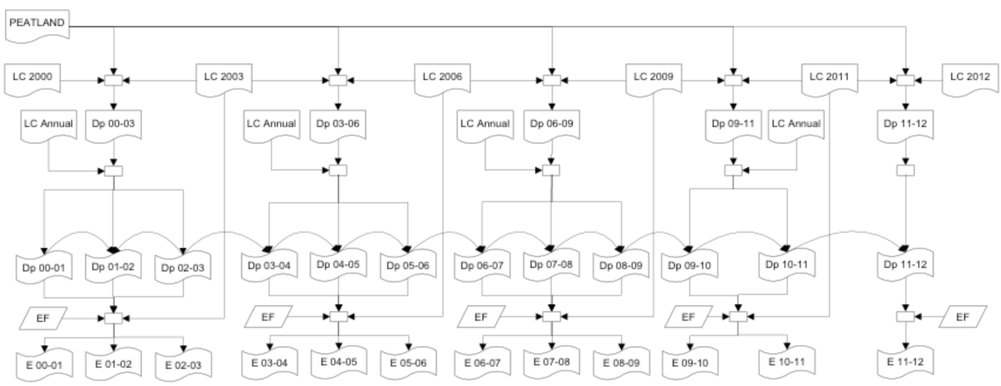


Figure 3. Calculation flow chart of peat decomposition emission in deforested peat forests. "LC" is land cover, "EF" is Emission Factor for peat decomposition, "LC Annual" is the proportion of annual deforestation derived from annual loss of primary forest data (Margono et al., 2014), "Dp" is deforested areas and degraded forest occurred in peat forests.

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

Step 1: Define deforested areas and degraded forests from each monitoring period within peat land.

Step 2: Assign annual proportion of forest change to deforested areas and degraded forests from related monitoring period, to generate annual deforested and degraded forest areas.

Step 3: Calculate current cumulative deforested areas and degraded forest by taking into account previous deforested areas and degraded forest, except from the base year 2000. For instance, to calculate current cumulative areas in 2001, deforested areas and degraded forests in 2001 were accumulated with deforested areas and degraded forests in 2000. To calculate current cumulative areas in 2002, deforested areas and degraded forests in 2002 was accumulated with deforested areas and degraded forests in 2001, and so forth.

Step 4: Calculate annual emissions by multiplying (1) new deforested areas with emission factors of bare land (51 $tCO2/ha/y$); (2) past deforested areas with emission factors of various new land-cover emission, and; (3) past and new secondary forest with emission factors of secondary forests (19 $tCO2/ha/y$).

Total annual emissions from peat decomposition were calculated by aggregating annual emission from deforestation, forest degradation and secondary forests.

4.2.5. 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 ground truth points. The assessment was conducted for all 23 classes and concluded that the overall accuracy is 88% (MoFor, 2011). For emission factor, the uncertainties were generated from the standard error of the carbon stock values from each forest types in each major island. The carbon stock was estimated using the NFI plots distributed systematically across the country. For peat decomposition,

uncertainty of activity data derived from the overall accuracy of peat land mapping, while for uncertainty values of emission factors were derived from IPCC (2013) default values. Since the AGB emissions calculation using Tier 2 accuracy, the uncertainty level for forest degradation and deforestation is lower than that of peat emissions.

A proportion of accuracy contribution (Cij) was calculated from activity j that occurs in forest cover class i, by involving the uncertainty (Uij), total emissions occurred in the corresponding forest cover classes and activities (Eij) and total emission from the corresponding year (E).

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

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

Total uncertainty of each year (TU), was derived from a square root of sum Cij.

RESULTS OF THE CONSTRUCTION OF FOREST REFERENCE EMISSION LEVEL (FREL)

5.1. Estimates of deforestation and forest degradation area

5.1.1. Deforestation

The annual rate of deforestation in Indonesia from 2000 to 2012 was 671,420 ha (see Figure 4). This figure accounts for 525,516 ha of deforestation in mineral land and 145,904 ha of deforestation in peat land. The highest rate of deforestation was during period of 2006 – 2009 accounted for more than 850 thousand ha.yr-1 and decreased in the next period to about 500 thousand ha yr-1 in 2011. The deforestation rate increased again to about 750 thousand ha.yr-1 during the period of 2011-2012. Most of deforestation during these periods occurred in secondary dryland forests and secondary swamp forests accounted for about 387 thousand ha yr-1 and 240 thousand ha yr-1, respectively (see Annex 5).

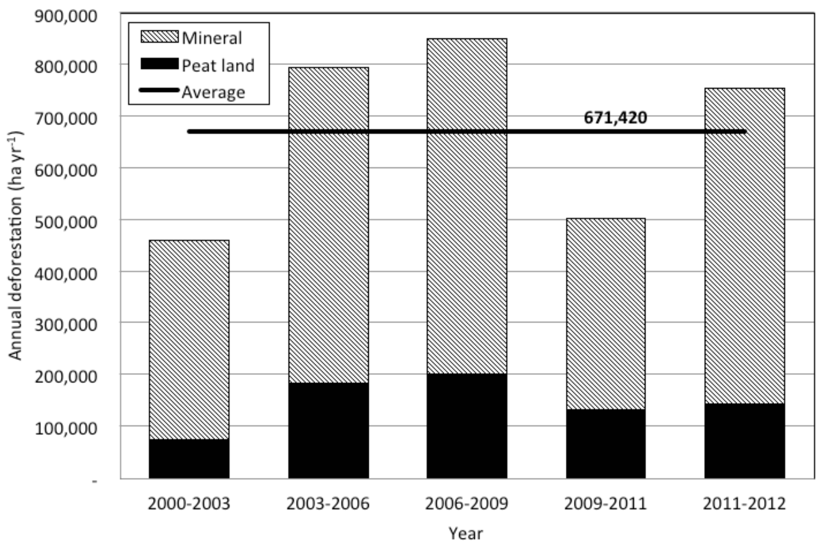


Figure 4. Annual deforestation in hectares. The black line depicts average annual deforestation from 2000 – 2012

More than 80% of deforestation occurred in Sumatra and Kalimantan. Sulawesi and Papua contributed to about 9% and 6%, respectively. As expected, the least forested regions, Java and Nusa Tenggara experienced very low deforestation, from which contribute to only 2% of total deforestation in Indonesia (Figure 5).

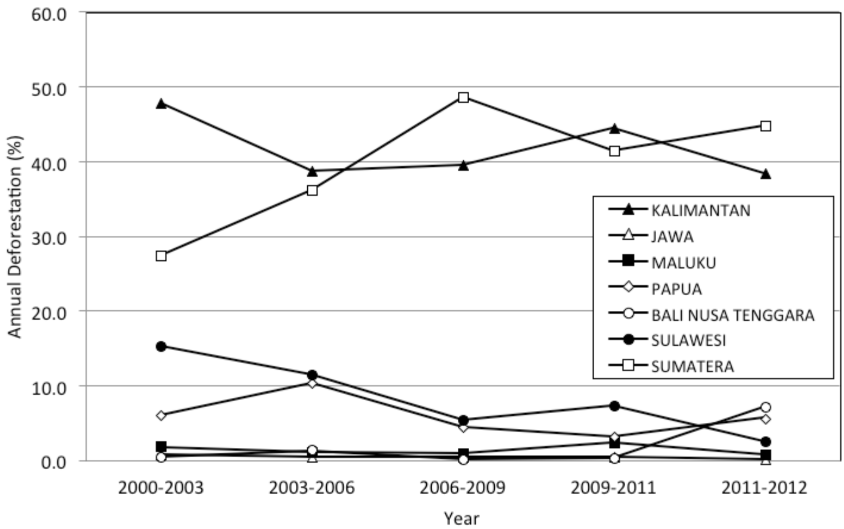


Figure 5. Annual deforestation (%) in Indonesia by 7 major islands or island groups.

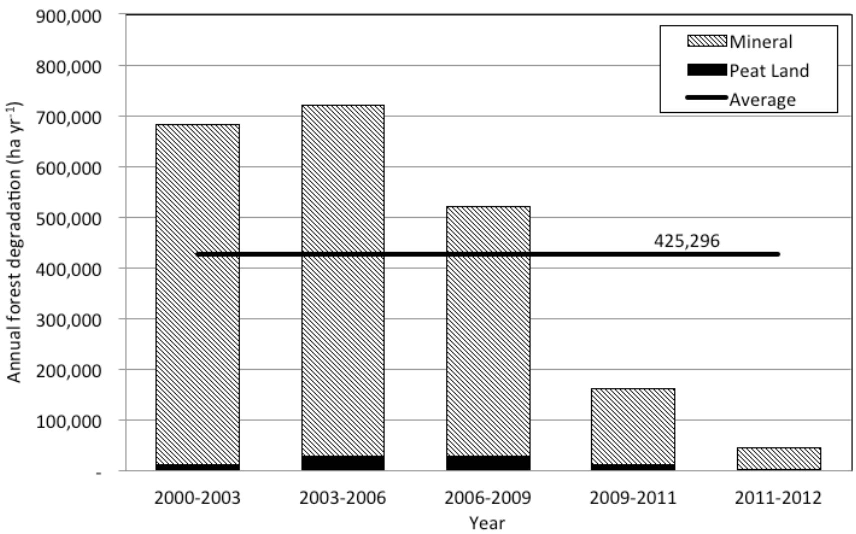


Figure 6. Annual forest degradation in hectares. The black line depicts average annual forest degradation from 2000 – 2012.

