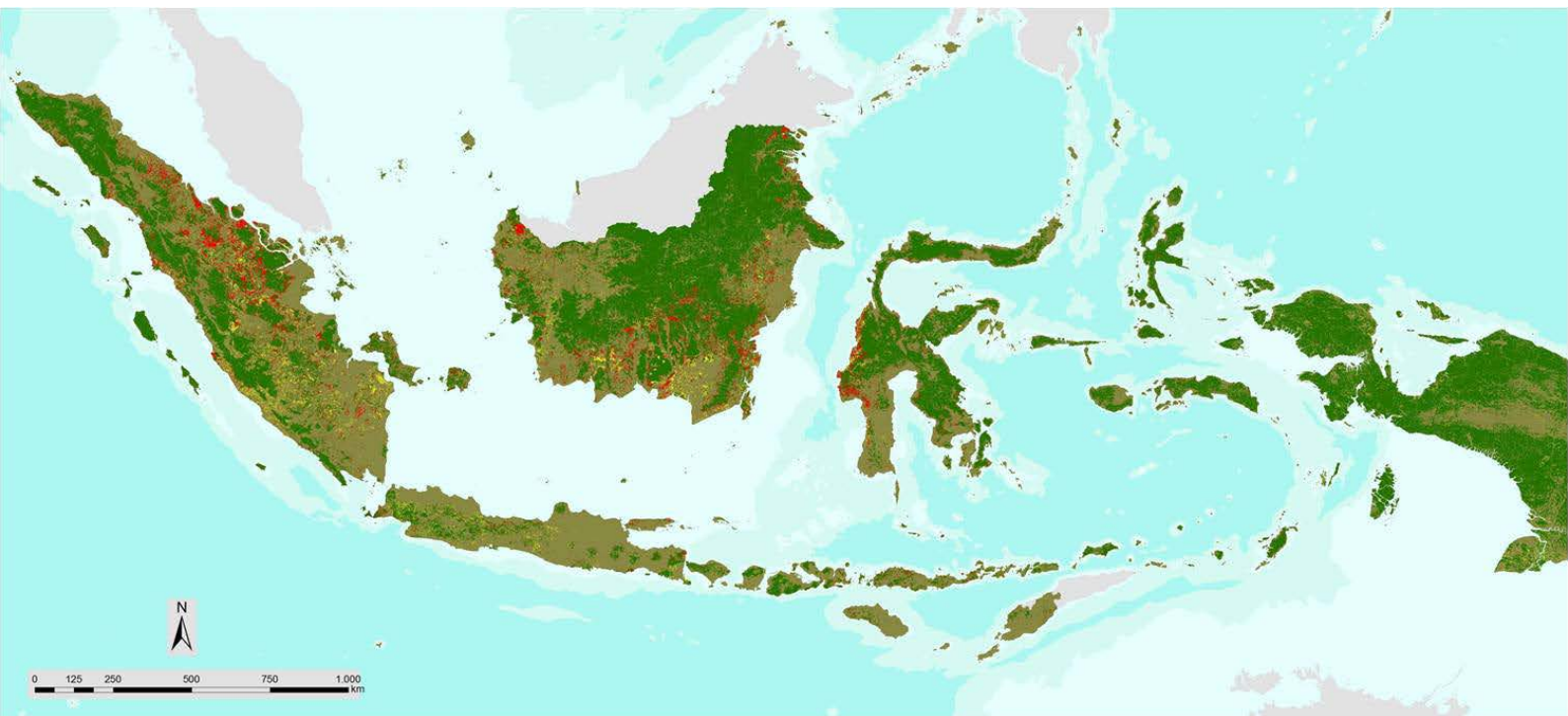


*Executive Summary extracted from*

# **The Remote Sensing Monitoring Program of Indonesia's National Carbon Accounting System: Methodology and Products**



**LEMBAGA PENERBANGAN  
DAN ANTARIKSA NASIONAL**  
*Indonesian National Institute  
of Aeronautics and Space*



*Executive Summary extracted from*

# **The Remote Sensing Monitoring Program of Indonesia's National Carbon Accounting System: Methodology and Products**



**June 2014**

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### **Cover picture:**

Forests cover and change map of Indonesia produced by LCCA

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# 1. INTRODUCTION

The Land Cover Change Analysis program (LCCA) is the remote sensing monitoring component of Indonesia's National Carbon Accounting System (INCAS). The body of this report provides a summary of the methods and products of the LCCA. This section provides a brief background of INCAS and its LCCA.

