

Standard Methods for Estimating Greenhouse Gas Emissions from Forests and Peatlands in Indonesia

(Version 2)



Chapter 8: Standard Method – Data Integration and Reporting



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Chapter 8: Standard Method – Data Integration and Reporting

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The other chapters and full publication are also available on the INCAS website www.incas-indonesia.org



STANDARD METHOD – DATA INTEGRATION AND REPORTING

8.1 PURPOSE

This standard method describes the process used by INCAS for modelling GHG emissions and removals from activities occurring on forest lands including 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.

Modeling 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.

Modeling 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-CO₂ emissions from fire, calculated using IPCC default N:C ratios and emission factors multiplied by carbon released from fire.

Carbon emissions and non-CO₂ emissions from organic soil (peat) are modelled using the INCAS standard method for peatland GHG emissions (described in Chapter 7).

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 Product, Version 1 (summarized in Standard Method - Forest Cover Change)*.
- IPCC (2003). *Good Practice Guidance for Land Use, Land Use Change and Forestry*
- IPCC (2006). *IPCC Guidelines for National Greenhouse Gas Inventories*
- IPCC (2014). *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*

Outputs from this standard method are expressed in tonnes of each GHG and CO₂-equivalent GHG emissions and removals. Time periods for reporting can be specified to meet reporting requirements.

8.2 DATA 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 8-1. Each standard method is specifically designed to produce credible, verifiable input data to underpin Indonesia’s net GHG emissions estimates from forests.

Table 8-1. Source of modeling input data.

Standard method	Modeling 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 fullCAM Database
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 Growth Database.
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 Event Database and the INCAS Suite Regime Database
Spatial allocation of regimes	Area by year by forest management regime to be modelled. Data are documented in the INCAS Regime Area Database

Peatland GHG emissions are calculated in the *Standard Method – Peatland GHG Emissions* (Chapter 7). The results are added to the outputs from modelling in this standard method to calculate total annual GHG emissions and removals.

8.3 ANALYSIS

Methodologies and emissions factors used for estimating GHG emissions and removals for the pilot province are summarized in Table 8-2. 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 were not available.

Table 8-2. Summary of methodologies and emission factors: Land use, land-use change and forestry sector.

Greenhouse gas source and sink	CO ₂		CH ₄		N ₂ O		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 ⁷	IE ⁸		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,⁹NA = not applicable, NE = not estimated, NO = not occurring, IE = included elsewhere,¹⁰T1 = Tier 1, T2 = Tier 2 and T3 = Tier 3

⁷ Biomass burning means burning of aboveground biomass and debris on site.

⁸ CO₂ emissions from biomass burning are included in calculations for SMF, degradation and deforestation using T3 models.

⁹ 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.

¹⁰ 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, except for oil palm and rubber estate crops.

GHG emission estimates are prepared for any period for which activity data is available and required for reporting. For the national GHG inventory, this was 2001 to 2012. The area of change represents a change in forest area from the previous year. For example, the area reported in 2001 represents a change in forest area from 2000 to 2001.

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 revegetation).

8.3.1 Forest land

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, enhancement of forest carbon stocks and the sustainable management of forest is the Full Carbon Accounting Model (FullCAM). FullCAM is a flexible integrating tool 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 8-1 summarizes the components and flows of carbon simulated within FullCAM for the national GHG inventory.