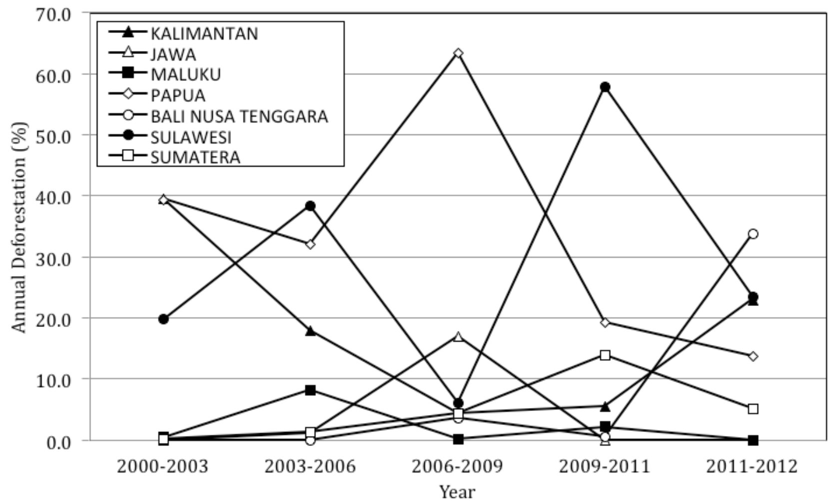


Figure 7. Annual forest degradation (%) in Indonesia by 7 major islands or island groups

5.2. Emissions from deforestation, forest degradation, and peat decomposition

5.2.1. Emissions from deforestation and peat decomposition

Average historical emission from deforestation from 2000 – 2012 in Indonesia accounted for 213 MtCO2e annually (see Figure 8). This figure accounts for 172 MtCO2e yr-1 of emission from deforestation in mineral land and 41 MtCO2e yr-1 of emission from deforestation in peat land. Additional GHG emission was taken from peat decomposition as an impact of deforestation activity that started from 3.3 MtCO2e yr-1 in 2000 – 2001 to 61.7 MtCO2e yr-1 in 2011 – 2012. Constant growth of emission from peat decomposition was influenced by inherited emission that occurs after deforestation activity.

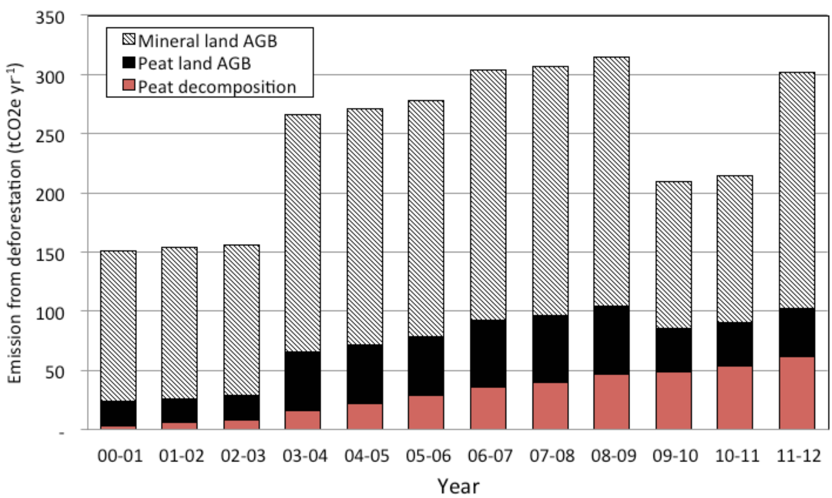


Figure 8. Annual historical emissions from deforestation expressed in millions tCO2e

5.2.2. Emissions from forest degradation and peat decomposition

Average historical emission from forest degradation from 2000 – 2012 accounted for 56.4 MtCO2e annually (see Figure 9). This figure accounts for 54.6 MtCO2e yr-1 of emission from forest degradation in mineral land and 1.8 MtCO2e yr-1 of emission from forest degradation in peat land. Additional GHG emission was taken from peat decomposition as an impact of forest degradation activity as well as the remaining secondary forest that started from 97 MtCO2e yr-1 in 2000 – 2001 to 75 MtCO2e yr-1 in 2011 – 2012. Constant reduction of emission from peat decomposition was influenced by the decrease trend of forest degradation as well as reduction of secondary forest because of deforestation.

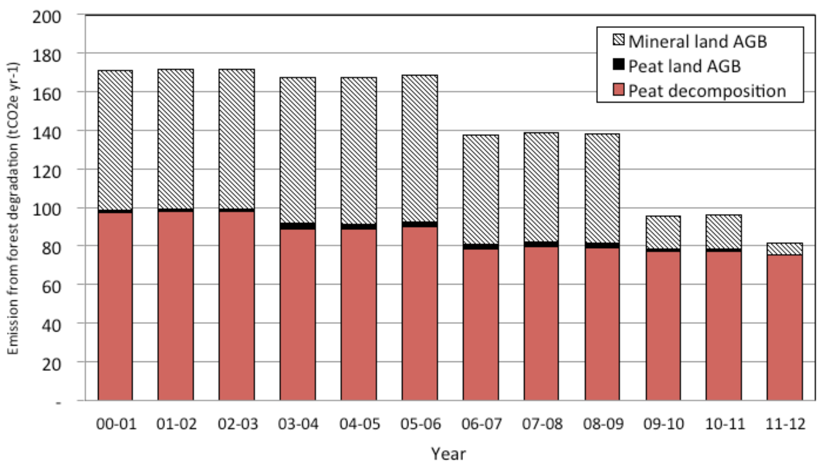


Figure 9. Annual historical emissions from forest degradation expressed in millions tCO2e.

5.3. Constructed National Forest Reference Emissions Level

The annual historical emission from deforestation, forest degradation and the associated peat decomposition (in MtCO2) from 2000 to 2012 is depicted in Figure 10. In average, the emissions from deforestation, forest degradation and the associated decomposition were accounted for 49.9%, 13.6% and 36.5%, respectively.

Using reference period of 2000 – 2012, forest reference emission level from deforestation and degradation was set at 0.269 GtCO2e yr-1. To this figure, the additional emission of 0.136 GtCO2e yr-1 from peat decomposition was added with annual increment as much as 2.87% because of inherited emission. This FREL will be used as the benchmark against actual emission starting from 2013 to 2020.

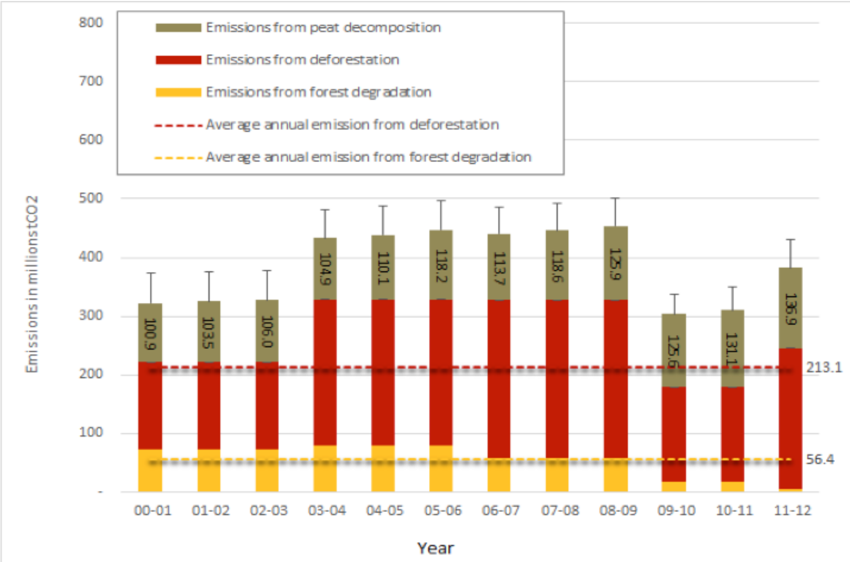


Figure 10. Annual and average historical emissions from deforestation, forest degradation and the associated peat decomposition (in MtCO2).

