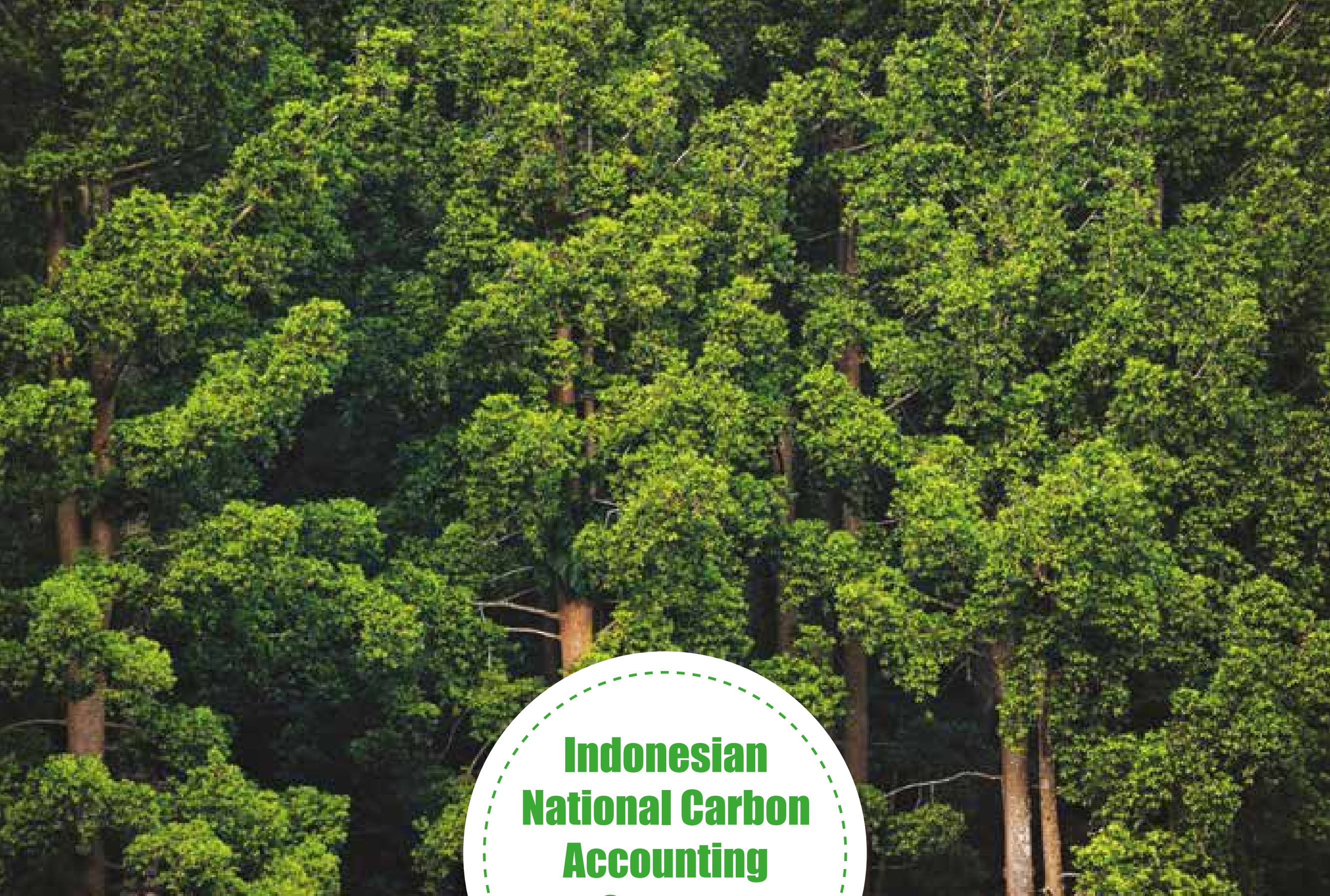

Indonesian National Carbon Accounting System (INCAS)

Standard Methods for Estimating Greenhouse Gas Emissions from the Forestry Sector in Indonesia (Version 1)

Ministry of Environment and Forestry
Forestry Research and Development Agency
Research and Development Center for Conservation and Rehabilitation

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FOREWORD

The Ministry of Environment and Forestry is developing the *Indonesian National Carbon Accounting System* (INCAS), to support Indonesia's greenhouse gas (GHG) emissions Measurement, Reporting and Verification (MRV) requirements for the land sector, including for REDD+ activities. The system provides a systematic and nationally consistent approach to measuring GHG emissions and removals for Indonesia's land sector in a geographically and temporally consistent manner.

I am pleased to present this important publication from the INCAS, featuring comprehensive methods used to estimate GHG emissions and removals under the current phase of the INCAS framework. These standard methods have been trialed over the REDD+ pilot province of Central Kalimantan and will be used to guide the official expansion of the INCAS to the national level.

I am hopeful that the establishment of the INCAS as Indonesia's official MRV system for the land sector will increase investor confidence in REDD+ activities in our country and will assist us in confidently transforming the way we manage our land sector in a more environmentally, socially and economically sustainable manner.

I congratulate the INCAS team, the Forestry Research and Development Agency (FORDA) and the Directorate General of Forest Planning in the development of the INCAS. I would also like to acknowledge the valuable contribution of the National Institute for Aeronautics and Space (LAPAN). I also thank the Australian Government, the former Indonesia-Australia Forest Carbon Partnership (IAFCP) and now the Center for International Forestry Research (CIFOR) for their assistance, and all other parties who have contributed directly or indirectly in the development of the INCAS.

In the months and years ahead, I look forward to seeing the continued development and expansion of the INCAS to provide national coverage and it being used as the official system for GHG inventory and reporting by all land sector agencies.

Jakarta, February 2015
Minister of Environment and Forestry,

Dr. Ir. Siti Nurbaya, M.Sc

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1 INTRODUCTION

This report describes in detail the standard methods developed by the Indonesian National Carbon Accounting System (INCAS) to quantify net greenhouse gas (GHG) emissions for the forestry sector in Indonesia in a transparent, accurate, complete, consistent and comparable (TACCC) manner. The standard methods were tested and refined to estimate emissions and removals from forest and peat lands in the Central Kalimantan as the REDD+ pilot province, the results of which are reported in *Estimation of Annual Greenhouse Gas Emissions from Forest and Peat Lands in Central Kalimantan* (Krisnawati et al., 2015).

The standard methods describe the approach and methods used for data collation, data analysis, quality control, quality assurance, modelling and reporting. Use of the standard methods ensures consistent methods are applied for every forest land sector GHG inventory conducted, regardless of the geographic or temporal coverage. The standard methods include:

1. *Standard Method – Initial Conditions*: describes the process for defining the initial conditions that are used as inputs for modelling GHG emissions and removals. This includes aboveground biomass, belowground biomass, litter and woody debris for each biomass class.
2. *Standard Method – Forest Growth and Turnover*: describes the process for defining rate of growth, turnover of aboveground and belowground biomass, and decomposition rate of debris, for each component of each biomass class, which are used as inputs for modelling GHG emissions and removals.
3. *Standard Method – Forest Management Events and Regimes*: describes the process for defining forest management events and regimes and their impact on carbon stocks as inputs for modelling GHG emissions and removals.
4. *Standard Method – Spatial Allocation of Regimes*: describes how available spatial data are used to consistently allocate management regimes to areas analyzed and to derive annual area statistics for use in INCAS modelling.
5. *Standard Method – Peatland GHG Emissions*: describes the process for quantifying GHG emissions from biological oxidation of drained peat, direct emissions from drained organic soils and drainage ditches, and emissions from peat fire.

6. *Standard Method – Modelling and Reporting*: describes the process used to bring together data from the other INCAS standard methods and to model GHG emissions and removals from deforestation, forest degradation, the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in Indonesia.

In addition to these, the standard methods used to monitor changes in forest cover in Indonesia are described in *The Remote Sensing Monitoring Program of Indonesia's National Carbon Accounting System: Methodology and Products, Version 1* (LAPAN, 2014).

This first version of the standard methods describes the methods and assumptions used to estimate GHG emissions and removals in Central Kalimantan as the REDD+ pilot province. However, the standard methods are designed to be used at the national level; this first version can be used as the basis for developing a national GHG inventory for Indonesia.

The standard methods should be updated as new data and technology become available, ensuring the continuous improvement of INCAS.

2 STANDARD METHOD – INITIAL CONDITIONS

2.1. PURPOSE

This standard method describes the process used by the Indonesian National Carbon Accounting System (INCAS) for defining the initial conditions that will be used as inputs for modelling GHG emissions and removals from deforestation, forest degradation, sustainable management of forests and enhancement of forest carbon stocks in Indonesia. This includes data collation, data analysis, quality control and quality assurance.

In the modelling of GHG emissions and removals, the initial conditions should be assigned for each biomass class. Biomass class represents forests with similar initial quantities of carbon that respond in similar ways to forest management events.

There are several factors that may affect the amount of carbon stored in the biomass, such as forest type, soil type, climate and historical land use. For the purposes of carbon stock estimation, each biomass class should be categorized into a series of classes that best explain the variation in carbon stocks. This variation needs to be identified to enable detailed modelling of GHG emissions and removals. Stratification of forest into biomass classes reduces variation and uncertainty of carbon stock estimates.

Classification of biomass by forest type and condition of forests on which management activities occurred is considered to be appropriate to reduce variation and uncertainty within the forests. For the pilot account of Central Kalimantan province, potential biomass class was defined based on the type and condition of forests including natural forests (i.e. primary dryland forest, secondary dryland forest, primary swamp forest, secondary swamp forest, primary mangrove forest, and secondary mangrove forest), and timber plantations. These seven classes follow the classification of forest land included in the Ministry of Forestry land cover map.

Biomass refers to all living material in the aboveground and belowground pools of forests. The aboveground biomass included aboveground trees and understorey vegetation. This includes stems, branches, bark and leaves. The belowground biomass includes coarse and fine roots.

Litter and coarse woody debris belong to the debris pool, but they are related to biomass classes and are included in the estimation. For each biomass class, representative quantities of these pools (aboveground biomass, belowground biomass, litter and woody debris) were estimated from available data (e.g. forest inventory plots, research plots and published information). Soil organic carbon was not included in this standard method, but it is critical to consider, particularly on peat swamp forest where soils may be an ongoing source of carbon emissions following disturbance. The approach for estimating changes in soil organic carbon on peatlands is described in the *Standard Method – Peatland GHG Emissions*.

The estimates of biomass for each component of the carbon pools (aboveground and belowground biomass and debris) for each biomass class is used as the initial values at the start of the simulation in modelling GHG emissions and removals.

Outputs from this standard method are expressed in dmt/ha (dry matter tonnes per hectare) for each component of biomass pools (aboveground biomass consisting of stem, branch, bark and leaves, and belowground biomass consisting of coarse and fine roots), and for debris pools (deadwood and litter) are expressed as tC/ha (tonnes carbon per hectare). These outputs are in the format required for inputs to the model described in the *Standard Method – Modelling and Reporting*.

2.2. DATA

2.2.1. Collation

Data used for defining the initial conditions were collated from a wide range of sources, primarily from forest inventory plots. Forest inventory data from both temporary and permanent sample plots were used to provide a sound basis for estimating biomass in each biomass class. Information, from biomass and carbon assessment-related studies reported in research papers, was used to fill critical information gaps not covered in the forest inventories.

For natural forests (i.e. primary dryland forest, secondary dryland forest, primary swamp forest, secondary swamp forest, primary mangrove forest and secondary mangrove forest), data used in defining initial conditions were analyzed from several sources including the National Forest Inventory (NFI), Periodical Comprehensive Forest Inventory (PCFI), Permanent Measurement Plots (PMP), and other forest inventory data such as vegetation monitoring plots established specifically for a research/project (Table 2-1). If data from these forest inventory plots were not available for the specific type of forest in the site being analyzed, information from previous studies conducted for this forest type in the region was used instead. The detail description of the data used for defining the initial condition of natural forests can be found in Krisnawati et al. (2014).

Table 2-1. Potential data source used for defining initial condition

Data	Description	Source
National Forest Inventory (NFI)	Aboveground biomass (DBH ≥ 5cm)	Ministry of Forestry
Periodical Comprehensive Forest Inventory (PCFI)	Aboveground biomass (DBH ≥ 10cm)	Ministry of Forestry
Permanent Measurement Plots (PMP)	Aboveground biomass (DBH ≥ 10cm)	Ministry of Forestry
Vegetation monitoring plots	Aboveground biomass	Related projects (e.g. KFCP)
Research plots	Various (include some or all components of aboveground tree biomass, understorey vegetation, belowground biomass (roots), debris, litter)	Ministry of Forestry (Forestry Research and Development Agency) and other research institutions
Information available from publications	Various (used to fill information gaps)	Research papers

Data from forest inventories were used as a basis to estimate aboveground biomass of trees. Carbon pools not measured in the forest inventories were estimated using relationships with aboveground tree biomass established in previous studies representing the site being analyzed, or elsewhere in the country which have similar environmental conditions (e.g. forest ecosystem type), and other locally collected information and literature (e.g. Krisnawati and Keith, 2010).

The values, assumptions and sources of the data used are documented in the INCAS Database [FullCAM Database_18052014.xlsb].

2.2.2. Collection

No new data collection methods were used.

2.3. ANALYSIS

The analysis approach described in this standard method follows the procedures for estimating forest biomass for quantifying CO_2 emissions described in Krisnawati et al. (2014). The procedure consists of methods for estimating:

- aboveground biomass (AGB):
  - AGB for trees (DBH ≥10cm)
  - AGB for trees (DBH <10cm; height > 1.5 m)
  - AGB for understorey vegetation (height < 1.5m);
- belowground biomass (BGB) or roots;
- litter; and
- woody debris.

The overview approach used to quantify forest biomass in each carbon pool is summarized below (Figure 2-1).

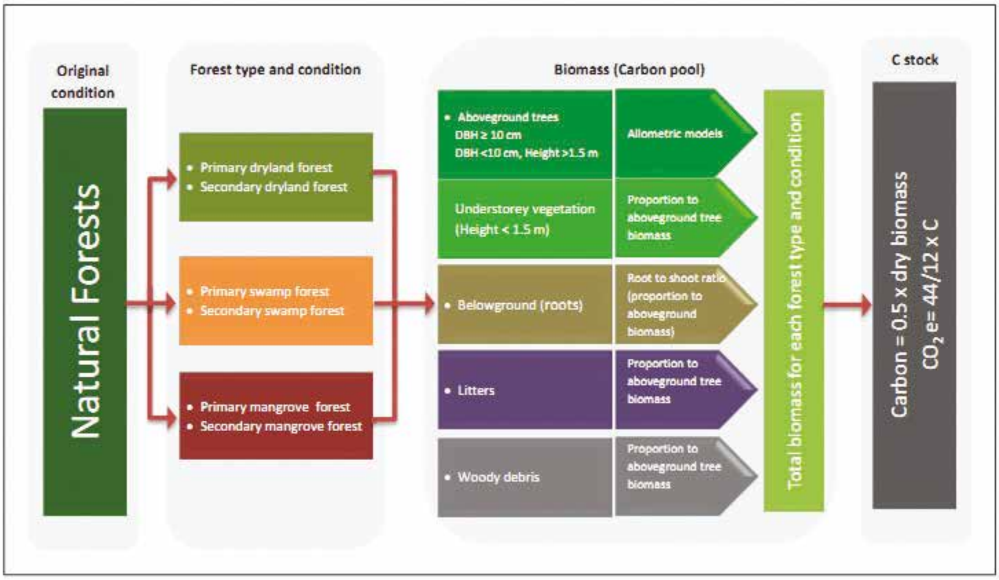


Figure 2-1. Overview approach used to quantify forest biomass in each carbon pool

The detailed methodology applied in quantifying forest biomass in each carbon pool is described in the following sections.

2.3.1. Estimating aboveground biomass (AGB)

AGB includes all trees and understorey vegetation. Data for all individual trees in the inventory plots (Table 2-1) were used to estimate AGB. In some plots, the trees were measured when the diameter at breast height (DBH) was 10 cm or larger, while for some of the other plots the minimum diameter of trees measured were smaller (e.g. DBH ≥ 5 cm for NFI plots; DBH < 5 cm and height > 1.5 m for KFCP plots).

AGB for trees (DBH ≥ 10 cm)

The AGB of individual trees (DBH ≥ 10 cm) in the plots was estimated using allometric models developed for specific sites or regions being analyzed (e.g. Kalimantan), following the monograph and the guideline on allometric models for estimating forest biomass and carbon stocks in Indonesia (Krisnawati et al., 2012; FORDA, 2013). The models were derived from destructively sampled trees (direct measurement) and easily measured biometric variables such as diameter (DBH). The resulting AGB is the total AGB of the tree (including stem, branches, twigs, leaves and fruit/flowers, if any) in dry weight (expressed in kilograms [kg]).

The total aboveground tree biomass for each plot was then quantified by summing aboveground biomass estimates for all trees on the plots in dry weight (expressed in megagrams (Mg) or tonnes (t)).

$$AGB_P = \sum_{1}^{n} AGB_T / A_P$$

where

AGB_P = aboveground biomass of plot (kg ha^{-1}), or expressed as (Mg ha^{-1}) or (t ha^{-1}) after multiplying with a conversion factor of 0.001;
AGB_T = aboveground biomass of measured tree (kg);
A_P = plot area (ha);
n = number of trees per plot.

AGB for trees (DBH < 10 cm; height > 1.5 m)

The AGB of trees with DBH < 10 cm and height > 1.5 m was estimated using the same procedure used for estimating AGB for trees with DBH ≥ 10 cm.

For inventory plots where the presence of trees with DBH < 10 cm was not included, the proportion derived from the plots having a complete pool of aboveground tree components was used and then the average proportion for the unmeasured component in the plots was applied. For example, the average proportion of AGB for trees with DBH < 10 cm; height > 1.5 m (derived from plots having complete data) to AGB for trees with DBH ≥ 10 cm was used to quantify the unmeasured component of aboveground tree biomass (DBH < 10 cm; height > 1.5 m) for swamp forests. The resulting proportions were 44.4% for primary and 48.1% for secondary swamp forests, respectively.

For dryland forests, the average proportion of AGB for trees with 5 cm ≤ DBH < 10 cm; height > 1.5 m to AGB for trees with DBH ≥ 10 cm (derived from NFI plots) was used to quantify the unmeasured component of aboveground tree biomass (5 cm ≤ DBH < 10 cm; height > 1.5 m). For primary and secondary dryland forests, the resulting proportions were 7.2% and 4.5%, respectively.

For the other unmeasured components of AGB for trees with DBH < 5 cm; height > 1.5 m, proportions of 0.2% for primary dryland forest and 1.1% for secondary dryland forests were adopted from a previous study in dryland protection forest (Krisnawati et al., 2013).

AGB for understorey vegetation (height < 1.5 m)

All inventory plots provide only aboveground tree components. Understorey vegetation (including seedlings, shrubs, vines, herbaceous plants, etc.), which forms part of the aboveground biomass in forest ecosystems, was not included. Aboveground biomass for understorey vegetation was estimated using a proportion based on the results of previous studies on the forest ecosystem type.

For swamp forests, the average proportion applied was derived from several studies conducted in Central Kalimantan (Jaya et al., 2007; Dharmawan, 2012), resulting in estimates of understorey vegetation biomass of 2.4% for aboveground tree biomass for primary swamp forest, and 3.8% for secondary swamp forest. For secondary dryland forests, the proportion of 2.7% of aboveground tree biomass was derived from studies conducted in Central Kalimantan (Junaedi, 2007; Hardiansyah, 2011). As no known studies have been conducted for primary dryland forest anywhere in Kalimantan, the proportion of 0.5% of aboveground tree biomass was adopted from a previous study in dryland protection forest in West Nusa Tenggara (Krisnawati et al., 2013).

2.3.2. Estimating belowground biomass (roots)

The estimates of belowground biomass (roots) can be derived from an allometric model or as a proportion of aboveground biomass, expressed as a root:shoot ratio (IPCC, 2003). A default value for the root:shoot ratio of the tree biomass has been published in the *Good Practice Guidance for LULUCF* (Land Use, Land Use Change and Forestry) and in the *REDD sourcebook*, i.e. 0.24 (0.22–0.33) (IPCC, 2003; GOFC–GOLD, 2009). However, the ratio will vary according to species, ecosystem type, soil and climatic conditions. The root:shoot ratio of 0.29 was adopted, as derived by Moser (2011) in tropical dryland forests. For swamp forest, an allometric model developed by Niiyama et al. (2005) was first applied to estimate belowground biomass for each plot with a complete measurement of the aboveground tree component, and the average proportion of belowground biomass to aboveground biomass was obtained, resulting in a root:shoot ratio of 0.22.

2.3.3. Estimating litter

Litter consists of remaining dead plant material (fruits, leaves, flowers) on the forest floor. A proportion of 3.0% of AGB was used for primary dryland forest; 3.5% was used for secondary dryland forest (Brown et al., 1995; Hardiansyah, 2011); 1.6% was used for primary swamp forest and 2.3% was used for secondary swamp forest (Jaya et al., 2007; Dharmawan, 2012).