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

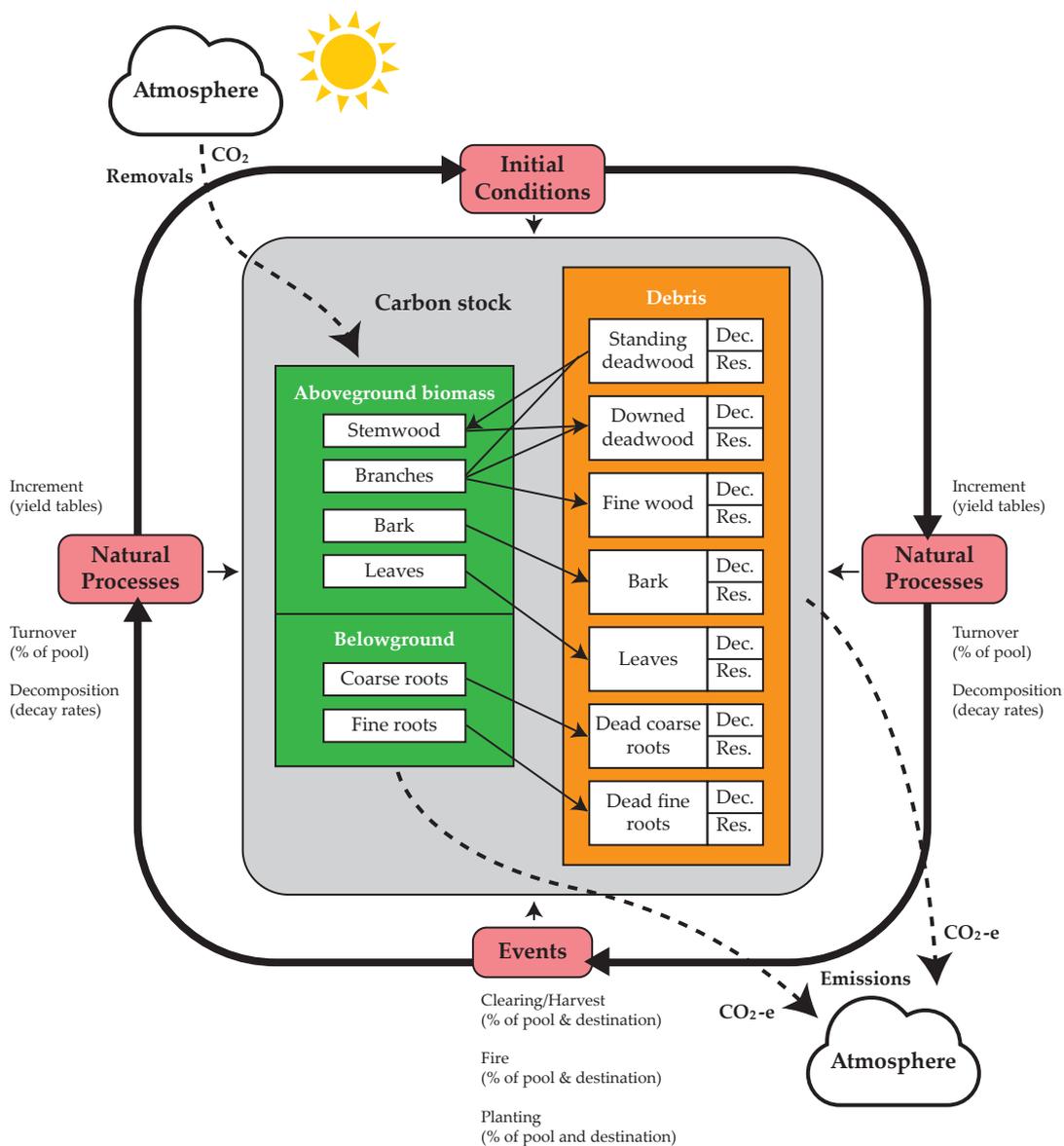


Figure 8-1. FullCAM components and carbon flows for tree and debris pools.

FullCAM quantifies 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) using decay curves. Each component of aboveground biomass, belowground biomass and debris pools is tracked throughout the simulation period.

Changes in carbon stock of forest products (e.g. sawlogs, veneer logs, pulpwood) can be tracked in INCAS, but for the current national 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 were 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, RothC, had not been calibrated to quantify changes in soil organic carbon in Indonesian soils. Hence, changes to soil organic carbon in mineral soils was quantified using other methods described later in this standard method and changes in soil organic carbon in organic soils were described in the *Standard Method – Peatland GHG Emissions* (Chapter 7).

FullCAM is a process-based, event-driven integrating tool, 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 quantified using 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* (Chapter 3).

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 national GHG inventory);
- forest fires – fire events that release carbon (as CO₂ and CH₄) and nitrogen (N₂O) 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* (Chapter 4).

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 quantify 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 quantify changes in carbon stocks across a group of forests (an estate).

Master plot file

Individual plot files are created for every potential combination of events and biomass classes to be analysed. For the national GHG inventory, the suites, management regimes and plot files are documented in INCAS Suites Database.

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 8-2 to Figure 8-6 provide examples of the outputs of plot files for deforestation, forest degradation, sustainable management of forest and enhancement of forest carbon stocks.

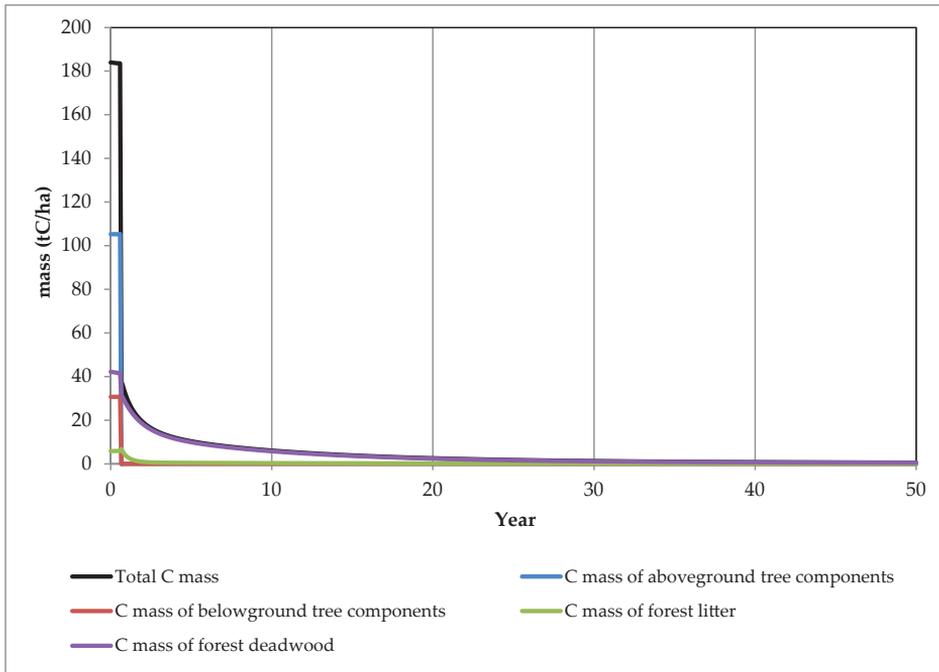


Figure 8-2. Example of the output of changes in carbon mass by carbon pool from deforestation.

