パプアニューギニア独立国
森林公社

# パプアニューギニア国
# 気候変動対策のための PNG 森林資源情報管理システムの活用に関する能力向上プロジェクト

# 業務完了報告書
# （添付資料 パート 2）

令和元年 9 月
（2019 年）

独立行政法人
国際協力機構（JICA）

国際航業株式会社

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# パート２

# その他のプロジェクト成果

## *添付資料 6*

## *プロジェクト Fact Sheet と Analytical Report*

Fact Sheet

| | |
|---|---|
| Fact Sheet No.1 | JICA-PNGFA PROJECT Outline |
| Fact Sheet No.2 | Papua New Guinea Forest Base Map 2012 |
| Fact Sheet No.3 | PNG-FRIMS |
| Fact Sheet No.4 | Forest Monitoring Unit (FMU) in Papua New Guinea Forest Cover Map |
| Fact Sheet No.5 | Constraints data – Natural condition layers in the PNG-FRIMS |
| Fact Sheet No.6 | Watershed and Catchment Data |
| Fact Sheet No.7 | Digitized Road Information |
| Fact Sheet No.8 | Forest Concession and Land Management Layers in PNG-FRIMS |
| Fact Sheet No.9 | Forest Cover Map 2015 |
| Fact Sheet No.10 | Drone Applications in Sustainable Forestry Management and Monitoring in PNGFA |

Analytical Report

| | |
|---|---|
| Analytical Report No.1 | Analysis of Drivers of Deforestation and Forest Degradation in Papua New Guinea |
| Analytical Report No.2 | Analysis of Future Forest Change Modeling in Papua New Guinea |
| Analytical Report No.3 | Potential in Papua New Guinea to estimate emissions from forest degradation caused by logging based on field methods (using FRIMS) |

# JICA-PNGFA PROJECT Outline

## Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change

Citation: JICA and PNGFA, 2017, '2014-2019 JICA-PNGFA Project Outline - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.1'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

## Outline of the Project

### Situation of Papua New Guinea

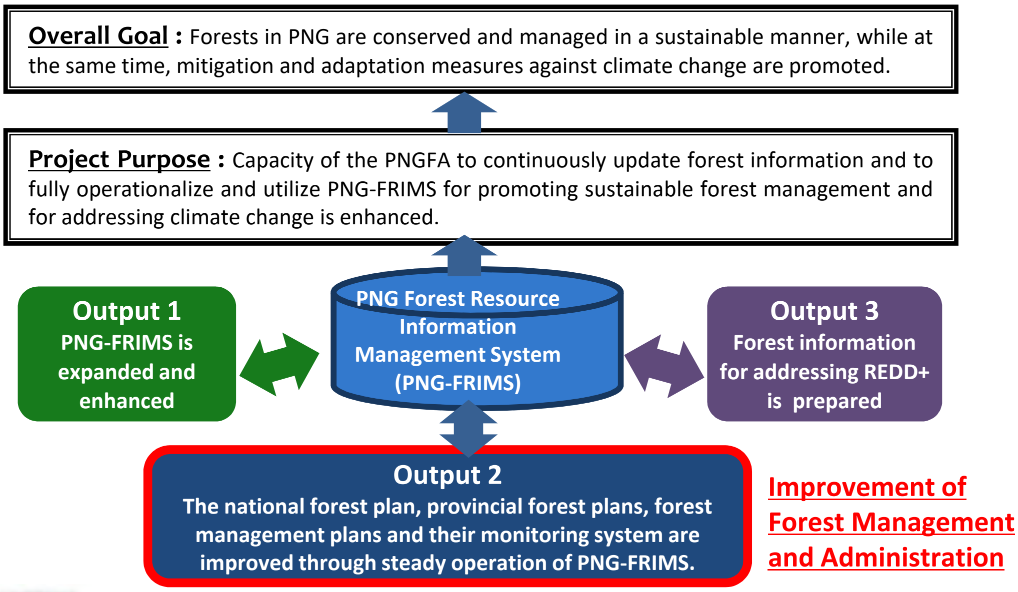
The forest of Papua New Guinea (PNG) contains some of the largest areas of tropical rainforest in the Pacific region. The tropical rainforest plays important roles in many aspects, contributing to the national economy through timber exports, rich biodiversity and mitigation of climate change. While alarming rate of loss and degradation of forest have been reported in recent decades, there was no robust forest monitoring system in PNG to detect these loss and degradation . In order to address this challenge, Japan International Cooperation Agency (JICA) and PNG Forest Authority (PNGFA) implemented a capacity development project from March 2011 to March 2014, combined with the Japanese Grant Aid Program that provided the project with remote sensing data, GIS equipment, and training program for the officers of PNGFA and other relevant government agencies.

### JICA-PNGFA Project 2011 – 2014 (Phase 1) : Achieved Outcomes

The project successfully developed a Nation-wide Forest Base Map 2012 that suggested a necessity of closer monitoring on forest operation and the extent of forest degradation and deforestation over the 37 million hectares of forest in PNG. The project also established a PNG Forest Resource Information Management System (PNG-FRIMS) based on a GIS system with remote sensing technology. Other outputs of the project include the proposals on some tools for forest monitoring such as radar technology and carbon estimation. The project also contributed in determining the threshold values of the national definition of forest for PNG.

### JICA-PNGFA Project 2014 – 2019 (Phase 2) : Planned Outcomes

In order to improve the cyclic management of forest in PNG in coherent manner, the new project aims to enhance capacity of PNGFA to continuously update forest information and to fully operationalize and utilize PNG-FRIMS for promoting sustainable forest management and for addressing climate change. The new project commenced in August 2014 and will terminate in August 2019.

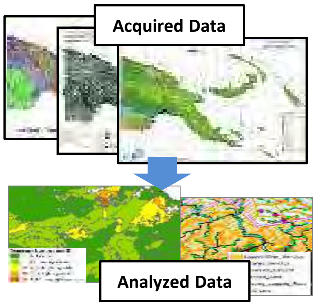



Observed logging impact (high & low) on RapidEye 5m resolution imageries

# Expected Outputs and Progress

## Output 1 Enhanced PNG Forest Resource Information Management System (PNG-FRIMS)

Progress : Enhanced Forest Base Map (national), Progressing Time-series Forest cover Maps & Future Model (2 province), Classifying Forest Disturbance, Creating Logging Roads (5 years), Demonstrating Land Change Modeling using FRIMS




**PNG-FRIMS**

- Vegetation area
- Timber volume
- Inventory data
- Carbon stock, etc.
- Concession area
- Logged area
-Landowner map
etc.

Forest Base/Cover Maps
Logging information
Constraints
Base/Topography

- Protected area
- Inundation area
- Mining lease
etc.
- Satellite Images
- Topo Maps
- Slope/Contour
- Road/River, etc.

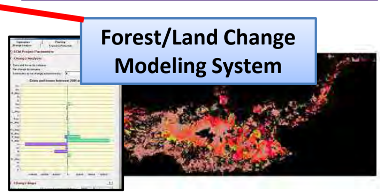
Detect forest change widely by frequent satellite image/data with logging plan and records

Examine loss drivers by reviewing high resolution satellite image/data and time series of dynamics

Provide analyzed change area without approved logging plans

**Integrated Management of Forest Information**




## Output 2 Improved National/Provincial Forest Plans, Management Plan/Monitoring System

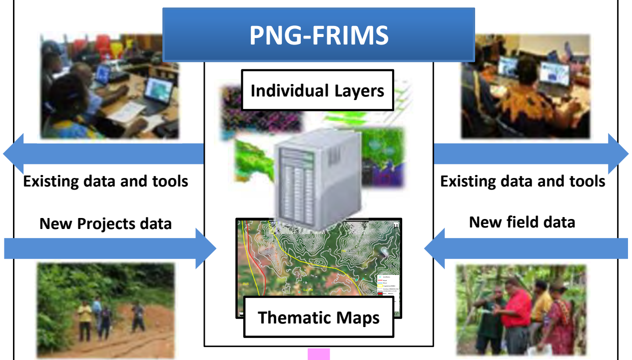
Progress : Considered utilization of PNG-FRIMS for forest planning/management, monitoring activities through trainings

**Forest Planning Activities**

National Forest Plan | Provincial Forest Plans

Project activities:
- Decision making support for land use planning
- Support for data management

Expected outcomes:
- Better planning
- Annual Allowable Cut volume calculation on a sustainable yield basis




**Forest Management Activities**

Monitoring logging operation | Forest plantation management | Map making support for landowners

Project activities:
- Capacity development for necessary tools operation
- Improvement of data sharing method

Expected outcomes:
- Enhanced field work
- Data updating on field basis

**Promoting Sustainable Forest Management (SFM)**

## Output 3 Prepared/Identified Forest Information for addressing/contributing-to REDD+

Progress: (1) Contributed to National Forest Monitoring System & Reference Level (2) Identified potential area for REDD+

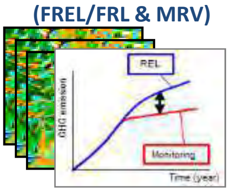
Input/Provide Info — **PNG-FRIMS** — Input/Provide Info

**UN-REDD/FAO**

Support National Forest Monitoring System (NFMS)

Disseminate Forest Info Web-Portal (Transparency)

Support Reference Level (FREL/FRL & MRV)




Consider Improvement of FREL/FRL (for future)

Monitor Logging Code of Practice (LCoP)

Reduce Degradation (Promote Regeneration)

**FCPF/UNDP**

Initiate Landuse & Landscape Planning

Reduce Deforestation (Proper Development)

Promote & Plan Forest Plantation

C-Stock Enhancement (Plan Afforestation)

**Exploring Potential Utilization of FRIMS for REDD+**


**PNG Forest Authority (JICA Project)**
Address: P.O.Box 5055, Boroko, National Capital District, Papua New Guinea
Email: cbigol@pngfa.gov.pg / dkadowaki@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/


Last updated on Feb. 2018

# Papua New Guinea Forest Base Map 2012

Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change

## 1. Background

### JICA PNGFA Project 2011-2014

Japan International Cooperation Agency (JICA) and PNG Forest Authority (PNGFA) implemented a capacity development project since 2011 to 2014 combined with the Japanese Grant Aid Program that provided the project with remote sensing data and GIS equipment. The project set up a PNG Forest Resource Information Management System (PNG-FRIMS) based on a GIS system with remote sensing technology (JICA and PNGFA, 2016).

### Development History of the Forest Base Map 2012

Before the project 2011-2014, national level Forest Base Map was created as at 1975 and had not been updated since minor update in 1996. This outdated map based on legacy technology caused various practical problems to PNGFA. Responding to this situation, The PNG Forest Base Map 2012 was initially developed as a main layer of the PNG-FRIMS in 2014. Following the successful completion of the project 2011-2014, new project 2014-2019 commenced for realizing the full operationalization of the PNG-FRIMS. The improvement and finalization of the Base Map 2012 was taken over by this new JICA-PNGFA Project 2014-2019 and completed in February 2016.

## 2. Development, improvement and finalization of the Base Map 2012

In order to cope with challenging conditions including rugged terrain, vast forest area, very poor road connection and landowner issue (97% of the land in PNG is customary owned by clans), Forest Base Map 2012 was developed using optical satellite imagery (RapidEye), Rader satellite data (ALOS-PALSAR) and other existing data. Significant improvements such as up-to-date information, finer segmentation size, forest/non-forest delineation including water area etc. are seen in the newly developed Forest Base Map 2012.

ALOS-PALSAR: The Advanced Land Observing Satellite (ALOS) "DAICHI" equipped with Phased Array type L-band Synthetic Aperture Radar (PALSAR) launched by Japan Aerospace Exploration Agency (JAXA) in 2006.

## (a) Data input and process

Satellite observation data used for developing the PNG Forest Base Map 2012 (Base Map 2012) include RapidEye (optical sensor, captured in 2010 and 2011) and ALOS-PALSAR (radar sensor, captured in 2007 and 2010). Airborne radar information shared from the PNG National Mapping Bureau (NMB) was also utilized as data for elevation from sea level.

Classification and its coding system of forest and other land-cover used in the Base Map 2012 was developed by integrating classification code necessary for PNGFA work and classes discernible from satellite imageries on the basis of the land cover classification and code registered in Forest Inventory Mapping System (FIMS) (Hammermaster & Saunders, 1995 and McAlpine, and Quigley, 1998,). 'Alpine grassland' and 'Subalpine grassland' were picked up from 'Grassland and Herbland' according to the elevation from sea level. 'Forest plantation' and 'Plantation other than forest plantation' are newly added to the Forest Base Map 2012. Details of the classification and coding system are illustrated in sub-section (b) below.

Segmentation and object-based classification of the land cover was done by using a software 'eCognition' for satellite imagery analysis as well as a software 'R' for statistical analysis of the segments. For this analysis, we utilized RapidEye satellite imageries (five bands), NDVI (Normalized Difference Vegetation Index) generated from analysis on RapidEye data, elevation data shared from NMB (five meter mesh), and slope and watersheds (or catchment boundaries) generated from analysis on NMB elevation data.

Automated classification of the segments were done for forest and other vegetation by 'eCognition' and 'R', after calculating 'feature parameters' of each segment by using statistical value including average and standard deviation of various parameters of all pixels in each segment. The classification was done by multi-stage classification following a forest classification flowchart tailored for this work, by using parameters including Brightness, Green, Near Infra-Red (NIR), NDVI, elevation from Digital Elevation Model (DEM), and slope.

Where we encountered with difficulty by cloud cover on optical RapidEye imageries, we interpolated forest/ non-forest distinction by utilizing PALSAR radar data.

Correction by human interpretation was made where we found automated classification is difficult for some classes (Larger Urban Centres, Bare Areas, Cropland/ Agriculture land, Woodland, Savanna, and Scrub) or obvious error classification made by automated process. The human interpretation was supported by photographs taken by digital camera on hand-held GPS (Global Positioning System) terminal from helicopter, verification by ground truthing, mobilization of existing knowledge, and literature study.

'Forest Plantation' was distinguished from 'Plantation other than forest plantation' by referring to plantation boundaries data owned by PNGFA. 'Forest Plantation' indicated on the Forest Base Map is not necessarily corresponding to the actual distribution of forest plantations since PNGFA does not have every boundary information of forest plantations which are often managed by private sectors.

Some classes (Cropland/ Agriculture land, Forest Plantation, and Plantation other than forest plantation) are delineated by human interpretation relying on local knowledge of PNGFA officers and staffs attached to Area and Provincial Forestry Offices by utilizing RapidEye imageries and geo-referenced photographs taken by handheld GPS terminal. The PNGFA officers and staffs used ultrahigh resolution satellite imageries on Google Earth and Bing Map, existing information on cropland (Mapping Agriculture Systems of PNG, MASP and Papua New Guinea Resource Information System, PNGRIS), and data on Digital Elevation Models (DEMs).

## (b) Typology of forests and other land use

| | | | |
|---|---|---|---|
| **P** | Low altitude forest on plains and fans – below 1000 m | **G** | Grassland and herbland |
| **H** | Low altitude forest on uplands – below 1000 m | **Ga** | Alpine grassland – above 3200 m |
| **L** | Lower montane forest – above 1000 m | **Gi** | Subalpine grassland – above 2500 m |
| **Mo** | Montane forest – above 3000 m | **M** | Mangrove |
| **D** | Dry seasonal forest | **O** | Cropland/Agriculture land |
| **B** | Littoral forest | **Qa** | Plantation other than forest plantation |
| **Fri** | Seral forest | **Qf** | Forest plantation |
| **Fsw** | Swamp forest | **E** | Waterbody |
| **W** | Woodland | **Z** | Bare area |
| **Sa** | Savanna | **U** | Larger urban centre |
| **Sc** | Scrub | | |

## (c) Appropriate scale of use

The ground resolution of the RapidEye imageries used for the development of the Forest Base Map 2012 data is five (5) meters (re-sampled from original six point five (6.5) meters) meanwhile it is ten (10) meters for PALSAR used for interpolating cloud cover area. The mapping scale is between 1/25,000 and 1/50,000 for the data development while minimum mapping polygon size is 1 hectare. Therefore, this map should be used at a scale between 1/25,000 and 1/50,000 with noting the constraint of location accuracy described in the sub-section (d) below.

## (d) Limitations of location accuracy and geographical coverage

Location accuracy: The location accuracy of the Forest Base Map 2012 is equal to that of orthorectified dataset of LANDSAT (Land Satellite) developed by United States Geological Survey (USGS) because the specification was designed in accordance with LANDSAT, taking account of the conditions of reference data available for PNG and future updating of data. According to the limitation of the resolution of LANDSAT, location error of plus or minus thirty (30) meters may have been included. Due to this limitation, it should be noted that the ground based positioning by GPS has higher location accuracy than that of this map.

Coverage: This map is developed for utilizing on purpose of forest management by the PNGFA. Therefore, the map does not exhaustively cover some small islands and other areas where forest management operation by PNGFA are not currently conducted.

Delineation of Cropland/Agriculture land: Since conditions of crop land varies depending on applied practice and cropping cycle, local knowledge and supplementary information is prerequisite for their interpretation and classification at much localized level. According to that nature, the map does not exhaustively cover all cropland and agriculture land.

Classification among Woodland, Savanna, and Scrub: The accurate delineation, verification and monitoring of boundaries of Woodland, Savanna, and Scrub cannot be done as long as relying on interpretation and classification solely on satellite imageries. The savanna, particularly in PNG, only occurs in limited areas resulting from repetitive human-induced burning under specific climatic and ecological conditions. The Scrub in PNG is also specifically defined as a low-rise forest vegetation comprised of specific tree species. Taking these conditions into account, these three classes are identified on the Forest Base Map 2012 by referring to FIMS and localities.

Distinction between P (Low Altitude Forest on Plains and Fans, Plain-Forest) and H (Low Altitude Forest on Uplands, Hill-Forest): The distinction between 'P' and 'H' type forest are made according to incline (or slope) in the Forest Base Map 2012. We are aware that the distribution of 'P' and 'H' are significantly different between the Forest Base Map 2012 and FIMS in Western Province where plains are dominant and topography is relatively gentle. This difference occurred mainly because the FIMS development process took account of composition of tree species as well. After consultations within JICA Project Team (comprised of PNGFA officers and JICA experts), we decided to keep the methodology for the Forest Base Map 2012 as it is because the classification depending on slope is important and useful information for forest management operations. The slope is often a main determinant of efficiency and practicability of the logging operations as it determines maneuverability of heavy machineries in field.

## 3. Contents of the 2012 map

| | VEG | VEGNAME | Area (ha) |
|---|---|---|---|
| | P | Low Altitude Forest on Plains & Fans | 8,707,393 |
| | H | Low Altitude Forest on Uplands | 12,264,035 |
| | L | Lower Montane Forest | 8,042,001 |
| | Mo | Montane Forest | 355,513 |
| | D | Dry Seasonal Forest | 935,368 |
| | B | Littoral Forest | 70,358 |
| | Fri | Seral Forest | 158,719 |
| | Fsw | Swamp Forest | 2,035,431 |
| | M | Mangrove Forest | 521,933 |
| | W | Woodland | 3,062,749 |
| | Sa | Savanna | 639,969 |
| | Sc | Scrub | 392,078 |
| | G | Grassland and Herbland | 3,231,935 |
| | Ga | Grassland (Alpine) | 110,602 |
| | Gi | Grassland (Subalpine) | 86,979 |
| | Z | Bare areas | 23,874 |
| | U | Larger Urban Centres | 23,896 |
| | E | Lake & Larger Rivers | 600,105 |
| | O | Cropland/Agriculture land | 4,413,543 |
| | Qf | Forest Plantation | 66,670 |
| | Qa | Plantation other than Qf | 411,614 |
| | | SUM | 46,154,764 |

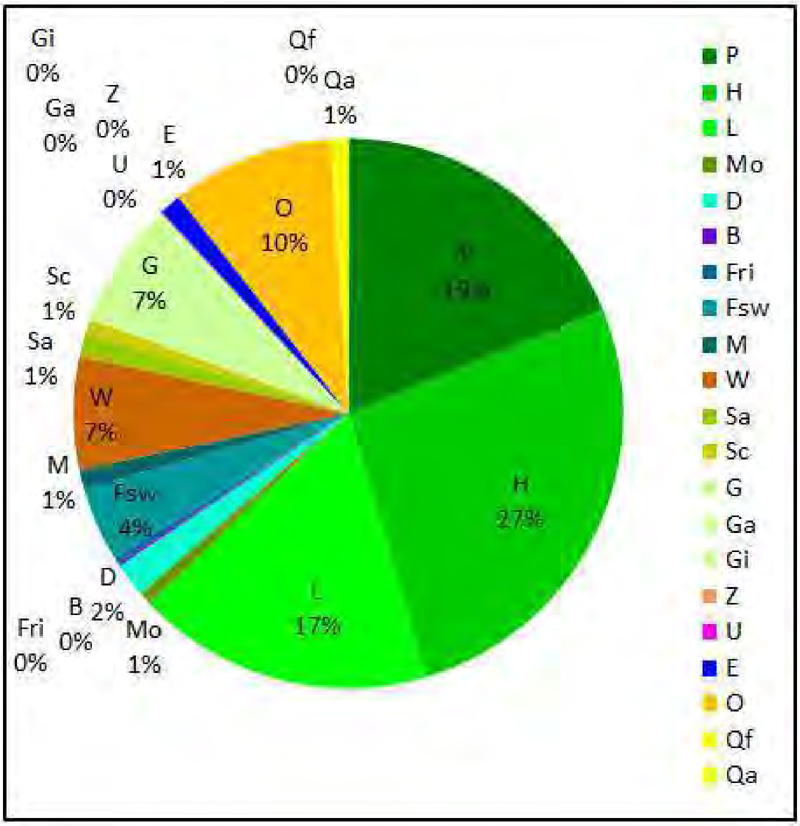



***Table 1. Forest area by forest type***

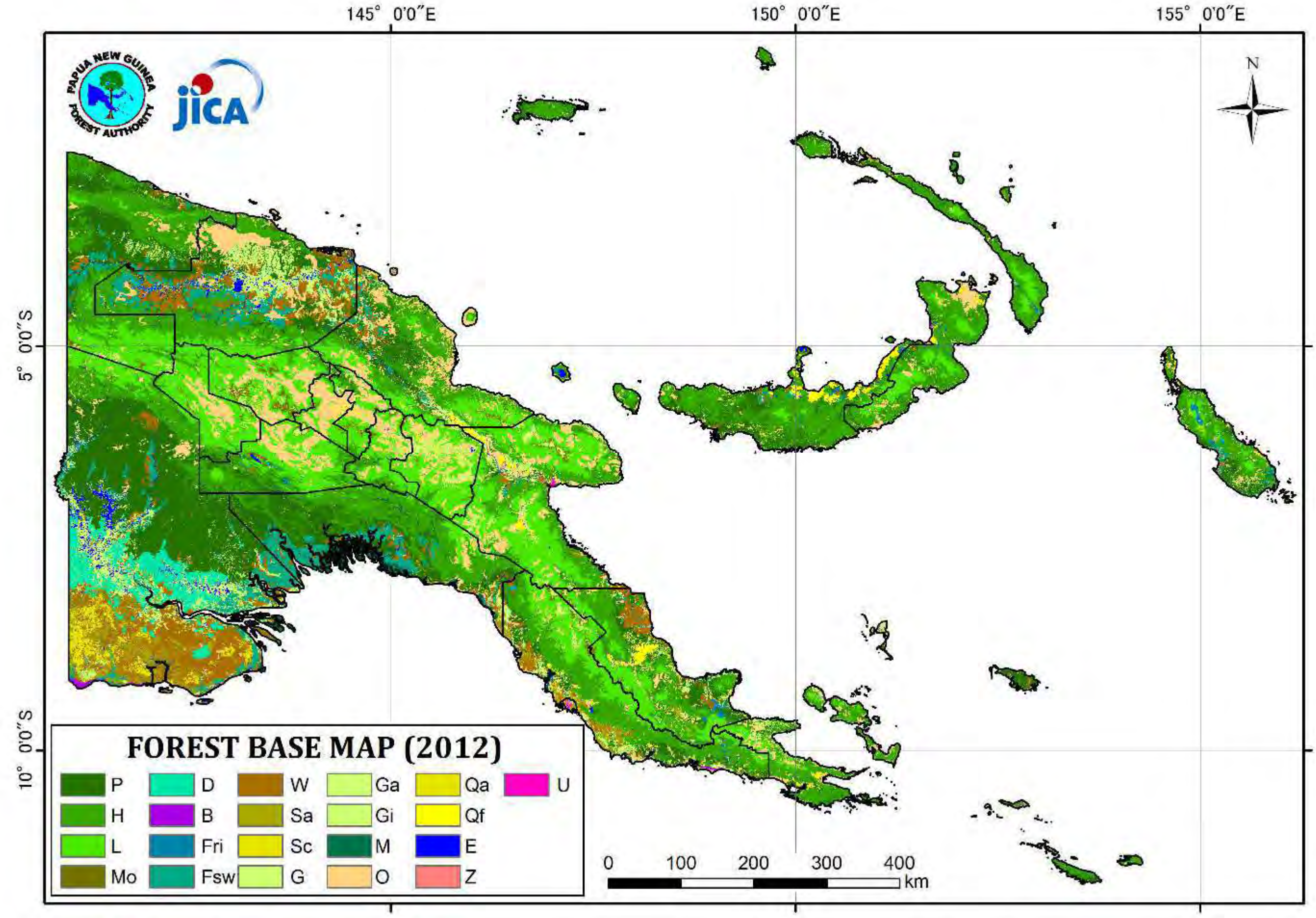



*Figure 1. Forest Base Map 2012*

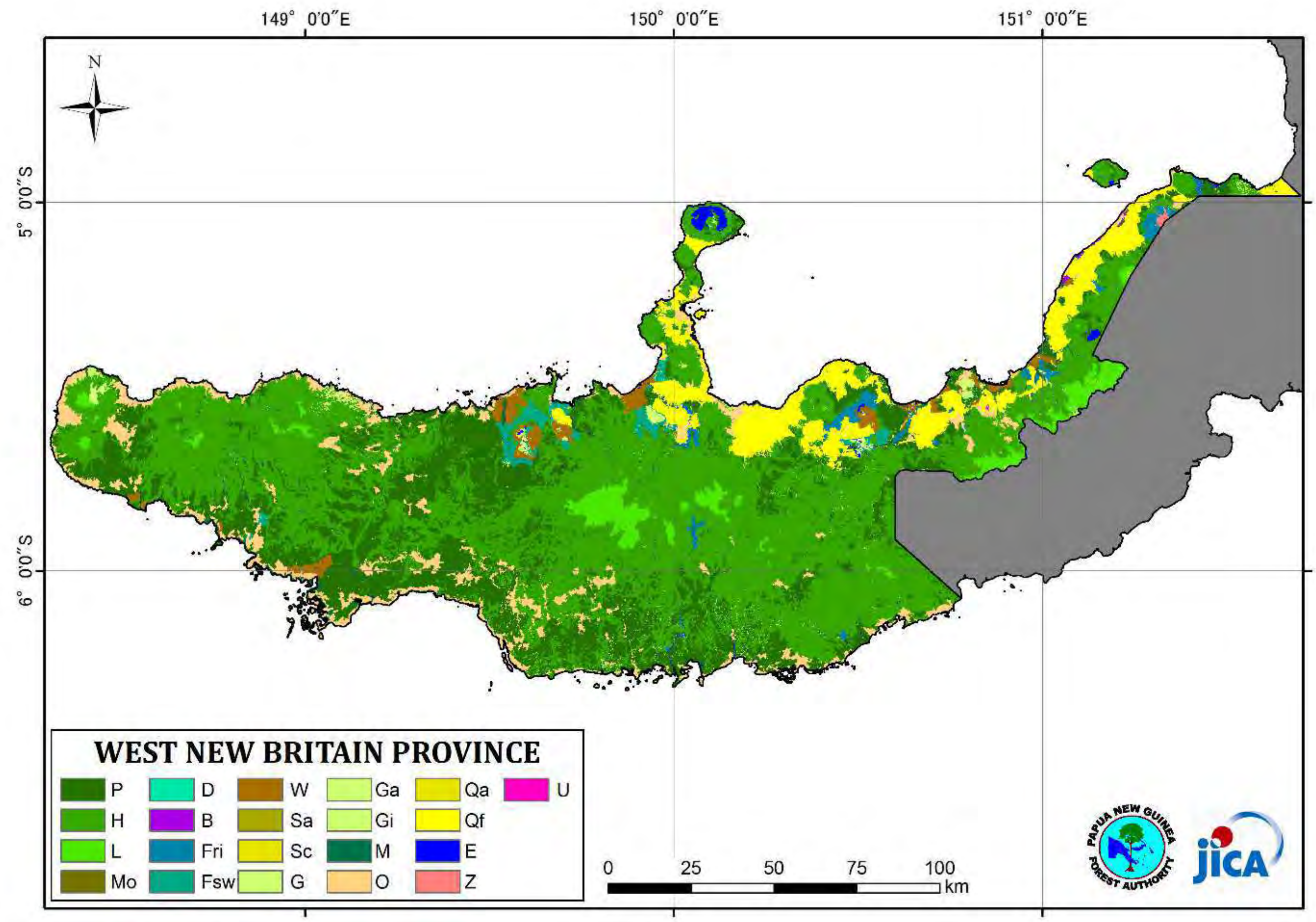



*Figure 2. Forest Base Map 2012 (West New Britain province)*

# 4. Data Access and contacts

## (a) Paper map 'PNG Forest Base Map 2012' by computer prints

| Coverage | Size | Scale | Price (See Note) |
|---|---|---|---|
| National | A0, A1, A2, A3, A4 | 1: 1,600,000 to 6,400,000 | K150, 100, 50, 40, 20 |
| Province | A0, A1, A2, A3, A4 | 1: 150,000 to 2,200,000 | K150, 100, 50, 40, 20 |

Note: Price in this table subject to change without further notice.

## (b) Digital format

| Format (See Note (1)) | Coverage | Fit to print on or scale at | Suitable medium | Price (See note (2)) |
|---|---|---|---|---|
| PDF | National | A3 | CD-ROM | K 50 |
| | Province | A3 | | K 50 |
| Raster on TIFF | Province | To be used from 1/50,000 to 25,000 | | K 20 (See note (3)) |

Note (1): Provision of other digital format map may be arranged and admitted for government and academic institutions for public and research purposes principally for mutual information exchange basis subject to agreement of Minutes of Understanding or other appropriate form of written consent.

Note (2): Price in this table subject to change without further notice.

Note (3): Raster on TIFF format may be shared subject to a written consent of usage and copyright credit obligation and citation with acknowledgement to PNGFA and JICA in case of further use in a publication, academic work and any other type of use of the data. A decision on this manner of distribution is made by the PNGFA and JICA according to the nature of the data and its usefulness for the social development of PNG as an information social infrastructure.

## (c) Contact information

Constin Otto Bigol, Manager, Forest Inventory and Mapping
PNG Forest Authority
Address: P. O. Box 5055, Boroko, National Capital District, Papua New Guinea
Email: cbigol@pngfa.gov.pg

## (d) Liability

In no event will the authors, its related partnerships or corporations be liable to anyone else for any decision made or action taken in reliance on the information in this map or for any consequential, special or similar damages, even if advised of the possibility of such damages.

## 5. Reference

Bourke, R.M., Allen, B.J., Hobsbawn, P. and Conway, J., 1998, 'Papua New Guinea: Text Summaries. Agricultural Systems of Papua New Guinea Working Paper No.1'. Department of Human Geography, Research School of Pacific and Asian Studies, The Australian National University, Canberra, Australia

Hammermaster, E.T. and Saunders, J.C., 1995, 'Forest Resources and Vegetation Mapping of Papua New Guinea. PNGRIS Publication No. 4'. AusAID, Canberra, Australia

McAlpine, J. and Quigley, J., 1998, 'Forest Resources of Papua New Guinea Summary Statistics from the Forest Inventory Mapping (FIM) System'. Prepared by Coffey MPW Pty Ltd for the Australian Agency for I international Development and the Papua New Guinea National Forest Service

JICA and PNGFA, 2016, '2014-2019 JICA-PNGFA Project Outline - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.1'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

## 6. Citation

JICA and PNGFA, 2017, 'Papua New Guinea Forest Base Map 2012 - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.2'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

**PNG Forest Authority (JICA Project)**
Address: P.O.Box 5055, Boroko, National Capital District, Papua New Guinea
Email: cbigol@pngfa.gov.pg / dkadowaki@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring

Last updated on Feb. 2018

JICA-PNGFA Forestry Project 2014-2019 - Fact Sheet No.3

# PNG-FRIMS

# Papua New Guinea Forest Resource Information Management System

Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change

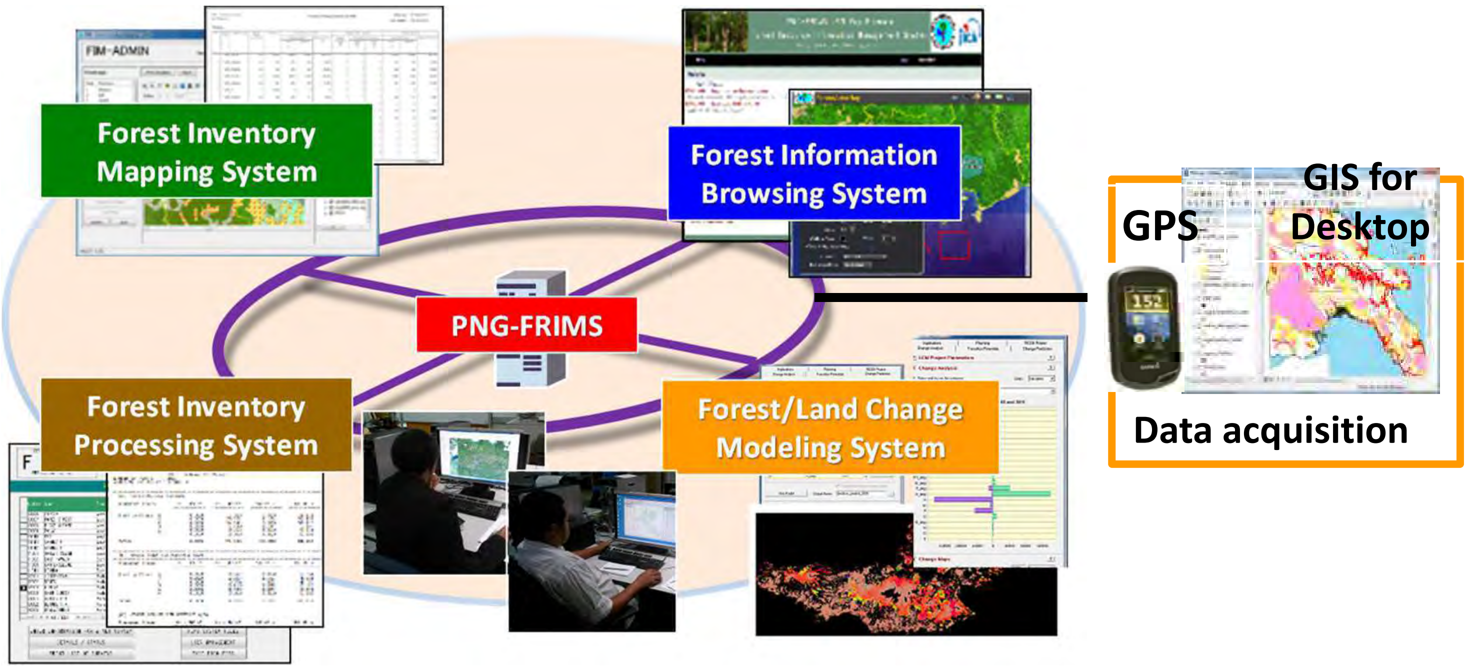
## 1. What is PNG-FRIMS?

### Overview

- PNG-FRIMS is a system responsible for acquiring, managing and using **"spatial information/data"** on forests in Papua New Guinea. This promotes efficiency and sophistication of forest administration, and supports PNGFA decision making.
- It is a system for browsing of various spatial information/data among PNGFA; estimation of forest area using Forest Base Map (which includes vegetation and topographical information); estimation of commercial timber volume / carbon stock amount using logging history; and projection of land use change using time series data.
- PNGFA can update forest resource information and geospatial data in PNG-FRIMS using field survey data with GPS, logging plan submitted from logging companies and forest area / condition change monitored using satellite images etc.