2.3.4. Estimating woody debris

Woody debris consists of all dead woody materials including standing dead trees, fallen trees, and part of trees (stems, branches, twigs) on the ground. This pool may be equivalent to 10–40% of aboveground biomass. The biomass contained in woody debris was estimated to be 18% of aboveground tree biomass for primary dryland forest and 33% for secondary dryland forest (derived from various sources as used in Krisnawati et al. (2014). For peat swamp forest, a proportion of 18.5% of AGB was used to estimate biomass in woody debris for primary swamp forest (Dharmawan 2012), and 23.9% for secondary swamp forest (Ludang and Jaya, 2007; Dharmawan, 2012).

2.4. QUALITY CONTROL AND QUALITY ASSURANCE

As inventory plots from different sources were established for different purposes, there is no standardized protocol for data collection (e.g. sampling design, plot size, coverage of measurement data, etc.). Consequently, the data has variable quality and coverage, both spatially and temporally. However, all the inventory plots share the following similar measurement standards: (1) located in forests with a total area inventoried of at least ≥ 0.1 ha; (2) all trees of at least ≥ 10 cm diameter at breast height (DBH) were measured for DBH, and (3) the species of measured trees were identified. The quality of measurement data from inventory plots was first checked to see if there was any error in data measurement and recording. The process included checking the measurement record and the information resulting from plot data (e.g. number of stems, basal area, volume, aboveground biomass). In addition, the accuracy of the information characteristics of the plot location such as: (1) administrative location (province, district, sub-district), (2) geographical position (longitudinal and latitudinal coordinates), (3) forest type, (4) climatic condition (rainfall, temperature), (5) soil type and (6) topographical conditions, were checked by overlaying with relevant maps.

2.5. OUTPUTS

The quantity of biomass (stored in aboveground trees, understorey vegetation, litter, woody debris, and roots) in each biomass class is used as the input for initial condition for modelling GHG emissions and removals from REDD+ activities, where the change in carbon stock is modelled based on the impact of specific events.

Outputs from this standard method are expressed in dmt/ha (dry matter tonne per hectare) for each component of biomass pools (aboveground biomass consisting of stem, branch, bark and leaves, and belowground biomass consisting of coarse and fine roots), and in tC/ha (tonne carbon per hectare) for debris pools (deadwood and litter).

The format for outputs of each biomass class is presented in Table 2-2.

Table 2-2. Output format for each biomass class

Carbon pool	Mean (dmt/ha)	95% Confidence interval (dmt/ha)	
1. **Aboveground biomass**			
1.a. Trees			
1.a.1. DBH ≥10 cm			
1.a.2. 5 cm ≤ DBH < 10 cm			
1.a.3. DBH < 5 cm (Height > 1.5 m)			
1.b. Understorey (Height < 1.5 m)			
2. **Belowground biomass (roots)**			
Carbon pool	**Mean (tC/ha)**	**95% Confidence interval (tC/ha)**	
3. **Debris**			
3.a. Litter			
3.b. Woody debris			

Outputs for aboveground biomass were further differentiated into components of stem, branch, bark and leaves, based on proportion of each component to aboveground biomass. The belowground biomass (roots) was divided into coarse root and fine roots. The proportion was derived from previous studies and documented in the INCAS Database [FullCAM Database_18052014.xlsb].

2.6. UNCERTAINTY ANALYSIS

Statistical analysis has been conducted for each carbon pool for each biomass class to determine the range of estimates at the 95% confidence interval level. The output of this analysis can be found in Krisnawati et al. (2014).

2.7. LIMITATIONS

The INCAS framework is designed to use the best available data, with assumptions used to fill data gaps. There are two examples of the limitations encountered.

- Only forest lands were included in the initial condition during the modelling period described in this standard method. There may be some other lands present at the beginning of the modelling period that require an initial condition to be assigned.
- Only forest ecosystem types were used as a basis for classifying biomass.

2.8. IMPROVEMENT PLAN

- The lands outside forest land may need to be included in future modelling of GHG emissions and removals from land-based sector and are assigned as new/additional biomass classes (e.g. estate crops such as oil palm and rubber, and may be non-forest lands). These types of lands were estimated separately.
- Factors other than forest ecosystem type may affect the amount of biomass and may need to be analyzed, e.g. soil type, elevation, rainfall, etc.

3 STANDARD METHOD – FOREST GROWTH AND TURNOVER

3.1. PURPOSE

This standard method describes the process used by the Indonesian National Carbon Accounting System (INCAS) for defining the forest growth and turnover that will be used as inputs for modelling GHG emissions and removals from deforestation, forest degradation, and the sustainable management of forests and enhancement of forest carbon stocks in Indonesia. This includes data collation, data analysis, quality control, and quality assurance.

The objective of this standard method is to describe the methodologies used for defining rate of growth, turnover of aboveground and belowground biomass and decomposition rate of debris, for each component of each biomass class.

Outputs from this standard method will be used as inputs in modelling emissions and removals for the processes of production, turnover and breakdown for each biomass class (documented in *Standard Method – Modelling and Reporting*).

3.2. APPROACH

INCAS adopted an event-driven modelling approach to account for changes in forest carbon stocks, which includes processes that continuously occur (e.g. production, turnover, breakdown), and events that periodically occur (e.g. harvesting, fire) which usually have an instantaneous impact on carbon flows.

The main processes modelled for INCAS included:

- production (growth) – moves carbon from the atmosphere to the biomass pools. Production is the combination of photosynthesis, which moves carbon from the atmosphere to biomass pools, and respiration, which moves a lesser amount of material in the opposite direction. The net result represents biomass growth.
- turnover (loss of material) – moves carbon from aboveground and belowground biomass pool to a debris pool as the material dies (e.g. leaf and branch fall, root loss).

- breakdown (decomposition) – moves carbon from the debris pool to the atmosphere or soil carbon pools.

In the INCAS modelling, “growth” can mean either “production and turnover” or “production only”, depending on the second setting used. There are two different ways of specifying forest growth:

- by yield changes — changes in yield with time.
- by NPP (net primary production) flows — amount of NPP added to the biomass component.

In practice, the material turned-over is hard to measure precisely, because material moving to debris via turnover is quickly dispersed into the environment. Yields are relatively easy to measure precisely using standard methods for measuring forest biomass.

INCAS uses an “increment” approach to quantify forest growth. This method uses a time series of volume or mass increments of new growth by calendar year or by tree age. Using this method, the allocations of growth can be set in terms of NPP or yields. This is the most suitable method for application in INCAS at this time given the availability of the data used as inputs to run the models. The increment method specifies the growth of the trees as either:

- volume increments of stems, expressed as cubic meters per hectare [m^3/ha];
- mass increments of stem, expressed as tonnes of dry matter per hectare [tdm/ha];
- aboveground mass increment, expressed as tonnes of dry matter per hectare [tdm/ha].

Stem volume increments are converted to stem mass increments by multiplying by the wood density. A compendium of wood densities for Indonesian tree species can be found in the INCAS Wood Density Database [Indonesia wood density database.xlsb]. The wood densities of Indonesian tree species vary from about 100 to 1320 kgdm/m^3 (mean = 680 kgdm/m^3).

The aboveground biomass is the combined mass (in tdm/ha) of the aboveground biomass components including stems, branches, bark, and leaves. It does not include the roots, or any debris or mulch or soil matter. It is a mass, measured in tonnes per hectare, of dry matter, not carbon mass.

3.3 DATA

3.3.1. Collation

Data used for defining forest growth were collated from various sources. This included information collated from time-series measurement data from permanent measurement plots (PMP) established in logged-over forests, and other forest inventory data, such as vegetation monitoring plots established specifically for research to quantify increment or forest growth-based data available for each biomass class. In addition, information available from the published literature (e.g. proceedings, journals, student theses, research reports) such as stand yield tables for the main plantation species in Indonesia were also used. These information sources were used as references for the increment approach in the modelling of GHG emissions and removals under INCAS to set the rate of growth, turnover of aboveground and belowground biomass, and decomposition rate of debris, for each component of each biomass class. Data values, assumptions and sources are documented in the INCAS Database [FullCAM Database_18052014.xlsb].

3.3.2. Collection

No new data collection methods are required for this standard method.

3.4. ANALYSIS

Methodologies used in determining forest growth in this standard method consist of constructing and analyzing growth and increment curves from the data and information collated from various sources.

All information available from the literature was reviewed through a quality control process to ensure only valid data was used. For each data set, the location of the sampling site, forest conditions and the parameters that affect the results were recorded. Some of the data and information obtained from the literature (e.g. Putz and Chan, 1986; Inoue et al., 1999; Simbolon, 2003; Hashimoto et al., 2004; Hiratsuka, 2006; Limbong, 2009; Meunpong et al., 2010; Krisnawati et al., 2011; Saharjo, 2011; Susilowati, 2011; Yuniawati et al., 2011; Dharmawan, 2012; Purba et al., 2012) were further analyzed and transformed to prepare forest growth and turnover rate data in the format required for modelling under INCAS.

Time series data obtained from permanent sample plots established in logged-over forests were analyzed to quantify aboveground mass increment over time after logging. Calculations of aboveground biomass were carried out using the approach described in the monograph and guidelines on *Allometric models for estimating tree biomass at various forest ecosystem types in Indonesia* (Krisnawati et al., 2012; FORDA, 2013).

Information available from stand yield tables (Suharlan et al., 1975) covering ten main species of timber plantations (i.e. Jati, Rasamala, Damar, Pinus, Sonokeling, Mahoni, Akasia, Sengon, Balsa, and Jabon) were re-analysed to produce average growth curves of various site index classes for each species. There are three phases of growth that will occur in a stand: (1) juvenile (young) phase with a fast growth rate, (2) full vigor phase with a constant growth rate and (3) senescent phase of declining growth rates. These three phases of growth will generally form a sigmoid curve (Figure 3-1).

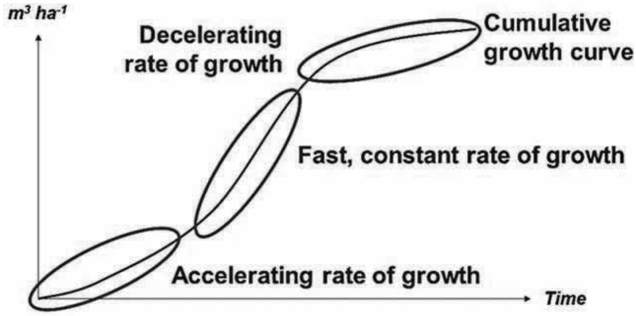


Figure 3-1. Phases of growth rates

Several other regression models that form the sigmoid curve/curve of growth (Weibull, root, modified exponential, logistic, logistics power, Gompertz, two-exponential association, three-exponential association), were tested to generate the corresponding growth curve and the selection was based on a combination of statistical and logical criteria. These analyses are documented in the INCAS growth database [GrowthDatabase_19062014.xlsb].

In terms of "increment", there are two types of curves (Figure 3-2):

- CAI (Current Annual Increment), defined as the increment over a period of 1 year at any stage in forest's life.
- MAI (Mean Annual Increment), defined as the mean increment of the forest until a specific age.

CAI of biomass and volume were used in the modelling under INCAS.

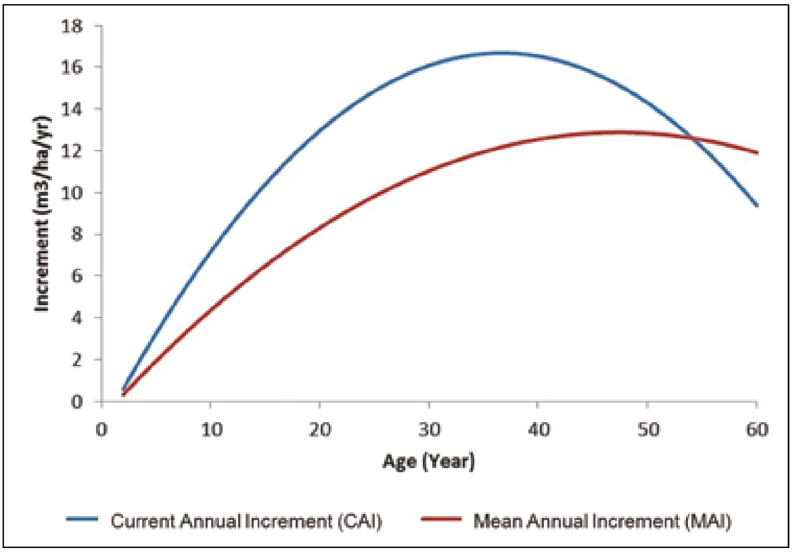


Figure 3-2. Increment curves

3.5. QUALITY CONTROL AND QUALITY ASSURANCE

Quality control processes were implemented to check that the methods used for data collection and analysis of data used met minimum standards for appropriateness and completeness. This included checking the quality of measurement data from inventory plots to see if there was any error in recording and measurement. Accuracy of the data was checked further by overlaying with relevant maps to check that forest types matched with species in the record. Some information such as stand density and basal area was used for checking the quality of the data.

3.6. OUTPUTS

Assumptions, data sources and results of the analysis that generated growth curves and increment tables for each species of timber plantation and each natural forest type are documented in the INCAS Database [GrowthDatabase_19062014.xlsb].

In terms of growth rate, the annual change in biomass carbon stocks can be estimated using the gain–loss method, which combines the annual increase in carbon stocks due to biomass growth with losses due to turnover and management events. Gain of biomass used in INCAS is characterized as plantation growth or natural growth. Plantation growth is defined as the growth of plants that are deliberately planted. Natural growth is defined as growth that occurs as a result of natural process of succession after disturbances in natural forests, e.g. fire, logging.

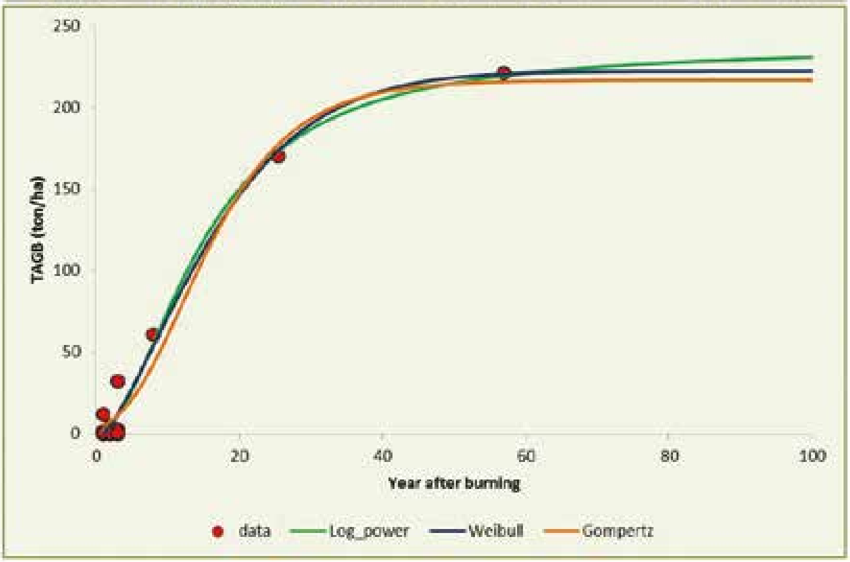
- Plantation growth
    - Agathis (*Agathis* sp.)
    - Akasia (*Acacia* sp.)
    - Balsa (*Ochroma bicholor*)
    - Jabon (*Anthocephalus cadamba*)
    - Jati (*Tectona grandis*)
    - Mahoni (*Swietenia* sp.)
    - Pinus (*Pinus* sp.)
    - Rasamala (*Altingia excelsa*)
    - Sengon (*Albizia falcataria*)
    - Sonokeling (*Dalbergia latifolia*)
    - Kemiri (*Aleurites moluccana*)
    - Environmental plantation (mix of species)

- Natural growth
    - After burning
    - After logging

INCAS assumes there is no net growth in primary forests, for which carbon stocks are assumed to be at equilibrium prior to human induced disturbances (i.e. growth is equivalent to turnover and decomposition).

An example of the outputs from growth analysis for secondary swamp forest after burning is presented below (Figure 3-3).

Model	Form	Parameter				Standard error	R-sq
		a	b	c	d		
Logistik power	a/(1+((x/b)^c))	237.01	15.03	-1.9		9.35	0.98
Weibull	a-b*e^(-c*(x^d))	222.38	226.33	0.015	1.43	10.2	0.98
Gompertz	a*e^(-e^(b-cx))	216.84	1.45	0.12		11.3	0.98



Year	CAI (ton/ha/yr)
0	0.0
1	1.6
2	7.6
3	8.1
4	8.5
5	8.7
6	8.8
7	8.8
8	8.8
9	8.7
10	8.5
11	8.3
12	8.0
13	7.7
14	7.4
15	7.1
16	6.8
17	6.4
18	6.1
19	5.8
20	5.4
21	5.1
22	4.8
23	4.5
24	4.2
25	3.9
26	3.6
27	3.4
28	1.5
29	0.9
30	0.5
31	0.3
32	0.2
33	0.2
34	0.2
35	0.0

Figure 3-3. The outputs from growth analysis for secondary swamp forest after burning

3.7. UNCERTAINTY ANALYSIS

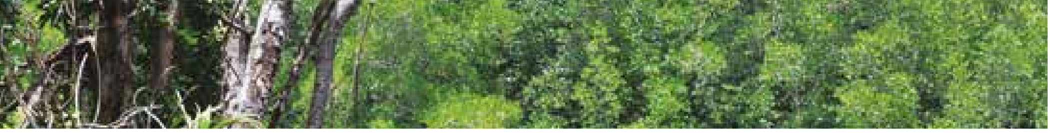
Quality control procedures were used to select the best available data for inclusion in the analysis. Statistical analysis was then conducted for a selection of the models to derive growth curves for plantations and natural forests following disturbance. Quantitative uncertainty analysis was undertaken for a selection of parameters using risk analysis software (Pallisade@ Risk). For further information see the *Standard Method – Modelling and Reporting*.

3.8. LIMITATIONS

- Some plantation species and some conditions of natural forest have no permanent sample plots with long/periodical measurements for describing the long-term impact of management/events on growth.
- The same growth curves have been applied to all rotations in timber plantations and for each natural forest biomass class because the current approach does not differentiate between site conditions or finer scale management. Initial attempts to derive biomass classes based on site biophysical characteristics did not result in sufficiently robust relationships. This should be re-tried once more data is available.
- Debris decay rates were not available for Indonesia, hence default decay rates were adopted from tropical rain forest in Australia as an interim measure, because these forests are expected to have similar decay characteristics, and detailed data is readily available.

3.9. IMPROVEMENT PLAN

- Data about plantation and natural forest growth could be improved by gaining access to additional existing data sets and through targeted research designed to fill knowledge gaps.
- Timber plantation growth curves could be improved by including more information about site biophysical characteristics and the impact of plantation management practices on growth, particularly site nutrition and water table management on peatlands.
- Secondary natural forest growth curves could be improved by including more information about site biophysical characteristics and the impact of management practices on subsequent growth.
- Research into decay rates in Indonesia should be undertaken to better understand the rate of decomposition under different natural forest and plantation conditions.



STANDARD METHOD – FOREST MANAGEMENT EVENTS AND REGIMES

4

4.1. PURPOSE

This standard method describes the process used by the Indonesian National Carbon Accounting System (INCAS) for defining the forest management events and regimes that may occur and need to be modelled for all biomass classes, including the main procedural steps. For this purpose, an event-driven model (as described in *Standard Method – Modelling and Reporting*), is used for tracking the GHG emissions and changes in stocks of carbon associated with land use and management events. In addition, it accounts for changes in major GHGs, and human-induced land-use practices. The sub-models used within the model can be integrated into various combinations to suit the available data and the required outputs. It may be used for tracking of carbon stock and flow in different forest systems.

There are many forest management events and regimes that can occur in Indonesia. The type and condition of forest and other lands, as well as the type of event and regime of management activities undertaken, need to be defined to enable detailed modelling of GHG emissions and removals.

A forest management event, as defined in this document, represents a particular forest management action that occurs occasionally or regularly, and is usually human-induced. A forest management regime describes the combination of forest management practices or events applied to a particular land use, and the timing of events that occur at a location.

The purpose of this document is to report the methods used in defining forest management events and regimes that will be used as inputs in the modelling and reporting of INCAS.

4.2. DATA

4.2.1. Collation

Several sources of data and information were collated from various government agencies and organizations, at both the national and provincial level. At the national level, spatial data were obtained from the Ministry of Forestry, Ministry of Agriculture, and National Space Agency (LAPAN). At the provincial level, relevant data and information were collated from the regional forestry offices within the Ministry of Forestry. These included the Agency for Monitoring of Production Forest Utilization (a technical unit under the Directorate General of Forest Utilization Development), Watershed Management Agency (a technical unit under the Directorate General of Watershed Management and Social Forestry), Agency for Strengthening Forest Area (a technical unit under the Directorate General of Forest Planning), and Natural Resource Conservation Agency and National Park (technical units under the Directorate General of Forest Protection and Natural Conservation). In addition, information was also collated from the Provincial Forestry and Estate Crops Offices as well as from forest concessionaires (logging companies).

In determining the possible events and management regimes, discussions and consultations were conducted with relevant forestry stakeholders from the agencies mentioned above. Prior to discussions, the possible management events and regimes that may be applied in Indonesian forests, particularly in the Central Kalimantan Pilot province, were identified based on existing knowledge and experience in the field. The discussions and consultations were carried out to verify the interim analysis, identify the available data and obtain more detailed data and associated information relating to forest disturbances and management types that may affect forest biomass loss and gain.