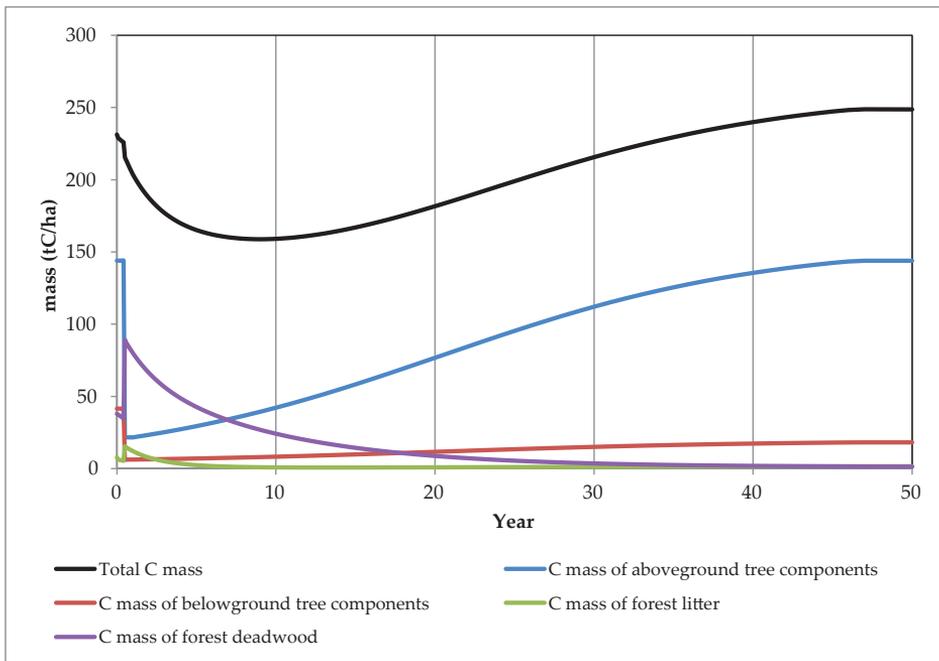


Figure 8-3. Example of the output of changes in carbon mass by carbon pool from forest degradation.

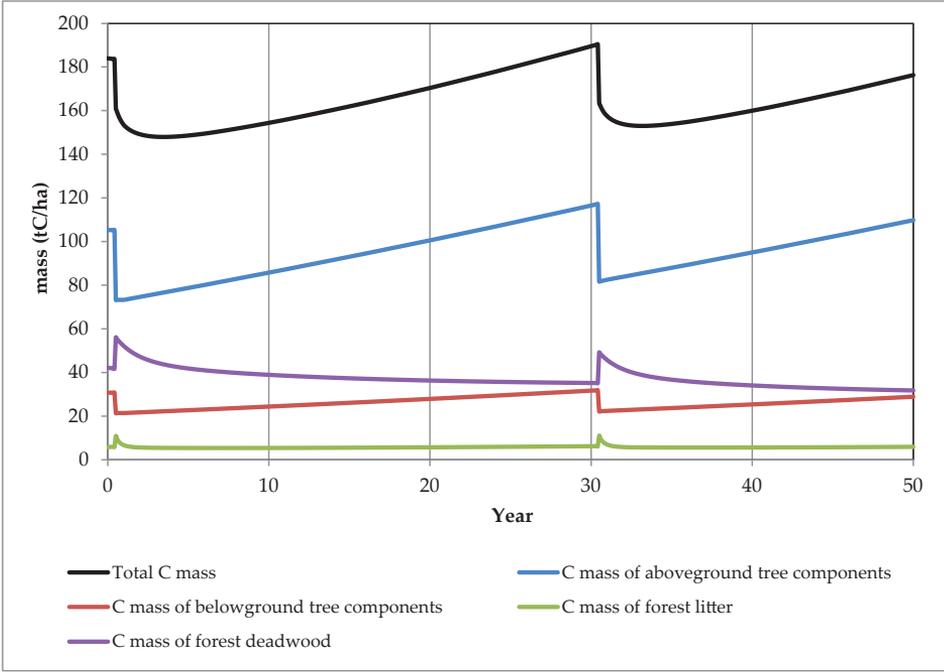


Figure 8-4. Example of the output of changes in carbon mass by carbon pool from sustainable management of forests.

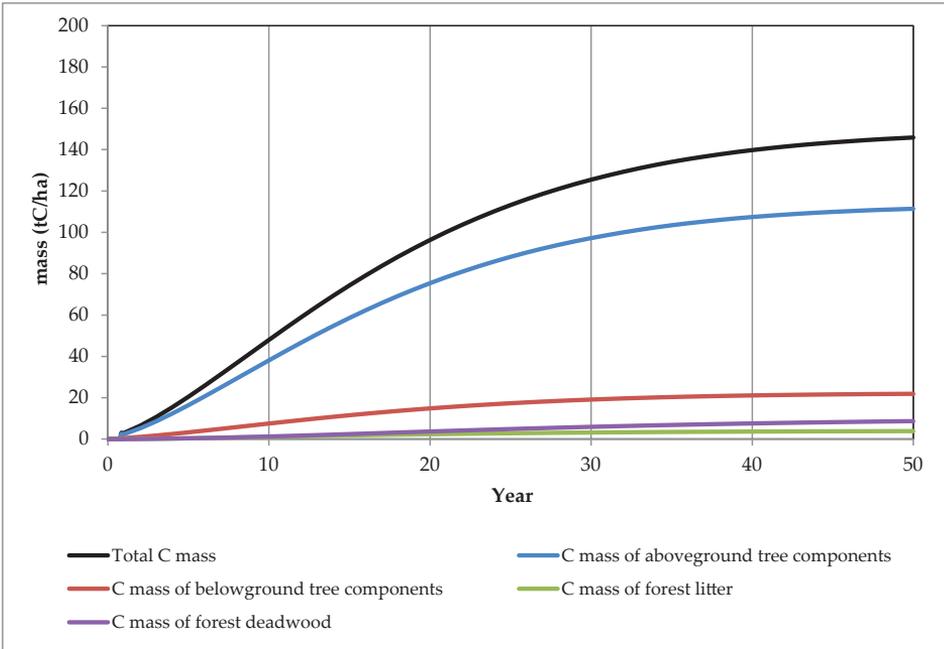


Figure 8-5. Example of the output of changes in carbon mass by carbon pool from enhancement of forest carbon stocks.