### PNG-FRIMS will support

- Planning National Forest Plan / Provincial Forest Plan
- The formulation of new logging project and negotiation with landowners
- Monitoring logging projects and implementation of LCoP (Logging Code of Practice)
- Finding candidate area for forest plantation and management of forest plantation

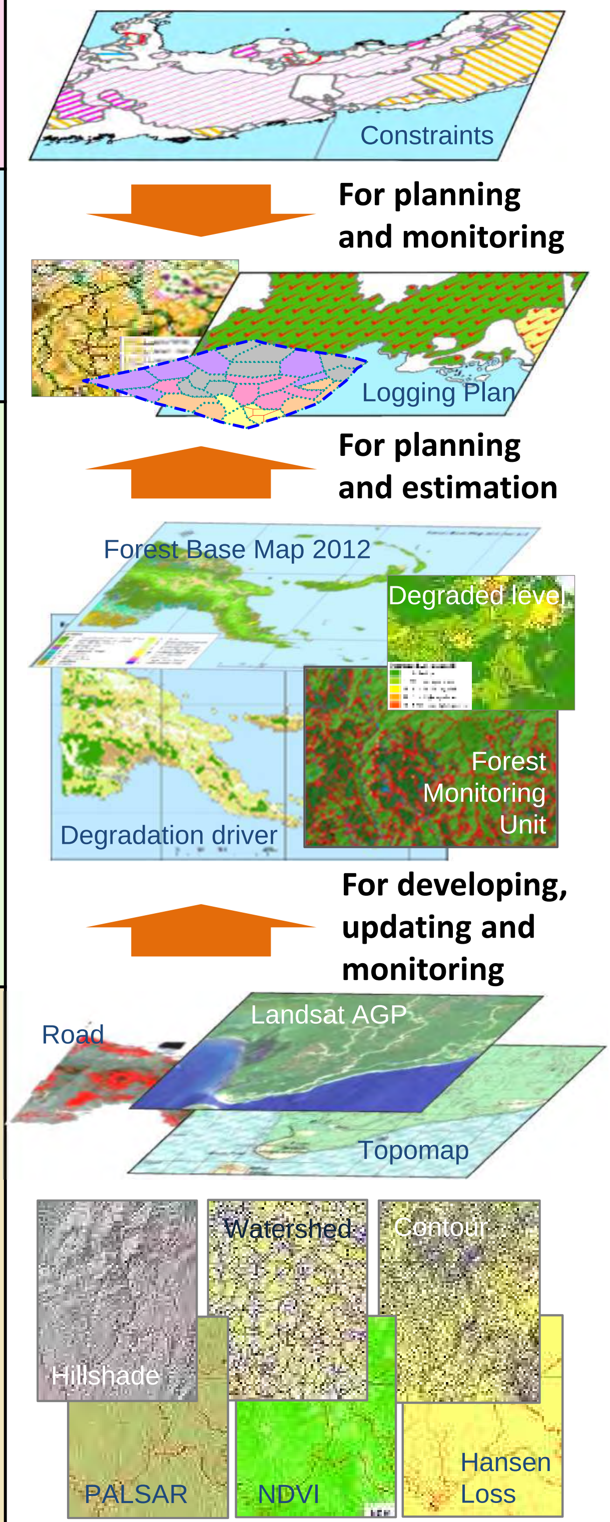


## 2. Information in PNG-FRIMS

There are four principal types of data in PNG-FRIMS:

- **Logging Concession Information;**
- **Constraints and Land Use;**
- **Forest Base/Cover Maps;** and
- **Base/Topography**,

| | |
|---|---|
| Logging Concession Information | Concession Area, Logged Area, Planned Area , Buffer zone<br>Topographic info: Logging road, River/ Stream, Contour<br>Facility info: Bridge/ Culvert, Campsite, Gravel pit, Log landing, Building, etc. |
| Constraints and Land Use | Social condition:<br>FCA (Forest Clearing Authority), Plantation, Protected Area, Mining operation area<br>Natural condition:<br>Slope (Extreme/ Relief), Altitude (Extreme), Karst, Inundation (Extreme/ Serious), Mangrove |
| Forest Base/ Cover Maps | Data:<br>Forest Base Map 1.1 (2012)<br>Time-series forest cover maps (2000/ 2005/2011) (WNB/ WSP, as of 15th Nov 2017)<br>Forest cover map 2015 (benchmark map) (ongoing)<br>Old vegetation (FIMS Forest Mapping Unit)<br>Collect Earth Landuse change Assessment (Point Sampling)<br>PSP (Permanent Sample Plots), © FRI (Forest Research Institute) All rights reserved.<br>Database of PINFORM (PNG International Tropical Timber Organization Natural Forest Model), © 1998 FRI All rights reserved.<br>Attributes:<br>Vegetation area, Tree crown size, Forest Zone, Timber volume, Carbon stock, Degradation driver, etc. |
| Base/ Topography | Satellite imagery:<br>RapidEye (2011), Landsat AGP (1990/ 1995/ 2000/ 2005/ 2010/ 2011/ 2014/ 2015), PALSAR (2010/ 2011)<br>Topomap (scale = 1:100,000, Raster)<br>Topography:<br>5m mesh Digital Elevation Model (Airborne Radar in 2006 from National Mapping Bureau), Hillshade, Slope, Contour (10m), Watershed (made from GeoSAR)<br>Global Dataset:<br>Hansen data (Tree cover loss/ lossyer/ gain)<br>Main road (time-series), River, Incorporated Land Group and Clan boundary/Settlement/ Local Level Government & District boundary/ Province-Region boundary (PNG Census 2000 and 2011), etc. |



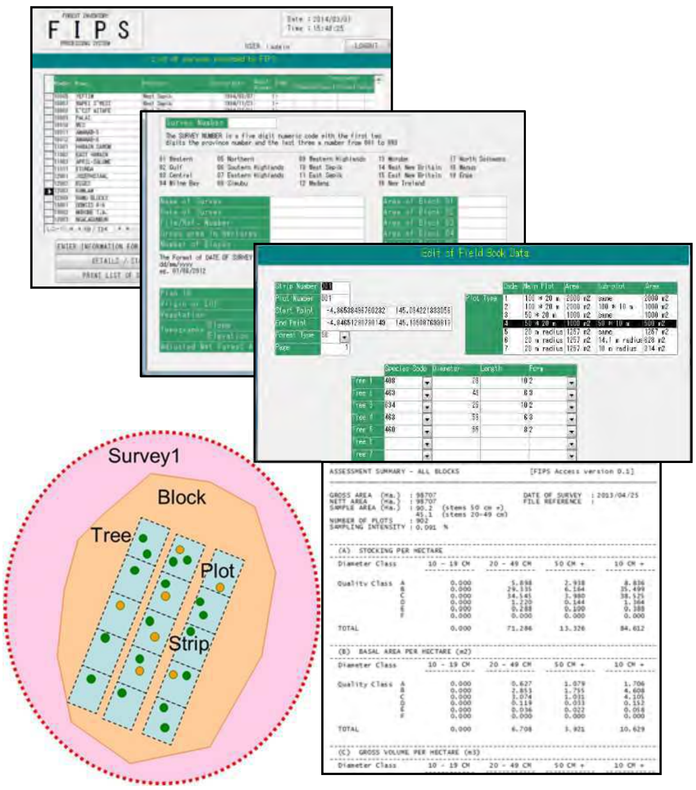

Database stores not only PNGFA data but also global dataset and the information from other organizations, which are updated and kept fresh periodically.

# 3. Functions of PNG-FRIMS

## (a) Forest Timber Volume Estimate (upgraded FIPS and FIMS)

JICA renewed and enhanced FIPS and FIMS which were developed in the previous century and integrated forest information for the estimation of timber volume into the PNG-FRIMS on the PNGFA's network.

### FIPS (Forest Inventory Processing System)



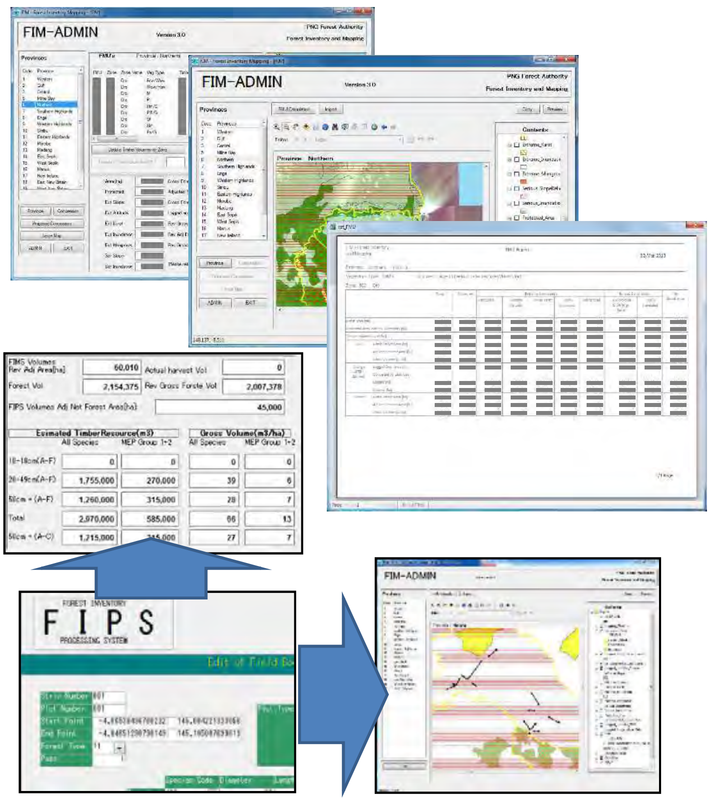

**Overview:**

- FIPS estimates the timber volume of the expected logging project area based on the data of the inventory survey.
- The estimated volume is to be used to determine an annual allowable cut of timber volume for the expected logging project.

**Basic functions:**

- Enter survey information and assessment data from field books (including species, diameter and length etc.)
- Edit and process assessment data
- Produce survey result and printout as summary report
- Import assessment data from Excel file into FIPS, and Export the Result of processed data from FIPS into Microsoft Excel format

### FIMS (Forest Inventory Mapping System)




**Overview:**

- FIMS calculates the potential timber volume in any level of area such as national, provincial and logging project.
- The volume is calculated using forest type per unit timber volume and to be adjusted by logged volume data.
- The volume estimate is to be utilized to develop forest plans (National/Provincial forest plan).

**Basic functions:**

- Manage not only planned and operational concession boundaries but also logged over areas reported by logging companies.
- Import assessment data from FIPS and show strip lines on map, which were used for surveys and timber volume processed by FIPS.

## (b) LAN (Local Area Network) Map Browser

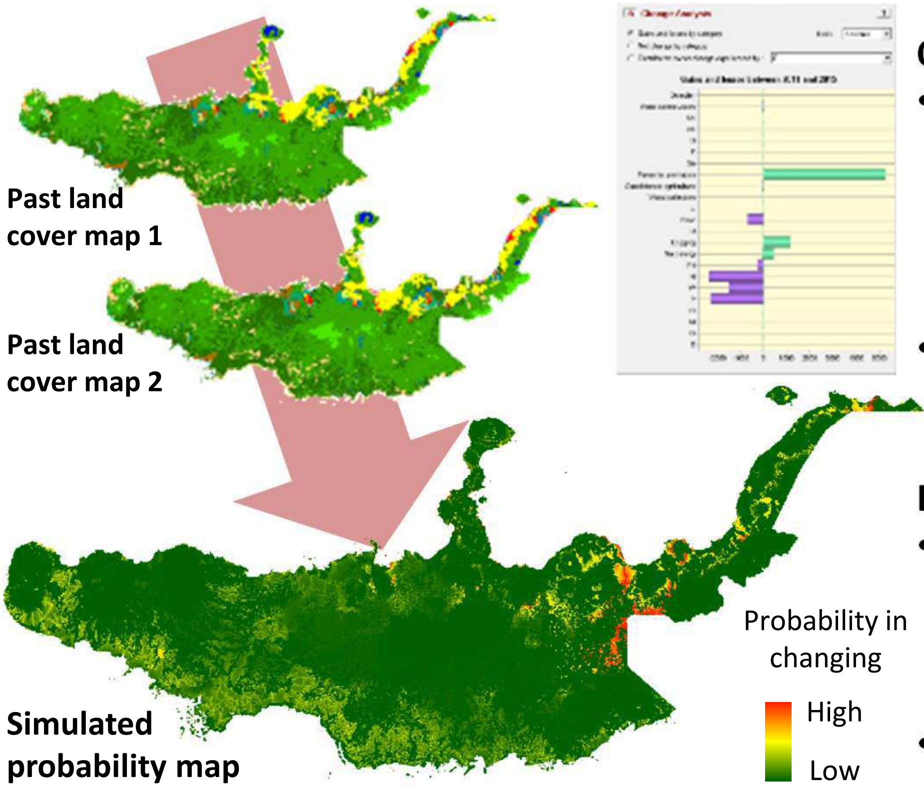
**Overview:**

- Sharing forest information stored in PNG-FRIMS database within PNGFA and promoting its utilization for PNGFA's daily activities.
- Authorized users can see thematic maps through a Web Browser without special software.

**Basic functions:**

- Turn forest info on and off on the map.
- Search for location/ point of interest.
- Measure length or area on the map
- Sketch simple graphics on the map.
- Print visible displayed map.
- Show attribute info of each graphics.
- Switch background maps (satellite imageries, topographic maps, etc.).
- Develop and add processing functions.

## (c) Forest Land Change Modeling System




**Overview:**

- Analyzing chrono-sequential spatial data including forest information, future land change (such as deforestation) and simulate probability in each location.
- This system uses Land Change Modeler, which is a product of Clark Labs, Clark University, USA.

**Basic functions:**

- The results of the simulation is useful for developing policies such as provincial forest plans and action plan of the national REDD+ strategy.
- Evaluation of the model is needed for utilization of the results.

**PNG Forest Authority (JICA Project)**
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Email: cbigol@pngfa.gov.pg / dkadowaki@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

Last updated on Feb. 2018

# Forest Monitoring Unit (FMU) in Papua New Guinea Forest Cover Map

Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change

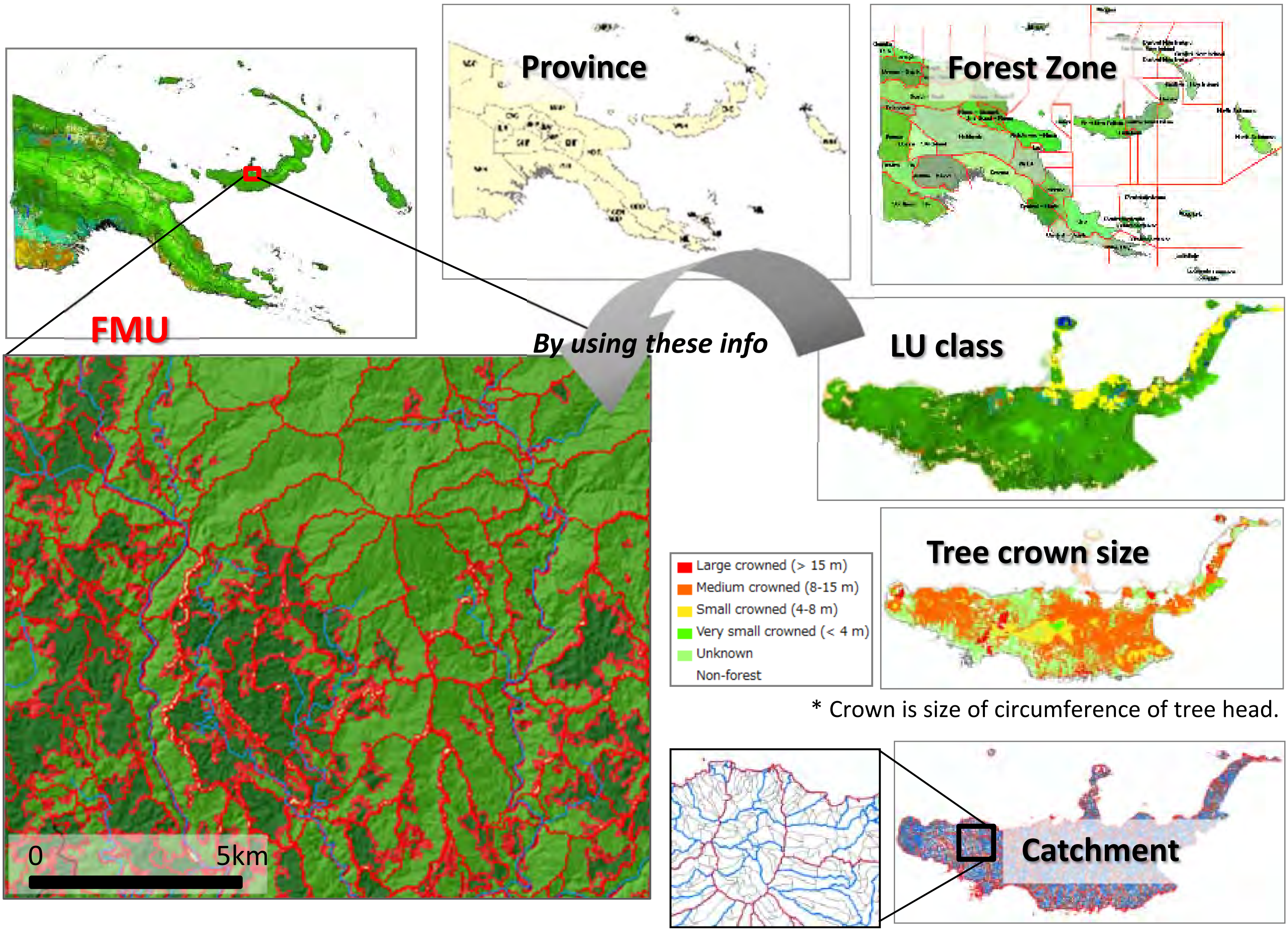
## 1. Background

National level vegetation map, which was created as at 1975 and updated in 1996, has been used in PNG Forest Authority (PNGFA). A unit of the vegetation map was called 'Forest Mapping Unit (FMU)' on PNG Resource Information System (PNGRIS) and Forest Inventory Mapping System (FIMS). This map caused various practical problems to PNGFA because it was out-dated and the units (FMU) were too large to capture forest conditions including timber volume. Responding to this situation, the PNG Forest Base Map 2012 was developed as a main layer of the PNG Forest Resource Information Management System (PNG-FRIMS) in 2014. A new unit of the Forest Base Map 2012 called 'Forest Monitoring Unit (FMU)' was redefined. This is because this unit is a base unit, which has and could have various information, so that it could be used for calculation of Annual Allowable Cut (AAC) volume and carbon stock, etc. by monitoring forest condition in the units.

## 2. FMU Definition and Selection Criteria

New 'FMU' was conceived as minimum unit of forest at 'not too small' scale for replacing legacy 'FMU (Forest Mapping Unit)'. The former FMU was 'too large' in relation to current available technology. The new FMU is to be used for monitoring and recording changes of forests on new PNG-FRIMS.

- The following name was decided: **Forest Monitoring Unit** on the Forest Base Map 2012 in the FRIMS
- Criteria used to delineate FMUs:
    - Province,
    - Forest Zone,
    - Catchment,
    - Landuse (LU) class, and
    - Forest type including crown size (see to next page)
- Minimum mapping unit (polygon) size: 1 hectare, while the mapping scale is between 1/25,000 and 1/50,000 for the data development.
- FMU has unique id (FMU_id) attribute, which would be used as a key attribute to link relational database.
- Subsequent forest cover maps to be developed will take over FMUs from the Forest Base Map.




* Crown is size of circumference of tree head.

Forest Base Map is divided into FMUs, which is composed of information above and could be added various attribute to monitor forest.

## 3. References

Hammermaster, E.T. & Saunders, J.C., 1995, 'Forest Resources and Vegetation Mapping of Papua New Guinea. PNGRIS Publication No. 4'. AusAID, Canberra, Australia

McAlpine, J. and Quigley, J., 1998, 'Forest Resources of Papua New Guinea Summary Statistics from the Forest Inventory Mapping (FIM) System'. Coffey MPW Pty Ltd for AusAID and PNGFA

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JICA and PNGFA, 2016, 'Papua New Guinea Forest Base Map 2012 - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.2'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

JICA and PNGFA, 2018, 'Papua New Guinea Forest Resource Information Management System - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.3'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

**PNG Forest Authority (JICA Project)**
Address: P.O.Box 5055, Boroko, National Capital District, Papua New Guinea
Email: rturia@pngfa.gov.pg / dkadowaki@pngfa.gov.pg
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Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

Last updated on Mar. 2019

# Constraints data

## Natural condition layers in the PNG-FRIMS

Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change

## 1. Background

Constraints data is one of the PNG Forest Resource Information Management System (PNG-FRIMS) data sets developed in the JICA-PNGFA Project. The data was sourced from legacy Forest Inventory Mapping System (FIMS). Constraints is significant information for PNG Forest Authority (PNGFA) since it defines natural conditions and constrains to logging activities. However, PNGFA, realizing some errors in the legacy data set, replaced it with a corrected data set.

To update constraints data, available and efficient data and methods were considered. Constraints data covers entire PNG and it should have enough accuracy while maintaining sufficient performance in actual use on PNG-FRIMS. The data and methods used are shown in section 3. Constraints layers in PNG-FRIMS were updated in December 2016.

This data set is mainly used to plan, control and monitor logging operations to assist in forest management decision-making.

## 2. Constraints Definition

The criteria for each constraint are defined in FIMS as described below.

| Layer | Description |
|---|---|
| Altitude | land over 2400m altitude. |
| Slope (Extreme) | land with over 30 degree dominant slope. |
| Slope (Serious) | land with dominant slope of 20-30 degrees and sub-dominant slope over 30 degrees and with high to very high relief. |
| Mangroves | land covered by mangroves. |
| Inundation (Extreme) | land permanently or near permanently inundated extending over more than 80% of the area of that land. |
| Inundation (Serious) | land permanently or near permanently inundated extending over 50-80% of the area of that land. |
| Karst | land with polygonal karst landform. |

Note: PNG Logging Code of Practice allows that selection logging in PNG may be practiced in forest areas which are not excluded by the following criteria:

- slope steeper than 30 degrees
- in areas of high relief on slopes steeper than an average of 25 degrees
- permanently inundated land
- limestone country (karst)
- mangrove areas

# 3. Method on update of Constraints data

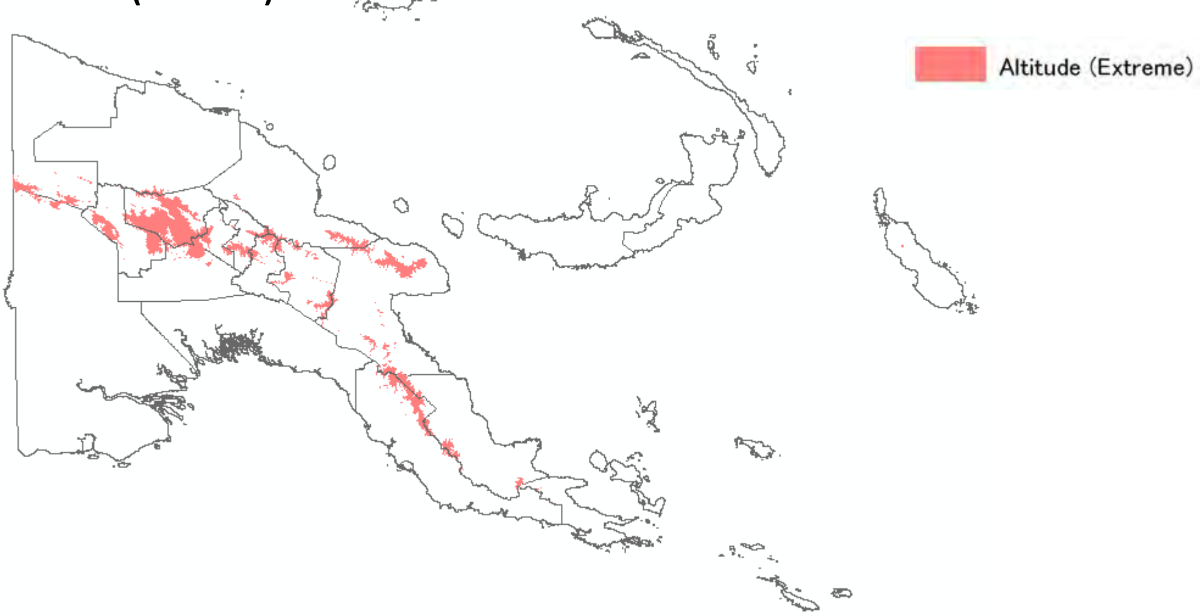
Constraints data was updated by the method shown in the table below.

| Layer | Data used | Method |
|---|---|---|
| **Altitude (Extreme)** | SRTM 30* | - Reclassify altitude with target altitude<br>- Convert to vector (simplify boundary)<br>**- Eliminate small polygons (smaller than 10ha)**<br>- Extract (Export) only target altitude<br>- Split with new provinces |
| **Slope (Extreme)** | SRTM 30 | - Reclassify slope with over 30 degrees<br>- Convert to vector (simplify boundary)<br>**- Eliminate small polygons (smaller than 50ha)**<br>- Extract (Export) only polygons over 30 degrees<br>->> continue to next process below |
| **Slope (Serious)** | SRTM 30 | - Reclassify slope with over 20 degrees<br>- Convert to vector (simplify boundary)<br>**- Eliminate small polygons (smaller than 50ha)**<br>- Extract (Export) only polygons over 20 degrees<br>- Union polygons over 20 degrees and polygons over 30 degrees above<br>- Split with new provinces<br>- Divide into polygons over 30 degrees and 20-30 degrees |
| **Mangroves** | Forest Base Map 2012 | - Extract mangrove class (Code: M, ID: 9) from the Forest Base Map 2012<br>- Merge all provinces |
| **Inundation (Extreme)** | PNGRIS 2008** | - Extract target inundation class from PNGRIS 2008<br>- Merge all provinces<br>- Dissolve polygons<br>**- Fill small gaps (smaller than 10ha)**<br>**- Remove small polygons (smaller than 10ha)**<br>->> continue to next process below |
| **Inundation (Serious)** | PNGRIS 2008 | - Extract target inundation class from PNGRIS 2008<br>- Merge all provinces<br>- Dissolve polygons<br>**- Fill small gaps (smaller than 10ha)**<br>**- Remove small polygons (smaller than 10ha)**<br>- Union polygons of inundation serious and extreme<br>- Simplify boundary<br>- Split with new provinces<br>- Divide into polygons inundation serious and extreme |
| **Karst** | PNGRIS 2008 | - Extract target karst class from PNGRIS 2008<br>- Merge all provinces<br>- Dissolve polygons<br>- Fix broken gaps<br>- Split with new provinces |

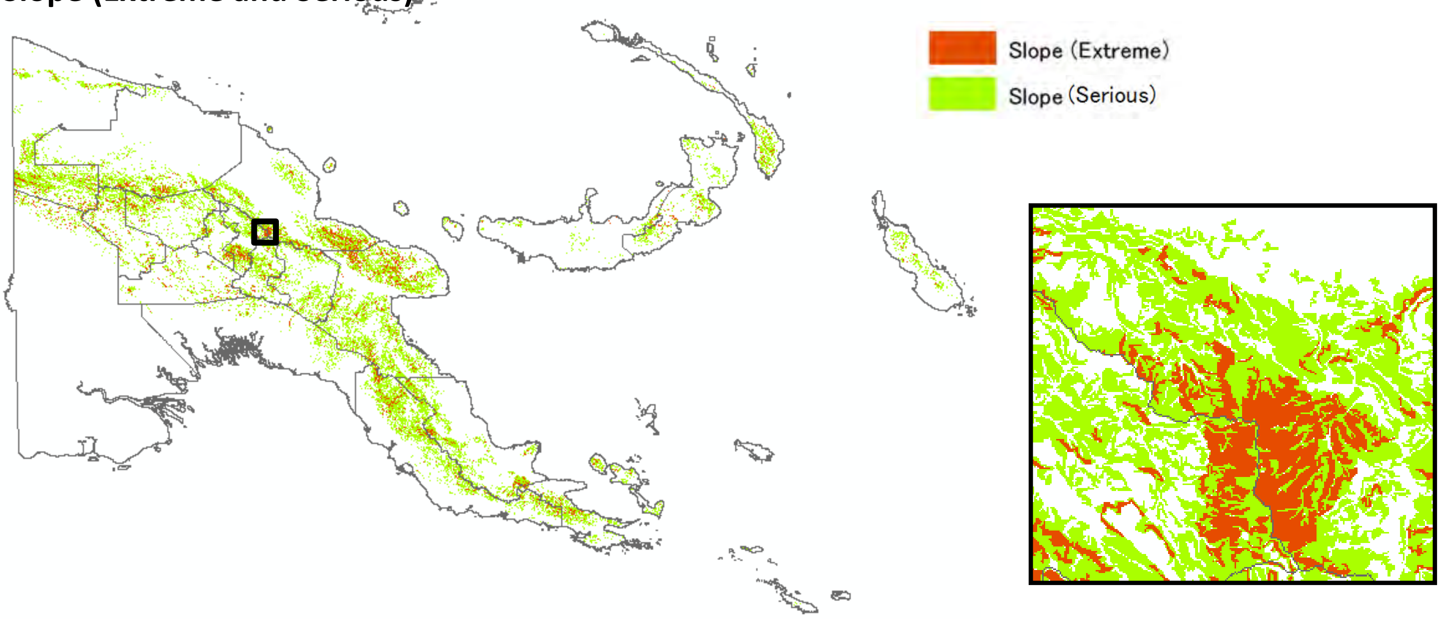
* Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global, https://lta.cr.usgs.gov/SRTM1Arc
** University of Papua New Guinea, 2008. Papua New Guinea Resource Information System

# 4. Updated Constraints layer

## Altitude (Extreme)

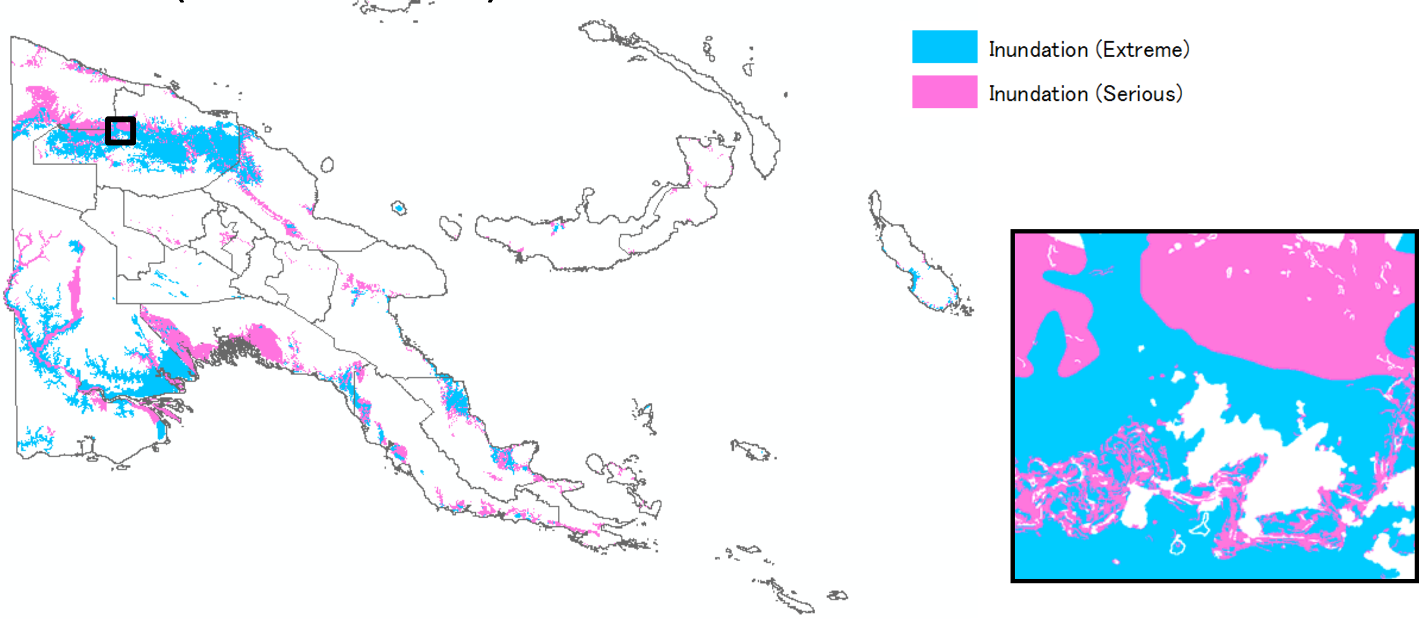



## Slope (Extreme and Serious)

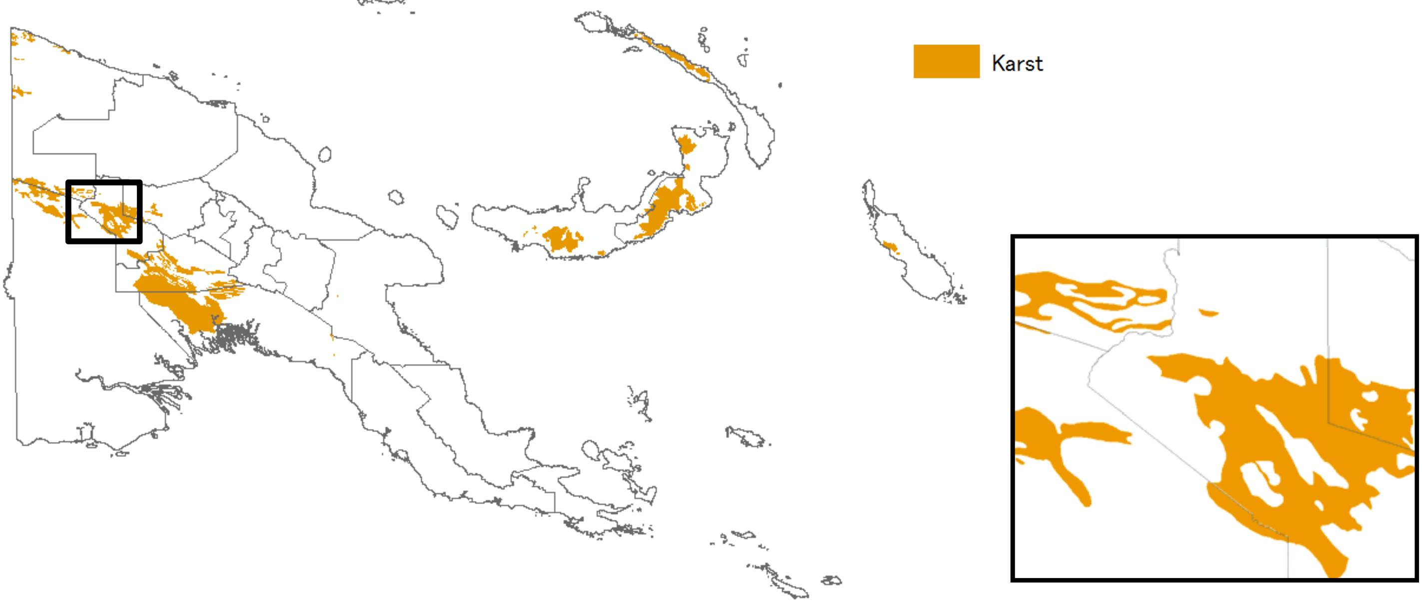



## Mangroves

**Inundation (Extreme and Serious)**




**Karst**




## 5. References

McAlpine, J. and Quigley, J., 1998, 'Forest Resources of Papua New Guinea Summary Statistics from the Forest Inventory Mapping (FIM) System'. Coffey MPW Pty Ltd for AusAID and PNGFA

Bryan, J.E. and Shearman, P.L., 2008, 'Papua New Guinea Resource Information System Handbook 3rd Edition. PNGRIS Publication No. 7.' University of Papua New Guinea, Port Moresby, Papua New Guinea

JICA and PNGFA, 2016, '2014-2019 JICA-PNGFA Project Outline - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.1'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

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Last updated on Mar. 2019

# Watershed and Catchment Data

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Introduction

A watershed refers to a river system, i.e., an area drained by a river and its tributaries. It is sometimes called a drainage basin (National Geographic, 2019). For this project and the development of the PNG-FRIMS, watershed data that is acquired and analysed is predominantly focused on the Watershed Boundary. The watershed boundary delineates the areal extent of surface water drainage to a point, accounting for all land and surface areas. The boundaries of the watersheds can be derived through watershed analysis on remote sensing data.

The watershed boundary in mountainous areas is located on ridge lines and saddleback areas, serving the function of inhibiting the flow of materials and demography, with the capability of separating living zones or cultural zones. In addition, there are cases that these living zones or cultural zones become administrative boundaries. The flow of materials and energy within the watershed acts continuously in the downstream direction, and the watershed becomes an ecosystem. Therefore, a grasp of the watershed boundaries needs to be obtained in order to conduct forest management, secure water resources, predict disasters and perform other such work.

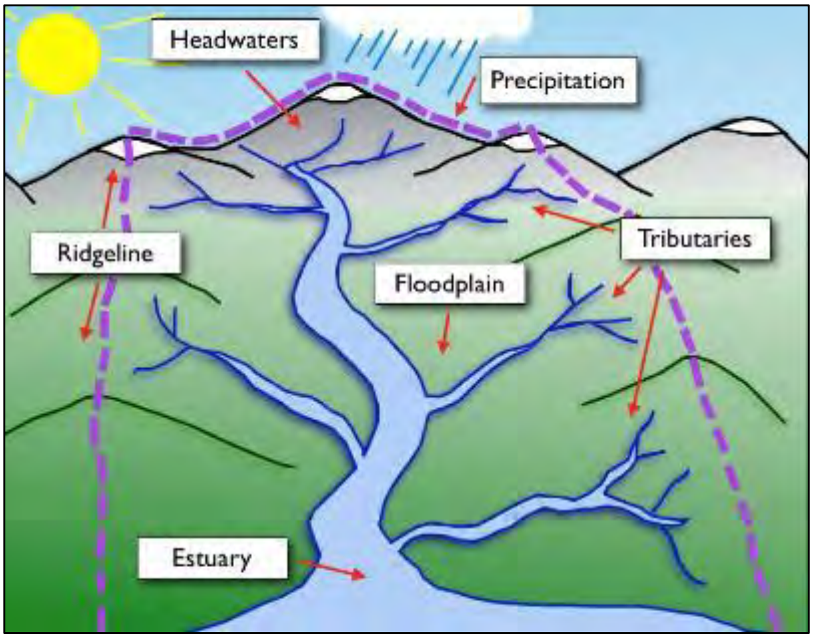


*Fig.1:*
*An illustration showing the different aspects of a watershed. The Watershed Boundary is symbolized with the striped purple line*

*(Image courtesy of the Central Sierra Environmental Resource Centre)*

# 2. Methodology

## Data Acquisition

The primary source of Watershed Boundary Data is Digital Elevation Model (DEM) datasets. A Digital Elevation Model (DEM) is a specialized database that represents the relief of a surface between points of known elevation. By interpolating known elevation data from sources such as ground surveys and photogrammetric data capture, a rectangular digital elevation model grid can be created. (Caliper Mapping & Transportation Software Solutions, 2019)

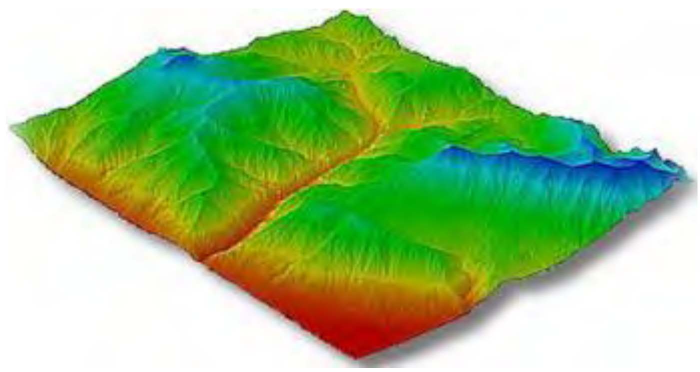

*Fig.2: A 3D representation of a DEM (Image courtesy of the GPS Power)*

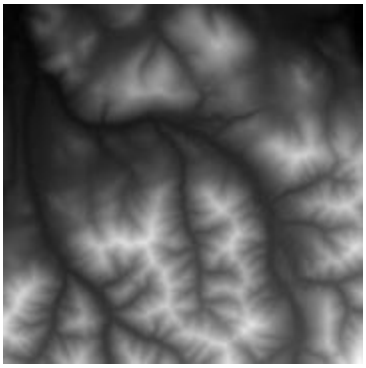

*Fig.3: A 2D representation of a DEM. (Image courtesy of University of Minnesota)*

The dataset that was used in this project was GeoSAR[1] DEM data with a high spatial resolution of 5 meters. It was acquired from the University of Papua New Guinea Remote Sensing Centre. Although the data covered the whole land area of Papua New Guinea, there were a few areas that did not have any data. To cater for the areas with missing data, SRTM DEM data with a resolution of 90 meters was used to supplement the data.