Four main management events were identified: land clearing, harvesting, burning and planting events.

- Land clearing was defined as a conversion of forest area of either primary or secondary forests into other land uses (e.g. settlement, mining, agriculture, etc.) and a conversion of natural forest into timber plantations. This event removed all of aboveground biomass from the site and moved some live biomass to debris pools.
- Harvesting events included both legal harvesting and illegal harvesting. A harvesting event was considered as legal if the activity was applied in managed/production forests (forest concession areas) with a harvesting permit. Several harvesting techniques that may have effects on biomass loss were identified, including clear-cutting, selective harvesting with conventional technique, and selective harvesting with reduced impact logging (RIL). Harvesting activity that occurred in forests other than production forests (e.g. protection forest, conservation area, national park) was considered as illegal harvesting. This event removes some or all of aboveground biomass from the site and moves some live biomass to the debris pools.

- Burning (forest fire) event was categorized into moderate and heavy fires. The event releases carbon (as CO_2, CO and CH_4) and nitrogen (N_2O and NO_x) to the atmosphere, and moves some carbon to the debris and soil pools.
- Planting activity included reforestation, rehabilitation and enrichment planting programs. It creates new forests on areas not containing forest that enhance its biomass stock.

All of these events were identified during the period of time covered in the analysis or modelling period. The spatial data used for analysis in this standard method are summarized in Table 4-1.

Table 4-1. Sources of data used in determining forest management events and regimes

Data	Description	Source
Forest extent and change	Annual forest/non-forest data derived from Landsat data, and the clearing and regrowth events derived by differencing the annual forest extents	LAPAN
Forest type (part of land cover map)	Primary and secondary dryland forest; primary and secondary swamp forest; primary and secondary mangrove forest; and timber plantations (all other land cover classes not used in this standard method)	Ministry of Forestry
Forest function	Production forest (production, limited production, and conversion); Conservation and protection forest	Ministry of Forestry
Soil type	Organic (peat) and mineral soil types	Ministry of Agriculture
Estate crops	Oil palm and rubber	Ministry of Forestry
Forest concessions	Area and operational year of forestry concessions including harvesting system applied (RIL or conventional)	Ministry of Forestry
Burnt area	Burn scar analysis	Remote Sensing Solutions GmbH

4.2.2. Collection

No new data collection methods are required for this standard method.

4.3. ANALYSIS

The collated data was reviewed as part of the INCAS quality control process to assess its quality and utility for modelling GHG emissions and removals. Unique combinations of biophysical conditions, management function and forest management activities were identified and used to establish INCAS suites. A suite represents a specific combination of site and management categories including initial forest type, forest function, soil type, harvesting system, estate crop, fire, forest/non-forest transition, subsequent land category, activity and management events. The conditions (associated with each category) that were used as a basis for determining suites and management regimes are shown in Table 4-2.

Table 4-2. Possible conditions in each category used for defining management regimes or suites

No.	Category	Condition
1.	Initial forest type	1. Primary dryland forest 2. Primary mangrove forest 3. Primary swamp forest 4. Secondary dryland forest 5. Secondary mangrove forest 6. Secondary swamp forest 7. Timber plantation
2.	Forest function	1. Conservation forest, Protection forest 2. Production forest
3.	Soil type	1. Mineral 2. Organic
4.	Harvesting system	1. No 2. Conventional 3. RIL
5.	Estate crop	1. No 2. Oil palm 3. Rubber
6.	Fire	1. Fire 2. No
7.	Transition	1. Clearing 2. Clearing, temporarily unstocked, re-vegetation 3. None 4. Re-vegetation 5. Re-vegetation, clearing
8.	Activity	1. Deforestation 2. Degradation 3. Sustainable management of forest (SMF) 4. Reforestation (Enhancement of forest carbon stocks)
9.	Subsequent land category	1. Other land uses 2. Forest land 3. Cropland 4. Timber plantation

No.	Category	Condition
10.	Event 1	1. High intensity fire 2. Moderate fire 3. Land clearing 4. Illegal clear harvesting 5. Conventional selective harvesting 6. RIL selective harvesting 7. Plant fast growing dryland species 8. Plant mangrove species 9. Plant fast growing swamp species 10. Plant dryland species 11. Plant swamp forest species
11.	Event 2	1. Plant oil palm 2. Plant rubber 3. Plant dryland species 4. Plant swamp species 5. Plant fast growing dryland species 6. Plant fast growing swamp species 7. Plant mangrove species

The description of the suites covering management regimes and events was documented in the INCAS Database [INCAS Suite_16062014.xlsx]. The final number of suites recorded after performing quality control and validation by reviewing and checking the activities was 119 suites. The number of suites and management regimes developed was deliberately constrained to simplify modelling for this pilot account. INCAS is capable of modelling many more management regimes, but this requires increasingly detailed spatial and management information.

To determine forest management events and regimes, some analyses were undertaken which included two main procedural steps:

1. All forest land areas were allocated to a management regime based on suite characteristics, starting in the first year of the simulation period, and repeated for each year during the simulation period (i.e. 2000 to 2011).
2. Areas subject to observed change (i.e. change detected from the LAPAN forest cover change analysis) were reassigned to other regimes based on the location, timing, type of change (i.e. forest loss or forest gain) and the suite characteristics.

Management regimes were then associated with REDD+ activities (i.e. deforestation, forest degradation, sustainable management of forest (SMF) and enhancement of forest carbon stocks) based on the following rules that need to be met for each activity:

- **Deforestation** occurs when forest cover loss is observed in primary or secondary forests as shown on the land cover map, and no forest cover gain is observed in the same pixel in subsequent years.

- **Forest degradation** occurs when there was a change from primary to secondary forest on the land cover map, but no forest cover loss was observed.
- **Sustainable management of forest** (SMF) occurs when forest cover loss is not observed within secondary forest as shown on the land cover map, but forest concession data indicated that a harvesting event has occurred (either using conventional or RIL technique). It assumes that in the SMF there will be regrowth back to secondary forest conditions.
- **Enhancement of forest carbon stocks** occurs when forest gain is observed within areas defined as timber plantation on the land cover map.

The impact of each management event on carbon stocks was quantified based on research and measurement data where available, or by management prescription and expert judgment where data were not available. Parameters for each management event are provided in the INCAS events database [Database_events_fullCAM_03072014.xlsb].

4.4. QUALITY CONTROL AND QUALITY ASSURANCE

Quality control and quality assurance processes were conducted as follows:

Quality control – Data checking and validation were conducted by the INCAS team for all data collated. This was done to ensure that data used for analysis was suitable for use and consistent with other data sets.

Quality assurance – The following quality assurance steps were undertaken by members of the INCAS team not involved in data analysis and by external advisors:

- review the methodology used to ensure no errors were introduced when combining data to produce management regimes and events;
- check and validate the suite and management regime results to ensure consistency and desired accuracy;
- review the final outputs to check that results are verifiable and comparable.

4.5. OUTPUTS

Outputs from this standard method were recorded in the INCAS database [INCAS Suites_16062014.xlsx]. A summary describing the types of regimes, events and suite characteristics are presented in Tables 4-3 – 4-5, respectively.

Table 4-3. Summary of regime description

No.	Regime description
1	Conversion of dryland primary forest to other land uses (settlement, mining, etc.)
2	Conversion of dryland primary forest to agriculture
3	Conversion of dryland secondary forest to agriculture
4	Conversion of dryland secondary forest to other land uses (settlement, mining, etc.)
5	Conversion of dryland secondary forest to timber plantation
6	Conversion of mangrove primary forest to other land uses (ponds, etc.)
7	Conversion of mangrove secondary forest to other land uses (ponds, etc.)
8	Conversion of swamp primary forest to agriculture
9	Conversion of swamp primary forest to other land uses (settlement, mining, etc.)
10	Conversion of swamp secondary forest to agriculture
11	Conversion of swamp secondary forest to other land uses (settlement, mining, etc.)
12	Conversion of swamp secondary forest to timber plantation
13	Forest disturbance (fire) followed by natural regrowth
14	Forest disturbance (illegal logging) followed by natural regrowth
15	Forest Management in dryland forest
16	Forest Management in swamp forest
17	Planting
18	Rehabilitation/environmental planting
19	Timber plantation management

Table 4-4. Summary of event description

No.	Event description
1	Clear harvest Illegal
2	Dryland forest selective harvest_conventional
3	Dryland forest selective harvest_RIL
4	High intensity fire
5	Land clearing
6	Moderate Fire
7	Plant dryland species
8	Plant fast growing dryland species
9	Plant fast growing swamp species
10	Plant mangrove species
11	Plant oil palm
12	Plant rubber
13	Plant swamp species

Table 4-5. Summary of the characteristics used to define suites and management regimes

Suite	Re-gime ID	F/NF Class	Initial Forest Type	Forest Function	Soil Type	Harvest system	Estate crop	Fire	F/NF Transition	Activity	Subse-quent Land Category
A	1	F	PDF	CPF	Mineral	No	No	Fire	Clr	Def	Other land use
B	2	F	PDF	CPF	Mineral	No	No	Fire	CTR	Deg	Forest land
C	4	F	PDF	CPF	Mineral	No	No	Fire	none	Deg	Forest land
D	6	F	PDF	CPF	Mineral	No	No	No	Clr	Def	Other land use
E	7	F	PDF	CPF	Mineral	No	No	No	CTR	Deg	Forest land
F	9	F	PDF	CPF	Mineral	No	Oil palm	Fire	Clr	Def	Cropland
G	10	F	PDF	CPF	Mineral	No	Oil palm	No	Clr	Def	Cropland
H	11	F	PDF	CPF	Mineral	No	Rubber	Fire	Clr	Def	Cropland
I	12	F	PDF	CPF	Mineral	No	Rubber	No	Clr	Def	Cropland
J	13	F	PDF	PF	Mineral	Conv	No	No	none	SMF	Forest land
K	14	F	PDF	PF	Mineral	No	No	Fire	Clr	Def	Other land use
L	15	F	PDF	PF	Mineral	No	No	Fire	CTR	Deg	Forest land
M	17	F	PDF	PF	Mineral	No	No	Fire	none	Deg	Forest land
N	19	F	PDF	PF	Mineral	No	No	No	Clr	Def	Other land use
O	20	F	PDF	PF	Mineral	No	No	No	CTR	Deg	Forest land
P	22	F	PDF	PF	Mineral	No	Oil palm	Fire	Clr	Def	Cropland
Q	23	F	PDF	PF	Mineral	No	Oil palm	No	Clr	Def	Cropland
R	24	F	PDF	PF	Mineral	No	Rubber	Fire	Clr	Def	Cropland
S	25	F	PDF	PF	Mineral	No	Rubber	No	Clr	Def	Cropland
T	26	F	PDF	PF	Mineral	RIL	No	No	none	SMF	Forest land
U	27	F	PMF	CPF	Organic	No	No	Fire	Clr	Def	Other land use
V	28	F	PMF	CPF	Organic	No	No	Fire	CTR	Deg	Forest land

Suite	Re-gime ID	F/NF Class	Initial Forest Type	Forest Function	Soil Type	Harvest system	Estate crop	Fire	F/NF Transition	Activity	Subse-quent Land Category
W	30	F	PMF	CPF	Organic	No	No	Fire	none	Deg	Forest land
X	32	F	PMF	CPF	Organic	No	No	No	Clr	Def	Other land use
Y	33	F	PMF	CPF	Organic	No	No	No	CTR	Deg	Forest land
Z	35	F	PSF	CPF	Organic	No	No	Fire	Clr	Def	Other land use
AA	36	F	PSF	CPF	Organic	No	No	Fire	CTR	Deg	Forest land
AB	38	F	PSF	CPF	Organic	No	No	Fire	none	Deg	Forest land
AC	40	F	PSF	CPF	Organic	No	No	No	Clr	Def	Other land use
AD	41	F	PSF	CPF	Organic	No	No	No	CTR	Deg	Forest land
AE	43	F	PSF	CPF	Organic	No	Oil palm	Fire	Clr	Def	Cropland
AF	44	F	PSF	CPF	Organic	No	Oil palm	No	Clr	Def	Cropland
AG	45	F	PSF	CPF	Organic	No	Rubber	Fire	Clr	Def	Cropland
AH	46	F	PSF	CPF	Organic	No	Rubber	No	Clr	Def	Cropland
AI	47	F	PSF	PF	Organic	Conv	No	No	none	SMF	Forest land
AJ	48	F	PSF	PF	Organic	No	No	Fire	Clr	Def	Other land use
AK	49	F	PSF	PF	Organic	No	No	Fire	CTR	Deg	Forest land
AL	51	F	PSF	PF	Organic	No	No	Fire	none	Deg	Forest land
AM	53	F	PSF	PF	Organic	No	No	No	Clr	Def	Other land use
AN	54	F	PSF	PF	Organic	No	No	No	CTR	Deg	Forest land
AO	56	F	PSF	PF	Organic	No	Oil palm	Fire	Clr	Def	Cropland
AP	57	F	PSF	PF	Organic	No	Oil palm	No	Clr	Def	Cropland
AQ	58	F	PSF	PF	Organic	No	Rubber	Fire	Clr	Def	Cropland
AR	59	F	PSF	PF	Organic	No	Rubber	No	Clr	Def	Cropland
AS	60	F	PSF	PF	Organic	RIL	No	No	none	SMF	Forest land
AT	61	F	SDF	CPF	Mineral	No	No	Fire	Clr	Def	Other land use

Suite	Re-gime ID	F/NF Class	Initial Forest Type	Forest Function	Soil Type	Harvest system	Estate crop	Fire	F/NF Transition	Activity	Subse-quent Land Category
AU	62	F	SDF	CPF	Mineral	No	No	Fire	CTR	SMF	Forest land
AV	64	F	SDF	CPF	Mineral	No	No	Fire	none	SMF	Forest land
AW	66	F	SDF	CPF	Mineral	No	No	No	Clr	Def	Other land use
AX	67	F	SDF	CPF	Mineral	No	No	No	CTR	SMF	Forest land
AY	69	F	SDF	CPF	Mineral	No	Oil palm	Fire	Clr	Def	Cropland
AZ	70	F	SDF	CPF	Mineral	No	Oil palm	No	Clr	Def	Cropland
BA	71	F	SDF	CPF	Mineral	No	Rubber	Fire	Clr	Def	Cropland
BB	72	F	SDF	CPF	Mineral	No	Rubber	No	Clr	Def	Cropland
BC	73	F	SDF	PF	Mineral	No	No	No	CTR	Deg	TP
BD	74	F	SDF	PF	Mineral	Conv	No	No	none	SMF	Forest land
BE	75	F	SDF	PF	Mineral	No	No	Fire	Clr	Def	Other land use
BF	76	F	SDF	PF	Mineral	No	No	Fire	CTR	SMF	Forest land
BG	78	F	SDF	PF	Mineral	No	No	Fire	none	SMF	Forest land
BH	80	F	SDF	PF	Mineral	No	No	No	Clr	Def	Other land use
BI	81	F	SDF	PF	Mineral	No	No	No	CTR	SMF	Forest land
BJ	83	F	SDF	PF	Mineral	No	Oil palm	Fire	Clr	Def	Cropland
BK	84	F	SDF	PF	Mineral	No	Oil palm	No	Clr	Def	Cropland
BL	85	F	SDF	PF	Mineral	No	Rubber	Fire	Clr	Def	Cropland
BM	86	F	SDF	PF	Mineral	No	Rubber	No	Clr	Def	Cropland
BN	87	F	SDF	PF	Mineral	RIL	No	No	none	SMF	Forest land
BO	88	F	SMgF	CPF	Organic	No	No	Fire	Clr	Def	Other land use
BP	89	F	SMgF	CPF	Organic	No	No	Fire	CTR	SMF	Forest land
BQ	91	F	SMgF	CPF	Organic	No	No	Fire	none	SMF	Forest land
BR	93	F	SMgF	CPF	Organic	No	No	No	Clr	Def	Other land use
BS	94	F	SMgF	CPF	Organic	No	No	No	CTR	SMF	Forest land

Suite	Re-gime ID	F/NF Class	Initial Forest Type	Forest Function	Soil Type	Harvest system	Estate crop	Fire	F/NF Transition	Activity	Subse-quent Land Category
BT	96	F	SSF	CPF	Organic	No	No	Fire	Clr	Def	Other land use
BU	97	F	SSF	CPF	Organic	No	No	Fire	CTR	SMF	Forest land
BV	99	F	SSF	CPF	Organic	No	No	Fire	none	SMF	Forest land
BW	101	F	SSF	CPF	Organic	No	No	No	Clr	Def	Other land use
BX	102	F	SSF	CPF	Organic	No	No	No	CTR	SMF	Forest land
BY	104	F	SSF	CPF	Organic	No	Oil palm	Fire	Clr	Def	Cropland
BZ	105	F	SSF	CPF	Organic	No	Oil palm	No	Clr	Def	Cropland
CA	106	F	SSF	CPF	Organic	No	Rubber	Fire	Clr	Def	Cropland
CB	107	F	SSF	CPF	Organic	No	Rubber	No	Clr	Def	Cropland
CC	108	F	SSF	PF	Organic	No	No	No	CTR	Deg	TP
CD	109	F	SSF	PF	Organic	Conv	No	No	none	SMF	Forest land
CE	110	F	SSF	PF	Organic	No	No	Fire	Clr	Def	Other land use
CF	111	F	SSF	PF	Organic	No	No	Fire	CTR	SMF	Forest land
CG	113	F	SSF	PF	Organic	No	No	Fire	none	SMF	Forest land
CH	115	F	SSF	PF	Organic	No	No	No	Clr	Def	Other land use
CI	116	F	SSF	PF	Organic	No	No	No	CTR	SMF	Forest land
CJ	118	F	SSF	PF	Organic	No	Oil palm	Fire	Clr	Def	Cropland
CK	119	F	SSF	PF	Organic	No	Oil palm	No	Clr	Def	Cropland
CL	120	F	SSF	PF	Organic	No	Rubber	Fire	Clr	Def	Cropland
CM	121	F	SSF	PF	Organic	No	Rubber	No	Clr	Def	Cropland
CN	122	F	SSF	PF	Organic	RIL	No	No	none	SMF	Forest land
CO	123	F	TP	PF	Mineral	Conv	No	No	CTR	Ref	Forest land
CQ	124	F	TP	PF	Organic	Conv	No	No	CTR	Ref	Forest land
CU	125	NF	SDF	PF	Mineral	No	No	No	Rev	Ref	TP
CV	126	NF	SMgF	PF	Organic	No	No	No	Rev	Ref	TP
CW	127	NF	SSF	PF	Organic	No	No	No	Rev	Ref	TP

Suite	Re-gime ID	F/NF Class	Initial Forest Type	Forest Function	Soil Type	Harvest system	Estate crop	Fire	F/NF Transition	Activity	Subse-quent Land Category
CX	128	NF	SDF	CPF	Mineral	No	No	No	Rev	Ref	Forest land
CY	129	NF	SMgF	CPF	Organic	No	No	No	Rev	Ref	Forest land
CZ	130	NF	SSF	CPF	Organic	No	No	No	Rev	Ref	Forest land
DA	131	NF	TP	PF	Mineral	Conv	No	No	RC	Ref	Forest land
DB	132	NF	TP	PF	Organic	Conv	No	No	RC	Ref	Forest land
DC	133	F	SDF	PF	Mineral	Conv	No	Fire	Clr	Def	Other land use
DD	134	F	SDF	PF	Mineral	Conv	No	No	Clr	Def	Other land use
DE	135	F	SDF	PF	Mineral	RIL	No	Fire	Clr	Def	Other land use
DF	136	F	SDF	PF	Mineral	RIL	No	No	Clr	Def	Other land use
DG	137	F	SSF	PF	Mineral	No	No	No	CTR	Deg	TP
DH	138	F	SSF	PF	Mineral	Conv	No	No	none	SMF	Forest land
DI	139	F	SSF	PF	Mineral	No	No	Fire	Clr	Def	Other land use
DJ	140	F	SSF	PF	Mineral	No	No	Fire	CTR	SMF	Forest land
DK	141	F	SSF	PF	Mineral	No	No	Fire	none	SMF	Forest land
DL	142	F	SSF	PF	Mineral	No	No	No	Clr	Def	Other land use
DM	143	F	SSF	PF	Mineral	No	No	No	CTR	SMF	Forest land
DN	144	F	SSF	PF	Mineral	No	Oil palm	Fire	Clr	Def	Cropland
DO	145	F	SSF	PF	Mineral	No	Oil palm	No	Clr	Def	Cropland
DP	146	F	SSF	PF	Mineral	No	Rubber	Fire	Clr	Def	Cropland
DQ	147	F	SSF	PF	Mineral	No	Rubber	No	Clr	Def	Cropland
DR	148	F	SSF	PF	Mineral	RIL	No	No	none	SMF	Forest land
DS	149	NF	SSF	PF	Mineral	No	No	No	Rev	Ref	TP

Remarks: F=forest; NF=non-forest; PDF=primary dryland forest; PMF=primary mangrove forest; PSF=primary swamp forest; SDF=secondary dryland forest; SMF=secondary mangrove forest; SSF=secondary swamp forest; TP=timber plantation; CPF=conservation & protection forest; PF=production forest; Conv=conventional; RIL=reduce impact logging; Clr=clearing; CTR=clearing, temporarily unstocked, re-vegetation; Rev=re-vegetation; RC=re-vegetation, clearing; Def=deforestation; Deg=degradation; SMF=sustainable management of forest; Ref=reforestation.

