PAPUA NEW GUINEA FOREST RESOURCE INFORMATION MANAGEMENT SYSTEM (PNG-FRIMS)

R. Turia, P. Malan, P. Laa, J. Antiko, M. Tongo, E. Kaidong,
D. Kadowaki, T. Koyama, M. Haraguchi, A. Ochi, Y. Okada,
T. Koide, H. Takahashi, S. Salim, B. Matambuai, J. Turia, E. Paul

Papua New Guinea Forest Resource Information Management System (PNG-FRIMS)

- Main Report -

R. Turia, P. Malan, P. Laa, J. Antiko, M. Tongo, E. Kaidong

D. Kadowaki, T. Koyama, M. Haraguchi, A. Ochi, Y. Okada,

T. Koide, H. Takahashi, S. Salim, B. Matambuai, J. Turia, E. Paul

Papua New Guinea

Forest Resource Information Management System

(PNG-FRIMS)

- Main Report -

Papua New Guinea Forest Authority (PNGFA)

Japan International Cooperation Agency (JICA) Project

The information in this document is subject to change without notice

1st Edition published August 2019

ISBN: 978-9980-908-76-6

PNG Forest Authority (JICA Project)

Address: P.O. Box 5055, Boroko, National Capital District, Papua New Guinea

JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html

Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

Table of Contents

List of Figures

List of Tables

I. Foreword

Implementing externally funded projects have their challenges and opportunities. As the donor for the project “Capacity development project for operationalization of PNG Forest Resource Information Management System for addressing Climate Change”, I am pleased on behalf of the people and Government of Japan, to present the output of this project through this Report. At the same time, I extend our well wishes to the people and Government of Papua New Guinea and in particularly the Papua New Guinea Forest Authority as they move forward to continue to update the data and apply it in their everyday monitoring of forestry operations in the country.

I am encouraged by what the project has achieved; including the earlier project which also resulted in another Report ‘Papua New Guinea Forest Base Map and Atlas’. I challenge the PNGFA officers to utilize the information in order that is produced as a result of the project and to continue to collect new data and update the data in order to provide accurate information on the forest resources of Papua New Guinea, moving forward.

Satoshi Nakajima

Ambassador of Japan to Papua New Guinea

II. Preface

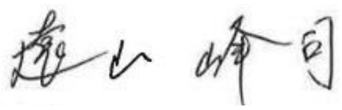
This Report details the output from the continuation of Japan's assistance to Papua New Guinea in the forestry sector through the project 'Capacity development project for operationalization of PNG Forest Resource Information Management System for addressing Climate Change'. The specific project has involved two (2) pilot provinces; West new Britain and West Sepik Provinces wherein the required data and tools needed to capture the data were tested with existing timber operations and PNGFA field officers.

Furthermore, the data and output of the project have become possible through many long hours by both the Japanese experts and the Papua New Guinea experts; some of whom are listed as the authors of this Report. The various tasks included; enhancing PNG Forest Resource Information Management System, Improving National/Provincial Forest Plans, Management Plan/Monitoring System, and Preparing/Identifying Forest Information for addressing/contributing-to REDD+ and producing reports to come up with the current system and applications, as will be presented in this Report.

The development of the PNG-FRIMS also took into account other work that has been developed and documented under the Papua New Guinea Forest Base Map and Atlas.

Any inquiries on the PNG-FRIMS, can be directed to the PNG Forest Authority at –

P. O. Box 5055, Boroko, N.C.D., Papua New Guinea. Telephone: (675) 3277800 or email: infor_general@pngfa.gov.pg



Takashi Toyama
Chief Representative, PNG office of JICA

III. About the Authors

PNG Forest Authority Project Team:

Dr Ruth Turia (Director, Forest Policy and Planning Directorate and Director of the JICA/PNGFA Project)

Mr Perry Malan (Senior Remote Sensing and GIS Officer, Inventory and Mapping Branch)

Mr Patrick Laa (Remote Sensing and GIS Officer, Inventory and Mapping Branch)

Mr Jehu Antiko (Remote Sensing and GIS Officer, Inventory and Mapping Branch)

Mr Margaret Tongo (Forest Plans Officer, Inventory and Mapping Branch)

Ms. Elizabeth Kaidong (Adaptation and Low Carbon Growth Officer, REDD and Climate Change Branch)

The JICA Project Team:

Mr Daisuke Kadowaki (Chief Adviser / Forest Management and Climate Change)

Mr Tsutomu, Koyama (Forest Planning / Coordinator)

Mr Masamichi Haraguchi (Expert on Forest Remote Sensing 1 / Forest GIS 1)

Ms Ayako Ochi (Expert on Forest Remote Sensing 2/ Forest GIS 2)

Mr Yasuyuki Okada (Expert on Forest Database 1)

Dr Takahiro Koide (Expert on Forest Database 2 / Database Management)

Mr Hirokazu Takahashi (Expert on Forest Database 3)

Mr Stephane Salim (Expert on REDD+ project planning assistance)

The JICA Project Casuals:

Mr Benjamin Matambuai (GIS Data Collection, Input and Organization 1)

Mr Joshua Turia (GIS Data Collection, Input and Organization 2)

Ms Everlyn Paul (Project officer)

IV. Acknowledgement

Papua New Guinea Forest Authority (PNGFA) and Japan International Cooperation Agency (JICA) Project: "Capacity Development Project for Operationalization of PNG Forest Information Management System for Addressing Climate Change" has been making efforts to prepare this report since the project started in 2014. However, it would not have been possible without the kind support and help of many organizations and individuals. We, PNGFA and JICA Project would like to extend our sincere thanks to all of them.

Any outcome of a project such as this Report is presenting cannot be accomplished without the involvement, participation and support of so many people whose names may not all be mentioned. However, the authors of this Report would like to sincerely acknowledge and thank everyone, and in particular the following:

Papua New Guinea Forest Authority (PNGFA), especially to the members of Forest Policy and Planning Directorate for their guidance and constant supervision as well as for providing necessary information regarding the project and also for their support in implementing the project, namely; Mr Rabbie Lalo, Mr Samuel Gibson, Mr Gewa Gamoga, Mr Guduru Rome, Mr Dambis Kaip, Mr Ledino Saega, Mr Goodwill Amos and Mr Constin Bigol, Mr Lyall Umbo and Mr Charles Pakure;

The PNG national consultant, Mr Oala Iuda and the JICA project casuals namely; Ms Aida Kai and Ms Dika Davai.

We would like to express our gratitude towards the members of Japan International Cooperation Agency (JICA) Head Quarters and PNG office for their kind co-operation and collaboration which helped us in the preparation of this report. And to our colleagues of the project from Forest Agency of Japan and Kokusai Kogyo Co., Ltd (KKC) for their hard working, without which this report would not have been prepared.

We would also like to express our special gratitude and thanks to the other developing partners, especially Food and Agriculture Organization of the United Nations (FAO) for collaborating with us on forest monitoring in PNG.

Our acknowledgement as well to the two (2) pilot Provinces timber operators and PNGFA officers that worked with us to implement this project. Without your support, the project and the envisaged outputs would not have been achieved.

V. Acronyms and Abbreviations

AAC	Annual Allowable Cut
ALP	Annual Logging Plan
CEPA	Conservation and Environment Protection Authority
CU	Census Unit
DEM	Digital Elevation Model
EF	Emission Factor
FAO	Food and Agriculture Organization of the United Nations
FBM	Forest Base Map
FCA	Forest Clearance Plan
FMA	Forest Management Agreement
FRL	Forest Reference Level
GeoSAR	Geosynchronous Earth Orbit Synthetic Aperture Radar
GIS	Geographic Information Science/System
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LCoP	Logging Code of Practice
NEFC	National Economic and Fiscal Commission
NFI	National Forest Inventory - *funded by FAO*
NFP	National Forest Plan
PMCP	Planning, Monitoring and Control Procedures
PNGFA	Papua New Guinea Forest Authority
PNGRIS	Papua New Guinea Forest Resource Information System
RAMS	Road Asset Management System
SABL	Special Agricultural Business Leases
SFM	Sustainable Forest Management
SRTM	Shuttle Radar Topography Mission
TRP	Timber Rights Purchase
UAV	Unmanned Aerial Vehicle - *drones*

1 Introduction

1.1 Background of Project

Situation of Papua New Guinea (PNG):

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 and then from August 2014 to August 2019. Some brief information on the two projects is provided below.

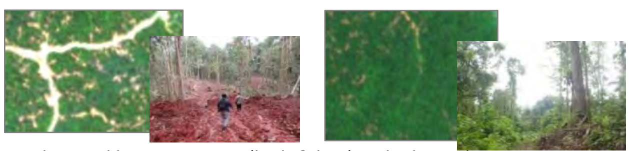
JICA-PNGFA Project 2011 – 2014 (Phase1):

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 36 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 (Phase2):

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. This project will terminate at the end of August 2019.

Capacity building of field survey and analysis



Observed logging impact (high & low) on high resolution imageries

1.2 Objectives of Project

This Project aims to achieve the project purpose through implementation of project activities under collaboration with Counterparts (C/P). The overall goal, purpose and outputs of this project are as follows:

Overall goal

Forests in PNG are conserved and managed in a sustainable manner, while at the same time, mitigation and adaptation measures against climate change are promoted.

Project purpose

Capacity of the PNGFA to continuously update forest information and to fully operationalize and utilize PNG Forest Resource Information Management System (hereinafter referred to as "PNG-FRIMS") for promoting sustainable forest management and for addressing climate change is enhanced.

Outputs

1. PNG-FRIMS is expanded and enhanced.
2. The national forest plan, provincial forest plans, forest management plans and their monitoring system are improved through steady operation of PNG-FRIMS.
3. Forest information for addressing REDD+ is prepared.

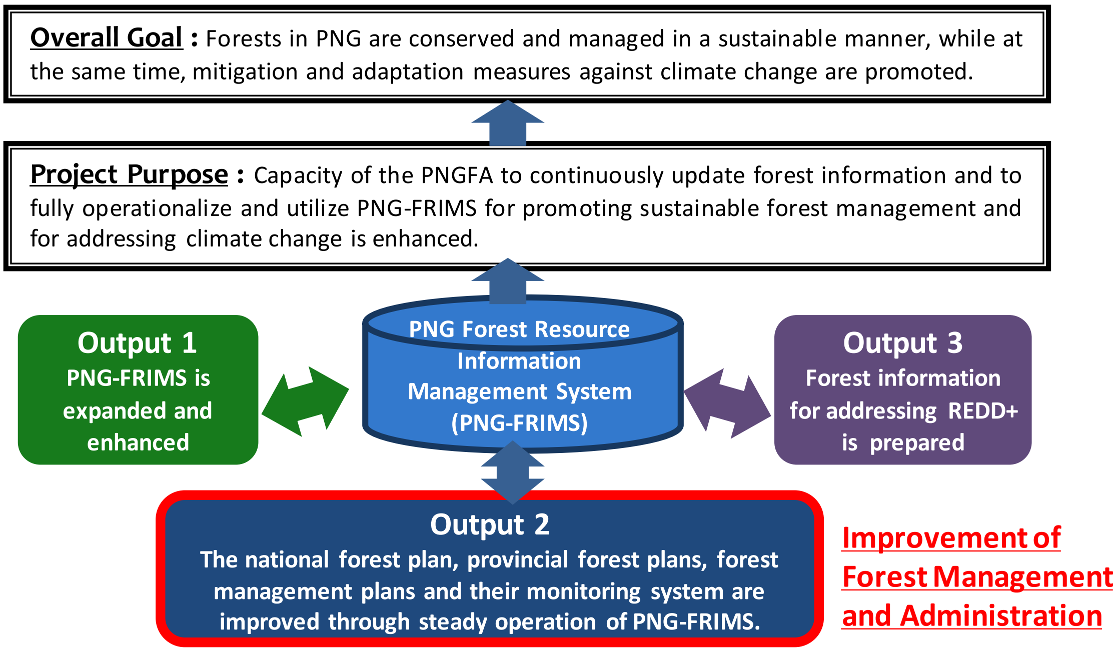


Figure 1.2.1: Overview of the Project

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

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

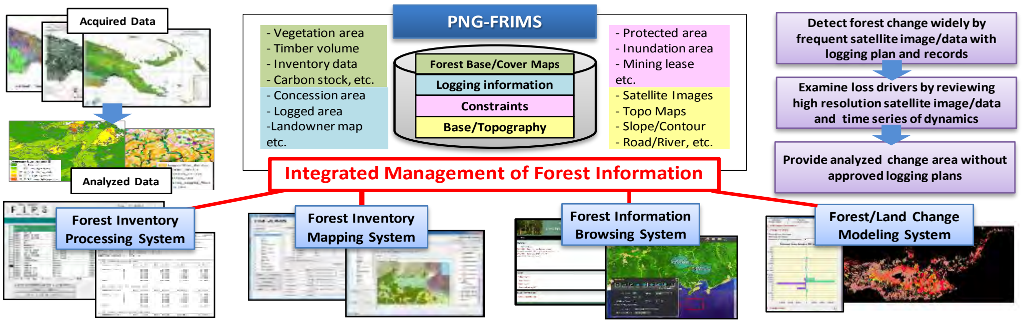


Figure 1.2.2: Overview of the Output 1

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

Utilization of PNG-FRIMS for forest planning/management, monitoring activities through trainings

Figure 1.2.3: Overview of the Output 2

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

(1) Contributing to National Forest Monitoring System & Reference Level (2) Identifying potential area for REDD+

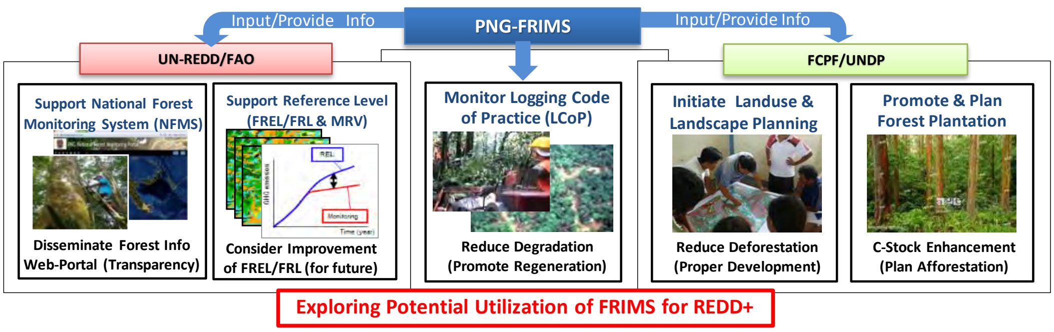


Figure 1.2.4: Overview of the Output 3

1.3 Overview of System

1.3.1 What is PNG-FRIMS?

PNG-FRIMS is a system responsible for acquiring, managing and using "spatial information/data" of 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 in - 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

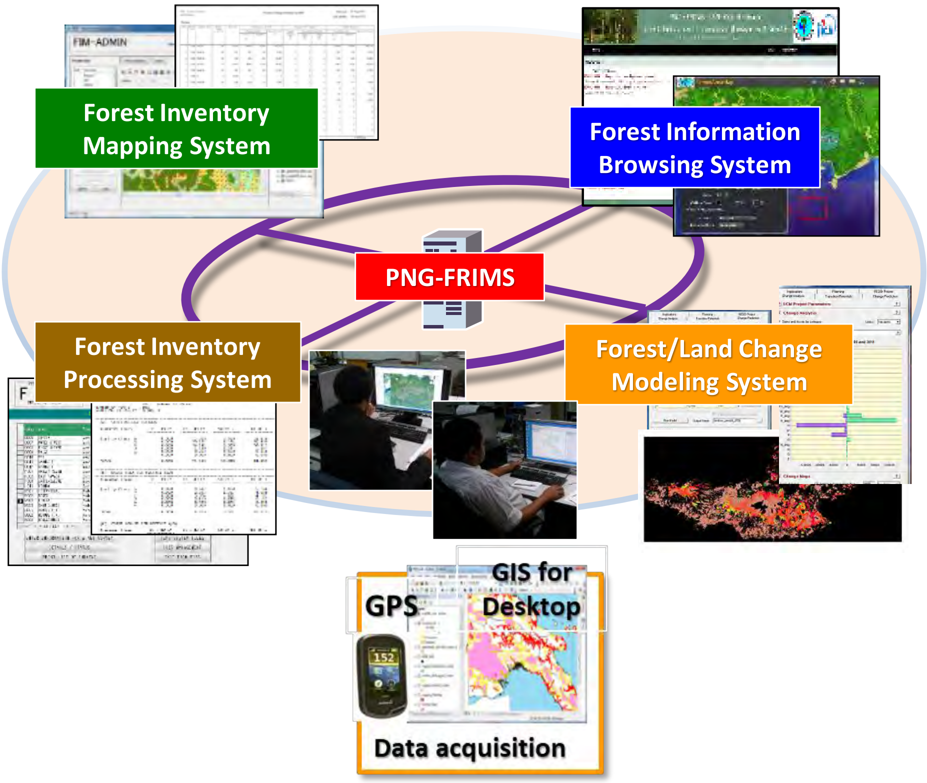


Figure 1.3.1: Overview of the PNG-FRIMS

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

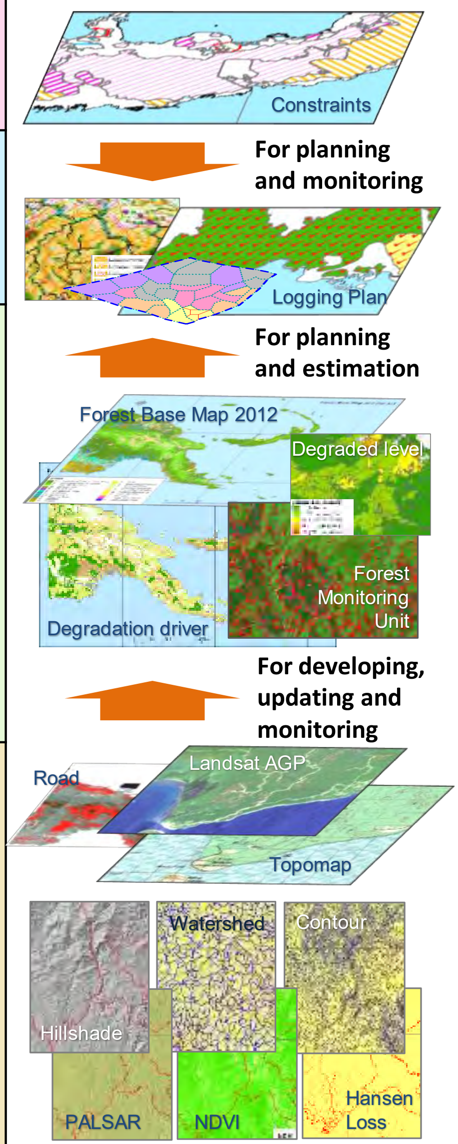


Figure 1.3.2: Information in PNG-FRIMS

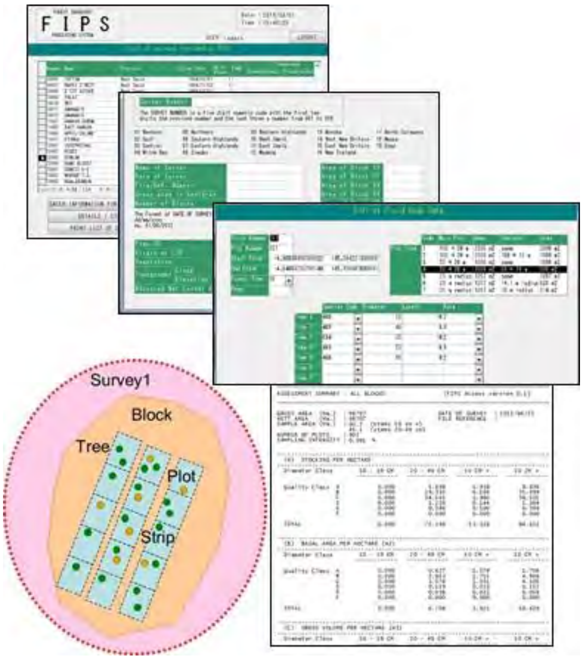
Database stores not only PNGFA data but also global dataset and the information from other organizations, which are updated and kept fresh periodically.

1.3.3 Functions of PNG-FRIMS

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

The project reviewed 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)



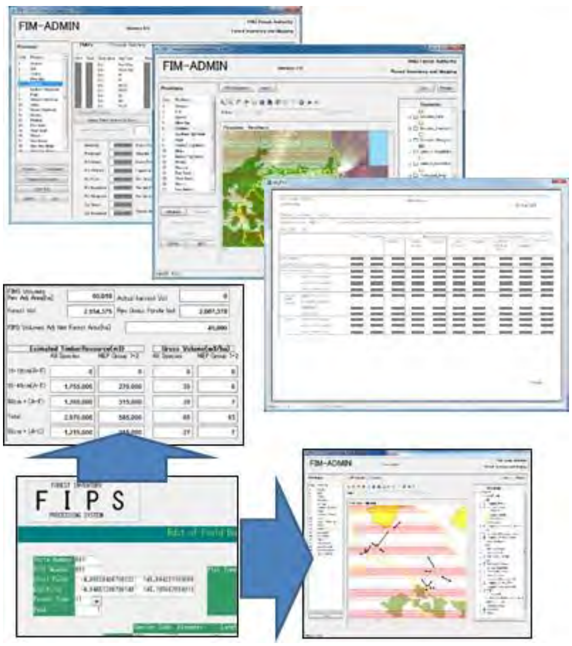
Overview

- 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

- 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

(b) LAN (Local Area Network) Map Browser

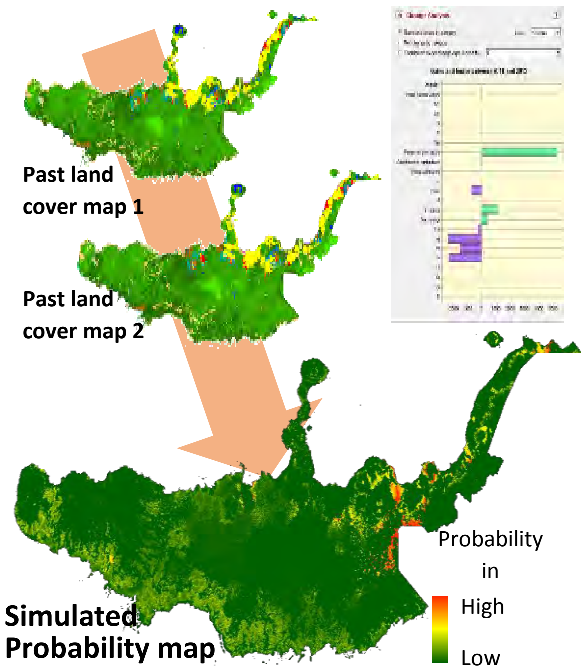
Overview

- 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.
- 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.
- This system uses Land Change Modeler, which is a product of Clark Labs, Clark University, USA.

2 The Outputs from the Project

2.1 Output 1

Enhanced PNG Forest Resource Information Management System (PNG-FRIMS)

Table 2.1.1 below lists all the various layers that are contained in PNG-FRIMS, which includes the Forest Base Map 2012. The detailed information on how the Forest Base Map 2012 was developed can be found in Turia *et al.* (2019), whereas this Report details the various layers and information that can be generated from PNG-FRIMS.

Table 2.1.1: List of Thematic Products in PNG-FRIMS (under Output 1)

	Map/Layers	Target Area	Organized Report
	Forest Base Map 2012 (Revised)	National	Forest Base Map and Atlas
	Forest Degradation Drivers Map	National	Appendix
	Forest Timber Volume Map (Draft)	National	Appendix
	Forest Cover Map 2015 (Updated)	National	Main Report
	Past Forest Cover Maps 2000/2005	WNB, WSP	Appendix
	Future Forest Change Modeling	WNB	Appendix
	Other Thematic Layers in FRIMS		
	- Forest Monitoring Unit (FMU)	National	Main Report
	- Updated Constraints Data	National	Main Report
	- Watershed (Catchment) Data	National	Main Report
	- Digitized Logging Road Data	National	Main Report
	- Forest Concession/Land Management	National	Main Report

Note: All the information can be viewed through LAN Map Browser of PNG-FRIMS

2.1.1 Forest Cover Map 2015 (Updated)

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.

Methods

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 2.1.2: The datasets used for constructing Forest Degradation Information

Layer (Dataset)		**Source**
Forest Base Map		Developed by the Project[1]
Hansen Loss-year		Developed by the Project
LANDSAT Annual Greenest Pixel (AGP)		Developed by the Project
RapidEye 2011		Procured by Grant Aid Program[2]
Google Earth Satellite Imagery		Google Earth
Reference data necessary for identifying	Mining	Mineral Resource Authority (MRA)
	Forest plantation (Qf) polygon in the Forest Base Map	Developed by the Project

[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)

drivers:	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
	Fire Watch PNG	University of Papua New Guinea Remote Sensing Centre

<u>Procedure</u>

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* 2.1.1) was identified.

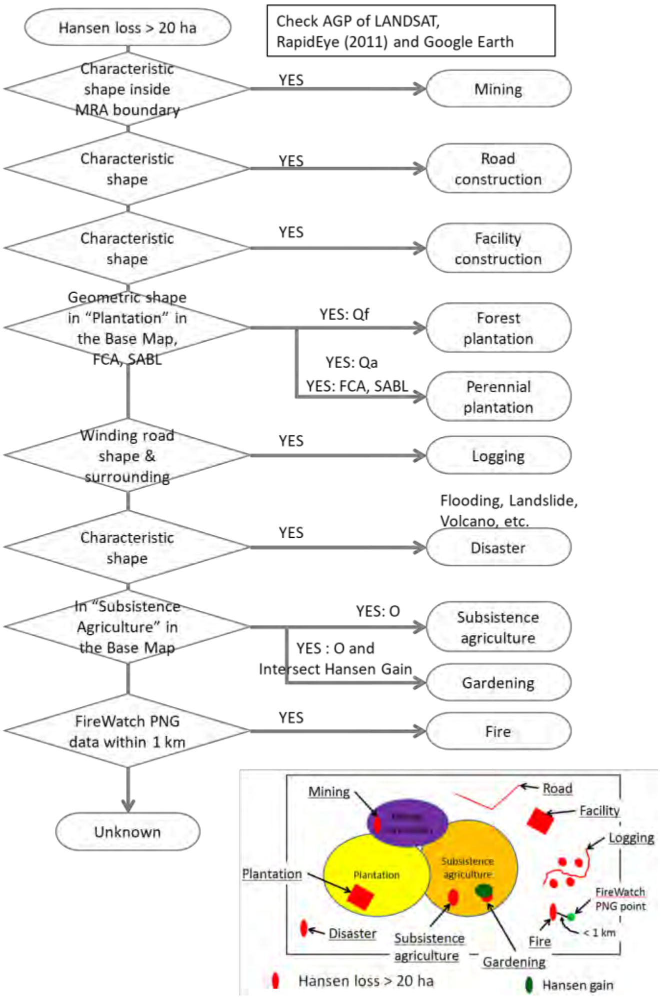


Figure 2.1.1: Flow of Driver analysis for Hansen loss-year polygons larger than 20 ha.

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* 2.1.2) by overlaying analysis with reference data.

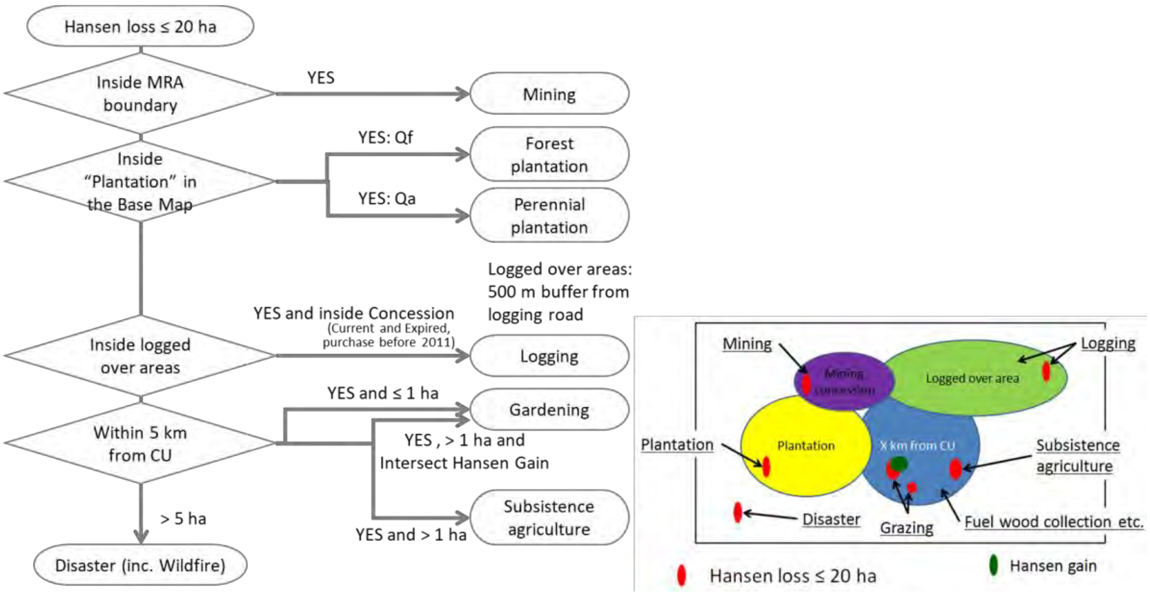


Figure 2.1.2: Flow of Driver analysis for Hansen loss-year polygons 20 ha and smaller

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* 2.1.3) by overlay analysis with reference data. FMU with no driver information were considered as intact forest.

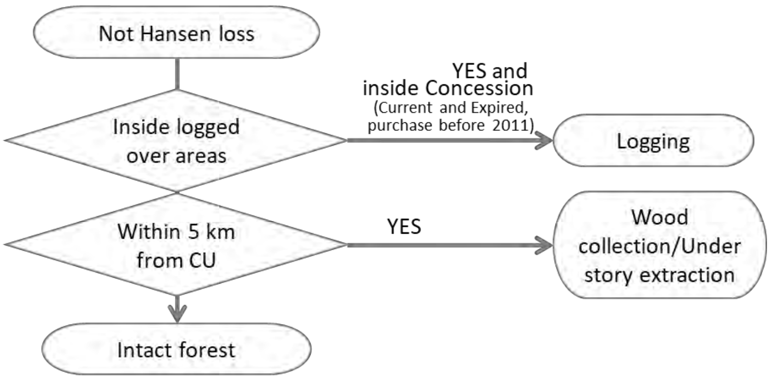


Figure 2.1.3: Flow of Driver analysis for Map polygons which do not intersect Hansen loss

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 land-use 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 hectare, and satellite imagery.