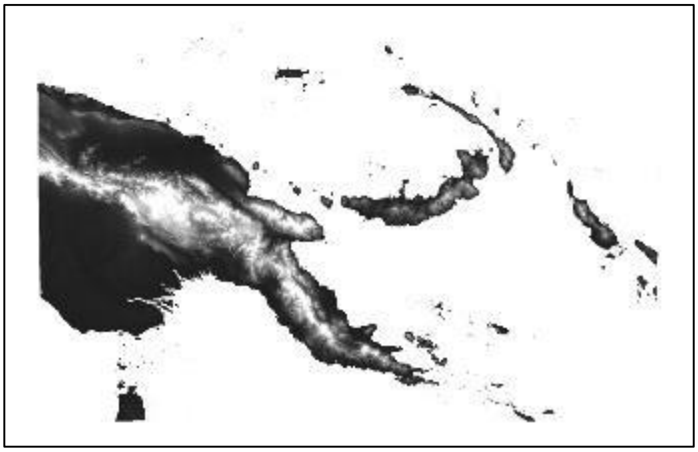

*Fig.4: SRTM 90 meter resolution DEM data covering the whole land area of Papua New Guinea*

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[1] GeoSAR: GeoSAR is an airborne dual band interferometric radar system flown by Fugro and capable of producing DSMs and DTMs even in cloudy terrains. The system was used to cover mainland PNG in 2006 and the data from the P Band DTM was acquired by the PNG Government with funding support from the Australian government. The main recipient of the data in PNG was the National Mapping Bureau (NMB) and PNG Forest Authority, both of which were granted use of the data for the objective of sustainable forest management in PNG. (BusinessWire, 2006)

## Procedures

The size of the watershed boundaries were created at three levels, from large watersheds to small watersheds, in consideration of usage at a variety of levels, such as the vegetation boundaries on forest cover classification. The process of creating watershed boundaries is shown in Figure 5.

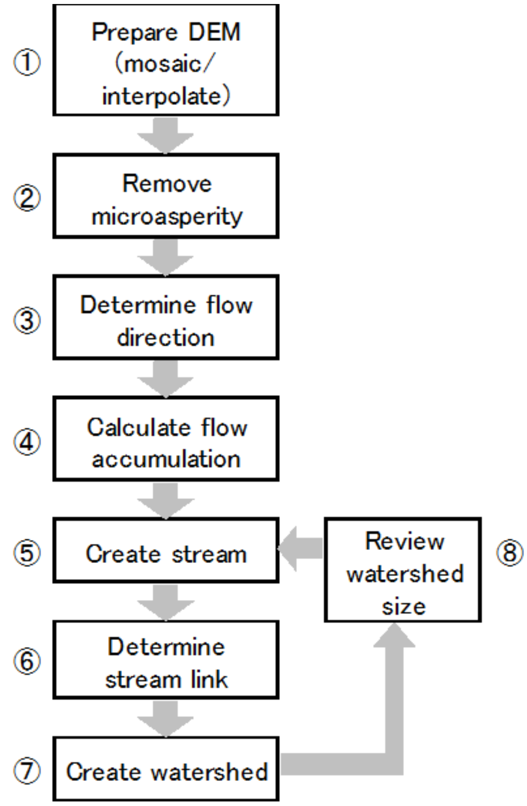


*Fig.5: The Work-Flow Diagram showing the processes involved in generating Watershed data from a DEM.*

**1. Prepare DEM (mosaic/interpolate)**
This process involves firstly "stitching" (mosaicking) together multiple GeoSAR DEMs to form a larger model, and the interpolation of the DEM to estimate values of unknown areas using the SRTM DEM data.

**2. Remove Microasperity**
The DEM will have to be "smoothened" out. This is done to remove small imperfections in the data.

**3. Determine Flow Direction**
The flow direction basically shows where the water is flowing or the direction in which the watershed is drained. This is done by calculating the elevation values of the DEM cells, and comparing each value to its surrounding values.

**4. Calculate Flow Accumulation**
The Flow accumulation is used to determine the path where the majority of the water are being drained to. The volume of Flow Accumulation shows a raster of accumulated flow to each cell, as determined by accumulating the weight for all cells that flow into each down-slope cell. This will highlight the watershed boundaries.

**5. Create Stream**
Once the watershed has been highlighted from the DEM cells, the streams can now be created by assigning them values according to their hierarchical order and creating a stream network.

**6. Determine Stream Link**
This assigns unique values to each of the links in the stream network. This is most useful as input to the Watershed tool to quickly create watersheds based on stream junctions. It can also be useful for attaching related attribute information to individual segments of a stream.

**7. Create Watershed**
This will create the watershed from the output Stream Network and the Calculated Flow Accumulation.

**8. Review watershed size**
Small watershed boundaries were created in a number of different sizes, and the respective watershed boundaries were overlaid with the satellite images in order to determine the watershed size that best

reflects the vegetation boundaries as shown in Figure 6. As a result of a review, the following conditions were established for the respective watershed boundary sizes: Cumulative flow volume of 50,000 cells or more for small watershed boundaries, 500,000 cells or more for medium watershed boundaries and 5,000,000 cells or more for large watershed boundaries.

| Watershed Boundary > 50,000 | Watershed Boundary > 100,000 | Watershed Boundary > 500, 000 |
|---|---|---|
|  |  |  |
| ❖ Preferred for Watershed Analysis | ❖ Less preferred for watershed analysis | ❖ Not preferred for watershed analysis |
| ❖ Excellent indicator for vegetation & forest classification especially at high altitude | ❖ Good indicator for vegetation & forest classification at both low and high altitudes. | ❖ Excellent indicator for vegetation & forest classification especially at low altitude. |

*Fig.6: Watershed Boundary sizes for Different Cumulative Flow Volume and Results*

**Note:** The cumulative flow volume for watershed boundary >500,000 is not preferred for watershed analysis since it contains large watershed boundaries, i.e., the larger the watershed boundaries the lesser the number of streams (drainage). However, it is a good indicator of the difference between low and high-altitude vegetation for initial planning of classification, where the vegetation types within the watershed boundary size of >500,000 are classified as low vegetation.

# 3. Results

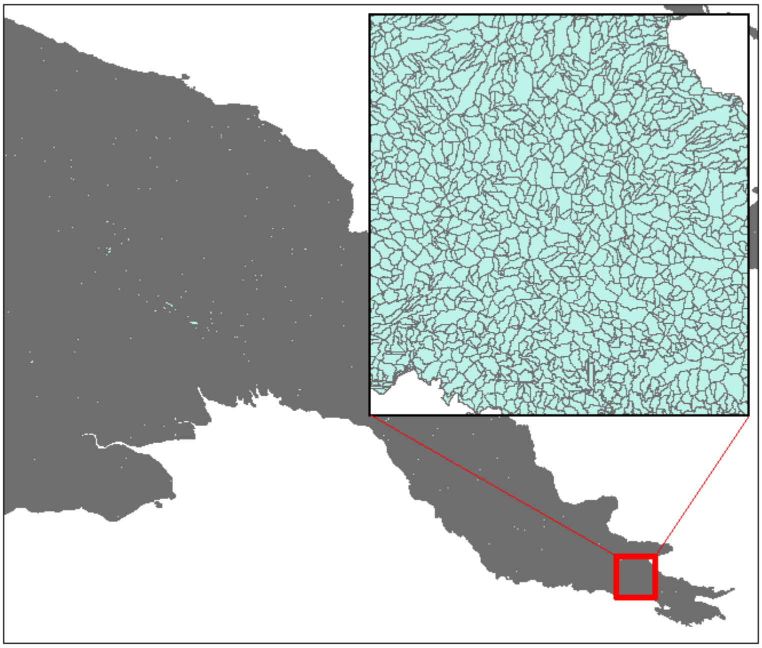

*Fig.7: Sample of PNG Small Watershed Boundaries shapefile created with DEM Data Analysis*

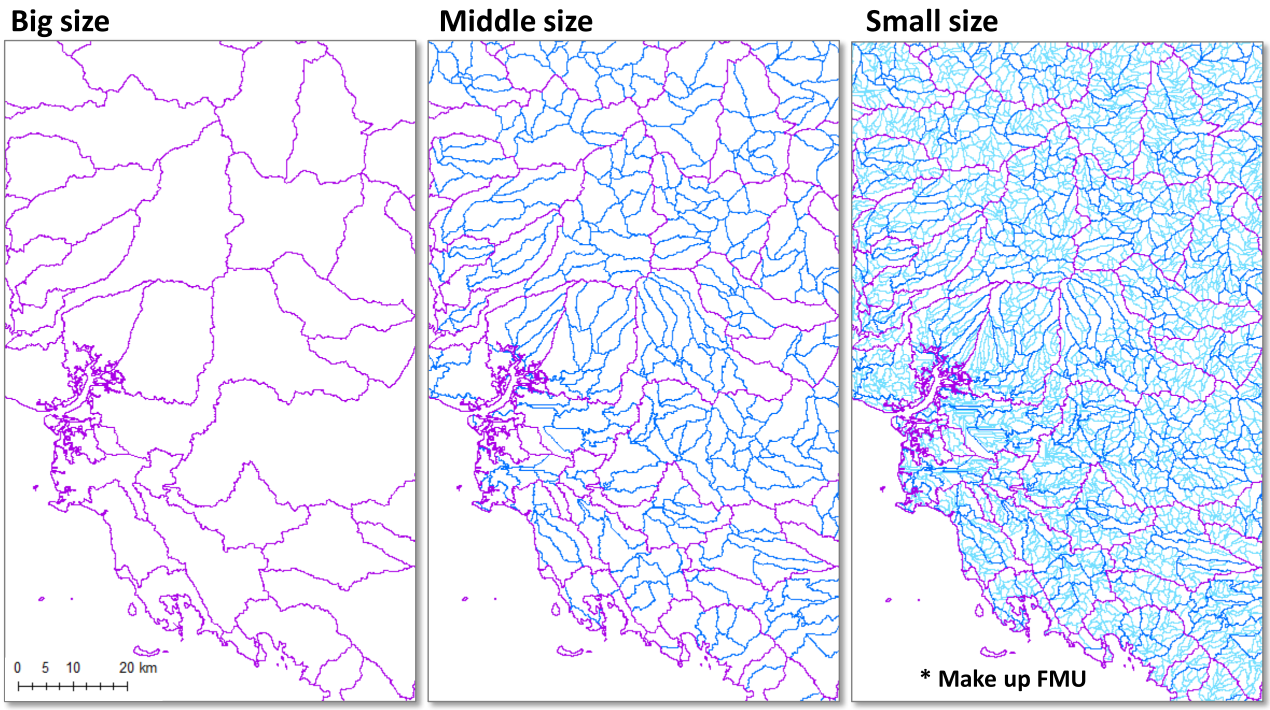


*Fig.8: Three level of Watershed Data of PNG*

**Note**: FMU – Forest Monitoring Unit; a minimum unit of forest at "not too small" scale for replacing legacy 'FMU – Forest Mapping Unit', which was 'too large' in relation to current available technology. The new FMU is being used for monitoring and recording changes of forests in PNG-FRIMS. The small size of the watershed makes up the FMU.

# 4. Discussions

## Issues and Recommendations

As all geographic representation processes are bound to have a few discrepancies, the production of Watershed Boundary Data encountered some minor issues:

1. Since accuracy of watershed data depends on accuracy of DEM data used for analysis, the accuracy of the watershed data in PNG-FRIMS is affected by the accuracy of the GeoSAR data used.

2. Since GeoSAR data was not calibrated well between the flight paths, the developed watershed data has some issues; includes some erroneous polygons.

3. The data does not necessarily mirror real-world watershed boundary, especially at complex topography areas and very gentle slope or flat areas since flow direction comes and goes.

Although the data has some issues, it is beneficial to know watershed information as there is no existing data which has been created using such a high resolution DEM data for the entire land mass of PNG. The main issue here lies in the acquisition of high resolution accurate data, that is able to undergo analysis without decreasing the accuracy of the overall process. Making sure that the DEM data is as accurate as possible before processing, will allow minimal errors that might cascade throughout the entire procedure.

## Applications

Watershed modelling simulates the hydrologic processes in a holistic approach with focus on a individual process or a combination of different processes at a relatively small scale. For instance:

- watershed data can be used to aid in the identification of suitable sites for small scale hydroelectricity dams to support small communities located along the tributaries leading to or exiting from a watershed.
- watershed combined with rainfall data can be used to determine the volume of water in a catchment, which can then be used to help locals identify suitable sites to set up ground water wells when further combined with soil data.
- A popular use of watershed data as used by parties interested in averting or avoiding natural disasters such as floods or landslides is disaster prevention policies/practices, in which case, watershed data combined with various other resources integrated into a Geographic Information System can be used to predict areas vulnerable to such natural disasters
- In Civil engineering, watershed data can be used to determine the flow impact a tributary would have on a bridge, in order to construct a bridge that can maintain its foundation when the flow impact is at its highest.

In Forestry, and particularly in PNG-FRIMS, the three (3) size level of watershed developed in this exercise could be indicators of levels of possible inundation constraints to logging in the planning stage of identifying potential forest development areas. The watershed can also serve as an excellent indicator for vegetation and forest classification at high and low altitude areas.

# 5. References


BusinessWire. (2006, May 31). EarthData Wins $16-Million Contract to Map Papua New Guinea; Company's Radar Mapping System Uniquely Qualified to Map Equatorial Regions Worldwide. Retrieved from BusinessWire: A Berkshire Hathaway Company: https://www.businesswire.com/news/home/20060531005172/en/EarthData-Wins-16-Million-Contract-Map-Papua-New

Caliper Mapping & Transportation Software Solutions. (2019, May 30). Caliper Mapping and Transportation Glossary. Retrieved from Caliper Mapping & Transportation Software Solutions: https://www.caliper.com/glossary/what-is-a-digital-elevation-model-dem.htm

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National Geographic. (2019, May 29). National Geographic Resource Library. Retrieved from Encyclopedic Entry: Watershed: https://www.nationalgeographic.org/encyclopedia/watershed/

Image Links: Fig. 1: https://www.cserc.org/sierra-fun/games/watershed-game/
Fig. 2: https://www.gpspower.net/igo-maps/331765-dem-digital-elevation-model-5.html
Fig. 3: https://www.pgc.umn.edu/data/elevation/



**PNG Forest Authority (JICA Project)**
Address: P.O. Box 5055, Boroko, National Capital District, Papua New Guinea
Email: infor_general@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/


Last updated on June. 2019

# Digitized Road Information

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Introduction

Road information is useful for estimating area affected by human activities. People move via roads quickly and enter into areas adjacent to the roads for various purposes, such as logging, subsistence agriculture, wood collection, mining, and plantations. As these activities continue to increase, so too does the need for more roads to cater for the logistics of these activities.

Road network is growing year by year, as a result, continuous updating of the information is necessary to grasp current status of the land. Satellite imagery is a strong tool for capturing up-to-date national scale road network information. This is made possible with the rising number of free mid-resolution satellite imagery such as LANDSAT and Sentinel-2 which are helpful in covering a nationwide network. While high resolution satellite imagery can detect more small and obscure ground features, the downside is that it is expensive and difficult to acquire.

With mid-resolution satellite imagery, it is simple to spot new constructed roads as the forest features and cleared areas for the new roads have dissimilar spectral reflectance, i.e., telling apart forests and new cleared areas for roads is easy due to their different colours on the satellite image. On the other hand, old cleared areas in forests which have already been covered by grass over time, are not as clear. This is due to the fact that the old cleared areas (covered in grass) have a similar spectral reflectance (same color) to forests, and thus, it is difficult to distinguish both features from each other on the satellite image. Timely updating of the road network after construction of new roads is necessary to keep the quality of the information.

Roads in cities, grasslands, agricultural fields are difficult to find because roads and the surrounding area shows similar color in mid-resolution satellite imagery. It is recommended to update road network information using road GIS information generated by institutions such as National Economic and Fiscal Commission, Department of Works & Implementation, and other government department or independent organizations that have up-to-date GIS Road data. This can also be done by acquiring high-resolution satellite imagery every decade.

As of August 2017, national road network, including all kinds of roads such as roads in forest, cities, agricultural field, etc. have been developed for the whole country in the years 2000, 2005, 2011 and 2015. In this Fact Sheet, the procedures followed to update this information is described.

# 2. Methods

## Data Acquisition

The data acquired for the use of digitizing roads were sourced from various government departments, donor agencies, and datasets that were developed by the Project.

*Table 1: The datasets used for digitizing road GIS information*

| Layer (Dataset) | Source | Remarks |
|---|---|---|
| Road GIS information | GeoBook | Derived from NEFC[1] 2005 Cost of Services surveys, satellite imagery and RAMS[2] data |
| River GIS information | GeoBook | Derived from 1:250 000 topographic maps |
| Census Unit Information | GeoBook | Derived from PNG 2008 Census |
| Provincial Boundaries | Developed by the Project[3] | |
| LANDSAT AGP[4] 2000 | Developed by the Project | |
| LANDSAT AGP 2005 | Developed by the Project | |
| LANDSAT AGP 2011 | Developed by the Project | |
| LANDSAT AGP 2015 | Developed by the Project | |
| RapidEye 2011 | Procured by Grant Aid Program[5] | |

**Types of Roads to be Digitized**

1. National Roads – Roads that are recognized as under the care and management of the National Government. These roads are the major highways and roads that connect the main centres and regions throughout the country.
2. Provincial Level Roads – Roads that are recognized as under the care and management of the Provincial Government. These roads are mainly found within the borders of a province.
3. Logging Roads – There are 4 main types of logging roads; 1) Main roads, 2) Secondary roads, 3) Feeder Roads and 4) Spur Roads. The main roads are connected to the provincial roads. The Spur roads are roads that have a specific use of connecting a particular location to the road network. The Feeder roads enable traffic coming from the Spur Roads to the Secondary roads, which then lead to the Main Roads.

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[1] National Economic and Fiscal Commission
[2] Road Asset Management System
[3] Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change
[4] Annual Greenest Pixel
[5] "The Forest Preservation Programme in the Independent State of Papua New Guinea" funded by the Government of Japan (2012 – 2013)

## Procedure

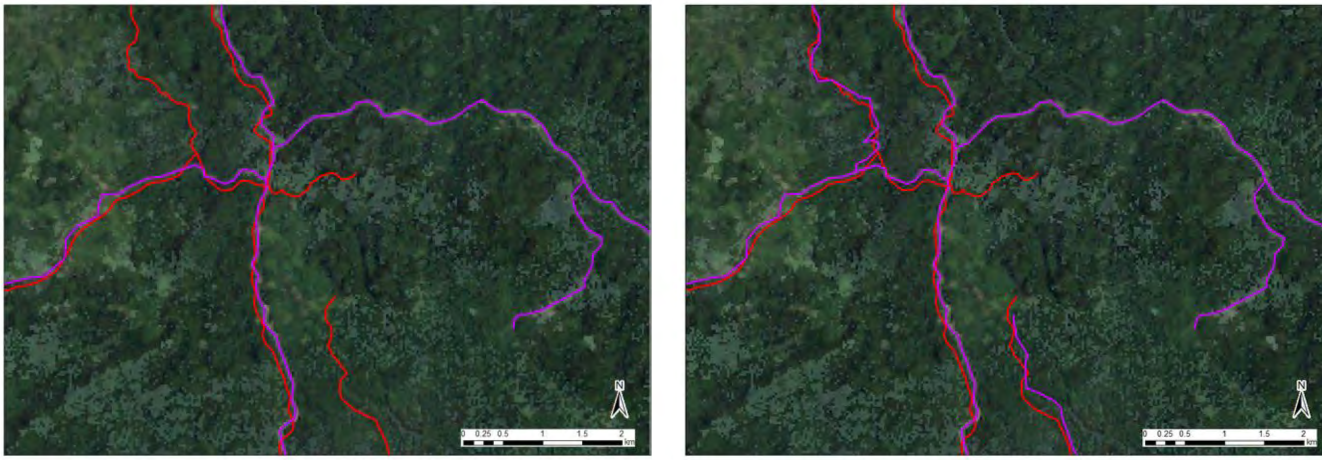
1. Road network of year 2000 was developed as the basis of the information.

   A. Digitize road directly based on the LANDSAT AGP (Year 2000) satellite image.


**Note**: Annual Greenest Pixel (AGP) refers to the mosaicked imagery including all the scenes in each year beginning from the first day of the year and continuing to the last day of the year obtained by specified satellite(s) with the greenest pixel on top, where the greenest pixel means the pixel with the greatest value of the Normalized Difference Vegetation Index (NDVI).

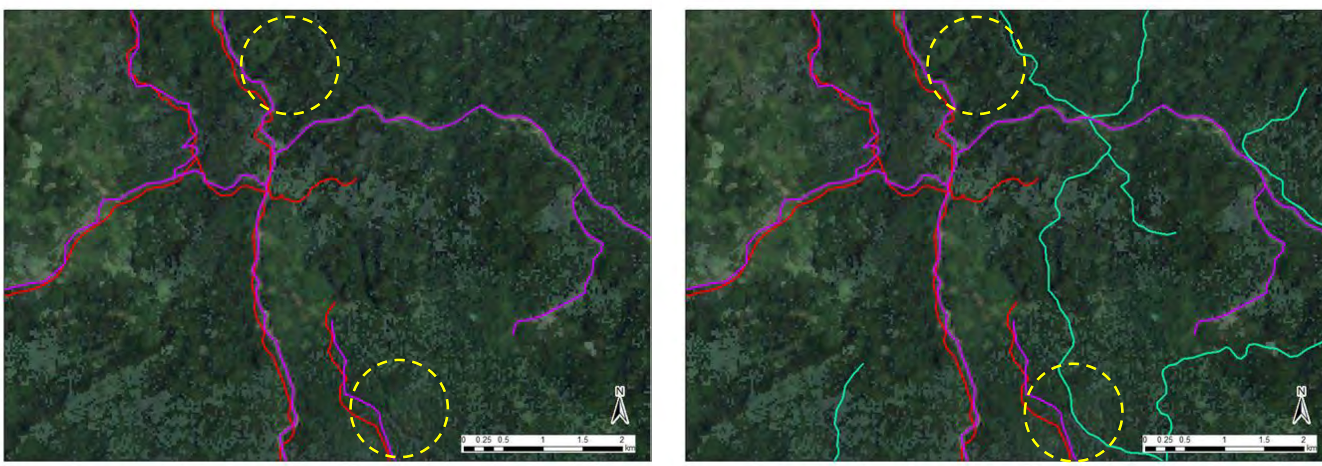

Use "Snapping" tool to connect line features.

B. Road information of Geobook is a good reference to digitize unclear roads on LANDSAT AGP.

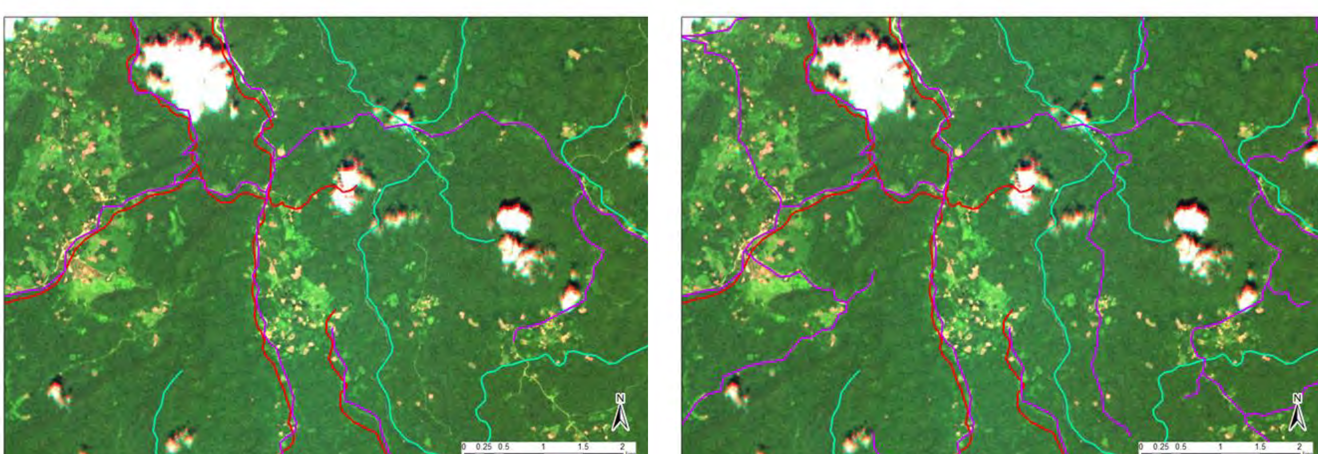



**Note**: Some roads may not be clear from the satellite images. This issue can be fixed by overlaying GeoBook information (red line) and using it as reference to digitize the roads (purple line).

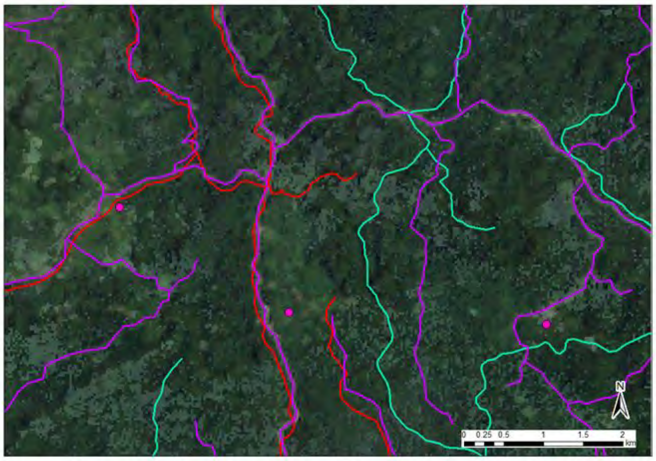
C. To avoid digitizing rivers as roads, refer to the river GIS information (light green line).

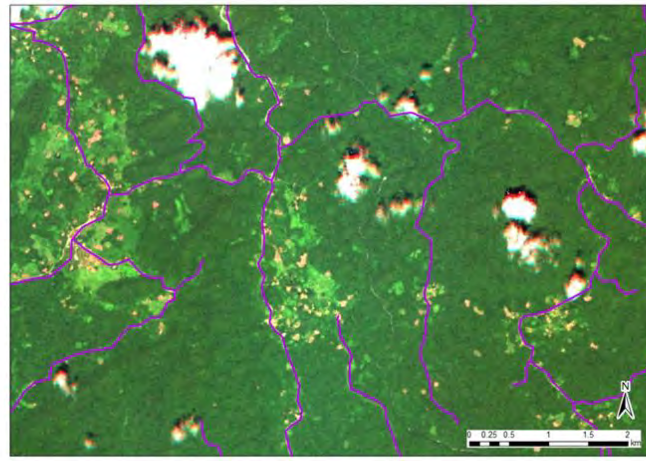



D. Comparing LANDSAT imagery (above) and RapidEye imagery (below), digitize unclear roads.

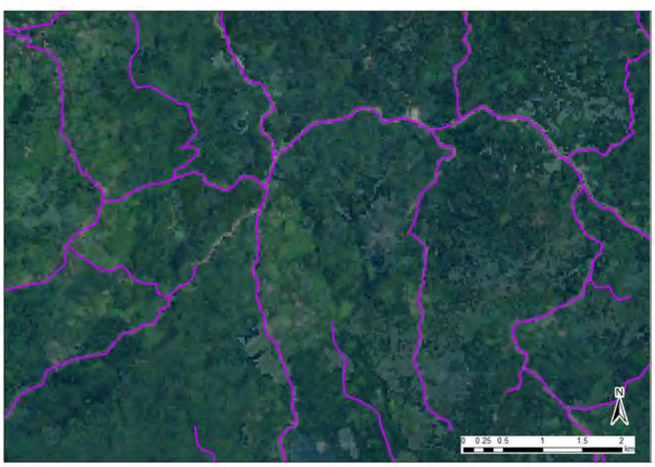


E. Census Unit information is also useful to estimate intensity of human activities. In the following images (below), the pink circles are Census Unit information. The color spotting around the points indicate existing of agricultural fields there.





2. Road network of year 2005, 2011 and 2015 were digitized in order from the oldest year adding line features on the road network feature on the older year.



LANDSAT AGP 2005 with the digitized road data (purple line) from the Year 2000 overlayed.

The road data is then digitized for the year 2005 (red line) by adding features from LANDSAT AGP 2005 to the road data from Year 2000.

# 3. Results

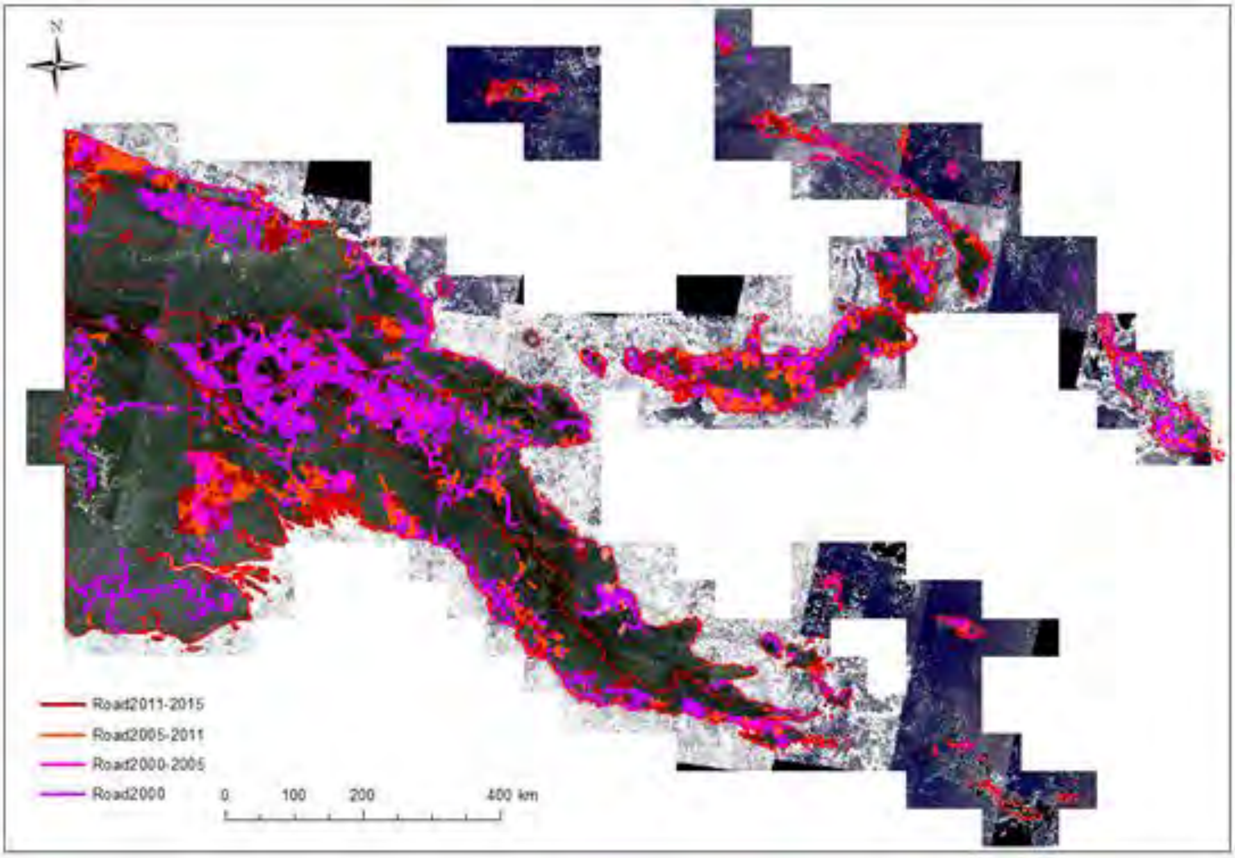



*Fig.1: Map of completed road GIS information*

# 4. Discussion

## Issues

The main issues faced during this exercise included:

1. Difficulty in identifying some of the minor road features (Feeder and Spur) from the mid-resolution satellite imagery. Although the satellite images were satisfactory in recognizing main roads, it lacked the clarity to display smaller logging roads as these roads are usually 40 meters wide. The spur, feeder, main, secondary roads are all logging roads as long as logging is active in setups and coupes until the roads are decommissioned. If decommissioned roads are maintained/used frequently they are visible and data can be captured by satellite imageries whereas if roads are not maintained over a certain period, they become invisible due to regrowth/secondary vegetation so data could be sourced from (previous) logging plans, existing/available data or from other relevant government agencies.

1. The presence of heavy cloud cover over most parts of the country, which made it difficult to identify road network from the satellite images.

## Recommendations

To fix these problems, high resolution satellite imagery would be much better to use in this exercise. But this again poses the question of cost and availability. Thus, as a compromise, supplementary data from donor agencies and other government departments were acquired. This included the data from the GeoBook and the RapidEye satellite imagery that were used to check and confirm the features identified in the LANDSAT AGP satellite imagery.

With regard to the smaller logging roads (Feeder and Spurs), as they cannot be captured with satellite imagery, the main supplementary source of data is the Annual Logging Plans (ALPs) and Forest Working Plans (FWPs). This being the case because the logging companies have up-to-date information on the status of the roads. Combining the data from the ALP's and the satellite images allows us to better identify these less clear road features for digitization.

# 5. Conclusion

Digitizing of road network in all of PNG was arduous and tedious work but the resulting data will be very useful in the future. The main complications faced were handled with the help of the reference data like the GeoBook and the Census data. This data was instrumental in the identification and digitization of the roads.

It would be wiser to update vital information on the road network in PNG from 2015 upward, and this can be done by utilizing LANDSAT AGP satellite images which are free to acquire. This data will greatly improve the ease of which digitizing can be performed with the use of already digitized data as a reference for subsequent years in the future.

**PNG Forest Authority (JICA Project)**
Address: P.O. Box 5055, Boroko, National Capital District, Papua New Guinea
Email: infor_general@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

# Forest Concession and Land Management Layers in PNG-FRIMS

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Background

**Overview**

As mentioned in Fact Sheet No.3, one of the four principal types of data in PNG-FRIMS is Logging Concession Information, however, Logging Concession Information in itself is very broad. This is why it has been broken down into 4 individual thematic layers:

- Logging Concession Boundary
- Logging Plan and Logged-over Area
- Forest Clearance Authority (FCA)
- Forest Plantation/Boundary Area

By overlaying these four layers, the result is the entirety of Logging Concession Information. The real value of overlaying layers comes from the ability to integrate only the relevant spatial information into one seamless map to derive spatial information not readily apparent to an observer. For instance, one viewer might want to see the extent to which an area inside a particular logging concession boundary has been logged-over, or see the geographical location(s) of the logging concessions in the country. These information can be found within the Forest Concession and Land Use layers in PNG-FRIMS.

## 2. Introduction

Logging concessions refer to the permits or licences to perform logging operations in an area which PNGFA has acquired and/or allocated. Currently there are three concession types; Timber Rights Purchase (TRP), Local Forest Area (LFA) and Forest Management Agreement (FMA). LFA's and TRP's are no longer being issued under the Forestry Act, 1991 (as amended), however they are still in use as they were saved under the Forestry Act, 1991 (as amended). FMA's are the only type of concession allowed under the Forestry Act, 1991 (as amended).

Generally, as most of the land in PNG is customary-owned, landowners who wish to allocate their land to generate revenue through forestry, transfer their timber rights in exchange for timber royalties and infrastructure developments. PNGFA then defines the land and enters into an agreement with the landowners on how the forest resources will be managed. PNGFA then allocates the concession area to a third party; in this case a logging company, to carry out the logging operation inside the concession boundary.

Logging plans refer to the sequence of logging proposals submitted by logging companies highlighting the areas in which they aim to commence their logging operations for the first 5 years and within the first year of operation (Annual Logging Plan and 5 Year Forest Working Plan); while the Logged-over Areas are the areas in which logging operations have already occurred. The Logging plans are broken up into smaller units called 'set-ups'. Set-ups represent the subsequent order in which logging operations are intended to occur or have occurred in respect to Logged-Over areas. Logging Code of Practice (LCoP) dictates that these two occurrences must have a duration of time in between so as to allow the logged over area to regenerate. Logging plans are mapped out and sent in by the logging companies for PNGFA to review and approve.

Forest Clearing Authority is a permit allowing a logging company to clear the forest over a defined land for other non-forest forms of land use, such as agricultural farming either under a Special Agriculture Business Lease (SABL) or on customary land where the owners have given consent for such non-forest activities to take place.

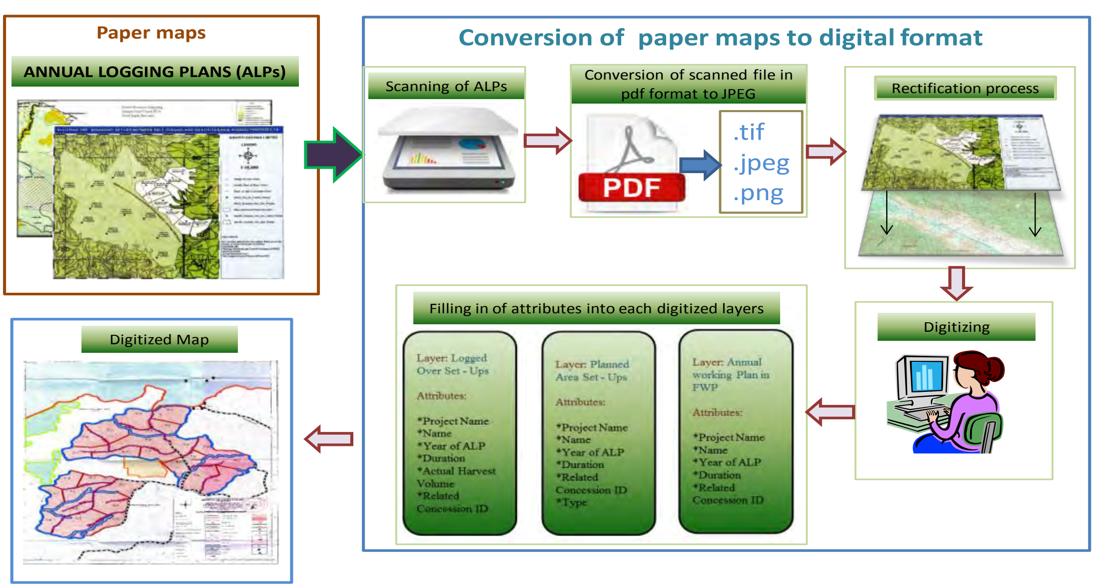
Forest Plantation Boundaries demarcate the areas managed by PNGFA and other logging companies for forest plantations as surveyed by GPS or extracted from the Forest Base Map 2012.