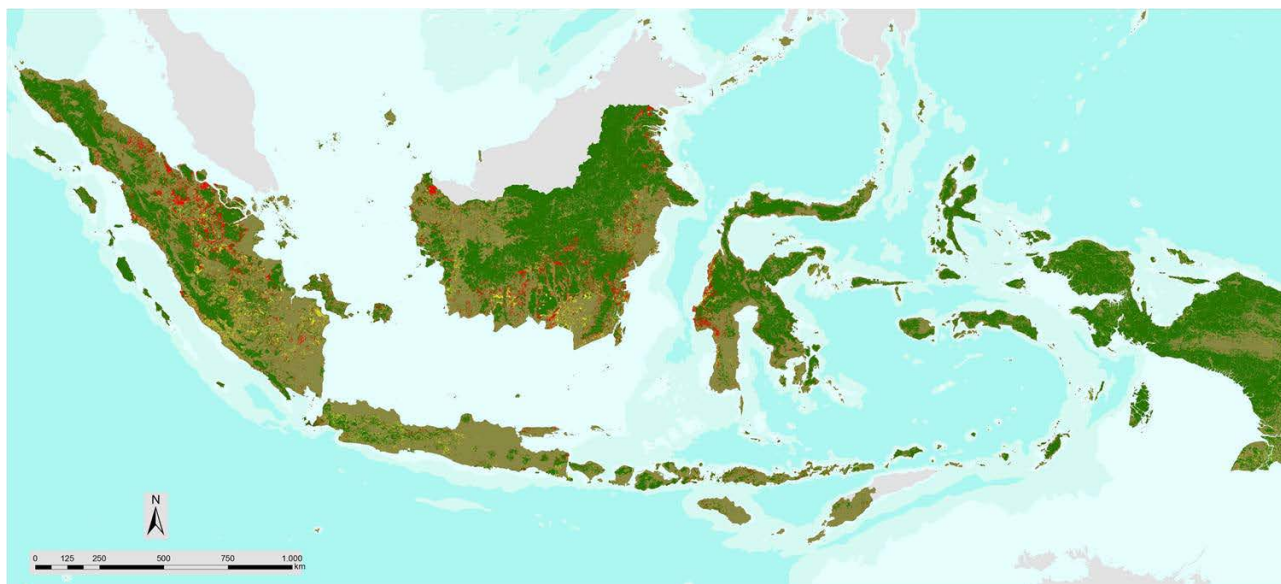


Figure 1.1. Forest extent and change map 2000-2009 for Indonesia produced by the LCCA. Dark green indicates areas that were always forest from 2000 to 2009, red shows forest loss between 2000 and 2009 while yellow indicates forest gain in the same period. [source: INCAS poster, Workshop on Earth Observation Satellite Data to Support REDD+ Implementation in Indonesia, February 2014]

Planning for the INCAS program commenced in 2008 as a collaboration between the Indonesian and Australian Governments. The aim was to build a credible and sustainable system in Indonesia to account for greenhouse gas (GHG) and allow for robust emissions reporting from Indonesia's land sector, with full national coverage. It was undertaken in response to national and international policy drivers with a focus on forests and forest change. Indonesia's forests are globally significant in terms of carbon storage and other values. Estimates suggest that the land sector has been the largest contributor to the nation's GHG emissions. Accurate estimation of deforestation rates has been a focus for local, national and international interest.

Decreasing rates of forest loss, improving forest management and establishing reforestation programs all present opportunities for Indonesia to benefit from international initiatives such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management and enhancement of forest carbon stocks). REDD+ is intended to provide economic incentives for these actions. In 2009, President Yudhoyono pledged to reduce Indonesia's GHG emissions by up to 26% below business as usual levels in 2020, with consideration of increasing this to 41% with sufficient international support. Following this the Government of Indonesia (GoI) signed a Letter of Intent with the Government of Norway, entering into a partnership on REDD+. A national system for monitoring and reporting forest change is required for participation in such programs. National policy drivers and international reporting requirements on Monitoring, Reporting, and Verification (MRV) also require such a system.