Results

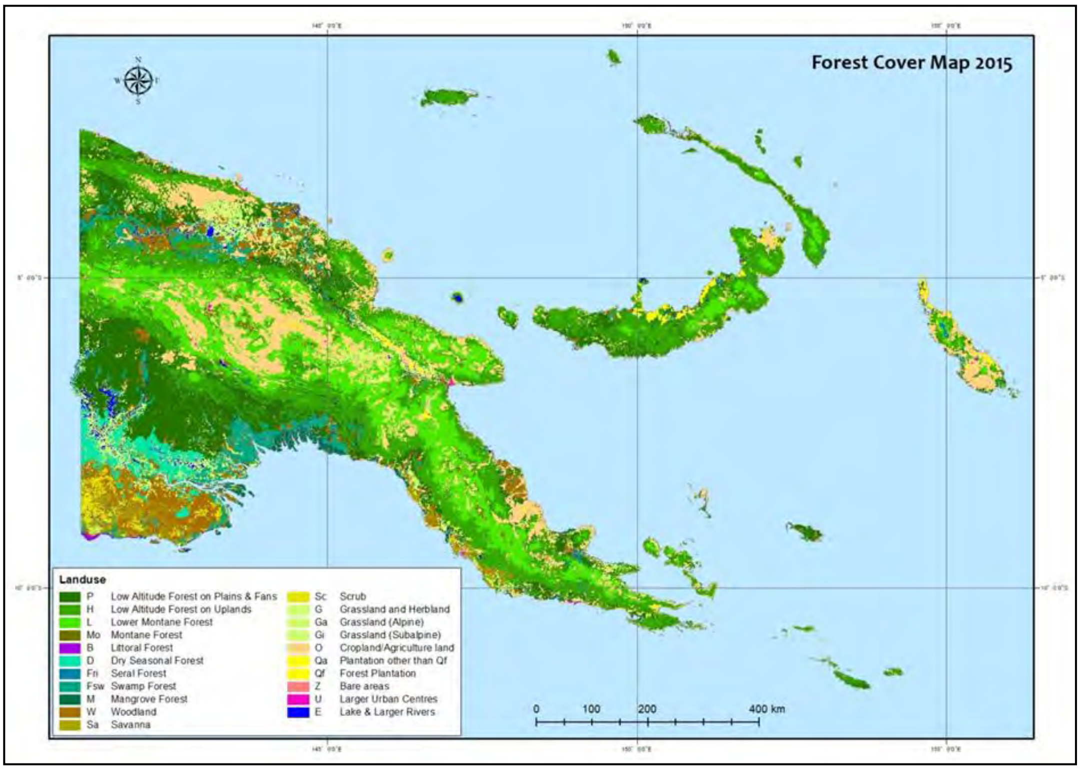


Figure 2.1.4: Forest Cover Map 2015 showing different landuse

	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

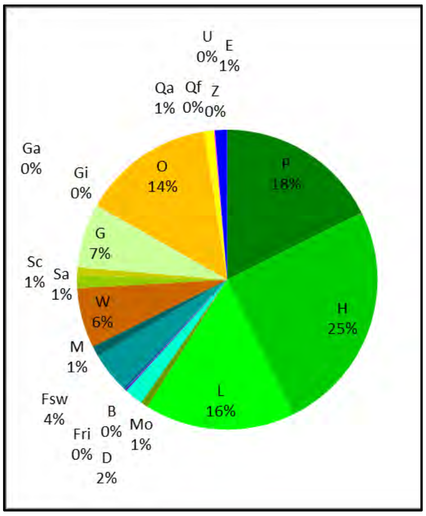


Figure 2.1.5: Vegetation cover with corresponding areas for the Forest Cover Map 2015

Discussions

- 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.

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 the assumption that the maps will be updated every five years) to keep track of changes in forest resources and related information in Papua New Guinea.

2.1.2 Other Thematic Layers in PNG-FRIMS

Forest Monitoring Unit (FMU)

Introduction

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 outdated 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.

Method

- **Definition and 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 and in the PNG-FRIMS
- Criteria used to delineate FMUs:
    - Province,
    - Forest Zone,
    - Catchment,
    - Land-use (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 a 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.

Results

Forest Base Map is divided into FMUs, which is composed of information above and could include other identifiable attributes to monitor forest changes.

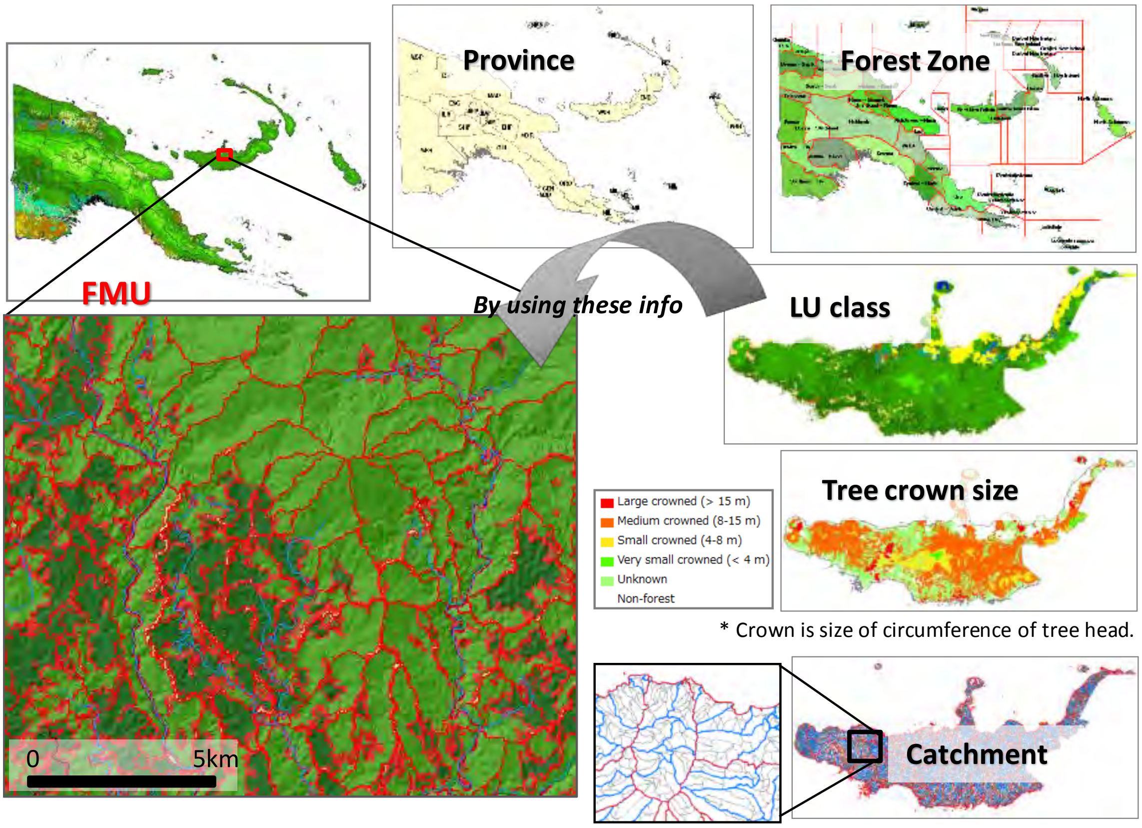


Figure 2.1.6: Development of Forest Monitoring Unit (FMU)

Updated Constraints Data

Introduction

Constraints data is one of the PNG-FRIMS data sets developed in the JICA-PNGFA Project. The data was sourced from legacy Forest Inventory Mapping System (FIMS). Constraints is a significant information for 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.

Method

- **Definitions**

The criteria for each constraint are defined in FIMS in *Table* 2.1.3

Table 2.1.3: Constraints data

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

Constraints data was updated by the method shown in the following table:

Table 2.1.4: Workflow Direction of Updating Constraints Data

Layer	Description	Data to be used	Brief work instruction
Altitude	Land over 2400m altitude.	SRTM 30	- Reclassify altitude with target altitude - Convert to vector (simplify boundary) - Eliminate small polygons (smaller than 10ha) - Extract (Export) only target altitude - Split with new provinces
Slope (Extreme)	Land with over 30-degree dominant slope.	SRTM 30	- Reclassify slope with over 30 degrees - Convert to vector (simplify boundary) - Eliminate small polygons (smaller than 50ha) - Extract (Export) only polygons over 30 degrees ->> continue to next process below
Slope/Relief	Land with dominant slope of 20-30 degrees and sub-dominant slope over 30 degrees and with high to very high relief.	SRTM 30	- Reclassify slope with over 20 degrees - Convert to vector (simplify boundary) - Eliminate small polygons (smaller than 50ha) - Extract (Export) only polygons over 20 degrees - Union polygons over 20 degrees and polygons over 30 degrees above - Split with new provinces - Divide into polygons over 30 degrees and 20-30 degrees
Mangroves	Land covered by mangroves.	Forest Base Map	- Extract mangrove class (Code: M, ID: 9) from the Forest Base Map - Merge all provinces
Inundation (Extreme)	Land permanently or near permanently inundated extending over more 80% of the area of that land.	PNGRIS 2008	- Extract target inundation class (INUNDATION: 5, 6) - Merge all provinces - Dissolve polygons (classes) - Fill (eliminate) small gaps (smaller than 10ha) - Remove small polygons (smaller than 10ha) ->> continue to next process below
Inundation (Serious)	50-80% permanent or near permanent inundation.	PNGRIS 2008	- Extract target inundation class (INUNDATION: 3, 4) - Merge all provinces - Dissolve polygons (classes) - Fill (eliminate) small gaps (smaller than 10ha) - Remove small polygons (smaller than 10ha) - Union polygons of inundation serious and extreme - Simplify boundary - Split with new provinces - Divide into polygons of inundation serious and extreme
Karst	Land with polygonal karst landform.	PNGRIS 2008	- Extract target karst class - Merge all provinces - Dissolve all polygons (classes) - Fix broken gaps (No need of topology check for overlap if polygons are dissolved) - 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

Results

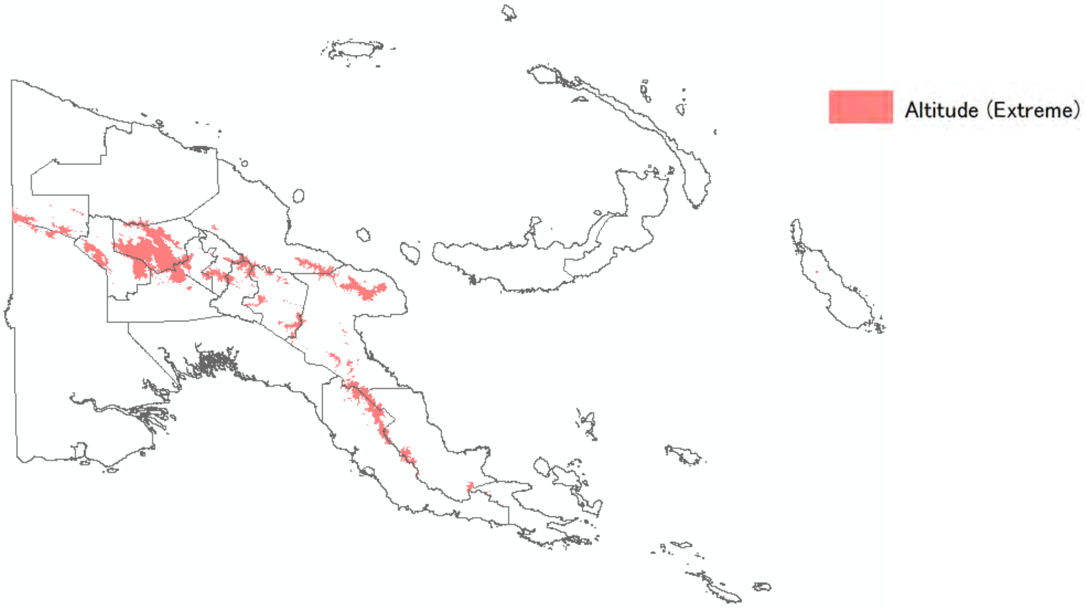


Figure 2.1.7: Data Comparison of Altitude (Extreme)

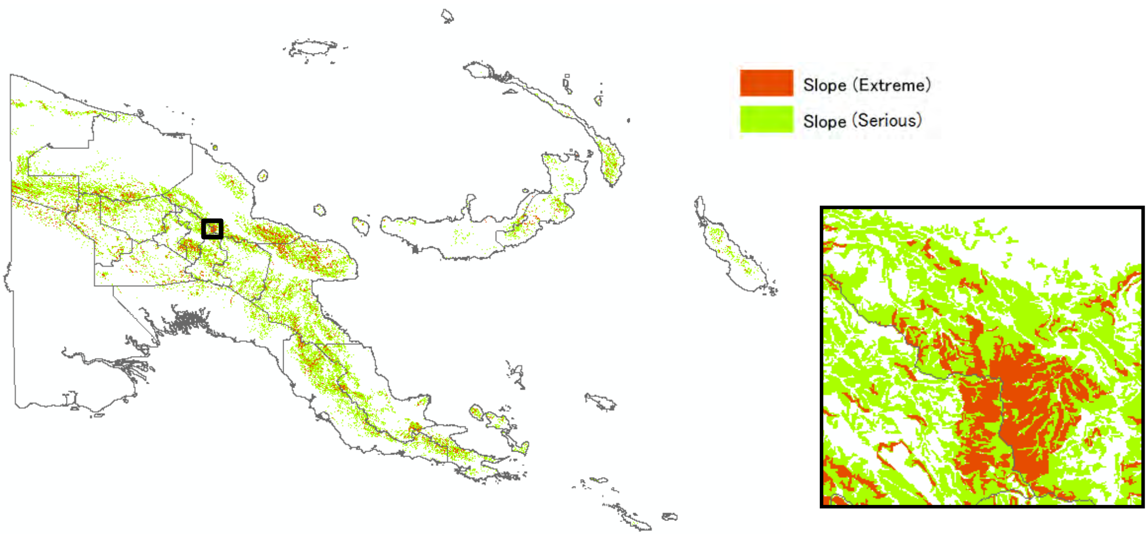


Figure 2.1.8: Data Comparison of Slope (Extreme and Serious)

Figure 2.1.9: Data Comparison of Mangroves

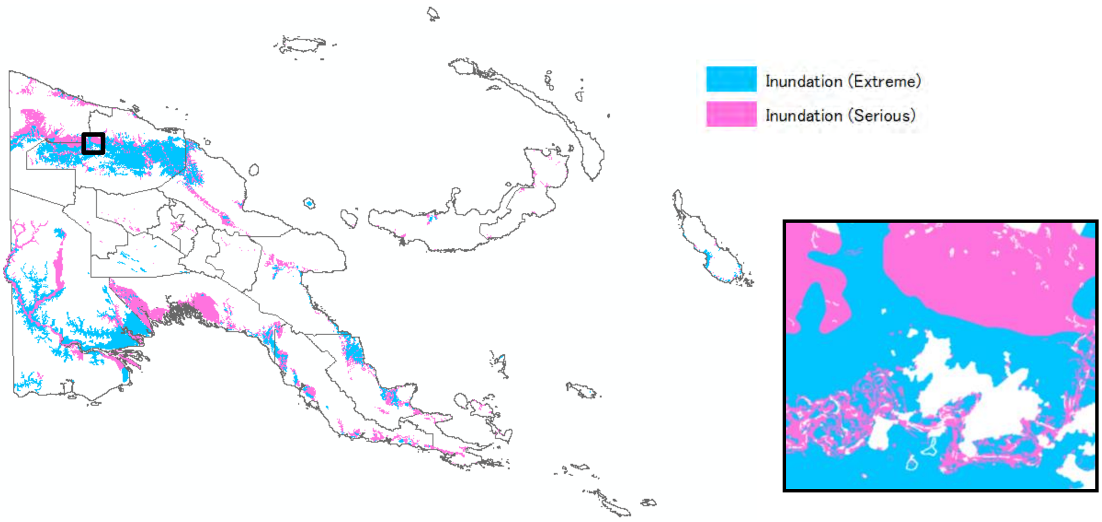


Figure 2.1.10: Data Comparison of Inundation (Extreme and Serious)

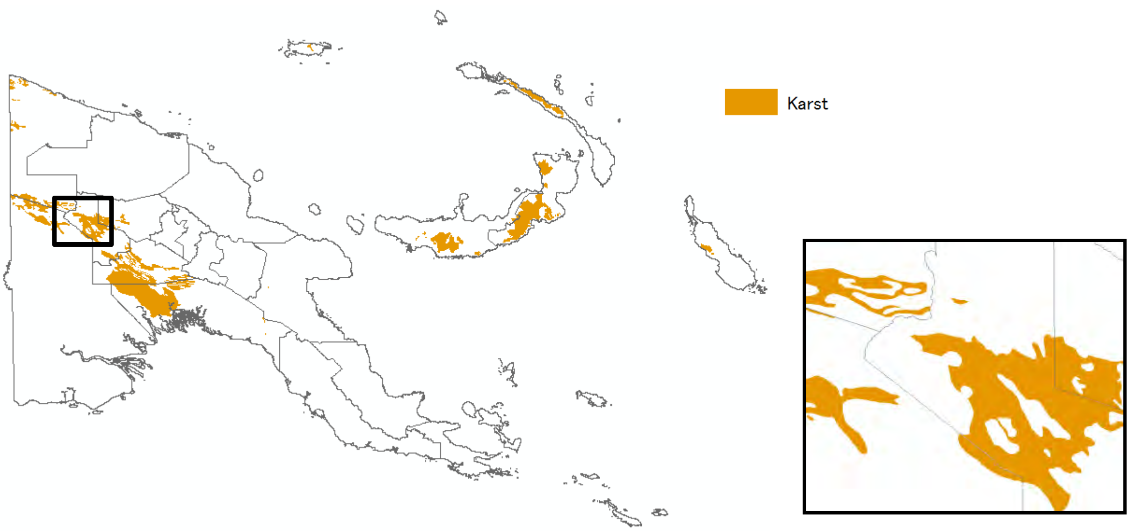


Figure 2.1.11: Data Comparison of Karst

Watershed (Catchment) Data

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 analyzed is predominantly focused on the Watershed Boundary. The watershed boundary delineates the 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 work.

Method

Data Acquisition

The primary source of Watershed Boundary Data is Digital Elevation Model (DEM) datasets. A 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)

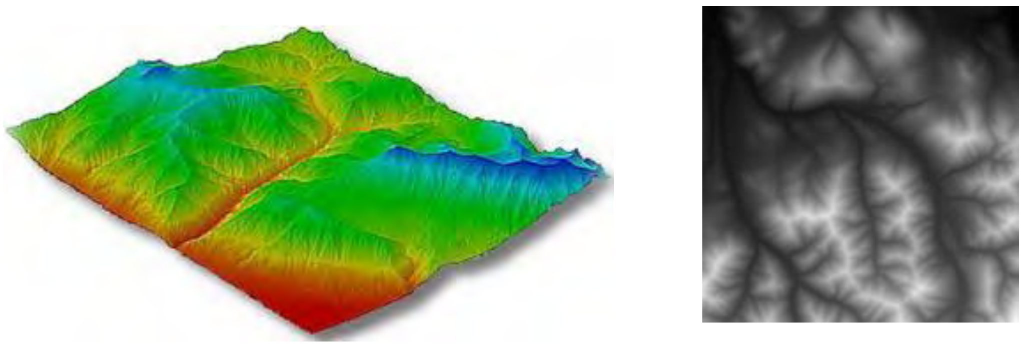


Figure 2.1.12: 3D and 2D representatives of DEM

The dataset that was used in this project was GeoSAR 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, *Shuttle Radar Topography Mission* (SRTM) DEM data with a resolution of 90 meters was used to supplement the data.

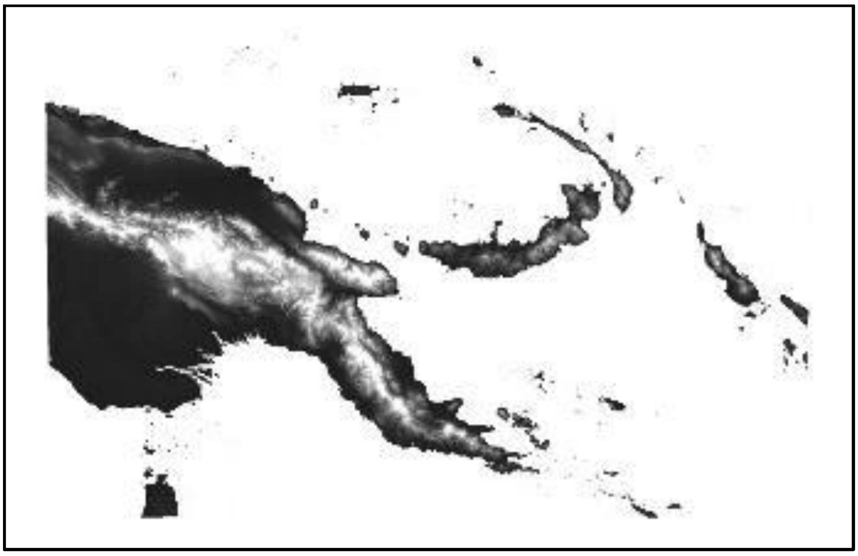


Figure 2.1.13: SRTM 90 meter resolution DEM data covering the whole land area of PNG

Procedure

The sizes 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* 2.1.14 and sample of a created small watershed boundary is shown in *Figure* 2.1.15.

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 Micro-asperity**

The DEM was then "smoothened" out. This was 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.

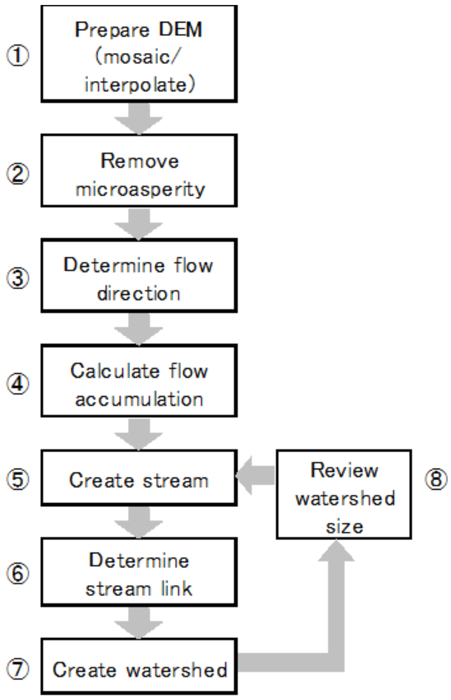


Figure 2.1.14: Work-flow involved in generating Watershed data from DEM

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 those 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* 2.1.15. As a result of the 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.

Figure 2.1.15: 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 >50,000 are classified as low altitude vegetation.

Results

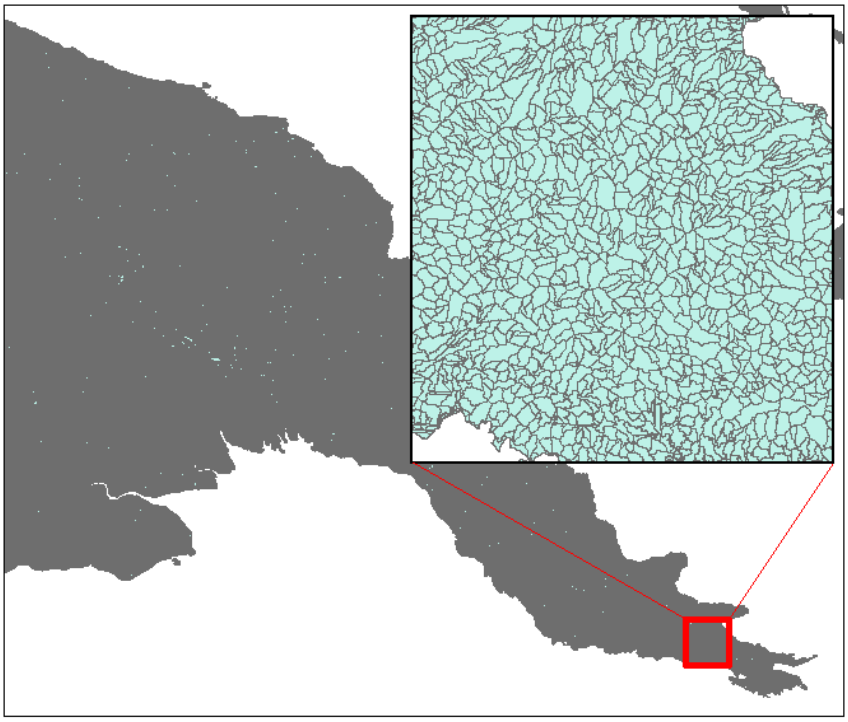


Figure 2.1.16: Sample of PNG Watershed Boundaries shapefile created with DEM Analysis

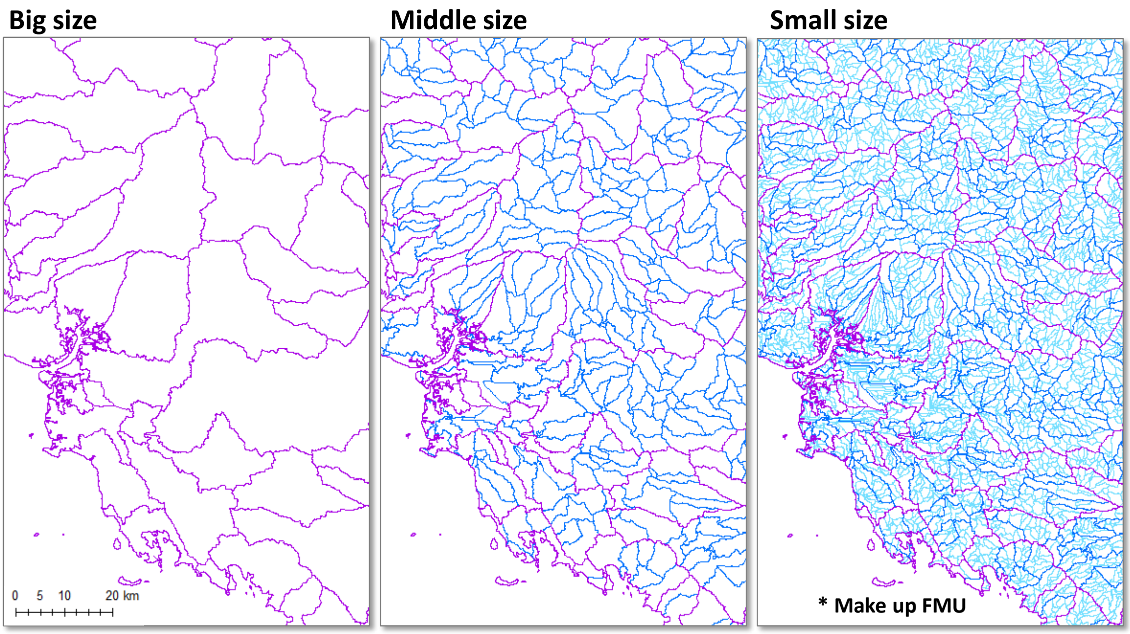


Figure 2.1.17: Three level of Watershed Data of PNG

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.

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 the accuracy of watershed data depends on the 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, which 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 an 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.

Digitized Logging Road Data

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 smaller 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 colors 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. The procedures followed to update this information is described below.

Method

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 2.1.5: The datasets used for digitizing road GIS information

Layer	Source	Remarks
Road GIS information	GeoBook	Derived from NEFC 2005 Cost of Services surveys, satellite imagery and RAMS 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	

LANDSAT AGP 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	

Types of Roads to be digitized

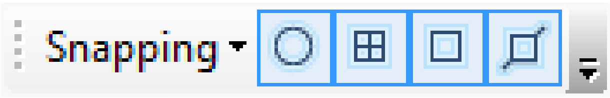
1. National Roads – Roads that are recognized as under the care and management of the National Government. These roads are the major highways and roads that connect the main centres and regions throughout the country.
2. Provincial Level Roads – Roads that are recognized as under the care and management 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.

<u>Procedure</u>

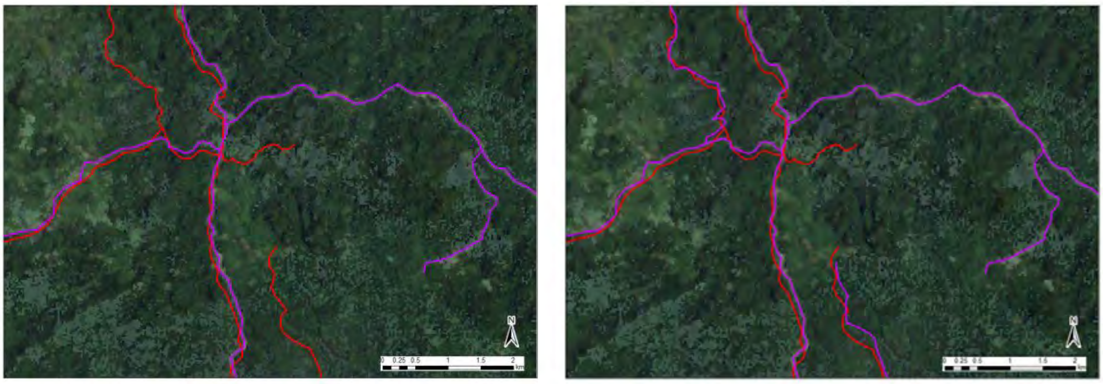
1. Road network of year 2000 was developed as the basis of the information mentioned in the data acquisition above.