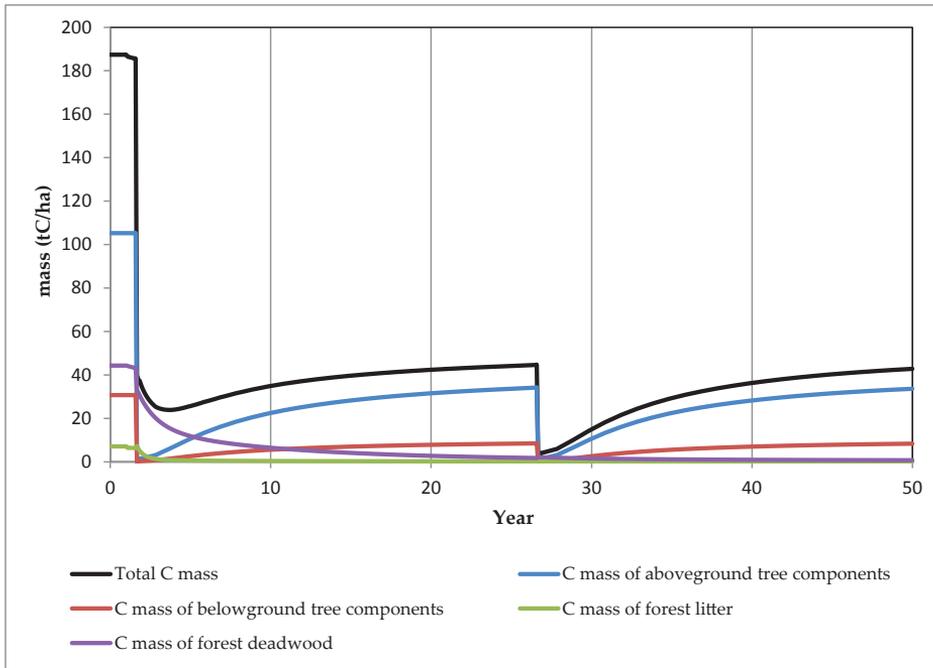


Figure 8-6. Example of the output of changes in carbon mass by carbon pool from conversion of forest to estate crop.

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* (Chapter 6).

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, enhancement of forest carbon stocks, sustainable management of forest, and forest degradation (noting these definitions are 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 national 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* (described in Chapter 6). For the national GHG inventory the areas are documented in INCAS Regime Areas database.

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 the national GHG inventory, subsequent cropland management events are only modelled for estate crops. All other crops are assumed to have a zero emission factor.¹¹ 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).

8.3.2 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 the forest land are excluded from the national 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.

To simplify calculations, 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 t C ha⁻¹.

¹¹Crops 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.

8.3.3 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 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 was 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 based on the annual cumulative area of land converted from forest to non-forest.

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.

No carbon emissions were assumed to occur on mineral soil for forest land which remained 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).

8.3.4 N₂O emissions from mineral soil

Annual N₂O emissions from disturbed mineral soil were 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 used the same area data and the carbon stock change data calculated above for annual carbon emissions from disturbed mineral soil. Calculations were performed in the same simple Excel-based model described above.

8.3.5 Non-CO₂ emissions from surface fire

Non-CO₂ emissions from burning biomass in surface fires were calculated using the carbon released from fire events modeled 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 were provided in Table 3A.1.15 and the N/C ratio for the fuel burnt was approximated to be about 0.01 (IPCC, 2003). Calculations of non-CO₂ emissions from burning biomass in the national GHG inventory were conducted in the simple Excel-based model.

Emissions were reported in total tonnes of CH₄, CO, N₂O and NO_x. Methane (CH₄) and N₂O emissions were converted to CO₂-equivalent emissions using global warming potentials of 28 and 265, respectively. As CO and NO_x are secondary GHGs they were not converted to CO₂ equivalent.

Non-CO₂ emissions from fire in peatlands are addressed in the *Standard Method – Peatland GHG Emissions* (Chapter 7).

8.4 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 the authors of source analyses.

Quality control should be undertaken by the team responsible for modelling.

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 national GHG inventory this was undertaken by INCAS team members not directly responsible for modelling and by external technical advisors.

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

8.5 OUTPUTS

8.5.1 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 2001. If forest is not detected in 2000 but forest is detected in 2001, then forest gain occurred in 2001.

8.5.2 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.

All non-forest land was assumed to be cropland or other land due to insufficient data available at the time of reporting to differentiate it into other land-use categories. Consequently, the land-use transition matrices were not included. The land-use transition matrices (e.g. Table 8-3) should be developed when better spatial data becomes available to enable differentiation between non-forest land uses.

Table 8-3. 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							

8.5.3 Reporting units

Outputs for each carbon pool are converted to common reporting units as shown in table 8-4.

Carbon stock ($t\ C\ ha^{-1}$) 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 $t\ C\ ha^{-1}\ yr^{-1}$.

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 $t\ C\ ha^{-1}$, from which annual N_2O emissions (in $t\ N_2O\ ha^{-1}$) 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 $t\ C\ ha^{-1}$, converted to CO_2 -equivalent emissions. Non- CO_2 emissions from peat fire are quantified directly in $t\ CO\ ha^{-1}$ and $t\ CH_4\ ha^{-1}$. Methane (CH_4) 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 (CH₄) and nitrous oxide (N₂O) emissions are converted to CO₂-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 8-4. Model outputs and reporting units.