4.6. LIMITATIONS

Some identified limitations of this standard method are:

1. The analysis of management events and regimes was only conducted on forest lands (primary dryland forest, primary mangrove forest, primary swamp forest, secondary dryland forest, secondary mangrove forest, secondary swamp forest, and timber plantation). Other non-forest lands may have management events and regimes that should be considered as a part of the continuous improvement plan.
2. Forest functions (consisting of production forest, limited production forest, convertible production forest, conservation forest and protection forest) were only categorized into two main functions in this standard method, i.e. production forest and conservation/ protection forest. Obtaining further detail about management practices for the full range of forest functions could improve the accuracy of GHG emissions estimates.
3. Due to insufficient detail about the spatial location of silvicultural systems, it was assumed that the whole area of managed forest in each concession was managed as either conventional harvesting or reduced impact logging (RIL). In reality, management of forest concessions may use a combination of both silvicultural systems.
4. The condition of timber plantations in the area detected as timber plantations was analyzed without considering the real plantation ages, due to a lack of data about plantation age classes. This affected the spatial allocation of timber plantation management regimes, particularly for plantations that existed at the start of the simulation period, for which a normal age class distribution was assumed. This will influence the timing of GHG removals and harvesting emissions.
5. Changes to silvicultural systems over time were not included. For example, silvicultural systems used prior to the start of the simulation period were not included. These activities may result in different forest conditions and the quantity of biomass and debris present on the site compared to the modelled management regimes. This will influence GHG removals through growth and emissions through decay of debris during the simulation period.

4.7. IMPROVEMENT PLAN

Further information about forest management regimes and their influence on biomass and debris, carbon stocks should be obtained and analyzed to improve GHG emissions and removals estimates. This may require further research into the impact of forest management events and regimes on residual carbon stocks.

5 STANDARD METHOD – SPATIAL ALLOCATION OF REGIMES

5.1. PURPOSE

This standard method describes the process used by the Indonesian National Carbon Accounting System (INCAS) for defining the areas used for each management regime in modelling GHG emissions and removals from natural forests, timber plantations and selected estate crops (oil palm and rubber). This includes data collation, data analysis, quality control and quality assurance.

There are many factors that are critical to determining variations in emissions from different REDD+ activities in Indonesia. The type and condition of forest and other land on which REDD+ activities occur, as well as the type of management activities undertaken, need to be spatially identified to enable detailed modelling of GHG emissions and removals.

The best available spatial data that could inform the areas in which each activity could potentially occur was identified and sourced. This included:

- Administrative boundary (BAPPEDA province)
- Forest type: 2000, 2003, 2006, 2009, 2011 (Ministry of Forestry)
- Forest function (Ministry of Forestry)
- Soil type - peat (Ministry of Agriculture)
- Forestry utilization boundaries: concessions (Ministry of Forestry)
- Estate crops (Ministry of Forestry)
- Annual forest extent and change: 2000–2012 (LAPAN)
- Annual burnt area: 2000–2012 (RSS).

These spatial data sets were created for a range of non-MRV related reasons. Consequently, the spatial and temporal quality is variable. This leads to inconsistencies between data sets, which in turn necessitates decisions about how each data set is to be used for the purpose of carbon accounting.

The purpose of this standard method is to describe how the available spatial data can be used to consistently allocate management regimes to areas within Central Kalimantan and to derive annual area statistics for use in INCAS modelling.

5.2. DATA

5.2.1. Collation

Data were collated from national and provincial level government agencies and organizations involved in land management. Collaboration with the provincial government of Central Kalimantan and other organizations involved in forest land management in the province facilitated meetings to discuss available data and forest management knowledge, and data sharing.

Spatial forest cover and forest cover change data was developed by LAPAN as part of INCAS Program.

Spatial data

Table 5-1 lists spatial data sets used to inform the possible areas in which REDD+ activities can occur. These data are used to create a series of 'suites', which describe the conditions under which a land management regime can occur. By using biophysical and management data in the identification of individual suites, it is possible allocate a derived area of land use and land-use change for modelling the impact on GHG emissions and removals.

Table 5-1. Source of spatial data

Data	Description	Source
Land cover type	Primary or secondary dryland forest, swamp forest or mangrove forest, timber plantations (and all other land cover classes not used in this method)	Ministry of Forestry
Forest function	Production, protection or conservation forest	Ministry of Forestry
Soil type	Organic (peat) and mineral soil types	Ministry of Agriculture
Estate crops	Area of oil palm and rubber plantations	Ministry of Forestry
Forest utilization	Area of forestry concessions	Agency for Monitoring of Production Forest Utilization – Central Kalimantan
Burnt area	Annual area burnt	Remote Sensing Solutions GmbH
Forest extent and change	Annual forest/non-forest data derived from Landsat data, and the forest loss and forest gain events derived by differencing the annual forest extents	LAPAN

The method used to derive forest extent and change data is described in LAPAN (2014).

The steps used in preparing spatial data for use in INCAS are described in Appendix 1: Steps for preparing spatial data for use in INCAS: *GIS analysis steps*.

A spatial layer showing the geographic extent of each suite was created for each simulation year (i.e. annually for 2000 to 2011) using the data in Table 5-1. Each suite is allocated a unique identifier (suite code) which links the spatial data to the management regimes produced as an output of the *Standard Method – Forest Management Events and Regimes*.

The suite code is a common attribute for all areas that will constitute the area of each regime in each year. The area of each suite will vary over time as forests transition from primary to secondary forest to non-forest conditions.

Management regimes

Management regimes describe the type and combination of management events applied to a particular land use, and the timing of events.

Once assigned to a management regime, an area continues to be managed according to that regime, in perpetuity, until a subsequent event is observed that causes a change in the management regime.

Suites for forest and cropland assessed in this standard method are produced using the *Standard Method – Forest Management Events and Regimes*. Management regimes for quantifying peat emissions are described in the *Standard Method – Peatland GHG Emissions*.

5.2.2. Collection

All data described in this standard method were collated from existing sources held by Government of Indonesia agencies and other organizations, with the exception of burnt area. The burnt area data was produced through a specially commissioned analysis conducted by RSS and described in the report, *Generation of spatial burned area data of the Central Kalimantan Province for the Indonesian National Carbon Accounting System (INCAS)* (Ballhorn et al., 2014).

No other new data collection methods were used.

5.3. ANALYSIS

The objective of the analysis is to calculate the area of land managed according to each management regime for every year of the simulation period. These areas form part of the inputs for the GHG emissions and removals estimation models described in the *Standard Method – Modelling and Reporting*.

Areas were allocated to a management regime based on suite characteristics and repeated for each year of the simulation period (i.e. 2000 to 2011).

Areas subject to observed change (i.e. change detected from the LAPAN forest cover change analysis) were assigned to regimes based on the location, timing and direction of change in conjunction with the other suite characteristics.

For an area to be allocated to a forest management regime it must meet the minimum forest area definition for Indonesia of 0.25 ha. As the analysis was completed on the change (activity) data, as opposed to forest extent, the area threshold was applied to the aggregate of all years of change. This allows for accounting of annual change of areas less than 0.25 ha, while ensuring that the cleared land meets the definition of forest.

The detail of the GIS processing is provided in Appendix 1.

All spatial data that was related to the location and extent of a regime in the carbon account was collated, converted to shape files and projected to a consistent coordination system.

Each REDD+ activity reported by INCAS was modelled as a separate estate – i.e. a file with the area and timing of each regime assigned by this standard method. REDD+ activities modeled in INCAS are deforestation, forest degradation, enhancement of forest carbon stocks and sustainable management of forest.

The criteria used to define each activity are presented in Table 4-5 of the *Standard Method – Forest Management Events and Regimes*. Each regime can be determined from the unique combinations of these spatial data values, and the area provided for modelling directly from the GIS outputs.

While there are a total of 119 different regimes, requiring different areas, the deforestation and reforestation activities were identifiable directly from combinations of the source data. However, some additional processing was required to deliver appropriate areas to model SMF and degradation.

Sustainable management of forest (SMF): This REDD+ activity fits within the forest land remaining forest land category of UNFCCC. It does not result in a discernible change in the forest canopy using the methods currently adopted by INCAS, yet has an impact on the carbon account.

The annual forest change data is only relevant to forest conversion activities that result in a discernible change in the forest canopy (i.e. harvesting does not result in removal of enough trees to reduce the forest canopy to below the 30% threshold that defines a forest).

The process to allocate area to these activities relied on forest type, forest function, concession boundaries, the absence of forest change and the proportion of forest available for harvesting, as follows.

- If the forest type was mapped as dryland forest, the usual SMF practice was assumed to be to harvest 40.6% of the forests over a 30-year period. This was calculated by assuming the effective area harvested in each concession area was 70%, corrected by average annual actual timber production of 0.58.

- If the forest type was mapped as swamp forest, the usual SMF practice was assumed to be to harvest 52.2% of the forests over a 40-year period. This was calculated by assuming the effective area harvested in each concession area was 90%, corrected by average annual actual timber production of 0.58.

Forest degradation: The determination of areas to assign to forest degradation activities required the creation of unique combinations of all the forest change data.

The year of forest loss and the year of forest gain were determined for each polygon. Polygons that recorded both loss and gain were subjected to a statistical analysis.

If the intervening non-forest period was 3 or more years, this met the criteria of temporarily unstocked, which resulted in the polygon being assigned to a forest degradation event.

- This analysis was conducted for areas of forest that were cleared and subsequently regrown, and allocated to the year in which the forest was lost. ('clearreveg')
- Conversely, polygons of multiple changes where the first event was a forest gain were identified as a degradation event beginning in the year of first forest gain. ('revegclear'). The assumption was that the land was temporarily unstocked prior to the availability of the first year of forest extent data (2000).

5.4. QUALITY CONTROL AND QUALITY ASSURANCE

All data are assumed to be correct from the data supplier.

All data were spatially complete for Central Kalimantan.

All data were combined into a single polygon data set for each year.

The resultant GIS table was then exported to Excel and each regime assigned based on the selection of the relevant attributes of each input data set.

All records that had an area less than 1 ha were deleted. These small polygons were visually inspected and determined to be the result of unintentional overlapping areas of differently derived spatial data. Thus, the filtering of thousands of rows of the database was used as a proxy for cleaning the input data to ensure that each combination of land use activity and function was logical.

The other main logic filter that was undertaken as part of the statistical analysis (as a proxy for a rigorous spatial analysis filter) was to ensure that all clearing and re-vegetation events were separated by a length of time determined to be suitable by the description of the defined regimes.

The analysis relied on high levels of understanding of statistics, spatial analysis, vegetation dynamics, forest management practices and the impact of a time series of events on the resultant carbon account.

5.5. OUTPUTS

Outputs from this standard method are expressed in hectares, by regime, by year. See [Regime Areas_14112014.xls].

A Unique Feature Identifier (FID) from the GIS data was maintained throughout this process so that the newly calculated "suite" field for each year could be joined back to the spatial data.

5.6. UNCERTAINTY ANALYSIS

No specific uncertainty analysis was undertaken on the area statistics.

The QA/QC processes and decision rules around minimum areas would have the effect of reducing uncertainty of the areas where each of the input data sources is assigned to the same area of land.

5.7. LIMITATIONS

Due to the known confusion between forest and estate crop species in the remotely sensed regrowth data, there are likely to be some areas of forest loss and gain that contain errors.

Spatial analysis tools were not fully developed when this analysis was undertaken which resulted in a large amount of data processing using manual processes. The efficiency of this process should be improved to reduce potential for errors and to reduce processing time, particularly for spatial allocation of regimes across all of Indonesia.

5.8. IMPROVEMENT PLAN

All input data can be characterized as the best available.

For the continuous improvement plan, it is recommended that each of the data sets supplied for this analysis are subjected to more rigorous pre-processing and standardization.

As new versions and updates to each of the input data sets are created, the modelling team will need to have access, permission and resources to repeat this methodology to update the areas for subsequent modelling of emissions and removals.

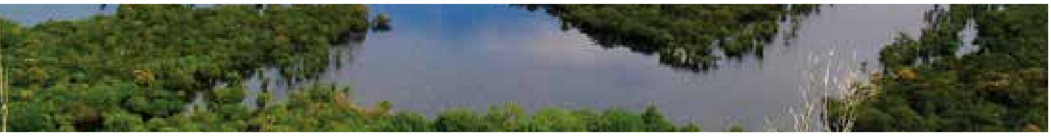
The improvement plan associated with the generation of the modelling and reporting requirements will also lead to a repetition of this spatial allocation to match any new suites.

Activities relying on the detection of conversion from non-forest to forest land (afforestation, reforestation and re-vegetation) were not able to be determined using satellite data without additional interpretation of the outputs. For example, palm trees meet the crown cover, height and area parameters given in the national definition of "forest", however the policy parameters require these to be identified as estate crop species.

The detailed spatial analysis of forest cover change from LAPAN combined with spatial data about forest types and management practices have greatly improved the identification of forest change events. This can be further improved by greater collaboration between forest cover mapping and spatial analysis processes. Development of a spatial analysis tool would improve the efficiency of the spatial allocation of regimes described in this standard method.

Results would be enhanced through a more detailed understanding of land management events prior to 2000, as this influences the estimation of forest biomass and the degree of peat degradation modelled during the period 2000 to 2011. This could be achieved by extending the annual forest cover change analysis back to 1990, and extracting more detailed information from historical land management records.

STANDARD METHOD – PEATLAND GHG EMISSIONS



6

6.1. PURPOSE

This standard method describes the process used by the Indonesian National Carbon Accounting System (INCAS) for modelling GHG emissions from peatland in Indonesia. This includes data collation, data analysis, quality control, quality assurance, modelling and reporting.

For this standard method, peatland is defined as land with organic soils. This represents areas with an accumulation of partly decomposed organic matter, with ash content equal to or less than 35%, peat depth equal to or more than 50cm, and organic carbon content (by weight) of at least 12%.

Peatland GHG emissions are estimated annually for the following sources and gases:

- Biological oxidation of drained peat: CO_2-C, CO_2-e
- Peat fire[1]: CO_2-C, CO_2, CO, CH_4
- Direct emissions from drained organic soils and drainage ditches: N_2O, CH_4

Outputs from this standard method can be expressed as tonnes for each GHG or expressed in tonnes CO_2-equivalent GHG emissions. Time periods for reporting can be specified to meet reporting requirements.

6.2. DATA

6.2.1. Collation

Spatial data used in this method are summarized in Table 6-1. Spatial data collation methods are described in the *Standard Method – Spatial Allocation of Regimes*.

[1]Note: Fire emission factors for N_2O and NO_x are not provided by IPCC at Tier 1 due to very limited data for N_2O and NO_x emissions from organic soil fires.

Table 6-1. Source of spatial data used

Data	Description	Source
Land cover type	Primary or secondary dryland forest, swamp forest or mangrove forest, timber plantations, estate crops (and all other land cover classes not used in this method).	Ministry of Forestry
Soil type	Organic (peat) and mineral soil types	Ministry of Agriculture
Estate crops	Oil palm	Ministry of Forestry
Burnt area	Annual area burnt (spatial)	Remote Sensing Services GmbH
Forest extent and change	Annual forest/non-forest data derived from Landsat data, and the forest loss and forest gain events derived by differencing the annual forest extents.	LAPAN

Input data for estimating GHG emissions from peat decomposition are shown in Table 6-2.

Table 6-2. Source of modelling input data

Data	Description	Source
Emission factors	Peat biological emission factors[2] and peat fire emission factors.	IPCC (2013); Hooijer et al. (2014)
Tier 1 default emission factors	Fire emissions (CO_2-C, CO and CH_4), direct nitrous oxide emissions from drained organic soil, CH_4 emissions from drained organic soil and drainage ditches.	IPCC (2013)
Drained peatland area	Annual area of drained peatland by land cover condition.	INCAS *Standard Method – Spatial Allocation of Regimes*
Burnt area	Annual area of peatland burnt in Central Kalimantan 2000 to 2012.	Remote Sensing Services GmbH (Ballhorn et al., 2014)

Two sets of emissions factors were used for quantifying emissions of CO_2, DOC and CH_4 for the Central Kalimantan pilot province inventory as shown in Table 6-3.

[2]KFCP biological oxidation emission factors include carbon dioxide, dissolved organic carbon (DOC), methane

Table 6-3. Emission factors for biological oxidation of peat in Indonesia

	KFCP EF biological oxidation[3] (*t C ha⁻¹ yr⁻¹*)		IPCC 2013			
KFCP land-cover type	First 5 years after drainage (oxidation and/or fire)	>5 years after drainage (only biological oxidation)	CO_2-C EF[4] ($t\ C\ ha^{-1}\ yr^{-1}$)	DOC EF[5] ($t\ C\ ha^{-1}\ yr^{-1}$)	CH_4 EF ($kg\ C\ ha^{-1}\ yr^{-1}$)	IPCC land-use category
A. Primary peatland forest, never logged and without drainage impacts	0	0				
B. Slightly drained peatland forest (selectively logged but no large canals within 1500 m and not burnt)	3.95	3.95	5.3	0.82	4.9	Forest land and cleared forest land (shrubland), drained
C. Moderately drained peatland forest (selectively logged and drained by large canals at 1000-3000 m intervals, but not burnt)	26	7.9	5.3	0.82	4.9	Forest land and cleared forest land (shrubland), drained
D. Fully degraded peatland (usually burnt at least twice with limited regrowth) that is drained by large canals at 1000–3000 m intervals	26	4.5	5.3	0.82	4.9	Forest land and cleared forest land (shrubland), drained
E. Plantations and croplands, with large canals at intervals of less than 1 km and/or field drains less than 400 m apart	49 [Hooijer et al., 2014]	15	11.0 15 20	0.82 0.82 0.82	0.0 4.9 4.9	Plantations, drained, oil palm[6] Plantations, drained, unknown or long rotations Plantations, drained, short rotations, e.g. acacia
			9.4	0.82	143.5	Cropland, drained, paddy rice

Source: IPCC (2013); Hooijer et al. (2014)

[3]Carbon loss determined from subsidence (biological oxidation) includes CO_2, DOC and CH_4 emissions [$t\ C\ ha^{-1}\ yr^{-1}$] (Hooijer et al., 2014).
[4]See Table 2.1 in IPCC 2013
[5]See Table 2.2 in IPCC 2013
[6]The majority of plantation and cropland areas identified in Central Kalimantan were oil palm. Hence, this EF was used for plantation and cropland calculations based on IPCC EFs.

Peat biological oxidation emission factors developed through the Kalimantan Forest and Climate Partnership (KFCP) project in Central Kalimantan, as documented in Hooijer et al. (2014), differ from those in the *IPCC 2013 Wetlands Supplement*. There is conjecture amongst peat scientists about which emission factors best represent the emissions profile in Central Kalimantan. Hence, for the Central Kalimantan pilot province inventory, INCAS calculated GHG emissions using both sets of input data, although only emissions calculated using the IPCC 2013 emission factors have been reported in Krisnawati et al. (2015). Ongoing review of these emission factors should be undertaken as part of the INCAS continuous improvement plan to incorporate findings from continuing peat GHG emissions research.

The KFCP derived emission factors include carbon emissions as CO_2, dissolved organic carbon (DOC) and CH_4. IPCC 2013 provides separate emission factors for CO_2, DOC and CH_4.

Emission factors for peat fires were also developed through the KFCP project. Hooijer et al. (2014) consider the fire emission factors resulting from the KFCP work to be more representative of normal fire conditions in Indonesia than the emission factors presented in IPCC 2013, which they consider overestimate fire GHG emissions due to the reliance on a small number of studies that are heavily influenced by extreme conditions in 1997/98.

INCAS has adopted the data underpinning the fire emission factors for the KFCP project site from Page et al. (2014), but adapted the emission factors to meet international reporting requirements that GHG emission estimates from organic soil fire should be expressed in tonnes of each GHG emitted. The method used for determining country-specific emission factors for Indonesia and used for the Central Kalimantan pilot province inventory follows the approach described in IPCC 2013, using Equation 2.8 as described in the box below.

EQUATION 2.8

ANNUAL CO_2-C AND NON-CO_2 EMISSIONS FROM ORGANIC SOIL FIRE

$$L_{fire} = A \bullet M_B \bullet C_f \bullet G_{ef} \bullet 10^{-3}$$

Where:

L_{fire} = amount of CO_2 or non-CO_2 emissions, e.g. CH_4 from fire, tonnes

A = total area burnt annually, ha

M_B = mass of fuel available for combustion, tonnes ha^{-1} (i.e. mass of dry organic soil fuel) (default values in Table 2.6; units differ by gas species)

C_f = combustion factor, dimensionless

G_{ef} = emission factor for each gas, g kg^{-1} dry matter burnt (default values in Table 2.7)

Mass of fuel available for combustion = Area (m^2) * burn depth (m) * bulk density (t/m^3)

Table 6-4 shows the input values, calculated mass of fuel available for combustion and resulting emissions of CO_2-C, CO and CH_4 in tonnes of each gas per hectare for three types of fire observed in the KFCP project site. Total annual emissions are calculated by multiplying the annual area burnt by the mass of emissions released for each gas.