A. Digitize road referring LANDSAT AGP 2000 directly

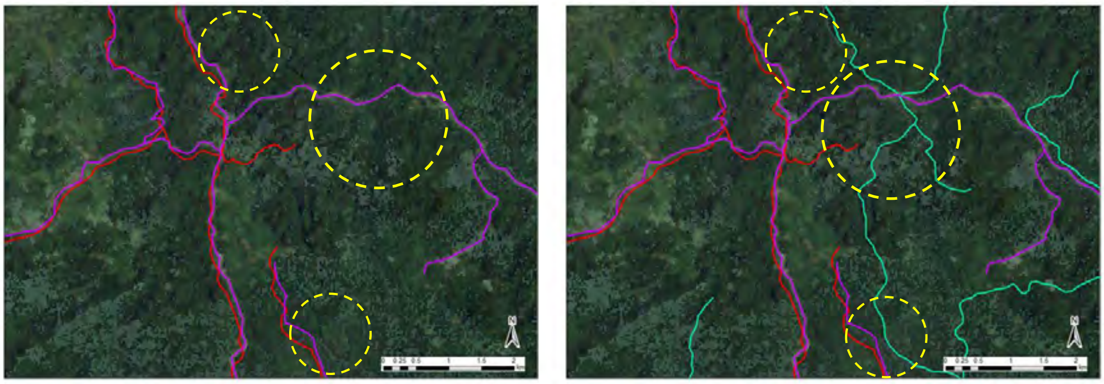
Use “Snapping” tool (from ArcGIS/ArcMap Toolbars) to connect line features.



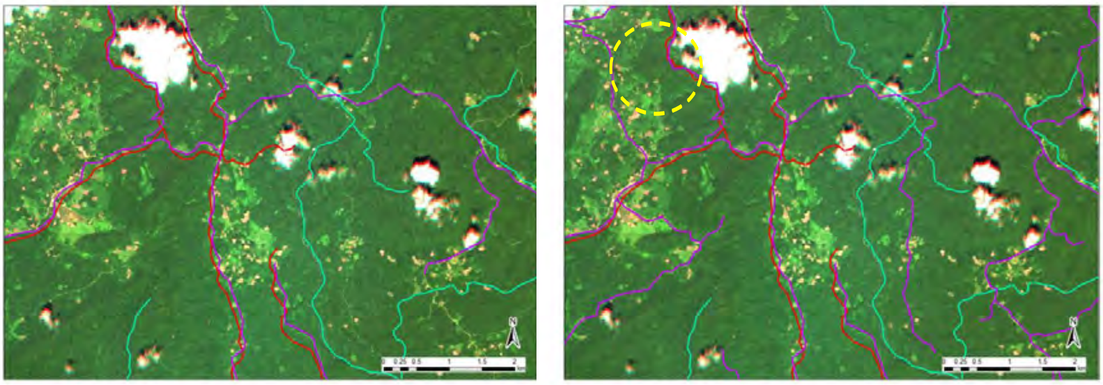
B. Road information of GeoBook is a good reference to digitize unclear roads on LANDSAT AGP.



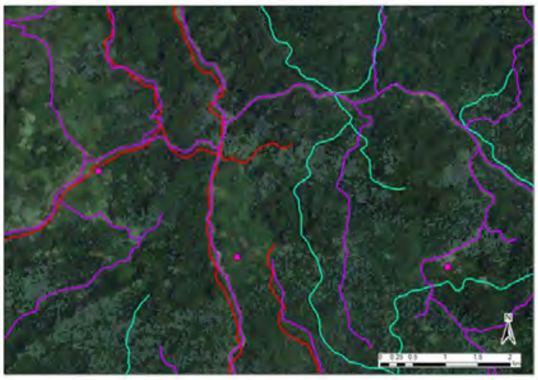
C. To avoid digitize rivers as roads, refer the river GIS information

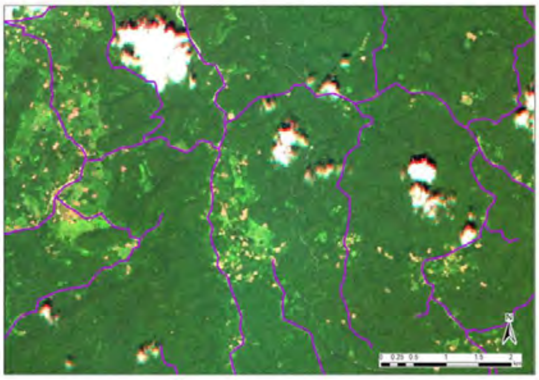


D. Comparing LANDSAT imagery and RapidEye imagery, digitize unclear roads.

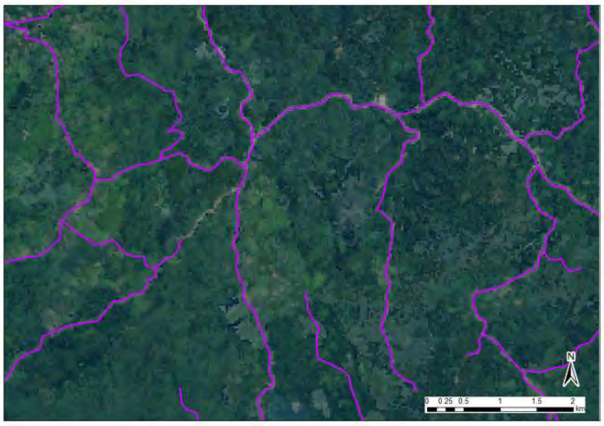


E. Census Unit information is also useful to estimate intensity of human activities. In the following image (top), the pink circles are Census Unit information. The color spotting around the points indicate existing of agricultural fields there.



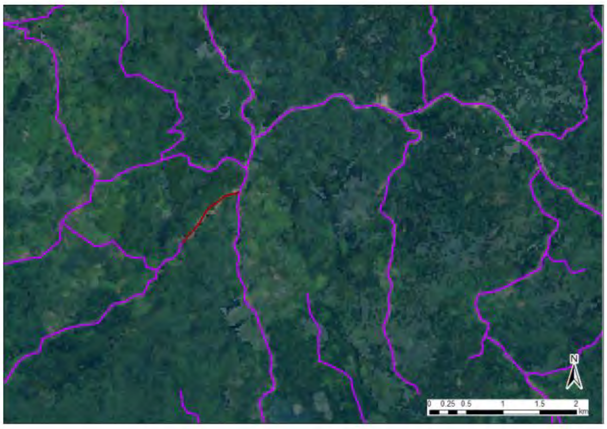


2. Road network of year 2005, 2011 and 2015 were digitized in order from the oldest year adding line features on the road network feature on the older year.



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.



Results

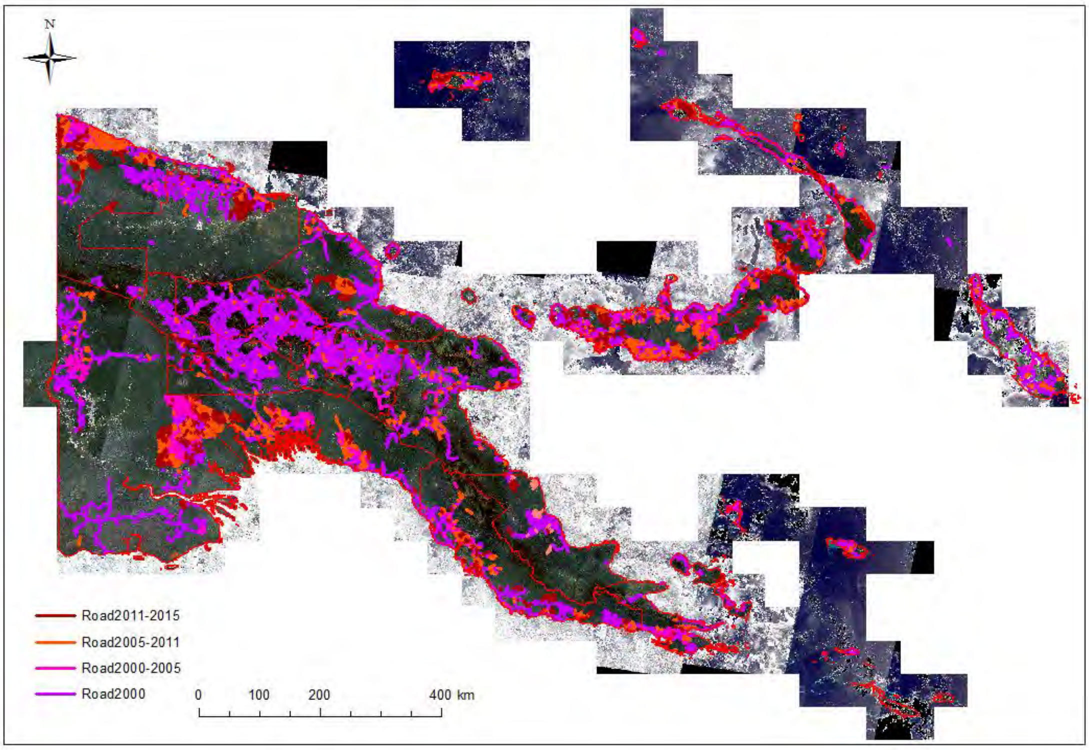


Figure 2.1.18: Map of completed road GIS information

Discussions

- **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.

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

- **Recommendation**

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.

- **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.

Concession/Land Management

Introduction

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.

Logging concessions refer to the permits or licenses 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.

Method

Data Acquisition

Table 2.1.6: Data, source and format of Forest Concession / Land Management Layers

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 PNG-FRIMS. Below is a diagram that illustrates the process in which data is acquired and processed for all logging plans.

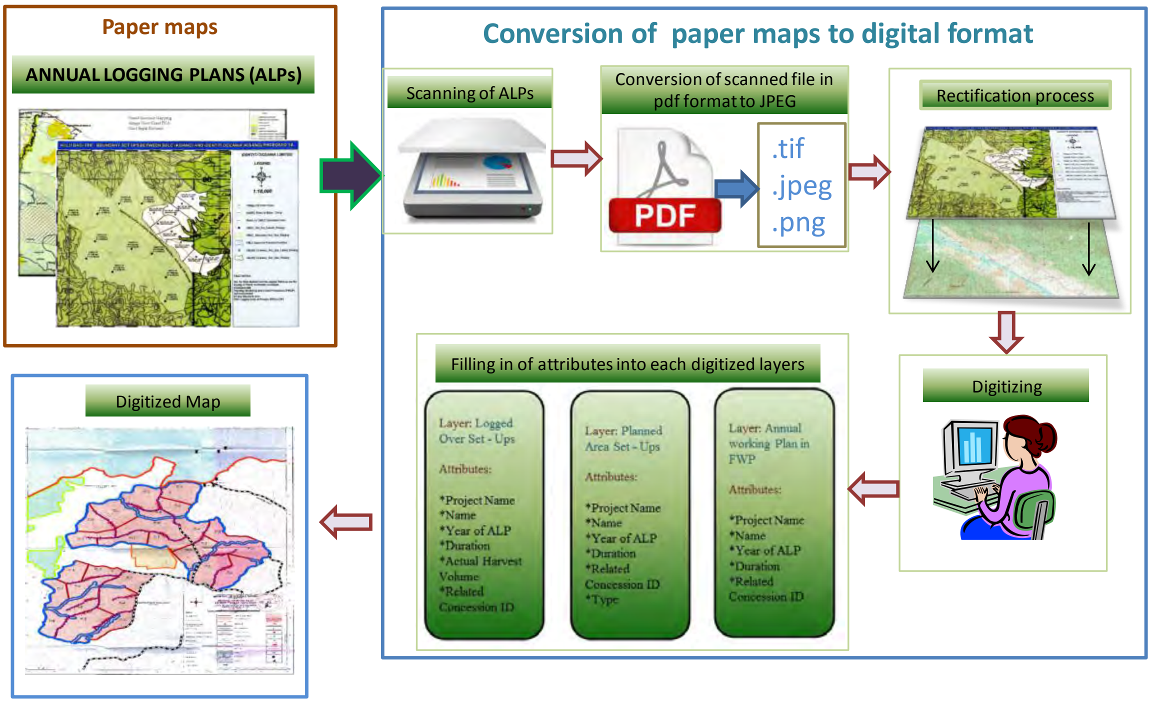


Figure 2.1.19: Process involved in digitizing the ALP's

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 user's 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.
4. For polygons, select points until coming back to the initial starting point, this is called closing the shape.
5. 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.
6. 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.

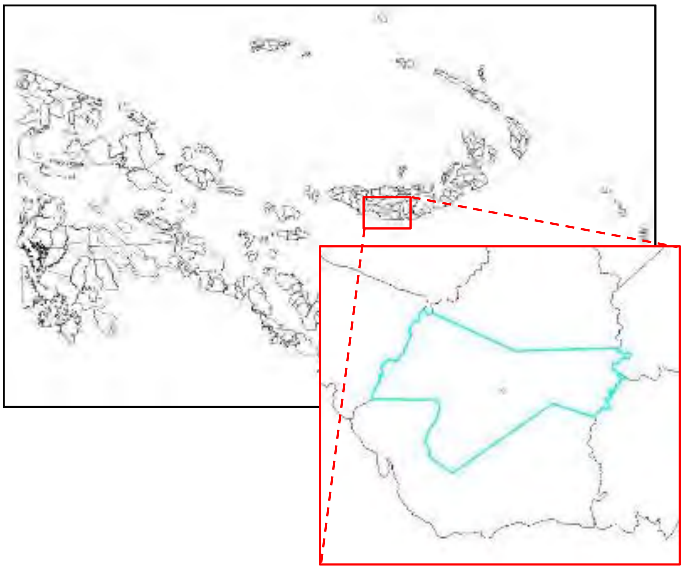
Table 2.1.7: Attributes of Forest Concession / Land Management Layers

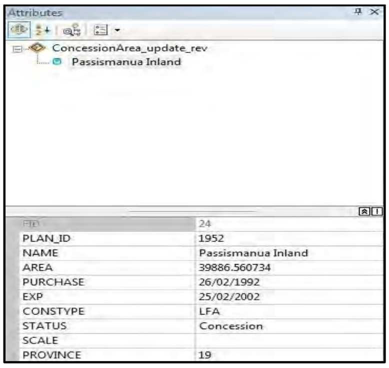
Layer	**Attributes**	Layer	**Attributes**
Logging Concession Boundary	Plan/Concession Id	**Logged Over Area**	Project Name
			Project Type
	Name		Name
	Area		Year of ALP
	Purchase Date		Duration
	Expiry Date		Harvest Volume (ha)
	Concession Type		Concession ID
	Status	**Forest Clearance Authority**	Project Name
	Scale		Project Type
	Province		Name
Logging Plan	Project Name		Year of ALP
	Project Type		Duration
	Name		Harvest Volume (ha)
	Year Of ALP		Concession ID
	Duration	**Forest Plantation Boundary**	ID Name
	Concession ID		Species Name
	Type		Date of Planting
			Date of Harvesting
			Area Size (ha)

Results

- **Logging Concession Boundary**

Below is an illustration on the logging concession boundaries nationwide and on the right is the attribute information for just Passismanua Inland Logging Concession.

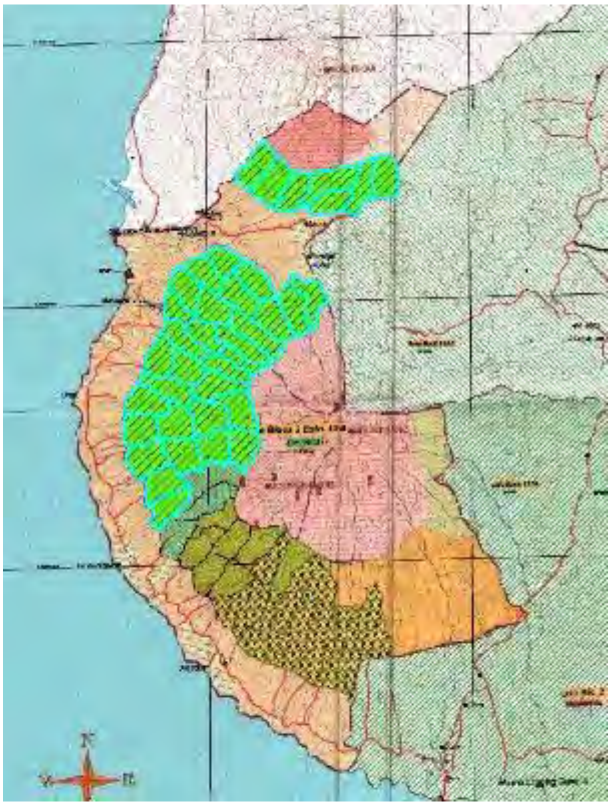


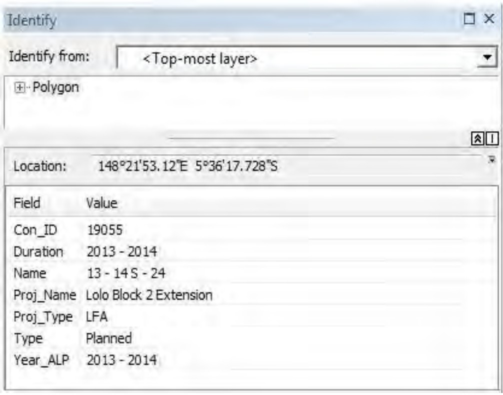


- **Logging Plan**

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]

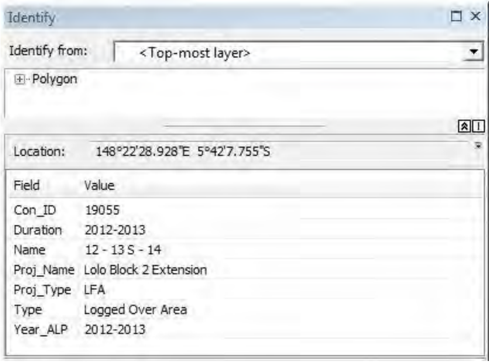




- **Logged Over Area**

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]



Discussions

- **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 Endeavor

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.

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.

2.2 Output 2

To achieve the fourth goal of the Constitution in PNG, PNGFA pursues optimized utilization of the forest resources; balancing economic development with preserving multiple functions of forest. This means that PNGFA implements sustainable forest management (SFM) according to well-designed forest planning system. PNGFA has also been applying SFM in practical phase from both aspect of enforcement of policy and improvement of surveillance capacity in the field. The Project supported these challenges by utilizing the functions of PNG-FRIMS.

First of all, issues to be solved in the planning and implementation of the forest planning system in PNGFA and its solutions were revealed through discussions with various directorates, including the Area and Provincial Offices as indicated in *Table* 2.2.1 and *Table* 2.2.2. To utilize PNG-FRIMS, selection and concentration had been done and the project supported PNGFA focusing on the following three activities for better forest planning in PNGFA.

- **Approach:** Enhance Annual Allowable Cut (AAC) calculation in PNG-FRIMS
  Target issue: Deficiency in Annual Allowable cut volume estimates
  Procedures:
  1. Design the new AAC calculation methodology and its application utilization in forest planning
  2. Redefine the calculation method and instalment of new DD in new function for regrowth volume calculation in the PNG-FRIMS
  3. Gather and update administrative information stored in PNG-FRIMS where necessary
  4. Apply the concrete role of updated AAC in forest planning using updated figures
  5. Clarify how to utilize updated AAC calculation function in PNG-FRIMS for forest monitoring
- **Approach:** Promote Provincial Forest Plans (PFPs) formulation
  Target issue: Inconsistency in the formulation of the Provincial Forest Plans over time.
  Procedures:
  1. Identify the role of Provincial Government and PNGFA in the PFP formulation and explore the supportive role of the Project
  2. Explore the possibility of revising PFP guidelines, and participate in the revision process where necessary
  3. Explore the possibility of assisting and participating in developing PFPs in some provinces where necessary
  4. Utilizing information in PNG-FRIMS to assist and provide guidance in PFP formulation and orientation in PFP guidelines
  5. Develop guideline and procedures on the collation and storage of data/information and utilization of PNGFRIMS for the PFP purposes.
- **Approach:** Improve the capacity to inspect/monitor the forest resources in the field
  Target issue: Lack of logistics and adequate resources (human) to adequately implement PNG Logging Code of Practice
  Procedures:
  1. Demonstrate by selecting and procuring appropriate tools and equipment for improving inspection/monitoring logging activities in pilot concession sites.
  2. Consolidate/develop methodology and training materials through trials in pilot sites
  3. Develop capacity of officers in the pilot concessions and other PNGFA officers through trainings and workshops to inspect logging operations and monitor forest resources using new tools and equipment where necessary
  4. Develop manuals/guidelines to fully operate tools and equipment to improve forest inspection/monitoring

Table 2.2.1: Issues and Solutions for Planning and Implementation of Forest Planning System

As of 24/Nov/2014, updated on 07/Jul/2019

	Contents	Current status	Issues/Problems	Methods/Solutions for addressing the issues with spatial information			
				Training (e.g. GIS,GPS)	**Review of working-flow**	**Preparation of data**	**Review of definition**
National Forest Plan	・National Forest Developmant Guidelines ・National Forest Development Programme ・Provincial Forest Plans ・Statement of annual cut volumes	・Draft NFP will be submitted to the national forest board in Nov. 2014, but not endorsed yet. ・Revised draft is being prepared.	・The lack of valid provincial forest plans. ・Deficient annual allowable cut volume contradinting the picture. ・The absence of the practical national forest inventory.				
Provincial Forest Plans	・Provincial Forest Developmant Guideline ・5 year rolling provincial forest development program	・Guidelines for provincial forest plans is being revised. ・WNB, ENB, and Madang province start reviewing their next provincial forest plans.	***Forest Plans Officer***				
			・The lack of updated area information(e.g. logged over area)		I & M, PAD		
			・The lack of proper definition, identification and <u>demarcation of forest areas</u>		I & M, PAD		I & M, FSD
Forest Management Agreement	・35 year plan for logging		***Acquisition Branch***				
			・Gap between 1. Possible missions and 2. Available resources. 1. (1) Required re-registration of all ILG boundaries for all existing FMAs. (2) Required registration of individual ILG boundary for proposed FMAs. 2. Available resources (finance, manpower and equipment) and skill (GPS, GIS and Map use).	I & M, ACQ			
Forest Management Operation Plans	・5 year forest working plan ・Annual Logging plan ・Set-up plan	・The lack of logistics and human resouces to adequately inspect/monitor the forest resources and logging operations	***Project Allocation Directorate***				
			・Lack of means to detect encroachment on Reserve Forest, Cultural Site and buffer zone (ex. village, river).	I & M, PAD		I & M, KKC	
			・Lack of means to prevent overlapping of FMA (TRP, LFA) and FCA (WMA, etc.).		I & M, PAD		
			・Lack of means to verify logging application for alleged Re-entry into logged over area in TRP and LFA.		I & M, PAD		
			Field Services Directorate				
			・A map on a scale of 1:100,000 with 40m contour interval is too coarse for assessing road system for Annual Logging Plan and Set-Up Plan.			I & M, KKC	
			・Lack of means to detect the discrepancy between the submitted plan and actual operations in the field (e.g. felling and skidding track).	I & M, FSD		I & M, KKC	
			・Lack of resource (finance, manpower and vehicles) and skill (use of maps, GPS and GIS).	I & M, FSD			
			・Lack of means to mediate disputes when landowners bring up boundary and ownership issue again.	I & M, FSD		I & M, KKC	
			・Boundary of land ownership is not readily available when boundary of Set-Up Plans are determined in Annual Logging Plan.	I & M, FSD		I & M, KKC	

List of Acronyms and Abbreviations

I & M	Inventory and Mapping Branch
ACQ	Acquisition Branch
PAD	Project Allocation Directorate
FSD	Field Services Directorate

Table 2.2.2: Issues and Solutions for Planning and Implementation in Area/Provincial offices

As of 22/Aug/2016

Type of Plan	Contents	Means or methods of assessment	Issues/Problems encountered by Area Office, Provincial Office and Project Officer	Methods/Solutions for addressing the issues with spatial information
Provincial Forest Plan	・Consultation for revision with PFMC ・Provision of FIMS data		<u>WNB</u> ・Less interests among stakeholders ・Low level of ownership of Provincial Government on PFP ・Infrequent updating of geographical and resource information	<u>WNB</u> ・New spatial information and satellite imagery may enhance interests of stakeholders ・More frequent update of spatial information (e.g. logged-over area) may help raise interest of stakeholders for revising PFP
Five Year Plan	・Field Inspection	<u>MLB</u> ・Checking the License、Timber Permit、Minimum and Maximum Annual Allowable Cut(AAC)、facility construction <u>WNB</u> ・Checking the location of strip inventory line on site	<u>WNB</u> ・Lack of resources to detect the location of strip line ・Gap between actually harvested log volume and estimation from strip line survey ・No means to verify the reliability of strip line survey ・Re-opening of project boundary issues by landowners	<u>WNB</u> ・Submission of field book data and latitude-longitude coordinates of inventory strip may help identify and verify the location of strip line inventory survey and its estimation ・New spatial information and satellite imagery with precise boundary may remind and convince landowners on exact authentic boundaries
Annual Logging Plan (ALP)	・Endorsment ・Pre-approval	<u>MLB</u> ・Comparing ALP with 5 year plan and Timber Permit <u>WNB</u> ・Checking the consistency between ALP and 5 Year Plan ・Verifying the positional relationship between maps and actual sites	<u>WNB</u> ・Current contour map (40m pitch) is too coarse ・Current map scale (1/100,000) is too small ・Lack of resources (especially GPS) ・Insufficient skill (GPS and map reading)	<u>WNB</u> ・Providing large scale (for example 1/10,000) and fine contour line (10 m pitch) map in digital format ・Procurement of hand-held GPS with digital camera ・Training for GPS and map reading
Set-up Plan	・Approval ・Monitoring	<u>MLB</u> ・Checking the marked trees and set-up boundaries in the field (selection of tree and felling direction) ・Checking the skidding track location	<u>MLB</u> ・Insufficiency of information sharing (Logged-over area (ALP)) ・Lack of resource (finance, manpower, internet communication and spatial information) and skill (GPS and GIS) ・inconvenience to supervise the project (because of remote location and access) <u>WNB</u> ・Mismatching between map and actual site due to map obsoleteness ・Gap between field survey and actual DBH and volume size caused by un-skilled surveyors ・Finding unexpected gardening after ALP was established ・Awareness of landowners/chainsaw operators on forest conservation (value of lowering logging impact) is not high <u>WSP</u> ・Lack of resources (finance (vehicle, laptops and GPS) and manpower) and skill (GIS)	<u>WNB</u> ・Providing updated map to developer for establishing more accurately practicable plan ・Awareness raising by providing satellite imageries which enables LLGs/ landowners/ operators/ surveyors/ camp managers visually grasp the acutual site situation and the impacts of their practices (logging and gardening)

2.2.1 Utilization of AAC derived from PNG-FRIMS for forest planning

Introduction

The Forestry Act, 1991 (as amended) and the National Forest Policy requires that any forestry program or activities are to be in accord with the National Forest Plan (NFP). These programs or activities are to be captured in the National Forest Development Programme which is a major component of the National Forest Plan (NFP). AAC is also another important component of the NFP as illustrated below in *Figure* 2.2.1. It is therefore important to have a robust NFP that is developed based on reliable and up to date data.

> ***"The National Forest Plan shall consist of a statement, prepared annually by the Board, of allowable cut volumes, being the amount of allowable cut for each province for the next succeeding year which will ensure that the areas of forest resource set out in the Provincial Forest Plan, for present or future production."***
> ***- Section 47(2)(c)(iii), the Forestry Act 1991***

Figure 2.2.1: The structure of NFP on the Act 1991

AAC is commonly defined as the volume of timber which may be cut in one year in a given area. Thus, AAC has an important role in planning and sustainable management of forest in PNG by indicating estimated volume to be logged in a certain area per year. Therefore, PNGFA has to ensure that there is a rationally well-designed methodology for collecting necessary data for calculating reliable AAC estimates.

AAC calculated using data stored in FIMS were found to be less reliable and raised a lot of questions as the forest resources continues to decreases as logging continuous. This was the result of some outdated concept/data such as disregard of regrowth volume in logged over area, threat of protection forest including constraint areas, definition of forest area and outdated FBM. To improve the reliability, a new calculation methodology of AAC was developed and install in the PNG-FRIMS, as discussed below.

The role of AAC in forest management cycle in PNGFA

On the occasion of re-designing AAC calculation, the diagrams below have been developed to give a clear view of what happens and how AAC can be calculated. The attempt of clarifying the forest management cycle in PNG was done using a causal loop diagram of the system thinking approach (*Figure* 2.2.2). Only Forest Management Agreement (FMA) and Forest Clearance Authority (FCA) are considered in this cycle, outlining the system which PNGFA demarcates the forest areas for development and managing the forest resources.

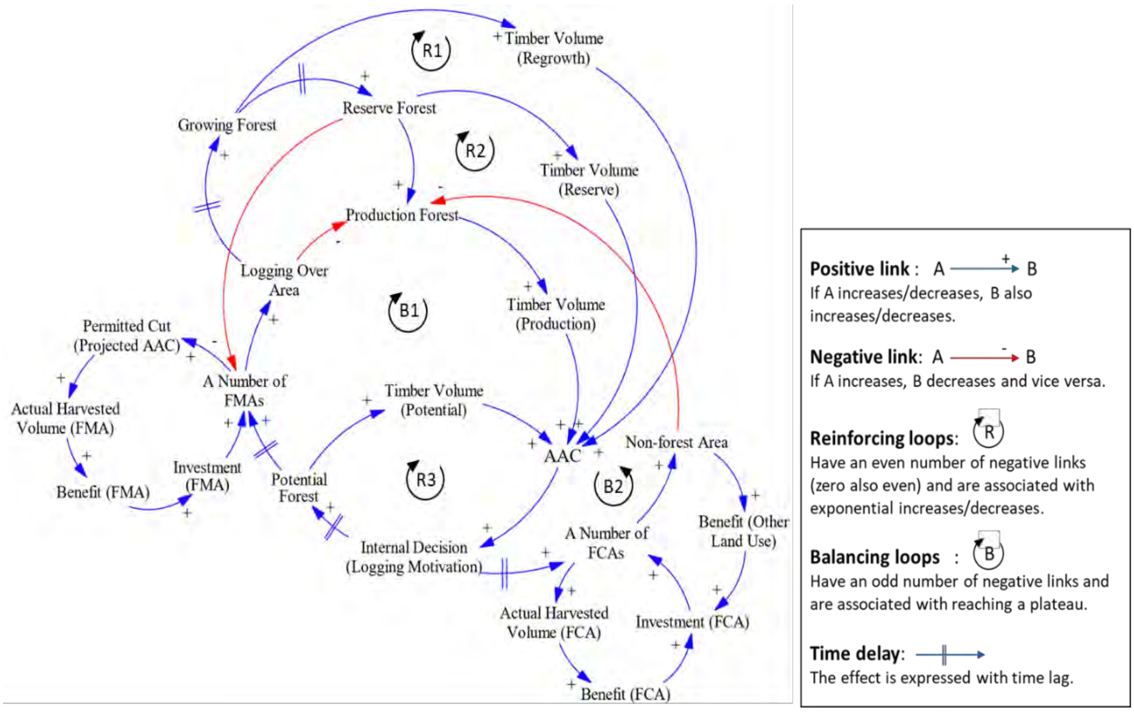


Figure 2.2.2: Causal loop diagram of the forest management cycle in PNG

Based on *Figure* 2.2.3, a new concept of AAC calculation in PNG-FRIMS was designed FIMS original calculated AAC in the production forest consistently decreases following logging. As a result, AAC based on B1 loop continues to decrease till AAC reaches down to nil and in some provinces negative resources. It should be realized that the more aggressive logging activities are, the less AAC will be available for the next cutting cycle.