Source	Model output	Initial output unit	Conversion factor	Reporting unit	GWP ¹²	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 ₂ O	tonnes N ₂ O ha ⁻¹	1	tonnes N ₂ O	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 ₂ O	tonnes N ₂ O ha ⁻¹	1	tonnes N ₂ O	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 ₂ O	tonnes N ₂ O ha ⁻¹	1	tonnes N ₂ O	265	tonnes CO ₂ -e

8.5.4 Reporting categories

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

¹² GWP – 100-year Global Warming Potential from (Myhre et al. 2013). CO and NO_x are secondary greenhouse gases and are not assigned GWP values.

Annual GHG emissions can be reported according to the UNFCCC reporting categories shown in Table 8-5 or as REDD+ categories. The correlation between REDD+ and UNFCCC categories adopted for the national GHG inventory are shown in Table 8-5.

Table 8-5. Comparison between UNFCCC reporting categories and REDD+ activities included in the national 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 <i>or</i> grassland <i>or</i> wetland <i>or</i> settlements <i>or</i> other land
Enhancement of forest carbon stocks	Cropland <i>or</i> grassland <i>or</i> wetland <i>or</i> settlements <i>or</i> other land converted to forest land

REDD+

The REDD+ categories reported cover total net GHG emissions per annum from activities on land associated with forestry and forest land-use change between 2001 and 2012.

Deforestation

The deforestation account represents the sum of annual GHG emissions and removals resulting from deforestation related events on forest lands for the time period analyzed and reported. Net emissions from subsequent land uses are included where known (e.g. establishment of estate crops on cleared forest lands are included in the deforestation account). In the absence of more detailed data about subsequent land uses on non-estate crop (cropland), it was assumed that all subsequent land uses were annual crops in which annual biomass gain and loss were equivalent, resulting in annual zero net emissions in years after deforestation. Emissions from decay of forest debris arising from the deforestation event are included, resulting in emissions for many years after each deforestation event. This also included ongoing emissions from the deforestation event occurred before 2000.

Forest degradation

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 human induced fire or clearing followed by natural regeneration) and ongoing selective harvesting using conventional technique in secondary forests.¹³

¹³ Ongoing selective harvesting using reduced impact logging (RIL) technique is included in sustainable management of forests.

Emissions from decay of forest debris arising from the forest degradation event are included, resulting in emissions for many years after each forest degradation event. This also included ongoing emissions from the forest degradation event occurred before 2000. Conversion of natural forest to timber plantations is also included in this category.

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 national 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 forests account represents the sum of annual GHG emissions and removals resulting from ongoing management using RIL technique of land that was classified as secondary forest at the start of the reporting period (i.e. forest land remaining forest land).¹⁴ Results represent changes to on-site carbon stocks resulting from a series of forest management events in 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 through time). This includes harvesting operations that may result in areas of temporarily unstocked forest.¹⁵ Ongoing harvesting and replanting of timber plantations is also included in this category.

Enhancement of forest carbon stocks

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

¹⁴ Ongoing selective harvesting using conventional technique in secondary forests is included in forest degradation due to the higher impacts on forest carbon stocks.

¹⁵ Temporarily unstocked forest is land that meets the forest definition when the forest reaches maturity, but due to a disturbance event does not contain forest at the specified point in time. The land is expected to regrow and meet the forest definition in the future.

8.6 UNCERTAINTY ANALYSIS

Uncertainty estimates are an important component of a national inventory. Their purpose is to help improve the accuracy of inventories over time by helping to guide decisions on methodological choice and priorities for inventory improvement. Uncertainty estimates are not used to question the validity of emissions estimates in the national inventory. These assessments are made through the review of technical assessment process. Estimating and communicating uncertainty must be both practical and scientifically defensible. For example, a practical approach recognises that producing quantitative uncertainty estimates will rely upon statistically quantified uncertainties as well as expert judgment.

Identifying the sources of uncertainty is the first step in estimating uncertainty. These sources are typically disaggregated into uncertainties related to emissions and removals (e.g. initial biomass, growth, turnover and decomposition rates) and uncertainties related to activity data (i.e. the area on which the emission has occurred). 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.

To demonstrate a typical approach to uncertainty estimates in national inventories, a quantitative uncertainty analysis was carried out on the deforestation components of the national GHG inventory using a Monte Carlo analysis (IPCC Tier 2). The uncertainty analysis was conducted to:

- demonstrate the use of Monte Carlo methods for assessing uncertainty at the national level;
- provide an indicative uncertainty estimate for the national GHG inventory for deforestation events;
- 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. Key assumptions are common across most methods and include:

- 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.

8.6.1 Method

The uncertainty analysis was conducted using the Excel spreadsheet version of the Carbon Accounting Model for Forests (CAMFor). This was selected because FullCAM uncertainty analysis was designed to run at a point level, not at the estate level as used in INCAS.

CAMFor is one module within FullCAM and is described in Richards and Evans (2000). CAMFor deals only with forest lands and is the component of FullCAM used by INCAS to quantify changes in forest carbon stocks. Consequently calculations of net GHG emissions and removals in this uncertainty analysis are fully consistent with estimates produced using FullCAM. The Excel version of CAMFor transparently shows all of the inputs and calculations and allows risk analysis software (Pallisade@Risk) to be run to undertake quantitative uncertainty analysis.

The first step in the method was to confirm that CAMFor accurately reproduces FullCAM outputs at the estate level. To do this, the national FullCAM plot files that included deforestation events were recreated in CAMFor. Quality assurance was undertaken to confirm that the results from CAMFor accurately represent the FullCAM outputs for each plot file. There are timing difference in how CAMFor accounts for events (end of year only) compared to FullCAM (any day of the year). As most deforestation in the INCAS were set to occur halfway through the year, this led to minor differences in the year of clearing (< 2%) (Figure 8-7). When FullCAM timings were set to the end of the year, the results from CAMFor exactly matched those from FullCAM. It was concluded that calculations in FullCAM and CAMFor are comparable.