# 3. Methodology

## Data Acquisition

| Data | Source | Format |
|---|---|---|
| **Logging Concession Boundary** | Acquisitions Branch - PNGFA | Hardcopy/Softcopy |
| **Logging Plan and Logged Over Area** | Annual Logging Plans or Forest Working Plans maps provided by logging company | Hardcopy/Softcopy |
| **Forest Clearance Authority** | Logging company or Allocations Branch - PNGFA | Hardcopy/Softcopy |
| **Forest Plantation Boundary** | Surveyed by GPS or extracted from Forest Basemap 2012 | Softcopy |

All data received in Hardcopy format is scanned and digitized so that it can be stored in FRIMS. Below is a diagram that illustrates the process in which data is acquired and processed for all logging plans.



As all four layers are in essence "*Boundaries*", they are created in a similar manner but for different purposes. Digitization is the process in which geographic data from scanned maps are converted into digital vector data formats and represented as point, polyline and polygon features. Point features are usually log ponds, base camps, bridges and culverts (proposed/existing), villages, quarries, gravel sources and cultural sites. Polyline features represent main boundaries, roads (existing/proposed) and strip lines. Finally, polygon features represent coupes, set-ups, plantations and buffer zones. Thus, all layers listed above are digitized and have attributes added to them for their served purposes.

## Basic Steps to Digitization

1. A shapefile is created in a folder location of the users choice.
2. The shapefile can be specified either as polygon, polyline or point depending on the user's needs.
3. If polyline or polygon is selected, select the editor tool and select points along the edges of the feature of interest.
    a. For polygons, select points until coming back to the initial starting point, this is called closing the shape.
    b. For polylines, select a point at the start of the feature of interest and continue to select points that run along the edges of that feature until coming to its end.
4. If point is selected, it is usually to digitize locational information, in which case, select the editor tool and select the locations of which the feature of interest is located.

## Attributes

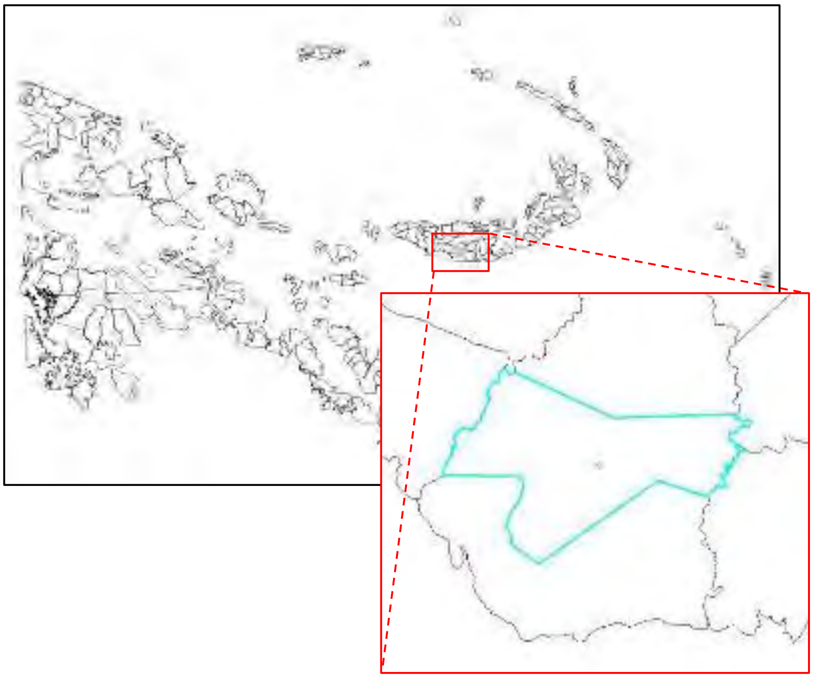
Once the shape file is created and the feature of interest has been digitized, the last step is to add attribute information to it. This is done by opening the attribute table of that feature and creating the necessary fields and entering its attribute information. Each of the layers are shapefiles, however, their attributes vary. The fields for the four layers are listed below.

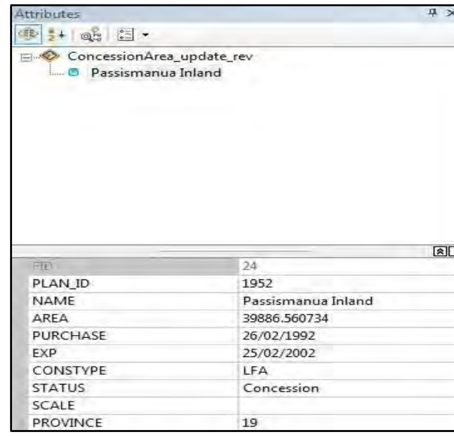
| Layer | Attributes |
|---|---|
| **Logging Concession Boundary** | Plan/Concession Id |
| | Name |
| | Area |
| | Purchase Date |
| | Expiry Date |
| | Concession Type |
| | Status |
| | Scale |
| | Province |
| **Logging Plan** | Project Name |
| | Project Type |
| | Name |
| | Year Of ALP |
| | Duration |
| | Concession ID |
| | Type |

| Layer | Attributes |
|---|---|
| **Logged Over Area** | Project Name |
| | Project Type |
| | Name |
| | Year of ALP |
| | Duration |
| | Harvest Volume (ha) |
| | Concession ID |
| **Forest Clearance Authority** | Project Name |
| | Project Type |
| | Name |
| | Year of ALP |
| | Duration |
| | Harvest Volume (ha) |
| | Concession ID |
| **Forest Plantation Boundary** | ID Name |
| | Species Name |
| | Date of Planting |
| | Date of Harvesting |
| | Area Size (ha) |

# 4. Results/Output

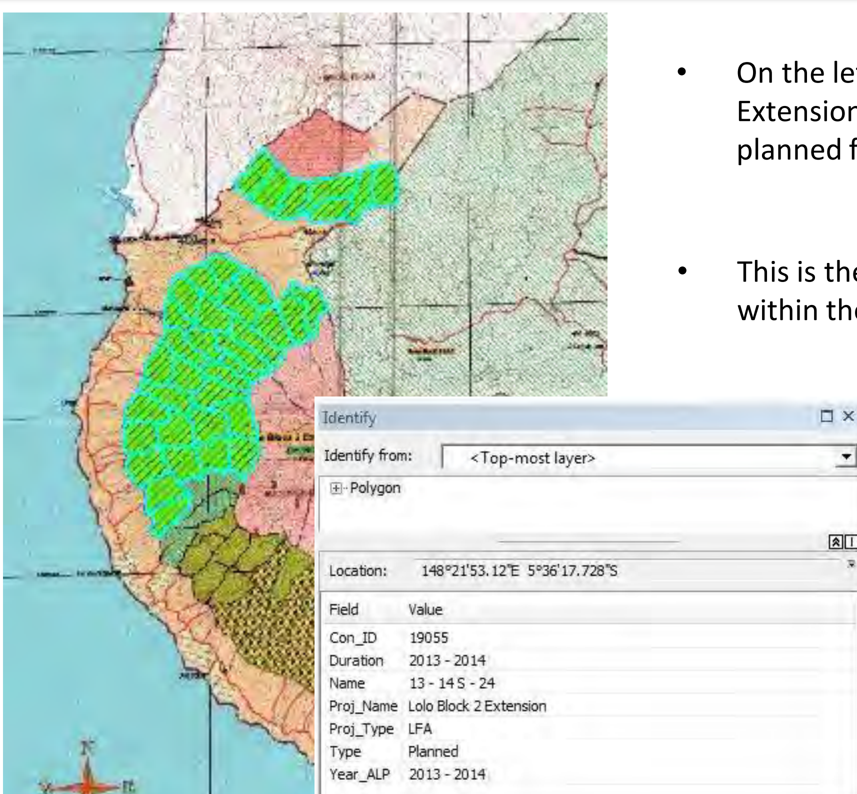
## Logging Concession Boundary





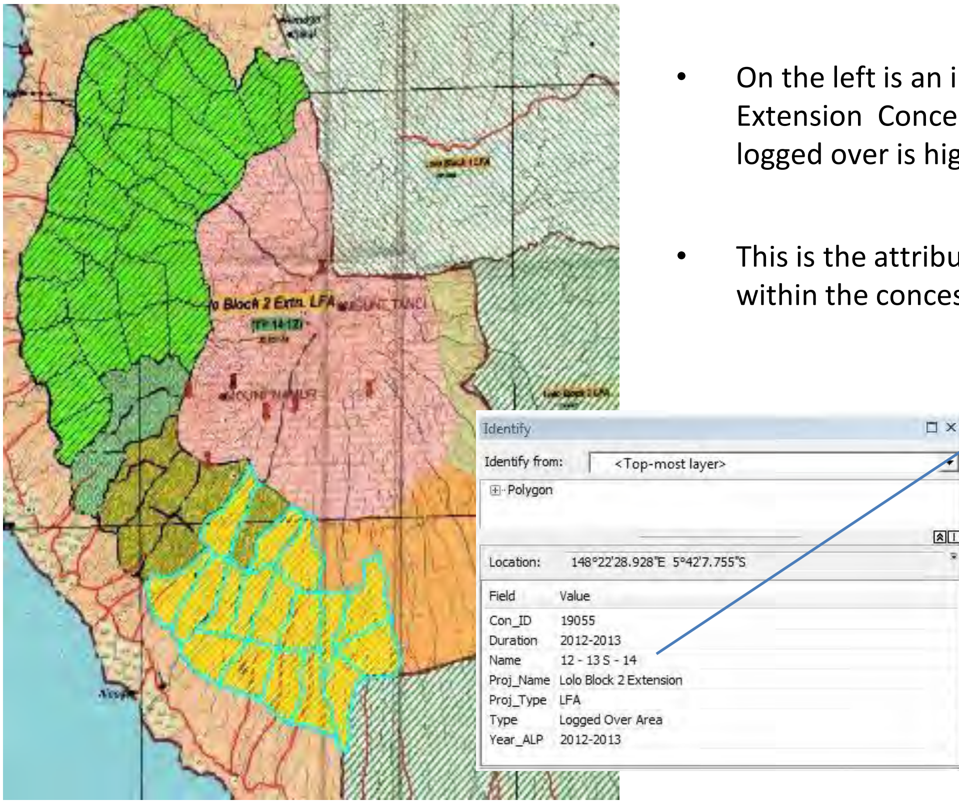

- Above is an illustration on the logging concession boundaries nation wide and on the right is the attribute information for just Passismanua Inland Logging Concession.

## Logging Plan




- On the left is an image of the Lolo Block 2 Extension Concession, in which the area planned for logging is highlighted.
- This is the attribute information for a set-up within the concession, i.e. [13-14 S – 24]

## Logged Over Area




- On the left is an image of the Lolo Block 2 Extension Concession, in which the area logged over is highlighted.
- This is the attribute information for a set-up within the concession, i.e. [*12-13 S – 24]*

# 5. Discussion

## Issues and Recommendations

While the task of digitizing the different layers was executed without any major setbacks, there were a few issues that arose during the exercise. Chief among those issues was the lack of cartography standards adapted by the logging companies that submitted in their ALPs and FWPs. This has resulted in the submission of hardcopy paper maps that were erroneous and lacking basic cartographic principles, such as:

- ❖ Properly labelling features
- ❖ Using correct and consistent visual representation of the features being portrayed in the maps
- ❖ Following guidelines in map production in balancing both the comprehension of the map aesthetics and the accuracy of the information shown in the map

Another issue faced was the task of digitizing itself being quite tedious and slow. Since the maps submitted are in the form of physical hard copy paper maps, they would have to be digitized so the information can be stored in PNG-FRIMS. Although, digitizing is an important task of converting analogue data into digital data, it is time-consuming and requires a lot of manpower to continuously keep up and maintain with the amount of hard copy maps being submitted.

## Future Endeavors

### Digital Data Submission

Currently, PNGFA is working towards a standardized process of digital map submission by logging companies, which is more preferred than the traditional paper maps. This is done through the initiative of the “Data Exchange Specification” which highlights the data requirements to be submitted. This will not only improve the efficiency and productivity of the geographic information contained in the PNG-FRIMS but also aid in dealing with most of the issues faced during the process of digitization. The standardized process of digital map data submission will ensure:

- ❖ Ease of use in data manipulation and data analysis; as all data will be in digital format. This will reduce issues such as scanning errors or any physical handling errors, which will improve the overall accuracy of the data being processed and stored in PNG-FRIMS and increase the availability of readily prepared information.
- ❖ Better data storage and data management. There will be no need for the physical storage of paper maps, or the issue of degradation of maps over time.
- ❖ Less amount of time spent on digitizing as the task itself is tedious. This will allow more concentration on data analysis and other data preparations for PNGFA’s needs or other stakeholders, such as logging companies, government departments and the general public.
- ❖ Efficiency in using the ALP data with other GPS/GIS data acquired by PNGFA officers

### Improvement of Plantation Data in PNG-FRIMS

Submission of softcopies of logging plans and plantation activity by logging companies will be encouraged by PNGFA. Plantation data in PNG-FRIMS is not sufficient to show the current situation of plantation in PNG. As a result, PNGFA needs more effort to improve it by increasing the capacity of relevant officers of PNGFA-managed plantations, as well as the capacity of logging companies, to acquire accurate plantation data with the use of GPS/GIS technologies.

# 5. Conclusion

These thematic layers are contained within PNG-FRIMS and provide information regarding Forestry in the country. This information can later be used in other applications, problem-solving scenarios and modelling geographical changes. With even more advancements and progress planned for the future uses of PNG-FRIMS, the full potential of geographic information has much to be realized.

# 6. References

JICA and PNGFA, 2018, ‘Papua New Guinea Forest Resource Information Management System - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.3’. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

**PNG Forest Authority (JICA Project)**
Address: P.O. Box 5055, Boroko, National Capital District, Papua New Guinea
Email: infor_general@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

JICA-PNGFA Forestry Project 2014-2019 - Fact Sheet No.9

# Forest Cover Map 2015

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Introduction

A forest cover map is an important source of information about the current status of forest areas, that if updated regularly, becomes an effective tool in sustainable forest management and monitoring in Papua New Guinea (PNG). Although the national report of PNG on Forest Reference Level (FRL) is based on the analysis of the Collect Earth system, the forest cover maps in 2015 and subsequent years are still useful for the verification of the Forest Reference Level (FRL) Report and the development of relevant road map to progress REDD+ in PNG.

On the assumption that the forest cover map will be updated at five-year intervals, a method for updating forest cover maps was developed with the consideration of giving consistency to a series of maps. It is based on creating past forest cover maps and of constructing and integrating deforestation and forest degradation (DD) information into forest cover maps.

During this operation, the Forest Cover Map 2015 was created from the Forest Base Map 2012, based on forest degradation and forest cover gain. The Forest Monitoring Unit (FMU) was revised for the areas of Large-scale forest loss (Hansen loss greater than 20 hectares) after 2011, which was then applied to Land Use, Land Use Change and Forestry (LULUCF). For the areas of smaller scale forest loss (Hansen loss smaller than or equal to 20 hectares) after 2011, the FMU was revised only when the extension of the area of degraded strata was confirmed on the satellite imagery. Other minor forest loss information were added to the map as disturbance and the areas that contained obvious forest recovery were revised referring to Hansen gain data larger than 1 hectare.

## 2. Method

The procedure consisted of two parts:

1. Constructing DD information, in which the deforestation and forest degradation drivers information were identified for each map polygon (FMU) and;

2. Detecting land use/cover change area, in which changes in the land use areas were identified.

# Data Preparation

Listed below are the datasets that were used during the process of creating the Forest Cover Map 2015, along with their respective sources from which these datasets were acquired.

*Table 1: The datasets used for constructing Forest Degradation Information*

| Layer (Dataset) | | Source |
|---|---|---|
| **Forest Base Map** | | Developed by the Project[1] |
| **Hansen Lossyear** | | Developed by the Project |
| **LANDSAT AGP** | | Developed by the Project |
| **RapidEye 2011** | | Procured by Grant Aid Program[2] |
| **Google Earth Satellite Imagery** | | Google Earth |
| **Reference data necessary for identifying drivers:** | Mining | Mineral Resource Authority (MRA) |
| | Forest plantation (Qf) polygon in the Forest Base Map | Developed by the Project |
| | Plantation other than forest plantation (Qa) polygon in the Forest Base Map | Developed by the Project |
| | FCA and SABL polygon | Acquired from PNGFA |
| | Subsistence agriculture (O) in the Forest Base Map | Developed by the Project |
| | 500m buffer from logging road (2000, 2000-2005, 2005-2011, 2011-2015) | Developed by the Project |
| | Concession (Current and Expired, purchase before 2014) | Acquired from PNGFA |
| | 5 km buffer Census Unit | Developed by the Project |
| | Hansen Gain | Developed by the Project |
| | FireWatch PNG | University of Papua New Guinea Remote Sensing Centre |

[1] Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change.
[2] "The Forest Preservation Programme in the Independent State of Papua New Guinea" funded by the Government of Japan (2012 – 2013).

# Procedure

## Constructing Forest Degradation (DD) Information

### 1. Identify drivers of large Hansen Loss-year polygons (greater than 20 hectares)

In this step, the Hansen Loss-year polygons larger than 20 hectares for the targeted year of 2011-2014 are selected. The driver for each Hansen Loss-year polygon on the bases of the flow right (see Figure 1) was identified.

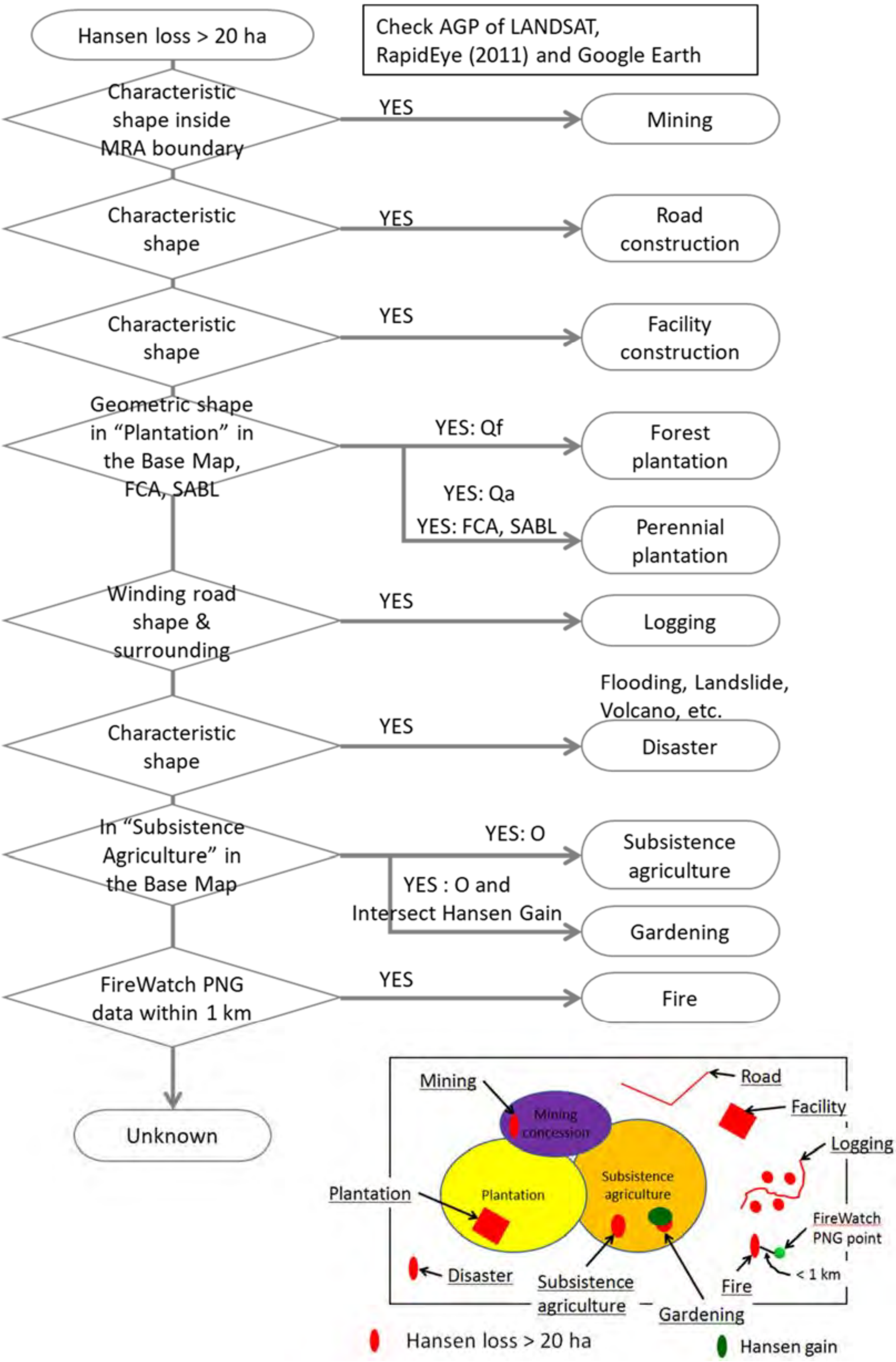



*Figure 1: Flow of Driver analysis for Hansen loss-year polygons larger than 20 ha.*

## 2. Identify drivers of small Hansen Loss-year Polygon (smaller than or equal to 20 hectares)

This next step involved the selection of; (I) Hansen Loss-year polygons smaller than or equal to 20 hectares for targeted years 2011-2014, and (II) the identified drivers for each Hansen Loss-year polygon, on the flow right (see Figure 2) by overlaying analysis with reference data.

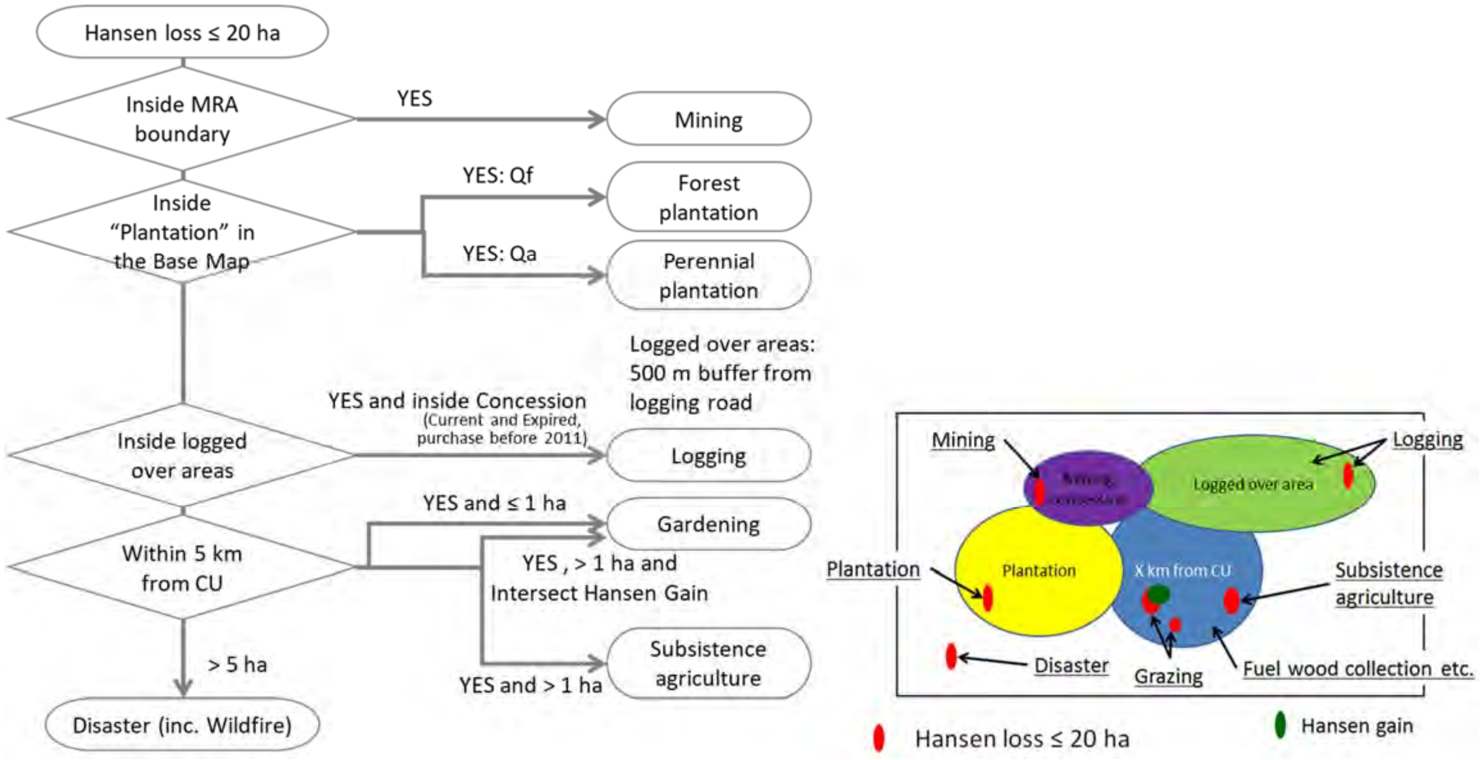



*Figure 2: Flow of Driver analysis for Hansen loss-year polygons 20 ha and smaller.*

## 3. Merging

This step involved the merging of the mapping files created in the steps 1 and 2.

## 4. Input driver information

This step involved integrating DD information for each FMU of the Forest Base Map by overlaying Loss-year polygons prepared in step 3.

## 5. FMU which do not intersect Hansen Loss polygon

This step involved identifying the drivers for each FMU on the basis of flow right (see Figure 3) by overlay analysis with reference data. FMU with no driver information were considered as intact forest.

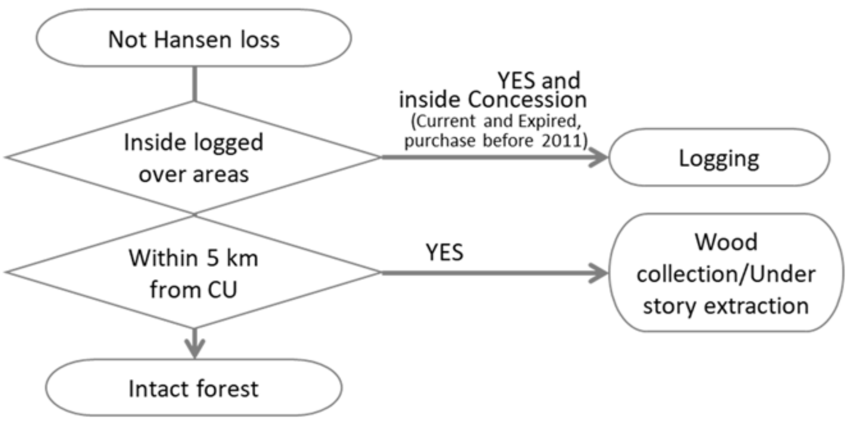



*Figure 3: Flow of Driver analysis for Map polygons which do not intersect Hansen loss*

## Detecting Land Use/Cover Change area

This particular process revised the area of Large-scale forest loss and area expansion after 2011. This was done by selecting Hansen Loss polygons (2011-2014) larger than 20 hectares that had expanded after 2011. For the Loss-year polygons, the changed areas (polygons) were cut, and identified as new landuse by referring to satellite imagery and reference data.

With regard to areas with obvious forest recovery, the changes were revised by referring to the Hansen Gain polygons that are larger than 1 hecatares, and satellite imagery.

# 3. Results

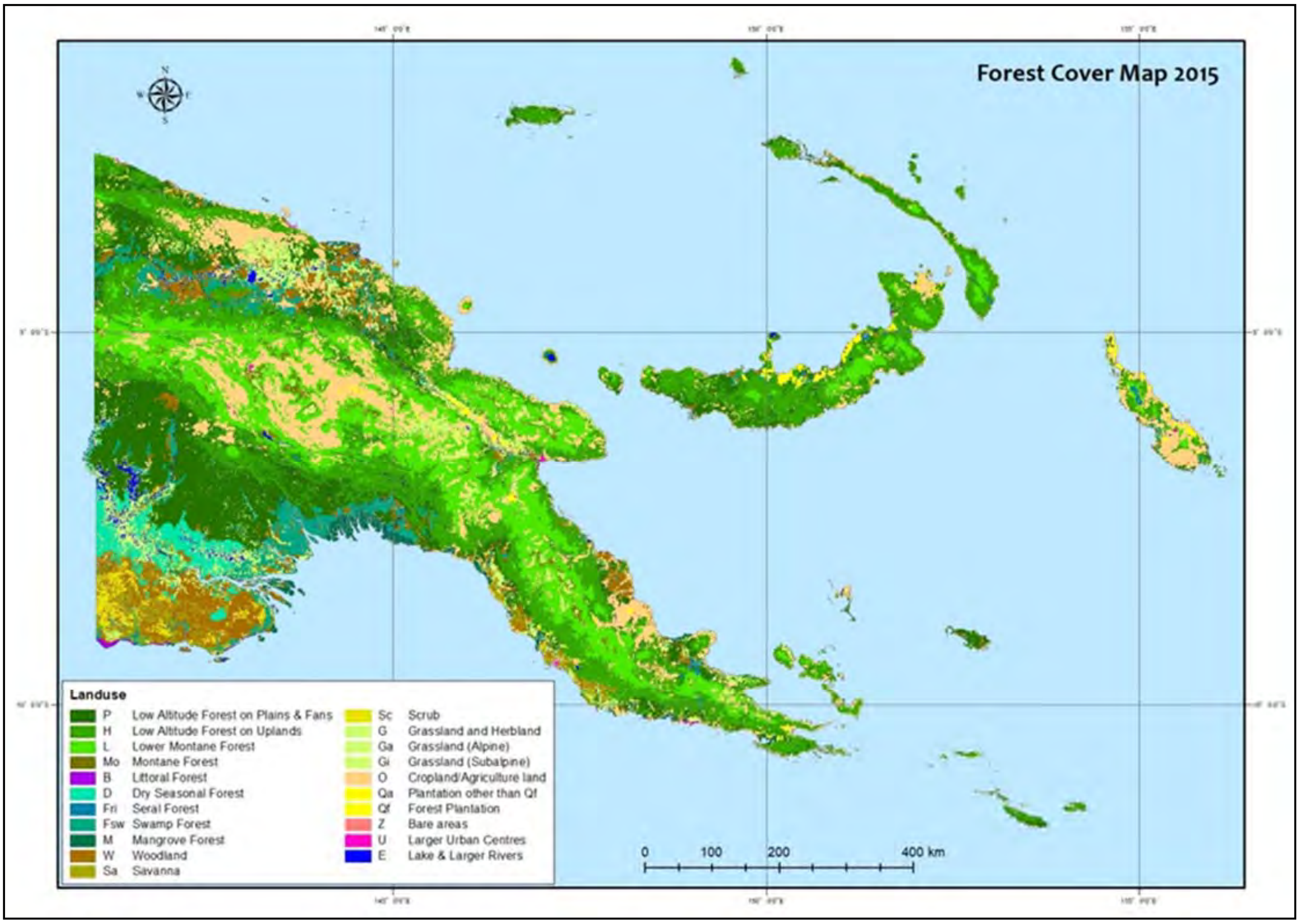



*Figure 4: Forest Cover Map 2015 showing different landuse.*

| | VEG | VEGNAME | Area (Ha) |
|---|---|---|---|
| | P | Low Altitude Forest on Plains & Fans | 8,133,318 |
| | H | Low Altitude Forest on Uplands | 11,603,863 |
| | L | Lower Montane Forest | 7,465,348 |
| | Mo | Montane Forest | 354,495 |
| | D | Dry Seasonal Forest | 935,207 |
| | B | Littoral Forest | 66,616 |
| | Fri | Seral Forest | 147,631 |
| | Fsw | Swamp Forest | 1,989,886 |
| | M | Mangrove Forest | 518,964 |
| | W | Woodland | 2,989,010 |
| | Sa | Savanna | 635,125 |
| | Sc | Scrub | 391,709 |
| | G | Grassland and Herbland | 3,005,981 |
| | Ga | Grassland (Alpine) | 107,065 |
| | Gi | Grassland (Subalpine) | 86,977 |
| | O | Cropland/Agriculture land | 6,577,558 |
| | Qa | Plantation other than Qf | 422,484 |
| | Qf | Forest Plantation | 67,951 |
| | Z | Bare areas | 24,151 |
| | U | Larger Urban Centres | 38,332 |
| | E | Lake & Larger Rivers | 599,488 |
| | | SUM | 46,161,159 |

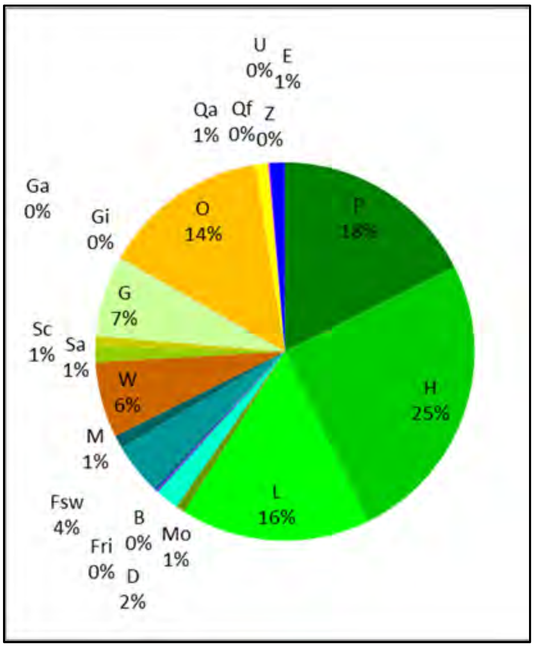



*Figure 5: The vegetation cover with their corresponding area in hectares for the Forest Cover Map 2015.*

# 4. Discussion

- The Forest Cover Map with Forest Degradation information has been updated for entire PNG, so that possible misclassification due to technical limitations in the Forest Base Map could be revised.
- Technical and operational findings from this trial and error work will be considered as a great help in the monitoring of forest resource for the future.
- Future forest cover maps should be updated on the basis of this method, but also by innovating new technologies.

# 5. Conclusion

Forest cover maps are very essential in forest monitoring and planning. The forest cover maps from subsequent years and 2015 have significantly aided in climate change control and has also paved a dynamic path for REDD+. Thus, it is very important that forest cover maps should be updated (upon assumption to be updated every five years) to keep track of  changes in forest resources and related information in Papua New Guinea.

# 6. References


JICA and PNGFA, 2016, 'Papua New Guinea Forest Base Map 2012 - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.2'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

JICA and PNGFA, 2019, 'Forest Monitoring Unit (FMU) in Papua New Guinea Forest Cover Map - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.4'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea



**PNG Forest Authority (JICA Project)**
Address: P.O. Box 5055, Boroko, National Capital District, Papua New Guinea
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JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/


Last updated on July. 2019

# Drone Applications in Sustainable Forest Management and Monitoring in PNGFA

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Background

### Overview of drone & utilization

The applications of drone technology in Forestry have reached new heights by providing up-to-date, high resolution aerial imagery with reduced costs and time. Employed as a better alternative to satellite imagery and manned flight aerial photography, drones are fast becoming widely used in the mapping of forest areas for the purposes of management and monitoring forest resources (Banu & Borlea, 2016). By using drones to inspect the current status of forest areas and logging operations, forestry activities can be regulated with efficiency.

The Forestry sector in Papua New Guinea is regulated by the PNG Forest Authority (PNGFA), through the application of the Forestry Act, 1991 (as amended) and the "Logging Code of Practice" (LCoP) and the "Planning, Monitoring and Control Procedures" (PMCP) in the country. In recent years, PNGFA, with the assistance of JICA, have begun to introduce the utilization of GPS/GIS/Drone technology to assist in the traditional inspection methods in the implementation of LCoP/PMCP. While the traditional methods are still sufficient, the main purpose of the introduction of GPS/GIS/Drone technology is to increase the productivity of inspection methods by decreasing the amount of manpower needed, the time taken to complete inspections, and provide a more reliable snapshot of the current status of the target forest areas. GPS/GIS/Drone technology, used in line with the PNG-FRIMS, allows the ease in which information pertaining to forest resources and activities can be acquired and updated.

In line with the JICA-PNGFA Project, *"Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change",* there have been three (3) drone training for PNGFA officers; in June 2018, October 2018 and February 2019. The aim of the training was to equip the PNGFA officers with the relevant knowledge and technical expertise in the use of GPS/GIS/Drone technology relating to Sustainable Forest Management (SFM) and to increase the capacity of the officers to be able to incorporate modern technology with the existing traditional inspection methods.

The training exercises were also instrumental in drafting the Drone Policy in PNGFA and the Safety Guidelines and Administration of Drone Usage. The policies and guidelines are key aspects of finding out where GPS/GIS/Drone technology is applicable and creating more innovative approaches in GPS/GIS/drone technology that will benefit both the JICA-PNGFA Project and PNGFA in the future.