It should be realized that in the real situation, growing stock slowly increases after logging in the logged or disturbed areas. This growing stock or regrowth volume should be counted on the AAC to grasp the more likely timber volume in the concession areas for management purposes considering the next 35 year cutting cycle if operation returns after 35 years. Thus, reinforcing loop "R1" was added to the new concept of AAC calculation.

Another improvement includes, timber volume in the reserve forest and the potential production forest were added into AAC. Timber volume in these areas, actually, exist out of concession area It is, however, important to determine AAC for the reserve forest and the potential production forest (R2 loop and R3 loop in the diagram) in order to discuss the future development and how to exploit outside the concession areas for SFM.

Through above discussion, two new concepts were designed to calculate more reliable AAC based on the planning process of PNGFA's forest management cycle.

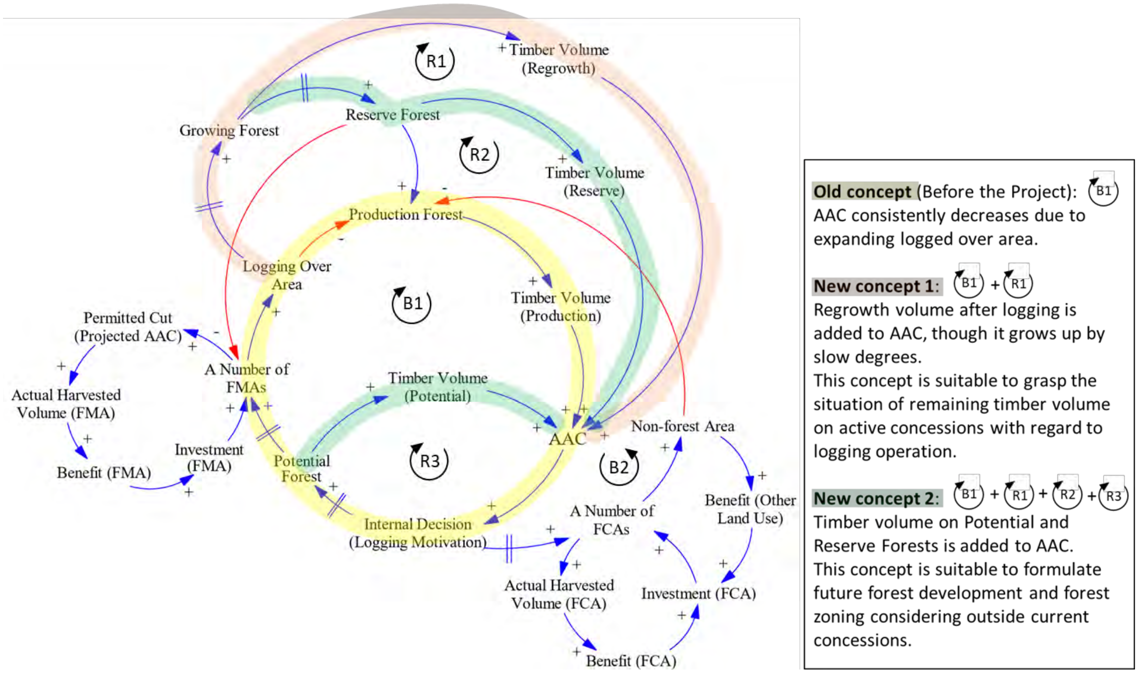


Figure 2.2.3: Before-after of the AAC calculation concept

Update of AAC calculation function in PNG-FRIMS

The calculation processes of AAC in PNG-FRIMS is briefly shown in *Table* 2.2.3 with differences of AAC calculation concept before the Project and after the Project is shown in *Figure* 2.2.4. PNG-FRIMS can compare differences in the reports based on each combination of choices. In "Function" of processes, AAC calculation or new concept calculates timber volume in the production forest, the logged over areas, the reserve forest and the potential production forest for each. So, from the above discussions, PNGFA can use the forest management cycle diagram considering AAC for planning and decision making when considering new projects especially FCA as it reduces the resources or volume in the potential and reverse forest.

Table 2.2.3: Calculation processes and choices of AAC in PNG-FRIMS

Basis of estimated timber volume	Function	Calculation unit	Remarks
Forest Base Map 2012	FMU calculation (old concept)	Province	Forest inside constraint (extreme slope, altitude, WMA and so on) are included.
		Concession area	
	AAC calculation	Province	Target area is only "Net Production Area"
		Concession area	
Old FMU (22 provinces)	FMU calculation (old concept)	Province	Forest inside constraint (extreme slope, altitude, WMA and so on) are included.
		Concession area	
	AAC calculation	Province	Target area is only "Net Production Area"
		Concession area	

Old Concept (before the Project)

$$AAC = (A_{total} - A_{logged}) * V_{standard} \quad / 35 * 0.4$$

Adjusting index

New concept (The Project's output)

$$AAC = \{(A_{net} - A_{logged}) * V_{standard} + V_{regrowth}\} / 35$$

Redefining net production area

Adding regrowth volume

Notice:
Formula calculates total volume of some concession by 35 years later after launching logging.

Abbreviation:

Atotal : Total Forest Area (inc. constraints)
Anet : Net Production Area (exc. constraints)
Alogged : Logged Over Area in net production area
Vstandard : Standard Volume of each forest type
Vregrowth : Regrowth Volume of each forest type

Figure 2.2.4: Differences of the concept of AAC calculation

Basis of estimated timber volume

There are two functions to estimate forest volume using Forest Monitoring Unit (FMU); information in PNG-FRIMS where each unit has several information such as timber volume per hectare as an attribute information) and FBM2012. FBM2012 was created under the Project, whereas FMU was created in 1990's.

Function

Differences between FMU calculation and AAC calculation are mainly the definition of forest area, definition of net production forest (whether potential forest and reserve forest are included in net production forest or not) and consideration of growing stock. Each difference is shown in *Table* 2.2.4.

Calculation Unit

It is possible to calculate AAC for each province or for each concession as will be discussed below.

Table 2.2.4: Differences FMU calculation and AAC calculation

	FMU calculation (old concept)	ACC calculation
Forest Area	Total area of vegetation which has a positive number other than zero (0) in timber volume	According to the definition of forest classification in PNG. Current figures include Sa and Sc, which are set to 0 in timber volume. Forest Area in ACC is larger than FMU calculation.
Timber Volume Calculated	Includes not only Production Forest but also Potential Production Forest, Reserve Forest and Protected Forests including Constraint Areas.	AAC calculation focus on only Production Forest inside operational concession areas. Total timber in each province is smaller than FMU calculation
Forest Regrowth	Only subtract the area of logged over areas, which will be regarded as no potential area (volume = 0). In order to recover the timber volume in FMU calculation, FIMS needs to remove logged over areas in specific areas.	Logged over area will recover over the 35 years linearly. The attribute of Harvested year is important. As of September 2018, AAC calculation uses the purchased year of concession because of no information about harvested year.

Adding regrowth volume is one of the big changes in the new concept of AAC calculation. When a logged-over area is digitized in a concession area, FRIMS (FIMS) regards the volume of the logged-over area as zero. The volume of the logged-over area will recover over the next 35 years linearly.

Example: Logging started in 2000 over the next 35 years

2000	2001	2002	2003	2004	2005	2006
2007	2008	2009	2010	2011	2012	2013
2014	2015	2016	2017	2018	2019	2020
2021	2022	2023	2024	2025	2026	2027
2028	2029	2030	2031	2032	2033	2034

Recovery ratio as of 2001 (2nd Year).

3%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%

Recovery ratio as of 2002 (3rd Year).

6%	3%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%
0%	0%	0%	0%	0%	0%	0%

Recovery ratio as of 2034 (35th Year).

97%	94%	91%	89%	86%	83%	80%
77%	74%	71%	69%	66%	63%	60%
57%	54%	51%	49%	46%	43%	40%
37%	34%	31%	29%	26%	23%	20%
17%	14%	11%	9%	6%	3%	0%

Recovery ratio as of 2036 (37th Year).

100%	100%	97%	94%	91%	89%	86%
83%	80%	77%	74%	71%	69%	66%
63%	60%	57%	54%	51%	49%	46%
43%	40%	37%	34%	31%	29%	26%
23%	20%	17%	14%	11%	9%	6%

Recovery ratio as of 2035 (36th Year).

100%	97%	94%	91%	89%	86%	83%
80%	77%	74%	71%	69%	66%	63%
60%	57%	54%	51%	49%	46%	43%
40%	37%	34%	31%	29%	26%	23%
20%	17%	14%	11%	9%	6%	3%

Recovery ratio as of 2068 (69th Year).

100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	97%

Recovery ratio as of 2069 (70th Year).

100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%
100%	100%	100%	100%	100%	100%	100%

Figure 2.2.5: Example of regrowth volume (growing stock) calculation

Calculating Formula of Regrowth Volume for 2034 ('V' = Forest Volume in the concession area before logging operation starts):

$$\left(\frac{V*1}{35}*\frac{97}{100}\right)+\left(\frac{V*1}{35}*\frac{94}{100}\right)+\left(\frac{V*1}{35}*\frac{91}{100}\right)+\cdots+\left(\frac{V*1}{35}*\frac{3}{100}\right)+\left(\frac{V*1}{35}*\frac{0}{100}\right)$$

Calculating Formula of Regrowth Volume for 2035:

$$\left(\frac{V*1}{35}*\frac{100}{100}\right)+\left(\frac{V*1}{35}*\frac{97}{100}\right)+\left(\frac{V*1}{35}*\frac{94}{100}\right)+\cdots+\left(\frac{V*1}{35}*\frac{6}{100}\right)+\left(\frac{V*1}{35}*\frac{3}{100}\right)$$

Calculating Formula of Regrowth Volume for 2036:

$$\left(\frac{V*1}{35}*\frac{100}{100}\right)+\left(\frac{V*1}{35}*\frac{100}{100}\right)+\left(\frac{V*1}{35}*\frac{97}{100}\right)+\cdots+\left(\frac{V*1}{35}*\frac{9}{100}\right)+\left(\frac{V*1}{35}*\frac{6}{100}\right)$$

Calculating Formula of Regrowth Volume for 2068:

$$\left(\frac{V*1}{35}*\frac{100}{100}\right)+\left(\frac{V*1}{35}*\frac{100}{100}\right)+\left(\frac{V*1}{35}*\frac{100}{100}\right)+\cdots+\left(\frac{V*1}{35}*\frac{100}{100}\right)+\left(\frac{V*1}{35}*\frac{97}{100}\right)$$

There can be two possible scenarios. In scenario 1, regrowth volume within each harvested area (logged over area) is counted as timber volume after 35 years of their logging. On the other hand, in scenario 2, it is counted from the next year of logging. Scenario 2 emphasizes the real amount of timber volume within harvested area as future potential for next logging in terms of future forest planning, whereas the scenario 1 estimates timber volume in a negative trend due to administrative regulations; 35 years after logging is needed for next logging as a cutting cycle. At this version, scenario 2 was adopted because recognition of total timber volume including future potential is important for better forest planning. Moreover, cutting cycle is strictly complied with under PNGFA's shrewd decision even if AAC includes regrowth volume in harvested area before 35 years. The default setting of recovery period is "35years" and the default setting of timing of starting re-growth is after each harvest year. It is possible to change both setting as necessary (*Figure* 2.2.6).

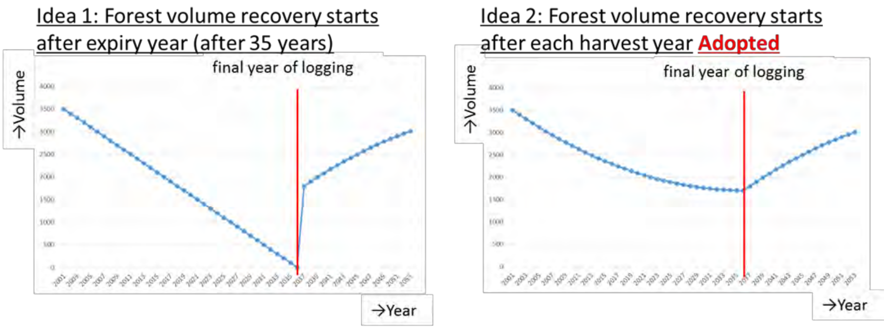


Figure 2.2.6: Timing of adding growing stock counting on AAC

Specification of AAC calculation

1) Forest information used for AAC calculation

Table 2.2.5: Forest information used for AAC calculation

Forest Information		Note
Vegetation	ForestBaseMap2012	New Vegetation Map
	FMU (Forest Mapping Unit)	OLD Vegetation Map stored in FIMS.
Logging Information	Concession Area	Operational Concession Areas (FMA, TPR and LFA) and Proposed Concession (PFD and Proposed PFD).
	Logged Over Area (Logged_NotLandUse)	Areas logged and left to regenerate. Currently, this layer is being updated using ALPs. In the future, Set-Ups boundaries can be identified.
	Logged Over Area (Logged_LandUse)	Areas logged and subsequently converted to other forms of non-forest forms of land use.
	Extreme Altitude	Land over 2400m altitude. (Based on SRTM30)

Forest Information		Note
Constraints (Protection Forests)	Extreme Inundation	Land permanently or near permanently inundated extending over more 80% of the area of that land. (Based on PNGRIS2008)
	Extreme Karst	Land with polygonal karst landform.
	Extreme Slope	Land with over 30-degree dominant slope. (Based on SRTM30)
	Mangrove	Land covered by mangroves. (Extracted form ForestBaseMap2012)
	Protected Area	Wildlife Management Area, etc. (From CEPA)
	Serious Inundation	*50-80% permanent or near permanent inundation. (Based on PNGRIS2008). AAC calculation ignores the Serious Inundation.*
	Serious Slope Relief	*Land with dominant slope of 20-30 degrees and sub-dominant slope over 30 degrees and with high to very high relief. AAC calculation ignores the Serious Slope Relief.*
Plantation	Forest Plantation	(Extracted form ForestBaseMap2012)
Grassland	FCA (Forest Clearance Boundary)	FCA boundary has not been prepared.

2) Vegetation type and forest classification

1. Forest Base Map 2012

Table 2.2.6: Vegetation type and forest classification in FBM2012

Vegetation Code (New Map)		Description	Classification
1	P	Low altitude forest on plains and fans - below 1000 m	Forest
2	H	Low altitude forest on uplands - below 1000 m	Forest
3	L	Lower montane forest - above 1000 m	Forest
4	Mo	Montane forest - above 3000 m	Forest
5	B	Littoral forest	Forest
6	D	Dry seasonal forest	Forest
7	Fri	Seral forest	Forest
8	Fsw	Swamp forest	Forest
9	M	Mangrove	Protection
10	W	Woodland	Forest
11	Sa	Savanna	Forest
12	Sc	Scrub	Forest
13	G	Grassland and herbland	Grassland
14	Ga	Alpine grassland - above 3200 m	Grassland
15	Gi	Subalpine grassland - above 2500 m	Grassland
16	O	Cropland/Agriculture land	Other Area
17	Qa	Plantation other than forest plantation	Other Area

Vegetation Code (New Map)		Description	Classification
18	Qf	Forest plantation	Forest Plantation
19	Z	Bare area	Other Area
20	U	Larger urban centre	Other Area
21	E	Waterbody	Other Area
22	Es	Sea	Other Area

2. FMU (Old vegetation map stored in FIMS)

Table 2.2.7: Vegetation type and forest classification in FMU

Vegetation Code (Old Map)		Description	Classification
1	Pl	Large to medium crowned forest	Forest
2	Po	Open forest	Forest
3	Ps	Small crowned forest	Forest
4	Hl	Large crowned forest	Forest
5	Hm	Medium crowned forest	Forest
6	HmAr	Medium crowned forest with Araucaria common	Forest
7	Hmd	Medium crowned depauperate/damaged forest	Forest
8	Hme	Medium crowned forest with an even canopy	Forest
9	Hs	Small crowned forest	Forest
10	Hse	Small crowned forest with an even canopy	Forest
11	HsAv	Small crowned forest with Araucaria common	Forest
12	HsCa	Small crowned forest with Castanopsis	Forest
13	HsCp	Small crowned forest with Casuarina papuana	Forest
14	HsN	Small crowned forest with Nothofagus	Forest
15	HsRt	Small crowned forest with Rhus taitensi	Forest
16	L	Small crowned forest	Forest
17	LAr	Small crowned forest with Araucaria common	Forest
18	LN	Small crowned forest with Nothofagus	Forest
19	Lc	Small crowned forest with conifers	Forest
20	Ls	Very small crowned forest	Forest
21	LsCp	Very small crowned forest with Casuarina papuana	Forest
22	LsN	Very small crowned forest with Nothofagus	Forest
23	Mo	Very small crowned forest	Forest
24	D	Dry evergreen forest	Forest
25	B	Mixed forest	Forest
26	Bce	Forest with Casuarina equiselifolia	Forest

Vegetation Code (Old Map)		Description	Classification
27	BMl	Forest with Melaleuca leucadendron	Forest
28	Fri	River line mixed successions	Forest
29	FriCg	River line successions with Casuarina grandis	Forest
30	FriK	Riverine successions with Eucalyptus deglupta	Forest
31	Fritb	Riverine successions with Terminalia brassii	Forest
32	Fv	Volcanic successions	Forest
33	Fsw	Mixed swamp forest	Forest
34	FswC	Swamp forest with Campnosperma	Forest
35	FswMl	Swamp forest with Melaleuca leucadendron	Forest
36	FswTb	Swamp forest with Terminalia brassii	Forest
37	W	Woodland	Forest
38	Wri	Riverine successions dominated by woodland	Forest
39	WriCg	Riverine successions with Casuarina grandis woodland	Forest
40	Wv	Volcanic successions dominated by woodland	Forest
41	Wsw	Swamp woodland	Forest
42	WswMl	Swamp woodland with Melaleuca leucadendron	Forest
43	Sa	Savanna	Forest
44	Saf	Savanna with galley forest	Forest
45	SaMl	Savanna with Melaleuca leucadendron	Forest
46	Sc	Scrub	Forest
47	ScBc	Scrub with Bambusa and Cyathea	Forest

3) Forest definition and AAC calculation order

Table 2.2.8: Forest definition for AAC calculation

<table>
<tr><th colspan="3">Item</th><th>Description</th><th>Calculation Order</th></tr>
<tr><td>a</td><td colspan="2">Total Land Area</td><td>The total area of Forest Base Map other than “Sea (code = Es)” by province. (b)+(h)+(i)</td><td>1</td></tr>
<tr><td>b</td><td colspan="2">Gross Forest area</td><td>(c)+(d)+(e)+(g)</td><td>9</td></tr>
<tr><td rowspan="2">c</td><td colspan="2">Production Forest</td><td>The forest area in the operational Concession Areas with FMA, TRP, LFA and TA-01 <u>other than the area overlapping with Protection Forest and Grassland.</u></td><td rowspan="2">6</td></tr>
<tr><td>Total</td><td>Un-logged area</td><td>The total forest area in the operational concession areas that have not been harvested.</td></tr>
</table>

Item			Description	Calculation Order
		Logged-over area	The total forest area in the Logged Over Areas in operational concession areas. Logged-over area includes two GIS layers. (1) 'Logged_NotLandUse', which are areas logged and left to regenerate. (2) 'Logged_LandUse', which are areas logged and subsequently converted to other forms of non-forest forms of land use. Re-growth does not happen in 'Logged_LandUse'.	
	FMA	Un-logged area	The total forest area in the operational FMAs not covered by Logged Over Area.	
		Logged-over area	The total forest area in operational FMAs overlapping with Logged Over Area.	
	TRP	Un-logged area	The total forest area in the operational TRPs not covered by Logged Over Area.	
		Logged-over area	The total forest area in the operational TRPs overlapping with Logged Over Area.	
	LFA	Un-logged area	The total forest area in the operational LFAs not covered by Logged Over Area.	
		Logged-over area	The total forest area in the operational LFAs overlapping with Logged Over Area.	
	TA01	Logged-over area	No data for now. Field Services has coordinates information of the center of each TA-01 on the map. It can be available to estimate forest area.	
d	Potential Production Forest		The forest area in Proposed Concession Areas other than the area overlapping with Protection Forest and Grassland. Proposed Concession for AAC calculation means PFD (Potential Forest Development) and Proposed PFD listed in Provincial Forest Plans. This calculation excludes the concession data having the attributes which are 'Status=proposed', and 'Remarks= tentative' or " Remarks = cancellation".	7
		Un-logged area	The total forest area in the proposed concession areas not covered by Logged Over Area	
		Logged-over area	The total forest area in the proposed concession areas overlapping with Logged Over Area	

Item			Description	Calculation Order
e	Reserve Forest		The forest area in the expired concession areas, and the forest area that has never been designated and planned as concession area.	8
		Un-logged area	The total forest area in the reserved forest not covered by Logged Over Area	
		Logged-over area	The total forest area in the reserved forest overlapping with Logged Over Area. This calculation regards whole area of expired concession as Logged-Over Area. Because it is too difficult to search for old maps recording logging history of expired concession, especially TRP.	
f	Protection Forest		Includes "Extreme Slope (> 30 degree)", "Extreme Altitude (> 2,400m)", "Extreme Karst", "Extreme Inundation (over more 80% permanent)", "Mangrove" of Forest Base Map, and "Protected Area". *Protection Forest excludes "Serious Inundation (50-80% permanent)" and "Serious Slope (20-30 degree)".*	4
		Mangrove	Pick out the area of Mangrove (Code = M) included in Forest Base Map	
g	Forest Plantation		Pick out the area of Forest Plantation (Code = Qf) included in Forest Base Map	5
h	Grassland (afforestation potential)		The area of Grassland other than the area overlapping with Protection Area. The area of FCA (Forest Clearance Boundary) other than the area overlapping with Protection and Grassland.	2
i	Other Areas		Pick out the area of Other area other than the area overlapping with Protection Area (Code = O, Qa, Z, U and E)	3

(Calculation order)
Grassland > Other Areas > Protection Forest > Forest Plantation > Production Forest > Potential Forest > Reserve Forest

4) Examples of output of AAC calculation

1. New concept 1: Net production area = Production Forest

Table 2.2.9: Example table of AAC output 1

Calculation Example 1 Net Production Area = Production Forest

Appendix 5a_1: Annual Allowable Cut for PNG in NFP 2015 – 2020

Province	Net Production Area (ha) (c)	Logged Over Area in Net Production Area (ha) (k)	Un-logged Area in Net Production Area (ha) (l) ((c)-(k))	Rerowth Volume in Logged Over Area (m³) (m)	Volume in Un-logged Area (m³) (n)*1	Gross Merchantable Volume (m³) (o) ((m)+(n))	AAC (m³) (p) ((o)/ 35)	Permitted Cut Under Projects (2013) (q)	Balance AAC (2013) (r) ((p)-(q))	Projected AAC 2015-2019 (000 m³) 2015	2016	2017	2018	2019
Western	1,221,000					0		826,000	817,793	736	736	736	736	736
Gulf	2,238,137					0		1,186,000	-348,997	1,046	1,046	1,046	1,046	1,046
Central	360,432					0		270,000	583,194	343	343	343	343	331
Milne Bay	113,720					0		58,000	228,773	109	109	109	109	109
Oro	221,000					0		288,000	422,728	153	153	153	153	153
Morobe	195,941					0		185,000	925,885	241	241	241	241	141
Madang	384,980					0		568,000	178,338	418	288	288	138	138
East Sepik	521,500					0		397,000	428,252	150	150	150	150	150
Sandaun	1,055,627					0		907,200	226,154	554	554	554	554	554
Manus	32,667					0		212,000	-177,880	146	146	132	132	132
New Ireland	209,115					0		180,000	-46,985	180	180	180	60	60
E.NB	215,689					0		562,500	-243,788	380	380	380	380	380
WNB	657,799					0		2,538,700	-2,307,765	2,434	1,704	1,549	1,549	1,549
AGB	46,720					0		0	254,716	0	0	0	0	0
SHP	98,750					0		80,000	924,292	80	80	80	80	80
EHP	0					0		0	385,002	0	0	0	0	0
Simbu	0					0		0	213,179	0	0	0	0	0
WHP	0					0		0	266,584	0	0	0	0	0
Enga	0					0		0	508,097	0	0	0	0	0
Total	7,573,077	0	0	0	0	0		8,258,400		6,970	6,110	5,941	5,671	5,559

Source: Original table and figures are prepared for NFB on 19th Nov. 2015 based on FIMS Database

*1: Volume is calculated by Forest Monitoring Unit of Forest Basemap 1.2 and its tentative volume

Figures in italic indicates original values copied from the draft prepared for NFB on 19th Nov. 2015

Table 2.2.10: Items for AAC calculation 1

Item		Description
c	Net Production Area	Net Production Area = Production Forest
k	Logged Over Area in Net Production Area	Logged over area in Production Forest
l	Un-logged Area in Net Production Area	(c)-(k) (As same as Un-logged area of (c))
m	Regrowth Volume in Logged Over Area	[Production Forest (c)] The volume of Logged Over Areas (of 'Logged_NotLandUse' layer) in the operational Concession Areas is calculated. The target Concession types are FMA and TRP except for LFA. Regrowth does not happen in LFA. (Option 1) The volume of the Logged Over Area with harvested year will recover over the 35 years linearly based on the harvested year per each polygon data of the logged over area. (Option 2) If Logged Over Areas in the operational concession area have no harvested year, the sum total area of the Logged Over Areas will be divided equally by elapsed years from the purchased year. The area divided will recover over the next 35 years linearly. The elapsed years increase up to 35. Option1 and Option2 are implemented in the AAC calculation function.

Item		Description
n	Volume in Un-Logged Area	The formula is as below. Volume per unit area of each vegetation type * area of each vegetation type inside Un-Logged Area.
o	Gross Merchantable Volume	(m) + (n)
p	AAC (m^3)	(o) / 35
q	Permitted Cut Under Projects (Year)	Permit Cut Volume that is managed by Project Branch will be entered. The year shown in the table will be designated by the editor of the Appendix 5a.
r	Balance AAC (Year)	(p) – (q) The year shown in the table will be designated by the editor of the Appendix 5a.
	Projected AAC	Projected AAC Volume will be entered by the editor of the Appendix 5a. The years shown in the table will be according to the planning year of the title.

2. New concept 2: Net production area = the production forest + the reserve forest + the potential production forest

Table 2.2.11: Example table of AAC output 2

Calculation Example 2 Net Production Area = Production Forest + Potential Production Forest + Reserve Forest

Appendix 5a_2: Annual Allowable Cut for PNG in NFP 2015 – 2020

Province	Net Production Area (ha) (j)	Logged Over Area in Net Production Area (ha) (k)	Un-logged Area in Net Production Area (ha) (l) ((j)-(k))	Rerowth Volume in Logged Over Area (m³) (m)	Volume in Un-logged Area (m^3) (n)*1	Gross Merchantable Volume (m³) (o) ((m)+(n))	AAC (m^3) (p) ((o)/ 35)	Permitted Cut Under Projects (2013) (q)	Balance AAC (2013) (r) ((p)-(q))	Projected AAC 2015-2019 (000 m^3)				
										2015	2016	2017	2018	2019
Western	3,221,592					0		*826,000*	*817,793*	*736*	*736*	*736*	*736*	*736*
Gulf	2,468,523					0		*1,186,000*	*-348,997*	*1,046*	*1,046*	*1,046*	*1,046*	*1,046*
Central	1,552,852					0		*270,000*	*583,194*	*343*	*343*	*343*	*343*	*331*
Milne Bay	796,250					0		*58,000*	*228,773*	*109*	*109*	*109*	*109*	*109*
Oro	932,528					0		*288,000*	*422,728*	*153*	*153*	*153*	*153*	*153*
Morobe	1,315,017					0		*185,000*	*925,885*	*241*	*241*	*241*	*241*	*141*
Madang	993,516					0		*568,000*	*178,338*	*418*	*288*	*288*	*138*	*138*
East Sepik	638,029					0		*397,000*	*428,252*	*150*	*150*	*150*	*150*	*150*
Sandaun	2,487,247					0		*907,200*	*226,154*	*554*	*554*	*554*	*554*	*554*
Manus	156,833					0		*212,000*	*-177,880*	*146*	*146*	*132*	*132*	*132*
New Ireland	611,473					0		*180,000*	*-46,985*	*180*	*180*	*180*	*60*	*60*
E.NB	767,447					0		*562,500*	*-243,788*	*380*	*380*	*380*	*380*	*380*
WNB	1,024,247					0		*2,538,700*	*-2,307,765*	*2,434*	*1,704*	*1,549*	*1,549*	*1,549*
AGB	681,643					0		*0*	*254,716*	*0*	*0*	*0*	*0*	*0*
SHP	503,929					0		*80,000*	*924,292*	*80*	*80*	*80*	*80*	*80*
EHP	59,256					0		*0*	*385,002*	*0*	*0*	*0*	*0*	*0*
Simbu	167,073					0		*0*	*213,179*	*0*	*0*	*0*	*0*	*0*
WHP	174,310					0		*0*	*266,584*	*0*	*0*	*0*	*0*	*0*
Enga	82,856					0		*0*	*508,097*	*0*	*0*	*0*	*0*	*0*
Total	18,634,621	0	0	0	0	0	0	*8,258,400*		*6,970*	*6,110*	*5,941*	*5,671*	*5,559*

Source: Original table and figures are prepared for NFB on 19th Nov. 2015 based on FIMS Database

*1: Volume is calculated by Forest Monitoring Unit of Forest Basemap 1.2 and its tentative volume

Figures in italic indicates original values copied from the draft prepared for NFB on 19th Nov. 2015

Table 2.2.12: Items for AAC calculation 2

Item		Description
j	Net Production Area	Net Production Area = Production Forest (c)+Potential Production Forest (d)+Reserved Forest (e)
k	Logged Over Area in Net Production Area	Logged over Area of (c) + Logged over area of (d) + Logged over area of (e)
l	Un-logged Area in Net Production Area	(j)-(k) (as same as Un-logged are of (c) + Un-logged area of (d) + Un-logged area of (e))
m	Regrowth Volume in Logged Over Area	[Production Forest (c)] As same formula as Appendix5a_1 [Potential Production Forest (d)] Regrowth is not taken into consideration if there are no harvested year information for Logged Over Area in Proposed Concession. If Logged Over Area have it, Regrowth volume can be calculated. [Reserve Forest (e)] This calculation regards whole area of expired concession as Logged-Over Area. Constant logging rate is adopted during the contract of TRP. (**see the following figures and formulas**)
n	Volume in Un-Logged Area	The formula is as below. Volume per unit area of each vegetation type * area of each vegetation type inside Un-Logged Area. The Un-Logged Areas are in Production Forest (c), Potential Production Forest (d) and Reserve Forest (e).
o	Gross Merchantable Volume	(m) + (n)
p	AAC (m^3)	(o) / 35
q	Permitted Cut Under Projects (Year)	Permit Cut Volume that is managed by Project Branch will be entered. The year shown in the table will be designated by the editor of the Appendix 5a.
r	Balance AAC (Year)	(p) – (q) The year shown in the table will be designated by the editor of the Appendix 5a.
	Projected AAC	Projected AAC Volume will be entered by the editor of the Appendix 5a. The years shown in the table will be according to the planning year of the title.