Work on INCAS commenced in 2009 under the Indonesia-Australia Forest Carbon Partnership (IAFCP). The program consists of two major technical components; the remote sensing component, and the emissions estimation component. The remote sensing component, LCCA, provides spatially detailed monitoring for the whole country of changes in forest area over time using satellite remote sensing imagery. The emissions estimation component

includes forest biomass measurement, forest disturbance mapping, and carbon stock assessment and emissions estimations to produce GHG accounts. In both components, the initial approach was to transfer and adapt knowledge and experience from Australia's national system (Caccetta et al 2013) to build operational systems and capacity in Indonesia. The Ministry of Forestry (MoF) is the lead GoI partner for the overall INCAS program and leader of the emissions estimation component. The LCCA remote sensing program is led by the Indonesian National Institute of Aeronautics and Space (LAPAN) in collaboration with MoF, the Indonesian Geospatial Information Agency (BIG), the IAFCP and others. Through IAFCP, international expertise has been provided to develop the LCCA program at LAPAN. CSIRO Australia has provided sustained technical support and training. The program has also had significant input and interaction with Professor Matthew Hansen of the University of Maryland and his group, who have conducted workshops and training with input from other international experts.

The monitoring system was designed in response to existing and anticipated international agreements and frameworks, including developments from the Kyoto protocol, IPCC guidelines and expectations for REDD+. The design requirements included (a) national coverage (b) sub-hectare spatial resolution (c) capacity to monitor historic changes over at least ten years, and to continue monitoring into the future. Landsat imagery, on account of its resolution and historic archive, was the only feasible data source to meet these requirements. Access to and processing of Landsat imagery were initial priorities for implementing the system.

The initial objective of the LCCA was to map the extent of forested land and the annual changes in the extent for the whole of Indonesia for the 10-year period from 2000-2009 to provide inputs for carbon accounting activities. For this purpose forest cover is defined as physical land cover irrespective of tenure; as a collection of trees with height greater than 5 metres and having greater than 30% canopy cover. Plantations of oil palm and coconut palm are considered as non-forest. All other land cover is considered non-forest. LCCA does not produce classifications of forest type from satellite imagery; forest type information in INCAS is provided from MoF during the biomass and emissions estimation process.

Commencing in 2009, Landsat data were sourced, assembled and processed to meet this primary objective. The LCCA data and products have since been extended to include recent 'update' years and now cover the period 2000-2012, with a commitment to complete 2013. A consistent, systematic forest monitoring approach is being applied to the whole of Indonesia for this period. Historic data were sourced from archives in Thailand, Australia and the United States as well as LAPAN's own Landsat archive. Since the LCCA program began, LAPAN has greatly expanded and strengthened Indonesia's data reception and archiving capacities through relationships with international agencies including the United States Geological Survey (USGS). Data received and archived in Indonesia will be used for future updates of the LCCA. Landsat 8 imagery is already received by LAPAN and likely to be the main monitoring data source for coming years. Other data sources have been considered to continue and complement the program, and LCCA methods can be applied or adapted to other optical data. In addition to providing forest change products for carbon accounting, the image and mosaic products from LCCA will have wide application to land use management and local government spatial planning in Indonesia.

Since work on the LCCA remote sensing component commenced, there have been significant developments in the variety and availability of remote sensing data systems and in computational capacity. LCCA has incorporated a 'continuous improvement' approach to adapt and evolve the system while maintaining consistency for monitoring purposes. Internationally, the importance of forest monitoring has driven efforts to coordinate and improve access to satellite observational data for this purpose through the Global Earth Observation System of Systems (GEOSS) and the Global Forest Observations Initiative (GFOI). Indonesia has been a key contributor to these activities and its experience in developing the LCCA is highly relevant.

This document provides a detailed summary of LCCA data, methods and products. The protocols for quality assurance and archiving are also described. Detailed descriptions of individual programs with operator manual level information will be produced in a separate document; referred to here as the Operational Manual.



## 2. LCCA STATUS AND FUTURE DIRECTIONS

The INCAS-LCCA program is ongoing. The IAFCP has supported the development of the methodology as well as developing the capability, capacity and infrastructure at LAPAN to allow for the continuation of the LCCA as an operational program within LAPAN.

By the middle of 2014, annual forest extent and change products for Indonesia from 2000-2012 will have been produced. The effort to initiate the program and to process this historical data has been considerable, but from the middle of 2014 the program will move to a single-year 'annual update' mode where much less effort is required. There is a commitment by LAPAN to continue the processing to produce an update using 2013 data. Discussions around extending the time series back to 1990 are ongoing.