# 2. Drone Policy in PNGFA and Possible Applications

## PNGFA Drone Policy: Key Principles for the Introduction of Drone Technology in PNGFA

- **Goal:** Drone technology is utilized as a part of forest monitoring framework in PNGFA, and accuracy and efficiency of forest monitoring is improved.
- **Selection and concentration: 1)** Plantation, **2)** Natural forest monitoring and, **3)** Forest Research (NFI)
- **Verification of possibility**
- **Cost analysis**
- **Risk management**

## Possible Applications of Drone Use in PNGFA

### 1. Possible Applications of Drone use in Plantations

- *Main Objective:* Strengthening capacity of plantation management contributing to increase timber production and economic growth in PNG.
- *Applicable/Possible Activities:*
  - Identification & security of potential areas for plantation development, Plantation management, Health Check, Area Calculation, Volume Estimation, Survival Assessment, etc.

### 2. Possible Applications of Drone use in Natural Forest Monitoring

- *Main Objective:* Improving efficiency and accuracy of forest monitoring in coordination with drone and other existent method in order to fully operationalize practicing LCoP/PMCP.
- *Applicable/Possible Activities:*
  - Natural forest monitoring based on LCoP, Planning, Regeneration planning, Site detection, Thresholds of re-entry, Rate of forest recovery, Invasive species, Spectral signature of flora, etc.

### 3. Possible Applications of Drone use in Forest Research

- *Main Objective:* Through research oriented activity, clarifying availabilities of drone to enrich and promote Plantation, Natural forest monitoring and NFI.
- *Applicable/Possible Activities:*
  - Measurement of tree height and crown size, Verification of vegetation types, Measurement of disturbance level, Determine crown & forest health

**Formulating the Policy**

The Drone Policy in PNGFA was first outlined during the discussions held in the first training. The policy covers much of the necessary precedents that needed to be achieved or established, the current situation of drone usage in PNGFA as well as laying the foundation for the Drone Applications in Sustainable Forest Management and Monitoring.

**Challenge for Forest Monitoring in PNG**

The two main points of raised in this respect refer to the Global Issue for Forest Monitoring and the Efficient Task Management by Promotion of Streamlining. The points highlight the responsibility of PNGFA in dealing with the balance of SFM and meeting the timber supply demands for both domestic and international markets, and how this balance can be maintained with the introduction of a more streamlined process, i.e., the use of GPS/GIS/Drone technology and PNG-FRIMS, working in harmony with existing traditional methods.

**Current situation and problem of Drone for Forest Monitoring**

As a monitoring tool, drones are robust and efficient with many different applications in Forestry. However, its use in PNGFA is still relatively a new undertaking and as such, guidelines, safety measures and verification of its feasibility in its incorporation into PNGFA is virtually non-existent. Furthermore, the possibility of introduction of drone use into PNGFA should not be seen as replacing traditional methods, but rather, adding onto it.

# 3. Standardization of Drone Usage

## Capacity Development

The table below highlights the activities that were undertaken during the three (3) trainings that were facilitated by JICA.

*Table 1: Summary of drone trainings*

| Training No. | First | Second | Third |
|---|---|---|---|
| Location(s) | ❖ PNGFA HQ, Port Moresby<br>❖ Kuriva Teak Plantation, Central Province | ❖ Sandaun PFO, West Sepik Province<br>❖ Amanab Blocks 1-4 FMA, West Sepik Province | ❖ PNGFA HQ, Port Moresby<br>❖ Marshall Lagoon FMA, Central Province |
| Date (Duration) | $12^{th}$ – $20^{th}$ June, 2018 (2 weeks) | $23^{th}$ – $28^{th}$ October, 2018 (1 week) | $18^{th}$ – $28^{th}$ February, 2018 (2 weeks) |
| Drone Used | DJI Phantom 4 Pro | DJI Phantom 4 Pro | DJI Mavic 2 Pro |
| Focus of training | 1. Safety measures and handling of drone equipment<br>2. Basic operation of drone flight<br>3. Image and Video Capture<br>4. Data processing<br>5. Drafting of the Drone Policy in PNGFA | 1. Review of skills, techniques and procedures from First Training<br>2. Discussions on the feasibility of Drone Utilization with LCoP/PMCP in Natural Forest Monitoring | 1. Review of skills, techniques and procedures from First and Second Trainings.<br>2. Practical applications of Drone Utilization with LCoP/PMCP and comparison with traditional methods of Forest Monitoring. |

*Fig.1: PNGFA officers learning the basic controls of drone flight.*

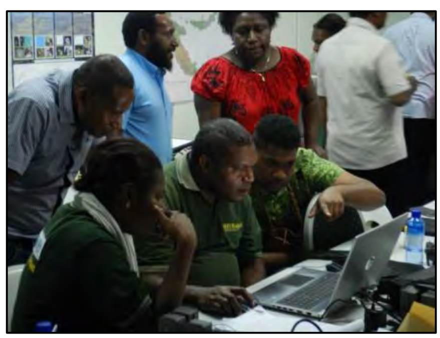


*Fig.2: PNGFA officers learning to process the drone-captured images*

*Fig.3: PNGFA officers performing manual inspection of forests.*

*Fig.4: JICA experts and PNGFA officers discussing the applications of drones in forest monitoring.*

*Fig.5: PNGFA officers and JICA experts monitoring an automated flight plan being executed by the drone.*

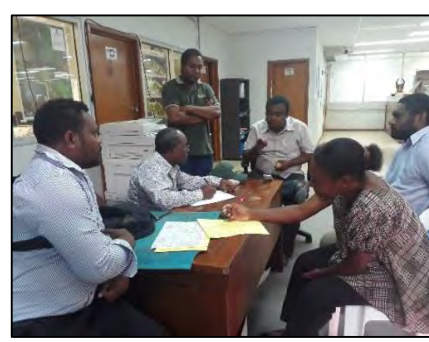


*Fig.6: PNGFA officers discussing and comparing manual inspection and drone-based inspection*

## Safe Administration Guideline for Drone Usage in PNGFA

Drones are fragile and delicate equipment and are prone to damage and loss. As such, safety measures regarding its use and operation must always be adhered to. This includes:

1. Making sure clearance is obtained from the Civil Aviation Safety Authority (CASA PNG), in reference to the drone specifications, airspace restrictions, exclusions zones and the purpose of drone use.
2. Maintaining a safe operating environment where there is acceptable weather conditions and optimal visibility. Preferable conditions include during the day, without windy or wet weather.
3. Handling of drone equipment is done with the utmost care during the assembly, flight and dismantling.
4. Pre-flight checks to inspect battery levels of devices, propellers, propeller guards, gimbal (camera) and other equipment must done before operation of drone.
5. Constant monitoring of the drone during flight to ensure control whether drone is in automated flight or manual flight. This is to prevent damage or loss in case of low battery or transmission problems.


*Fig.7: PNGFA officers learning how to properly assemble and dismantle the drone.*


*Fig.8: The Pre-flight Checklist published by CASA PNG (Excerpt from Post Courier - January 21st, 2019)*

# 4. Summary of Drone Performance

Currently, PNGFA has four drones in use today; three of which are Mavic 2 Pros and one Phantom 4 Pro. The Phantom 4 Pro was used in the first and second trainings. The Mavic 2 Pros were used in the third training. Their performance during training are shown below:

*Table 2: Phantom 4 Pro performance during First and Second trainings*

| Parameter | First Training | Second Training |
|---|---|---|
| Coverage Area | 4.5 ha | 187.56 ha |
| Flight Length | 1,119 m | 35,336 m |
| Flight time | 8 min | 2 hrs 10 min |
| Overlaps (vertical, horizontal) | 90%, 70% | 90%, 70% |
| No. of photos taken | 84 | 1194 |
| Batteries | 1 pack | 7 packs |
| Speed | 4.3 m/s | 7 m/s |
| Max. transmission distance | 500 m | 1000 m |

*Table 3: Mavic 2 Pro performance during Third Training according to each group*

| Parameter | Group 1 | Group 2 |
|---|---|---|
| Coverage Area | 154 ha | 133.34 ha |
| Flight Length | 22,832 m | 28,489 m |
| Flight time | 2 hrs 10 min | 66 min |
| Overlaps (vertical, horizontal) | 90%, 70% | 90%, 80% |
| No. of photos taken | 1,208 | 1,372 |
| Batteries | 12 | 6 |
| Speed | 6 m/s | 8.6 m/s |
| Max. transmission distance | 1200 m | 1000 m |

| Parameter | Group 3 | Group 4 |
|---|---|---|
| Coverage Area | 175 ha | 14.99 ha |
| Flight Length | 32,000 m | 2,640 m |
| Flight time | 2 hrs 32 mins | 13 min |
| Overlaps (vertical, horizontal) | 90%, 70% | 75%, 60% |
| No. of photos taken | 2,243 | 85 |
| Batteries | 12 packs | 1 pack |
| Speed | 7 m /s | 5 m/s |
| Max. transmission distance | 1200 m | 500 m |

## Limitations of Drone Utilization

During the course of the trainings, there were a few limitations experienced that can affect the outcome of an operation. Listed below are some of the limitations and issues faced during the course of the trainings with regard to the drones that were used:

❖ ***Battery life***
The battery life (30 minutes) affects the missions with larger areas that need hours of operational flight time as there will be a need for constant charging and changing of batteries during missions

❖ ***Weather***
Drone operations can only be done during day time without foggy, wet or windy conditions. This conditions can damage the drone, limit battery life, and cause the loss of the drone.

❖ ***Details of features may not be visible by drone photos***
The photos taken with the drone may not always show features of interest. To increase the image resolution will require the drone to be flown at a low altitude, although this will affect the flight time.

❖ ***Skills/Knowledge of using Drone***
More trainings to be conducted to improve technical expertise and confidence of officers to properly pilot the drones.

❖ ***Access to Internet connections***
Internet connection is needed for the softwares to be used but this is lacking in the forest areas

# 5. Drone Utilization in PNG-FRIMS

## Natural Forest Monitoring and the Logging Code of Practice (LCoP)

The second and third training activities primarily featured the use of drones in Natural Forest Monitoring in implementing the Logging Code of Practice (LCoP). The flight missions undertaken were focused on the four (4) phases of logging operations; Pre-logging, Active Logging, Post Logging and Degraded. Each of the phases are accompanied with their own checklists based on the requirements and standards set in the LCoP. Shown below are samples of the checklist filled out by PNGFA officers:

| # | LCoP Activities | Key Standard | Available Measure | | | |
|---|---|---|---|---|---|---|
| | | | Surface Study | | Drone | |
| | | | Tape/Pole | GPS | Manual | Ortho |
| **Planning - Question crews about the marking system** | | | | | | |
| 1 | If crews know the marking system | - | ✓ Interview | | | |
| **Road construction - Inspect at least 4 length of 200 metres** | | | | | | |
| 2 | If roads are constructed to approved standards | - | * | ✓ | * | * |
| 3 | If excluded areas are free of soil | 6 | | ✓ | * | * |
| 4 | If roads are properly compacted | 7 | | ✓ | | |
| 5 | If roads follow approved surveyed roadlines | 8 | * | ✓ | * | * |
| 6 | If road corridor is less than 40 metres wide | 9 | * | ✓ | * | * |
| 7 | If adjacent streams are free of soil | 10 | | ✓ | * | * |
| 8 | If roads are properly drained | 11 | | ✓ | * | |

*Fig.9: A sample of the check list for the Active Logging Site. The check list contains items from the Key Standards in the LCoP, which the officers fill out the best option and alternative option for the monitoring of these items, in ticks and asterisks respectively.*

## Plantation Monitoring

The first training activities focused on using drones to monitor Plantations. Drones were used to collect image data, which was then subsequently used to update the plantation inventory.

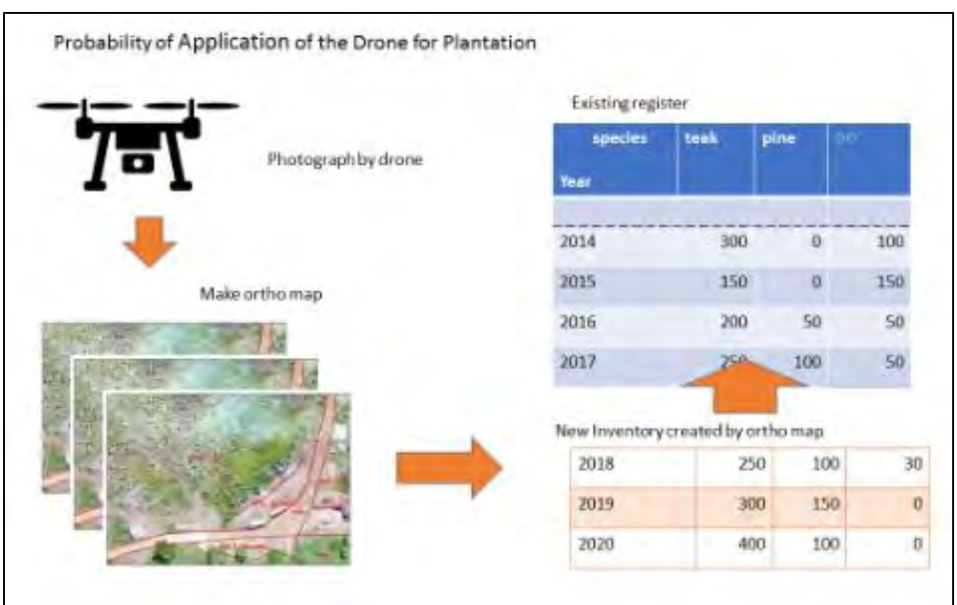



*Fig.10: The process of capturing images using drones and producing orthophotos for updating new information into the Plantation Inventory.*

*Fig.11: Orthophoto to be used for Inspection of Natural Forests (overlayed in Google Earth)*

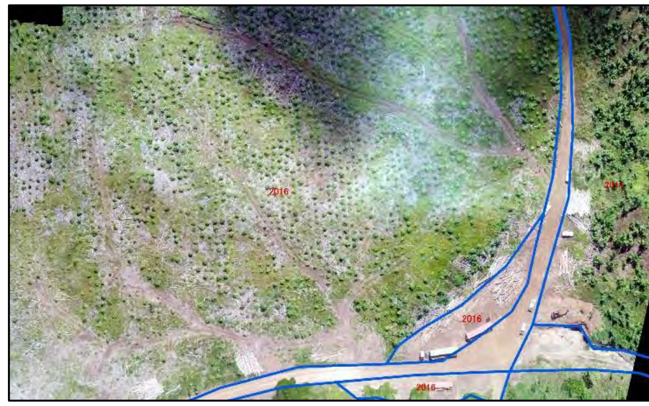


*Fig.12: Orthophoto to be used for updating Plantation Inventory (overlayed over existing information)*

## Forest Degradation Assessment

Forest Degradation Assessments aim to assess the reduction of the capacity of a forest to provide goods and services. In regard to the training exercises conducted, the degradation refers to the felling gaps and skid trails that result from the harvesting of logs in a forest area. The felling gaps and skid trails can be identified by the process shown below:

1. Image capture by drones, before and after logging operation
2. Removing logging roads from the analysis due to its dimensions (road width)
3. Running the images (IR band) through segmentation analysis in ENVI
4. Subtracting the log extraction data from the output by using field data.

The final result is the percentage of felling areas and skid trails that make up the degradation of the forest area.

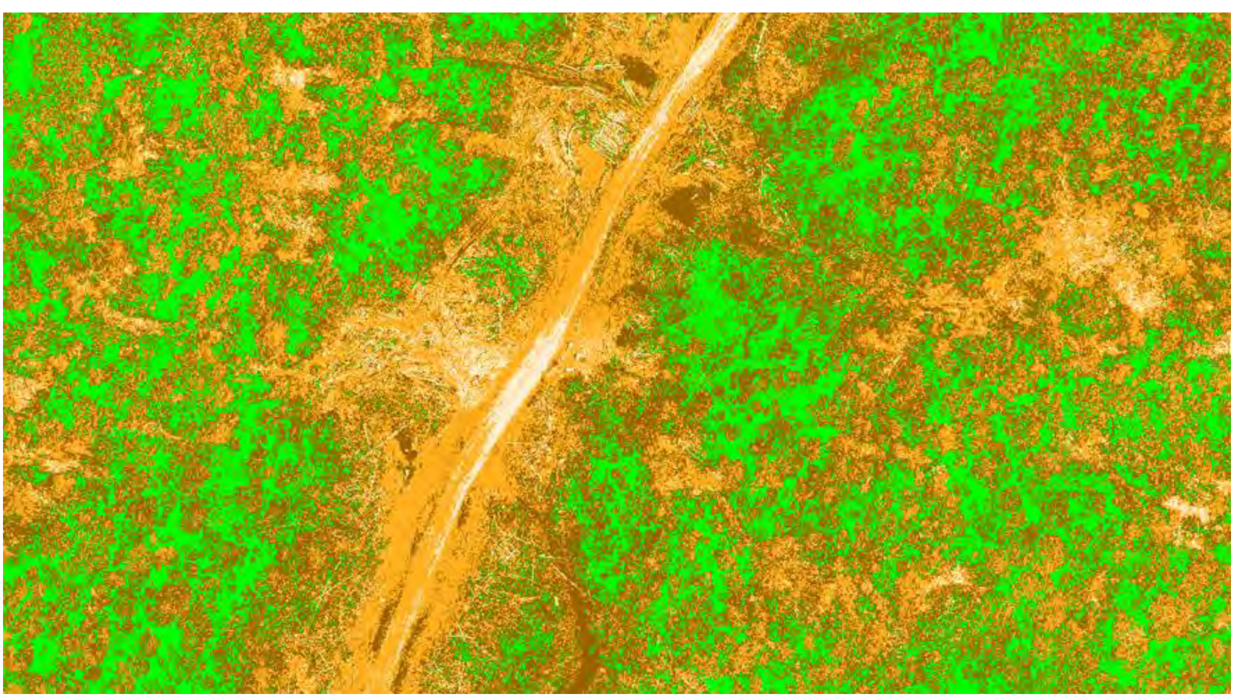


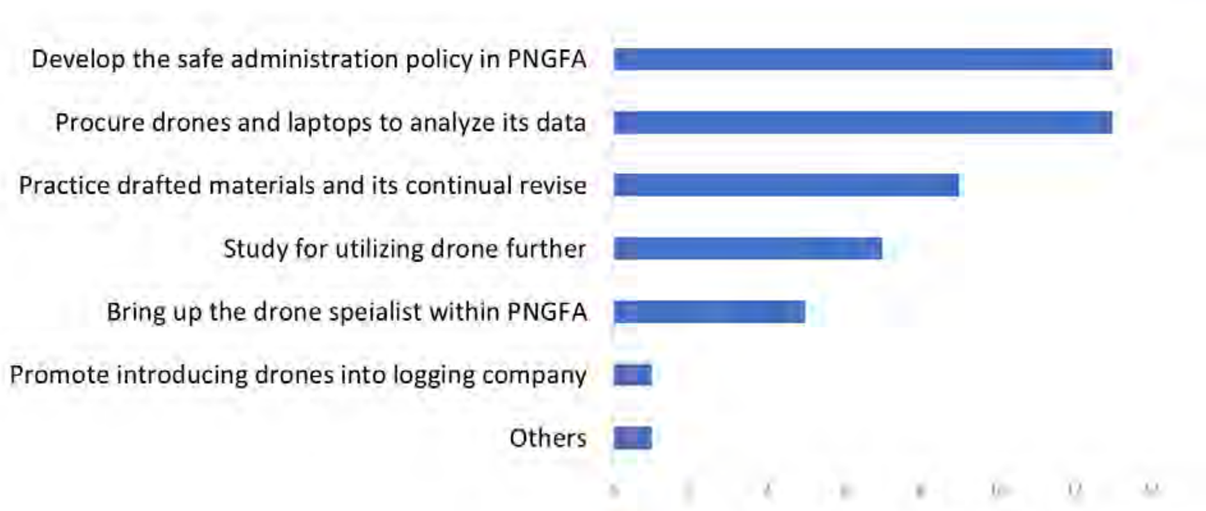
*Fig.13: The calculated aerial imagery showing the areas of degradation in orange and vegetation in green.*

# 6. Future Scenario

## Summary of Questionnaire Results

During the third training, survey questionnaires were given to the PNGFA Officers to gather opinions and experiences on the current inspection methods and the applicability of drones in field monitoring according to the LCoP. All officers agreed on the fact that the utilization of drones in PNGFA is important and that it is applicable in field inspections and monitoring. However, it was the general consensus that while drones are a powerful monitoring tool, further training is needed to better understand its full potential; thus, the optimal course of action is to integrate the use of drones with existing inspection methods.

The graph below shows a the overall opinion of the participating officers with regard to the improvement of field inspection with the utilization of drones in the future:




*(N=18, choose up to three items)*

The future of drone utilization in PNGFA is rife with potential. The three trainings conducted were very educational and motivating for PNGFA Officers who participated. The trainings have set the foundation and paved the way for the further development of capacity building, integration of modern technology into existing methods of forest monitoring and promotion of Sustainable Forest Management.

# 7. References


1. Banu, P. T., & Borlea, F. G. (2016, November). The Use of Drones in Forestry. Retrieved from Research Gate: https://www.researchgate.net/publication/316802665_The_Use_of_Drones_in_Forestry



**PNG Forest Authority (JICA Project)**
Address: P.O.Box 5055, Boroko, National Capital District, Papua New Guinea
Email: infor_general@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

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# Analysis of Drivers of Deforestation and Forest Degradation in Papua New Guinea

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Background

The tropical rain forest in PNG plays an important role in many aspects, contributing to the national economy through timber exports, rich biodiversity and mitigation of climate change; however a significant rate of forest loss and degradation have been reported in recent decades. Generally, Deforestation and forest Degradation (DD) are said to be caused by timber harvesting, clearing forests to develop cropland, and natural disasters such as forest fires and floods. For PNG Forest Authority (PNGFA) to figure out distribution of intact (primary) forest, create forest plans, and manage natural forests in a sustainable manner, it is essential to understand the process of DD through identifying and quantifying DDs and their drivers using a map-based method.

In this JICA project, PNGFA staff and JICA experts (the Project team) studied DD drivers in three steps: The Project team began by defining terminology such as land use classes, land transition and its drivers (see section 2). The Project team then examined useful data sources (see section 3) and availability of satellite images. Finally the Project team established operational procedure and criteria of detecting land transition in forest area (see section 4) and conducted analyses of DD drivers.

The Forest Mapping Unit (FMU) used in the formerly developed Forest Inventory Mapping System (FIMS) indicates timber volume value among other attributes. The new PNG-FRIMS (see Fact Sheets No.2 & 3) includes a Forest Base Map, which also has timber volume and forest disturbance information, as one of its map contents. The Forest Base Map gives information on where intact (primary) forest may be, versus where forest disturbance has already taken place, etc. for forest management and planning, through a redefined Forest Monitoring Unit (FMU*).

The Forest Base Map covers the whole of PNG and shows forest information as of 2012. Statistical DD driver analysis was conducted to additionally produce Forest Cover Maps for 2000 and 2005, of West New Britain Province and West Sepik Province (see section 5), also included in PNG-FRIMS.

The Project team then assessed the effectiveness of the methodology used by the Project team by comparing results to DD drivers identified by the "Collect Earth" tool by UN-REDD, noting the differences (see section 6) and lessons learned (see section 7).

*FMU (Forest Monitoring Unit) is a minimum polygon of forest cover on a map, used as a unit of data management in PNG-FRIMS. FMU is delineated by Province boundaries, Forest Zone, Catchment area, Land use class, forest type including crown.

# 2. Definitions of Land Use Classes, Land Transition and its Drivers

## Definitions of Land Use (LU) classes

Prior to defining LU transition and its drivers, LU classes and its strata were defined, based on IPCC's six land use categories.

| LU classes (IPCC*) | LU strata |
|---|---|
| Forest land (Natural Forest) | Primary forest |
| | Logged over forest |
| | Non-logged degraded forest (driven by activities other than formally planned logging, such as fuelwood collection, gardening, small scale logging for mobile sawmills) |
| Forest land (Plantation Forest) | Open-canopy plantation (premature or harvested) |
| | Closed-canopy plantation (mature) |
| Cropland | Annual crops (herbaceous) |
| | Perennial plantations (ligneous) |
| Grassland | Shrub (not defined in the Forest Base Map) |
| | Grassland |
| Settlements | Infrastructure (other than roads) |
| | Road |

* IPCC categories 'Wetlands' and 'Other Land' not shown in this table

## Definitions of Land Transition and its Drivers

This set of typology and definitions takes into consideration technical limitations associated to Remote Sensing analysis. Some definitions were deliberately simplified to facilitate analyses of drivers.

### Deforestation

Deforestation is a land transition; for example, "Forest land" class is converted to other LU classes such as "Crop land," driven by drivers such as "Subsistence agriculture".

Forest land → Another land use class

| Initial LU class/ strata | Driver | Final LU class/ strata |
|---|---|---|
| Forest land/ whichever strata | Subsistence agriculture | Cropland/ Annual crops<br>Grassland/ Shrub<br>Grassland/ Grassland |
| | Commercial agriculture | Cropland/ Perennial plantations |
| | Large fire | Grassland/ Grassland |
| | Mineral extraction | Settlements/ Infrastructure |
| | Road construction | Settlements/ Road |
| | City expansion & settlements | Settlements/ Infrastructure |

## Degradation

Degradation is a land transition where “Primary forest" strata is converted to other LU strata under “Forest land” class, or "Closed-canopy plantation" is converted to "Open-canopy plantation”.

- Primary forest → Logged over forest
- Primary forest → Non-logged degraded forest
- Closed-canopy plantation → Open-canopy plantation

| Initial Forest land strata | Driver | Final Forest land strata |
|---|---|---|
| Primary forest | Authorized selective logging | Logged over forest |
| Primary forest | Wood collection (non-authorized logging + fuel wood collection) | Non-logged degraded forest |
| Primary forest | Gardening (shifting agriculture) through slash and/or burn (including small fires) | Non-logged degraded forest |
| Closed-canopy plantation | Logging in forest plantations | Open-canopy plantation |
| Primary forest | Grazing (usually happens in Grassland, yet may have a potential of forest degradation) | Grassland/ Shrub Grassland/ Grassland |

## Regeneration

Regeneration is a "positive" land transition under "Forest land" class where "Logged over forest" or "Non-logged degraded forest" is converted to "Primary forest", or "Open-canopy plantation” is converted to "Closed-canopy plantation”.

- Logged over forest → Primary forest
- Non-logged degraded forest → Primary forest
- Open-canopy plantation → Closed-canopy plantation

| Initial Forest land strata | Driver | Final Forest land strata | Area type |
|---|---|---|---|
| Logged over forest | Assisted regeneration/Natural regeneration | Primary forest | Managed by PNGFA programme in logging concessions |
| Non-logged degraded forest | Natural regeneration | Primary Forest | Not in concessions |
| Open-canopy plantation | Plantation | Closed-canopy Plantation | Managed by PNGFA or private sector |

## Reforestation

Reforestation is a "positive" land transition where LU class such as "Grassland" or "Cropland" is converted to "Forest land (Plantation forest)" by plantation activities.

Grassland or Cropland → Forest land

| Initial LU class/ strata | Driver | Final Forest land strata | Area type |
|---|---|---|---|
| Grassland/ Shrub | Plantation | Forest land (Plantation forest) | Managed by PNGFA or private sector |
| Grassland/ Grassland | | | |
| Cropland/ Perennial plantations | | | |

## General scale of degradation associated with each driver

The general scale of degradation associated with each potential DD driver was used to determine the smallest size of "Hansen loss"* areas for which drivers will be analyzed and interpreted manually. The cut-off was determined to be 20 ha, according to the analysis below.

* "Hansen loss" data is a dataset developed by Hansen, et al. (2013), showing yearly forest reduction since 2001 based on an algorithm to extract areas where decrease of vegetation taller than 5 m was occurring, utilizing imagery of LANDSAT 7 and LANDSAT 8.

| Drivers | Associated scale | Notes and useful information for analysis |
|---|---|---|
| **Mining / Extractive industry** | Generally > 50 ha<br>Sometimes > 30 ha | Deforestation caused by constructing pipelines for oil and gas. Forest areas are cleared for facility construction including the construction of townships with workers compounds, schools, hospitals, administrative centers and recreational areas. |
| **Road construction** | Generally<br>40 to 60 ha | Normal width: 40 m road line corridor (20 m on either sides)<br>Normal road length added per year: 10,000 to 15,000 m<br>40x (10,000 to 15,000) = 400,000 to 600,000 $m^2$ per annum |
| **Facility construction (e.g. School)** | Generally 2 ha | Schools and logging camps are usually around 2 ha in size.<br>Schools are usually constructed in the village and most schools are not detected as Hansen Loss.<br>Facility construction usually appear along the road, grassland, and other non-forest lands. |
| **Agricultural plantation associated with FCA** | Generally > 50 ha | Most activities via Forest Clearance Authority (FCA) occur at a larger scale than 50 ha.<br>Developer can clear forests up to 1,000 ha a year. |
| **Logging (and logging roads)** | Generally<br>20 to 40 ha | The maximum width allowed for main logging roads, which logging trucks and other vehicles will use, is 40 m. Spur roads are also considered to be logging roads but are not commonly used by vehicles.<br>Normal road length added per year: 5 to 10 km for main logging roads.<br>40 x (5,000 to 10,000) = 200,000 to 400,000 $m^2$ per annum |
| **Disasters** | Generally 5 ha | Main types of disasters in PNG are landslides, from flood and soil erosion especially along the Highlands Highway, or earthquakes (in ENB). The latter could happen in natural forest but hard to identify. |
| **Subsistence agriculture** | Generally 1 to 5 ha | Definition: shifting and permanent agriculture, cultivation, and gardening, occurring within 5 to10 km from Census Unit (CU).<br>*The 2010 Census Information is available from the National Statistics Office. Some of this information is already stored in PNG-FRIMS. |
| | 1 ha for non-commercial crops | Size of agricultural land for non–commercial crops is usually 1 ha. |
| | 5 ha for cash crops | Agriculture for cash crops (e.g. cocoa, cacao, etc.) is usually 5 ha. |
| **Fire** | 1 to 5 ha | Difficult to obtain actual information as the Natural Disaster Office doesn't publish datasets. Natural fires are rare in PNG and thus fires are usually man-made. Major causes are:<br>- Preparation for gardening (1 to 5ha)<br>- Hunting fire in grassland (1 to 5ha) to chase animals<br>- Accidental or careless fire (1 to 5ha) from smoking, cooking, etc. |

It is noted that DD Drivers such as **facility construction**, **disaster**, **subsistence agriculture** and **fire** may not be identifiable through the analysis of DD Drivers, however:

- Hansen Loss due to facility construction is not so common.
- Fire will be identified by FireWatch.
- Distinction between 'disaster' and 'subsistence agriculture' drivers can be made using information and assumptions presented below (see notes on subsistence agriculture).

Characteristics of other activities, listed below, may facilitate the association of drivers to the remaining Hansen Loss points:

| Drivers | Notes and useful information for analysis |
|---|---|
| **Plantations** | Replanting periods for each species type are useful in identifying plantations.<br>Forest plantations:<br>Kamerere: 20 years, Teak: 30 to 40 years, Klinkii: 30 to 35 years, Acacia: 8 to 10 years, Pinus spp.: 30 to 35 years, and Hoop: 30 to 35 years<br>Plantations other than forest plantations:<br>Cocoa: 20 to 30 years (upper trees are remaining), Oil palm: 20 years, Rubber: 30 years, and Coconut: 50 years |
| **Settlements** | Normally built in non-forest areas and very unlikely detected as Hansen Loss points |

The activities, below, cannot be tied to a particular scale of deforestation, but are nevertheless identified as drivers:

| Drivers | Notes and useful information for analysis |
|---|---|
| **Grazing** | Usually happens in Grassland |
| **Wood collection** | Dead trees & twigs are normally collected from gardening site |
| **Logging** | Logging data is assumed to be entered as forest working plans, and the volume subtracted in FIMS.<br>Small logging could be operated with chainsaws and portable sawmills. |
| **Building materials collection** | People cut down and collect trees for building materials. |

## Notes on subsistence agriculture

**Definition**: Shifting and permanent agriculture cultivation and gardening; occurs within 5 km from Census Unit (CU)

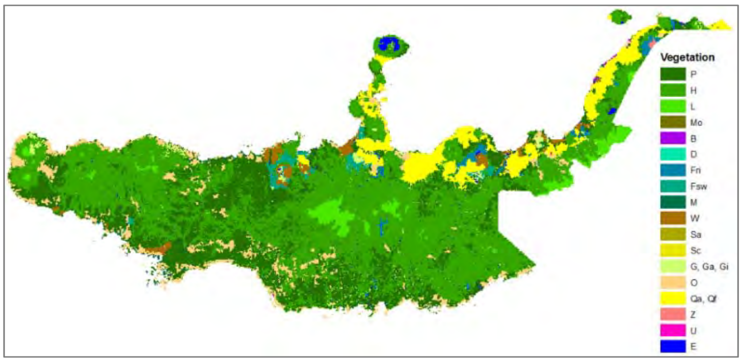
**Means to identify small agriculture patches**

- Hansen Loss larger than 1 to 5 ha, that is adjacent to the Forest Base Map LU class "Cropland/Agriculture land" but not in characteristic shapes of mining, road, other facilities, plantation, or logging.
- A set of expedient criteria for classifying Hansen Loss data is shown below.

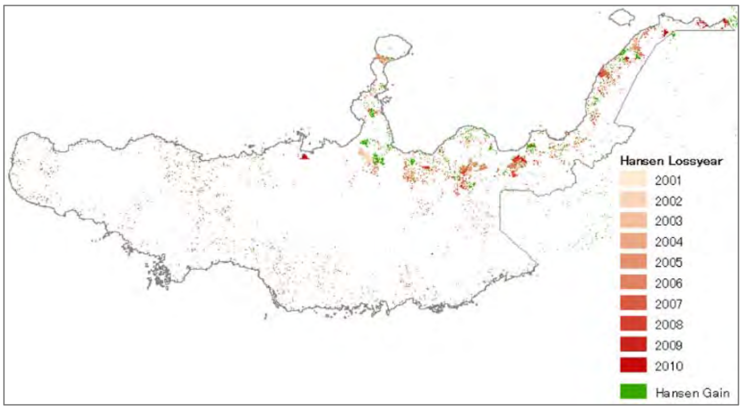
| Distance from CU | Size of Hansen Loss data | Disturbance type |
|---|---|---|
| **No longer than 5 to 10 km** | 5 to 20 ha | Commercial agriculture |
| | Up to 1 to 5 ha | Small agriculture patches |
| | Less than 1 ha | Other disturbance |

# 3. Information used for DD Driver Identification

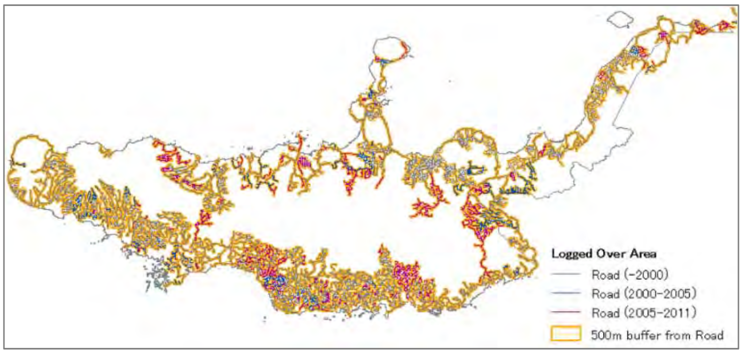
The following information was identified as useful for the identification of DD drivers.



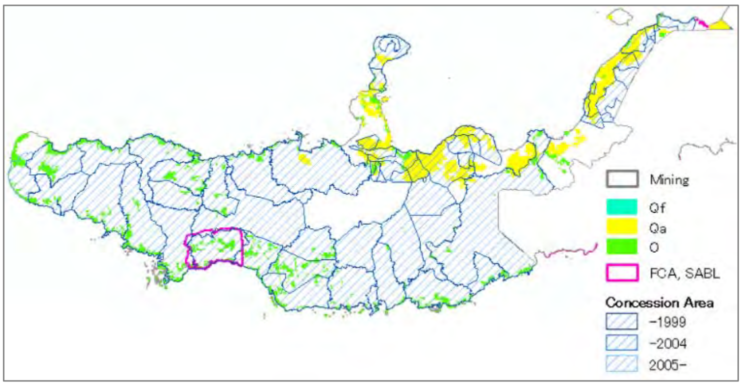

**Forest Base/Cover Maps**: Forest cover information in PNG. Driver information was added to each FMU.




**Hansen Data (Lossyear/Gain):** Annual pixel-by-pixel representation of deforestation areas. Used for identifying the location of both deforestation and degradation.




**Logged over areas:** Dataset created by the Project, marking logged over areas under the assumption that logging activities take place within a 500 m buffer from road data in 2000, 2005 and 2011.




**Mining:** Boundaries of mining activity by the Mineral Resource Authority.

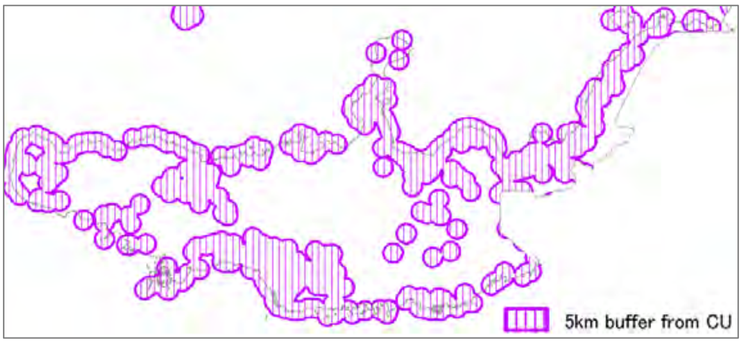
**Plantation**: Plantation data (Qf/Qa) from the Forest Base Map.

**Subsistence agriculture:** Agriculture data (O) from the Forest Base Map.

**Boundaries of Forest Clearance Authority** (FCA): Areas of forest clearance by developers within SABL boundaries.

**Boundary of Special Agriculture and Business Leases (SABL)**: Areas permitted for development for agricultural purpose leasing customarily-owned land.

**Concession Area:** Timber concession boundaries.




**Census Unit**: Representative point of settlements. Used for creation of 5 km buffer zone.

**FireWatch PNG:** Data obtained from a web site (http://fire.pngsdf.com/home.php) developed by the University of Papua New Guinea with the support of the EU.

# 4. Detection and Analysis of Forest Area Changes and their Drivers

## (a) Hansen Loss polygons larger than 20 ha

The definitions of DD drivers as discussed in section 2, was used in combination with available satellite imagery and other data listed in section 3, to analyze forest area changes and their drivers, based on presence or absence of Hansen Loss polygon and its size.