Outputs and its Usage for forest planning

Two types of AAC based on new concept are shown in Appendix: Table 3-2-1 and Appendix: Table 3-2-2. In both outputs, below processes were selected.

- Basis of estimated timber volume: **FBM2012**
- Function: **AAC calculation**
- Calculation unit: **Province**

Focusing on the timber volume within only concession areas, National estimated AAC is approximately 3.8 million cubic meters. In the long-term growing stock or regrowth volume in the logged over areas will gradually flourish much more. On the other hand, as long as logging activities continue within the same concession areas, AAC decreases in the short term. That is why the harvested timber volume is deducted from AAC immediately when a certain area is logged, whereas the yield ratio of growing stock is apparently slow than the elimination by logging activities

Total estimated AAC outside the concession area is over 23 million cubic meters. This means that there is a possibility in PNG to expand or acquire further production forest areas. We, however, have to contemplate that the areas of FCA and small-scale logging including the activities under Timber Authority are not eliminated from AAC. It may need to stand a conservative position for ensuring sustainable yield in the future. Whatever the case may be, it is important to use this figure as one of tools to decide any measures and policies such as NFP and PFPs, embracing attention to the technical and administrative limitation of AAC calculation and the figures of AAC are not exact.

Permitted Cut and Actual Harvested Volume are also good indicators to grasp the actual condition of total amount of timber volume allowed to holders of timber permit and actual condition of logging under Permitted Cut. Whereas AAC is for planning, these figures are useful to check the implementation of logging activities. Comparison of AAC to Permitted Cut and Actual Harvested Volume and National Sustainable Cut will contribute to reliable cross check between planning and implementation of logging operations. Summation of Permitted Cut often exceed estimated AAC and National Sustainable Cut. In the case of 2017, Permitted Cut counted approximately 7 million cubic meters, whereas estimated AAC within concession areas at 2019 becomes approximately 3.8 million cubic meter and National Sustainable Cut constantly equals 3.5 million cubic meters. Although this may look like there is over-logging outside the reach of sustainability at a glance, we can check its adequacy comparing to Actual Harvested Volume. It is an integral part of wise planning to comprehensively do a comparison of these figures.

For the purpose of better forest planning, discussions based on the reliable indicators is essential. Estimated AAC is able to directly affect the decision making of demarcation of forest areas. On the other hand, Permitted Cut will be automatically calculated when the concession areas are developed. Permitted Cut is subsequent figures after decision making of forest area based on estimated AAC. But paying attention to Permitted Cut and Actual Harvested Volume and comparing it to estimate AAC enrich more fruitful discussion in decision making such as formulation of NFP and PFPs (*Figure* 2.2.7). Decision making for future development of the project and demarcating between forest (FMAs) and non-forest (FCAs) is also affected by NFP, and AAC provides estimated timber volume in NFP for forest management cycle in PNG.

To understand the differences between Permitted Cut and estimated AAC derived from PNG-FRIMS, it is important to view the comparisons between the two. Basically, estimated AAC and Permitted Cut have a similar concept, but this often causes misunderstanding and disruption because each estimated figure looks quite different.

$$\frac{Volume\ * Area}{Cutting\ Cycle}$$

This difference mainly derives from two reasons of each calculation scheme. First, regarding area, net production area of AAC is extracted according to Forest Base Map and GIS function of PNG-FRIMS, though non-productive area of Permitted cut is extracted according to stereo type guidelines of PNGFA, e.g., Conservation area: 10%). Second, AAC is affected by logged over area, though Permitted Cut continues based on initial condition of forests, which has flourished timber volume as intact forest, till concessions expire. Thus, AAC gets decrease easily rather than Permitted Cut because logged over area affects AAC immediately, but expired concessions as Reserve Forest do not appear until 35 years later.

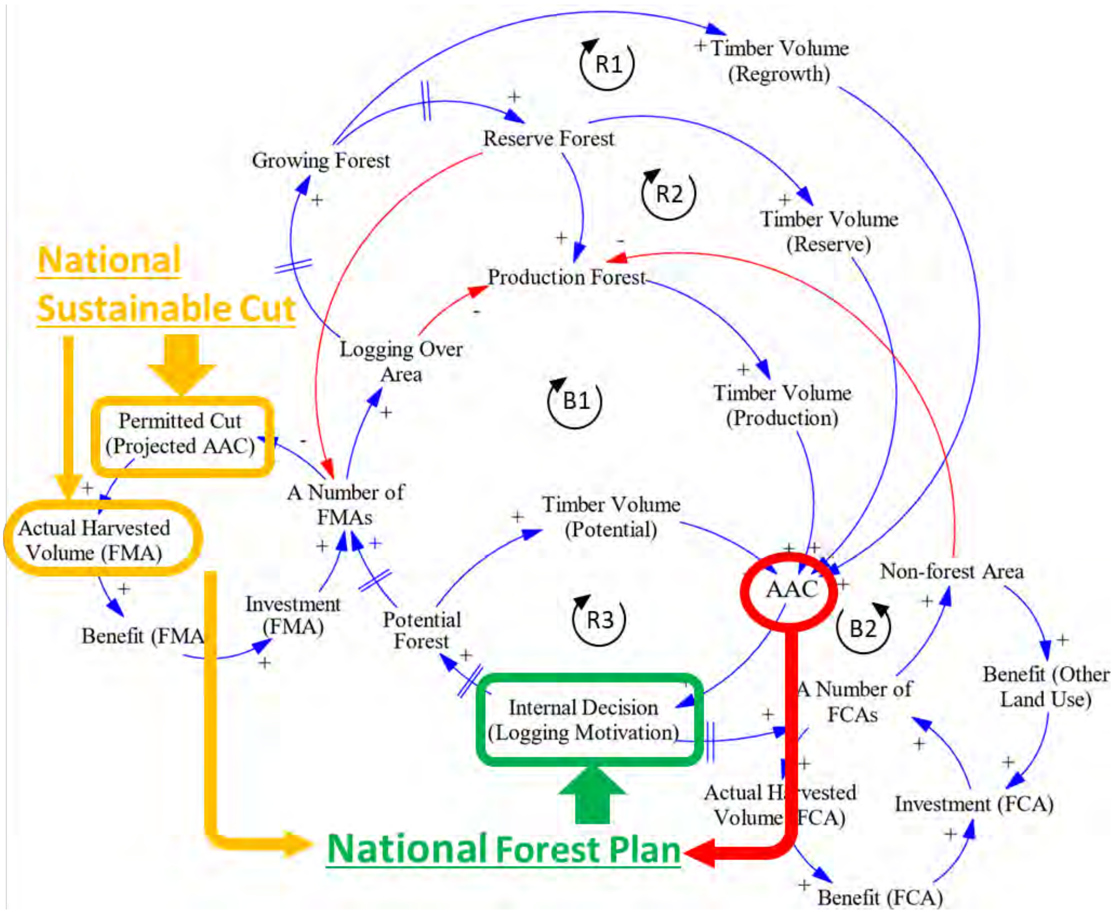


Figure 2.2.7: Role of AAC and Permitted Cut for the forest plannning

Discussions

New AAC is automatically calculated when such information as logged over area, concession boundary, constraints, etc. is updated. In order to make AAC reliable, it is important to maintain the freshness of each data stored in PNG-FRIMS. Especially, information of logged over area is key factor to grasp the regrowth volume and should be frequently updated.

The data of logged over areas is described in maps being attached to Annual Logging Plans (ALPs), which logging companies are required to submit to PNGFA every year. Currently, most ALPs are submitted as hard copy which requires scanning, digitizing and storing of these information into PNG-FRIMS. At the same time, PNGFA encourages logging companies to submit forest management plans as soft copy according to the format PNGFA requires.

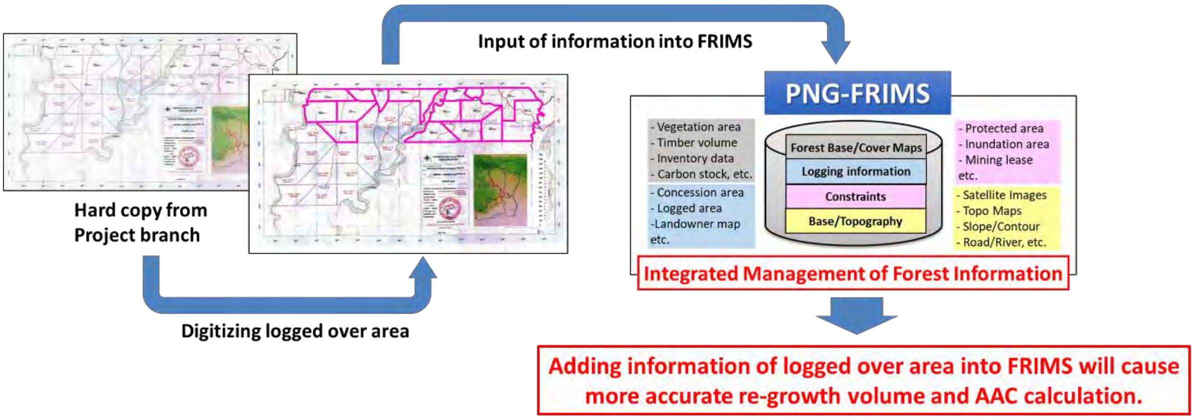


Figure 2.2.8: Digitizing logged over areas and stored it into PNG-FRIMS

Furthermore, PNGFA is promoting the efficiency of ALPs' circulation within PNGFA. *Figure* 2.2.8 shows the current circulation scheme of ALPs after logging companies submit it to PNGFA. Firstly, Projects Branch receives ALPs and stores them in warehouse in PNGFA Headquarters. Request are made to Project Branch whenever other divisions and branches want to access to these ALPs. Since current scheme of ALPs' circulation within PNGFA is complex, maps being attached to ALPs and even ALPs itself often get lost in the process.

On the other hand, other options to systemize the ALPs' circulation within PNGFA. These schemes are simplified to make the ALPs flow within PNGFA smoothly and to avoid loss of logging maps.

In addition to retaining the integrity of data stored in PNG-FRIMS, some information should be added in AAC calculation such as reliable plantation area and FCA boundaries. These information affect the output of AAC, particularly timber volume in Reserve Forest and Potential Production Forest. For better forest planning and forest zoning or demarcation, we have to consider how to treat these information in the future.

2.2.2 Reviewing of PFP guidelines and PFP formulation

Introduction

The importance of Provincial Forest Plans (PFPs) has roots in section 47 and 54 of Forestry Act, 1991 (as amended). Section 47 of the Act prescribes how the National and Provincial Governments intend to manage and utilize the country's forest resources, and section 54 stipulates that "Forest resources shall only be developed in accordance with the National Forest Plan." This means that all forest development activities in each province, such as developing new Forest Management Agreement, Forest Clearing Authority, forest plantation area and so on, must harmonize with NFP. Section 47 also stipulates that PFPs is one of the four components within NFP. Thus, PFPs have a significant role for the legal harvesting of forest resources in PNG as part of NFP.

The concept, the required contents and the formulating procedure of PFPs are prescribed in section 49, 50 and 51 of the Act. Provincial Governments must be proactive in developing their PFP in consultation with Provincial Forest Management Committee (PFMC) to develop their Provincial Forest Development Guidelines and a five-year rolling forest development programme in conformity with the 2009 National Forestry Development Guidelines. Furthermore, it is requirement for Provincial Governments to renew or revise their PFPs in every five years. It is unavoidable that Provincial Governments spend quite a lot of workload to develop a satisfactory PFP at regular intervals.

PNGFA functions as a formulator of NFP pursuant to the provision of section 7 of the Act. PNGFA is also required to pursue the balance with economic growth and the management, development and protection of the Nation's forest resources in harmony with the environmental benefits based on the provision of section 6 of the Act. NFP should direct whole nation's forest resources sustainable development compiling and selecting all provinces' strategy which should contain the future proposed potential forests or the next expected forest concessions at least. Through the PFPs, each provincial government is given the opportunity to plan for the wise use of their forest resource in accordance with their goals and development plans for these reasons, it is a critical component for each provincial government and PNGFA to collaborate with each other in order to formulate consistent and down-to-earth PFPs and NFP.

Guidelines for Provincial Forest Plans was developed by PNGFA in 1995. This Guidelines was intended to assist the Provincial Governments to formulate their PFP. Although the Guidelines has still being used, emerging issues such as implementing sustainable forest management, addressing climate change and ensuring timber legality are not addressed. Therefore, PNGFA decided to review the Guidelines to guide Provincial Governments develop their future PFPs. For the purpose of supporting PNGFA to review the Guidelines and to provide necessary technical supports of developing it, the Project considered utilization of PNG-FRIMS for this matter.

Collaborative approach with UNDP/FCPF Project

At the same time of the Project's attention to the PFP, the United Nations Development Program through the Forest Carbon Partnership Facility (NDP/FCPF) Project also launched an activity as part of the REDD+ Strategy to support Provincial Governments to develop their PFPs from the perspective of addressing climate change. They were also involved in revising the 1995 PFP Guideline by assisting in the formation of both National and Technical Working Committees. The core responsibilities of the committees are to revise and produce an updated PFP Guideline which would then be used to develop PFPs for the three Pilot provinces of East New Britain, West

New Britain and Madang and afterwards for the other provinces across the country. Dominant stakeholders Iin the review of PFP Guideline and PFP formulation are; PNGFA, Provincial Forest Management Committee (PFMC), Climate Change Development Authority (CCDA), Conservation & Environment Protection Authority (CEPA), Provincial Governments and private sector.

Through activities of the team, the Project supported reviewing the Guidelines and developing PFPs from the perspective of implementing sustainable forest management in harmony with UNDP/FCPF Project (*Figure* 2.2.9).

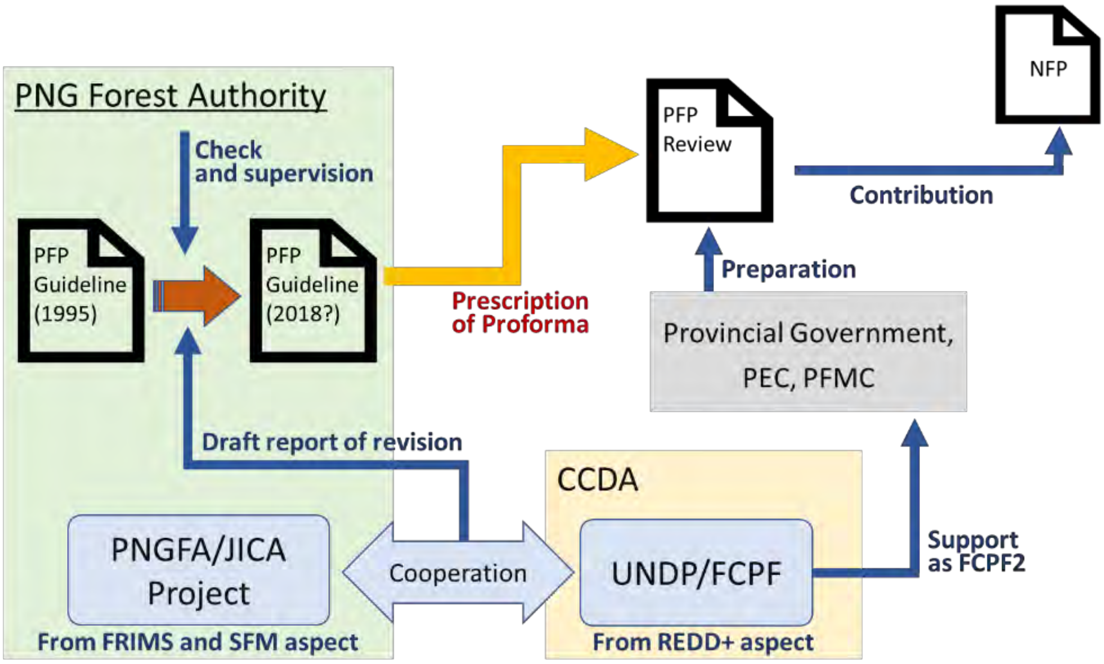


Figure 2.2.9: Scheme to support PNGFA in harmony with UNDP/FCPF Project

Workshop in Bialla to develop next West New Britain's PFP

After several consultation meetings with the core team of PNGFA, UNDP and JICA the West New Britain Provincial Government formed their Provincial Technical Working Committee and has started the review process of revising their PFP. A Workshop as a first official process was convened at Bialla from 3rd to 5th June, 2019. During the workshop, following functions of PNG-FRIMS were identified as useful to developing PFPs. (For more information of each function, please see the sections of "Output 1" and "Output 3" in this document.)

- **Forest Base Map and Forest Cover Map**
  To grasp the outline of forest vegetation distribution in each province, we have to refer to reliable information and map. Forest Base Map and Forest Cover Map are updated base map in PNGFA and reliability of it has increased than past one developed 1970's and 1990's owing to using advanced remote sensing techniques and compiling broad administrative knowledge. Updated maps can also show the statistics of the area by each forest vegetation type and forest coverage. These maps and statistics are useful in providing an overview of the current forest circumstances in each province. Moreover, to use uniform format of maps and statistics is necessary to compile each PFP to National Forest Plan.

- **Thematic Layered Maps**
  PNG-FRIMS has also accumulated broad aspects of databases such as topographical

information; elevation, extreme slope, watershed and so on, administrative information; concession, road line, protection area and so on. PNG-FRIMS shows these information as a map when these information of layers are overlaid on Forest Base Map and Forest Cover Map. By visualizing complex information as a map, discussion of PFP formulation will be smoothened. Furthermore, thematic layered maps make it easier for Provincial Governments to determine the areas of potential production forest.

- **AAC**
  As mentioned above, AAC calculation method in PNG-FRIMS was updated. The more administrative information such as logging activities including logged over area are updated, the more its output in enhancing the credibility of AAC is improved. AAC by each province and by each project (or concession) contribute to Provincial Governments' strategy on how to develop forest resources, which areas should be protected and how to decide demarcation between forest (Forest Management Agreement) and non-forest (Forest Clearing Authority). Nevertheless, PNGFA has to pursue further reliability of AAC in the future.

In addition to above functions in PNG-FRIMS, land change modeling was also recognized as potentially useful for PFPs formulation. By deep understanding of each function (including both effectiveness and limitation) in PNG-FRIMS and consecutive update for information, Land Change Modeler supports PNGFA by assisting in PFPs formulation as a technical cornerstone.

Provincial administrator, WNB

Senior forest plan officer, PNGFA

Director of Forest Policy & Planning, PNGFA

Team leader of TWG, UNDP/FCPF Project

Discussion

Discussion

Reviewing process of Guidelines for Provincial Forest Plans 1995

Review of the 1995 PFP Guideline commenced late last Year in November in which an analysis was made by the project to determine the deviation of the guideline. This followed by drafting of a proposed content which was used in the Bialla Workshop to test it. Following the workshop in Bialla, the team expand on the proposed content to develop a draft updated PFP Guideline taking into account the information in PNG-FRIMS. Possible use of PNG-FRIMS for PFP formulation

For the purpose of maintaining the usefulness of PNG-FRIMS to formulate PFPs, it is essential to update information stored in PNG-FRIMS. Although several functions and information has already gathered attention, other information should also be collected in preparation for further utilization in the future. After validating the evidence of necessity and reliability, PNGFA can judge further use of PNG-FRIMS for formulation PFPs. *Table* 2.2.13, shows candidate information to be stored into PNG-FRIMS and its access point.

Table 2.2.13: Preferable data stored in PNG-FRIMS for developing PFPs (as of 10 June 2019)

Information sought for planning		**Original data possessor**	**Availability in PNG-FRIMS**	
			Current situation	**Recommended approach (to enhance FRIMS)**
Forest resources information and map	*1) Forest Base Map (FBM) / Forest Cover Map (FCM)*	IM Branch (PNG-FRIMS)	FBM 2012 can be released.	- Check the quality of FCM 2015 - On-going design of FCM 2020
	2) Forest resources (area and volume for each forest type)	IM Branch (PNG-FRIMS)	Available with technical limitations	On-going design of FCM 2020

Information sought for planning		Original data possessor	Availability in PNG-FRIMS	
			Current situation	Recommended approach (to enhance FRIMS)
	3) Estimated timber volume (including AAC)	IM Branch (PNG-FRIMS)	Available with technical limitations.	To continue updating logged over areas.
	4) Forest constraints (Slope, altitude, karst, inundation, mangrove)	IM Branch (PNG-FRIMS)	Available.	On-going design of FCM 2020
Administrative information on forest	*5) Concession area (FMA, TRP, LFA)*	Acquisition Branch	Available	To update each concession information at regular intervals.
	6) Logged over area	Project Branch (Annual logging plans)	Available, but not completely digitized.	To finish digitizing ALP (timeframe indication) and update regularly.
	7) Topographic information	Project Branch (Forest working plans and its derivative plans, annual logging plans)	Available	To check the adequacy by means of submitted plans with an occasional, and update it where necessary.
	8) Facility Information	Project Branch (Forest working plans and its derivative plans, annual logging plans)	Available	To check the adequacy by means of submitted plans with an occasional, and update it where necessary.
	9) Timber Authority	Provincial forest offices	Unavailable (not exist in FRIMS)	To ask PFO to provide information and store it into FRIMS.
	10) Forest Clearance Authority	Allocation Branch, DAL	Available, but outdated/imprecision.	To ask Allocation Branch and DAL to provide information and update it where necessary.
	11) Protected Area	CEPA	Available, but outdated/imprecision.	To ask CEPA to provide information and update it where necessary.

Information sought for planning		Original data possessor	Availability in PNG-FRIMS	
			Current situation	Recommended approach (to enhance FRIMS)
	12) Valued area (High Conservation Value, High Carbon Stock)	CEPA and other ach accredited company/organization	Unavailable (not exist in FRIMS)	To store it into FRIMS based on adequate information supplement.
	13) Accredited forest (FSC)	Each accredited company/organization	Unavailable (not exist in FRIMS)	To store it into FRIMS based on adequate information supplement.
	14) Small scale logging	Provincial governments	Unavailable (not exist in FRIMS)	To store it into FRIMS based on information supplement from each provincial government.
Other administrative information	*15) Elevation (5m DEM, 10m counter)*	National Mapping Bureau, IM Branch (PNG-FRIMS)	Available	
	16) Main (permanent) road	IM Branch (PNG-FRIMS)	Available	To check the adequacy by means of updated satellite imageries with an occasional, and update it where necessary.
	17) River	IM Branch (PNG-FRIMS)	Available	To check the adequacy by means of updated satellite imageries with an occasional, and update it where necessary.
	18) Boundary information (ILG, Clan, Settlement)	PNG Census	Available	To check the adequacy by means of updated census data with an occasional, and update it where necessary.
	20) Boundary Information (District, Province, Region)	PNG Census	Available	To check the adequacy by means of updated census data with an occasional, and update it where necessary.

Discussions

All data have a certain level of contingency in a lesser or greater degree; PNG-FRIMS also contains some data that are unreliable. But in order to use these data for the purpose of decision makings, deep understanding of characteristic and limitation of each data allows PNGFA to become tolerant toward contingency of data because knowledge and experiences help to understand or make decisions on what actions to take. In terms of PFPs formulation, PNGFA and all relevant organizations should understand the limitation of the PNG-FRIMS functions and contingency of stored information itself, as well as limitation and contingency in order to make wise decisions.For the purpose of maintaining the usefulness of PNG-FRIMS to formulate PFPs, it is essential to update information stored in PNG-FRIMS. Although several functions and information has already gathered attention, other information should also be collected in preparation for further utilization in the future. After validating the evidence of necessity and reliability, PNGFA can judge further use of PNG-FRIMS for formulation PFPs. *Table* 2.2.13, shows candidate information to be stored into PNG-FRIMS and its access point.

Table 2.2.13 is useful for PNGFA to consider the priority to be dealt with in the future. They can gather information and update it into PNG-FRIMS as needed, moreover, reform of PNG-FRIMS functions should be considered depending on administrative significance.

Another important note is the compliance to outputs of PNG-FRIMS when it is used for any purposes. Especially, if the data or outputs of PNG-FRIMS would be opened to public, it is essential for its users to gain consciousness of compliance in accordance with the impact it affects to society. In the formulation of PFPs, not only PNGFA but all Provincial Governments have a responsibility for adherence to the usage of PNG-FRIMS in order to avoid misleading interpretations, which can lead to poor policy directions and hence other social disruptions.

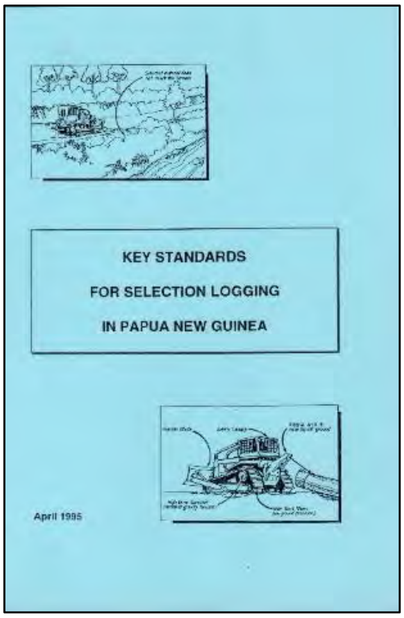
2.2.3 Systematic scheme of field monitoring/inspection for SFM

As part of the creation of the PNGFA in the early 1990 and the need to have in place relevant Guidelines to guide timber utilization and management PNGFA created three major documents as listed below-

- **Key Standards** for Selection Logging in Papua New Guinea,
- **P**lanning, **M**onitoring and **C**ontrol **P**rocedures for natural forest logging operations under timber permit, and
- Papua New Guinea **L**ogging **C**ode **o**f **P**ractice.

These documents are standardized and are still being used today to guide monitoring and inspecting logging concessions in natural forests though discussions that these documents should be reviewed in the light of tide of the time and new insight. In this section, an overview of each document is presented.

1. Key standards for selection logging in Papua New Guinea

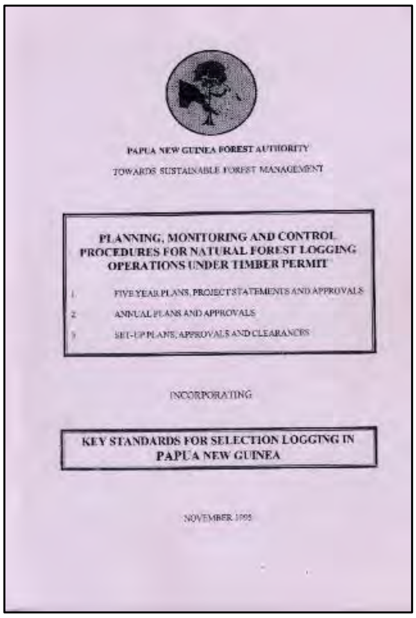


Key Standards, or Key Standards for selection logging in Papua New Guinea was published in collaboration with PNGFA and the department of environment and conservation (reorganized to CEPA in the present day) in April, 1995. Total of 24 standards which direct how logging operation should be conducted are compiled into Key Standards representing an effective approach towards management of the forest as a sustainable resource as well as protecting its ecological and cultural functions.

Key Standards is also being used for the monitoring and control of logging operations by field officers in PNGFA primarily. Other agencies such as CEPA and forest resource owners are able to access and use Key Standards as needed. In order to cover broader range of logging operation that logging operators and forest managers in logging companies should adhere to, the content of Key Standards was intended to be eventually incorporated into LCoP being developed in those days.

In some specific situations, Key Standards is also accepted that the minimum standards prescribed here may need to be strengthened by one or other of the agencies with the appropriate regulatory powers. Additionally, it was recognized that although Key Standards can be implemented in the field straight away, logging companies will need time to implement Key Standards which require investment in capital equipment and training of field operators. At this time, Key Standard 7 has been suspended from being applied as it is considered impractical by the timber operators.