The technical capacity and data streams exist to continue the annual updates of LCCA into the future. Technical challenges of new data sources, such as Landsat 8 imagery, are being addressed.

Institutional support is equally important for continuity of the program – it is important that a clear mandate for the LCCA exists and key to this will be an evident strong demand from stakeholders for the generation of credible land cover change products.

Resourcing levels to perform an annual update (the process of adding one year sequentially to the time series) can be estimated based on recent milestone progress in the LCCA. Currently, three new years (2010-2012) are being added across the whole country over a period of approximately seven months by an experienced team, many contributing in part-time roles. The total effort is equivalent to approximately 14 full time staff. This would indicate that an experienced team of around six staff should be able to complete an annual update within six months. In practice a larger team will be needed, as it will be vital to maintain skilled staff within the team, and to plan for training and succession of staff.

As well as routine update activities, an ongoing INCAS-LCCA should involve continuous improvement activities in a research component. This will include activities to evaluate new methods and to incorporate new data, and possibly to examine distribution of products in different forms. It will include research aimed at improving the accuracy of the products and at improving the efficiency of creating the products.

Activities for improving the accuracy of the products that are being discussed include:

- Adopting a new ortho-rectification base derived from SPOT 6 imagery currently being worked on by BIG.
- Using SPOT 6 and Pleiades high resolution image data (acquired through a collaboration with Airbus Defence and Space) to assess and improve the forest extent mapping.
- Identifying cloud gaps in the Landsat image mosaics in important areas of change and searching for alternative optical image sources to fill the gaps. SPOT 4 and SPOT 5 may do this for the more recent years.
- Using radar data sources to separate some land cover types that are more difficult to separate using optical data.

Activities for improving the efficiency of the creation of the products that are being discussed include:

- More automated cloud-masking, particularly taking advantage of the improved signal quality and new image bands available in Landsat 8 data.
- Porting the software for the mostly automated processing steps to run on new data servers with faster I/O capabilities and/or faster network connections.

To guide the continuous improvement process, feedback from the data users and data processing team should be sought to identify the issues that have the biggest effect on the efficiency or suitability of the products. Research tasks will be designed to develop and test new methods against the current results for both accuracy and efficiency. If new methods, or new data sources, prove to be better, training in the new processing will be provided to the processing teams and the operational methodology updated. This cycle of evaluating, testing and improving can be continued throughout the program life.

In parallel with improving the methodology, the infrastructure for data processing, data archiving and data delivery should be reviewed. Substantial improvements in technology have already been adopted in the LCCA through developments in LAPAN's Remote Sensing Technology and Data Centre. Multi-CPU blade server computational technology has become available for the most computationally intensive steps in the processing and the data archive is being transferred to new, faster servers in the Data Centre.

There is also a need to educate the user community about the current products – their strengths and limitations for particular purposes and seek feedback on how best to deliver information products for applications other than the original carbon accounting purpose.

The INCAS-LCCA is one of a number of programs being developed for forest monitoring purposes both within and outside Indonesia. A formal accuracy assessment process should be developed to compare different products, noting that they will most likely have different purposes and different policy drivers. For example, LAPAN are developing a rapid response, 'early warning' forest detection methodology. The temporal resolution is much finer and the spatial resolution is much coarser than the INCAS-LCCA. The accuracy requirement is also lower. All areas of possible forest clearing are detected and provided to local/regional agencies for on-ground verification. Only those areas that are confirmed by these sources are acted upon. Opportunities for coordination and cooperation between these two projects are being considered as well as with other research activities.

Finally, the LAPAN team now has the capability to consider developing new products to complement the current forest extent and annual change maps. Such developments must be undertaken in collaboration with the other stakeholders, and will typically involve other data in addition to remote sensing.

### 3. SAMPLE RESULTS

The primary objective of the LCCA is to produce annual forest extent and change products. Figure 1.1 in the first section shows the forest extent, forest loss and forest gain from 2000-2009. Figure 3.1 shows the 2000-2012 product in more detail for Kalimantan.