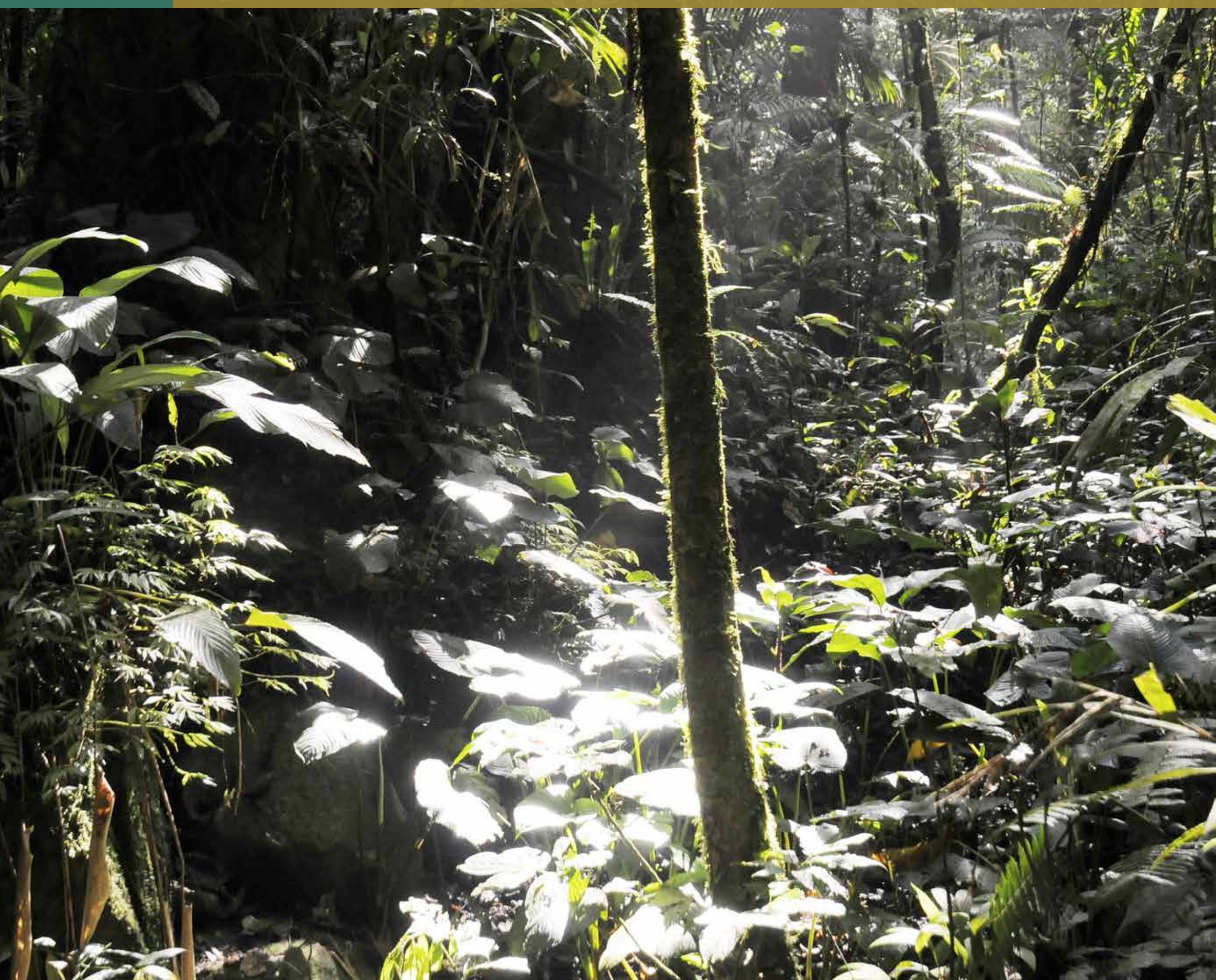
The emission from deforestation, forest degradation and the associated emission from peat decomposition for 2013 will be projected as 0.41 GtCO2e. In 2020, the emission figure will increase to 0.441 GtCO2e. For annual monitoring, Table 4 should be used as a benchmark for evaluating emission reduction activities during the implementation period.

Table 4. Annual REL for deforestation, forest degradation and the associated peat decomposition (in tCO2)

YEAR	DEFORESTATION	FOREST DEGRADATION	PEAT DECOMPOSITION	TOTAL ANNUAL EMISSION
2013	213,129,100	56,405,744	140,866,421	410,401,265
2014	213,129,100	56,405,744	144,909,287	414,444,131
2015	213,129,100	56,405,744	149,068,184	418,603,028
2016	213,129,100	56,405,744	153,346,440	422,881,285
2017	213,129,100	56,405,744	157,747,483	427,282,328
2018	213,129,100	56,405,744	162,274,836	431,809,680
2019	213,129,100	56,405,744	166,932,124	436,466,968
2020	213,129,100	56,405,744	171,723,076	441,257,920

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

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. Back to the earlier periods, timber was a major source of export earning for Indonesia, second only to oil, where much of the exported timber came from Kalimantan. The large-scale timber cuts began in 1967 when all Indonesian forests were declared as the state forests. The enactment of Basic Forestry Law (UU No.5/1967), Foreign Capital Investment Law in 1967 and the Domestic Capital Investment Law in 1968, coupled with the issuance of various forestry regulations and incentives, had stimulated investments in timber industries.

In the 1980s, a national forest map called Forest Land Use by Consensus (Tata Guna Hutan Kesepakatan/TGHK) was developed to administer state forest lands in outer Islands. The TGHK has become the basic reference for natural forest utilization with a definite planning prepared by the Ministry of Forestry (MoFor). Along with its implementation, however, the map needs to be synchronized with Provincial Spatial Planning.

Synchronization between TGHK and Provincial Spatial Planning was carried out between 1999 and 2000, resulted in maps of Provincial Forest Area that were legalized by Forestry Ministerial Decree. These maps defined forest areas into three broad categories based on function namely Protection Forest, Conservation Forest and Production Forest. The land that was not designated as a forest was entitled to non-forest area (areal penggunaan lain/APL).

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

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

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

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

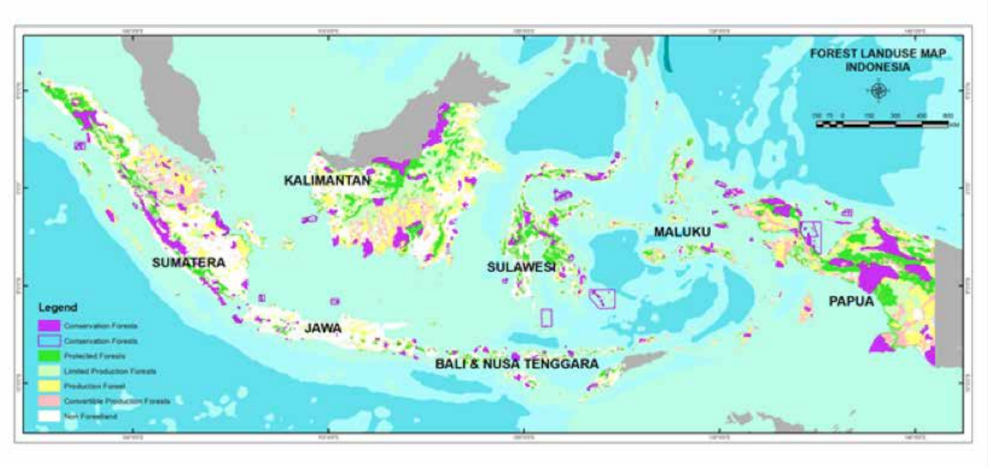
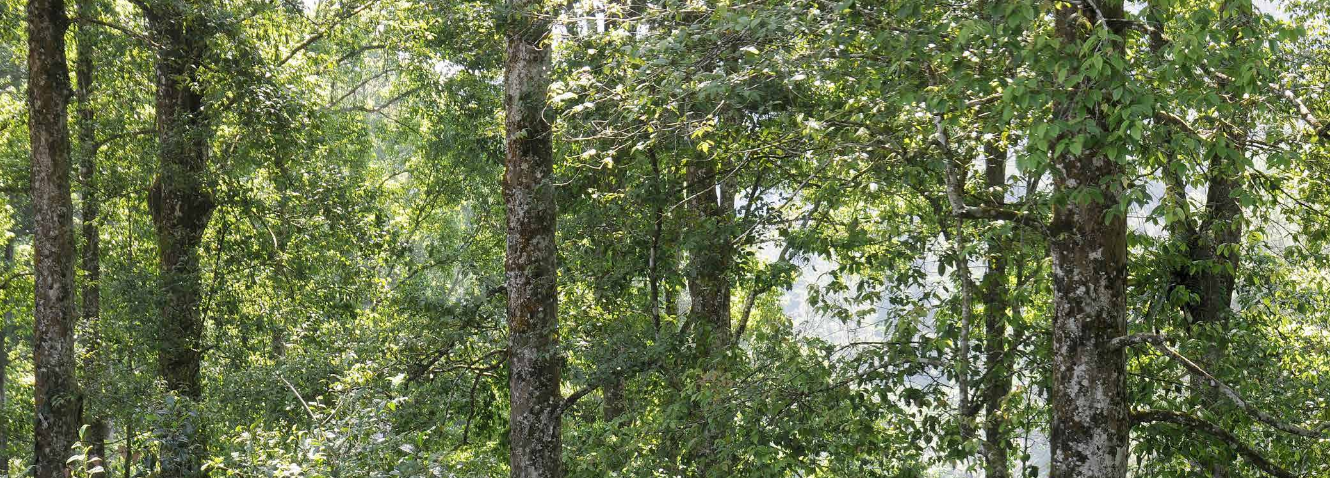


Figure 11. Map of Forest Area Designation (MoFor, 2013)

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 National Planning Agency/BAPPENAS (2013) stated that the Indonesian annual population growth is projected to reach 1.19 percent (from 238 million of population in 2010 to 296



million of population in 2030). 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.