2. Planning, Monitoring and Control Procedures for natural forest logging operations under timber permit

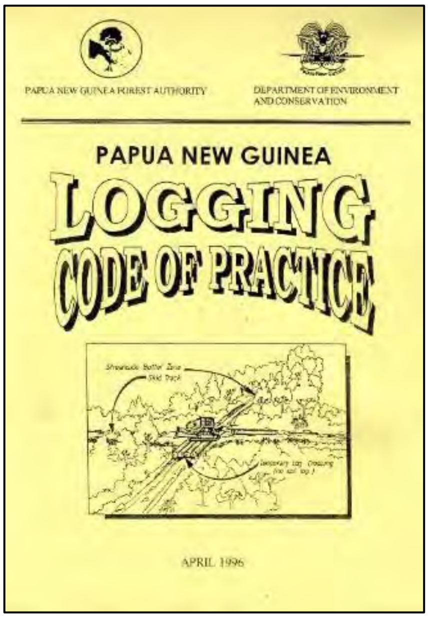


PMCP, or Planning, Monitoring and Control Procedures for natural forest logging operations under timber permit was issued in order to assist timber permit holders (or their logging contractors) and officers in PNGFA in November, 1995, because the responsibility for the management of the forestry sector in PNG had passed from the Provincial Forestry Departments to the new centralized PNGFA. These standardized procedures are being introduced for a range of planning, monitoring and control functions including field monitoring/inspection.

It is confidently expected that all forestry sector relevant personnel affected by PMCP will contribute to their successful operation. Although PMCP itself requires continual monitoring by PNGFA and should be amended from time to time where improvements can be made, there is no modification done so far.

Conceivably, PMCP is still available and is a beneficial procedure to manage logging operations in natural forest for both logging companies and officers in PNGFA. Moreover, set-up monitoring and control logbook, a part of PMCP, includes comprehensive check lists on how field officers in PNGFA should monitor/inspect their assigned logging inspections. This logbook also incorporates the same contents of the Key Standards.

3. Papua New Guinea Logging Code of Practice



LCoP, or Papua New Guinea Logging Code of Practice was formally adopted by GoPNG in March, 1996. Before LCoP adopted, there were several conditions under each document including timber permits and associated permit conditions, project agreement, five-year forest working plans, and the environmental plan and associated permit conditions. In order to address these condition's shortcomings, a range of conditions had combined agreed standards, prescriptions and best management practice for selection logging in to one document as LCoP. Taking into account the concept of LCoP with a very broad base, PNGFA have drafted it with the Department of Environment and Conservation collaboratively. Moreover, opinions from logging companies, non-governmental organizations, training institutions and other government departments were reflected in LCoP. All contents of Key Standards are identified throughout LCoP.

As full implementation of the standards and operating practices set out in LCoP will take time, it was accepted that in the future this document will require review and amendment as both operational findings from its implementation and research will add new information. Several reports have been documented suggesting to add more realistic and positive analysis into LCoP in accordance with advancement in monitoring technology and new insights surrounding forest and forestry under the project among PNGFA, FAO and the Australian Government Department of Agriculture, Fisheries and Forestry (Wilkinson 2013, McIntosh 2013, Munks *et al* 2013, Munks 2013). PNGFA has drafted a reviewed LCoP and tried to endorse it in 2014 and 2015 but it is still awaiting formal government endorsement through the National Executive Council (NEC).

2.2.4 Capacity improvement to implement LCoP

Introduction

It is obviously one of the most consequential factors for contributing to the National Goals and Directive Principles of PNG that the PNGFA strengthens its capacity to monitor and evaluate the forest resources in a correct manner (*Figure* 2.2.10). That is to say, timber volume being logged must be completely controlled by rational intervention of governmental regulation to avoid depletion of forest resources arising from unregulated logging. Not only that, logging plan must be drawn up, be monitored and be evaluated in conformity with environmental and social benefit. For the purpose of deriving full benefit of forest resources by wise use of it, official body in each country fulfill a significant role which realizes that. In PNG, PNGFA has centralized control over that under the National Forest Policy and the Forestry Act 1991.

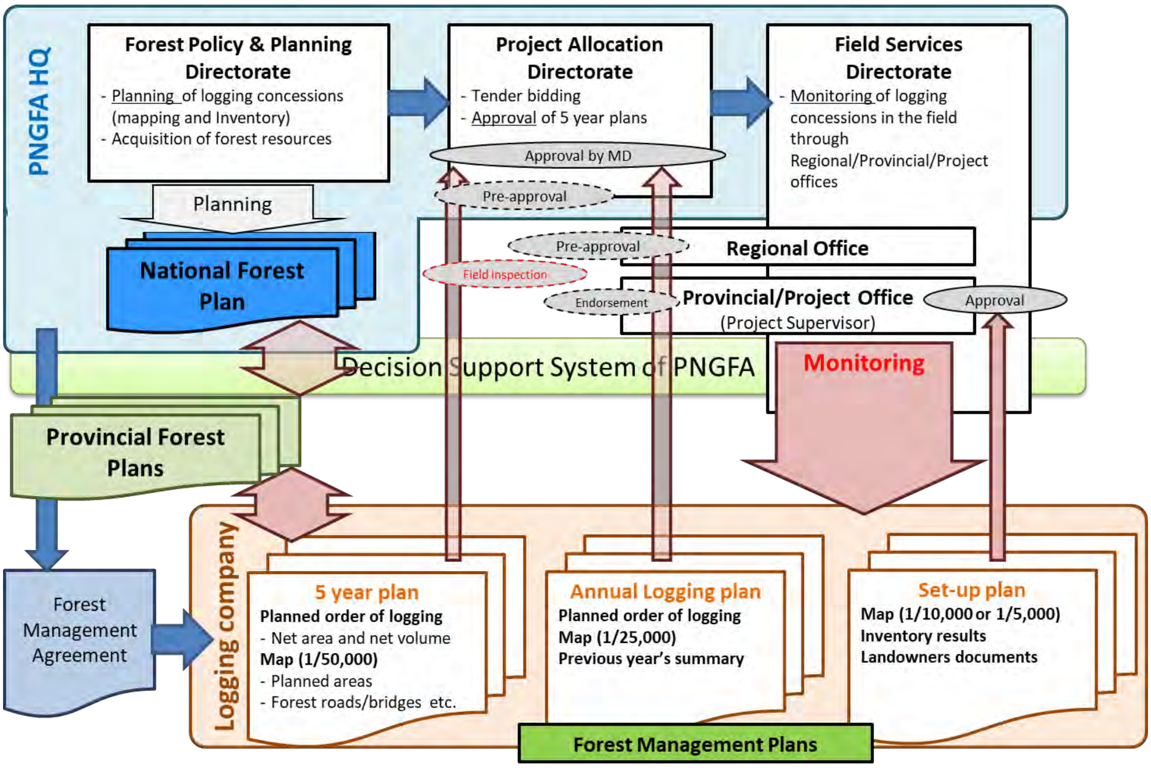


Figure 2.2.10: Procedure to approve forest management plans

Capacity development for field inspection/monitoring

PNG-FRIMS can be utilized more efficiently and accurately to assist in field inspections and monitoring in practical terms through the application of the LCoP/PMCP in logging concession. For that reason, the Project trained field officers to obtain basic usage skills of hand-held GPS, or

Global Positioning System, GIS or Geographical Information System and Drones (UAV), as well as their management skills.

1) Engaged People

1. Trainees

A series of training had been conducted to obtain basic usage and management skill of GPS/GIS as an end user, targeting at mainly field officers in West New Britain Province (WNB) and West Sepik Province (WSP) which are the Project's pilot sites. The Project's relevant officers in Headquarters (HQ) also attended these trainings. It is expected that the field officers attending this training will disseminate their skills of using and managing GPS/UAV/GIS to their province's officers who could not attend this training.

2. Trainers

A series of training had been conducted by the expert of Japan International Cooperation Agency (JICA) and Cartographers in HQ of PNGFA. Some inventory officers in Area Office with experience of GPS/UAV/GIS usage also played a role as a trainer. Cartographers and inventory officers in Area Office also developed user-friendly manuals for trainees as end users (see below for detail). These materials were developed as tools to guide so that trained skills were continuously transferred to all officers in PNGFA who could not attend the training.

2) The contents of training

Basic training for GPS/GIS usage was held in not only the pilot provinces (WSP and WNB), but also headquarters and other regional offices. These trainings were composed of four elements which include; topographic map decipher, GPS usage, GIS usage and accessing to digital forest area map. Each training had been conducted for all provincial officers in combination with some elements. Brief design of each element is described below.

Topographic Map decipher

Lecture and practical of topographic map decipher were conducted with aim to equip officers who monitor forest resources or supervise logging concessions to acquire the skill of reading condition of geographical features from maps. This element was initially conducted before element of GPS/GIS training because of its general versatility, such as contribution to their field work and application for GPS/GIS usage.

GPS usage

Although GPS had already been introduced in PNGFA before the project launch, GPS usage training was conducted because PNGFA, particularly officers who engage in field work required advance dissemination of GPS application in a comprehensive and systematic fashion. This element was identified as one of the hub activities in a series of this training.

UAV (drones) usage

UAV or drones were introduced in PNGFA to enhance the capacity of inspection/monitoring of the forest resources. Limitations of human resources and logistics were a main hindrance to inspect/monitor the forest more efficiently and accurately by PNGFA. To overcome this limitation, the Project had searched for alternative methodology. Taking the opportunity of a training in Japan held in August 2017, some PNGFA participants in that training focused attention to drones. After consideration under the Project, PNGFA decided to introduce drones into their assigned task such as forest inspection/monitoring.

GIS usage

It is obviously helpful for PNGFA to utilize GIS so that field officers improve forest monitoring and its management, whereas a large fraction of regional officers in PNGFA were unacquainted with it. In fact, this element often accounted for a large portion of training and involved most activities as well as GPS usage.

Accessing to a digital forest area map

For the purpose of connection to PNG-FRIMS and forest monitoring and management in field which was controlled and managed at headquarters, the project developed a Map browsing system through Local Area Network within PNGFA Headquarters (LAN-Map). The system would enable regional officers to access to the integrated information stored in PNG-FRIMS including digital forest area map and disseminate it through a series of this training. LAN-Map is expected to be fully utilized after expanding intranet throughout regional offices in PNGFA with Decision Support System.

3) Record of the trainings

A total of 14 trainings and two workshops were conducted during thirty-nine months from March 2016 to May 2019. A total training period including workshop is fifty-two days. Total number of participants to trainings and workshops is 114 trainees. Thus, total man-days of trainings and workshops counts to 496 man-days.

At the first part of trainings, participants focused on the GPS and GIS (from March 2016 to April 2017). After PNGFA decided to introduce drones to pursue the accuracy and efficiency to field inspection/monitoring, the Project launched to train from how to operate drones to how to apply drones to inspect/monitor the forest more accuracy and efficiently. For the limitation of the Project's period, Drone trainings and workshops were convened in mainly PNGFA Headquarters and its neighboring plantation and concession sites in Central Province except for each pilot sites' activity (*Table* 2.2.14).

4) GPS/UAV/GIS manuals

Through the trial activities in each pilot sites, training materials were developed. During the trainings, participants used these materials and gained the capacity on how to use GPS, Drones and GIS. For the purpose of disseminating its technical know-how in a sustained manner after the Project ends, the materials are compiled as manuals; Manual for GPS/GIS and Manual for drones or UAV (*Figure* 2.2.11). Some of the participants in the trainings and workshops got enough capacity to train PNGFA officers who do not use these items yet and give guidance about utilization of these items for adequate monitoring of logging activities. It is expected that the manuals are utilized for these purposes after the Project.

Table 2.2.14: Record of the Project's training and workshop for GPS/UAV/GIS

Place	Session		Training Period (Days)	Participants (Trainees)	Man-Days	Contents				
	Month	Year				Training	Workshop	GPS	GIS	UAV(Drones)
Area Office - WNB*	March	2016	2	15	30	✓		✓	✓	
Provincial Forest Office - MBP	March	2016	3	6**	10	✓		✓		
Area Office - WNB*	June	2016	2	11	22	✓		✓	✓	
Headquarters	November	2016	3	22	66	✓		✓	✓	
Provincial Forest Office - WSP*	November	2016	3	8	24	✓		✓	✓	
Area Office - Momase	November	2016	2	6	12	✓		✓	✓	
Area Office - NGI	December	2016	2	6	12	✓		✓	✓	
Bulolo plantation	March	2017	3	10	30	✓		✓	✓	
Headquarters	April	2017	2	6	12	✓		✓	✓	
Headquarters/Kuriva	June	2018	10	13**	58	✓	✓		✓	✓
Provincial Forest Office - WSP*	October	2018	4	9**	34	✓				✓
Headquarters/Kupiano	February	2019	10	16	160	✓	✓		✓	✓
Area Office - WNB*	April	2019	1	11	11	✓				✓
Provincial Forest Office - WSP*	May	2019	5	3	15	✓			✓	✓
Total Number			52	114	496	14	2	9	11	5

** The place which includes pilot site of the project in its administrative jurisdiction.*

*** Trainees participated in the training in defferent days.*

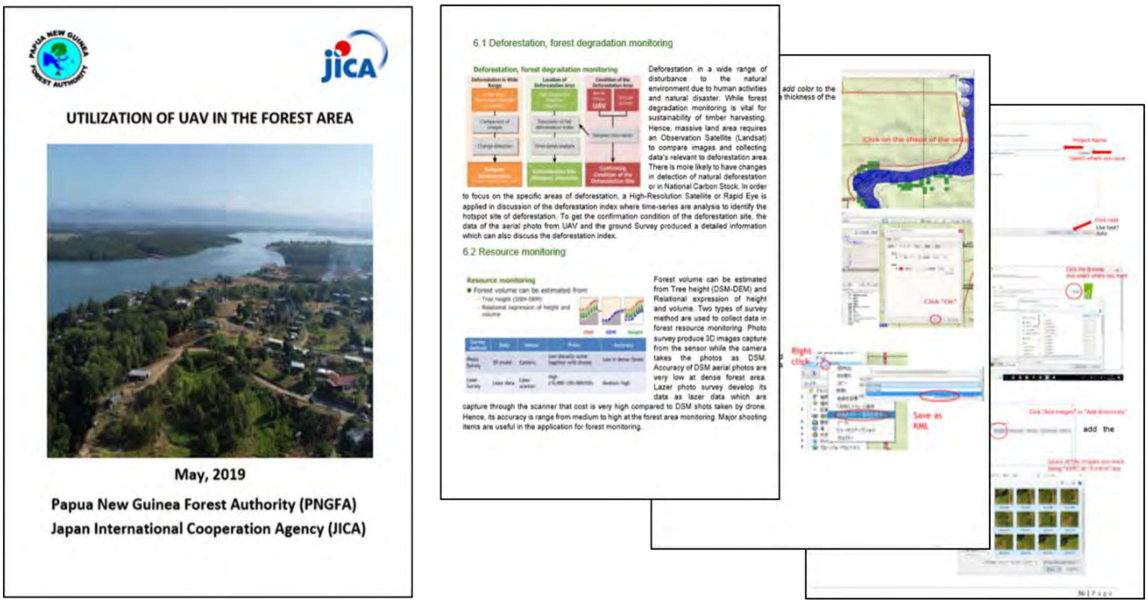
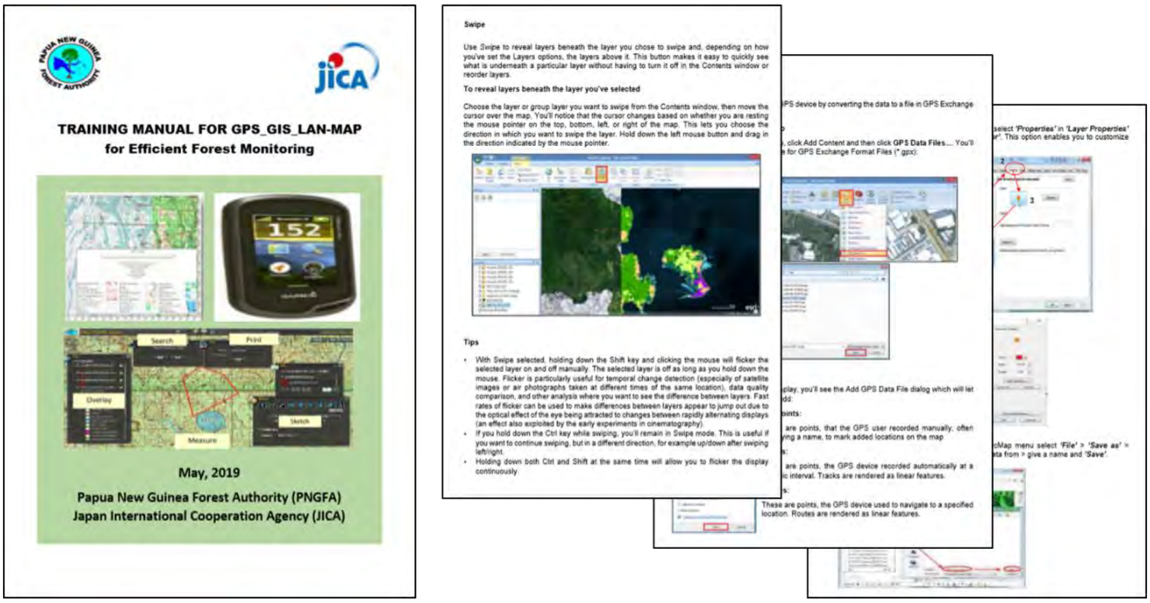
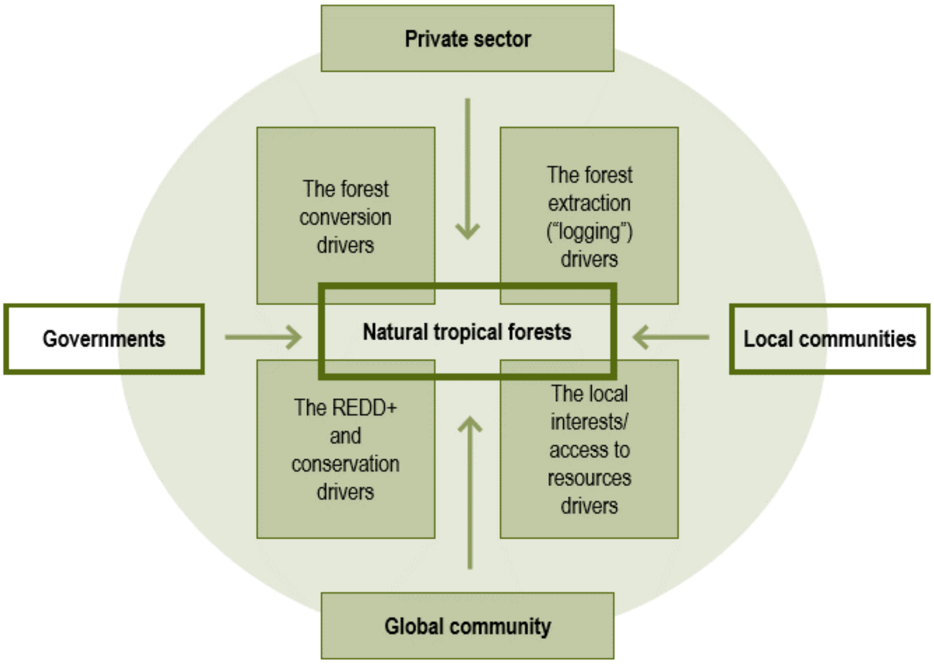


Figure 2.2.11: Manuals for GPS/GIS and drones (UAV)



Voluntary guidelines to implement LCoP

Taking into consideration the international drive towards forest conservation and timber legality, especially in tropical countries, such as concepts of REDD+ and TLVS can be applied to manage deforestation, forest degradation and illegal logging which affects the health of forests. In PNG, commercial logging is the highly probable largest driver of carbon emission (GoPNG, 2017). In order to ensure that timber harvesting and trade are conducted in accordance with the laws of the land, forest officers are located in most timber concession areas to ensure that the logging company complies with the terms and conditions of its operation permit/agreement, nevertheless, its powers are limited to ensure its legality or detect its illegality (Turia, 2010). These facts indicate that well-managed logging concession in natural forest will contribute to both the requirements of international standards and public mandate in PNG.



Source: ITTO (2015).

Figure 2.2.12: Various sectors with direct influence on sustainable management of forest

PNGFA is responsible to pursue the wise use of the forest resources in PNG in a sustainable manner in line with the National Goals and the Directive Principles as declared in a preamble of the Constitution and the 1991 National Forest Policy and the Forestry Act, 1991 (as amended). In accordance with fundamental principles of these policy documents, some considerable work was undertaken in the middle of the 1990's, which included the national forest plan, provincial forest plans, forest management plans and its monitoring standards/procedures. This framework should be reviewed in consonance with the tide of the times and new insight in the right place at the right time. Conceivably, we can say that PNGFA have equipped sufficient regulations with regard to the selection logging in natural forest to achieve SFM.

On the other hand, PNGFA has been struggling to attain SFM due to various limitations, such as human resources and logistics and land ownership conflicts to monitor logging operations in the field even though methodologies to conduct the field monitoring/inspection in natural forest have been established. These includes Key Standards, PMCP and LCoP - (See the section2 for more information).

As part of the Project, the improvement of forest planning system in PNG both at the national scale and in the field level utilizing PNG-FRIMS has been conducted as previously mentioned - (See Section 2). In this light, the Project has developed a 'Voluntary Guidelines to Implement GPS/UAV/GIS for SFM' which gives field officers the opportunities of getting geographical position with photos using GPS, capturing aerial photographs easily using UAV, making ortho-photos by processing software and analyze it using GIS etc. As just described, GPS/UAV/GIS must contribute to improve forest monitoring/inspection in field level in terms of time efficiency, accuracy and verifiability. On the other hand, these tools are not perfect for implementing forest monitoring/inspection but have a certain limitation even if PNGFA makes full use of these tools.

1) Objectives of the guidelines

The Purposes of the "Voluntary Guidelines to Implement LCoP utilizing GPS/UAV/GIS for SFM" (hereafter referred to as "the Guidelines") are to:

- embed GPS/UAV/GIS into implementation of LCoP as a material for further discussion
- provide information on what is the positive and negative aspects of each tools to monitor forest resources through application of LCoP,
- help field officers in PNGFA to monitor forest resources or inspect logging concessions more efficiently, accurately with verifiability,
- help field officers in PNGFA to advise logging companies operating concessions in adequate manner, and
- give logging companies tips how to abide by LCoP.

The Guidelines has been drafted taking into account the Project activities in the field as described in above section. Continual validation of the Guidelines and its optimization based on the actual data aggregation and data analysis is strongly encouraged in the future.

GPS training in West New Britain in 2016

Drone training in PNGFA HQ in 2019

Expected audience

As referred to above, the Guideline was developed with the assumption that it will support field officers of PNGFA, as well as logging companies on how to utilize GPS/UAV/GIS for their assigned tasks, especially to improve implementation of LCoP. At the same time, the International Tropical Timber Organization [ITTO] (2015) insists that many actors have interests in forests (*Figure* 2.2.12). Although all stakeholders in PNG aspire to keep balance economic activity of logging concession in natural forest and its conservation, they place different level of importance for each standpoint.

Compatibility with relevant documents

The Guidelines is designed as a supporting document to the PMCP and other operational guidelines in order that officers in PNGFA, especially field officers such as project supervisors and project monitoring officers, are able to overcome their limitations by improving efficiency, accuracy and verifiability with the assistance of introduced monitoring tools as mentioned above. The Guidelines also focuses on how they implement LCoP. Thus, the Guidelines is expected to contribute to achieving SFM as a part of the institution in PNGFA in field level.

2) Examples of the guidelines

The guidelines consist of 31 criterions, each criterion fully corresponds to LCoP 1995, and guides how to fulfill the requirement of LCoP utilizing and assembling traditional method of PNGFA and GPS, drones (UAV) and GIS. Some guidelines of criterion as examples are shown below, although, for more detailed information, please refer to original guidelines "Voluntary Guidelines to implement LCoP utilizing GPS/UAV/GIS" and note that these guidelines are supposed to be repeatedly reviewed through trial and error in field on a case-by-case basis.

Example 1: Minimum Buffer Zone Widths (as criterion 1 in the guidelines)

Required widths of buffer zone in each category should be properly preserved and marked in the field by the logging company before logging (set-up approval) to be assessed by the project supervisor, for the purpose of ensuring safe and secure use of water for local community and the lessening of soil encroachment.

Guideline

During the pre-logging (the step of set-up approval), to check marking on ground survey with GPS and to validate the evidence pairing field record (GPS location and photos) with FWP and environmental plan (EP) is the most reliable approach for this criterion, even though it costs too much time. On the contrary, in the duration of active logging and post logging (the step of monitoring during logging and set-up clearance), making ortho-photos by drones and evaluate the widths for each buffer zone is not only less time consuming rather than walking around the bush, but also more accurate and verifiable than that.

Quick reference guide

Criterion 2: Minimum Buffer Zone Width					
Practices		Tips	Applicability		
			other	GPS	Drones
2.1	Minimum buffer zone widths should be ensured as below: • Cultural sites, reserves, conservation and garden areas: **100m** • Village areas: **500m** • Lakes, lagoons coastal shoreline, swamps (as defined in the Annual Logging Plan from time to time): **100m** • Class 1 permanent stream: **50m** • Class 2 permanent stream: **10m** • A stream (permanent or non-permanent) of any width used by the community: **50m** • Non-permanent watercourses and streams less than 1 meter not used by the community: **no buffer** • Log pond and wharf: **no buffer, maximum shoreline clearance 100m**	Drones will be considered for larger areas like lakes and villages. *FWP *Use of GIS *Environmental Plan (EP)	✓	✓	✓✓

Example 2: Forest Roads – Road Decommissioning (as criterion 8 in the guidelines)

Although forest roads after project are often stranded because of the preparation for re-opening and the contribution to local communities, the logging company must, as a general rule, decommission forest roads with its adjuncts after completing the project at their side. Decommissioning forest roads causes a large amount of soil and wooden rubbish as well as industrial waste such as excess oil, plastic and broken piece of the concrete construct.

Guideline

The inspection for road decommissioning should be done as soon as possible after all objects have been decommissioned for the purpose of properly confirmation of the current situation. It may cause passing over something to be advised to the logging company on account of flowing excess oil or soil off long by water or hiding of rubbish in flourished or recovered vegetation. Drones are a useful took to catch the outline of the situation remotely as well as criterion 7.

Quick reference guide

Criterion 8: Forest Roads – Road Decommissioning					
Practices		Tips	Applicability		
			other	GPS	Drones
8.1	Remove log culverts, culverts and temporary bridges to allow unobstructed water flow where the decision is made to decommission a forest road. As a general rule all feeder forest roads (not village feeder roads) should be decommissioned. The decommissioning of a main forest road will require consultation with the landowners. If the road is to be kept open there is a need to decide who will maintain the road.	*Regular field monitoring	✓	✓	✓✓
8.2	Restore stream beds and banks to aid unimpeded water flow in more or less natural conditions.	*Regular field monitoring	✓✓		
8.3	Out slope roads and remove any edge berms to allow cross road water flow without concentration. When out sloping is not possible provide water bars.	*Regular field monitoring	✓✓		✓
8.4	Remove debris from the log landings and roads (waste oil, lubricants, fuel, old wire rope, oil drums, oil filters). Bury rubbish at an approved land fill disposal site (waste pit) away from the high water table and watercourses.	*Regular field monitoring	✓	✓	✓✓
8.5	Consider the impacts of decommissioning the road where uses other than logging have developed during its life.	*Regular consultation with LOs	✓✓		

Example 3: Forest Roads – Log Ponds (as criterion 12 in the guidelines)

Log ponds are often deployed at near cove, gulf and bay so that efficiency of commerce between the logging company with traders due to geographical and infrastructural reasons in PNG where timber trade is mainly conducted by marine transportation. Once a log pond is constructed, it is going to last for a long period and sometimes accepts a number of the timber from more than one log pond. Then, log ponds are a relatively great facility and should be located and planned carefully in consideration of social impact as well as environmental. During a log pond is constructed, maintained and decommissioned, the constructor must not default for ecological sensitivity.

Guideline

It is encouraged that pairing several measures, including documents (FWP, ALP, EP etc.) examination, getting location information by GPS, observation or capturing of aerial situation by drones, and analyzing and mapping these by GIS, is required in order to assemble the plan of location, maintenance and decommission with the logging company and/or the constructor.