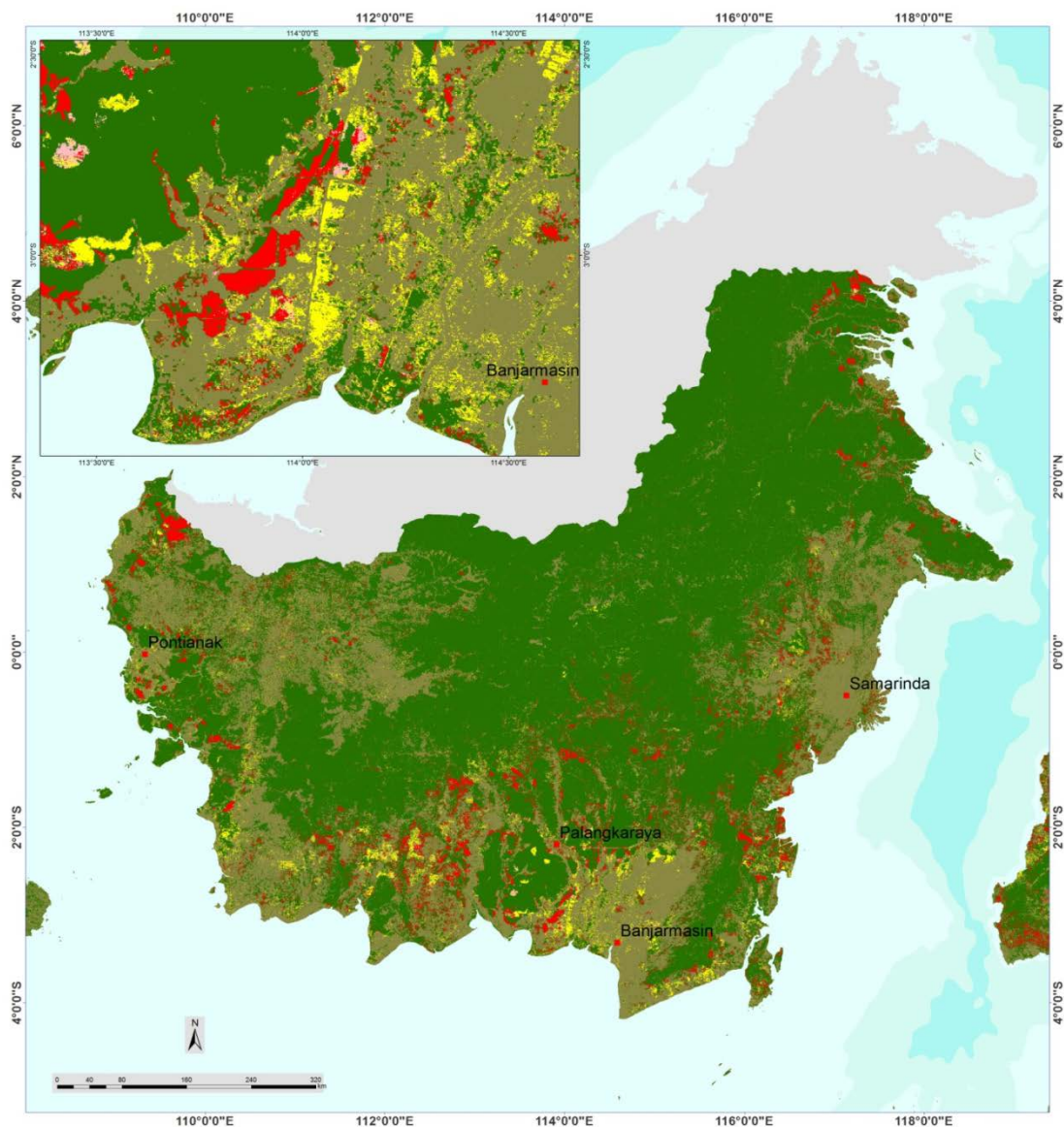


Figure 3.1. Forest extent and change map 2000-2012 for Kalimantan produced by the LCCA. Dark green indicates areas that were always forest from 2000 to 2012, red shows forest loss between 2000 and 2012 while yellow indicates forest gain in the same period. [source: INCAS poster, Workshop on Earth Observation Satellite Data to Support REDD+ Implementation in Indonesia, February 2014].

The change in forest extent is available on an annual basis, as shown in Figure 3.2. Statistical summaries of forest extent and change at national, regional and provincial levels can be produced from the digital products.