Table 6-4. Input parameters and CO_2-C, CO and CH_4 emissions per hectare for organic soil fire

Peat fire EF calculation	First fire	Second fire	Third fire and subsequent fires
Burn depth (cm)	18	11	4
Area (ha)	1	1	1
Bulk density (g cm^{-3})	0.121	0.121	0.121
Combustion factor	1	1	1
EF CO_2-C (g kg^{-1})	464	464	464
EF CO (g kg^{-1})	210	210	210
EF CH_4 (g kg^{-1})	21	21	21
Mass of fuel available for combustion (t dm ha^{-1})	217.8	133.1	48.4
CO Emissions (t CO ha^{-1})	45.7	28.0	10.2
CH_4 Emissions (t CH_4 ha^{-1})	4.6	2.8	1.0
CO_2-C Emissions (t C ha^{-1})	101.1	61.8	22.5
CO-C Emissions (t C ha^{-1})	19.6	12.0	4.4
CH_4-C Emissions (t C ha^{-1})	3.4	2.1	0.8
Total C Emissions (t C ha^{-1})	**124.1**	**75.8**	**27.6**

Source of CO_2-C, CO and CH_4 emission factors: Table 2.7, IPCC (2013).
Source of burn depth, bulk density and combustion factor: Page et al. (2014).

Note: Emission factors for N_2O and NO_x are not provided by IPCC at Tier 1 due to limited data for N_2O and NO_x emissions from organic soil fires.

Nitrous oxide emissions from drained soil

Annual nitrous oxide emissions from organic soil were calculated by multiplying the annual area of drained peatland in a land-use category by Tier 1 default emission factors from IPCC 2013 (Table 6-5).

Table 6-5. Default nitrous oxide emission factors from organic soil

Land-use category	Emission factor ($kg\ N_2O\text{-}N\ ha^{-1}\ yr^{-1}$)
Forest land and cleared forest land (shrubland[7]), drained	2.4
Plantation: oil palm	1.2
Plantation: sago palm	3.3
Cropland except rice	5.0
Rice	0.4
Grassland	5.0

Source: IPCC (2013).

For the Central Kalimantan pilot province inventory the 'plantation: oil palm' emission factor was applied for all plantation and estate crops as oil palm represents the majority of plantations on peatland in the province. The 'forest land and cleared forest land (shrubland), drained' emission factor was used for all land other than plantation and estate crops and rice paddy.

6.2.2. Collection

No new data collection methods are required for this standard method.

6.3. ANALYSIS

The overall approach is illustrated in Figure 6-1. Total annual GHG emissions are estimated by multiplying the area affected by drainage or fire by an activity specific emission factor. Separate emission factors are used for peat biological oxidation and peat fires. Emissions in fire years are comprised of both biological oxidation and peat fire emissions.

[7]Shrubland refers to any type of land sparsely or fully covered with shrubs or trees that may fulfill the national forest definition. It extends to degraded lands that cannot be clearly classified as forest or non-forest.

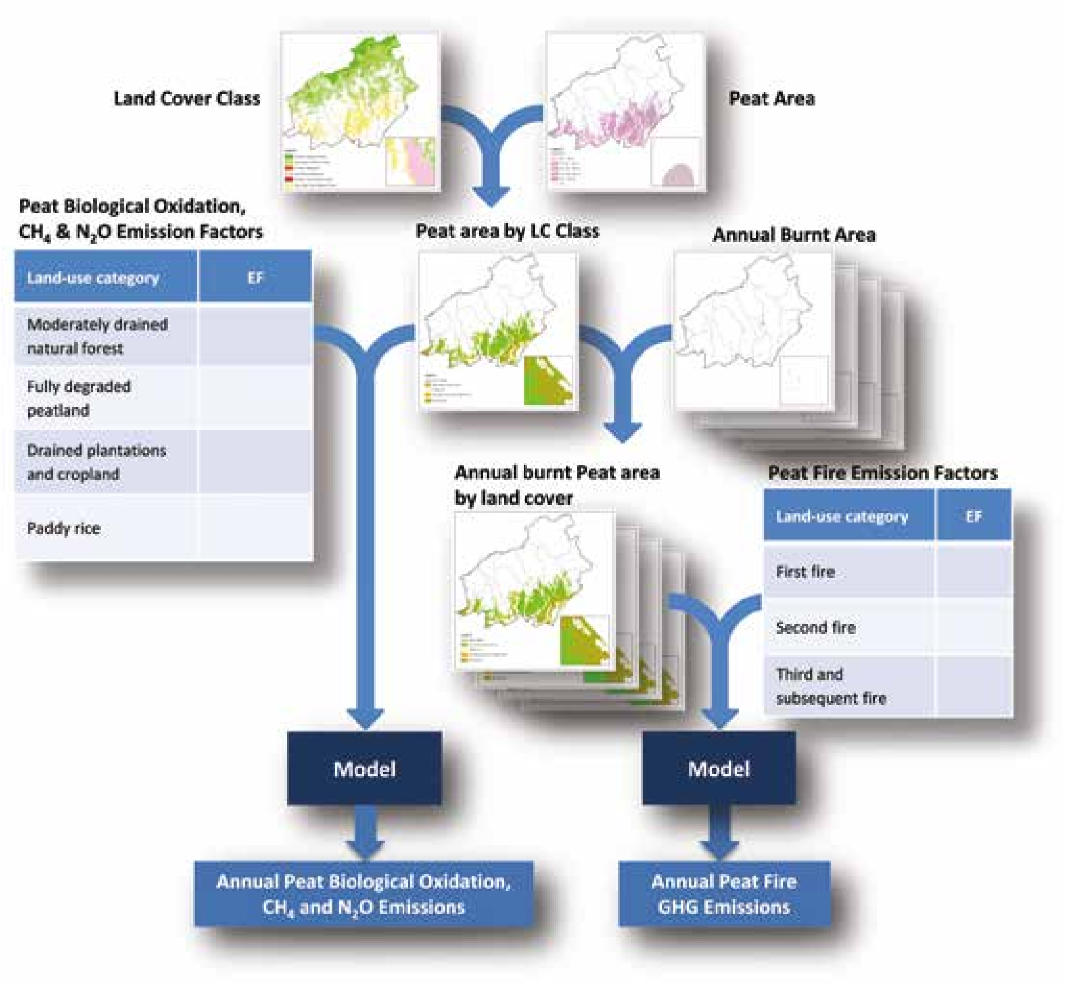
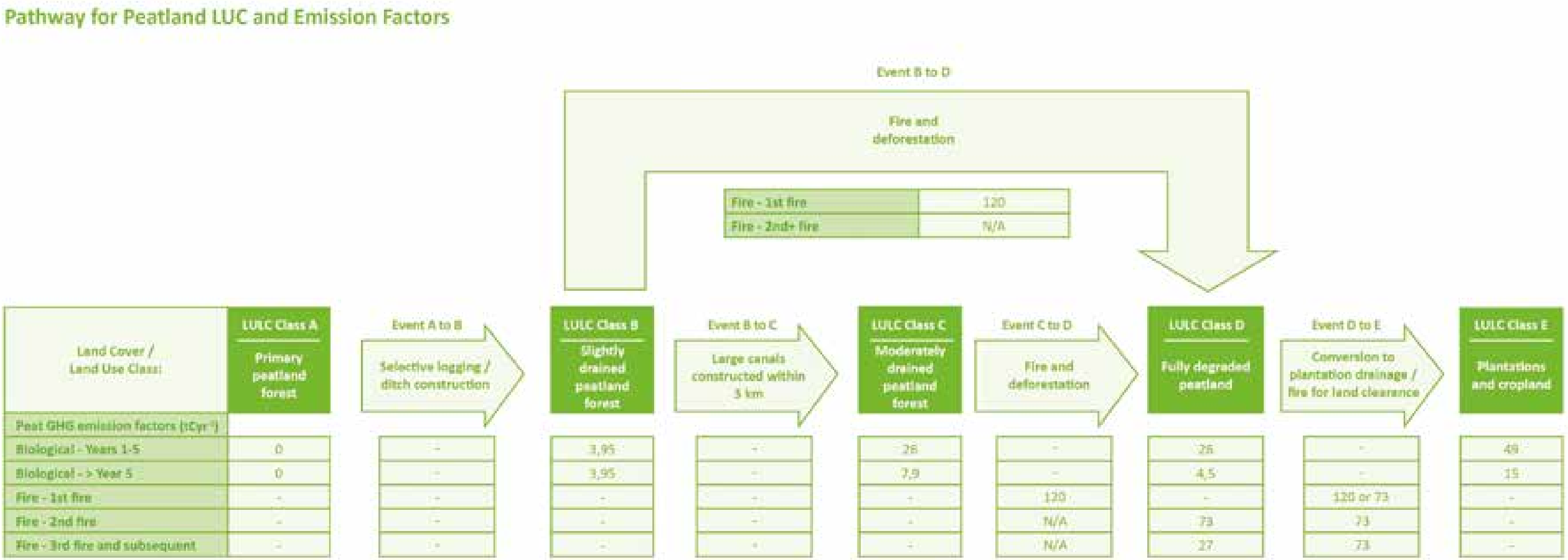


Figure 6-1. Overview of INCAS peat GHG emissions estimation approach for Central Kalimantan

The approach to estimating peat GHG emissions is consistent with the approach used in INCAS for modelling GHG emissions and removals from biomass and debris. Both approaches are event-based, in which emissions are triggered by land management events. This is illustrated in Figure 6-2 that shows the transition of peatland between land cover types, the causative events and associated emission factors determined for the KFCP project site. Fire emission factors used by INCAS for the main GHGs differ to those determined for the KFCP project site as described in the data section of this standard method.



Source: Hooijer et al. (2014)

Figure 6-2. Pathway for peatland land-use change and peat emission factors determined from KFCP project

6.3.1 Model

An Excel-based model was developed to estimate GHG emissions resulting from the land management events outlined in Figure 6-2, as well as direct nitrous oxide, dissolved organic carbon (DOC) and methane emissions from drained organic soil. The model consists of a series of input work sheets, a series of locked calculation work sheets, and an output work sheet where total annual GHG emissions results are displayed for each gas. Operation of the model is described in the 'Instructions' work sheet in the Excel file 'INCAS Peatland Model - Kalteng Detailed System_all17112014.xlsx'. The management regimes modelled can be selected and each scenario saved as a separate Excel file.

The model is designed to allow management regimes to be developed based on changes in land cover type and the timing of peat fires which can be determined from spatial analysis of forest cover and fire areas. Emission factors can be applied based on the type of event and subsequent peatland cover class.

The annual area applied to each management regime was determined using the approach described in the *Standard Method – Spatial Allocation of Regimes*.

For the Central Kalimantan pilot province inventory, the burnt peatland area was calculated using the annual spatial burnt area data provided by Remote Sensing Services (Ballhorn et al., 2014) based on the following assumptions.

- The first fire occurs where forest clearing and fire occur in the same year.
- The second fire occurs on non-forest land where a first fire has occurred within the analysis period, or where the first fire is detected on non-forest land (assuming the first fire occurred prior to commencement of the analysis period).
- The third and subsequent fires occur on non-forest land where a second fire previously occurred.

Peat fire emissions were calculated in a separate spreadsheet (PeatFireKalteng07112014.xlsx) using the emission factors from Table 4 and the annual burnt area by fire type described above.

6.4. QUALITY CONTROL AND QUALITY ASSURANCE

Quality control and quality assurance of emission factors and area input data was conducted by the authors of the reports Hooijer et al. (2014), Ballhorn et al. (2014) and IPCC (2013).

Quality assurance of area and emissions calculations was conducted by INCAS technical advisors.

6.5. OUTPUTS

Greenhouse gas emissions from peatland are reported in their native gases and where possible as CO_2-equivalent emissions as shown in Table 6-6.

Carbon emissions from biological oxidation of peat and peat fire are quantified as change in peat carbon stock in tonnes C ha^{-1}, converted to CO_2-equivalent emissions by multiplying by 44/12 (ratio of molecular weight of CO_2 to carbon).

Non-CO_2 emissions from peat fire are quantified directly in tonnes CO ha^{-1} and tonnes CH_4 ha^{-1}. Methane emissions are converted to CO_2-equivalent emissions.

Methane (CH_4) and nitrous oxide (N_2O) emissions are converted to CO_2-equivalent emissions by multiplying by the 100-year global warming potentials for each gas, which are 28 and 265, respectively (Myhre et al., 2013).

Table 6-6. Modelling outputs and reporting units

Source	Model output	Initial output unit	Conversion factor	Reporting unit	GWP[8]	Common reporting unit
Biological oxidation of drained peat	CO_2-C	tonnes C ha^{-1}	44/12	tonnes CO_2	1	tonnes CO_2-e
Peat fire	CO_2-C	tonnes C ha^{-1}	44/12	tonnes CO_2	1	tonnes CO_2-e
	CH_4	tonnes CH_4 ha^{-1}	1	tonnes CH_4	28	tonnes CO_2-e
	CO	tonnes CO ha^{-1}	1	tonnes CO	NA	NA
Direct emissions from drained organic soils	CH_4	tonnes CH_4 ha^{-1}	1	tonnes CH_4	28	tonnes CO_2-e
	DOC	tonnes C ha^{-1}	44/12	tonnes CO_2	1	tonnes CO_2-e
	N_2O	tonnes N_2O ha^{-1}	1	tonnes N_2O	265	tonnes CO_2-e

[8]GWP – 100-year Global Warming Potential from (Myhre et al. 2013). CO and NOx are secondary GHGs and are not assigned GWP values.

6.6. UNCERTAINTY ANALYSIS

Adoption of Indonesia specific emission factors developed from research within Central Kalimantan and the *IPCC 2013 Wetlands Update* that relied on Indonesian data for tropical soils, reduces the level of uncertainty from emission factors, although there is still conjecture amongst peat scientists about the accuracy of derived emission factors. Additional research is required to expand the type of land and management activities covered by emission factors, which would further reduce uncertainty associated with these emission factors.

For the Central Kalimantan pilot province inventory, uncertainties associated with spatial data vary considerably for different data sets. These are discussed in the *Standard Method – Spatial Allocation of Regimes*. The INCAS program has identified key spatial data sets required for analysis. Improvement of these data sets will reduce uncertainty of GHG emission estimates.

6.7. LIMITATIONS

For the Central Kalimantan pilot province inventory, the main limitations of the peatland GHG emissions estimation approach relate to data availability and quality.

- Consistency between spatial data sets is important. Some data overlap or have inconsistent information for the same areas between data sets.
- Spatial extent of annual burnt area is important. Further work is needed to accurately determine areas burnt and fire intensity for historical fires.
- Methane emissions from drainage ditches are noted in IPCC 2013 as potentially significant. Although these were accounted for by using Tier 1 methods, insufficient information was available about drainage ditch location and size to improve upon these in the Central Kalimantan pilot province GHG inventory. Further work is required to provide more comprehensive data about drainage ditch location, sizes, condition and the distance from ditches that is impacted by drainage.
- Peat mapping, including peat boundaries and depth, needs to be improved.
- Land management information of peatlands, particularly land uses and intensity of management following forest clearing, were limited and should be improved.
- Data about water table depth in disturbed and managed peatland was not available for the whole Central Kalimantan province. Further research should be undertaken to develop relationships between land management, canal management (including canal blocking) and water table depth, and the resultant GHG emissions.
- Emission factors for the first 5 years after clearing were estimated for some land uses in the KFCP research. Further research should be undertaken to improve these estimates in terms of the quantity and timing of emissions.

6.8. IMPROVEMENT PLAN

Greenhouse gas emissions from organic soil in the Central Kalimantan pilot province inventory are substantially higher than net emissions from other carbon pools associated with deforestation, forest degradation, sustainable management of forest and enhancement of forest carbon stocks, which are modelled using higher tier methods. This indicates that further work is needed to reduce uncertainty associated with peat GHG emission estimates. Ongoing research will help to reduce some sources of uncertainty. However, greater collaboration between custodians of data about peat and peatland management and further analysis of these data could yield earlier substantial improvements in peatland GHG emissions estimates. A detailed, prioritized, continuous improvement plan should be developed for peat activities and an overarching coordination body appointed to manage their implementation.

7 STANDARD METHOD – MODELLING AND REPORTING

7.1. PURPOSE

This standard method describes the process used by the Indonesian National Carbon Accounting System (INCAS) for modelling GHG emissions and removals from deforestation, forest degradation, the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in Indonesia. This includes data collation, data analysis, quality control, quality assurance, modelling and reporting.

Modelling of the following carbon pools and GHG emissions uses a mass balance, event-driven approach in which changes to carbon stocks in each carbon pool and flows of carbon between pools are quantified:

- live aboveground biomass
- live belowground biomass
- debris (deadwood, litter)
- carbon emissions from fire

From these, annual GHG emissions and removals are derived for defined periods of interest. This approach is used for natural forest, timber plantations, oil palm and rubber estate crops.

Modelling of other carbon pools and GHG emissions described in this standard method are:

- carbon emissions from mineral soil, calculated using IPCC default emission factors and activity data;
- non-CO_2 emissions from fire, calculated using IPCC default N : C ratios and emission factors multiplied by carbon released from fire.

Carbon emissions and non-CO_2 emissions from organic soil (peat) are modelled using the INCAS standard method for peatland GHG emissions (described in Chapter 6 of this document).

Input data used for modelling GHG emissions and removals are collated from the outputs of the following INCAS standard methods and other documents:

- *Standard Method – Initial Conditions*
- *Standard Method – Growth and Turnover*
- *Standard Method – Forest Management Events and Regimes*
- *Standard Method – Spatial Allocation of Regimes*
- *Standard Method – Peatland GHG Emissions*
- LAPAN (2014). *The Remote Sensing Monitoring Program of Indonesia's National Carbon Accounting System: Methodology and Products, Version 1*.
- IPCC (2003). *Good Practice Guidance for Land Use, Land Use Change and Forestry*
- IPCC (2006). *IPCC Guidelines for National Greenhouse Gas Inventories*

Outputs from this standard method are expressed in tonnes of each GHG and CO_2-equivalent GHG emissions and removals. Time periods for reporting can be specified to meet reporting requirements.

7.2. DATA

7.2.1. Collation

Input data for modelling GHG emissions and removals are collated from a wide range of sources through a series of INCAS standard methods shown in Table 7-1. Each standard method is specifically designed to produce credible, verifiable input data to underpin Indonesia's net GHG emissions estimates from forests.

Table 7-1. Source of modelling input data

Standard method	Modelling input data
Initial Conditions	Carbon stocks for each component of aboveground and belowground biomass and debris for each biomass class[9] at the start of the simulation. Data values, assumptions and sources are documented in the INCAS Database [Database fullCAM_18052014.xlsb].
Forest Growth and Turnover	Rate of growth, turnover of aboveground and belowground biomass, and decomposition rate of debris, for each component of each biomass class. Data values, assumptions and sources are documented in the INCAS Database [GrowthDatabase_19062014.xlsb].
Forest Management Events and Regimes	Impact of forest management events on carbon stocks for each component of aboveground and belowground biomass and debris for each biomass class, and the timing of events allocated to management regimes and specific areas of forests. Data values, assumptions and sources are documented in the INCAS Database [Database_events_fullCAM_03072014.xlsb, INCAS Suites_16062014.xlsx].
Spatial Allocation of Regimes	Area by year by forest management regime to be modelled. Data are documented in [Regime Areas_14112014.xlsx]

Peatland GHG emissions are calculated in the *Standard Method – Peatland GHG Emissions*. The results are added to the outputs from modelling in this standard method to calculate total annual GHG emissions and removals.

7.2.2. Collection

No new data collection methods are required for this standard method.

7.3. ANALYSIS

Methodologies and emissions factors used for estimating GHG emissions and removals for the pilot province are summarized in Table 7-2. Methodologies consist of a combination of Tier 2, Approach 2 method and Tier 3 (model), Approach 2 method using a mixture of Indonesia specific data and other defaults. Some Tier 1 default methods were applied where Indonesia specific data was not available.

[9]Biomass class represents forests with similar initial quantities of carbon that respond in similar ways to forest management events. Stratification of forest into biomass classes reduces variation and uncertainty of carbon stock estimates.

Table 7-2. Summary of methodologies and emission factors – Land use, land-use change and forestry sector

Greenhouse gas source and sink	CO_2		CH_4		N_2O		NO_x, CO	
	Method applied	EF	Method applied	EF	Method applied	EF	Method applied	EF
A. Forest land								
1. Forest land remaining forest land								
Managed natural forests (SMF)	T3	M						
Managed natural forest (forest degradation)	T3	M						
Biomass burning[10]	IE[11]		T2	D	T2	D	T2	D
Emissions from drained organic soils	T1/T2	D/CS	T1	D	T1	D		
Peat burning	T1	CS	T1	CS	NE		T1	CS
2. Land converted to forest land								
Enhancement of forest carbon stocks	T3	M						
B. Cropland								
1. Cropland remaining cropland	NE							
2. Land converted to cropland (deforestation)								
Oil palm plantations	T3	M						
Rubber plantations	T3	M						
Other crops	T1	D						
Biomass burning	IE		T2	D	T2	D	T2	D
Emissions from drained organic soils	T1/T2	D/CS	T1	D	T1	D		
Peat burning	T1	CS	T1	CS	NE		T1	CS
Emissions from mineral soil	T1	D			T1	D		
C. Grassland								
1. Grassland remaining grassland	NE							
2. Land converted to grassland	IE							
D. Wetlands								
1. Wetlands remaining wetlands	NE							
2. Land converted to wetlands	NE							
E. Settlements								
1. Settlements remaining settlements	NE							
2. Land converted to settlements	IE							
F. Other lands								
1. Other lands remaining other lands	NE							
2. Land converted to other lands								
Mining	IE							

EF = emission factor, CS = country specific, D = IPCC default, M = model,[12] NA = not applicable, NE = not estimated, NO = not occurring, IE = included elsewhere,[13] T1 = Tier 1, T2 = Tier 2 and T3 = Tier 3

[10]Biomass burning means burning of aboveground biomass and debris on site.
[11]CO_2 emissions from biomass burning are included in calculations for SMF, degradation and deforestation using T3 models.
[12]Models are used instead of single value emission factors to simulate forest dynamics such as growth, turnover and decomposition processes and the impacts of management events on carbon stocks and flows.
[13]All land converted from forest land to grassland, wetland, settlements and other land are included in forest land converted to cropland (other crops). Net emissions and removals are assumed to be zero after conversion.