Quick reference guide

Criterion 12.1: Forest Roads – Log Ponds (Location and Planning)					
Practices		Tips	Applicability		
			other	GPS	Drones
12.1.1	Locate, following discussion and approval with landowners. Locate to provide the best sheltered access to both ships and incoming road transport taking into account the existing uses of the area and its importance to river/marine ecology i.e. fish breeding ground. The log pond must be located 500m from a village.	*GIS, ALP & FWP		✓✓	✓
12.1.2	The area should be elevated at least 1 meter above the highest tide level and should be graded to provide drainage. Typically, areas will require a cross fall of 5% to have adequate drainage. Swampy and flat areas will have problems. Pre-construction planning should be undertaken for all facilities, giving particular attention to drainage and log pond effluent discharging into the body of water.	*Log pond plan *Regular Field Monitoring	✓	✓✓	✓
12.1.3	All land-based or water-based “log ponds” require a Water Use Permit from the Bureau of Water Resources if they take or discharge water.	*Environmental Plan, FWP & Log Pond Plan	✓✓	✓	
12.1.4	Any alteration of the shoreline including the reclamation or excavation of inter tidal or marine areas, including coral reefs, mangroves and seagrass beds, requires	*Environmental Plan, FWP & Log Pond Plan		✓	✓✓

	specific approval from Department of Environment and Conservation. (Now, DEC is reorganized as CEPA.)				
12.1.5	Access ways through these coastal buffer zone should be marked and should have a maximum cleared width of 40 meters. The access route should not purposely take an indirect route unless it is sensible to do so to avoid an obvious obstacle.	*Environmental Plan, FWP & Log Pond Plan		✓	✓✓
12.1.6	Storm water drains must be kept clean and operation at all times. If it is possible for oil, fuel, chemicals to enter the drain special provision, such as filters and/or oily water separators, must be made before the drain discharges to a body of water.	*Log Pond Plan *Regular Field Monitoring	✓✓	✓	
Criterion 12.2: Forest Roads – Log Ponds (Construction and Maintenance)					
Practices		Tips	Applicability		
			other	GPS	Drones
12.2.1	For minimum disturbance to the site use excavators during construction. Compact the log storage areas to ensure the surfaces remain in good working condition.	*Log Pond Plan & *Regular field Monitoring	✓✓		
12.2.2	Surface drainage requires a minimum drainage of 5% slope/gradient. A storm water drainage system is required.	*Use of Clinometer *Regular field Monitoring	✓✓	✓	✓
12.2.3	Logs should be stacked to prevent them rolling onto the shoreline.	*Log pond Plan *Regular field Monitoring	✓✓		
12.2.4	Lading machinery should not operate on the shoreline.	*Regular Field Monitoring	✓✓		
12.2.5	Prevent logs, off cuts or trimmings from entering the sea or river. Remove debris from the log ponds (drums, oil filters, ropes etc.) and bury at an approved land fill disposal site (waste pit) away from the high water table and watercourses, as detailed in the Waste Management Plan. Logs, off cuts and trimmings cause problems for landowners as they either float or sink in the shallow water and obstruct dinghies and canoes. Log off cuts should be used wherever possible or disposed of on dry land in a tidy manner	*Environment Plan FWP, & Log Pond Plan *Regular Field Monitoring	✓✓		✓

	above the high tide mark.				
Criterion 12.3: Forest Roads – Log Ponds (Decommissioning)					
Practices		Tips	Applicability		
			other	GPS	Drones
12.3.1	Ensure the drainage system is left in a manner which requires minimal maintenance to avoid storm water runoff flows combining into a stream which may cause scouring. Provide water bars if needed.	*Log Pond Plan	✓		✓✓
12.3.2	Restore any stream beds and banks to aid unimpeded water flow in more or less natural conditions.	*Regular Field Monitoring	✓✓		
12.3.3	Waste oil, lubricants, fuel, old wire rope, oil drums and all other rubbish, should be disposed of in an approved area.	*Log Pond Plan	✓✓	✓	✓
12.3.4	Consider the impacts of decommissioning the log pond where uses other than logging have developed during its life.	*Consult with Landowners	✓✓		

3) Importance of feedback of ground survey

Promoting the utilization of ICT items and GIS for forest monitoring/inspection for field officers' means that it will assist them to streamline their tasks. Moreover, with regard to the international drive to address issues such as sustainable forest management, climate change and timber legality, the forestry sector in PNG is required to report their forest management in the field level with integrity based on evidence, more than ever. In that light PNGFA field officers are encouraged to continuously report their tasks based on forest policy and regulations including LCoP and PMCP using unified format or template with this guideline.

Figure 2.2.13 is the promising reporting format to comprehensively report field officers' task, although some modifications are needed in the future. This reporting format is developed based on elaborated field trials in West New Britain Area Office, and designed as the monitoring tool for Provincial Forest Officers and Area Managers to know what is happening in their area and whether any concerns have been raised. Furthermore, communication between Headquarters and each area office will be promoted if this reporting format is utilized as an official reporting format in PNGFA.

Thus, utilizing ICT items based on this guideline for forest monitoring/inspection and subsequent continuous reporting of field officers' assigned tasks should be promoted to implement LCoP and PMCP. This is one of the best ways to move PNGFA's forest management drive to achieve some real sustainability in the forests of PNG.

Figure 2.2.13: Reporting format to feedback the field inspection/monitoring result

Discussions

This guidelines is an introductory full-scale attempt to guide the methodology of implementing LCoP utilizing current technologies more efficiently and accurately against limitations indwelling within PNGFA. It is also expected that this guidelines will be utilized as a trigger to enhance the movement to develop the field monitoring/inspection capacity in PNGFA to achieve sustainable forest management. Thus, trial and error based on this guidelines is the essence to improve this more than ever. It is also recommended that further autonomic activity by PNGFA itself will overwrite more advanced experience and knowledge on this guidelines and make it more reliable.

Practical application of drones for forest inspection/monitoring in PNGFA

Utilization of drone image

After the training of drone usage in HQ and Kupiano, it is expected to clarify the purpose of drone utilization for forest monitoring in PNGFA. This report is aiming to show some examples of drone utilization in field monitoring.

Drone image capturing flow

Drone image capturing operation is conducted by “GS Pro” which is automated fight plan application for iPad. It is possible to upload kml file or shape file to “GSpro”, so we can prepare the flight plan before field monitoring. When you captured drone images, it is good to organize your data the same day with your fresh memories. Then you start processing with Pix4D to get ortho image. This process takes a few hours, so you can leave processing overnight. Once you get ortho image of your set-up site, it is easily to calculate distance, or area with your GIS.

Utilization of tablet or smart phone with GIS data

Tablets or smart phone applications is a powerful tool with GIS data when trying to locate the exact set-up location. Currently some of PNGFA officers and timber companies use "Locus map". But in the event that it is difficult to get them, another app "Avenza map" which has a photomap made by satellite image (drone image, too) is really useful map for forest monitoring.

Figure 2.2.14: Locus map (Free version)

Figure 2.2.15: Avenza map (Free version)

GIS map data should be converted to GeoTIFF (or GeoPDF) for Avenza map. We can make GeoTIFF file with QGIS or ArcGIS. It is needed to determine where you will go for field survey. This GeoTIFF can be downloaded from your Google drive or SD card (or just connect to computer directly) to use at Avenza map.

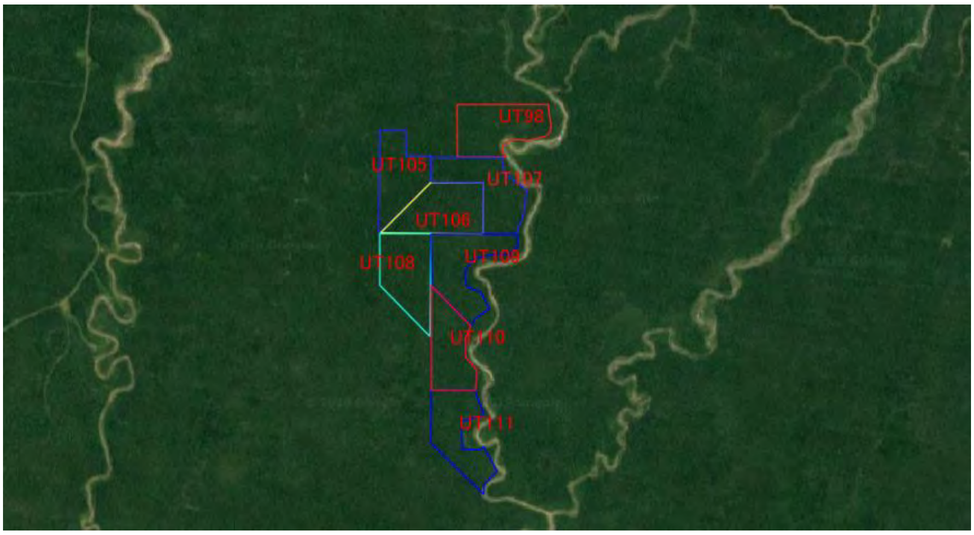


Figure 2.2.16: GeoTIFF data image used at this forest monitoring.

Pre-logging

Pre-logging image is not only useful for grasping current situation for inspection, but also for logging company. This can be used to discuss the logging plan with logging companies

Figure 2.2.17: Pre-logging MU83 (2018-19) ortho image, captured by Mr. Kallan Ramute.

Active-logging

Active-logging site is suitable for drone image analysis, because you can grasp the real situation of the ongoing logging such as width of logging road or situation of gaps and skid trail with ortho image and GIS software. This information is not only helpful for inspection, but also improve communication with logging company.

This information leads us to better selective logging management in near future.

Figure 2.2.18: Active-logging UT110 (2018-19) ortho image, captured by Mr. Kallan Ramute.

Post-logging

At post-logging site, drone image is a better tool to check regeneration of log pond, skid trail, and gap and so on. It is better to capture images as soon as logging is over.

Figure 2.2.19: Post-logging UT98 (2018-19) ortho image, 7 months after logging

Time series images of set-up

Comparison of drone images captured at different periods is valuable information for grasping logging site. For example, comparison of post-logging (*Figure* 2.2.19) and active-logging (*Figure* 2.2.20) will tell us regeneration situation of the post-logging.

Figure 2.2.20: UT98 (2018-19) ortho image at different period.

After-logging site

After-logging site image show progress of regeneration. The images below (*Figure* 2-2-20: 5 years after logging, *Figure* 2.2.22: 10 years after logging) show that regeneration is in progress. It is already difficult to distinguish skid trail.

Figure 2.2.21: After logging WA54 ortho image, 5 years after logging (2013-2014)

Figure 2.2.22: After logging site FF03 ortho image, 10 years after logging (2009-2010)

Palm oil Plantation

Drone image is not only useful for selective logging monitoring, but also for plantation monitoring. Oil palm plantation compartment has dense road network and palm tree is not such high as natural forest, so you can easily fly drone for capturing images. Also, you can set flight plan at the field using location information of drone. You can let the drone fly over your AOI (area of interest), like plantation site, then tap iPad and you can easily cover flight area. Once you make ortho image of plantation, you can grasp the growth situation. This information can be utilized when you discuss with plantation company.

Figure 2.2.23: Palm oil plantation ortho image, at WSP, captured by Mr. Jehu Antiko.

4. LAN-MAP

GIS software, or Geographical Information System, is useful to visualize and analyze data acquired by hand-held GPS and drones and it is useful for environmental analysis including forest monitoring. The Project developed LAN-MAP as a part of PNG-FRIMS. This is a kind of GIS software and enables data exchange between headquarters and regions in PNGFA where field officers would get timely access to the forest base map with several information prepared at headquarters. If field officers get some data using hand-held GPS and drones as mentioned above, they can evaluate their monitoring/inspection by LAN-MAP measuring width, distance and area.

PNGFA, however, has to put intranet or local area network in place to expand use of LAN-MAP. Until then, it is encouraged that field officers use free GIS software.

Discussions

These guidelines are an introductory full-scale attempt to guide the methodology of implementing LCoP utilizing current technologies more efficiently and accurately against limitations indwelling within PNGFA. It is also expected that these guidelines will be utilized as a trigger to enhance the movement to develop the field monitoring/inspection capacity in PNGFA to achieve sustainable forest management. Thus, trial and error based on these guidelines is the essence to improve this more than ever. It is also recommended that further autonomic activity by PNGFA itself will overwrite more advanced experience and knowledge on these guidelines and make it more reliable.

2.3 Output 3

2.3.1 Examine Carbon Emissions from Logging

Introduction

Forest resources are the basis of livelihood for rural population and timber a key asset for economy with more than 8 million hectares designated for production. However, commercial logging is identified as one of the main drivers of forest degradation which accounts for more than 80% of land emissions. This makes the estimation of forest degradation and associated emissions becomes particularly important to regulate environmental impact and sustain forest resources.

In this context, PNG Forest Authority is engaged to improve the compliance of activities with the Logging Code of Practice (LCoP). Different supports from JICA aim at facilitating the monitoring of field operations such as the improvement of spatial information in PNG-FRIMS and the development of capacities for using satellite images, GIS software, GPS and drones. Among LCoP items, many parameters are linked with carbon levels such as the extent of roads, infrastructures, collateral damage on surrounding trees and wasted logs. So improved capacities to implement LCoP can facilitate monitoring of carbon emissions.

Emissions from forest degradation were assessed in the PNG's Forest Reference Level (FRL). Remote Sensing images were analyzed to determine deforestation areas (forest to non-forest), degradation areas (primary to degraded forest) and carbon stock enhancement (non-forest to forest). Emission Factors (EF) of forest degradation corresponds to the carbon stock difference between before and after logging so it also includes post-logging degradation (e.g., gardening, fire, fuel wood collection) and natural regeneration.

It is interesting to study alternative approaches such as field estimation of direct impact from harvesting activities. However, to use methods based on field parameters, historic data of harvested volumes must be collected for at least the last 10 years and EF determined for each source of emissions. Providing such information may be challenging for some countries and hinder proper estimation.

As part of this project, we have considered additional methods to contribute to PNG's FRL centrally, but also for further purposes linked with forest management. As such, Output 3 describes the main methodologies recommended by Intergovernmental Panel on Climate Change (IPCC) and applied in FRLs, but concentrated more on calculation steps of emissions in the 'Volume' method analyses; a method which PNG can potentially include in its future FRL from on-going initiatives, and proposes possible way of integrating additional methods and evaluates possible utilization of outcomes from developing the Volume method for forest management purposes.

Methodology

1. Methodologies that estimate carbon emissions from logging

According to the driver of forest degradation, different methods exist to estimate emissions. Emissions that occur in harvesting sites are particularly challenging to measure because sources of emission are diverse and field parameters are complex to monitor. This part summarizes main methodologies that specifically account for carbon emissions from forest degradation caused by commercial logging. General methodologies recommended in IPCC framework and methods adopted in the past by REDD+[3] countries in their FRL are indicated.

1.1. Methods recommended in IPCC

Emissions from Forestry sector are calculated by deriving activity data (magnitude of human activity resulting in emissions or removals) and emission factors representing the change in carbon stocks as a result of the activity (IPCC's AFOLU[4] guidelines, 2006). See Equation 1.

Net emissions (Em) = Activity Data (AD) x Emission Factor (EF) (Eq. 1)

Two main methodologies to estimate logging impact on forest carbon (GOFC-GOLD[5], 2016) are:

1. The Remote sensing (RS) method using medium-resolution imagery to estimate degraded areas (AD) and Stock-Change method for EF,
2. A combination of timber extraction rates (volume method), management plans, and/or high-resolution imagery for AD and Gain-Loss for EF.

Method 1 is also applicable to deforestation and forest degradation from drivers other than logging. EF is the carbon stock difference (SD) between primary and secondary forest areas. Method 2 is specific to logging emissions and AD is based on harvested volumes ("Timber extraction rates") or on areas of managed forestland (“Management plans”) if volume data are not reliable (e.g., no FLEGT[6], high illegal logging or over cut of AACs). EF is calculated by the Gain-Loss method with a focus on biomass loss. The method is designed to provide EFs for all emission sources during operations.

1.2. Methods adopted in Forest Reference Levels (FRLs)

FRL offer a good example of application of IPCC guidance. FRL is a benchmark for assessing each country’s performance in implementing REDD+ activities (UNFCCC[7] Decision 12/CP.17). Estimation methods used by countries should be explained in FRL reports. Fourteen parties out of over 38 that have submitted their FRLs include forest degradation, and the distinction of degradation drivers varies according to the importance of logging and existing capacities/data in the country. See *Table* 2.3.1.

---

[3] REDD+: Reducing emissions from deforestation and forest degradation, (+); 3 additional activities; enhancement of forest carbon stocks, sustainable management of forest and forest conservation.
[4] AFOLU: Agriculture, Forestry and Other Land use
[5] GOFC-GOLD: Global Observation for Forest and Land Cover Dynamics
[6] FLEGT: Forest Law Enforcement, Governance and Trade
[7] UNFCCC: United Nations Framework Convention on Climate Change

Table 2.3.1: Methodologies proposed in FRL submissions for assessing forest degradation

Countries	**Activity Data (Methods)**	**Emission Factor (Methods)**
Include all drivers		
Cambodia, Chile, Indonesia, Mongolia, Panama, **PNG**, Uganda, Viet Nam	Land use transitions (RS method)	Carbon content variation (Stock-difference)
Lao	Land use transitions (RS method)	Biomass variation (Stock-difference also based on counting of stumps)
Specific to commercial logging		
Congo, Ghana, Guyana, Suriname	**Timber extraction (Official statistics)**	**Carbon losses (Gain-Loss)**
Ghana	Monitored log numbers (Official statistics)	Carbon losses (Gain-Loss)
Specific to drivers other than logging		
Ghana, Nepal	Fuel wood collect (Model supply-demand balance)	Carbon losses (Gain-Loss)
Ghana, Chile	Fire (MODIS method: MODerate resolution Imaging Spectro-radiation)	Carbon losses (Gain-Loss)

Based on FAO. 2018. From reference levels to results reporting: REDD+ under UNFCCC. 2018 update. Rome.

The RS method is the most commonly used. Its utilization is facilitated by free satellite images at medium resolution (30m) mainly from LANDSAT 7 and 8. PNG opted for this method in FRL (*Table* 2.3.2).

Table 2.3.2: Calculation of total emissions in the RS method (ex.: PNG)

REDD+ activities	**Sources of emission**	**AD (method)**	**EF (method)**
Deforestation	Forest land => Other land use tCO_2e	Land use transitions ha	Biomass difference tCO_2e/ha

REDD+ activities	Sources of emission	AD (method)	EF (method)
Forest degradation	Forest land => Forest land (emissions) tCO_2e	Land use transitions ha	Biomass difference tCO_2e/ha

Similar approach (Remote Sensing method for AD and Stock-Difference method for EF) is conducted for deforestation, forest degradation and carbon stock enhancement. EF for forest degradation is calculated in logged areas so it may include post-logging degradation from other drivers (small-scale logging, fire, gardening, etc.) and natural regeneration. *Figure* 2.3.1 summarizes the approach in PNG.

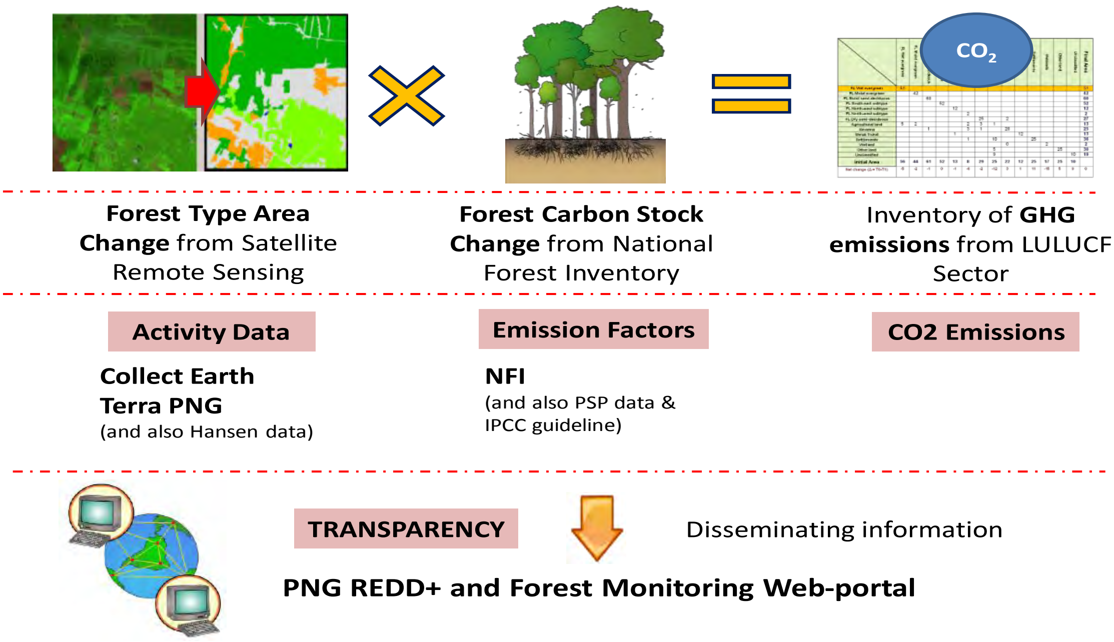


Figure 2.3.1: Calculation of emissions in the Forest reference Level of Papua New Guinea

Amongst improvement in the fields identified by PNG in its FRL (2017), several points are directly linked with the issue of estimation of logging emissions:

1. Develop a specific method for forest degradation and specific EF for logging and other drivers
2. Provide a breakdown of emission at the level of provinces or districts
3. Include Sustainable Forest Management (SFM) in the scope of REDD+ activities by providing data at concession level for quantifying emissions from conventional forest management as opposed to SFM.
4. Provide values of deadwood (critical to assess logging impact).

According to Pearson *et al*. (2014), it is more appropriate to assess direct emissions in harvesting sites. The 'Volume' method based on extracted/harvested timber volumes is the only method applied so far in FRL that is specific to logging as method for AD and EF cannot be used for other drivers. Guyana (2015), Congo (2017), Ghana (2017) and Suriname (2018) opted for this methodology (see *Table* 2.3.3).

Table 2.3.3: Calculation of total emissions in the 'Volume' method (4 FRL countries)

REDD+ activities	Emission sources	AD	EF
Deforestation	Forest land => Other land use	Land use transitions	Biomass difference
	tCO_2e	ha	tCO_2e/ha
Forest Degradation	Industrial timber production tCO_2e	Extracted volumes m^3	Biomass loss associated to extract tCO_2e/m^3

The method for forest degradation from logging is different than for deforestation and degradation from other drivers. The Volume method is an interesting approach here as it involves a proxy and field parameters. It will be detailed throughout this report.

Another method recommended by IPCC (2006) is based on 'areas of managed forest land'. According to *Table* 2.3.1, no parties have used this method so far for their FRLs. The challenge to delimit active and logged over areas is common to many forest countries. Improve mapping may facilitate this method. And to be exhaustive, one more 'Volume' method exists; it estimates extraction based on exported figures. No party have used this method yet. It was tested in PNG by PNGFA Forest Research Institute (2015, unpublished). Collateral damage was estimated from national values and assumptions. Interesting recommendations are made concerning volume data:

1. Official records of harvested volumes should be compared with logging operational plans
2. Possible time lag between actual extraction of logs and issuance of export data
3. Consider logged areas in deforestation or degradation emissions according to the harvesting method (clear cutting or selective cutting)
4. Consider IPCC and other FRL approaches to develop EF in PNG
5. Compare benefits from Remote Sensing and Proxy approaches with the help from consultancies and workshops.

Methodologies based on field assessment and proxy such as harvested volumes exist and would provide interesting results. However, field methods of vegetation analysis are usually time-consuming, extended and complex.

2. Procedures of field monitoring and methods of calculation of logging emissions

The volume method is an interesting approach to estimate the carbon impact of logging operations as it is based on in-house figures of harvested volumes and field parameters usually monitored by PNGFA Field Services Directorate. But to measure logging collateral damage may be very challenging. This part provides detailed information on procedures to determine AD and calculate EF. Main emission sources to consider and methods to monitor field parameters are presented.

2.1. Recommended procedures to determine AD

For AD, IPCC (2006) recommends providing data and information that are transparent, complete, consistent over time and accurate. To develop a robust method by using harvested volumes, relevant FRLs (four countries cited above) provided AD corresponding to the total annual extraction, in all concessions, recorded at regional and summed at national scale, and resulting in any log products such as round wood, sawn wood or plywood. Volume data come from annual reports and statistics from the State, log tracking systems, forest concession planning or operational log books.

Existing FRLs presented a representative trend by providing AD for more than 10 years: 13 years in Congo, 15 years in Ghana, 12 years in Guyana and 16 years in Suriname.

2.2. Definition of EFs

The Volume method is designed to provide emission factor for all sources of emission as a function of the unit of timber production (ton of carbon per cubic meter extracted) as indicated in Equation 2.

Total Emission Factor (TEF) = ELE + LDF + LIF (Eq. 2)

Definitions below are compiled from IPCC (2006) and relevant FRLs. TEF is the total loss of live biomass caused by immediate damage that occurs during operations. ELE (Extracted Log Emission) corresponds to extraction of the selected merchantable trees. LDF (Logging Damage Factor) accounts for log biomass left behind in felling gaps and incidental damage to surrounding trees. LIF (Logging Infrastructure Factor) accounts for dead wood biomass caused by infrastructures built for removing logs out of the forest. LIF includes skidding trails caused by the use of bulldozers or other equipment to transporting logs from felling areas to roads; logging decks (or landings) where logs skidded out from forest are piled waiting transport; and logging roads used by vehicles to transport logs out of the forest. We propose a representation of different sources of emission (*Figure* 2.3.2).

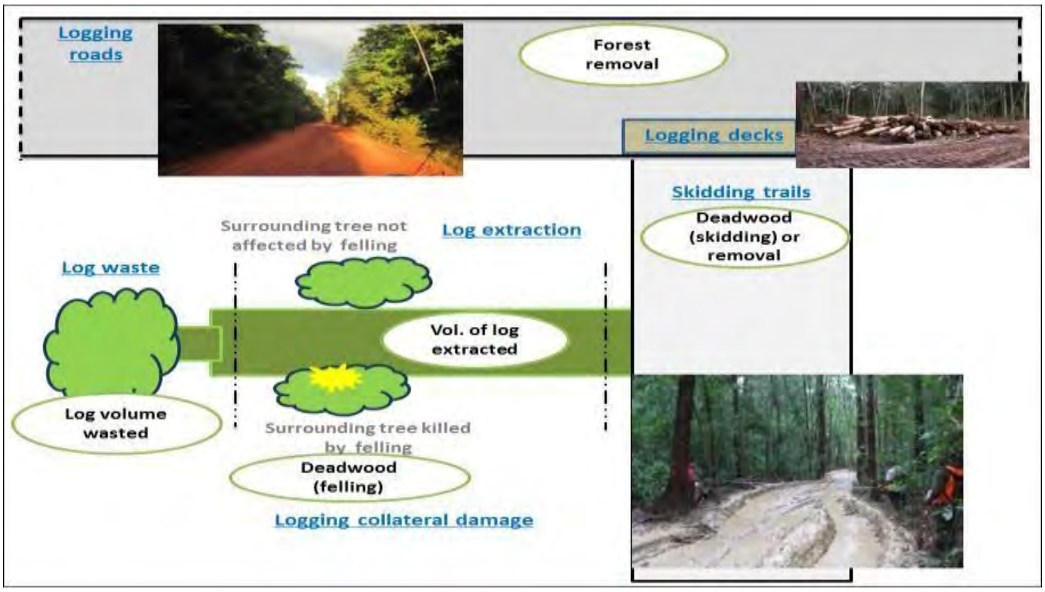


Figure 2.3.2: Main sources of emission from commercial logging

To calculate each EF (and estimate each emission source), It is recommended to use parameters directly assessable on the ground and good indicator(s) of carbon impact. See *Table* 2.3.4.

Table 2.3.4: Utilization of field parameters to calculate logging EFs

EFs	Sources of emission	Monitoring parameters
ELE (extraction)	Removal of biomass of the whole tree felled	Extracted/harvested log
LDF (collateral damage)	Log left behind as trimmed or abandoned	Wasted logs
	Damage on trees surrounding the felled tree	Deadwood (DW) caused by felling
LIF (road & infrastructure)	Skidding trails	Skidding deadwood or carbon loss
	Logging roads	Road carbon loss
	Logging landings/decks, ponds and camps	Infra carbon loss

Methodology implementers are actually free of following their own choice unless all sources of possible emission are recorded and the entire procedure remains logic and conform to IPCC (*Table* 2.3.5).

Table 2.3.5: Correspondence between EFs and Field parameters in IPCC and FRL countries

Parameters assessable on field	IPCC/Pearson	Congo	Ghana	Guyana	Suriname
Extracted log	ELE	ELE	ELE	ELE	ELE
Wasted logs	LDF	ELE	LDF	ELE	LDF
Felling DW	LDF	DF	LDF	LDF	LDF
Skidding carbon loss	LIF	DF	Skid EF	LIF	Skid EF
Road carbon loss	LIF	DEF	Road EF	DEF	DEF
Infra carbon loss	LIF	DEF	Infra EF	DEF	DEF

DF: Damage Factor; DEF: Deforestation.

In three out of four FRL countries, emissions from logging roads and infrastructure are accounted as deforestation (DEF) so monitored by RS. Congo and Guyana included log landings in roads as they are often an extension of road areas. The Republic of Congo simplified categories from three

(ELE, LDF, LIF) to two (ELE and Damage Factor). ELE regroups extracted and wasted logs and DF regroups felling and skidding deadwood. This approach has benefit to ease field measurements and facilitate development of two Damage Factors: one for "certified" and one for "non-certified" concessions.

2.3. Methods to monitor carbon parameters and calculate EFs

Extracted Log Emissions

Volumes of both log and entire tree are estimated from log diameter measured on the ground or obtained from records. It is recommended not to fix a sample area (just adapt to the felling gap) and to use fresh gaps. Mean-ELE is the sum of gap-ELEs divided by the number of gaps sampled. For converting log diameters into emissions, methodologies referred in Chave *et al.* (2005). See *Table* 2.3.6.

Table 2.3.6: Conversion steps from log diameter to CO_2e emissions

Steps	Initial	Converting factors	Final
1	**Diameter** & length (m)	f(DBH,H) allometric eq.	Log volume (m^3)
2	Log volume (m^3)	Density (tdm/m^3)	Log biomass (tdm)
3	Log biomass (tdm)	Biomass Expansion Factor	AGB (tdm)
4	AGB (tdm)	1+ Ratio aerial/roots	Tree biomass (tdm)
5	Tree biomass (tdm)	Carbon Fraction (tC/tdm)	Tree carbon (tC)
6	Tree carbon (tC)	Conversion Fac. tCO_2e/tC	**Emission** (tCO_2e)

Three of the four FRL countries opted not to consider long term carbon sequestration in wood products assuming that all carbon extracted is emitted at harvest time. Additional methods exist to consider sequestration with the application of a set of equations and national values.

Logging Damage Factor

LDF includes wasted log pieces and surrounding trees killed or damaged by the fall of the felled tree.

<u>1- Wasted logs</u> i.e. trimmed, defected and abandoned logs can be estimated by several methods:

- Assumed as 20% of gross tree volume (10% from trimming; 10% from abandon), cf. Congo FRL
- Subtract the registered log volume to gross tree volume
- Inventory diameter of stump (or bottom of the log if no stumps) (4), stump height (5), length of pieces (6), diameter of bottom (7) and top of pieces (8). See *Figure* 2.3.3.