Increasing trend of agricultural production (e.g. palm oil, rubber, coffee, cacao, pepper) is also connected to the increasing global demand on agricultural products. The data from the Ministry of Agriculture/MoA (2012) showed that production of fresh fruit bunch of palm oil has increased from 17.54 million tons in 2008 to 23.52 million tons in 2012, with annual increase on production of 7.7 percent, the highest palm oil production in the world. The MoA also recorded annual increase on rubber production of 2.95 percent, while the annual increase on pepper production, clove and cacao were 2.33 percent, 2.69 percent and 3.11 percent, respectively. Without adequate provision on genetically improved seeds and sustainable practices, increasing demand for such agricultural products may lead to increasing demand for additional land for agriculture, hence it may increase pressure to forest land.

The new government has declared a new agenda for development namely NAWA CITA (Jalan perubahan untuk Indonesia yang berdaulat, mandiri dan berkepribadian/The road of change for the sovereignty, self-reliance and integrity of Indonesia) that emphasizes on debottlenecking actions in three main areas, namely: human resources, energy sovereignty and food sovereignty. NAWA CITA consists of nine priority agenda that also covers food security, based on community agribusiness and energy security, for the sake of national interest. This important agenda will consequently affect the future characteristic of land-based emission in Indonesia. It is expected that agricultural production for rice, corn, soybean, palm oil and livestock will increase within the next five years. It is expected that similar trend will take place for mining and forest products.

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, 2013). In the 15.2 million ha of HPK, the total remaining natural forest in 2012 were 7.24 million ha, distributed across seven major/groups of islands (Figure 12). Other than the above forested area, there are also 7,48 million ha of natural forest of 2012 which is located in the APL (other land-uses/non forest land). Hence, the total area of natural forests that can be converted from HPK and APL is 14.72 million ha (Figure 13).

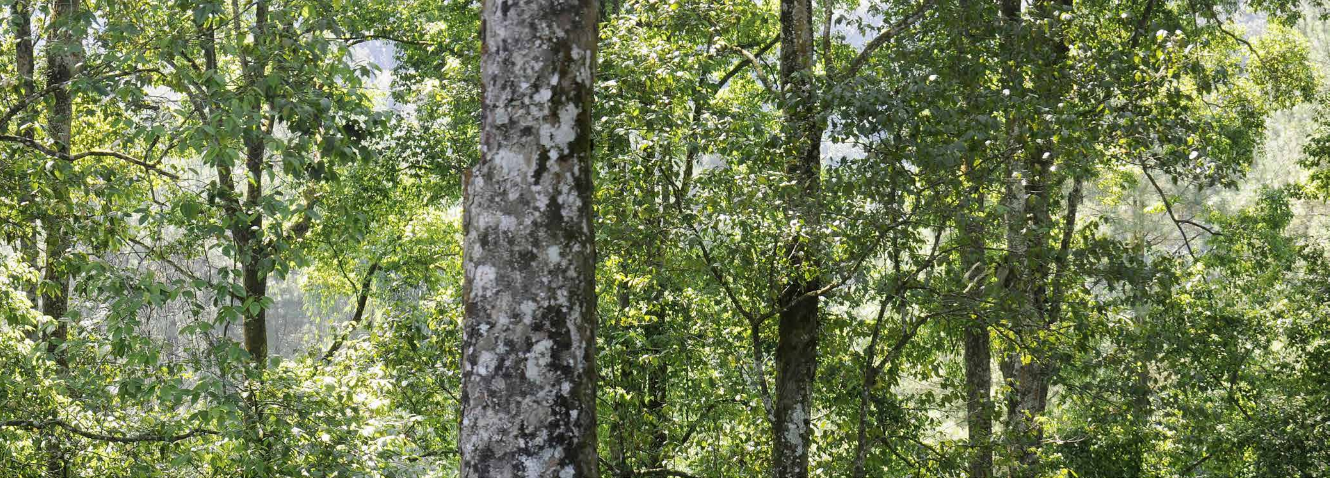


Figure 12. Distribution of natural forests that allowed to be converted (MoFor, 2013)

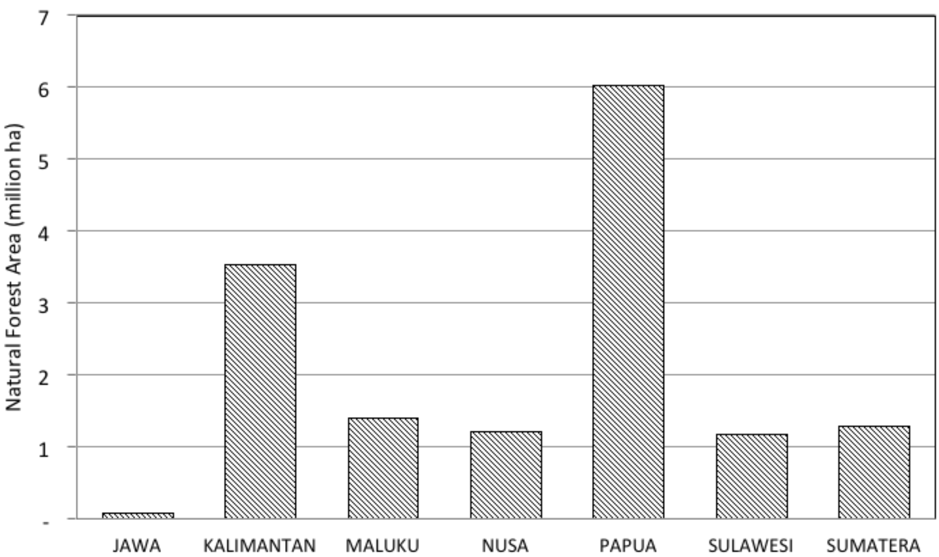


Figure 13. Area covered by natural forest that allowed to be converted to other land uses

6.3. Policy implication to planned and unplanned deforestation

Planned deforestation refers to forest conversion that is legally allowed to take place for various purposes of development, namely in the HPK and APL. Planned deforestation occurred due to transmigration, regional development, mining, agricultural expansion, and settlements.

Unplanned deforestation occurred in forest areas other than HPK and APL. The unplanned deforestation can occur from several causes, for example: illegal logging, overcutting and forest encroachment.

Natural forest area of 14.72 million ha in HPK and APL is by law allowed to be converted to other land uses (planned deforestation), and so, this needs to be taken into account in the FREL construction. Since forest area allocation for conversion is indicative in nature and is only allowed to be converted if needed for development purposes, there have not been specific planning on area and timing for the conversion of these forests. Hence, assumption needs to be made to enable estimation of the associated emissions. However, in the absence of adequate basis for making assumption for FREL construction, the FREL construction for this publication did not differentiate between planned and unplanned deforestation.

For reducing planned deforestation, government of Indonesia has enacted policy on moratorium of natural forest conversion, as well as in the process of implementing land swap policy. In this policy, the convertible forested lands may be swapped with non-forested lands which by law are not allowed for conversion.

Government of Indonesia has also carried out significant effort to reduce unplanned deforestation particularly in open access forest areas. Open access area is the forest areas that have no on-site agencies who are responsible for managing the areas, mostly areas where concession permits have been terminated. The Ministry of Forestry (now Ministry of Environment and Forestry/ MoEF) has planned 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, bringing in average of establishment of 30 units per year. With such rate, Indonesia will only manage to establish less than 500 units by 2020. The establishment of FMU will therefore need to be prioritized in regions with high deforestation risk. It is expected that with the establishment of FMU, the rate of unplanned deforestation will decrease in the future compared to the historical rate.

OPPORTUNITY FOR IMPROVEMENT

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

Towards further improvement in the future, there have been a number of on-going initiatives, including for example improvement of activity data, improvement of forest emission factor (carbon stock), and improvement of emission factor from peat land and mangrove ecosystems, in which the results have not been fully used in the FREL construction for this publication.

7.1. Improvement of activity data

Future improvement of activity data may cover two major aspects pertaining to latest technology utilization and methodology enhancements.

Utilization of advance technology in remote sensing will be explored for improving wall-to-wall monitoring of deforestation and forest degradation. By using current land-cover data derived from historical Landsat images (TM, ETM, OLI), it is possible to detect deforestation with good accuracy, but it is still problematic to monitor various forest degradation levels with the same levels of uncertainty. The potential use of high-resolution image data such as SPOT image for filling the gaps will be further explored in coordination with Indonesia's Aeronautics and Space Agency (LAPAN) under the One Gate Policy for high-resolution satellite image provision. Furthermore, the increasing use of LiDAR technology will be further explored for validating biomass values in remote areas. As such, accuracy of biomass estimates of degraded forests could be increased and the level of forest degradation can be quantified.