Uncertainty analysis was then run for each CAMFor file using Pallisade@Risk to conduct Monte Carlo analyses. To do this, CAMFor was run one thousand times for each plot. For each run, the parameters were varied within a set range (as set by the user) and the results (both inputs and outputs) loaded to Pallisade@Risk. Results were produced to show the effect of varying parameters on total annual emissions for the INCAS simulation period of 2001 to 2012.

The key parameters input from the INCAS analyses (tree and debris masses) were varied within the 95% confidence interval of the mean as shown in Table 2-2. As the biomass data are based on several hundred plots, the confidence intervals are tight. This represents the mean for the entire forest estate rather than a single piece of forest.

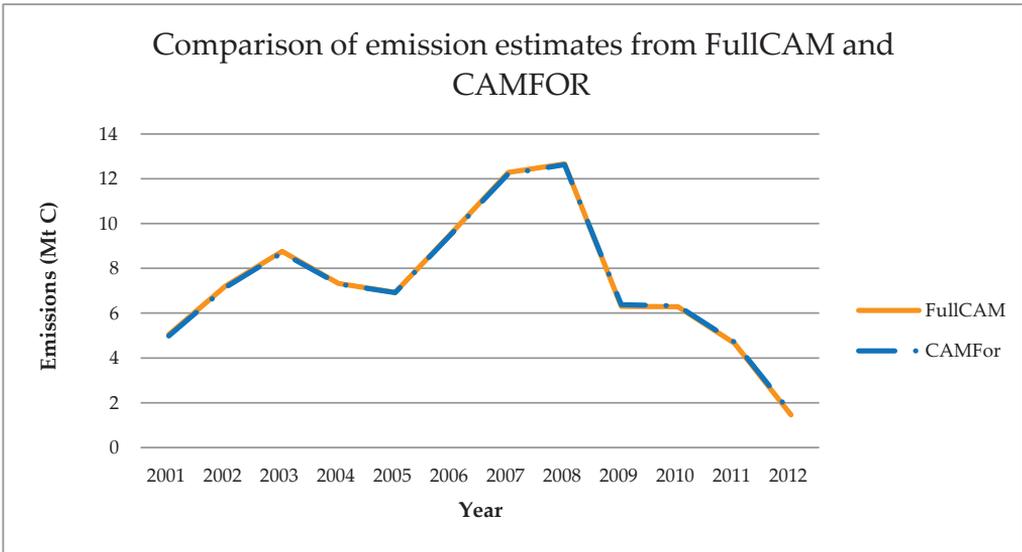


Figure 8-7. Comparison in annual emissions from deforestation events as estimated from FullCAM and CAMFor, indicating very little variation between the two tools.

As Indonesia specific data for turnover rates, fraction of decomposable material and breakdown rates were not available, the parameters were varied by +/-50%. The area estimates and carbon fractions were varied by +/- 10%. This is likely an overestimate for some parameters, but without further information, this is considered reasonable. Further assessment will be conducted as part of the continuous improvement program as more data becomes available.

Indonesia's National Forest Inventory data, supplemented with research plot data, was used to produce estimates of total aboveground biomass. For use in FullCAM/CAMFor it is necessary for data to be divided into components (stem, branch, bark and leaves). Each of these components was subject to Monte Carlo analysis, but was varied dependently (e.g. all component masses would increase or decrease by the same proportion) as the input data is based on AGB. If these components were measured separately, then it would be more appropriate to vary components individually. However, in this case, such a method would underestimate uncertainty.

8.6.2 Uncertainty analysis results – Plot level uncertainty

Figures 8-8 to 8-11 provide 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 (Palisade@Risk).

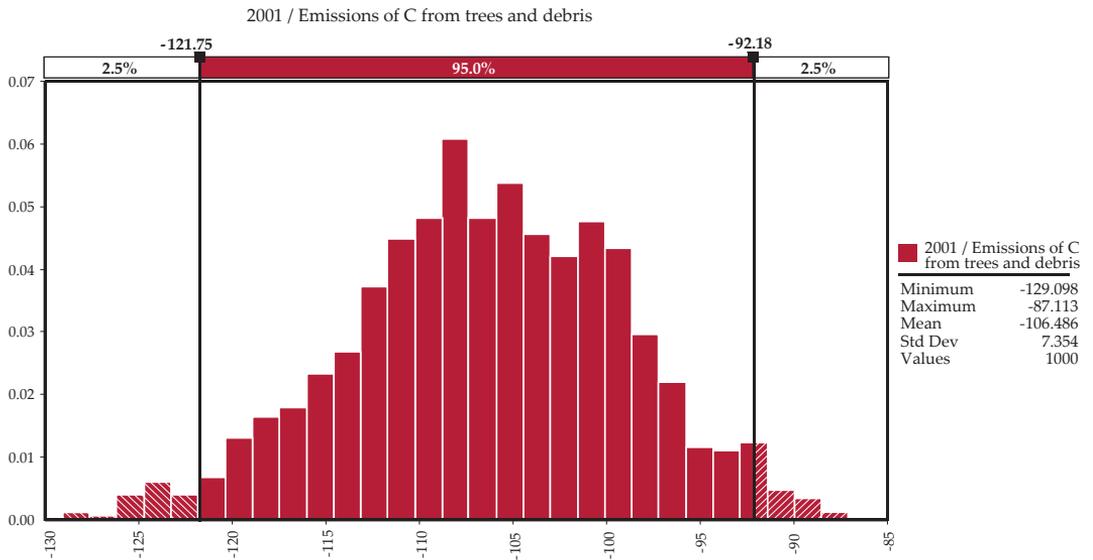


Figure 8-8. Distribution for net carbon mass emitted in secondary swamp forest due to deforestation in the first year of the simulation.