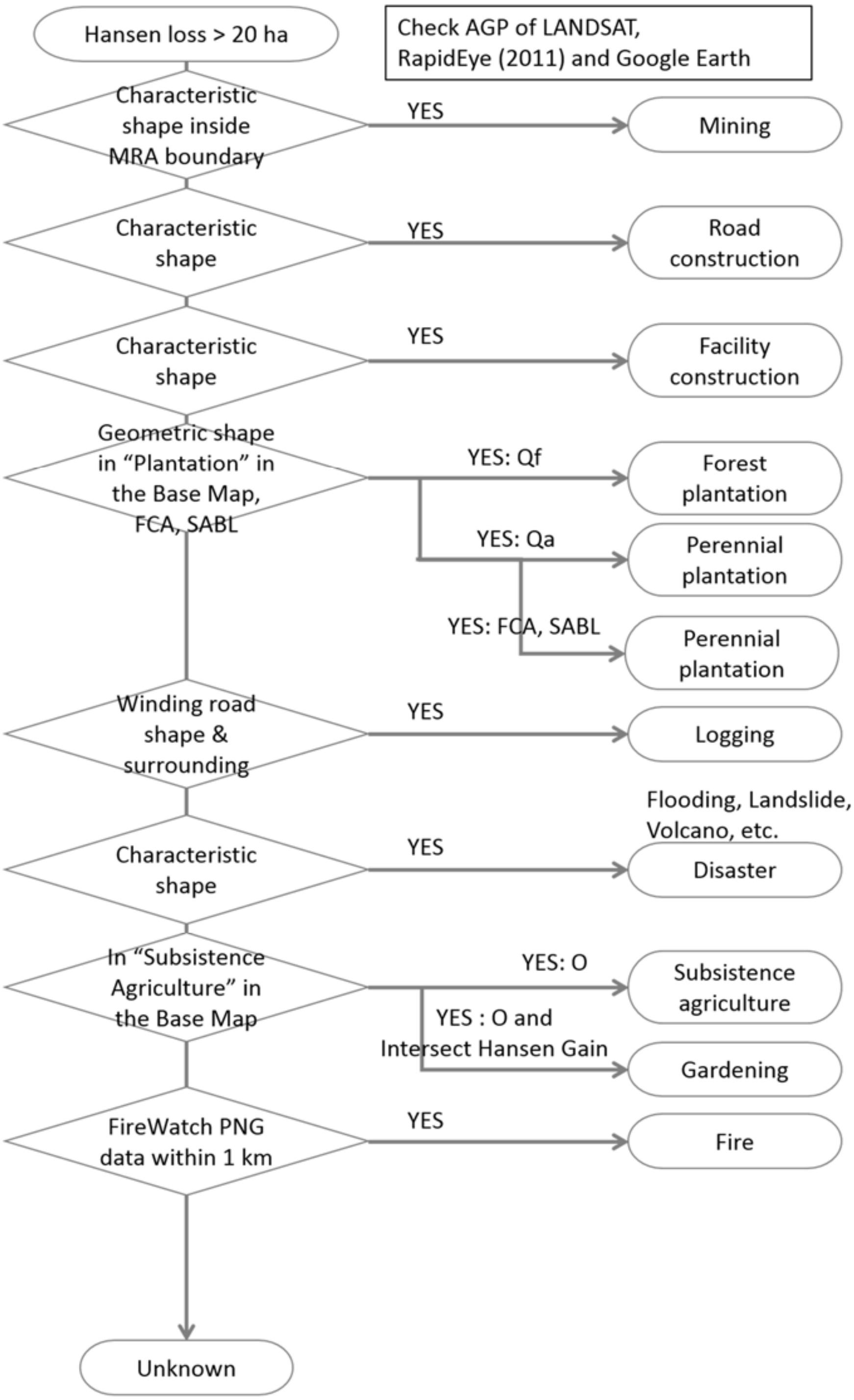
DD drivers for Hansen Loss polygons larger than 20 ha in targeted years 2001-2010 were identified by visual observation utilizing LANDSAT imagery, RapidEye Imagery (2011), and Google Earth.

The drivers were identified using the key-out method according to the rules shown in the flowchart (right). Using this method, drivers are exclusive to each other, and multiple operators will identify the same driver for the same deforestation area.

The flowchart started with drivers that are more obvious and easily identifiable, such as mining activities and plantations, and then progressed to drivers that are more difficult to interpret via satellite imagery, such as fires.

The driver "unknown" was assigned to deforestation areas for which no driver could be identified until the end of the flowchart.

The description of the DD driver (e.g. “Mining”) was added to each FMU of the Forest Base Map, as well as past forest cover maps.

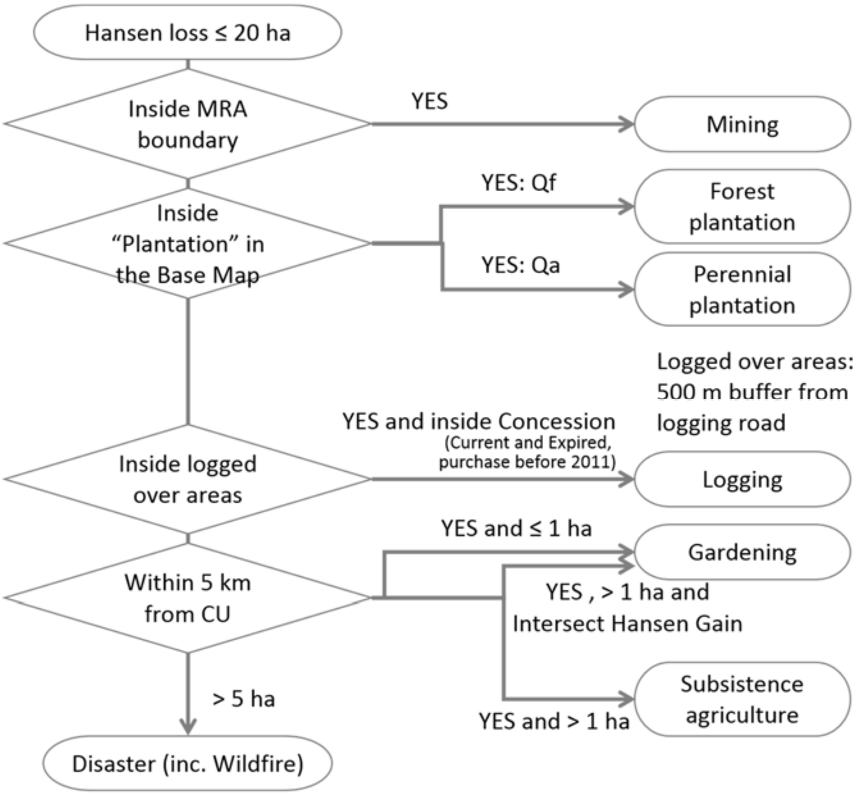


## (b) Hansen Loss polygons 20 ha and smaller

The Hansen Loss polygons 20 ha or smaller in targeted years 2001-2010 were automatically classified to DD driver using GIS data and GIS process.

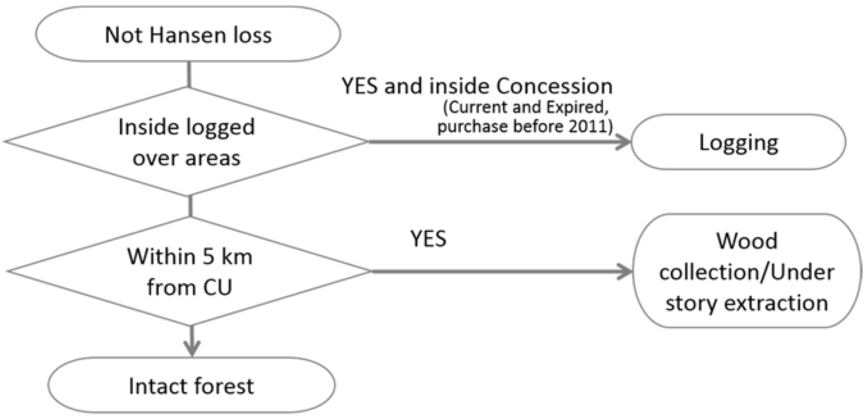
The drivers were identified according to the rules shown in the flowchart (right).

The description of the DD driver (e.g. “Mining”) was then added to each FMU of the Forest Base Map, as well as past forest cover maps. The identification of drivers of Hansen Loss polygons larger than 20 ha (see (a) above) was conducted earlier, chronologically. When a FMU overlapped with 2 or more Hansen Loss polygons, the driver identified and entered earlier was prioritized.




## (c) Driver analysis of FMUs without Hansen Loss polygon overlap

Following the above steps, each remaining FMU polygon that indicated change in LU class/ strata pointing to DD, but without driver information from Hansen Loss, was analyzed according to the flowchart (right), and its driver information was added to FMU directly.




## (d) Analysis of past forest cover maps

For West New Britain (WNB) and West Sepik (WSP) province, driver analysis was conducted on past forest cover maps using the same methodology, but using different datasets.

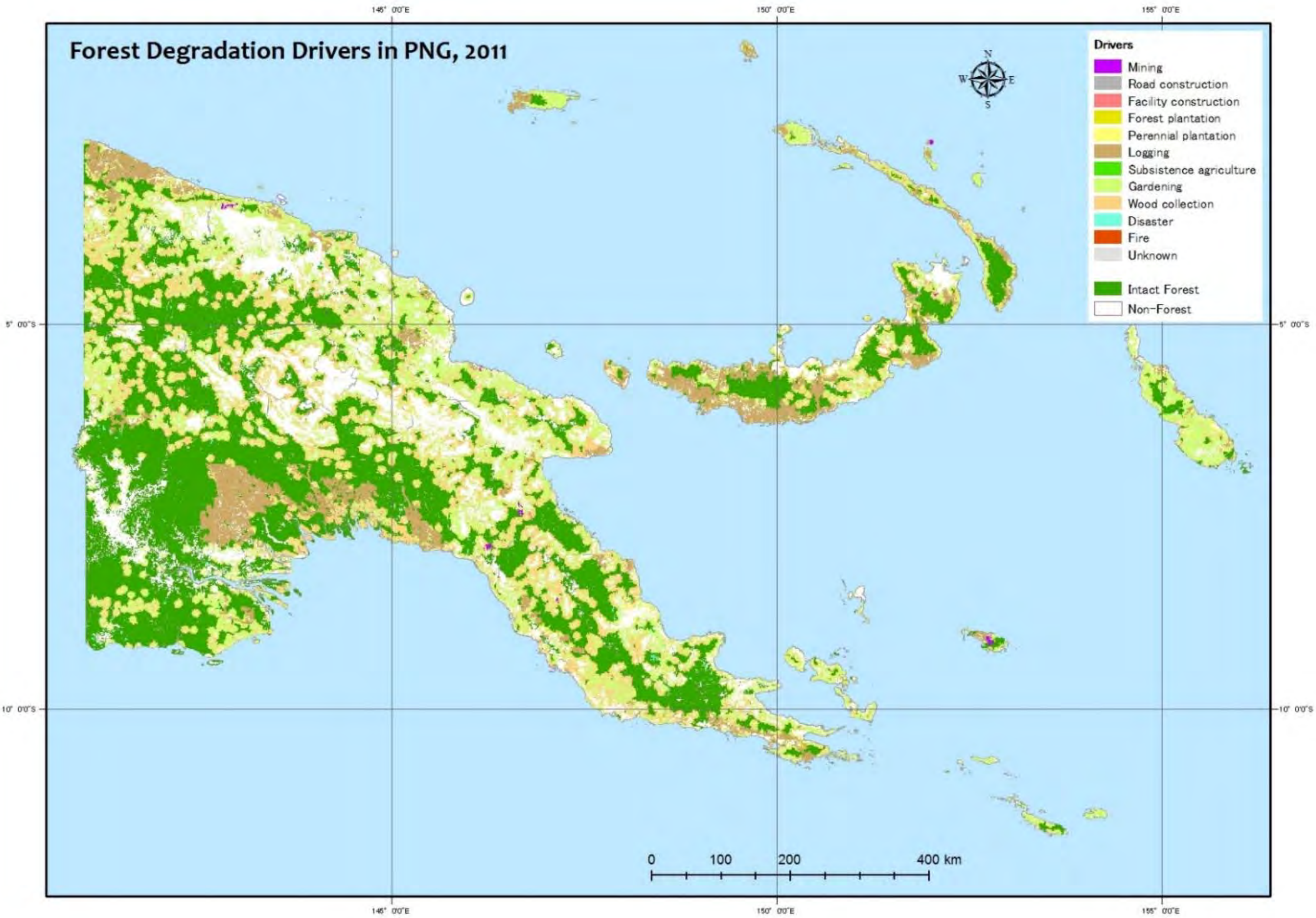
__Data used for the Forest Cover Map 2005__:
Hansen Loss polygon for 2001-2004, logging road data before 2005, concession purchase before 2004, and Qf, Qa and O in the forest cover map 2005 data.

__Data used for the Forest Cover Map 2000__:
Logging road data before 2000 and concession purchase before 1999.

# 5. Outcomes

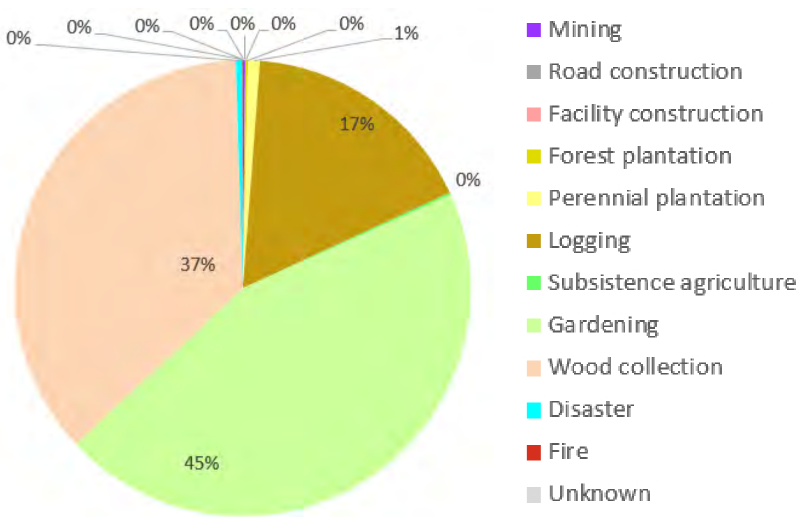
## Forest Degradation Drivers in PNG, 2011

DD drivers in 2011 was mapped across PNG, by entering information on drivers to each FMU of the Forest Base Map. FMUs without degradation are shown as Intact Forest (green) or Non-Forest (white).




**DD drivers in PNG, 2011**

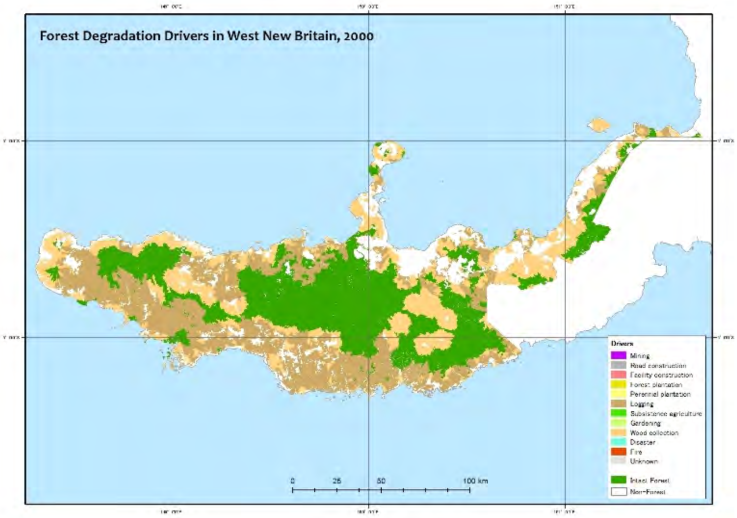
| | Drivers | SUM |
|---|---|---|
| | Mining | 37,262 |
| | Road construction | 2,722 |
| | Facility construction | 1,630 |
| | Forest plantation | 34,225 |
| | Perennial plantation | 175,703 |
| | Logging | 3,512,466 |
| | Subsistence agriculture | 35,869 |
| | Gardening | 9,293,873 |
| | Wood collection | 7,578,478 |
| | Disaster | 90,487 |
| | Fire | 6,542 |
| | Unknown | 2,457 |
| | (Intact Forest) | 16,109,308 |
| | SUM | 36,881,022 |




**Area (ha) and % total area affected by each DD driver, 2011**

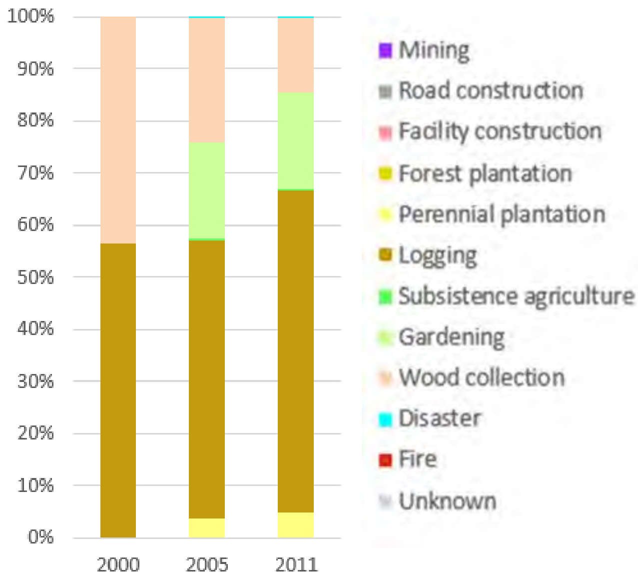
## Forest Degradation Drivers analyzed using past forest cover maps

For WNB and WSP, DD drivers for years 2005 and 2000 were analyzed, by entering information on drivers to each FMU using Forest Cover Map for those years, and compared to DD drivers for 2011.

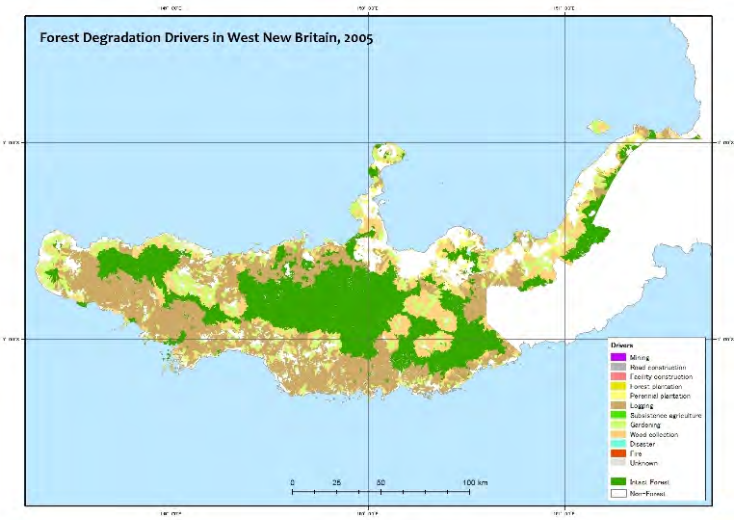



DD drivers in WNB, 2000

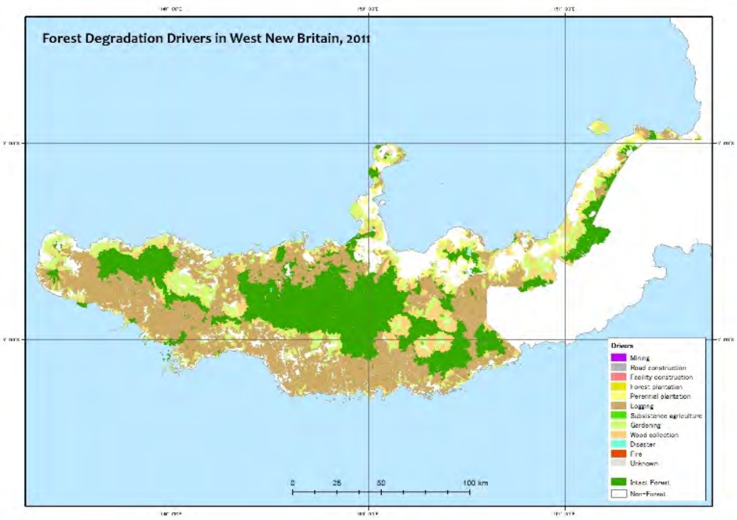
| | Drivers | 2000 | 2005 | 2011 |
|---|---|---|---|---|
| | Mining | - | 0 | 0 |
| | Road construction | - | 0 | 0 |
| | Facility construction | - | 0 | 180 |
| | Forest plantation | - | 0 | 137 |
| | Perennial plantation | - | 39,818 | 54,294 |
| | Logging | 614,318 | 592,924 | 724,572 |
| | Subsistence agriculture | - | 1,862 | 2,003 |
| | Gardening | - | 207,225 | 214,989 |
| | Wood collection | 474,105 | 265,713 | 169,140 |
| | Disaster | - | 1,209 | 1,306 |
| | Fire | - | 0 | 0 |
| | Unknown | - | 0 | 0 |
| | (Intact Forest) | 669,525 | 629,811 | 550,934 |
| | SUM | 1,757,949 | 1,738,561 | 1,717,558 |




Comparison of DD drivers and area affected for WNB: years 2000, 2005 and 2011




DD drivers in WNB, 2005




DD drivers in WNB, 2011

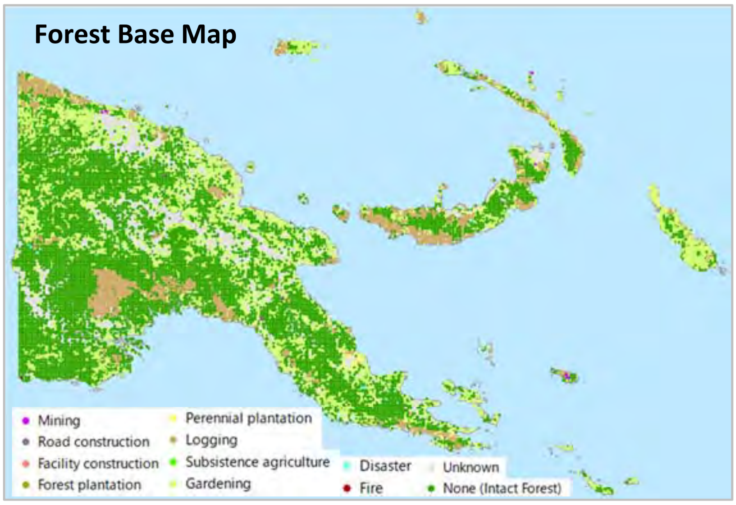
# 6. Assessment of DD Driver Analysis using Collect Earth Data

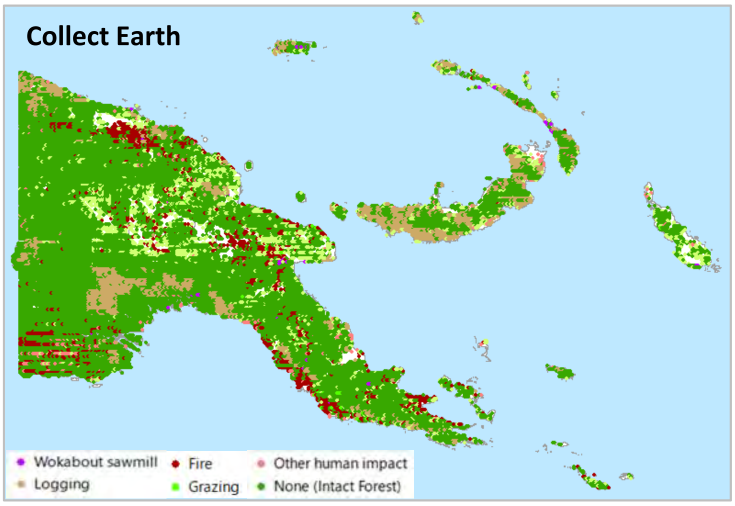
## Comparison of DD drivers identified in the Forest Base Map and Collect Earth

To assess the effectiveness of DD Driver analysis developed and conducted by the Project team, DD drivers identified on the Forest Base Map were compared with "impact type" identified by Collect Earth, by overlaying with Collect Earth plots.

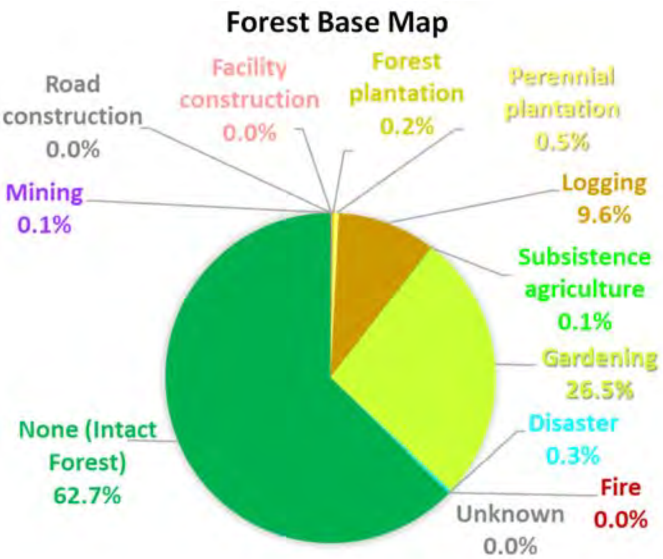
Notes on methodology:

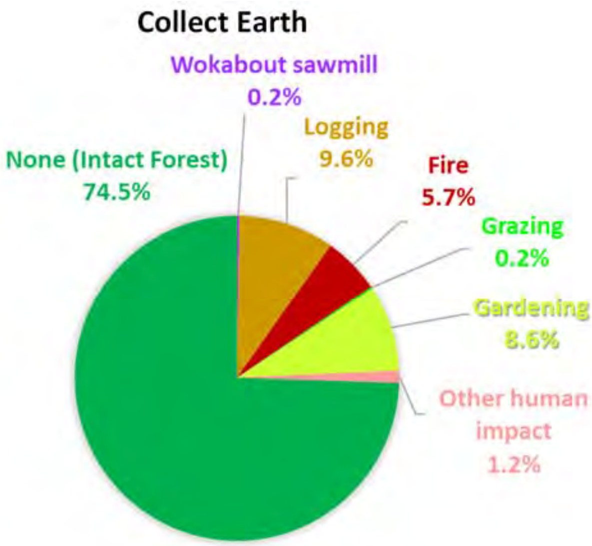
- Data from the revised forest cover map 2011 were used for WSP and WNB, and the Forest Base Map for other Provinces (hereinafter collectively referred to as "Forest Base Map").
- The comparison was conducted on geographical plots about which both Forest Base Map and Collect Earth data existed, that is, 25,122 plots out of 25,279 plots of Collect Earth data for PNG. The process further concentrated on the targeted land use class, Forest, for which 19,743 plots existed in the Forest Base Map and 19,292 plots in Collect Earth.
- In the full DD Driver analysis, areas within 5 km from Census Unit (CU) were marked as areas possibly affected by wood collection. However, for this assessment, wood collection is included into intact forest since impact of disturbance is presumed to be limited.
- Impact type in the Collect Earth data is determined by interpretation of satellite imagery. The Forest Base Map determines some drivers, such as Gardening, by inference (e.g. proximity to settlements), not actual image interpretation.



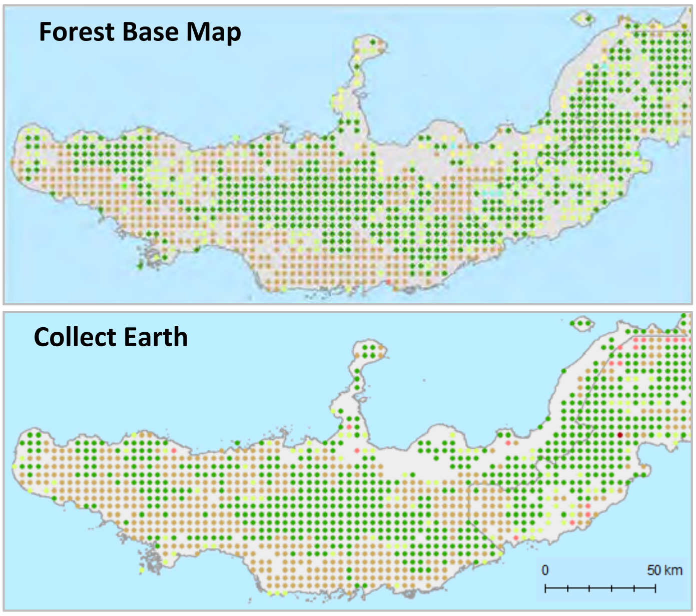




**DD Driver and impact type distribution: PNG**

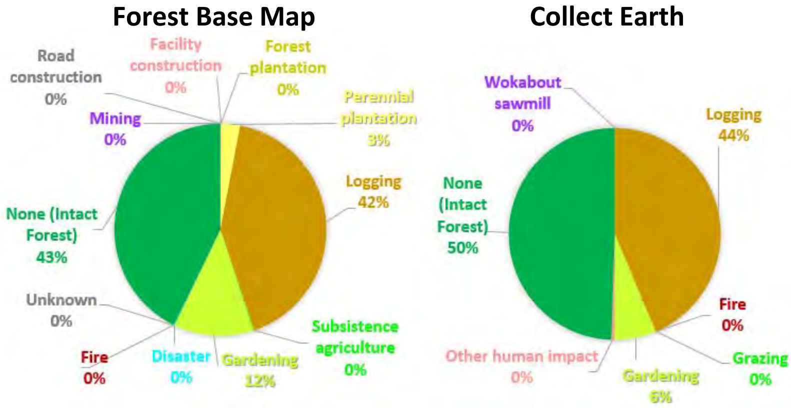



**DD Driver and impact type composition: PNG**




**DD Driver and impact type distribution: WNB**

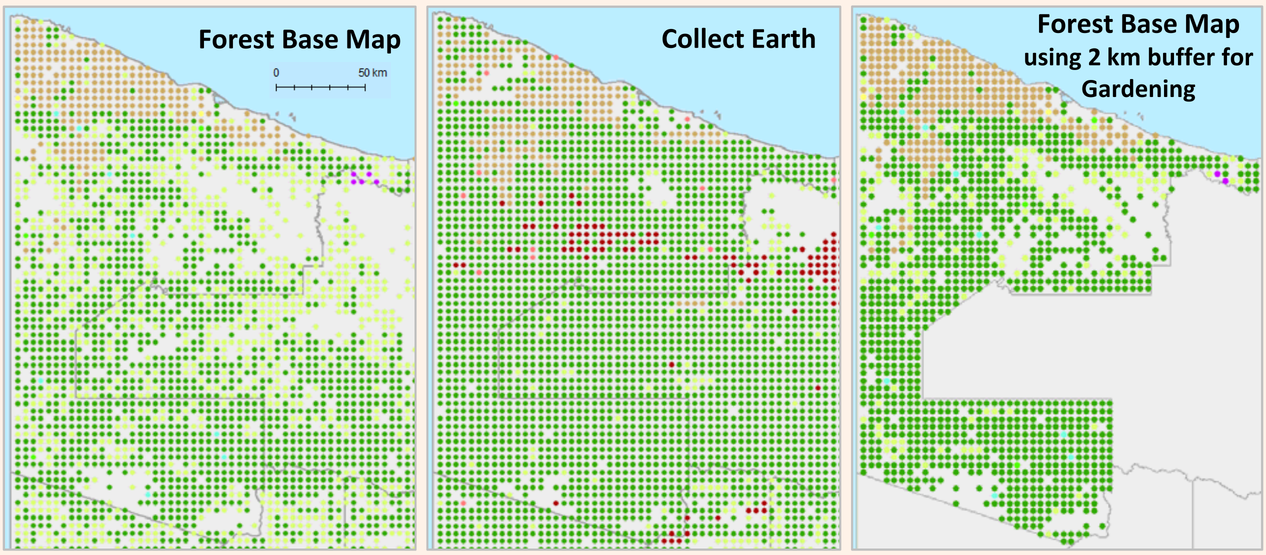



**DD Driver and impact type composition: WNB**

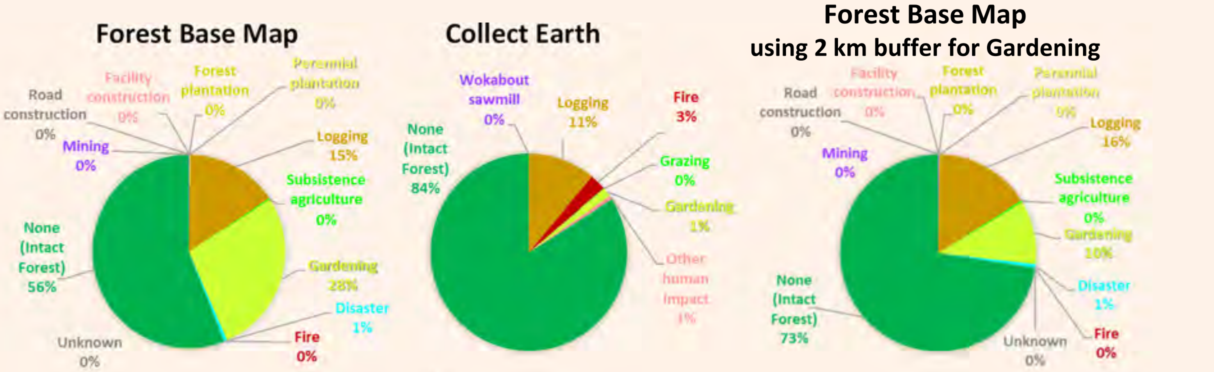
## Box: Trial-basis adjustment in Garden driver parameters using WSP data

The cause of the prevalence of areas affected by Gardening as a DD driver in the Forest Base Map, immediately noticeable upon comparison with Collect Earth data, was investigated through a trial-basis adjustment of buffer distance used in the detection of the Gardening driver.

Under the original methodology, Hansen Loss polygons 20 ha or smaller and within 5 km from Census Unit was assigned to the Gardening driver, drawing from studies and discussion on general scale of degradation (see section 2). However, on a trial basis, the buffer distance of 2 km was applied to WSP data.




**DD Driver and impact type distribution: WSP**




**DD Driver and impact type composition: WSP**

# 7. Discussion and Lessons Learned

The Project team designed a methodology of DD Driver analysis that makes possible a wall-to-wall mapping of the drivers of deforestation and forest disturbance in PNG. **This methodology maps DD drivers to FMU and allows the monitoring of the dynamic state of forests.**

In the methodology described in this Analytical Report, forest disturbance is recorded either as present or absent in an FMU, a binary value (i.e. either black and white, and no shades of grey). If desired, it is possible to capture the level of disturbance (i.e. the shades of grey) by analyzing the ratio of Hansen Loss areas in an FMU in future analyses.

**The methodology can be applied to past forest cover map data, but care must be taken when comparing across years and datasets.** As shown in the analysis of past Forest Cover Maps of WNB and WSP, care should be taken in noting and accounting for limitations in data in the interpretation process. Data limitations may translate to fewer types of identifiable DD drivers, and thus the absence of certain drivers purely as an artefact of methodology.

Overall the results of DD Driver analysis carried out by the Project team and impact data provided by Collect Earth (CE) corroborated each other. **Notable characteristics of the Forest Base Map that may be better understood through the comparative analysis are:**

- The ratio of area classified as intact (primary) forest, versus total area, is smaller in the Forest Base Map, compared to CE data. This is due to **the wall-to-wall and binary nature of the Forest Base Map dataset**; FMUs containing any amount of forest loss was classified as degraded area.
- Logging as a DD driver accounted for about the same ratio of forest degradation in both datasets. Fire accounts for a much smaller amount of forest degradation in the Forest Base Map compared to CE; due to the difficulty in identifying the Fire driver in the methodology used by the Project team.
- Gardening was identified as a much larger DD driver in the Forest Base Map, compared to CE data. This is because small patches of Hansen Loss areas, which were not classified to preceding drivers in the methodology flowchart, and located within 5 km from a Census Unit (CU), were classified to Gardening. Due to the wall-to-wall nature of the Forest Base Map, an FMU containing even small patches of disturbed area by Gardening is indicated as non-intact, non-primary forest in the DD Driver analysis. It should be understood that **FMUs marked as 'disturbed by gardening' in the Forest Base Map is not an area that is entirely turned into a garden, but rather, a forest area that contains disturbance by gardening activities**.
- Due to concerns that the initial methodology may have led to over-emphasis of Gardening as a DD driver, the Project team experimented with changing the buffer distance from 5 km to 2 km from a CU. Even with distance set to 2km, Gardening still shows up as a driver of degradation over a much larger area, compared to CE data; the key lesson learned is that **care should be taken when using buffer analysis**. It should be noted, however, that there is also a possibility that CE data under-estimates Gardening as a driver, and that further analyses are necessary to solve the discrepancy.
- In such further analyses, it is also possible to adjust buffer distance by population size, region, landform, or other factors that may affect migration distance. To determine the best methodology for detecting Gardening as a DD driver, a trial-and-verification process, where detection methods are verified by manual identification of Gardening based forest degradation for sample areas, may need to be conducted in the future.

- The Project team utilized Hansen Loss data in the analysis of DD drivers. This led to more areas classified as disturbed in comparison with other datasets such as Collect Earth, since Hansen Loss also captures naturally occurring gaps, such as a fallen tree caused by wind.

**An understanding of these characteristics of data and methodology is necessary for the appropriate use of the Forest Base Map.** With such understanding, the Forest Base Map is already useful in identifying a mass of intact (primary) forest, estimating timber volume based on type of disturbance, and obtaining other meaningful information for forest management and the planning of logging activities. The DD Driver analysis was only a trial assessment preceding a full quantitative assessment; discussions and lessons derived are hoped to contribute to the development of better methods of forest resource data use.

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JICA-PNGFA Forestry Project 2014-2019 – Analytical Report No.2

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# Analysis of Future Forest Change Modeling in Papua New Guinea

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Introduction

PNG Forest Authority (PNGFA) developed forest cover map in 2000, 2005, 2011 and 2015 utilizing archives of LANDSAT imageries and time series of deforestation data published by Maryland University. For the development of the maps, PNGFA analyzed drivers of deforestation / forest degradation, so that deforested area can be clarified with its driver. It is possible to simulate deforestation probability refined by driver information analyzing the time series of maps. Because the fate of carbon status after deforestation is depending on the drivers, simulation of deforestation with its drivers is useful information to estimate carbon stock in the future.