GHG emission estimates are prepared for any period for which activity data is available and required for reporting. For the Central Kalimantan pilot province, this was 2000 to 2011.

When new activity data becomes available (e.g. a new year of forest cover change data is processed or a new forest map becomes available) the entire time series should be reprocessed. This is necessary to ensure time series consistency of data and to ensure that transitions that occur over multiple years are correctly identified (e.g. clearing followed by temporarily unstocked land followed by re-vegetation).

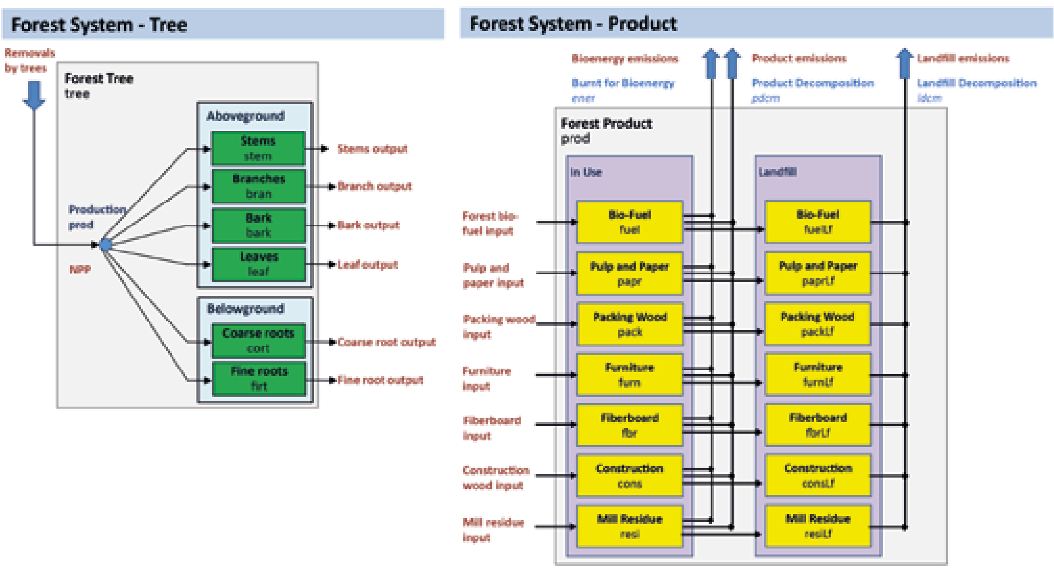
7.3.1. Forest land, oil palm and rubber estate crops

Carbon emissions and removals from above- and belowground biomass, debris and fire

The interim tool adopted in this standard method for quantifying GHG emissions and removals from deforestation, forest degradation, the role of conservation, enhancement of forest carbon stocks and the sustainable management of forest is the Full Carbon Accounting Model (FullCAM). FullCAM is a flexible integrating model that enables Tier 2 or Tier 3 spatial or nonspatial estimates of GHG emissions for agriculture, forestry and other land uses. It has been widely peer-reviewed and subjected to UNFCCC review processes as part of other national inventories. Indonesian data can be readily entered or default assumptions used where Indonesian-specific data is not available. Full details of FullCAM design and application can be found in Richards (2001; 2005).

Figure 7-1 summarizes the components and flows of carbon modelled within FullCAM for the Central Kalimantan pilot province GHG inventory.

Other process-based models may become available in the future and should be evaluated for their suitability for Tier 3 modelling of GHG emissions and removals from forests in Indonesia.



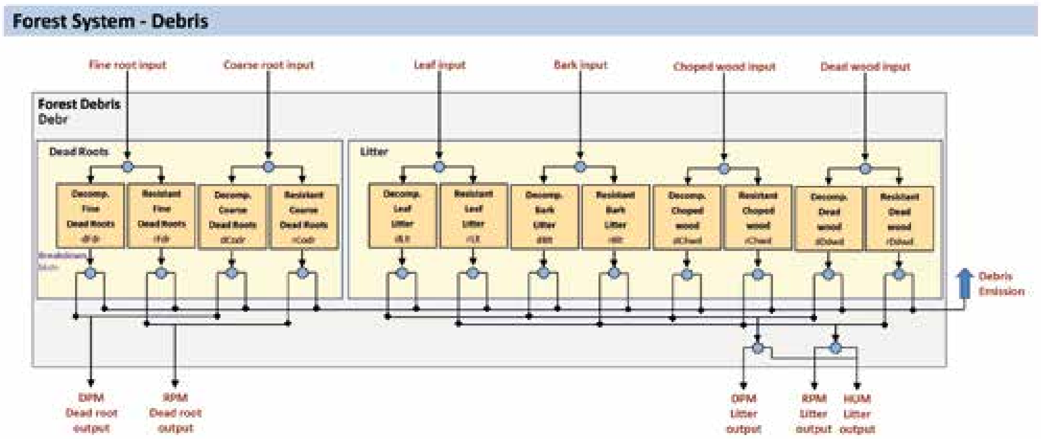


Figure 7-1. FullCAM components and carbon flows for tree, debris and product pools

FullCAM models changes in tree components as a result of production (growth) and turnover (loss of material, e.g. leaf and branch fall, root loss). FullCAM models changes in debris pools through inputs from turnover, and losses from breakdown (decomposition). Each component of aboveground biomass, belowground biomass and debris pools is tracked throughout the modelling period.

Changes in carbon stock of forest products (e.g. sawlogs, veneer logs, pulpwood) can be tracked in INCAS, however for the Central Kalimantan pilot province GHG inventory, these were not tracked due to insufficient data on wood product quantities and decay rates of wood products in use. However, carbon flows into the forest product pools are used to indicate whether carbon stocks impacted by forest management events stay on site (in debris pools) or leave the site (in forest product pools). Carbon entering the debris pools breaks down over time, gradually entering the soil or leaving the site as emissions to the atmosphere. Carbon entering the forest product pool is assumed to leave the site at the time of harvest as an emission to the atmosphere.

The soil model incorporated into FullCAM is not appropriate for modelling changes in soil organic carbon in Indonesian soils. Hence, changes to soil organic carbon in mineral soils are modelled using other methods described later in this standard method, and changes in soil organic carbon in organic soils are described in the *Standard Method – Peatland GHG Emissions*.

FullCAM is a process-based, event-driven model, meaning that changes in carbon stocks occur as a result of processes that continuously occur (e.g. production, turnover, breakdown) and events that periodically occur (e.g. harvesting, fire), usually with instantaneous impacts on carbon flows.

Processes

The main processes modelled for INCAS are:

- Production – moves carbon from the atmosphere to the plant pools. Production is the combination of photosynthesis, which moves carbon from the atmosphere to plant pools, and respiration, which moves a lesser amount of material in the opposite direction. The net result represents plant growth.
- Turnover – moves carbon from a plant pool to a debris pool as the material dies.
- Breakdown – moves carbon from the debris pool.

Data for the processes of production, turnover and breakdown are input to FullCAM for each biomass class based on data outputs from the *Standard Method – Growth and Turnover*.

Events

Events modify the quantity of carbon in each carbon pool and the destination of moved carbon. Event types include:

- thinning – harvesting events that remove some or all of aboveground biomass from the site and move some live biomass to debris pools;
- planting trees – tree planting events create new forests on areas not containing forest, or where a primary forest is being replaced by a secondary forest that has different growth characteristics to the primary forest;
- forest treatment – forest treatment events (e.g. fertilizer application) change forest growth rate when the inbuilt tree yield formula is used to model production (this was not used for INCAS for the Central Kalimantan pilot province GHG inventory);
- forest fires – fire events that release carbon (as CO_2 and CH_4) and nitrogen (N_2O) to the atmosphere, and move some carbon to the debris and soil pools.

Total carbon stock at any point in time represents the result of a series of events applied to the initial carbon stock, influenced by production, turnover and breakdown processes.

Event and forest management regime data are input to FullCAM based on data outputs from the *Standard Method – Forest Management Events and Regimes*.

FullCAM plot files

Data are input to FullCAM plot files that are 'run' to produce outputs. A plot file represents a unique combination of biomass class and management regime that impacts on carbon stocks over time. A management regime consists of a series of events occurring at specified times.

Plot files can be 'run' individually to model changes in carbon stocks for a given biomass class managed according to a given management regime with outputs expressed on a per hectare basis. Alternatively, plot files can be allocated areas and combined with other plot files in an estate file to model changes in carbon stocks across a group of forests (an estate).

Master plot file

A single master plot file was created containing parameters for all standard events and each biomass class and plantation type to be modelled. This acts as a database of FullCAM parameters from which all plot files are created.

Plot files

Individual plot files are created for every potential combination of events and biomass classes to be modelled. For the Central Kalimantan pilot province GHG inventory, the suites, management regimes and plot files are documented in the Excel file 'INCAS Suites_16062014. xlsx'.

For plot files containing natural primary or secondary forest, all tree and debris carbon pools are assumed to be in equilibrium prior to the first event. For secondary forests this is a simplifying assumption because it is likely that some ongoing growth would occur in the tree biomass pools and some debris from previous harvests would still be decaying. However, due to lack of data, a state of equilibrium is used as a conservative assumption.

Figure 7-2 provide examples of the outputs of plot files for deforestation, forest degradation, sustainable management of forest, and enhancement of carbon stocks.

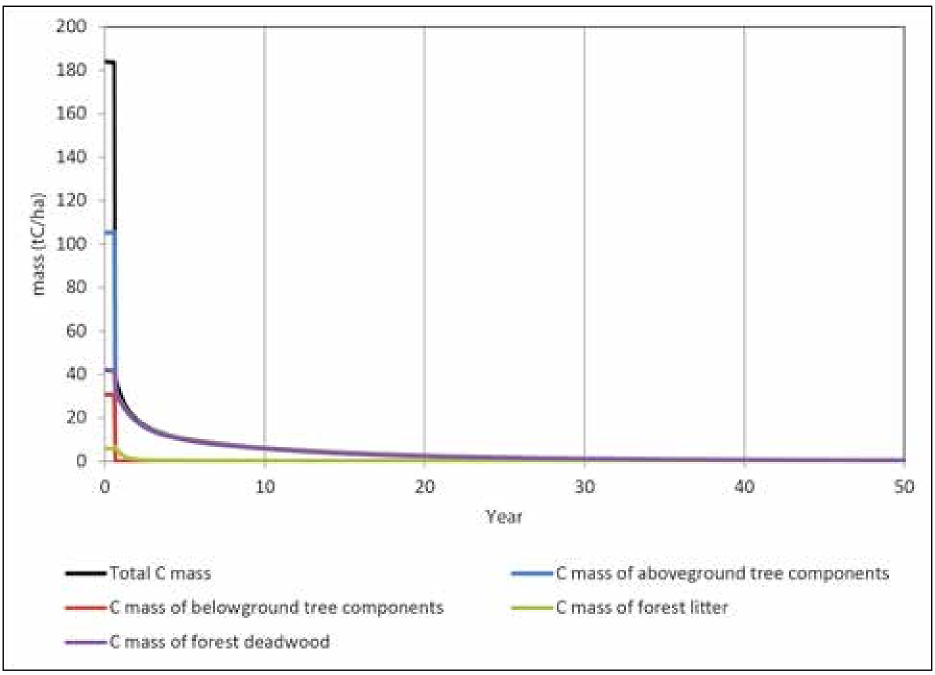


Figure 7-2. Example of the output of changes in carbon mass by carbon pool from deforestation

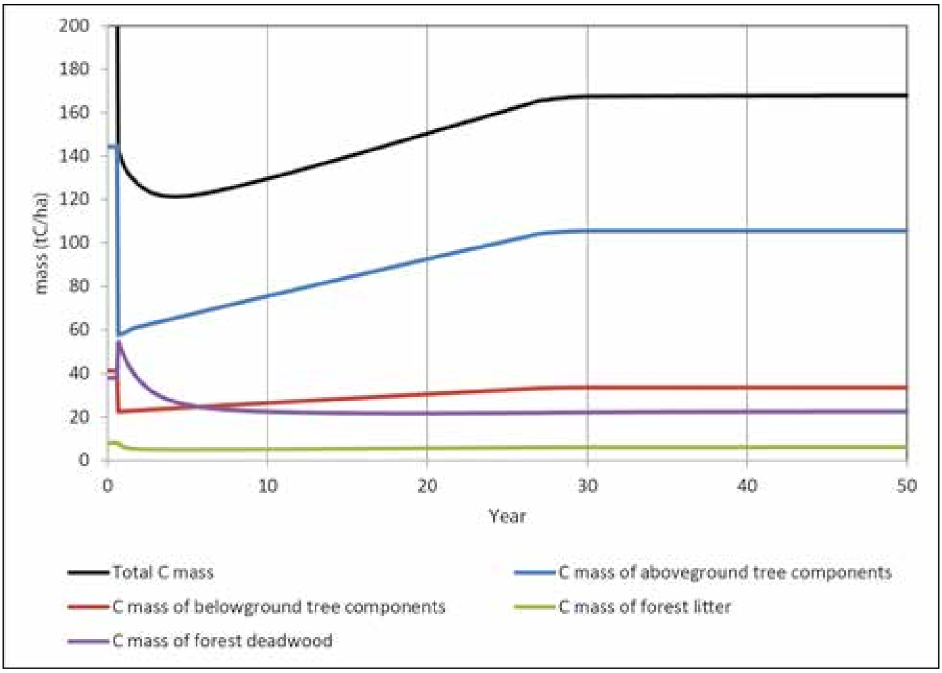


Figure 7-3. Example of the output of changes in carbon mass by carbon pool from forest degradation

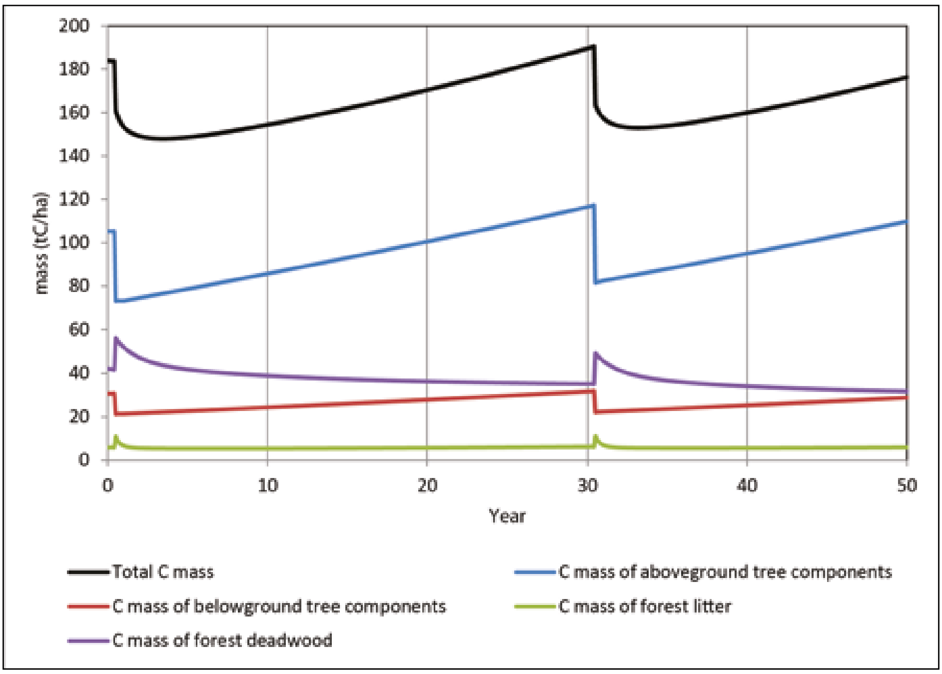


Figure 7-4. Example of the output of changes in carbon mass by carbon pool from sustainable management of forests

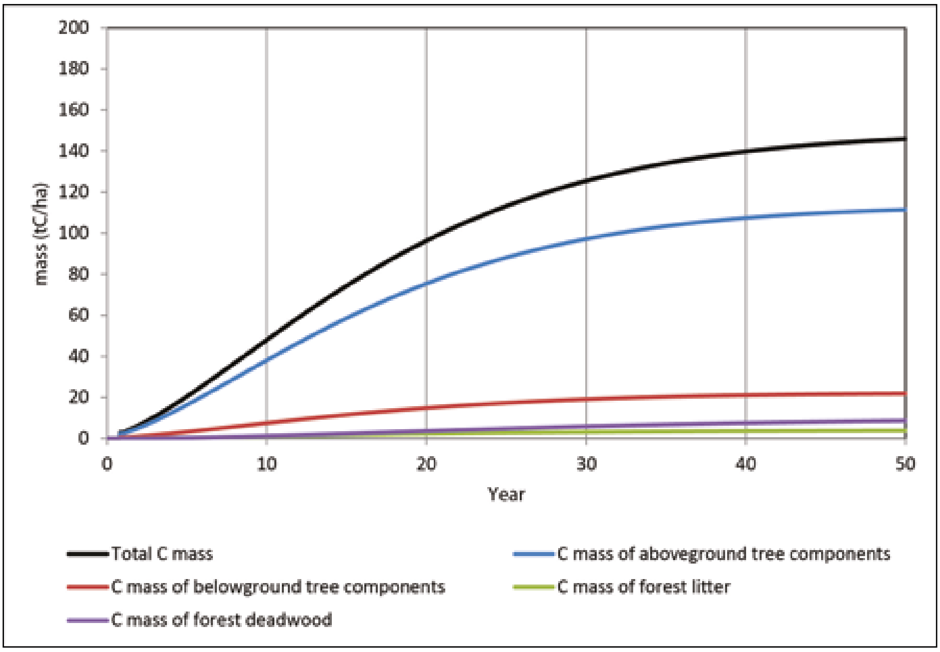


Figure 7-5. Example of the output of changes in carbon mass by carbon pool from enhancement of forest carbon stocks

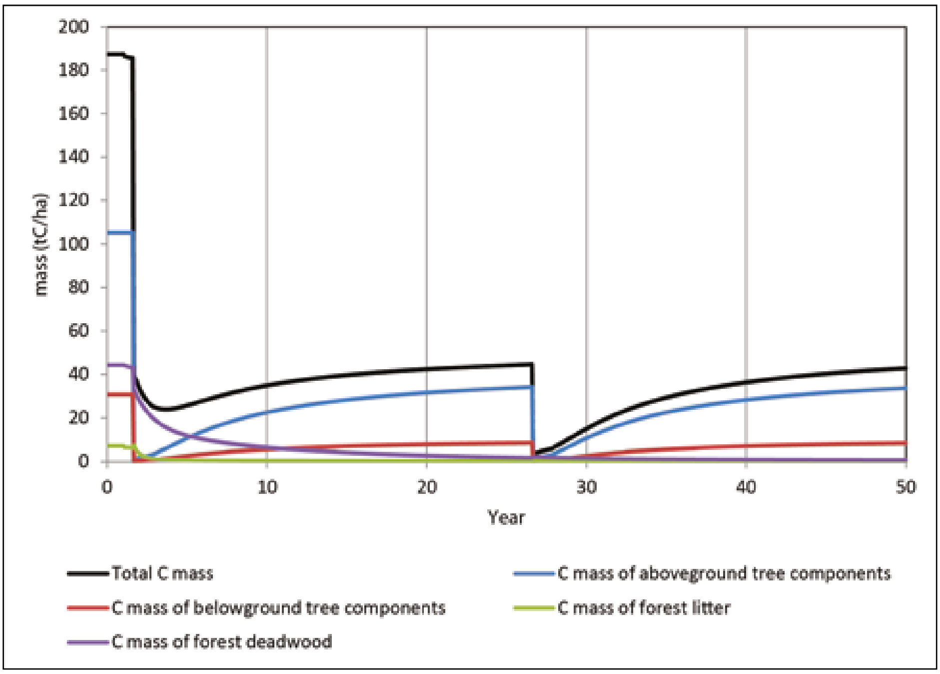


Figure 7-6. Example of the output of changes in carbon mass by carbon pool from conversion of forest to estate crop

Estate files

An estate file enables multiple plot files to be assigned an area for each year and modelled as a single group of forests. Area is derived from the spatial allocation of regimes process described in the *Standard Method – Spatial Allocation of Regimes*.

Depending on the reporting classes adopted by Indonesia, separate estate files can be run for specific locations (e.g. national, province, district, project) or reporting purposes (e.g. REDD+, UNFCCC BUR and National Communications, domestic land-use planning).