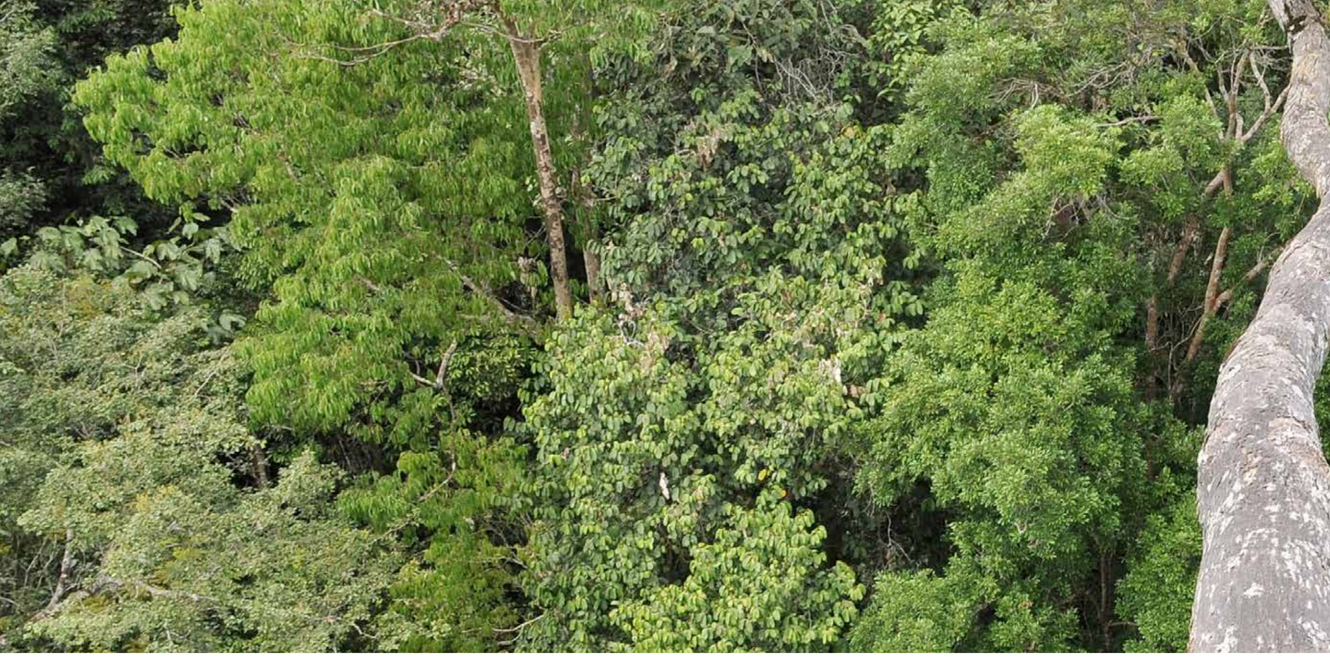
On the methodological aspect, producing annual cloud-free image is increasingly possible by utilizing current pixel selection methodology (e.g. Hansen et al., 2012). Referring to this result, the possibility for mapping annual wall-to-wall land-cover for the next monitoring period will be high.

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

7.2. Improvement of forest emission factor (carbon stock)

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

More pools that significantly contribute to total forest biomass need to be measured and included in the next plan to improve NFI system, i.e. necromass and below ground biomass. Several forest carbon inventory methods have been developed to include all carbon pools in a practical and robust way (SNI 7724: 2011 on Measurement and Carbon Stock Accounting-Field Measurement to measure forest carbon stock; Kaufman and Donato, 2010; Ravindranath and Oswald, 2008; Pearson et al., 2005).



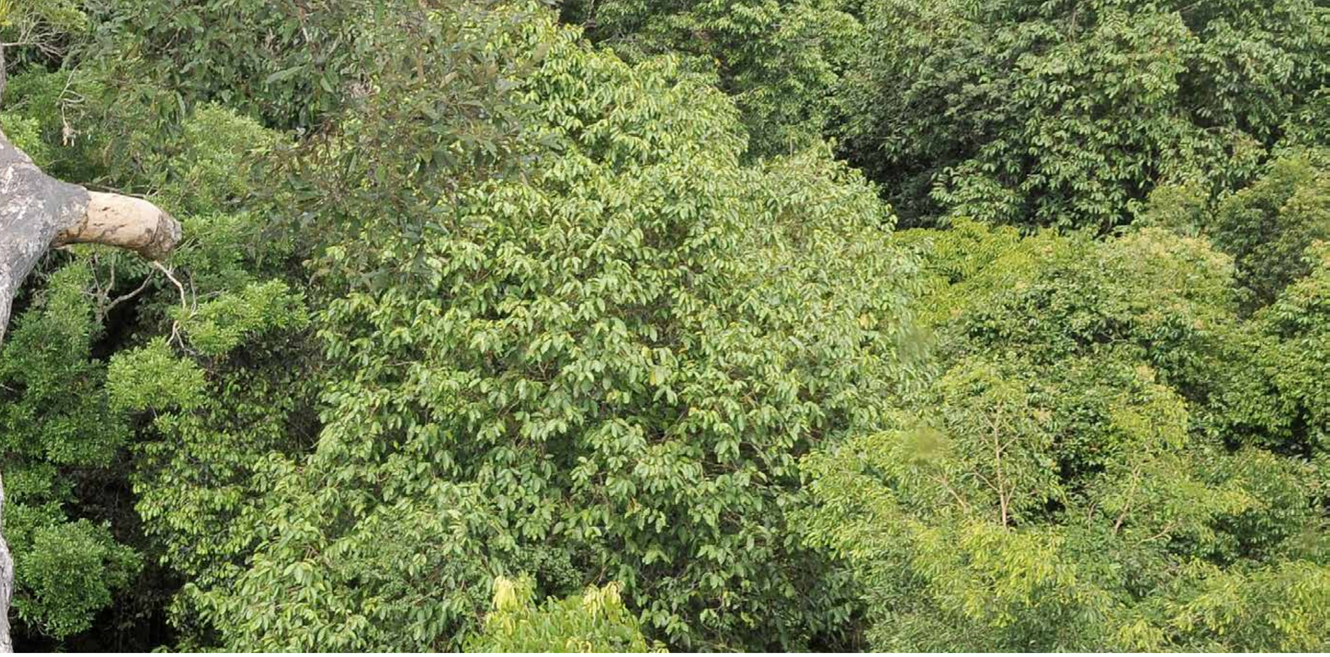
Improvement of NFI can be carried out through validating existing plots and ensuring accurate measurement in future measurements. Capacity building will be crucial to support this improvement plan, as it requires skillful and well-trained field operators. Utilizing current advance information technology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

7.3. Improvement of Peat land Emission Factor

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

7.4. Estimating Peat land Fire Emission

Various researches used optical images for burnt area mapping, namely Landsat (Phua et al., 2007) and SAR images (Siegert and Ruecker, 2000). Cloud cover persistence after fire season is the biggest challenge to acquire cloud-free optical images. In addition to that, vegetation growth after fire is tremendously fast in tropical region, leading to a narrow window for image acquisition that depicts the burnt area. In East Kalimantan, Siegert and Hoffman (1999) undertook burn scar mapping after fire episode in 1997/1998, which compare SAR images before



and after the fire. At global level, NASA and Maryland University developed an algorithm to generate burnt scar maps from MODIS data (Li et al., 2004). However the product has not been validated for Indonesia. Another initiative utilizes low-resolution input. This was a research project conducted and tested in Central Kalimantan (MRI, 2013). The study used hotspot data to estimate burn scar areas by filtering annual fire hotspots using 1x1 km grid. This method is easy to apply, but the uncertainty was unknown. Due to unavailability of similar data sets, the method proposed by MRI was applied to generate burnt area maps at national level. Detail method of peat fire emission calculation is described in Annex 4. The emission factor from peat fire was formulized according to the IPCC Supplement (2013).

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

7.5. Inclusion of other REDD+ Activities

Following the development and improvement of activity data, Indonesia may include other REDD+ activities in future submissions. Indonesia is currently piloting REDD+ activities in Central Kalimantan Province that include activities of deforestation, forest degradation, sustainable management of forests, enhancement of forest carbon stocks; and biological oxidation and fire on disturbed peat lands. The estimation of the annual GHG emissions and removals from the activities in this REDD+ activities has used approach in the Indonesia's National Carbon Accounting System (INCAS), that has potential to be scaled up for national level carbon accounting in forest and other land sector.

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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 could only be updated every three years based on data availability, due to problems of clouds and haze. In total, + 217 Landsat TM/ETM+ scenes are required to cover the entire land area of Indonesia, excluding additional scenes to minimize/ remove clouds and the presence of haze. Up to around 2006, other data sets such as SPOT Vegetation 1000 meters and MODIS 250 meters were used for alternative, especially when the purchased Landsat data were not ready for processing and classification processes.

More consistent data was available from 2009; following the change in Landsat data policy of the United States Geological Survey (USGS) in 2008, that has made Landsat data available free of charge over the internet. The new Landsat data policy, automatically benefits Indonesia by increasing the number of data available for supporting the mapping system. In 2013, MoFor started to use the newly launched Landsat 8 OLI to monitor Indonesian land cover condition and placed the Landsat 7 ETM+ as a substitution for cloud elimination. More data available through free-download has opened opportunities for Indonesia to change the three interval year into annual basis. Up to now, land-cover data is available for the years of 2000, 2003, 2006, 2009, 2011, 2012, and 2013. To maintain continuous improvement, collaboration between LAPAN for Landsat data preparation and the MoFor for classification process will be a valuable support for future works. The existing system is known as the National Forest Monitoring System (NFMS). It is available online at http://nfms.dephut.go.id/ipsdh/, coupled with webGIS at http://webgis.dephut.go.id/ for display and viewing.

