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

(Version 2)

Chapter 5:

Standard Method – Forest Cover Change

MINISTRY OF ENVIRONMENT AND FORESTRY
RESEARCH, DEVELOPMENT AND INNOVATION AGENCY

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

5 STANDARD METHOD – FOREST COVER CHANGE

5.1 PURPOSE

This standard method describes the process used by INCAS remote sensing program, known as the Land Cover Change Analysis (LCCA) program, to monitor changes in forest cover in Indonesia. The LCCA is designed to provide a wall-to-wall, spatially detailed monitoring of Indonesia's forest changes over time. The objective of the LCCA is to produce annual maps of national forest extent and change from Landsat imagery time series. The initial objective of the LCCA is to produce maps of the annual forest extent and changes for the 13-year period from 2000 to 2012, to provide inputs for carbon accounting. The system has been built based on regional analyses, i.e. Kalimantan, Sumatra, Papua, Sulawesi, Java, Nusa Tenggara and Maluku Islands, using a nationally consistent methodology.

Sources of data and methods used for analysis and generating annual forest extent and changes in Indonesia under the LCCA program are described in LAPAN (2014) *The Remote Sensing Monitoring Program of Indonesia's National Carbon Accounting System: Methodology and Products, Version 1*. The following is a short summary.

5.2 DATA COLLATION

It was important to gain access to data from multiple international archives covering Indonesia. The policy requirements for national coverage, sub-hectare spatial resolution and historical and current time periods meant that Landsat was the only feasible data for the operational program. Landsat imagery was sourced from the GISTDA (Thailand), GeoScience Australia, USGS and LAPAN (Indonesia) archives.

Landsat imagery of LS-5 and LS-7 was chosen as the only feasible data source to provide monitoring information for the implementation of LCCA. LS-5 is the preferred source for most of the period due to a technical problem with the scan line corrector ('SLC-off') that affected LS-7 from mid-2003. Both instruments have collected regular repeat coverage every 16 days over the period, but not all overpasses were received and archived.

The most complete archive of LS-5 imagery for western Indonesia for the period was held at Thailand's GISTDA receiving station; Australia's archive, held at Geoscience Australia (GA) covers far eastern Indonesia (Papua to eastern Nusa Tenggara) with LS-5 and LS-7 imagery. LAPAN's receiving station at Parepare covers all of Indonesia, except for the very western tip of Sumatra, but only limited scenes had been archived. The main source of data for the central region was the USGS archive, which was far from complete for LS-5 as it consists of a sample of scenes selected for on-board storage and downloaded in the USA. GA coordinated the image acquisition of Landsat imagery from these international data agencies. All selected data was delivered to Indonesia for processing within the LCCA program.

Samples derived from high-resolution satellite imagery (e.g. GeoEye, Ikonos, Quickbird and WorldView2) were used as references to accurately interpret the land cover classes. Such image resolution was able to estimate tree density and tree height from shadow.

5.3 ANALYSIS

The general processing steps to produce annual forest extent and change maps are summarized in Figure 5-1.