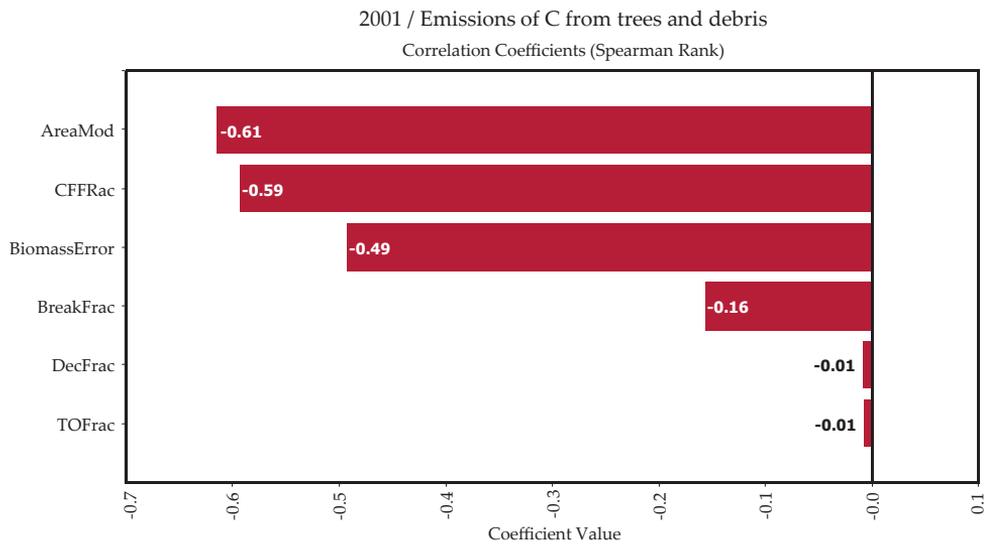


Figure 8-9. Regression sensitivity for net carbon mass emitted in secondary swamp forest due to deforestation in the first year of the simulation.

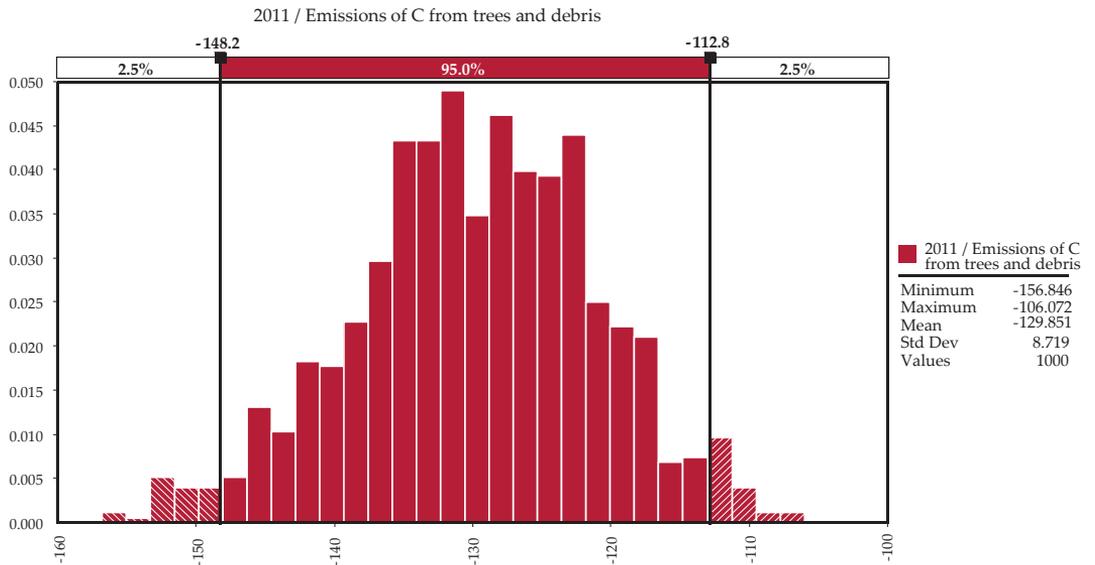


Figure 8-10. Distribution for net carbon mass emitted in secondary swamp forest at 10 years after deforestation.

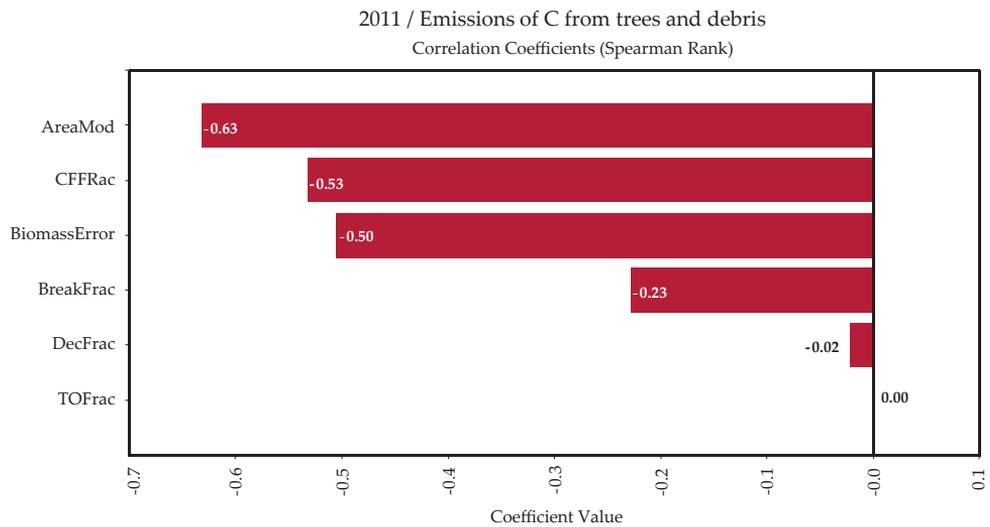


Figure 8-11. Regression sensitivity for net carbon mass emitted in secondary swamp forest at 10 years after deforestation.