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

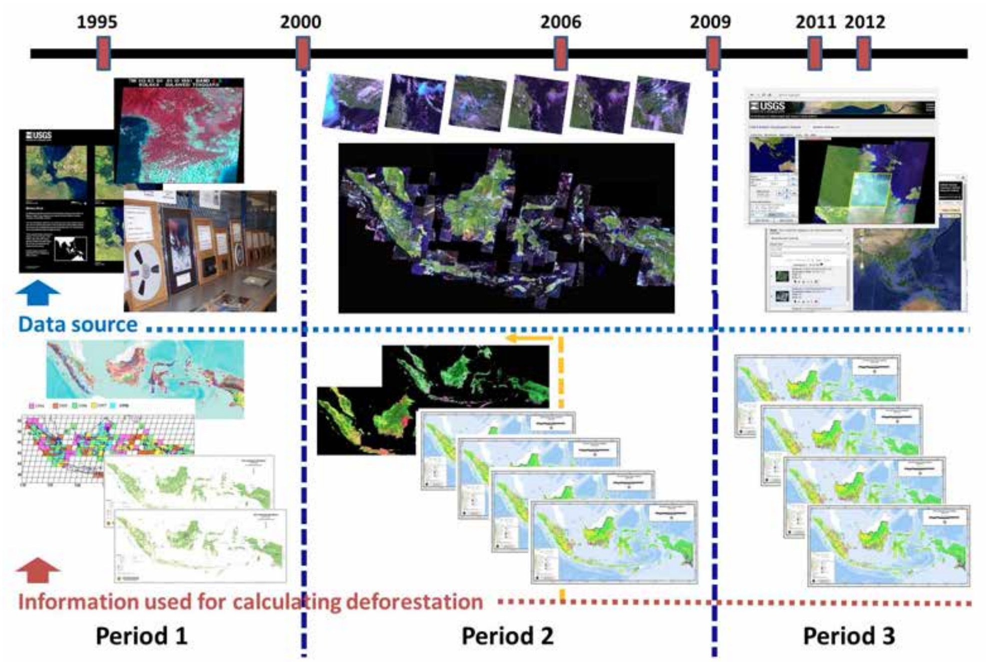

Figure Annex 1.1. Historical condition and improvement in establishing the land-cover map of Indonesia that consists of three significant periods.

Within Period 1 (prior 2000), all available data including analog data, and Landsat hard copy that was delineated manually and digitized, were used. For Landsat, most scenes either use softcopy in CCT format as well as the hard copy were not within the same year interval, but at Period 1, that was the only data available for generating land cover. Products were generated under the National Forest Inventory (NFI) activity and later published on Holmes (2000, 2002). Period 2 (2000-2009) is the period of using merely digital data. However the manual classification method employed is time consuming and delayed the product delivery, especially when experiences in wall-to-wall mapping are limited. Alternative approach by using SPOT Vegetation 1000 meters and MODIS 250 meters was done for immediate reporting. Landsat data at 30 meters resolution, which was later available, submitted and published on FAO-FRA (2010). Within period 3 (2009 onward), data availability is no longer a constraint, and only Landsat data has been used as a data source. Here, overcoming the time consuming manual classification process is becoming a concern. Significant improvements were carried out at the previous period (2006) and becoming a major concern at the beginning of the Period 3 (2009); that intended to migrate every single layer of time-sequential land cover data (2000, 2003, 2006, and 2009) into a single geodatabase. A geodatabase is a solution to improve interdependency among layers.

The land cover map of Indonesia is presented in 23 classes, including 6 classes of natural forests, 1 class of plantation forest, 15 classes of non-forested, and 1 class of clouds-no data. Name of the 23 classes and description are in table annex 1.1; with the series of monogram for those 23 classes is described in Annex 6.

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

NO	CLASSES	DESCRIPTION
Forest		
1	Primary dryland forest	Natural tropical forests grow on non-wet habitat including lowland, upland, and montane forests with no signs of logging activities. The forest includes pygmies and heath forest and forest on ultramafic and lime-stone, as well as coniferous, deciduous and mist or cloud forest.
2	Secondary dryland forest	Natural tropical forest grows on non-wet habitat including lowland, upland, and montane forests that exhibit signs of logging activities indicated by patterns and spotting of logging. The forest is including pygmies and 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 grows on wet habitat including brackish swamp, sago and peat swamp, with no signs of logging activities
4	Secondary swamp forest	Natural tropical forest grows on wet habitat including brackish swamp, sago and peat swamp that exhibit signs of logging activities indicated by patterns and spotting of logging
5	Primary mangrove forest	Inundated forest with access to sea/brackish water and dominated by species of mangrove and Nipa (Nipa frutescens) that has no signs of logging activities
6	Secondary mangrove forest	Inundated forest with access to sea/brackish water and dominated by species of mangrove and Nipa (Nipa frutescens) that exhibit signs of logging activities indicated by patterns and spotting of logging
7	Plantation forest	Planted forest including areas of reforestation, industrial plantation forest and community plantation forest
Non-Forest		
8	Dry shrub	Highly degraded log over areas on non-wet habitat that are ongoing process of succession but not yet reach stable forest ecosystem, having natural scattered trees or shrubs
9	Wet shrub	Highly degraded log over areas on wet habitat that are ongoing process of succession but not yet reach stable forest ecosystem, having natural scattered trees or shrubs

NO	CLASSES	DESCRIPTION
10	Savanna and Grasses	Areas with grasses and scattered natural trees and shrubs. This is typical of natural ecosystem and appearance on Sulawesi Tenggara, Nusa Tenggara Timur, and south part of Papua island. This type of cover could be on wet or non-wet habitat
11	Pure dry agriculture	All land covers associated to agriculture activities on dry/non-wet land, such as tegalan (moor), mixed garden and ladang (agriculture fields)
12	Mixed dry agriculture	All land covers associated to agriculture activities on dry/non-wet land that mixed with shrubs, thickets, and log over forest. This cover type often results of shifting cultivation and its rotation, including on karts
13	Estate crop	Estate areas that has been planted, mostly with perennials crops or other agriculture trees commodities
14	Paddy field	Agriculture areas on wet habitat, especially for paddy, that typically exhibit dyke patterns (pola pematang). This cover type includes 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 yet, including open exposure areas, craters, sandbanks, sediments, and areas post fire that has not yet exhibit regrowth
18	Mining areas	Mining areas exhibit open mining activities such as open-pit mining including tailing ground
19	Settlement areas	Settlement areas including rural, urban, industrial and other settlements with typical appearance
20	Port and harbor	Sighting of port and harbor that big enough to independently delineated as independent object
21	Open water	Sighting of open water including ocean, rivers, lakes, and ponds
22	Open swamps	Sighting of open swamp with few vegetation
23	Clouds and no-data	Sighting of clouds and clouds shadow with size more than 4 cm2 at 100.000 scales display

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

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

Data validation to assure the classification results was carried out by comparing land cover map to the post classification field data. Stratified random sampling is a selected approach to verify the classification map to the field reality. Compilation of several field visit data within a specific year interval was exercised for accuracy assessment. Comparison results performed on table of accuracy (contingency table), yielding an overall accuracy of 88 percent for all 23 classes, and 98 percent for aggregated classes of forest and non-forest (MoFor, 2011, Margono et al., 2012).

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

Other data-set introduced in this report

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

Land Cover map of Margono et al. (2014)

Study of Margono et al. (2014) has been published in journal of Nature Climate Change, available online since June 2014. The study generates three main land cover classes: primary forest, consisting of primary intact and primary degraded classes; and non-primary forest (other land). Referring to the supplementary material of the NCC publication, 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 km2 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, and primary degraded forest refers to secondary forest (hutan sekunder) of the MoFor. Those are consistent with the forests description of the MoFor land-cover classes (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 and 2012. For MoFor, it equaled primary plus secondary forest categories. This was performed to assess the primary forest reference mask. The primary forests class of Margono et al. (2014) and that of MoFor yielded a 90 percent agreement with an 80 percent Kappa and balanced omission and commission errors (Table Annex 1.2).

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

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

ASSESSMENT FOR AGREEMENT	PRIMARY FOREST (INTACT AND DEGRADED)	
	2000	2012
Overall agreement	90.7	90.9
Producer's agreement	92.1	90.7
User's agreement	90.1	90.6
Kappa statistic	81.0	81.0

Land cover map of INCAS

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 of INCAS was conducted in LAPAN (National Institute of Aeronautics and Space of Indonesia) and assisted by CSIRO Australia.

Forest is defined as a collection of trees with height greater than 5 meters and having greater than 30% canopy cover. For this activity, Landsat 5 (LS-5) and Landsat 7 (LS-7) were chosen as the only feasible data source in providing such monitoring Information. Samples derived from high-resolution satellite imagery were used as a 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-INCAS, including image preparation, forest extent and change mapping, as well as review of the product. The outputs from previous steps are automatically used as the input for the next step. Image preparation is intended to produce a free-cloud mosaic. At first the images in scenes (path/row) are selected and geographically corrected, if necessary, as those scenes should be aligned to each other and to other maps used as reference. Corrections to normalize every pixel value to be more consistent through time are subsequently executed. Contaminating data, such as clouds and shadows, haze, smoke and image noise that obscures the ground cover are masked. The individual selected-corrected images are then consolidated into mosaic tiles, to simplify the following process.