For example, for REDD+ reporting, each REDD+ activity reported is modelled as a separate estate: deforestation; the role of conservation; enhancement of forest carbon stocks; sustainable management of forest; and forest degradation (noting this definition has yet to be formally agreed by GOI). Descriptions of each of these REDD+ categories are provided below. Similarly, once more detailed spatial data for non-forest land uses is available, separate estates can be modelled for each UNFCCC reporting category. For the Central Kalimantan pilot province GHG inventory a simplifying assumption is applied resulting in all deforestation causing a transition from forest land to cropland.

Areas for each plot file within an estate are assigned using the *Standard Method – Spatial Allocation of Regimes*. For the Central Kalimantan pilot province inventory the areas are documented in 'Regime Areas_14112014.xlsx'.

Deforestation estate file

The deforestation estate file consists of plot files that model changes to forest carbon stocks and GHG emissions from clearing harvest and fire events resulting in deforestation. Decay of the debris pools may continue for many years after the initial events. For Central Kalimantan, subsequent cropland management events are only modelled for estate crops. All other crops are assumed to have a zero emission factor.[14] More detailed cropland management events should be included in the deforestation estate file once area and emissions data become available as part of the continuous improvement plan.

Forest degradation estate file

The forest degradation estate file consists of plot files that model changes to on-site carbon stocks resulting from events that result in primary natural forests becoming secondary natural forests (e.g. through selective harvesting, human induced fire or clearing followed by natural regeneration).

[14]Crops other than estate crops are assumed to emit all carbon removed each year through growth due to harvesting cycles of less than one year. i.e. All carbon sequestered is emitted at the time of harvest.

Sustainable management of forests estate file

The sustainable management of forests estate file consists of plot files that model changes to on-site carbon stocks resulting from a series of forest management events in secondary natural forests managed on a long-term harvesting cycle using planning and management methods that have minimal net impact on on-site carbon stocks in the long-term (i.e. emissions and removals are equivalent but separated over time).

Enhancement of forest carbon stocks estate file

The enhancement of forest carbon stocks estate file consists of plot files that model changes to on-site carbon stocks resulting from tree planting and subsequent management (including harvesting and fire) that results in the conversion of non-forest land to forest land.

Alternative estate files

Estate files can also be constructed to monitor GHG emissions and removals from other spatial and activity categories. For example, estates can be used to simulate GHG emissions and removals according to forest function as specified by the Ministry of Forestry (e.g. production forest, conservation and protection forest). This could include an estate file to monitor emissions from the REDD+ activity 'The role of conservation'.

7.3.2. Estate crops and other croplands

Emissions from oil palm estate crops and rubber estate crops on cropland converted from forest land within the modelling period are modelled using the process-based model described earlier. All other oil palm and rubber estate crops present at the commencement of the modelling period or subsequently established on land outside land controlled by the Ministry of Forestry are excluded from the Central Kalimantan pilot province GHG inventory. The approach for quantifying net emissions from these areas should be developed as part of the agriculture land use inventory component under the continuous improvement plan.

All other areas with a land-use change from forest to non-forest are assumed to have a common emission profile (i.e. common emission factor) from the year of deforestation onwards in perpetuity. Annual emissions for these areas are calculated by multiplying the total annual area in all non-forest land uses by the common emission factor.

To simplify calculations for the Central Kalimantan pilot province it was assumed for these lands that all biomass increment is removed during the same year as harvested crops (i.e. there is no net change in annual biomass in non-forest areas, hence no net emissions from biomass in non-estate crop croplands). This is equivalent to applying an emission factor of 0 tonnes C ha^{-1}.

Using these assumptions, there is no need to calculate net emissions from subsequent land use on lands converted from forest land to cropland, grassland, wetlands or other land. Hence, there is also no need to calculate areas by land cover class following conversion from forest land to other land uses other than estate crops. If other assumptions are used these calculation methods will need to be updated.

7.3.3. Carbon emissions from mineral soil

Annual carbon emissions from disturbed mineral soil are calculated using the Tier 1 method outlined by IPCC (IPCC 2003) in Section 3.3.2.2 for conversions from forest land to cropland and in 3.4.2.2 for conversions to grassland in order to estimate the effects of deforestation, as recommended in the *Global Forest Observation Initiative Methods and Guidance Document* (GFOI, 2013). The majority of deforestation events in the Central Kalimantan pilot province were conversion of forest land to cropland, with the remainder being conversion of forest land to other land uses. Detailed information for subsequent land uses after deforestation are not currently available. Hence, all areas of deforestation were assumed to represent forest land converted to cropland. Some deforestation areas may actually represent clearing of oil palm plantations that were misidentified in the forest cover change analysis.

Hence, calculations were based on conversion of forest land to cropland using Equation 3.3.3 in IPCC 2003.

Calculations are conducted in a simple Excel-based model (Mineral Soil Calc - Kalteng17112014.xlsx) based on the annual cumulative area of land converted from forest to non-forest.

For the Central Kalimantan pilot province, a single emission factor was applied to mineral soil in all non-forest land based on the assumption that all mineral soils were soils with low activity clay (LAC) minerals (see Table 3.3.3 in IPCC 2003). This could be improved in the future through use of more detailed soil information.

For the Central Kalimantan pilot province, no carbon emissions are assumed to occur on mineral soil for forest land which remains as forest land, in accordance with IPCC guidance which states:

> *"Under Tier 1, it is assumed that when forest remains forest the carbon stock in soil organic matter does not change, regardless of changes in forest management, types, and disturbance regimes … in other words that the carbon stock in mineral soil remains constant so long as the land remains forest (IPCC, 2003)."*

7.3.4. N_2O emissions from mineral soil

Annual N_2O emissions from disturbed mineral soil are calculated using the Tier 1 method outlined by IPCC (IPCC, 2003) in Section 3.3.2.3 for conversions from forest land to cropland. This uses the same area data and the carbon stock change data calculated above for annual carbon emissions from disturbed mineral soil. Calculations are performed in the same simple Excel-based model (Mineral Soil Calc - Kalteng17112014.xlsx) described above.

7.3.5. Non-CO_2 emissions from surface fire

Non-CO_2 emissions from burning biomass in surface fires are calculated using the carbon released from fire events modelled in FullCAM multiplied by IPCC default N/C ratios and emission ratios described in Section 3.2.1.4 (IPCC, 2003) and using Equation 3.2.19.

Required emission ratios are provided in Table 3A.1.15 and the N/C ratio for the fuel burnt is approximated to be about 0.01 (IPCC, 2003). Calculations of non-CO_2 emissions from burning biomass in the Central Kalimantan pilot province inventory are conducted in the simple Excel-based model (Fire_non_CO2emissions_Kalteng_V2_20141117.xlsx).

Emissions are reported as total tonnes of CH_4, CO, N_2O and NO_X. CH_4 and N_2O emissions are converted to CO_2-equivalent emissions using global warming potentials of 28 and 265, respectively. CO and NO_x are secondary GHGs and are not converted to CO_2 equivalent.

Non-CO_2 emissions from fire in peatlands are addressed in the *Standard Method – Peatland GHG Emissions*.

7.4. QUALITY CONTROL AND QUALITY ASSURANCE

Quality control focused on ensuring that data obtained from standard methods and other sources was in the format required for modelling and met the requirements for accuracy, consistency, comparability and completeness. This included checking that all required data input parameters were available, correct units were used, the geographic and temporal coverage for the region and time period being modelled was fully covered, and data sources were clearly documented. If inconsistencies are found, these should be resolved prior to proceeding with modelling. Resolution may require revisiting the standard methods or other source documents and/or seeking clarification from authors of source analyses.

Quality control should be undertaken by the team responsible for modelling. For example, in the Central Kalimantan pilot province GHG inventory, this was undertaken by the INCAS team.

Quality assurance should be conducted at each step in modelling and reporting, including:

- reviewing all steps of the modelling process to ensure they have been followed;
- ensuring that data outputs from each step are correctly calculated (by manually checking a sample of individual calculations);
- confirming that correct units are used and conversions between units have been accurately calculated;
- ensuring that the outputs are correctly transcribed from models to reports.

Quality assurance should be undertaken by an independent party not involved directly in conducting the calculations. For example, in the Central Kalimantan pilot province inventory this was undertaken by INCAS team members not directly responsible for modelling and by external technical advisors provided by IAFCP.

Quality assurance may identify errors in data, methods, calculations or reporting that should be rectified prior to finalizing the reporting.

7.5. OUTPUTS

7.5.1. Reporting years

GHG emissions and removals can be estimated for any time period using the INCAS approach, provided the historical data is available, or forecast (historical or future) activity data is assumed (e.g. through scenarios). The period for reporting should be selected to meet reporting requirements.

Emissions and removals from land use are assigned to the year in which activities occur, or the year in which lag emissions occur from events in previous years (e.g. decay of forest debris from logging in earlier years). For some data the exact date of the activity may be unknown, but the year of activity can be estimated. For example, if forest cover is detected at a specific location in 2000 but not in 2001, then a forest loss event occurred in 2000. If forest is not detected in 2000 but forest is detected in 2001, then forest gain occurred in 2000.

7.5.2. Land-use transition matrices

The annual area by land-use class and the change from one class to another is reported in the following land-use transition matrices. A separate table is required for each year included in the GHG inventory period. The area reported in the final area column is the land area by category at the end of the year.

Forest located on peat soils is included in the forest land class, not in the wetland class.

For the Central Kalimantan pilot province, all non-forest land was assumed to be cropland or other land due to insufficient data available at the time of reporting to differentiate into other land-use categories. Consequently, the land-use transition matrices were not included. The land-use transition matrices (e.g. Table 7-3) should be developed when better spatial data becomes available to enable differentiation between non-forest land uses.

Table 7-3. Land use transition matrices

Year	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Final area
Forest land							
Cropland							
Grassland							
Wetlands							
Settlements							
Other land							
Initial area							
Net change							

7.5.3. Reporting units

Outputs for each carbon pool are converted to common reporting units as shown in Table 7-4.

Carbon stock (tonnes C ha^{-1}) by carbon pool is quantified in FullCAM at each time step in the simulation. Change in carbon stock between points in time is calculated outside FullCAM by exporting outputs to Excel and calculating the difference between the time steps of interest. For INCAS, this is annual carbon stock change, measured in tonnes C ha^{-1} yr^{-1}.

Non-CO_2 emissions from burning forest biomass are calculated by exporting to Excel from FullCAM the annual quantity of C mass emitted due to fire from trees and forest debris, and converting these to emissions of CH_4, N_2O, CO and NO_x using the default emission ratios and N/C ratio (IPCC, 2003).

Emissions from organic matter in disturbed mineral soil are quantified as annual change in carbon stock in tonnes C ha^{-1}, from which annual N_2O emissions (in tonnes N_2O ha^{-1}) are calculated. Both carbon stock change and N_2O emissions are converted to CO_2-equivalent emissions.

Carbon emissions from biological oxidation of peat and peat fire are quantified as change in peat carbon stock in tonnes C ha^{-1}, converted to CO_2-equivalent emissions. Non-CO_2 emissions from peat fire are quantified directly in tonnes CO ha^{-1} and tonnes CH_4 ha^{-1}. Methane emissions are converted to CO_2-equivalent emissions.

Change in carbon stock is converted to CO_2-equivalent emissions by multiplying by 44/12 (ratio of molecular weight of carbon dioxide to carbon).

Methane (CH_4) and nitrous oxide (N_2O) emissions are converted to CO_2-equivalent emissions by multiplying by the 100-year global warming potential for each gas, which are 28 and 265 respectively (Myhre et al., 2013).

Table 7-4. Model outputs and reporting units

Source	Model output	Initial output unit	Conversion factor	Reporting unit	GWP[15]	Common reporting unit
Biomass and woody debris	CO_2-C	tonnes C ha^{-1}	44/12	tonnes CO_2	1	tonnes CO_2-e
Biomass burning	CH_4	tonnes CH_4 ha^{-1}	1	tonnes CH_4	28	tonnes CO_2-e
	N_2O	tonnes N_2O ha^{-1}	1	tonnes N_2O	265	tonnes CO_2-e
	CO	tonnes CO ha^{-1}	1	tonnes CO	NA	NA
	NO_x	tonnes NO_x ha^{-1}	1	tonnes NO_x	NA	NA
Mineral Soil	CO_2-C	tonnes C ha^{-1}	44/12	tonnes CO_2	1	tonnes CO_2-e
	N_2O	tonnes N_2O ha^{-1}	1	tonnes N_2O	265	tonnes CO_2-e
Biological oxidation of drained peat	CO_2-C	tonnes C ha^{-1}	44/12	tonnes CO_2	1	tonnes CO_2-e
Peat fire	CO_2-C	tonnes C ha^{-1}	44/12	tonnes CO_2	1	tonnes CO_2-e
	CH_4	tonnes CH_4 ha^{-1}	1	tonnes CH_4	28	tonnes CO_2-e
	CO	tonnes CO ha^{-1}	1	tonnes CO	NA	NA
Direct emissions from drained organic soils	N_2O	tonnes N_2O ha^{-1}	1	tonnes N_2O	265	tonnes CO_2-e

7.5.4. Reporting categories

Reporting categories should be defined by the Government of Indonesia, and may change as domestic and international reporting commitments change.

Annual GHG emissions can be reported according to the UNFCCC reporting categories shown in Table 7-5 or as REDD+ categories. The correlation between REDD+ and UNFCCC categories adopted for the Central Kalimantan pilot province GHG inventory are shown in Table 7-5.

[15]GWP – 100-year Global Warming Potential from (Myhre et al. 2013). CO and NOx are secondary greenhouse gases and are not assigned GWP values.

Table 7-5. Comparison between UNFCCC reporting categories and REDD+ activities included in the Central Kalimantan pilot province GHG inventory

REDD+ activity	UNFCCC reporting category
Sustainable management of forest	Forest land remaining forest land
Forest degradation	
The role of conservation	
Deforestation	Forest land converted to cropland *or* grassland *or* wetland *or* settlements *or* other land
Enhancement of forest carbon stocks	Cropland *or* grassland *or* wetland *or* settlements *or* other land converted to forest land

REDD+

For the Central Kalimantan pilot province, the REDD+ categories reported cover total net GHG emissions per annum from activities on land associated with forestry and forest land-use change between 2000 and 2011.

Deforestation

The deforestation account for Central Kalimantan represents the sum of annual GHG emissions resulting from deforestation related events across the entire province for the time period modelled (i.e. conversion of forest land to non-forest land).

Note: Future emissions arising from past disturbances should be included in any forward-looking accounts generated.

Forest degradation

There is no currently agreed definition of forest degradation. For this GHG inventory, the forest degradation account represents the sum of annual GHG emissions and removals from events that result in primary natural forests becoming secondary natural forests (e.g. through selective harvesting, human induced fire, or clearing followed by natural regeneration). Conversion of natural forest to timber plantations would also be included, however no areas were able to be identified using currently available data.

The role of conservation

There is no currently agreed definition for how to quantify the role of conservation. For the purpose of GHG inventory, the role of conservation could represent the sum of annual GHG emissions avoided by implementing (or enforcing) management practices in conservation or protection forests. This could include actions that avoid illegal logging or encroachment on conservation or protection forests. INCAS is designed to model the impact of such activities. However, the role of conservation was not included in the Central Kalimantan pilot province GHG inventory due to insufficient clarity about land management activities to be modelled. Further analysis of the types of conservation activities and their impact on GHG emissions should be included in the INCAS improvement plan.

Sustainable management of forest

The sustainable management of forest account for Central Kalimantan represents the sum of annual GHG emissions and removals resulting from ongoing management of land that was secondary natural forest at the start of the reporting period (i.e. forest land remaining forest land).

Enhancement of forest carbon stocks

The enhancement of forest carbon stocks account for Central Kalimantan represents the sum of annual GHG emissions and removals resulting from replanting of forest on deforested land that has been included in the pilot province account (i.e. conversion of non-forest land to forest land).

7.6. UNCERTAINTY ANALYSIS

The INCAS framework has been designed to use the best available data for each input. Every effort has been made to reduce uncertainty for each input variable and modelling step through quality control and quality assurance processes.

An initial quantitative uncertainty analysis was carried out on key plot files using a Monte Carlo Method (IPCC Approach 2). The uncertainty analysis was conducted to:

- demonstrate the use of Monte Carlo methods for assessing uncertainty;
- provide an indicative uncertainty estimate for the Central Kalimantan pilot province account;
- identify the key parameters that drive emissions estimates to allow more targeted research under the continuous improvement plan.

The uncertainty analysis is based only on the statistical ranges of the data used in FullCAM. It does not deal with assumptions used in the system such as:

- the average carbon stock of a forest type is the same as the carbon stock of the forest that is changing;
- the methods used to calculate inputs are unbiased, in particular the use of allometric models to convert basic measurements to biomass.

7.6.1. Testing the approach 2 method

An uncertainty analysis was conducted in FullCAM using risk analysis software (Pallisade@Risk). FullCAM uses @Risk to conduct Monte Carlo analyses. To do this, FullCAM runs thousands of times. For each run the parameters are varied within a set range (as set by the user) and the results (both inputs and outputs) loaded to @Risk. Results were produced to show the effect of varying parameters on total emissions in the first year of the simulation (where most emissions occur due to deforestation) and at year 10 to assess the effects of parameters on lag emissions.

The key parameters input from the INCAS analyses (tree and debris masses) were varied within the 95% confidence interval of the mean. As these data are based on several hundred plots, the confidence intervals are tight – for living biomass in secondary swamp forests the 95% CI was +/-1.45%. This represents the mean for the entire forest estate rather than a single piece of forest.

For parameters where Indonesia specific data (turnover and decomposition rates) were not available the parameters were varied by +/-50%. This is likely an overestimate for many parameters, but without further information, this is considered reasonable.

The forest inventory data was used to produce estimates of total aboveground biomass. For use in FullCAM these data were divided into components (stem, branch, bark and leaves). Each of these components was subject to Monte Carlo analysis. However, using Monte Carlo analysis in this way would lead to an underestimate of uncertainty as the components vary independently (e.g. stem mass could increase, while others could decrease). If these components were measured separately this would be valid, but this is not the case when they have been derived from a total AGB. To prevent this error, these parameters were correlated using a correlation matrix.

7.6.2. Uncertainty analysis results – Plot level uncertainty

Figures 7-7 – 7-10 provides examples of uncertainty analysis to show the effect of varying parameters on total emissions in the first year of the simulation and at year 10 to assess the effects of parameters on lag emissions using risk analysis software (Pallisade@Risk).