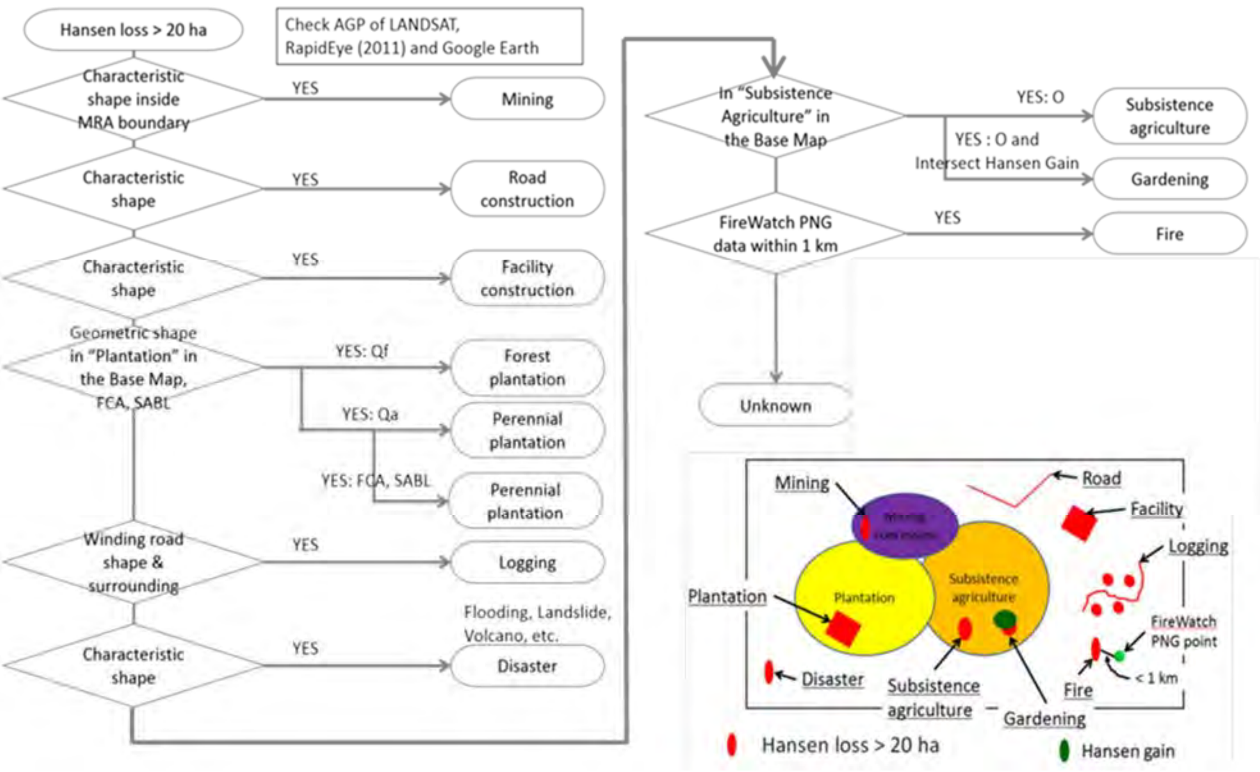


*Figure 1: An example of flow chart of DFFD driver analysis*

## 2. General Conditions

| | |
|---|---|
| Target Area: | West New Britain Province, Papua New Guinea |
| Area Size: | 2,034,000 ha |
| Population: | 210,000 (2008) |
| Applied Maps: | Forest Cover Map 2005, 2011, 2015 developed by PNGFA |
| Tool: | Land Change Modeler for ArcGIS 2.0 (Clark University) |

## 3. Case Studies

### 1) Simulation on effects of enlargement of plantation and agricultural field

Land Change Modeler enables estimation of the drivers for deforestation through comparison of land cover at two points in time and enables simulation of a case in which deforestation would continue at the current pace (business-as-usual (BAU) case). In this section, the flow of the simulation on effects of enlargement of plantation and agricultural field around Kimbe, West New Britain Province, is described. An area (of approx. 4,870 km2) in the pilot province of West New Britain Province, where the developments of plantations along with population growth have been causing rapid deforestation, was used in the simulation. A 2011 Forest Base Map and a 2014 forest cover map, which was created by comparing the Forest Base Map with a LANDSAT Greenest Pixel and a corrected base map of the changes detected in the comparison, were used as the land cover maps of two points in time (Figure 2).

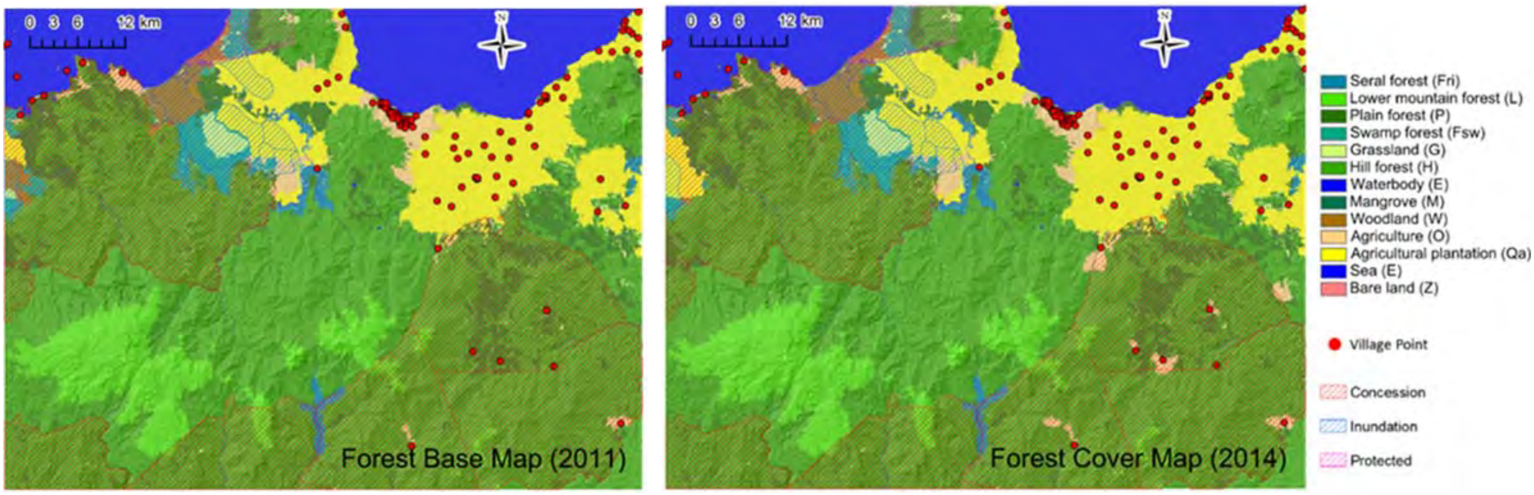


*Figure 2: Forest maps of two points used in simulation with Land Change Modeler*

In the beginning, the maps of 2011 and 2014 were compared to elucidate what types of land cover increased and what types of land cover decreased between 2011 and 2014 (Figure 3). The comparison revealed that the areas of agricultural plantations (Qa) and subsistence farmland (O) had increased and the areas of lowland forest (P), hill forest (H), wetland forest (Fsw), open woodland (W) and grassland (G) had decreased between 2011 and 2014. Therefore, the development of agricultural plantations and subsistence farmland was selected as the driver of deforestation and their distribution in the future (in the year 2030) was estimated. The elevation (SRTM, resolution of 30 m), slope, distance from the sea, population density (Kernel analysis), boundaries of reserves, wetland and active concession areas and the land cover boundaries in 2011 were used as the model parameters.

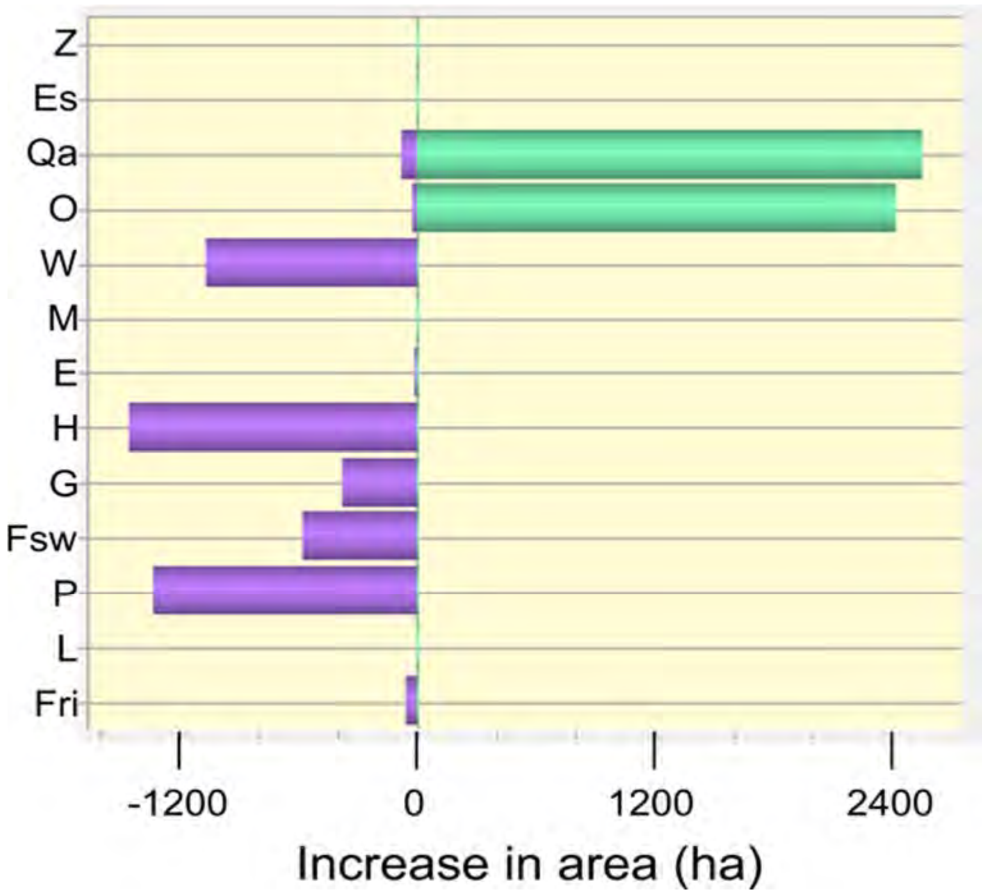


*Figure 3: Changes in the land cover between the two points in time*

The accuracy of the model of agricultural plantations was estimated at 80.83%. Because this figure is larger than the threshold for the sufficient accuracy of 80%, this model is considered a valid model (Table 1). The boundaries of inundation area are the parameters that have the largest influence on the accuracy of the model, followed by, in descending order, the following: the land cover boundaries of 2011 (base map), protected area boundaries, active concession boundaries, elevation (SRTM, resolution of 30 m), distance from the sea, population density and slope.

*Table 1: Influence of parameter with on accuracy of model for agricultural plantation*

| Model | Accuracy (%) | Skill measure | Influence order |
|---|---|---|---|
| With all variables | 80.83 | 0.787 | N/A |
| Without SRTM_30 m | 69.44 | 0.6605 | 5 |
| Without slope | 78.38 | 0.7598 | 8 (Least influential) |
| Without distance from sea | 69.69 | 0.6632 | 6 |
| Without population density | 75.02 | 0.7224 | 7 |
| Without protected area | 46.72 | 0.408 | 3 |
| Without inundation area | 40.69 | 0.341 | 1 (Most influential) |
| Without concession area | 65.03 | 0.6115 | 4 |
| Without base map | 43.97 | 0.3775 | 2 |

A forest cover map of 2030 was created in the simulation using these models (Figure 4). The map predicts increases in the areas of agricultural plantations and subsistence farmland by 17.7% and 124.9%, respectively, and decreases in the areas of lowland forest, hill forest, wetland forest, open woodland and grassland by 16.7%, 2.8%, 31.8%, 64.6% and 26.6%, respectively (Table 2). This map is considered representative of the land cover pattern in 2030 if the current trend in deforestation and forest degradation (BAU) continues till 2030.

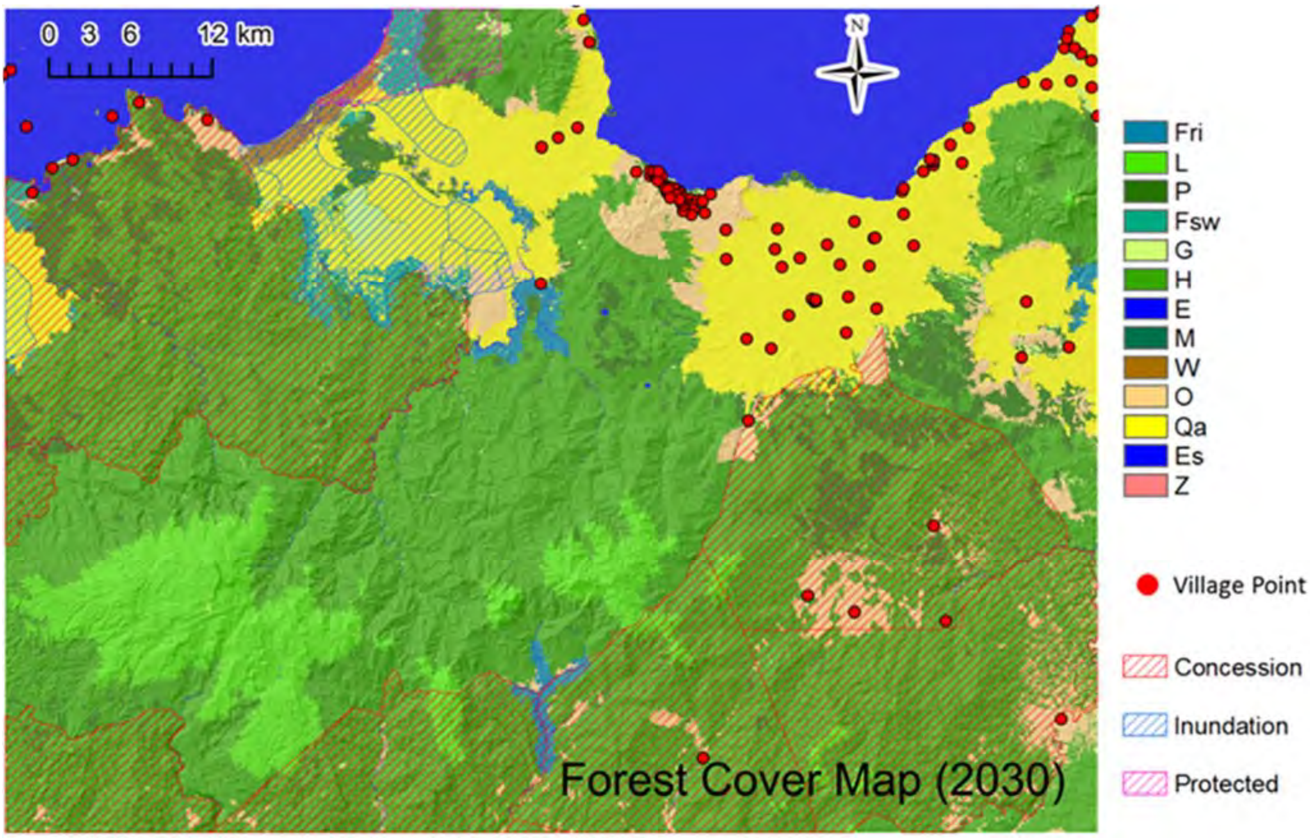


*Figure 4: Forest cover map of 2030 simulated with Land Change Modeler*

*Table 2: Influence of parameter with accuracy of model for subsistence farmland*

| Land cover | Area 2011 (ha) | Area 2014 (ha) | Area 2030 (ha) | Change in area comparing 2014 and 2030 (%) |
|---|---|---|---|---|
| P | 39,564 | 38,232 | 31,848 | -16.7 |
| H | 271,024 | 269,568 | 261,913 | -2.8 |
| Fri | 4,131 | 4,070 | 4,070 | 0 |
| Fsw | 8,373 | 7,791 | 5,314 | -31.8 |
| W | 6,010 | 4,942 | 1,749 | -64.6 |
| L | 32,018 | 32,018 | 32,018 | 0 |
| M | 108 | 108 | 108 | 0 |
| G | 5,879 | 5,503 | 4,039 | -26.6 |
| Z | 51 | 51 | 51 | 0 |
| E | 1,505 | 1,497 | 1,497 | 0 |
| Es | 60,864 | 60,864 | 60,864 | 0 |
| Qa | 51,572 | 54,054 | 63,606 | 17.7 |
| O | 6,907 | 9,307 | 20,930 | 124.9 |

The biomass of the vegetation in the area concerned was estimated by multiplying the area of each land cover type on the map by the default factors of IPCC (Table 3). All the agricultural plantations in this area were assumed to be oil palm plantations. The biomass of the vegetation in this area was estimated to decrease by 4.1 Mt in the period between 2014 and 2030. This figure corresponds to 7.5 Mt $CO_2$-eq and, thus, a loss of approx. US$ 37 million, on the belief that 1t $CO_2$-eq is worth US$ 5.

*Table 3: Comparison between the biomass in 2014 and the estimated biomass in 2030*

| Land cover | Biomass 2014 (Mt) | Biomass 2030 (Mt) | Change in biomass comparing 2014 and 2030 (Mt) |
|---|---|---|---|
| P | 11.5 | 9.6 | -1.9 |
| H | 80.9 | 78.6 | -2.3 |
| Fri | 1.2 | 1.2 | 0 |
| Fsw | 2.3 | 1.6 | -0.7 |
| W | 0.6 | 0.2 | -0.4 |
| L | 4.5 | 4.5 | 0 |
| M | 0 | 0 | 0 |
| G | 0 | 0 | 0 |
| Z | 0 | 0 | 0 |
| E | 0 | 0 | 0 |
| Es | 0 | 0 | 0 |
| Qa | 7.4 | 8.7 | 1.3 |
| O | 0 | 0 | 0 |
| Total | 108.4 | 104.3 | -4.1 |

The area of agricultural plantation is expected to increase by 9,552 ha between 2014 and 2030. If this area is assumed to increase at a constant rate in this period, the cumulative area increase will be 81,192 ha × year. If the yield of palm oil per unit area is assumed at 3.74 t $ha^{-1}$ $year^{-1}$ ([1]) and its price is assumed at US$ 562 $t^{-1}$ ([2]), the revenue from the sales of palm oil is expected to increase by US$ 170 million in this period. The total area of lowland and hill forests is expected to decrease by 14,040 ha in the same period. If this area is assumed to decrease at a constant rate, the cumulative area loss will be 119,348 ha × year. If the harvesting period and price per unit volume of timber are assumed for 35 years at US$ $142m^{-3}$ ([3]), respectively, a loss of approx. US$ 17 million is expected from the area loss. In conclusion, an increase in the revenue of US$ 116 million is expected from the deforestation and forest degradation on the BAU basis in the period between 2014 and 2030 (Table 4).

An estimation similar to the one mentioned in the preceding paragraph was conducted in the cases in which 1) only open woodland and grassland could be converted to agricultural plantations and 2) only grassland could be converted to agricultural plantations. Increases in the revenue of US$ 85.2 million and US$ 28 million in the period between 2014 and 2030 were expected in cases 1) and 2), respectively. As restriction on the changes in land cover increases, the increase in the revenue from the changes decreases. The policy of the government on forest management will depend on whether it can find value in conserving the forests themselves without deforestation and forest degradation.

*Table 4: Comparison of increased revenue between 2014 and 2030 with scenarios*

| | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Net forest loss | 19,711 ha | 14,816 ha | 11,623 ha |
| Net P&H loss | 14,040 ha | 11,623 ha | 11,623 ha |
| Net plantation gain | 9,552 ha | 4,657 ha | 1,464 ha |
| Price of increased carbon due to plantation development | -37.3 mil USD | 2.00 mil USD | 1.82 mil USD |
| Price of palm oil from newly developed plantation | 171 mil USD | 83.2 mil USD | 26.2 mil USD |
| Price of increased timber due to developing oil palm plantations | -16.9 mil USD | 0 mil USD | 0 mil USD |
| Net increase in profit | 116 mil USD | 85.2 mil USD | 28.0 mil USD |

*Note) Scenario 1: BAU; Scenario 2: Newly developing plantation is only allowed in W and G after 2014, increasing in subsistence agriculture is BAU; Scenario 3: Newly developing plantation is only allowed in G after 2014, increasing in subsistence agriculture is BAU*

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[1] http://www.soyatech.com/Palm_Oil_Facts.htm (accessed on 03 April 2017)
[2] http://www.indexmundi.com/commodities/?commodity=palm-oil&months =300 (accessed on 09 June 2016)
[3] https://www.wageningenur.nl/upload_mm/5/c/1/b0b121e8-469b-4e65-9689-c4e6fd7c8d1e_WOt-technical%20report%2010%20webversie.pdf (accessed on 03 April 2017)

## 2) Simulation on distribution of deforestation and forest degradation

In this section, the flow of the simulation on distribution of deforestation and forest degradation in West New Britain Province is described.

The whole area of the pilot province of West New Britain Province was used in the simulation. A 2011 Forest Base Map and a 2005 forest cover map were used as the land cover maps of two points in time. Information of drivers of forest degradation and deforestation were attached with each polygon in each map in advance. In this analysis, (1) forest land cover with drivers such as facility construction, road construction, forest plantation, perennial plantation, subsistence agriculture, "gardening" and selective logging was assumed as "degraded forest" and (2) forest land cover with drivers such as disasters and wood collection or without any drivers was assumed as "non-degraded forest" (Figure 5).

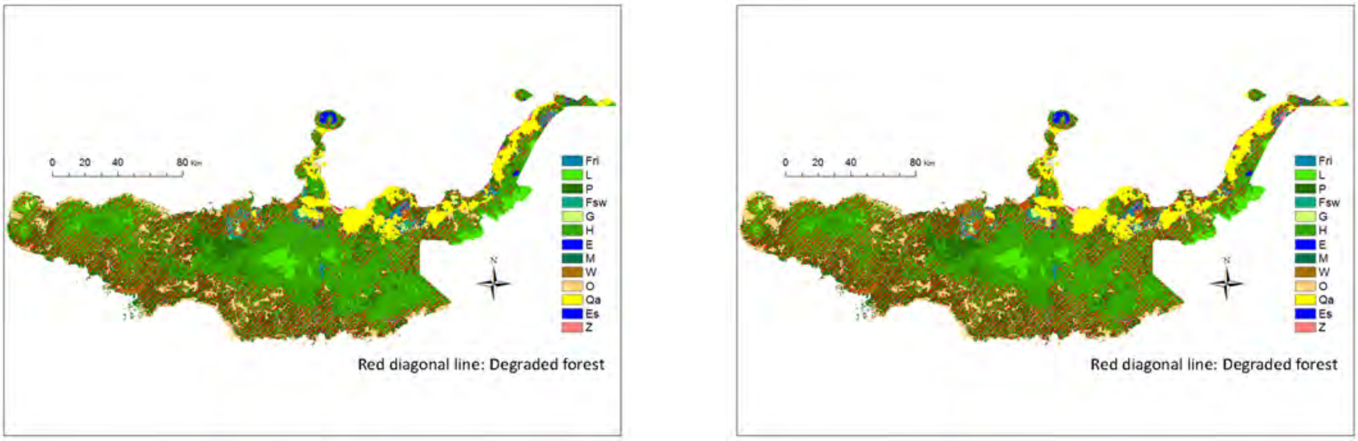


*Figure 5: Forest Cover Map in 2005 (left) and Forest Base Map in 2011 (right)*

In the beginning, the maps of 2005 and 2011 were compared to elucidate what types of land cover increased and what types of land cover decreased between 2005 and 2011. The comparison revealed that main changes in land cover were degradation of hill forest (H), plain forest (P) and woodland (W) and conversion of P into perennial plantation (Qa) and subsistence agriculture field (O) (Table 5). These land cover changes were put in a model to estimate land cover in 2026. The following were as the model parameters: elevation (SRTM, resolution of 30 m), slope, distance from the sea, distance from rivers, distance from forest edge, distance from forest/perennial plantation, distance from subsistence agriculture field, distance from degraded forest (as of 2005), population density (Kernel analysis), boundaries of reserves, wetland, active concession areas (as of 2005) and forest types.

*Table 5: Five major land cover changes between 2005 and 2011 in West New Britain*

| Rank | Land cover in year 2005 | Land cover in year 2011 | Area (ha) |
|---|---|---|---|
| 1 | H | H (Degraded) | 142,000 |
| 2 | P | P (Degraded) | 41,000 |
| 3 | W | W (Degraded) | 4,900 |
| 4 | P (Degraded) | Qa | 7,000 |
| 5 | P (Degraded) | O | 4,800 |

The accuracy of the model was estimated at 82.31%. Because this figure is larger than the threshold for sufficient accuracy of 80%, this model is considered a valid model (Table 6). The forest types are the parameters that have the largest influence on the accuracy of the model, followed by, in descending order, the following: distance from forest/perennial plantation, distance from subsistence agriculture field, distance from forest edge, active concession areas and distance from road.

*Table 6: Influence that each parameter has on the accuracy of the model*

| Model | Accuracy (%) | Skill measure | Influence order |
|---|---|---|---|
| With all variables | 82.31 | 0.801 | N/A |
| Population density | 82.29 | 0.8007 | 15 |
| Active concession area as of 2005 | 80.04 | 0.7755 | 6 |
| Distance from Non-forest land cover | 74.88 | 0.7174 | 5 |
| Distance from rivers | 81.82 | 0.7955 | 12 |
| Distance from roads as of 2011 | 80.37 | 0.7792 | 7 |
| Distance from sea | 82.26 | 0.8005 | 13 |
| Inundation area | 81.71 | 0.7943 | 11 |
| Slope | 82.31 | 0.801 | 16 (least influential) |
| Altitude | 82.29 | 0.8007 | 14 |
| Distance from CU points | 81.27 | 0.7893 | 10 |
| Distance from protected area | 80.51 | 0.7807 | 8 |
| Distance from "plantation" | 70.29 | 0.6657 | 3 |
| Distance from "Agricultural land cover" | 72.02 | 0.6852 | 4 |
| Distance from Degraded forest | 49.87 | 0.436 | 2 |
| Distance from logged-over area | 80.81 | 0.7841 | 9 |
| Forest type | 48.37 | 0.4192 | 1 (most influential) |

A forest cover map of 2026 was created in the simulation using this model (Figure 6). The map predicts increases in the areas of degraded H, degraded P and degraded W by 33.8%, 7.3% and 47.7%, respectively, and decreases in the areas of non-degraded H, non-degraded P and non-degraded W by 51.7%, 54.0% and 55.4%, respectively (Table 7). This map is considered representative of the land cover pattern in 2026 if the current trend in deforestation and forest degradation (BAU) continues till 2026.

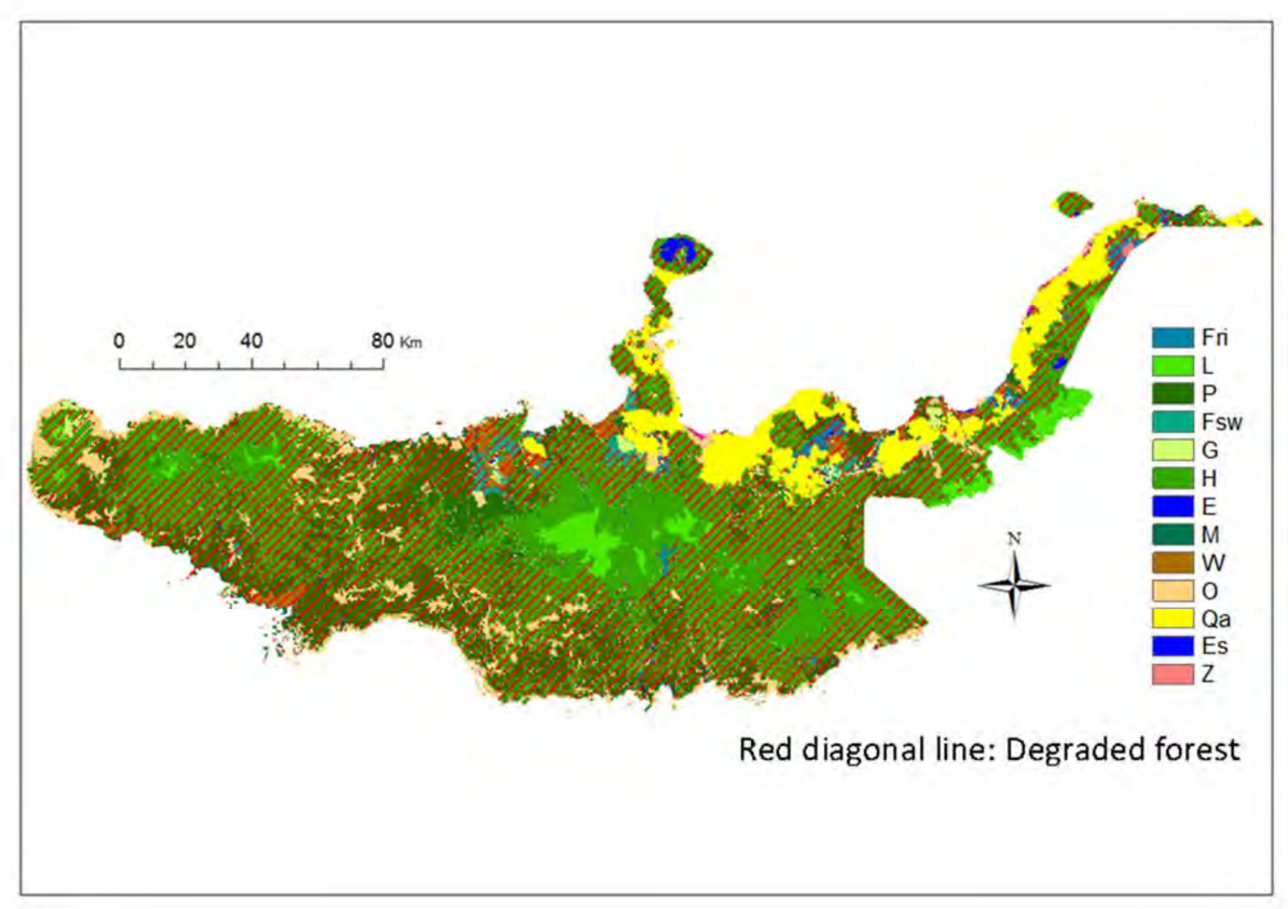


*Figure 6: Simulated Forest cover map of 2026*

*Table 7: Changes in areas of each land cover*

| Change in area of Land cover other than degraded forest | | | |
|---|---|---|---|
| Land cover | Area in year 2011 (ha) | Aria in year 2026 (ha) | Change ratio |
| B | 250 | 249 | -0.40% |
| Fri | 5000 | 5004 | 0.10% |
| Fsw | 5587 | 5584 | -0.10% |
| H | 414485 | 200291 | -51.70% |
| L | 62089 | 62109 | 0.00% |
| M | 4910 | 4905 | -0.10% |
| P | 103129 | 47430 | -54.00% |
| Sc | 112 | 113 | 0.50% |
| W | 16732 | 7458 | -55.40% |
| E+Es | 14431 | 14433 | 0.00% |
| G | 30721 | 30723 | 0.00% |
| O | 122038 | 135033 | 10.60% |
| Qa | 147766 | 160785 | 8.80% |
| U | 651 | 652 | 0.20% |
| Z | 1137 | 1135 | -0.10% |

| Change in area of degraded forest | | | |
|---|---|---|---|
| Land cover | Area in year 2011 (ha) | Aria in year 2026 (ha) | Change ratio |
| B_deg | 861 | 863 | 0.20% |
| Fri_deg | 15366 | 15361 | 0.00% |
| Fsw_deg | 18622 | 18606 | -0.10% |
| H_deg | 633555 | 847772 | 33.80% |
| L_deg | 4224 | 4224 | 0.00% |
| M_deg | 4643 | 4642 | 0.00% |
| P_deg | 408523 | 438148 | 7.30% |
| Sc_deg | 0 | 0 | 0.00% |
| W_deg | 19471 | 28760 | 47.70% |

This indicates that areas of non-degraded forest would decrease from about 612,000 ha in 2011 to 333,000 ha in 2026 and areas of degraded forest would increase from about 1,105,000 ha in 2011 to 1,358,000 ha in 2026. Pearson *et al.* (2014) suggests that carbon emission from a unit area caused by forest degradation reaches 12% of that of deforestation. About 165,000 ha of areas are simulated as experiencing forest degradation by logging between 2011 and 2026. Assuming average forest carbon stock of 200 Mg C $ha^{-1}$, carbon emission from the forest degradation by logging during this period is estimated as the following:

$$165{,}000 \times 200 \times 0.12 = 396{,}000 \text{ (Mg C)}$$

Further, assuming 1 t $CO_2$-eq = 5 USD, the estimated value of carbon emitted due to forest degradation by logging activity between 2011 and 2026 in West New Britain Province is estimated as the following:

$$396{,}000 \times (44/12) \times 5 = 7{,}260{,}000 \text{ (USD)}$$

## 3) Simulation on possible location of future deforestation

To predict exact location of deforestation in the future is very difficult because it is depending not only on geospatial conditions but also on social circumstances, such as traditional practices of the various habitats, change in the policies, activities of private companies, etc. However, locations with high probability of deforestation can be predicted because lands suitable for human activities tend to distribute in areas with some conditions, such as flat, warm, close to roads, close to villages, etc. This kind of information can be used for choosing area for protection, for example. In this section, conditions which affect deforestation are estimated and probability of deforestation in each location is predicted in the West New Britain Province, Papua New Guinea.

The Forest cover maps in Year 2005, 2011 and 2015 were used for the analysis. Firstly, deforested areas were identified with each driver of the deforestation comparing maps of two time points, namely Year 2005 and 2011 and Year 2005 and 2015. Then, two maps were obtained; containing forest cover information in Year 2011 with deforestation information during Year 2005 – 2011 and forest cover information in Year 2015 with deforestation information during Year 2005 – 2015, respectively (Figure 7 & Figure 8). These two maps were utilized for the analysis.

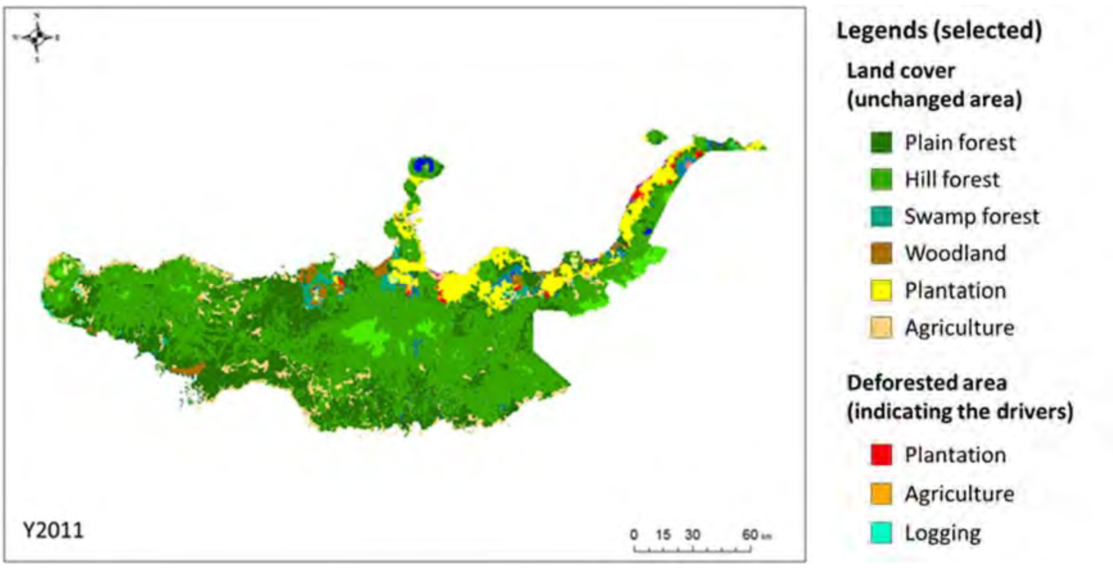


*Figure 7: Forest Base Map with deforestation info. in Y2011*

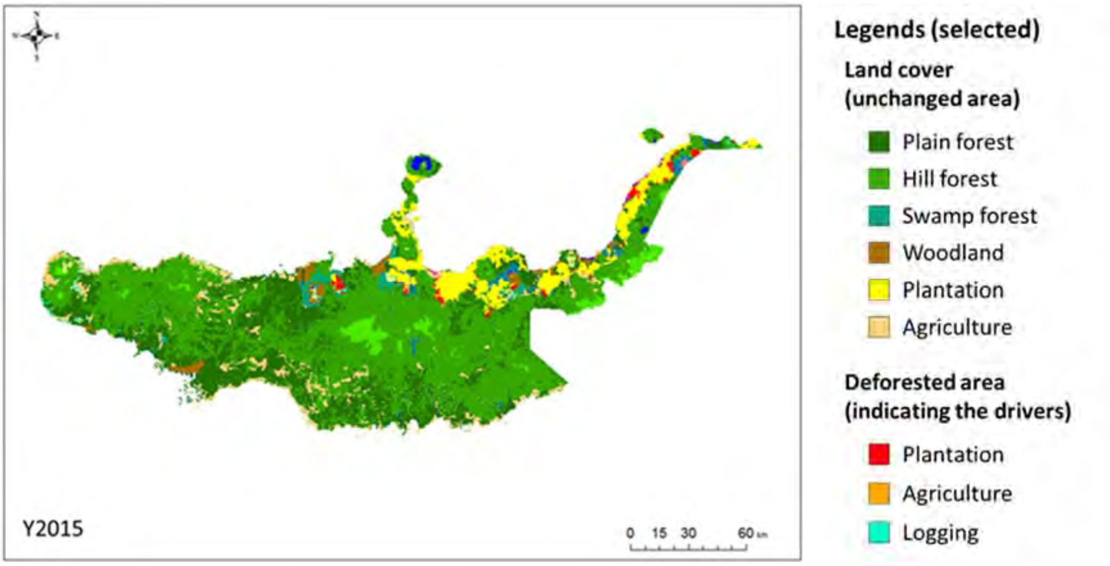


*Figure 8: Forest Cover Map with deforestation info. in Y2015*

The deforestation rates between Year 2005 and 2011 and Year 2005 and 2011 were 1.08% and 1.42%, respectively. The deforestation was caused by various drivers such as agriculture, logging, wood collection, plantation, road construction and disaster. Among the drivers, plantation, agriculture and logging were the major drivers of the deforestation. The deforestation was occurring mainly in four types of forest, namely hill forest, plain forest, woodland and swamp forest. In this analysis, only land transitions sized larger than 200 ha in whole West New Britain Province were simulated. The simulated transitions are listed in Table 8.