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

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

ASSESSMENT FOR AGREEMENT	TREE COVER	
	2000	2012
Overall agreement	78.7	78.1
Producer's agreement	75.6	73.6
User's agreement	89.7	88.7
Kappa statistic	56.0	56.0

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

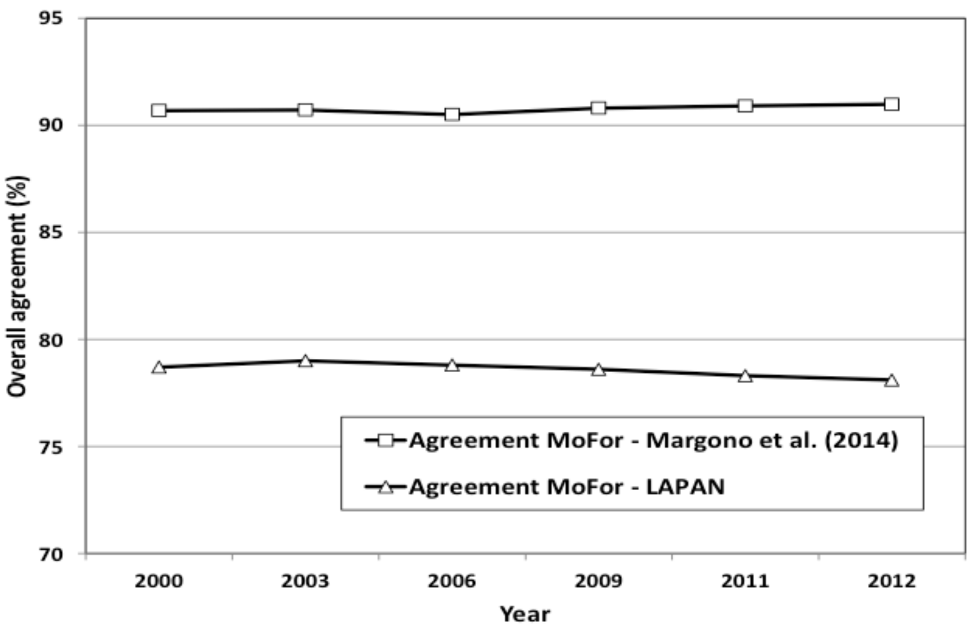

Figure Annex 1.2. Graph comparison, shows agreement of the land cover data MoFor used in this analysis to the other two independent studies (Margono and LAPAN/LCCA-INCAS).

Annex 2. Documentation and specification of the peat land data

Peat land mapping activities in Indonesia are closely related to soil mapping projects for the purpose of agricultural development programs conducted by the Ministry of Agriculture. Due to the dynamics of the data availability used for peat mapping, peat land maps of Indonesia have been updated and released several times. For the purpose of this FREL publication, the peat land map used for calculating FREL is the latest 1:250.000 scale of Peat land Map 2011 edition. This map was prepared based on the data and information resulted from the land/soil Resources mapping from 1989 - 2011 done by the Agricultural Research and Development Agency of the Ministry of Agriculture. The peat land map was made from the available data in Indonesia, as a result of soil mapping that has been carried out in various levels/scales and ground truth activities.

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

Data Input:

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

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

Method:

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

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

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

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

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

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

Background information

NFI was initially a Word Bank supported project to assist the Ministry of Forestry (MoFor) of Indonesia for conducting forest resource enumeration during the period of 1989 to 1996. The implementation was carried out through technical assistance from FAO-UN. The goal of NFI project was to support the development of a forest resource information system and institution, including for the purpose of establishing a Forest Resource Assessment (FRA). The implementing agency of NFI project was the Directorate General of Forest Planning or Planology (DGFP) of 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. All plots were distributed in lowland area below 1000 m above sea level. In addition to that, land and forest cover map were digitized at scale of 1:250,000 based on satellite images covering national area.

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

NFI sampling design

The purpose of the plots established by NFI project was to conduct forest resource assessment at national scale. Those 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 tracts with 500 m distance between them. The 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 areas (25 m x 25 m). The numbering of plots and recording units is depicted in Figure Annex 3.1.

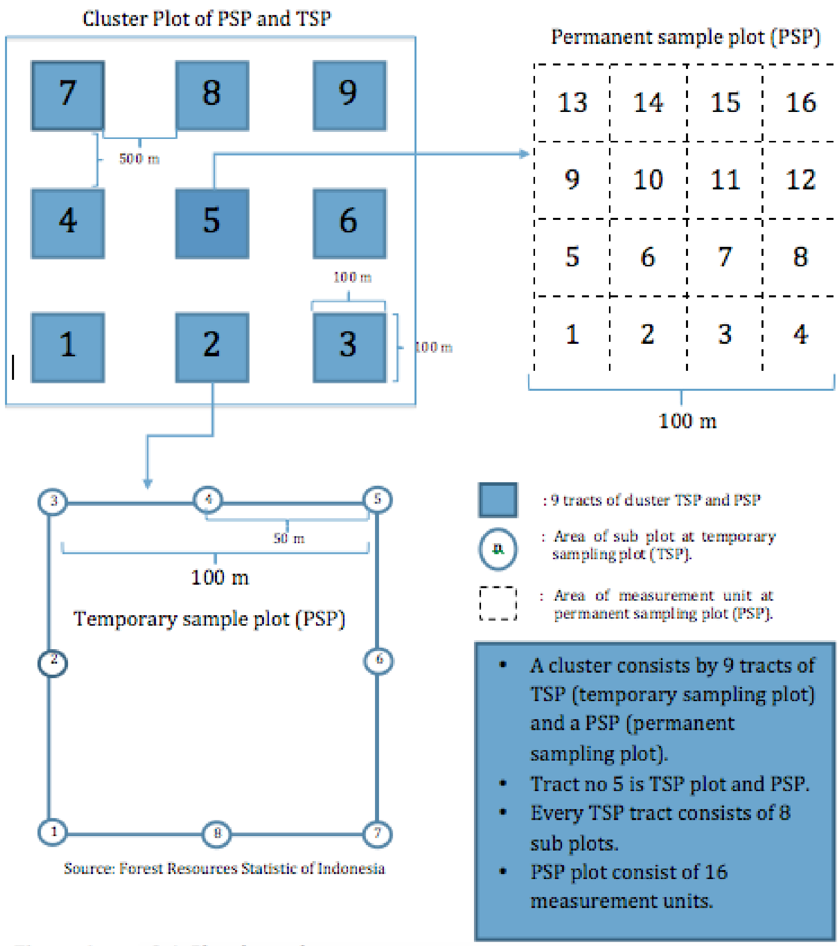

Figure Annex 3.1. Plot cluster layout.

NFI Cluster distribution

NFI clusters were systematically distributed at 20 km x 20 km covering all forest and land cover types within the forest area of Indonesia. Most of the clusters are located in the area with altitude below 1000 m 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 forest area, even though it is forested areas.

Since the commencement of the NFI program in 1989, PSP/TSP that have been established and measured until 2014 totaling 3928 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.

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 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 to those of land-cover categories used for FREL.

NFI data calculation

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

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

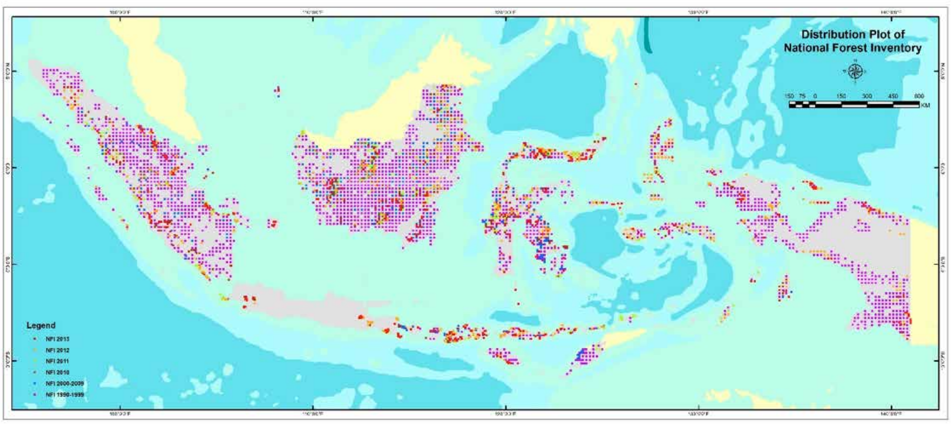

Figure Annex 3.2. NFI's PSP/TSP distribution map.

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

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

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 (exclude soil carbon). A compiled dataset from 4 independent researches carried out in Sumatra and Kalimantan was used for this analysis, these are:

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

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

	Understorey and seedlings		AGB		BGB		Necromass		Litter		Total	Sites
Forest types	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%**		

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

Annex 4. Measuring emissions from peat fire

According to the IPCC Supplement for Wetland (IPCC, 2013), emissions from organic soil fires are calculated in the following formula:

$$L\_fire = A \times MB \times CF \times G\_ef$$

Where, L_fireis 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 is emissions factor.