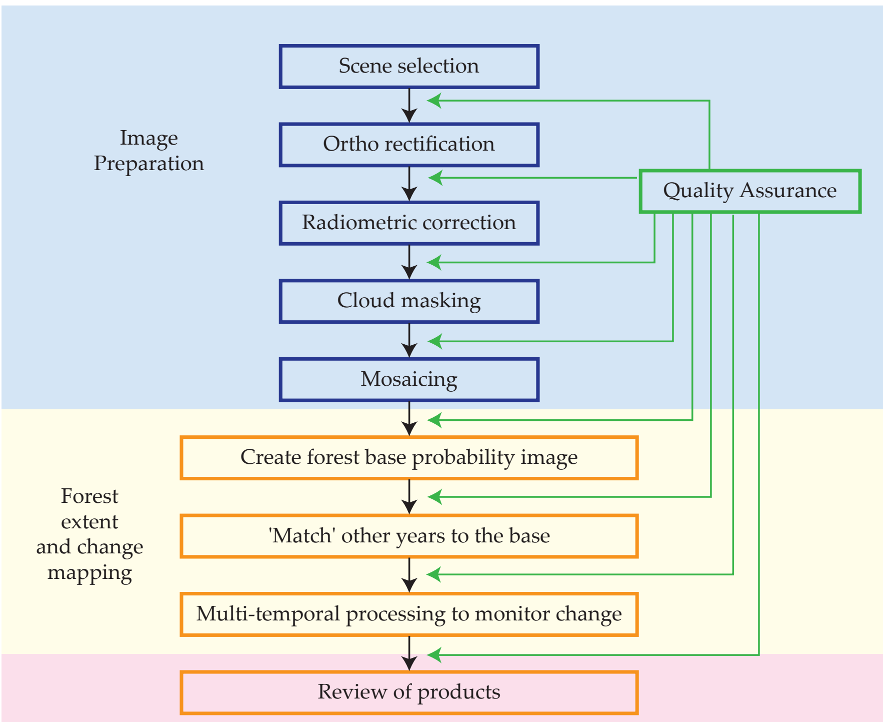

Figure 5-1. Flowchart of the steps in INCAS-LCCA processing sequence (LAPAN, 2014).

The major steps in the Landsat image preprocessing and subsequent forest extent mapping are described below. All stages of image processing must pass documented quality assurance checks.

Cloud cover is a major limitation to the use of optical imagery over much of Indonesia. A time series of annual Landsat mosaics with minimal cloud-affected area was created for each area from multiple scenes prior to classification. Browse images from all archives were assembled and images with minimal cloud cover were selected. For each year and path/row up to five images (typically 2–3) were acquired to provide increased cloud-free land area.

Sample high-resolution imagery was used to provide ground-truthing for the forest extent mapping from Landsat and experts from regional forestry offices provided interpretation of land cover in the forest extent mapping stages.

All satellite images were ortho-rectified to a common spatial reference (USGS GLS 2000) that was available from USGS or processed locally for images from Thailand and Australian sources and calibrated with a procedure that incorporates radiometric corrections. Terrain illumination corrections were then applied using the Shuttle Radar Topography Mission (SRTM) DEM and the C-correction method. Cloud masking using a semi-automated approach developed in the program was then applied to remove cloud and haze prior to combining individual images from each year into regional mosaics. Typically, even using multiple images, each mosaic contained areas of missing data due to persistent cloud.

Forest extent mapping for each region was carried out by classifying a chosen 'base' year Landsat mosaic. For training and validation, experts with local knowledge of land cover and forest types played an active role in base classification. Samples of high-resolution satellite imagery were used in stratification and analysis and in optimizing a classifier based on locally optimal indices and thresholds. The result was a base map of forest-non-forest probabilities for the chosen base year. Automated matching was then applied to all other years to produce a time series of annual forest probabilities.

The capacity to produce change maps that are accurate and consistent through the time series is critical; post-classification differencing of hard labels from individual dates is not appropriate, as it would result in unacceptable errors. A multi-temporal probabilistic framework was applied to the time series to produce the final series of classifications of forest/non-forest over the period from which change areas could be identified. As well as the time series of input forest probabilities, estimates of classification accuracies and temporal transition probabilities were required. This approach could use all of the available data to handle uncertainties in the inputs and to predict missing observations in particular years. The effect was to minimise errors arising from individual year classifications and to provide temporally consistent change information. In addition, cover was predicted in cloud-affected areas from surrounding years.

Finally, a process of manual inspection was applied to the cover and change products, again with the participation of local experts. This process removed errors arising from spectral overlap and labelled particular classes for the purposes of providing inputs to carbon accounting.

5.4 QUALITY CONTROL AND QUALITY ASSURANCE

As described in Figure 5-1, after each step in the image processing, the quality assurance process was conducted to check that the method has been correctly applied and the results met the required accuracy standards. If an image did not meet the standards for the step, the cause was investigated and the image was reprocessed to correct the problem and checked again. The next step was not taken until the current step had been successfully completed. The quality assurance checks also ensured consistency between data processed by different operators and at different times during the activities.

5.5 OUTPUTS AND UNCERTAINTY ANALYSIS

The key outputs produced is the forest extent maps for each year (2000, 2001, 2002, 2003,…). The products were produced in both local NUTM projection and geodetic projection. The titles in the geodetic projection were mosaiced into whole island regions. The resolution of all LCCA products in NUTM was 25 m, in geodetic it was 0.000025 degrees. An example of the products is presented in Figure 5-2 that shows the forest extent for Indonesia in 2009 and for Kalimantan as a regional example.