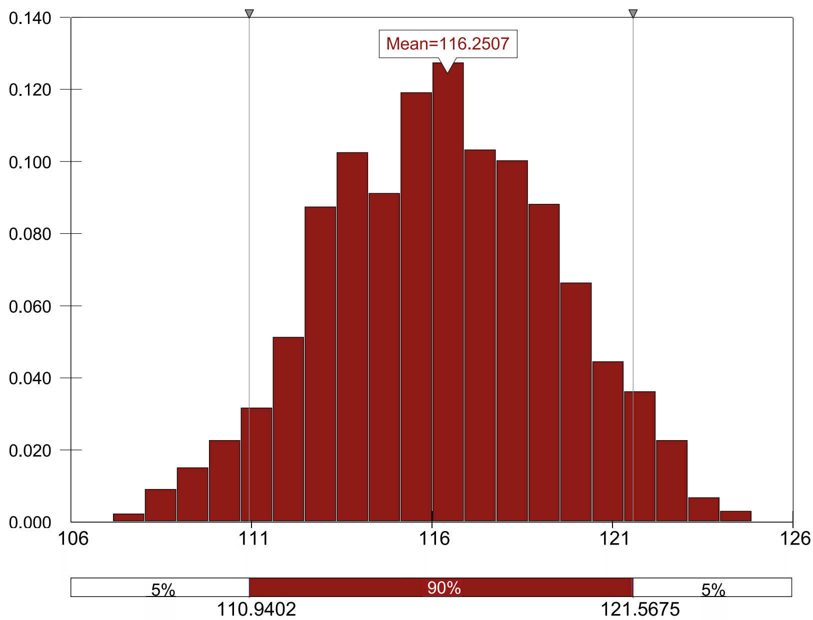


Figure 7-7. Distribution for net carbon mass emitted in secondary swamp forest due to deforestation in the first year of the simulation

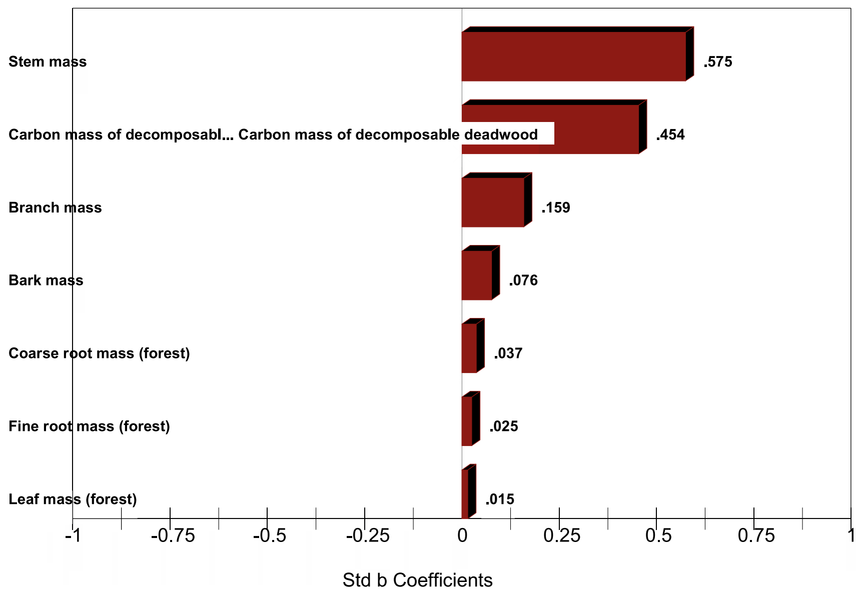


Figure 7-8. Regression sensitivity for net carbon mass emitted in secondary swamp forest due to deforestation in the first year of the simulation

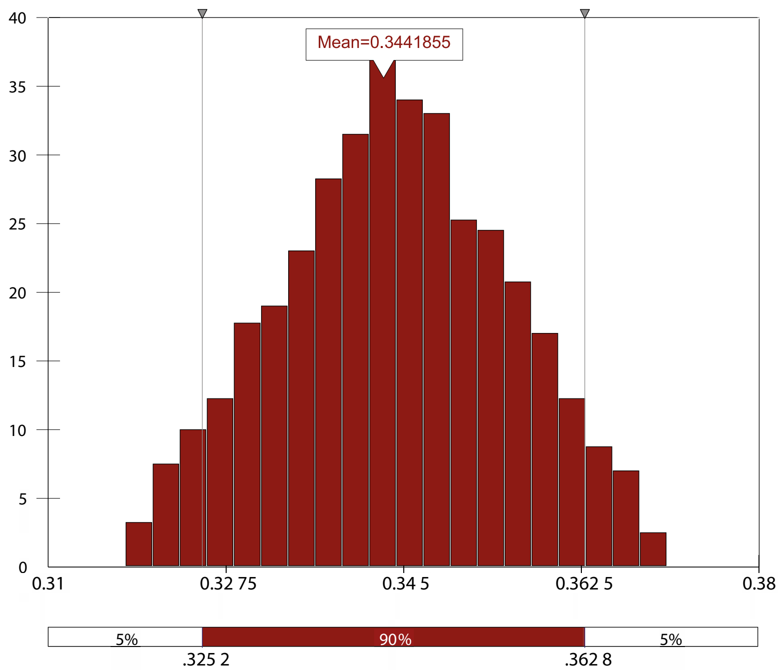


Figure 7-9. Distribution for net carbon mass emitted in secondary swamp forest at 10 years after deforestation

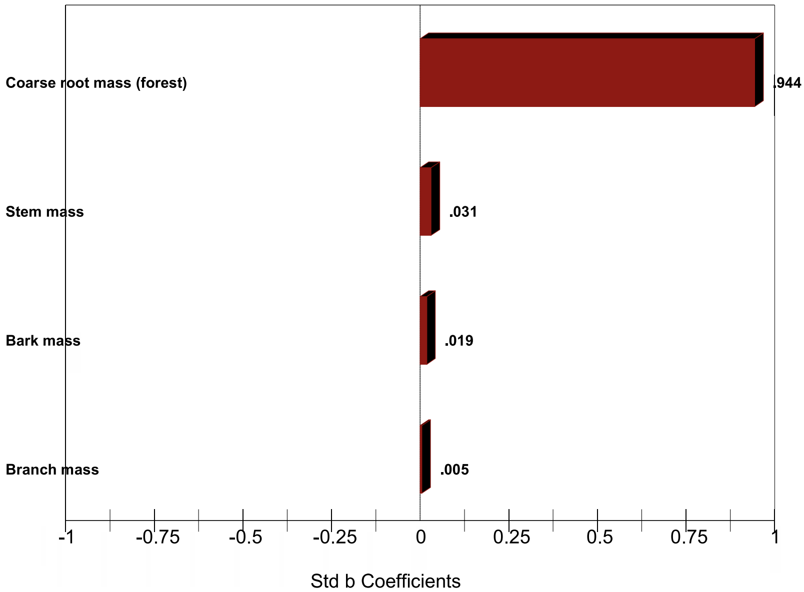


Figure 7-10. Regression sensitivity for net carbon mass emitted in secondary swamp forest at 10 years after deforestation

7.6.3. Uncertainty analysis discussion

The uncertainty analysis suggested that the provincial level estimates of emissions are reasonably accurate. This is largely due to the large number of plots that were used to estimate the average carbon stocks for trees and debris. However, this does not account for the assumptions used. The results should be considered indicative until further testing of the assumptions is completed.

The uncertainty presented here is for a single forest type. It does not include the effects of uncertainty in area. To do this would require a detailed analysis of the final, spatially allocated land-use change products. This will be undertaken as part of the continuous improvement process of INCAS.

The key finding is that the parameters that affect emissions from deforestation vary depending on the time interval since deforestation occurred. In the year of deforestation the initial mass of the trees, in particular aboveground biomass, is most important. However after 10 years the initial mass of root that remained on-site to decay was more important. As the total area in the account increases through time, the importance of parameters that affect lag emissions will increase. This is particularly important for peatlands that may continue to emit GHG for decades following clearing. The analysis shows that incorporating all these emissions within a single system is important when trying to estimate uncertainty.

The uncertainty estimates produced here are at the provincial level. They do not represent the uncertainty of the model for a single point or forest in the landscape, but rather the uncertainty in the provincial level estimates. Point level uncertainty would be considerably greater due to the variability in the results. The Monte Carlo approach is suited to the more advanced methods used in this detailed account. These will be refined in future accounts.

7.7. LIMITATIONS

Data limitations are described in each of the standard methods that produced modelling inputs. The INCAS framework is designed to enable modelling to proceed using the best available data, with assumptions used to fill data gaps. When improved data becomes available the system can be rerun for the entire time series producing consistent inter-annual results. Examples of data limitations for the Central Kalimantan pilot province GHG inventory are:

- broad biomass classes had to be adopted due to data limitations preventing more detailed forest stratification;
- not all available spatial data could be used. This limited the level of detail attainable for area data, which reduced the potential accuracy of model outputs, because activity data (i.e. area) is one of the main factors influencing GHG emission estimates;
- forests that occur outside land designated by the Ministry of Forestry as one of six natural forest classes or timber plantations were excluded from the analysis because no data was available about forest type, condition or management;
- spatial and temporal accuracy of burnt area data has high uncertainty;
- the lack of clear definitions for forest degradation and sustainable management of forest made it difficult to differentiate between these REDD+ activities, potentially resulting in misallocation of area between these activities.

Modelling limitations arise due to the characteristics of Indonesian forest management systems, forest types, soil types and data availability; this mean that some processes and events in Indonesia are not easily modelled using FullCAM, which was originally designed to meet specific GHG emissions reporting requirements for Australia's national GHG inventory reporting.

- FullCAM does not permit planting events to occur if there is already a forest present. This means that enrichment planting cannot be modelled as a single event.
- FullCAM cannot model a thinning response when using yield tables (e.g. when a primary forest is selectively harvested to become a secondary forest) as required in Indonesia, due to the unavailability of data required to use the tree yield formula. This means that when modelling a selective harvest in primary forest (resulting in a secondary forest) it is necessary to firstly clear the existing forest, then plant a new secondary forest with initial biomass equivalent to the biomass stock of a mature secondary forest.

- Soil models within FullCAM are not suitable for Indonesian mineral soil types.
- FullCAM does not include organic soil (peat) as a pool that can be modelled.
- Some data required by FullCAM is not available in Indonesia, requiring default values or assumptions to be adopted (e.g. debris decay rates were not available for Indonesia, hence default decay rates were adopted from tropical rain forest in Australia).

7.8. IMPROVEMENT PLAN

- Model parameterization and running should be an iterative process to enable data limitations to be effectively identified and rectified. For example, an iterative process between spatial analysis and suite and regime development would provide a more efficient and comprehensive basis for spatial allocation of regimes.
- Streamlining of spatial allocation of regimes would significantly improve the efficiency of modelling and enable greater use of available spatial data. Development of a spatial analysis tool should be a priority.
- Improved methods for determining burnt area spatial extent, timing and frequency of fires should be developed.
- Cropland management events should be included in the deforestation estate file once area and emissions data become available.
- The approach for quantifying net emissions from oil palm and rubber estate areas should be developed as part of the agriculture land-use inventory component of future GHG inventories.
- More detailed soil information should be developed.
- More comprehensive uncertainty analysis should be conducted.

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APPENDIX 1:
STEPS FOR PREPARING SPATIAL DATA FOR USE IN INCAS

GIS ANALYSIS STEPS

Rename all shape files to conform to a standard naming convention.

1. These should be short (no more than 8 characters).
2. The name should describe the purpose of having these data in the analysis.
3. It must contain the year (if appropriate).

Central Kalimantan boundary	Bound
Forest function	function
Soil type	peat
Forestry utilization	concess
Estate crops	Crop
Burnt areas	Fire00, Fire01, fire02,… fire12
Forest type - 2000, 2003, 2006, 2009, 2011	type00, type03, type06, type09, type11
Annual forest clear - 2000–2012	clear00, clear01,…., clear11
Annual forest reveg - 2000–2012	reveg00, reveg01,…., reveg11

4. There is no need for information about projection, source, location or previous processing steps. However, first make sure that all data have the same projection information in their metadata statement.

Create standard attributes for each input shape file.

1. Each data set should only contain data that will be needed to identify the suite.
2. Remove all fields that are not needed in the next steps (e.g. pre-calculated area attributes are confusing in the outputs of unions).
3. Field names should match the column headings from the regime and activity database tables.

bound	Kalteng
function	function
peat	peat
concess	concess
crop	comodity
Fire01, fire02,... fire09	fire
type00, type03, type06, type09, type11	PL{yr}_ID
clear00, clear01,...., clear12	clear{yr}
reveg00, reveg01,...., reveg11	reveg{yr}
clearreveg	Clearreveg
revegclear	revegclear

Create standard values for each input shape file.

1. Each field should only contain values that will be needed to identify the suite.
2. The value should match the entries in each row from the regime and activity database tables.

kalteng	0/1 (ie 1 = inside province, 0 = outside province)
function	Conservation, protection, production
peat	0 /1 (ie 1 = peat, 0 = mineral)
harvest system	RIL, conventional, No
commodity	Karet (rubber) , Kelapa Sawit (oil palm)
Fire{yr}	0/1
PL{yr}-ID	2001, 2002, 2004, 2005, 20041, 20051, 2006
Clear{yr}	0/1
Reveg{yr}	0/1
clearreveg	Year of start of transition (2000–2008)
revegclear	Year of start of transition (2000–2008)

Select relevant LAPAN forest cover change data

1. Rename LAPAN clearing (forest loss) data to standard naming convention **clear00**, **clear01**,..., **clear11 & reveg00**, **reveg01**,..., **reveg11.**
2. Sum all annual LAPAN clearing data to create a new shape file called **everclear.**
3. Sum all annual LAPAN **reveg** data to create a new shape file called **everreveg.**
4. Union everclear and everre-veg to create a single shape file of all LAPAN change data keeping all annual attributes.

5. Create a new field called area and calculate the area in hectares of each new unique combination of polygons of change through time.
6. Remove all polygons with an area less than 0.25Ha.
7. Save a new shape file for each year based on each annual attribute having a value of 1.

Forest Change Areas (6 natural classes, plus plantation areas)

1. The 6 natural forest types and plantation forest were extracted from land cover map into a separate shape file.
2. Intersect the relevant years of deforestation one at a time and union the data sets that relate to only 1 time step.

Union the data sets that are constant through time

Suitebase = union (bound, function, peat, concess, crop)

Create Suite data sets

Union the data sets that relate to only 1 time step

Temp00 = union (clear00, reveg00, fire00, type00)

Temp01 = union (clear01, reveg01, fire01, type00)

Temp02 = union (clear02, reveg02, fire02, type00)

Temp03 = union (clear03, reveg03, fire03, type03)

Temp04 = union (clear04, reveg04, fire04, type03)

Temp05 = union (clear05, reveg05, fire05, type03)

Temp06 = union (clear06, reveg06, fire06, type06)

Temp07 = union (clear07, reveg07, fire07, type06)

Temp08 = union (clear08, reveg08, fire08, type06)

Temp09 = union (clear09, reveg09, fire09, type09)

Temp10 = union (clear10, reveg10, fire10, type09)

Temp11 = union (clear11, reveg11, fire11, type11)

Create the multiple transition data sets

1. Use Excel to determine which polygons had a clear event followed by a reveg event PLUS a re-veg event followed by a clear event.
2. Calculate new fields for each (value being the year of the first event) to join using the excel field that matches the shape file polygon ID.
3. The output of this action was a new shape file called clearreveg00 -> 11 and revegclear00-11.

4. Union each of the shape files with an annual component to the base union

Suite00 = union (suitebase, temp00, clearreveg00, revegclear00)

Suite01 = union (suitebase, temp01, clearreveg01, revegclear01)

Suite02 = union (suitebase, temp02, clearreveg02, revegclear02)

Suite03 = union (suitebase, temp03, clearreveg03, revegclear03)

Suite04 = union (suitebase, temp04, clearreveg04, revegclear04)

Suite05 = union (suitebase, temp05, clearreveg05, revegclear05)

Suite06 = union (suitebase, temp06, clearreveg06, revegclear06)

Suite07 = union (suitebase, temp07, clearreveg07, revegclear07)

Suite08 = union (suitebase, temp08, clearreveg08, revegclear08)

Suite09 = union (suitebase, temp09)

Suite10 = union (suitebase, temp10)

Suite11 = union (suitebase, temp11)

Note: due to the fact that the decision rules on temporary unstocking was a minimum gap of 3 years, cycles after 2009 will only be able to be determined after the remote sensing data for a longer time series is available.

Calculate Suite values

Assign the value to each polygon from the database

1. Delete any unnecessary columns (such as the Feature IDs and areas from individual shape files that were unioned) as these no longer relate to the final spatial data.
2. Add an item for ***area*** and calculate it for all polygons.
3. Add a new field called FID_Unique and calculate it to be the same value as FID – this will allow the completed spreadsheet to be joined back to the spatial data.
4. Export to Excel format.

Find areas to allocate to each suite (Excel calculation)

1. Identify all polygon records that relate to the same unique criteria set out in the regime database table.
2. Move all the columns so they are in a consistent order.

FID	Area	Forest type	Function	Soil	Concess	Crop	Fire	Clear reveg clearreveg revegclear

For each column, calculate a new single number code to represent the value options. E.g.

Field Concess:

value = Conventional -> code 1

value = RIL -> code 2.

As the current value for forest type can be either 4 or 5 characters, the raw input has 100,000 added so all new codes are the same length.

All no-data values are given a code of 9.

A new "transition" field was created from the values for Clear, reveg, clearreveg, revegclear – in that order.

i.e. 1999 = clearing, 9199 = reveg, 9919 = clearreveg, 9991 = revegclear

For all other recode values see Look up table in Excel spreadsheet.

By concatenating all these codes, a new unique combination code of all the criteria is created.

There are no regimes on forest type 100000 (originally 00000).

Note: When copying this code it is a formula and in text format. So, you need to 'paste values' then convert to a number - ensuring the formatting style is 'number' – default for a number this big is 'scientific'.

3. Remove all polygons where the forest type is not identified as one of the 6 natural forest classes or plantation forests – this does not appear in a regime to be modelled and is only in the data as not all input layers were clipped to this layer prior to union.

4. Remove all polygons with an area less than 1 ha. (NB. This is NOT a minimum area calculation it is purely to limit the number of rows to allow the Excel calculation to take place in a reasonable amount of time (i.e. less than 24 hours).

   The cause of many of the rows of data with an area of less than 1 ha is (spatially) just slivers from where the polygons of all the various source data sets overlap unintentionally.

   This process is repeated for all Excel files representing the annual GIS data, and a new column added and filled with the relevant year these polygons came from.

5. The key columns (spatial FID, code, area, year) for all years are then copied to a new spreadsheet.

   The same unique combination process has been done on the regime database with relevant plot file information enabling this code to be used as a unique ID and join the regime to each polygon record (using 'vlookup' command).

6. A pivot table is created to output the area of each regime in each year.

7. Calculate Peat regimesSum all PL2000, PL2003, PL2006, PL2009, and PL2011 to create a new shape file called everPL

   Peat area= clip (peat, everPL)

   Peat everfire = clip (peat, everfire)

   Peat everclear = clip (peat, everclear)

   Peat Regimes = union (peat area, peat everfire, peat everclear)

   Note: Peat regime areas are calculated for the entire peat area in Central Kalimantan. Land cover maps (MoF) are used for all forested and non-forested areas to derive areas of peatland to be modelled. This includes paddy rice, crop, plantations and other non-forest area in addition to the 6 natural forest classes and timber plantations.

Spatial Quality Assurance

1. Add the suite{yr} shape files to ArcGIS and join the annual regime area tables using FID_Unique and Spatial_ID.
2. Classify the symbology using the joined item "regime".

   Eversuite = union (suite00, suite01, suite02, suite03, suite 04, suite 05, suite 06, suite07, suite 08, suite 09, suite, 10, suite 11).

   Note: For any suites that "look wrong" identify the regime it belongs to and decide if the area needs to be removed from the estate file before running the account.

APPENDIX 2: RULES FOR SPATIAL ALLOCATION OF REDD+ AND UNFCCC CATEGORIES

The following rules are used by INCAS to define changes that affect forest carbon stocks and GHG emissions.

REDD+ activity	UNFCCC reporting categories	INCAS detailed system – rules for spatial allocation
Deforestation	Forest land converted to cropland Forest land converted to grassland Forest land converted to wetland Forest land converted to other land	Where forest cover loss occurs (LAPAN data) within primary and secondary forest land cover classes (Planology data) and forest cover gain (LAPAN data) does not occur during the modelling period (i.e. the land stays as non-forest). UNFCCC 'converted to' categories are determined using land cover classes (Planology data) in the table below.
Forest degradation	Forest land remaining forest land	1) Where forest land cover class (Planology) changed from primary forest to secondary forest and LAPAN did not identify forest cover loss. 2) Where forest cover loss was detected (LAPAN) followed by forest cover gain (LAPAN) within primary forest land cover class, during the modelling period. This represents 'temporarily unstocked' forest land.
Sustainable management of forest	Forest land remaining forest land	1) Where LAPAN did not identify forest cover loss within primary or secondary forest land cover classes (Planology data) but concession data indicates harvesting occurring (reduced impact logging or conventional logging). 2) Where forest cover loss was detected (LAPAN) followed by forest cover gain (LAPAN) within secondary forest land cover class, during the modelling period. This represents 'temporarily unstocked' forest land.
Enhancement of forest carbon stocks	Cropland converted to forest land Grassland converted to forest land Wetland converted to forest land Other Land converted to forest land	Where plantation forest land cover class (Planology data) occurs where it did not occur in the previous year. Concession data is used to determine plantation establishment year.
	Cropland remaining cropland	Cropland categories as shown in Planology land cover classes.

Note: The Planology land-cover classes do not capture smallholder plantations and re-vegetation activities outside of areas under the jurisdiction of the Ministry of Forestry. These are excluded from INCAS at this stage.

Forest as defined by GOI as 0.25 ha. Areas where the LAPAN analysis does not identify enough adjacent pixels to meet this threshold are removed from the analysis and thus do not appear in the change statistics. If the area of forest is decreased below this threshold by an annual change event, the change is included. This allows for the eventuality that the adjacent land may recover and restore the isolated pixels as a forest, and not overestimate the carbon removal associated with that event.

Relationship between UNFCCC categories and Ministry of Forestry Directorate General of Planning land cover classes.

UNFCC category	Ministry of Forestry's land cover category
Forest land	Primary dryland forest
	Secondary dryland forest
	Primary peat swamp forest
	Secondary peat swamp forest
	Primary mangrove forest
	Secondary mangrove forest
	Plantation forest
Cropland	Shrub-Mixed dryland farm
	Dryland agriculture
	Estate crop plantation (including oil palm, rubber, tea plantations)
	Rice field
Grassland	Grassland
	Shrub
Wetlands	Swamp
	Swamp shrub
Settlements	Settlement area
Other land	Barren land
	Fish pond
	Airport
	Mining area
	Water
	Cloud covered

Source: Krisnawati et al. (2012)

This publication describes in detail the standard methods of the Indonesian National Carbon Accounting System (INCAS) to quantify net greenhouse gas (GHG) emissions for the forestry sector in Indonesia in a transparent, accurate, complete, consistent and comparable (TACCC) manner. The standard methods describe the approach and methods used for data collation, data analysis, quality control, quality assurance, modelling and reporting. These include: (i) Initial Conditions, (ii) Forest Growth and Turnover, (iii) Forest Management Events and Regimes, (iv) Spatial Allocation of Regimes, (v) Peatland GHG Emissions, and (vi) Modelling and Reporting. This first version of the standard methods were tested and refined to estimate emissions and removals from forest and peat lands in Central Kalimantan as the REDD+ pilot province, the results of which are reported in 'Estimation of Annual Greenhouse Gas Emissions from Forest and Peat Lands in Central Kalimantan'. The standard methods are designed to be used at the national level; this first version can be used as the basis for developing a national GHG inventory for REDD+ activities in Indonesia.

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