It is noted, in the context of carbon accounting, that not all change is relevant to reporting requirements. The identification of relevant land units for inclusion in a national carbon account is dependent on policy decisions from the national reporting agency.

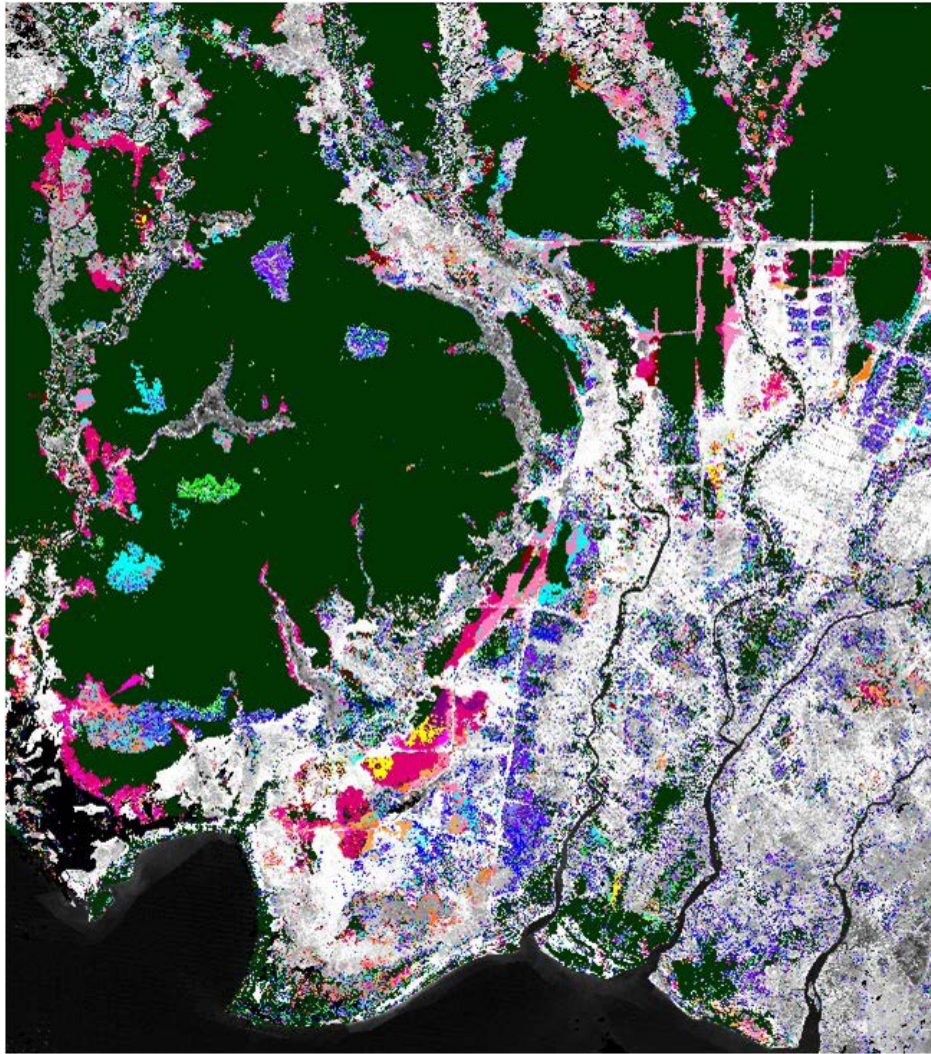


Figure 3.2. Forest extent and change map 2000-2012 for a region in Central Kalimantan produced by the LCCA. Dark green indicates areas that were always forest from 2000 to 2012, shades of red, orange, yellow and pink show forest loss between 2000 and 2012. Each shade corresponds to a different year (e.g 2000-2001, 2001-2002, ... , 2011-2012). Shades of green, blue and purple indicate reforestation in the same period. [source: INCAS poster, Workshop on Earth Observation Satellite Data to Support REDD+ Implementation in Indonesia, February 2014].

Some of the datasets assembled during the LCCA processing are useful products for a range of other applications. The individual geometrically and radiometrically corrected images are available along with corresponding cloud masks. Regional and national mosaics are also available. An example is shown in figure 3.3.



Figure 3.3. 2007 Landsat mosaic of Nusa Tenggara with bands 3,4,5 in BGR. The area shown is approximately 1500km by 500km. Black areas within the islands indicate areas of missing data due to cloud in 2007.