*Table 8: Seven major types of deforestation between 2011 and 2015 in West New Britain*

| Rank | Land cover in year 2011 | Land cover in year 2015 | Area (ha) |
|---|---|---|---|
| 1 | Plain forest | Deforested (Plantation) | 1,813 |
| 2 | Hill forest | Deforested (Plantation) | 1,800 |
| 3 | Woodland | Deforested (Plantation) | 1,331 |
| 4 | Swamp forest | Deforested (Logging) | 435 |
| 5 | Plain forest | Deforested (Logging) | 310 |
| 6 | Hill forest | Deforested (Agriculture) | 294 |
| 7 | Hill forest | Deforested (Logging) | 255 |

As the independent valuables for establishing a model to predict land cover change potential, 17 kinds of geospatial data stored in the PNG-FRIMS were employed. The list of the valuables with the influence order on the model of each is shown in Table 9. The total accuracy of the model was 76.04%. The most influential valuable on the model was distance to plantation, followed by Land cover in 2011, Timber volume, etc.

*Table 9: Sensitivity of the model to forcing a single independent variable to be constant*

| Model | Accuracy (%) | Skill measure | Influence order |
|---|---|---|---|
| (With all variables) | 76.04 | 0.7365 | N/A |
| Distance to Plantation | 51.41 | 0.4655 | 1 (most influential) |
| Land cover in 2011 | 56.34 | 0.5197 | 2 |
| Timber Volume | 64.85 | 0.6133 | 3 |
| Active Concession | 68.03 | 0.6484 | 4 |
| Distance to village point | 69.89 | 0.6688 | 5 |
| Distance to Sea | 73.71 | 0.7108 | 6 |
| Driver of Deforestation | 74.69 | 0.7216 | 7 |
| Slope | 75.54 | 0.731 | 8 |
| Distance to Road | 75.81 | 0.7339 | 9 |
| Year of disturbance | 76.02 | 0.7362 | 10 |
| Distance to Forest edge | 76.02 | 0.7363 | 11 |
| Elevation | 76.04 | 0.7365 | 12 |
| Forest density | 76.04 | 0.7365 | 13 |
| Deforestation density | 76.04 | 0.7365 | 14 |
| Standard deviation of elevation | 76.04 | 0.7365 | 15 |
| Population density | 76.04 | 0.7365 | 16 |
| Distance to Agriculture | 76.14 | 0.7375 | 17 (least influential) |

Figure 9 shows the relationships between land change and the most influential independent valuables. Most part of deforested areas were distributed within 5 km from boundaries of plantations. Land cover change between 2011 and 2015 occurred intensely in Woodland (4.1%) and Swamp forest (2.4%). Areas with high timber volume tended to experience land cover change largely. The simulated model seemed to reflect effects of physiographic features employed as the independent variables with high influence.

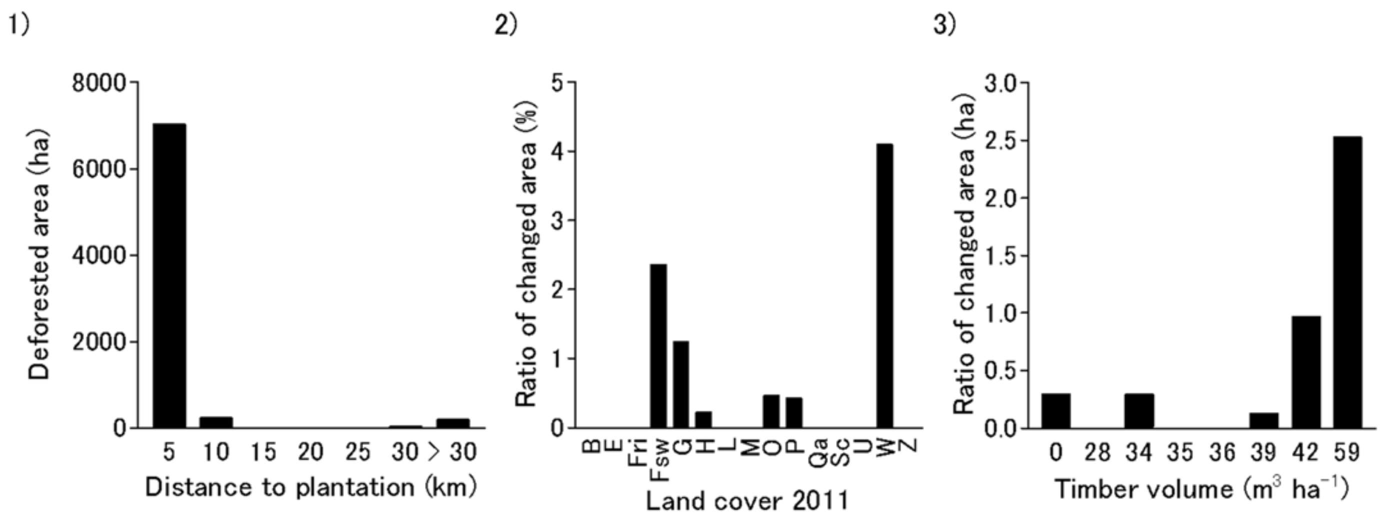


*Figure 9: Relationships between deforested areas and distance to plantation, land cover of Year 2011 and timber volume*

Utilizing the simulated model, probability of land cover change in each location was estimated in the entire West New Britain Province. Figure 10 shows the result of the estimation in a part of the western part of the West New Britain Province. Lands with high probability of land cover change are unevenly distributed. Comparing with Figure 11, it is found that areas with high probability are located along the boundaries of plantations and roads. The high probability areas also related with distribution of areas with high timber volume. Besides, distribution of active concessions, village points, etc. may be affecting the result of the estimation. This sort of analysis would be useful for helping make decision on forest managements, such as setting protected areas.

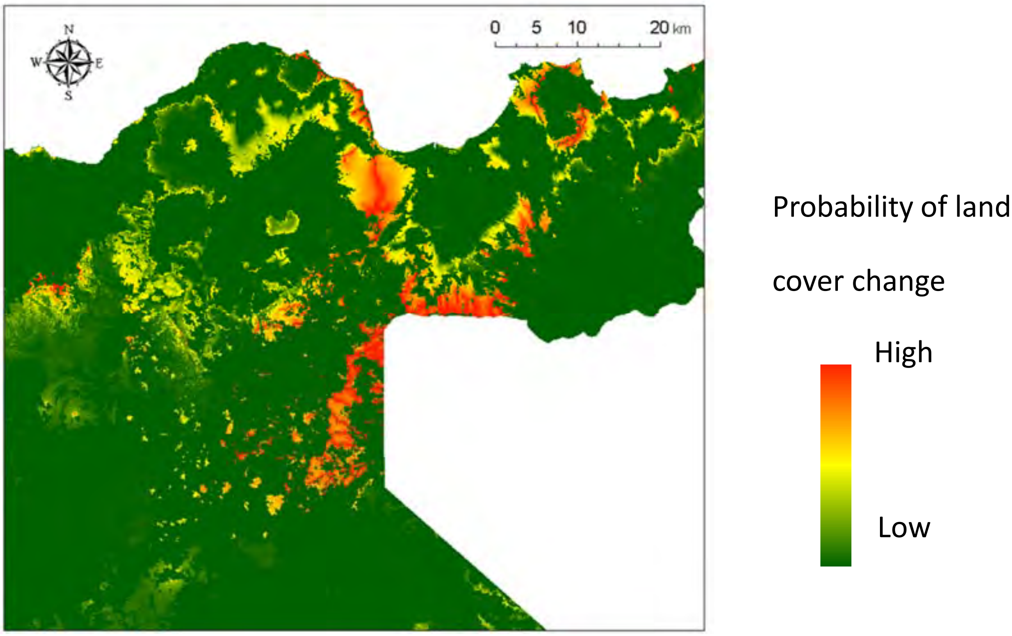


*Figure 10: Probability of land cover change in the western part of West New Britain Province*

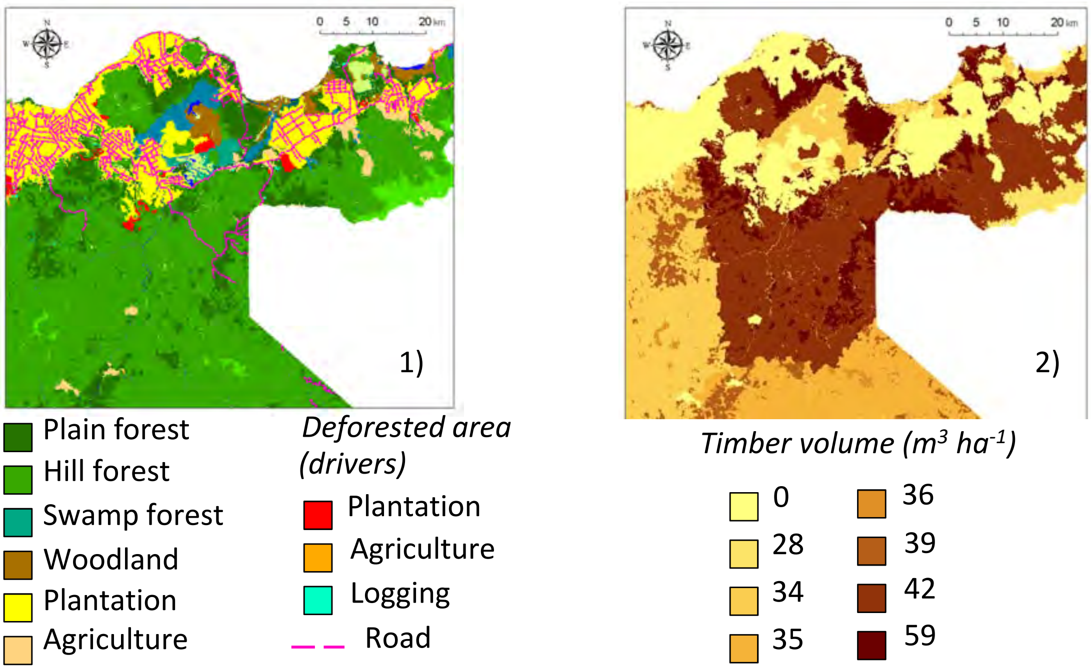


*Figure 11: Land cover and road (1) and timber volume distribution (2) in the western part of West New Britain Province*

# 4. Discussion

**FREL/FRL construction**

Spatial models simulate the expected location of future land change (deforestation). Their use for FREL/REL construction may provide a more accurate estimate of the carbon contents of forest expected to be lost in the future. But it should be noted that since spatial models is not good at simulating the quantity of future deforestation, therefore their use in calculating may be limited.

**REDD+ context**

The use of spatial modeling to predict the location of future change may serve the following purposes:

- Inform policy making and the national REDD+ strategy;
- Provide information on where the greatest deforestation pressures may be;
- Help choose the location of REDD+ activities;
- Help in the design of monitoring efforts and additional (intensified) data collection in anticipated deforestation hotspots.

**Limitation**

Spatial models have a limited ability to evaluate conditions not observed in the past (National Research Council 2014). Some variables may be highly dynamic and can significantly change the land change probability (e.g. New roads, new mining concessions, significant population migration, etc.).

**Future action**

- Simulation in other Provinces implementing capacity buildings of the staffs in PNGFA.
- Examining the other use of the Land Change Modeler other than deforestation simulation, such as plantation, logging etc.
- Comparing with results of the other modelling activities such as FCPF's deforestation modelling.

# 5. References

National Research Council 2014. Advancing Land Change Modeling: Opportunities and Research Requirements. Washington, DC: The National Academies Press.

JICA and PNGFA 2019. Analysis of Drivers of Deforestation and Forest Degradation in Papua New Guinea - JICA-PNGFA Forestry Project 2014-2019 Analytical Report No.1. Port Moresby: Papua New Guinea Forest Authority.



Last updated on May 2019

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# Potential in Papua New Guinea to estimate emissions from forest degradation caused by logging based on field methods (using FRIMS)

### Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change

## CONTEXT

- **Forestry development in Papua New Guinea** (PNG) contributes significantly to the national economy but is also one of the main causes of deforestation and forest degradation.
- **Estimating the logging impacts in the forest is important as it will enable PNG to address its obligations relating to climate change in terms of emissions of green house gases.**
- **Carbon stock is one good indicator to assess logging impacts**
- **PNG** assessed degraded areas through Remote Sensing analysis to make projections for its Forest Reference Level (FRL). These areas may also include post-logging emissions (from fire, gardening, etc.) and removals from regrowth because measures were taken in different times after logging (1 to 10 years).
- **Some FRL reporting countries** estimated forest degradation by measuring the impacts directly and solely linked to harvesting practices which are observable in sites right after operations.
- **Most of the information on logging impacts is actually available in PNGFA** from timely activities of monitoring so there is a potential to utilize field records for carbon monitoring.

**PNG has prioritized to improve the compliance of timber extraction** with PNG's Logging Code of Practice (LCOP). Different supports from the JICA Project aims at facilitating the monitoring of field operations:

- **Improvement of spatial information in PNG-FRIMS database**
- **Development of monitoring capacities for using satellite images, GIS software, GPS and drones.**

**Among LCOP items many parameters are linked with carbon levels** (Roads, collateral damage…)
=> So improving capacities to monitor LCoP can facilitate carbon monitoring

Considering features of field methods to estimate logging impact on forest carbon for PNG's FRL and further purposes linked with forest management.

# THE VOLUME METHOD

## Methodologies recommended by Intergovernmental Panel on Climate Change (IPCC)

There are two main methodologies to estimate logging impact on forest carbon (GOFC-GOLD, 2016)

1. The Remote sensing (RS) method using medium-resolution imagery for determining Activity data (AD) and the Stock-Change method for calculating Emission Factor (EF)

2. A combination of timber extraction rates, management plans and/or high-resolution imagery (for AD) and the Gain-Loss method (for EF).

## Methodologies developed in FRLs

1. Many FRL reporting countries opted for Method 1. This choice was facilitated by open sourced 30 m resolution images. In PNG, **RS** was applied to determine AD of both deforestation and forest degradation.
2. Four countries (*the Republic of Congo*, *Ghana*, *Guyana and Suriname*) chose the **Volume Method** (VM), to count direct loss in the ground associated to extraction. Measures to be taken as soon after harvest.

## Developed by Pearson et al.(2014)

| **Net emissions** | = | **Activity Data** | x | **Emission Factor** |
|---|---|---|---|---|
| Emissions from industrial timber production<br>tCO2e | | Extracted volumes<br>m3 | | Biomass loss associated to timber extraction activities<br>tCO2e/m3 |

**Activity Data**: use actual harvested volume data which are:

- Complete ⇔ Covering all production areas
- Accurate ⇔ From reliable monitoring
- Transparent ⇔ From reliable sources
- Consistent ⇔ Over more than 10 years

**Emission Factor**: account all emission sources associated to harvest (sampling approach)

| Sources of emission | Monitoring parameters |
|---|---|
| ELE (extraction) | Extracted/harvested log |
| LDF (Logging (collateral) Damage) | Wasted logs, Deadwood(DW) caused by felling |
| LIF (Road & Infra) | DW (or carbon loss) from skidding; Carbon loss roads, log ponds, decks, camp |

**Total Emission Factor (TEF) = Extracted Log (ELE) + Logging Damage (LDF) + Logging Infrastructure (LIF)**

# Emission Factor (EF)

- **EF** is always determined through a forest inventory (not by RS) because EF represents carbon loss (killed trees) associated to land activities. There are also tow (2) methods to calculate EF according to the methodology used to estimate degradation **("RS method" or "Volume Method").**

- In PNG, land use transitions (deforestation, forest degradation and carbon stock enhancement) were determined by RS. EF of forest degradation was calculated as the difference in carbon stocks between before and after logging.

- **RS method**
  - EF ($tCO_2e/ha$) is actually the difference between carbon stock (whole vegetation)
  - Measured in primary forest and carbon stock measured in logged forest.
- **Volume method**
  - EF ($tCO_2e/m^3$) is the sum of carbon losses ( dead trees) during timber extraction from road & infra, felling and extraction itself. It is not an inventory of the whole vegetation in logged areas but only an inventory of dead trees and where the area had been cleared for roads and other infrastructure, an estimation is made.

EF calculated in the "RS method" is necessarily a resultant of emissions from logging, other drivers and removals from regrowth. The value of EF captures all degradation in logged areas (harvest + post-harvest degradation). However with the VM it estimates only direct impact from harvesting practices. In this case, other drivers and regeneration are either excluded or accounted for different methods.

Based on these different characteristics, a country chooses its own method to determine degradation.

The VM is particularly interesting for the domestic purpose. It allows assessing effectiveness of Policy and Measures (PaMs) that promote a reduction of emissions from harvesting practices. In the "RS method", logging EF includes regeneration and post-drivers so it is not possible to know if total reduction of emissions are due to better practices or other reasons.

Countries that uses VM in their FRL have identified logging as one of their the major source of degradation and 'addressing logging impact' as a top priority policy and PNG is no difference to these countries.

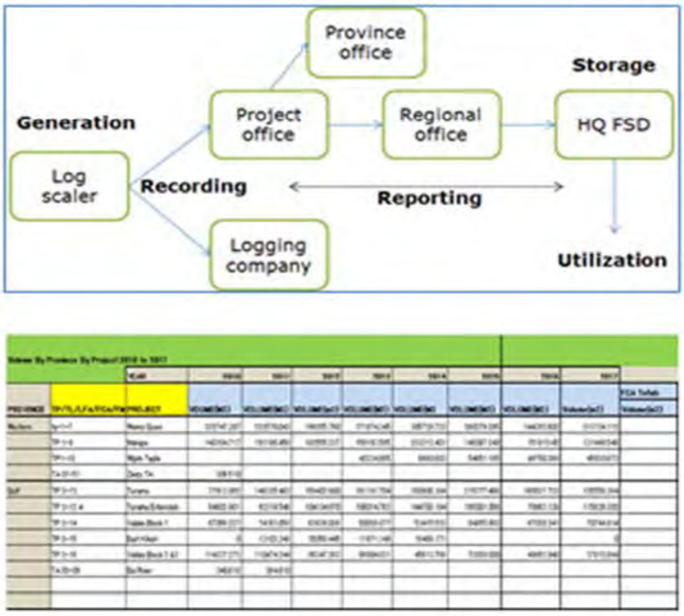
# POTENTIAL IN PNG TO USE THE VOLUME METHOD

## ❑ Potential in PNG to determine AD

Timber extracted volumes are recorded in the Field Services Directorate (FSD) database for all provinces, projects and since 2000 (digitized from 2010).

**Harvested Volume data in PNGFA**

**Data on harvested volumes in Setup scaling sheets**




**Potential to provide AD accurate, complete and consistent**

| Conditions | PNG potential | Explanation |
|---|---|---|
| All concessions | Yes | All projects are monitored |
| National scale | Yes | Provincial & regional production reported to central DB |
| Annual data | Yes | Issued each February in FSD Annual Reports |
| Period of > 10 yr. | Yes | 2000 -2018 (data digitized from 2010) |
| Reliable sources | Yes | PNGFA official records |
| Accuracy | Yes | Review by PNGFA supervisors, operators and landowners. Possible errors of 5% (pers. com.) |

## ❑ Potential in PNG to calculate EF

Information on collateral damage is recorded in setup logbooks (but not in database) except for skid track areas and felling deadwood.

| Sources of degradation | | Data (unit) | Documents |
|---|---|---|---|
| Logging infrastructure Factor | Forest clearance for roads | - L, W, Area (ha)<br>- Merchantable volume (m3) | - Setup logbook<br>- Setup scaling sheet |
| | Forest clearance for log decks | - L, W, Area (ha)<br>- Merchantable volume (m3) | - Setup logbook<br>- Setup scaling sheet |
| | Forest clearance for skid trails | - L, W, Area (ha)<br>- Merchantable volume (m3) | **- NO RECORD**<br>- Setup scaling sheet |
| Logging Damage Factor | Felling | Felling deadwood | **NO RECORD** |
| | Wasted log pieces | Stump, top, buttress (m3) | **Post harvest assessment** If available |
| Extracted Log Emission | Log extraction | Merchantable log volume (m3) | Setup scaling sheet and DB |

# POSSIBLE UTILIZATION FOR FRL

## Simulation of AD

**=> Sort out Volumes according to origin of timber**

Assumption

+ TRP/LFA and FMA volumes => **Forest degradation**

+ FCA volumes => **Deforestation** (assuming all FCA areas clear cut*)
(underestimation of total emissions but conservative)

+ TA volumes => Not counted

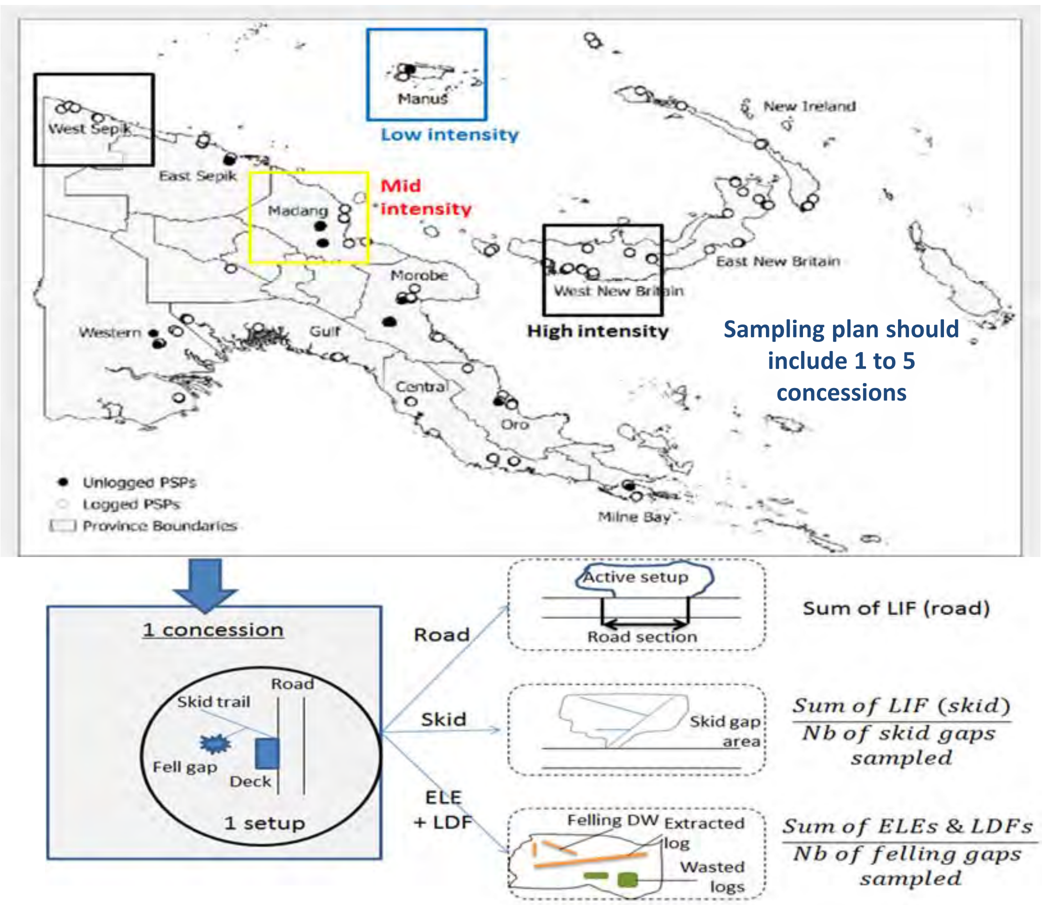
***: Clear cutting volume and selective logging volume coming from FCA area are not distinguishable in FSD database.**

=> **Activity Data in the Volume Method** = Total annual actual timber harvested volumes

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| AD (Million m3) | 3.11 | 2.65 | 2.6 | 2.79 | 3.29 | 3.64 | 2.28 | 3.45 |

## Simulation of sampling plan for developing Logging EF (in the Volume Method)

*An example of activities to sample field parameters*



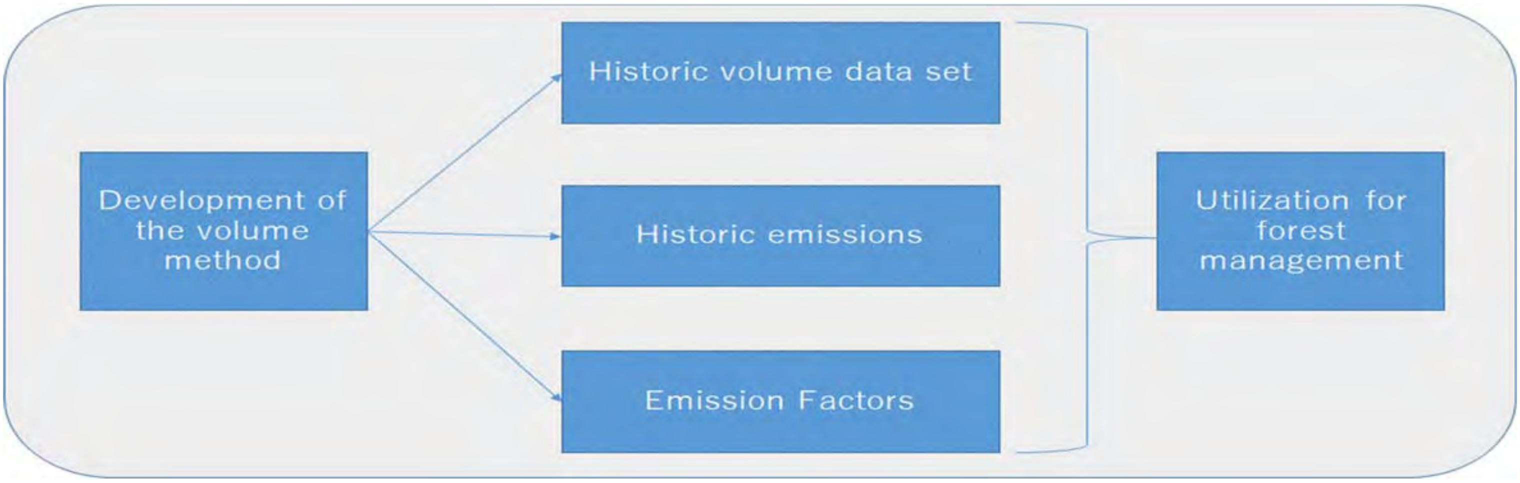

To develop a logging EF, field parameters can be measured from two methods:

1. information from Setup logbook (when available) or
2. from sampling approach.

A sampling plan should clarify sample plots, items, and number of repetitions.
Zones with data already available are preferred. For instance, it could be advantageous to use PNGFA Permanent Sampling Plots and project pilot areas.

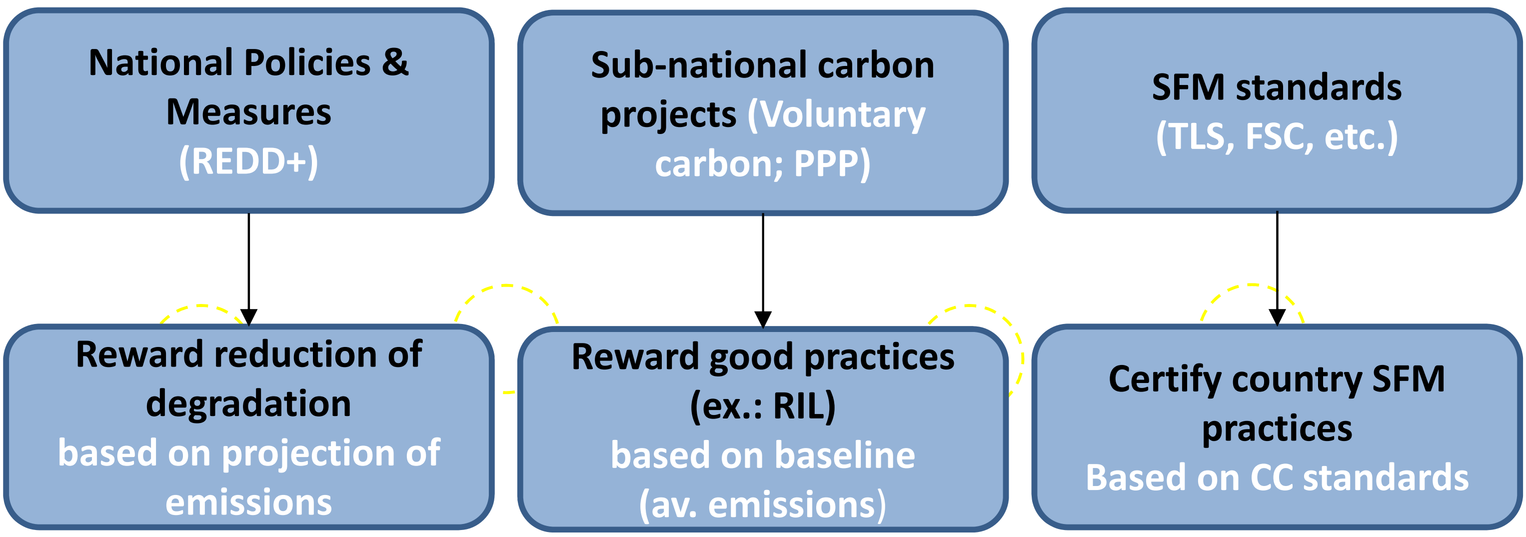
# POSSIBLE USE FOR FOREST MANAGEMENT / REDD+

## ☐ Information produced from the development of the Volume method in a country




- **VOLUME DATASET**: trends in the timber production can be used for general purpose of forest management including AAC (Annual Allowable Cuts) and province extraction rates.
- **LOGGING EF** ⇔ Environmental (carbon) efficiency of harvesting practices
  - ✓ Compare sustainability between countries, provinces or concessions (develop several EFs)
  - ✓ Differentiate environmental/carbon efficiency between conventional and improved practices
  - ✓ Use as tool to give incentive to logging operators for their improvement in practices

## ☐ Context of utilization of values of emission estimated by field methods



# WAY FORWARD

## Key findings

- Volume Method (VM) is specific to forest degradation (different method for deforestation) and specific to logging (not including other drivers in logged areas)
- FSD volume data can be used to determine PNG's logging AD. A country-specific logging EF can be developed based on PNGFA information available from routine forest monitoring and a full sampling plan.
- Most of data required are available in PNGFA (at least not less than in the four FRL countries cited along this report)
- Challenging information types are deadwood from felling and skid track extent areas. These could be addressed through field inventory or new technologies introduced by JICA such as drones.
- Outcomes such as values of Emission, EFs and volume datasets are useful for forest management.

## Main constraints

- The Volume method does not cover post-logging regrowth, and degradation (illegal logging, gardening, fire…)
- Capacity and availability of technical experts for developing EF
- Limited scientific publications on logging emission sources.

## Next steps

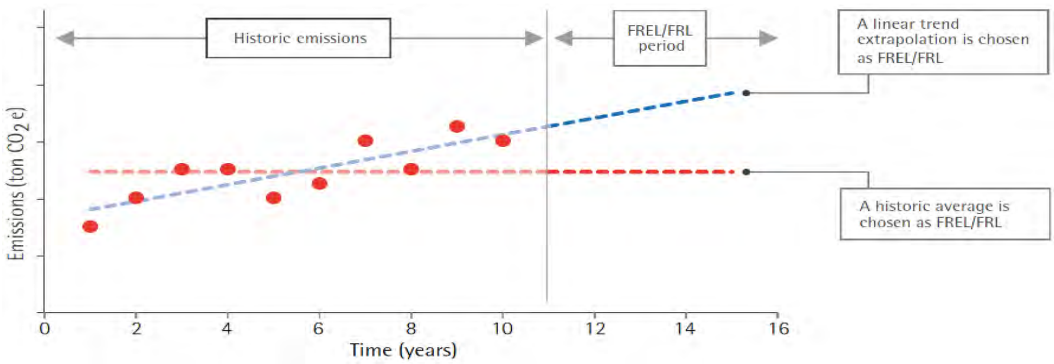
- Complementary review of guidance and FRLs to consider regrowth and post-logging degradation with the Volume Method
- Develop technical support by promoting Forest Research notably to develop a Logging EF
- Further develop methods of monitoring notably for estimating skidding and collateral damage using drones
- Rapid operationalization of DSS to improve management of actual harvested volume.



Last updated on August 2019

# Concept of FREL and FRL

**F**orest **R**eference **E**mission **L**evel and **F**orest **R**eference **L**evel (**FREL/FR**L) are **benchmarks** for assessing the performance of implementing REDD+ activities.

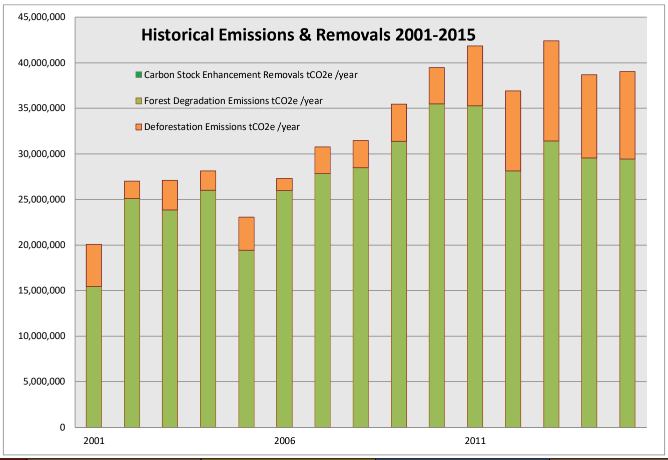


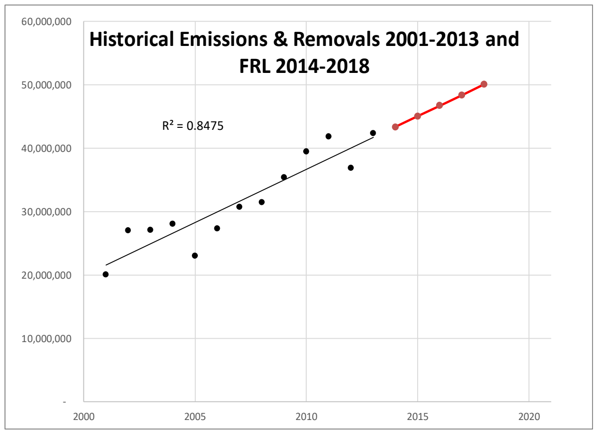


## Why develop a FREL/FRL?

1. **Domestic purpose**: Assess effectiveness of PAMs &/or meet a national objective
2. **Global responsibility**: Demonstrate national contribution to mitigation of climate change
3. **Results-based REDD+ finance**: For reducing emissions below a certain level

# (The Remote Sensing method: example in PNG_FRL only)




| Years | Primary Deforestation | Secondary Deforestation | Post-Deforestation Regrowth | Deforestation | Forest Degradation | Carbon Stock Enhancement | Total Emissions and Removals 2001-2013 | | Regression 2001-2013 / FRL 2014-2018 |
|---|---|---|---|---|---|---|---|---|---|
| | *Emissions* | *Emissions* | *Removals* | *Emissions* | *Emissions* | *Removals* | *Emissions & Removals* | | *Emissions & Removals* |
| | *tCO2e /year* | *tCO2e /year* | *tCO2e /year* | *tCO2e /year* | *tCO2e /year* | *tCO2e /year* | *tCO2e /year* | | *tCO2e /year* |
| 2001 | 2,067,030 | 2,721,258 | - 165,272 | 4,623,017 | 15,441,146 | - | 20,064,162 | | 21,492,824.59 |
| 2002 | - | 2,189,016 | - 277,525 | 1,911,491 | 24,952,653 | - | 26,864,144 | | 23,135,270 |
| 2003 | 1,633,740 | 2,030,276 | - 414,734 | 3,249,282 | 23,834,478 | - | 27,083,761 | | 24,777,716 |
| 2004 | 1,951,160 | 691,861 | - 511,867 | 2,131,153 | 25,602,243 | - | 27,733,397 | | 26,420,161 |
| 2005 | 2,090,426 | 2,202,716 | - 656,727 | 3,636,414 | 19,272,288 | - | 22,908,702 | | 28,062,607 |
| 2006 | - | 1,838,795 | - 740,296 | 1,098,500 | 25,969,659 | - | 27,068,159 | | 29,705,052 |
| 2007 | 2,043,601 | 1,771,267 | - 878,143 | 2,936,725 | 27,593,488 | - | 30,530,213 | | 31,347,498 |
| 2008 | 2,662,314 | 1,367,741 | - 1,015,677 | 3,014,378 | 28,145,718 | - | 31,160,096 | | 32,989,944 |
| 2009 | 1,871,909 | 3,389,611 | - 1,214,349 | 4,047,172 | 31,078,554 | - | 35,125,726 | | 34,632,389 |
| 2010 | 2,715,841 | 2,713,741 | - 1,408,035 | 4,021,547 | 35,312,006 | - | 39,333,554 | | 36,274,835 |
| 2011 | 4,712,034 | 3,641,949 | - 1,735,812 | 6,618,171 | 34,760,737 | - | 41,378,908 | | 37,917,280 |
| 2012 | 3,740,834 | 7,208,970 | - 2,151,678 | 8,798,126 | 27,678,049 | - | 36,476,175 | | 39,559,726 |
| 2013 | 6,820,550 | 6,892,420 | - 2,706,436 | 11,006,534 | 30,783,944 | - | 41,790,478 | | 41,202,172 |
| 2014 | | | | | | | | | 42,844,617 |
| 2015 | | | | | | | | | 44,487,063 |
| 2016 | | | | | | | | | 46,129,508 |
| 2017 | | | | | | | | | 47,771,954 |
| 2018 | | | | | | | | | 49,414,399 |