8.6.3 Uncertainty analysis results – National level uncertainty¹⁶

Figure 8-12 shows annual aggregated estimates of emissions and the associated uncertainty (error bars) for clearing and fire events associated with deforestation across Indonesia. This demonstrates that it is possible to aggregate uncertainty estimates to produce total national uncertainty estimates. However, while this provides an overall picture of uncertainty, this is less valuable for identifying opportunities to reduce uncertainty than using the plot level uncertainty analysis results.

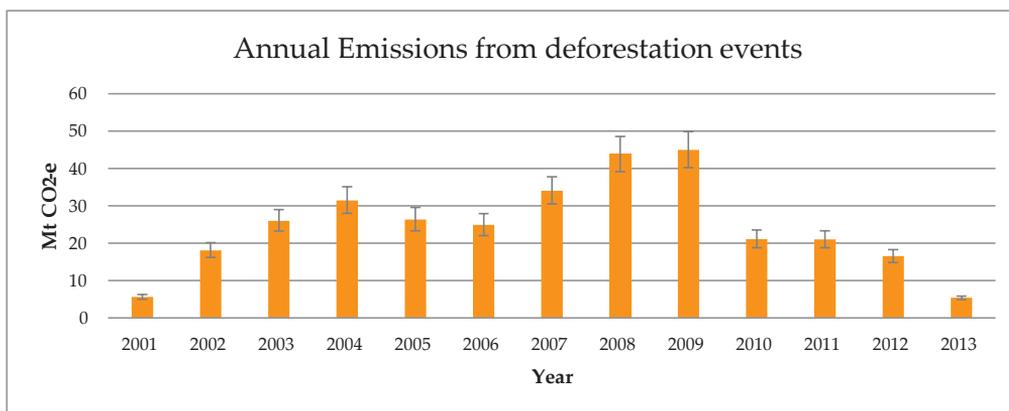


Figure 8-12. National level uncertainty results for clearing and fire events associated with deforestation.

8.6.4 Uncertainty analysis discussion and improvement plan

The approach for determining the uncertainty associated with an estimate must consider the individual uncertainties of inputs used in obtaining the estimate, and a process for aggregating the uncertainties. For estimating the emissions from a deforestation event, inputs are needed for mass of tree components (e.g. stem, branches etc.), carbon fraction of tree components, decomposition rates of components, biomass turnover rates, debris decomposition rates and area of each event. By using CAMFor and risk analysis software (e.g. Palisade@Risk) it was possible to account for these individual uncertainties and aggregate them into a single estimate of uncertainty. Further, it is possible to determine the contribution of input values in the overall uncertainty of plot level estimates.

The analysis conducted identified some limitations in the uncertainty analysis such as data gaps for Indonesia specific decomposition and turnover rates and better estimates of uncertainty associated with area. However, overall the analysis demonstrates that a similar approach can be undertaken to account for all events and processes reported under INCAS.

¹⁶Note: Totals differ from the deforestation results presented in the report because the uncertainty analysis only includes clearing and fire events associated with deforestation, whereas the deforestation account includes all activities on deforested land, including lag emissions from deforestation that occurred prior to the simulation period.

A Tier 2 analysis is readily amendable to estimating the significance of individual input values on overall uncertainty estimates. This contrasts with the Tier 1 analysis (aggregation), which provides an estimate of overall emission but is less amenable to estimating the significance of individual components. Through identifying the input values with the most significance on uncertainty, research can be appropriately prioritized to reduce the overall uncertainty of the inventory. This aligns with the objective of the uncertainty analysis, which is to assist in improving inventories over time, not to validate the emissions estimates. As such, the Tier 2 analysis has clear benefits over a Tier 1 analysis.

8.7 LIMITATIONS

Data limitations are described in each of the standard methods that produced inputs. The INCAS framework is designed to enable simulations 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 national GHG inventory are outlined below.

- 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;
- Spatial and temporal accuracy of burnt area data has high uncertainty;
- The lack of clear definitions for forest degradation and sustainable management of forest meant that assumptions about inclusion of activities in each activity were needed. Different assumptions would lead to different allocation to each REDD+ activity.

Analysis limitations arise due to the characteristics of Indonesian forest management systems, forest types, soil types and data availability; this means that some processes and events in Indonesia are not easily quantified 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 quantified 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 quantifying emissions from 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 quantified.
- 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).

8.8 IMPROVEMENT PLAN

- Parameterization and running the analysis 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 the process 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, and the 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.

This publication describes in detail the standard methods of the Indonesian National Carbon Accounting System (INCAS) to quantify net greenhouse gas (GHG) emissions from forests and peatlands in Indonesia in a transparent, accurate, complete, consistent and comparable manner. The standard methods describe the approach and methods used for data collation, data analysis, quality control, quality assurance, modelling and reporting. The standard methods cover (i) Initial Conditions, (ii) Forest Growth and Turnover, (iii) Forest Management Events and Regimes, (iv) Forest Cover Change, (v) Spatial Allocation of Regimes, (vi) Peatland GHG Emissions, and (vii) Data Integration and Reporting. This second version of the standard methods includes improvements implemented in preparing the first comprehensive national GHG inventory for forests and peatlands, the results of which are reported in *National Inventory of Greenhouse Gas Emissions and Removals on Indonesia's Forests and Peatlands*. This publication has been prepared and published by the Indonesian Ministry of Environment and Forestry, under the Research, Development and Innovation Agency.



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