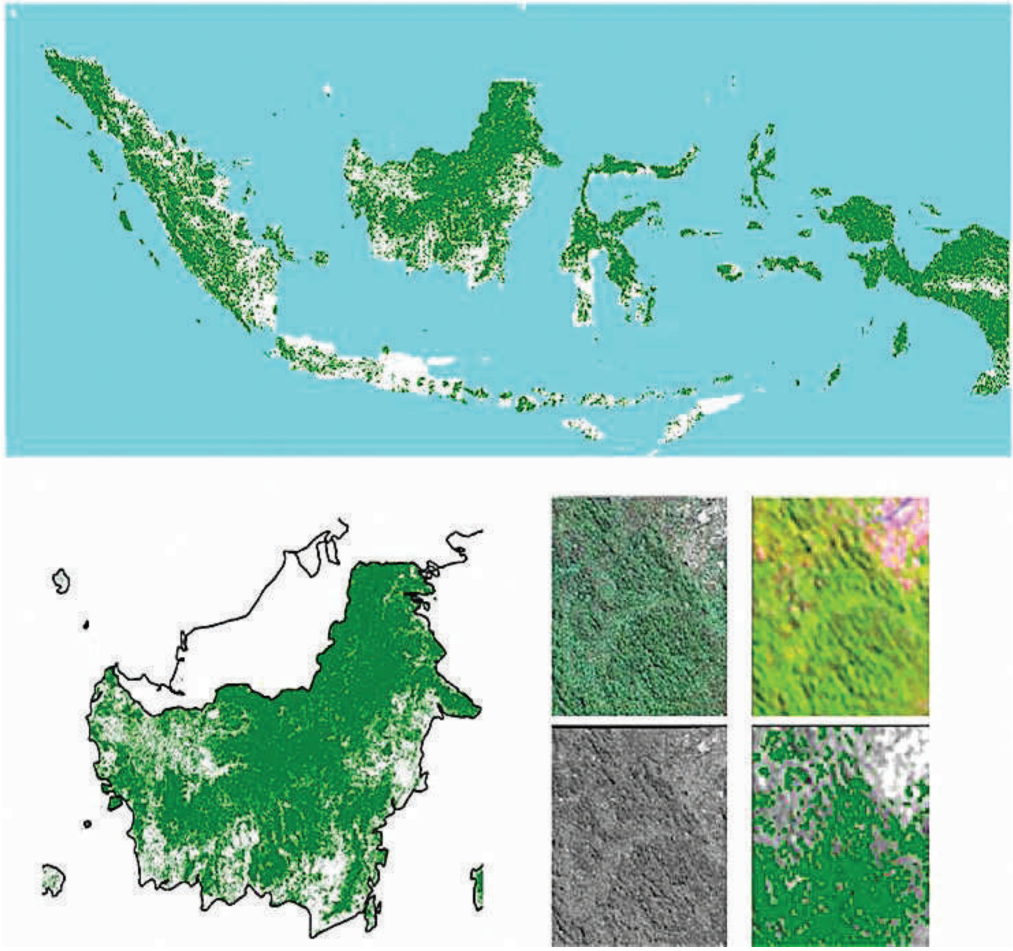

Figure 5-2. Example of the products of forest extent (in 2009) at national, regional and local scale. The local scale includes comparison with Landsat and high-resolution imagery (LAPAN, 2014).

The capacity to produce change maps that are accurate and consistent through the time series is critical. INCAS applies a multi-temporal probabilistic framework to the time series to produce a final series of classifications of forest/non-forest over the period from which change areas can be identified. As well as the time series of input forest probabilities, estimates of classification accuracies and temporal transition probabilities can be produced. The approach can use all of the available data to handle uncertainties in the inputs and to predict missing observations in particular years. The effect is to minimise errors arising from individual year classifications and to provide temporally consistent change information. In addition, cover can be predicted in cloud-affected areas from surrounding years.

5.6 LIMITATIONS

The initial objective of the LCCA is to produce maps of the annual forest extent and changes from 2000 to 2012. Integration of the LCCA analysis and the other spatial analyses used by INCAS was needed to improve the efficiency of both processes.

5.7 IMPROVEMENT PLAN

Satellite reception and archiving capacities in Indonesia have increased during the period of INCAS development; it is anticipated that the program will continue with the use of Landsat 8 and possibly other optical data streams. It would be valuable to extend the historic monitoring to include the period 1990 to 1999 using Landsat imagery and the current processing methods. The 1990s were years of major policy-driven land-use change in some provinces and consistent information on historic changes from this period is of wide interest. There is also a need for greater integration of the LCCA analysis and the other spatial analyses used by INCAS to improve efficiency of both processes.

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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