Burned peat area

The possibility to use MODIS active fires product to produce burned area map was explored. This is mainly because MODIS collection 5 burned area (MCD45A1) data has no observation over SE Asia regions, especially for major Islands of Indonesia. Generation of MODIS burned area based on MODIS active fire data is explained in the following. First, fire hotspots data was analyzed and use only those with certainty level >80%. Second, a raster map with 1×1 km grid (pixel size) was generated and overlaid on the top of the hotspots data. Pixels without hotspots were excluded from the analysis. For each burned pixel, of about 75 percent of 1×1 km of areas was assumed to be burned (i.e. 7,500 ha) and this rule applies for each pixel regardless the amount of hotspots within that particular pixel (Figure Annex 4.1). This methodology was adopted from demonstration activity project conducted and tested in Central Kalimantan (see MRI, 2013).

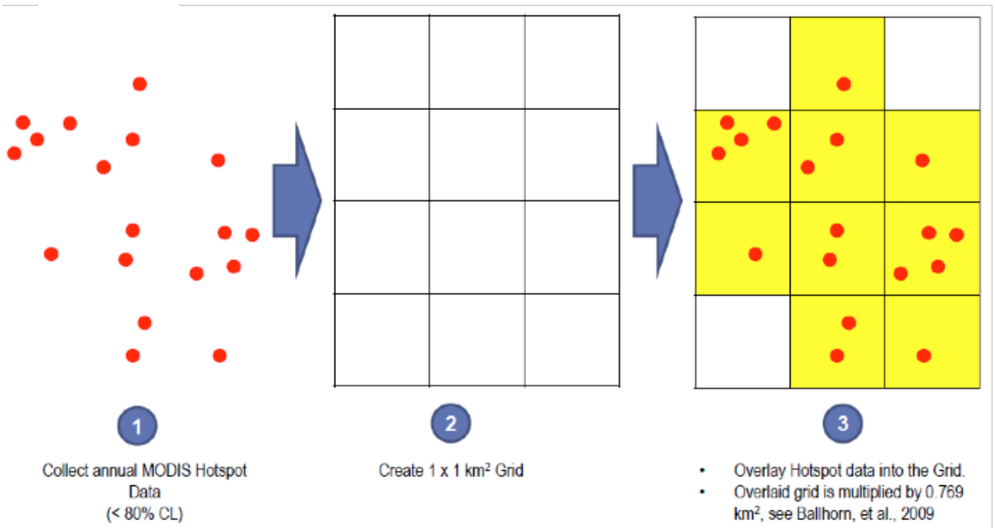

Figure Annex 4.1. Methodology to derive burned area (activity data)

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/m3 (Mulyani et al., 2012). Resulted mass available for combustion is 0.05049 ton/m2 or 504.9 ton/ha.

Emission factor

CO2 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 :

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

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 estimate, 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, considering peat lands suffer more than one fire event release half of CO2 compared to that of the previous burning, e.g. first burning of 1 ha peat emits 923.1 tCO2, while the subsequent burning of exactly the same area will release 462 tCO2.

Historical emission from peat fire

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

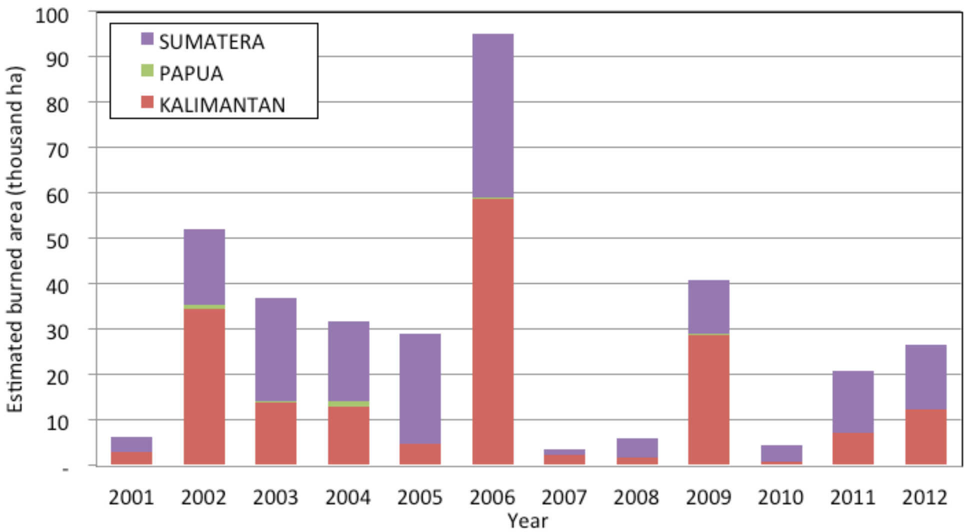

Figure Annex 4.2. Estimated burned peat area (in the natural forest of 2000)

Emission from burned peat was calculated historically as described in Figure Annex 4.3. Average emission from peat fire from 2000 – 2012 was 27.1 MtCO2e yr-1. The method used for burned area mapping has not been verified using ground-thruthing or other high-resolution data. Therefore uncertainty level cannot be estimated.

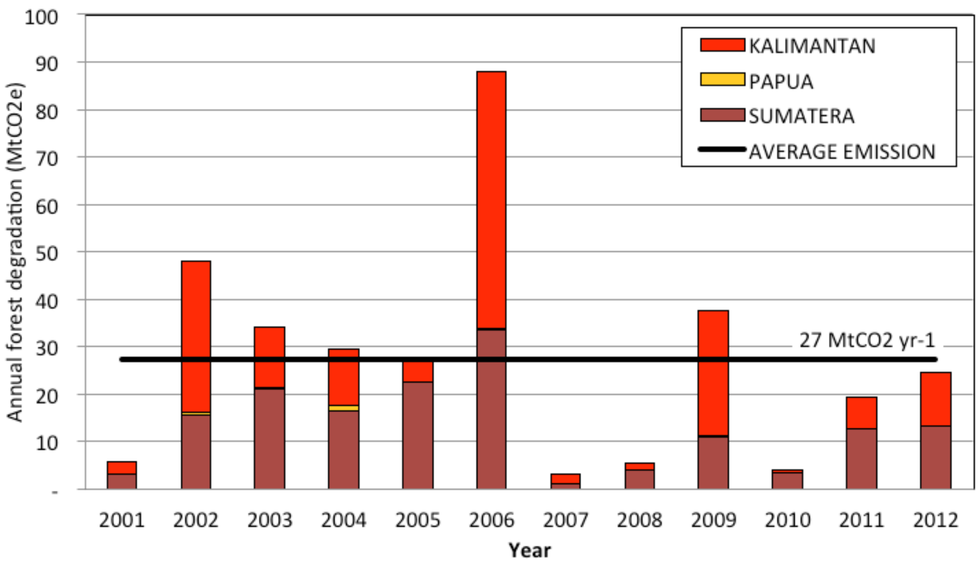

Figure Annex 4.3. Estimated historical emission from burned peat (in the natural forest of 2000)

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

Table Annex 5.1. Deforestation

ISLAND	MINERAL LAND / PEAT LAND	DEFORESTATION (HA)				
		2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
JAWA	Mineral	11,489	12,508	11,665	5,709	1,260
	Peat	0	0	0	0	0
KALIMANTAN	Mineral	580,675	772,086	790,971	355,481	239,944
	Peat	78,582	151,639	219,564	91,008	50,100
MALUKU	Mineral	26,066	28,437	25,903	24,581	6,670
	Peat	0	0	0	0	0
BALI NUSA TENGGARA	Mineral	8,003	33,679	4,860	3,602	54,541

ISLAND	MINERAL LAND / PEAT LAND	DEFORESTATION (HA)				
		2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
	Peat	0	0	0	0	0
PAPUA	Mineral	70,992	234,624	103,203	30,151	41,919
	Peat	12,319	12,392	12,006	1,729	1,039
SULAWESI	Mineral	211,540	273,040	139,902	74,422	19,532
	Peat	0	0	0	0	0
SUMATERA	Mineral	250,185	478,501	869,690	247,658	246,906
	Peat	127,290	383,545	372,783	168,127	91,244
GRAND TOTAL		1,377,141	2,380,451	2,550,547	1,002,468	753,155
ANNUAL RATE		459,047	793,484	850,182	501,234	753,155

Table Annex 5.2. Forest Degradation

ISLAND	MINERAL LAND / PEAT LAND	FOREST DEGRADATION (HA)				
		2000-2003	2003-2006	2006-2009	2009-2011	2011-2012
JAWA	Mineral	774	28,274	266,692	0	0
	Peat	0	0	0	0	0
KALIMANTAN	Mineral	807,390	385,643	69,448	17,853	10,210
	Peat	2,678	3,011	740	166	0
MALUKU	Mineral	11,826	180,103	5,204	7,441	0
	Peat	0	0	0	0	0
BALI NUSA TENGGARA	Mineral	3,551	3,369	59,403	2,107	14,997
	Peat	0	0	0	0	0
PAPUA	Mineral	777,718	632,984	944,190	56,232	5,444
	Peat	31,391	62,516	47,719	5,939	710
SULAWESI	Mineral	406,415	831,600	97,438	186,711	10,462
	Peat	0	0	0	0	0
SUMATERA	Mineral	429	13,337	36,489	29,742	118
	Peat	3,406	17,210	33,571	15,421	2,228
GRAND TOTAL		2,045,579	2,158,046	1,560,895	321,612	44,169
ANNUAL RATE		681,860	719,349	520,298	160,806	44,169