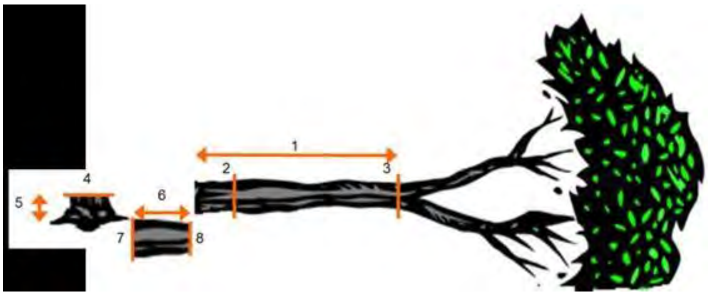


Figure 2.3.3: Inventory method to estimate extracted and wasted volumes

<u>2- Felling deadwood</u>: diameter of deadwood* created during felling is measured in felling gaps so that it corresponds with extracted volume. Deadwood refers to two categories of damage: trees snapped (main branches broken) or uprooted (lying on the floor). There is unanimity within 4 FRL countries for measuring deadwood by field inventory. Deadwood from waste, felling and skidding can overlap the same area. So felling deadwood is sometimes accounted with other parameters such as wasted logs (in Ghana and Suriname) or skidding deadwood (in Congo). Assessed together, deadwood in skidding and felling gaps can be a good option to simplify inventory and use very high-resolution imagery to assess the sum of all gaps (GOFC-GOLD, 2016).

** Trees surrounding felled trees that are killed by felling together with waste logs is sometimes referred to as the sensu stricto definition of collateral damage. The sensu extenso definition includes in supplement road and infrastructure. The definition widely varies in the literature, here we use the large definition unless we bring precision.*

LIF for skid tracks

Emission Factor of skid trails is calculated by associating emissions due to tracks created with the volume of logs extracted by using this skid track (eq. 4). Note that log extracted volume does not only refer to volume of merchantable trees from track clearing but also includes logs extracted from felling gaps and from the clearing of log decks.

LIF [skid] (tC/m^3) = Skidding Emissions (tC) / Log extracted volume (m^3) (Eq. 4)

The four relevant FRLs calculated Skid Emissions by using a Skid factor. See Equation 5.

SE (tC) = Skid Factor (tC/ha) x Skid Area (ha) (Eq. 5)

Skid Factor (SF) or carbon content in skid trail areas can be estimated by 3 methods:

1. SF = Carbon stock of unlogged (or pre-logged) forest. This is applied in the case where skidding tracks are wide and completely cleared of vegetation (GOFC-GOLD, 2016)

2. SF = 88% of carbon stock of the forest strata. This is applied when vegetation is not completely removed and assuming dozers avoid trees with diameter > 20 cm (Kongsager *et al.*, 2011). Ghana FRL showed that trees with diameter < 20cm correspond to 12% of vegetation. Applying this assumption, a country can realize its own study or the potential use of this method.
3. Inventory of all deadwood (diameter > 10cm) lying or fatally snapped in skid tracks plus a buffer zone of 2 m each side to appraise trees damaged by skidding. Deadwood can be sampled in sampling plots along skid trails.

Skid area is calculated based on width and length. A mean width can be obtained from several measurements. Although not mentioned in FRLs, width can be assumed at least equivalent to mean size of dozer blades (3-4 m). Skid length is measured but there is no mention of tools used. We assume GPS, tape meter or foot steps are utilized. The whole sampling approach is schematized in *Figure* 2.3.4.

Also, area can directly be assessed by high resolution RS (GOFCGOLD, 2016).

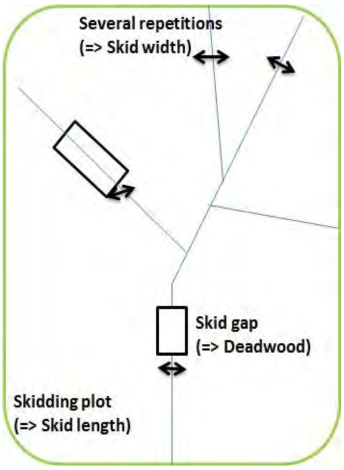


Figure 2.3.4: Sampling of skid trails

LIF for logging roads and log landings

Under some accounting schemes, roads and decks (but also log ponds and camps) are counted as deforestation because they show up in moderate resolution imagery analysis (e.g. Landsat), and their emissions can be addressed through Stock-Difference approach (see Part 1). However, the direct correlation with logging makes it logical to include all sources of emissions under timber management (Suriname FRL). In that case, Gain-Loss method and EF per cubic meter extracted are applied, same as for skid trails. Emissions from roads and decks can be calculated as below:

1. Road and Deck Factor corresponds to the carbon stock of forest strata (GOFC-GOLD, 2016)
2. Road area is estimated either directly by RS or based on a mean width (repetitions using GPS or RS) and road length (using GPS and a vehicle, or RS)
3. Deck area is estimated in each deck or only in one or two decks to get mean value. Mean area is then multiplied by the number of decks in the active area.

Total Emission Factor (TEF)

<u>Summary of options to determine/measure field parameters</u>: a summary of different options recommended to measure parameters necessary to calculate EFs is presented (*Table* 2.3.7). The IPCC has classified the methodological approaches in three different Tiers, according to the quantity of information required, and the degree of analytical complexity (IPCC, 2003, 2006). EF is generally determined by default in Tier 1, nationally or country specific values in Tier 2 and by higher order methods in Tier 3.

Table 2.3.7: Measurement options and corresponding IPCC Tier

Emissions	Measurement options		
	Tier 1	Tier 2	Tier 3
ELE			
Extracted logs			Inventory
LDF			
Wasted logs	20% of tree biomass	= volume of tree – volume of log	Inventory
Felling Deadwood			Inventory
Felling gap area			High resolution RS images (drone photo)
LIF [Skid]			
Skid Factor		- Carbon stock of trees > 20cm - Carbon stock unlogged	Inventory
Skid width and length		Average dozer blade	Tape meter, GPS
Skidding gap area			High resolution RS
LIF [Road and Deck]			
Road Factor / Deck Factor			Carbon stock unlogged
Road area		LCoP threshold width (40m)	RS, Tape meter, GPS-Car
Deck number			Counting, RS
Deck area			Tape meter, RS

Calculation: *Table* 2.3.8 summarizes the method to calculate each component of the Total Emission Factor.

This table highlights required correlation between emissions and associated log volumes.

Table 2.3.8: Correlation between emissions and associated extraction

Sampling plot	Emissions (tC)	Corresponding vol. (m^3)	EF (tC/m^3)
1 felling gap	Extracted log	Vol. of the log extracted in the felling gap	ELE
1 felling gap	Wasted logs + Killed trees		LDF
1 felling gap	Extracted + Wasted + Killed		ELE + LDF
1 skidding gap	Deadwood or Removal	Vol. extracted via this trail	LIF [skid]
1 road section	Forest removal	Vol. extracted by this road	LIF [road]
1 log deck	Forest removal	Vol. stored in this deck	LIF [landing]

2.4. Sampling approach to determine logging EF

Exhaustive measurement of carbon parameters in concession area is too constraining. All countries adopt a sampling approach with different sampling methods and units. See examples in *Table* 2.3.9.

Table 2.3.9: Sampling method developed in FRLs for calculating logging EFs

Sampling items	Sampling units	Sampling repetitions (FRL and Pearson)
Extracted log (diameter and length when possible)	Felling gap	46-105 per concession (Pearson *et al.*) 25 per concession (Suriname FRL) 31 per concession (Gabon and Medjibe, 2011)
Wasted logs (same)		
Felling DW (same)		
Biomass loss from skid trails	Skidding gap	164 per concession (Ghana FRL) 39 per concession (Gabon; Medjibe *et al.*, 2011)
Biomass loss from roads	Road section	11 per concession (Ghana FRL)
All above items	Concession	1 to 4 (Pearson, Ghana, Congo) and 10 (Suriname) concessions on a wide range of terrain conditions, extraction intensities and management types

In conclusion, specific methods exist to estimate logging emissions. An interesting point is that they are generally "in-house" methods, i.e. based on data ordinarily produced within the

National Forest Service. However, the Volume method does not capture emissions from post-harvest, gardening, small-scale logging, etc. Further review is necessary on how these issues are considered in international methodologies and FRLs. Recent developments in technical guidance for inventory are key sources of information for tropical forest country governments to apply such methods.

3. Potential in PNG to estimate logging emissions

In order to estimate direct emissions from logging, PNG needs to acquire historic data of timber volumes produced and develop a sampling plan to calculate logging EFs. Actual routine activities of forest management conducted by PNGFA generate a lot of relevant data. This Part describes information collected from ordinary forest monitoring and examines possible utilization for determining AD and EF. Statements reported in this Part can be subject to further investigations.

3.1. Activity Data

Information collected on harvested volumes

All logs produced by individual felling or by extraction of merchantable species during the clearing of skid tracks and decks are stored and scaled in log decks. Log scaler is an agent of the logging company who has a license issued by PNGFA. For each log, there is a record of diameters, lengths, and the corresponding Setup number. Logs from merchantable species extracted during clearing of log ponds and camps are attributed to Setup following Annual Logging Plans. For roads it is a bit more complex as roads cross several Setups, and they are set before operations. For royalty reason, volumes from road clearing are spread out along the road to attribute logs equally between Setups (and corresponding landowner groups) deserved by the road.

Diameter data are reported in 'Log scaling record sheets' and volume data in 'Setup scaling sheets'. Setup scaling sheets are sent by project to province and regional (or Area) offices which store data in regional database. Area data are transferred to the central database of Field Services Directorate (FSD) located in PNGFA headquarter and are used for policy design (part of FSD Annual Report), verification of exported volumes and royalty calculation (*Figure* 2.3.5).

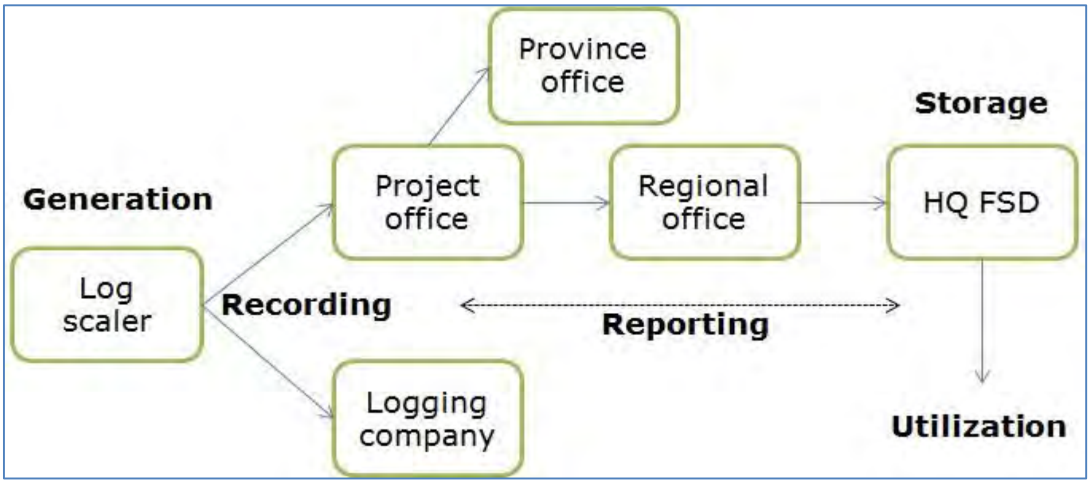


Figure 2.3.5: Flow of harvested volume data in PNGFA from scaler to central database

Total volumes in closed Setups are reported as result in next Annual Logging Plan (ALP). The production of ALP and thus the issuance of volume data do not follow fiscal calendar. However, 'FSD Annual reports' showing yearly production by province and project are submitted in the beginning of each year. So, all timber produced the previous year in Setup already closed is available. The national database is physically corresponding to an Excel matrix stored in FSD (*Figure* 2.3.6).

Volume By Province By Project 2010 to 2017

		YEAR	2010	2011	2012	2013	2014	2015	2016	2017	FCA Totals
PROVINCE	TP/TL/LFA/FCA/FM	PROJECT	VOUME(M3)	VOLUME(M3)	VOLUME(m3)	VOLUME(M3)	VOLUME(M3	VOLUME(M3)	VOLUME(M3)	Volume(m3)	Volume(m3)
Western	tp-1-7	Wawoi Guavi	232747.307	222570.043	198255.760	171974.345	305729.733	280279.295	144392.602	213124.112	
	TP 1-9	Makapa	140164.717	193186.458	182555.337	159193.595	233312.401	148087.249	151819.45	131449.546	
	TP1-10	Wpim Tapila				42334.665	6680.803	54651.185	49750.388	45030.673	
	TA 01-51	Ziegu TA	306.510								
Gulf	TP 2-12	Turama	77913.992	149325.462	159407.660	161191.704	150906.184	215777.466	165521.723	125558.384	
	TP 2-12 A	Turama Extension	64803.901	92318.548	104134.970	108014.763	144703.184	185001.056	79963.138	115626.302	
	TP 2-14	Vailala Block 1	67056.237	74163.058	63636.038	50028.877	53415.522	84855.962	87029.241	70744.914	
	TP 2-15	East Kikori	0	13103.348	25058.445	11971.148	16466.171			0	
	TP 2-16	Vailala Block 2 &3	114337.272	110474.244	85347.283	65904.831	45613.798	73028.000	49862.948	37812.894	
	TA 02-09	Ela River	340.618	254.610							

Figure 2.3.6: View of the Excel matrix in PNGFA-FSD storing Volume data

The matrix contains key information for calculating emissions such as provinces with active concession, cutting authorization types [Timber Permit (TP/TRP), Timber Authorization (TA), Forest Clearing Authority (FCA), Forest Management Agreement (FMA)], project concession name, and annual timber extraction (m^3) here for 2010-17 but data are available from 2000 (except for 2004).

Potential for determining Activity Data

PNG dataset of actual harvested volumes needs to fill certain requirements to produce reliable AD for emission calculation (see Part 2). Findings for the dataset available in PNG are summed up in *Table* 2.3.10.

Table 2.3.10: Conditions of the volume dataset to calculate emissions are filled in PNG

Conditions	PNG potential	Explanation
All concessions	Yes	All projects are monitored
National scale	Yes	Provincial & regional production reported to central DataBase
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.)

It should be noted that PNG has a specific method to measure log dimension on the field. This method is based on the measurement of a certain part of the log. This aspect should be further investigated more in detail in order to fit with international guidance for conversion from log diameter to log and whole tree volume. Harvested volumes are reviewed by PNGFA and forest companies (which record diameters and calculate volumes), landowners (for royalty reasons) and export data auditors. It seems that Integrated Land Groups (ILG) are more and more proactive in the control of scaling and acquire means for that (accounting capacities, light material such as calculators, etc.). However, FSD evaluates possible errors in recording g and diverse other data at more or less 5% (FSD, pers. discussion). Also, 10% of the scaling is checked by PNGFA supervisors in log ponds and which is further verified by SGS[8] before exporting of round logs. For quality control of carbon estimation, an exhaustive verification is recommended ideally. In FRI study on exported volumes (2015), records of harvested volumes were found to be incomplete and inconsistent but data can be easily collected. Recommendations were made for comparing central FSD data with data in logging companies and export databases (SGS).

3.2. Emission Factors

Information collected about field parameters

Figures of biomass loss caused by extraction, felling, skidding and hauling activities are required. Two types of management activities in PNGFA generate information on such field parameters:

① Recording of log volumes extracted during the construction of infrastructures (see Section 3.1)

② Monitoring of operations to evaluate the compliance of operations with 1996 Logging Code of Practice (LCoP) by supervisors. *Table* 2.3.11 highlights correspondence between field parameters assessed in routine monitoring and the ones to be assessed for carbon monitoring.

Table 2.3.11: Threshold values checked for carbon parameters in routine monitoring

Thresholds checked for operations' control	Indications for carbon monitoring
Width < 40 m	Forest removal from roads
Area < 0.25 ha per setup	Forest removal from log landings
Width < dozer blade (current LCoP) Area < 10% of total setup area (proposed LCoP)	Area of skid tracks
Directional felling application	Deadwood due to felling
Total log wasted/abandoned < 5%; Stumps < 50cm	Wasted logs (stump, top and abandoned logs)

Results of LCoP monitoring are reported in 'Field assessment sheets' but not as quantitative

[8] SGS: Society Generale de Surveillence Group is the world's inspection and verification organization, specializing in independent 3rd party verification of custody transfers of all types of commodities.

values. Apart of that, the size of infrastructures is recorded in Setup logbooks together with Setup scaling sheets. See *Table* 2.3.12 for a summary of field information that are effectively and regularly gathered.

Table 2.3.12: Carbon-related information available from PNGFA logging operations control

Sources of degradation		Data (unit)	Source documents
Logging infrastructure	Forest Clearance for Camp sites	Length & width or Area [ha]	Camp plan
		Merchantable timber volume [m3]	Setup scaling sheet
	Forest Clearance for permanent roads	Length & width or Area [ha]	Road line Setup log book
		Merchantable timber volume [m3]	Setup scaling sheet
	Forest clearance for feeder and spur roads	Length & width or Area [ha]	Setup logbook
		Merchantable timber volume [m3]	Setup scaling sheet
	Forest clearance for log landings	Length & width or Area [ha]	Setup logbook
		Merchantable timber volume [m3]	Setup scaling sheet
	Forest clearance for skid trails	Length & width or Area [ha]	**No records**
		Merchantable timber volume [m3]	Setup scaling sheet
Logging damage	Disturbance from felling.to surrounding trees	Deadwood in felling gaps [m3]	**No records**
	Log wasted volume	Wasted log pieces (stump, top, buttress) [m3]	Post-harvest assessment sheet (in theory)
Log extraction	Log extracted volume	Merchantable timber volume [m3]	Setup scaling sheet but also in DB (see Volume info)

Skid trails and collateral damage are assessed on the ground from supervisor's eyes. Only 10% of total skid tracks is checked. There is no record of the area of skid trail (although timber extraction is recorded) or deadwood in felling gaps. Also, there is no scaling done for wasted log pieces. Post- harvest assessment would be done when project supervisors recognize the volume of waste logs overpasses 5% of total extracted volume in the Setup. But it seems that the assessment is rarely realized. To sum, Setup logbooks provide much information but not gathered into database; information is at the project side in the hands of field officers and logging companies.

Potential for calculating EFs

<u>+ Extracted Log Emission (ELE):</u> Setup scaling sheets provide volumes of log extracted which can be extrapolated into emissions (full tree) then reported to the log volume extracted in the felling gap.

<u>+ Logging Damage Factor (LDF)</u>: for the inventory of deadwood caused by felling, challenges in PNGFA are reported as to be less at the capacity level (inventory method well known) than ability level (manpower, car and fuel). Then the emissions are reported to the log volume extracted in the felling gap to calculate LDF (tC/m^3).

+ Logging Infrastructure Factor (LIF): for estimating carbon impact from roads and infrastructures (including skid tracks) by sampling, the challenge is to associate infrastructure areas with a known value of extracted volume. Setup logbooks provide infrastructure area for the entire roads, camps or decks, at the time they are built. But to obtain the length of a specific road section (e.g.: road section associated to one setup), different methods can be applied:

- *Direct measurement*
- *Utilization of information from setup logbooks*: when the area that is sought for sampling is directly available in Setup logbook. In the case where only length is available, an assumed width of roads of 40m and skid tracks of 4 m can be used.
- *Utilization of concession maps*: map is usually attached to logging plans, designed by operators and stored in PNGFA. Actual area of roads can be calculated based on Eq. 6.

Road area (ha) = **Road length on the map (m) x Scale of the map x Average width (m)** (Eq. 6)

- *Proxy method based on extracted volumes*: the area of a road corresponding to one or several setups can also be calculated based on the volume of merchantable species that was extracted during the clearance of this road, and by using timber average density of 15 m^3/ha. This method can be very useful for skid tracks. See Equation 7.

Road area (ha) = **Extracted volume kid Factor (m3) / Average density (m3/ha)** (Eq. 7)

- *Remote sensing* can be used for logging roads and landings with medium resolution and for skid tracks with high resolution. The purpose of this report is to examine potential of field methods but new technologies providing very high resolution can be valuable which will complement the field monitoring aspects. (Part 4).

+ Total Emission Factor

EF are expressed in tonnes (t) of carbon (or CO_2 equivalent) per cubic meter (m^3) of timber volume. Each source of emission should be associated to a level of production (extracted volume). However, harvested volumes are known with available data only for the following areas: felling gaps, setups and Concessions (as shown Part 3.1). Emissions due to felling (from extracted logs, wasted logs and deadwood) should be associated to the log volume extracted in one gap (1 to 3 trees) to calculate emission factors ELE and LDF. To calculate EF for skid trail, we need to know skid emissions and associated extracted volume. Skid emission is generally calculated based on forest removal as shown Part 2. The value of log extracted from one skid trail is not known because not usually recorded in PNGFA records. But the volume extracted in one setup is known/recorded so the skid EF should be calculated based on the sum of emissions from all skid tracks of one setup (e.g..: 5 tracks) as Skid Emission and based on the volume extracted in this setup (which is known). Same approach can be used for decks, roads and log pond (see *Table* 2.3.13) regroup the sampling strategy to get the right correspondence between extracted volume and sampled emissions. Associated volumes mentioned in red are generally not available, the option right below offers a possible alternative.

Table 2.3.13: Sampling strategy to calculate emissions (in red data generally not available)

Sampling options	Sources of Emission (tC)	Associated volumes (m^3)
1 Felling gap	Extracted tree	Log volume extracted from 1 gap
1 Felling gap	Wasted logs	
1 Felling gap	Deadwood caused by felling	
1 skid trail	Skid Emission (SE)	Extracted volume from 1 skid track not available
No of trails in 1 setup (ex.: 5)	Sum of SE for 5 skid tracks	Log volume recorded in the setup
Canopy openings	All gaps created by felling and skidding	Log volume recorded in the setup
1 log deck/landing	Deck Emission (DE)	Extracted volume from 1 log landing not available
No of decks in 1 setup (ex.: 3)	Sum of 3 DE	Log volume recorded in the setup
1 road section deserving 3 setups	Road Emission	Log volume recorded in 3 setups
1 log pond	Pond Emission (PE)	Extracted volume from 1 log pond
No of log ponds in 1 project (ex.: 2)	Sum of 2 PE	Log volume recorded in the concession

Generally, every source of emissions can be accessed based on PNGFA information. But sampling methods to determine EF can become very time consuming as several repetitions are necessary. Complementary methods, tools or approach would be supportive such as shown Part 4.

4. Future potential based on on-going initiatives in PNG

PNG is engaged in sustainable forest management. As such many efforts are on-going to improve the management of data related to Forestry and the Logging sector. To complete the comprehension of PNG potential in calculating logging emissions, we need also to analyze future potential created from initiatives in development in PNGFA under JICA project; PNG-FRIMS and further initiatives in the National Forest Inventory, the Decision Support System and the Timber Legality and Verification System when they are completed.

Most of future initiatives have the potential to facilitate volume data management. The originality of JICA project is that it may facilitate calculating EF by improving field monitoring methods. Contribution from PNG-FRIMS and further relevant initiatives are summed up in *Table* 2.3.14.

Table 2.3.14: Future supports from PNG-FRIMS and NFI in the estimation of logging EF

On-going Initiatives	Methods/systems	Parameters that can be estimated
Collect Earth FAO) and pilot (JICA)	**RS** (30m) / GIS	- Deforestation and Degradation areas - Roads areas
	Digitizing of **ALP**	- Road areas - Infrastructure location
PNG-FRIMS (JICA)	**GPS** / **Drone**	- Canopy gaps (felling / skidding DW) - Infrastructure
	AGB updates	- Road or Infrastructure Factor
NFI (EU, FAO)	**Deadwood** info	- DW in Fell/Skid gaps
	Decision Support System / SGS database	- Volumes (acquisition and storing in a central database)
Other	Timber Legality Standards (**TLS**)	- Volumes (improve data quality and management)

5. Integration of the Volume method in PNG's FRL

The estimation of the logging impact can allow determining a large part of emissions from forest degradation in countries like PNG where timber production is the major source of degradation. This Part describes procedures to integrate the Volume method in current PNG's FRL methodology, strategic choices associated with this option, and a sampling plan to develop a logging EF.

5.1. Methodological choices

Several countries developed methods that are specific to one driver of forest degradation. They are set out in *Table* 2.3.15.

Table 2.3.15: Methods specific to degradation drivers developed in FRLs

Countries	Degradation drivers accounted by specific methods
Guyana	Logging
Suriname	Logging
Congo	Logging, fuel wood collect
Ghana	Logging, illegal logging, fire, fuel wood collect
Nepal	Fuel wood collect
Chile	Fire

In PNG, almost all forest degradation is caused by commercial logging (PNG, 2017). Most of small-scale logging is considered in TA which few are significant in terms of volumes and emissions. The collection of fuel wood seems significant but no reliable records exist. For forest fire, no records exist but only 6% seems to occur in closed canopy areas. So PNG can justify calculating historic emissions based on two distinct and complementary methods (like in Suriname and Guyana): the 'Remote Sensing - Stock Difference' method to estimate emissions from deforestation and the 'Volume - Gain/Loss' method for forest degradation from logging. (*Figure* 2.3.7).

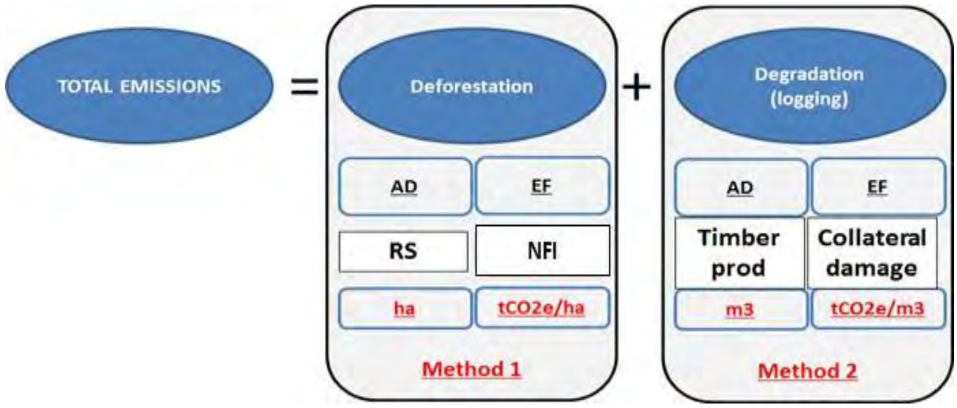


Figure 2.3.7: Estimation of emissions based on 2 distinct and complementary methods

The country process would follow a wise step approach. The first step corresponded (in 2017 FRL) to the utilization of available data from RS to estimate land use transitions (all types). The second step could provide a method specific to logging because logging is the major source of forest degradation and volume information are available and information on collateral impacts are more and more accessible. And the final step could provide details of degradation drivers other than logging which are less significant and more difficult to access. This step wise approach is summarized in *Figure* 2.3.8.

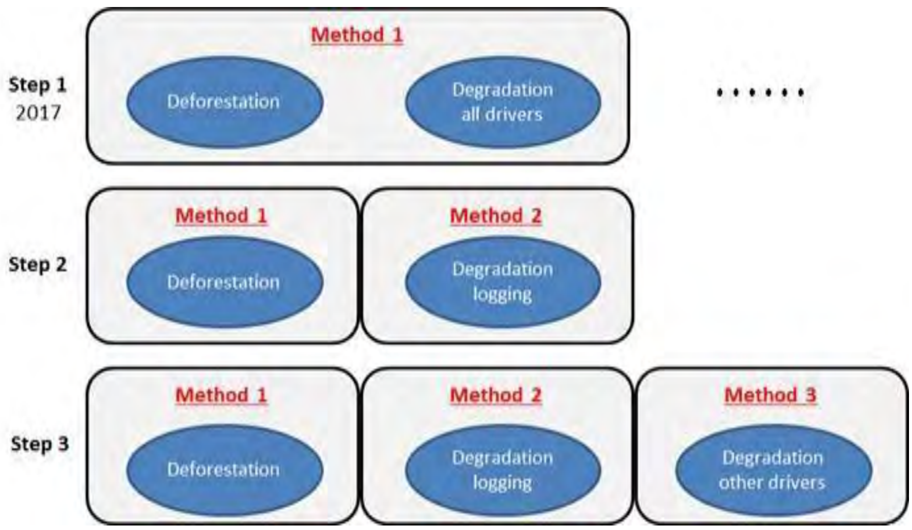


Figure 2.3.8: Possible step wise approach in FRL construction in PNG

5.2. Possible benefits from the previous FRL

Table 2.3.16 provides a summary of improvement fields that were identified by PNG in its current FRL and possible benefits from the Volume method.

Table 2.3.16: PNG FRL improvement fields and possible contribution by Volume Method

FRL improvement fields	Possible inputs from the Volume Method
Method specific to Logging (AD and EF)	Volume method accounts emissions associated to timber production
Develop EF for each degradation driver	Vol. method accounts impacts on forest carbon from commercial logging only. EF for additional drivers of forest degradation can be developed in the future by introducing additional method
Include SFM (REDD+ activity) by developing 2 EFs one for improved and one for conventional practice	This method allows by the development of two EF, made possible from acquired methodologic experience, to compare carbon "efficiency" in two types of logging concessions (ex.: certified vs. not certified)
Consider other carbon pools	Deadwood needs to be inventoried in felling and skidding gaps.
Breakdown AD, EF and emissions at province level	Harvested volumes data available for each concession allows calculating emissions for district, province and national level

It is important to note that province estimation of historic net emissions is a good basis to develop provincial REDD+ activities. Better evaluation of logging impact, Emission Reduction (ER) potential and associated financial benefits can be useful to develop suitable policies, actions and measures (PaMs). Based on improvement for example in PNGFA-JICA project in the two pilot provinces (West New Britain and West Sepik), these provinces will be good candidates for a provincial ER program (targeting reduce impact logging). Test in the provinces can provide lessons learnt for the nation-wide REDD+ Strategy. Different activities can be tested with stakeholders of the Logging sector such as PNGFA field supervisors and operators.

Concepts and technologies introduced by JICA project can support this initiative.

5.3. Simulation of the national FRL

To determine AD, timber volumes must be accounted as either degradation or deforestation according to the origin of timber (type of permit). Below is a proposition of sharing:

- Forest degradation for productions from TRP/TP, LFA and FMA

- Deforestation for productions from FCA by assuming all FCA areas will be clear cut by the end of the projects. Many examples showed the utilization of FCA (which is basically a lease for developing agriculture activities) for Forestry purposes i.e. for timber. These examples will be accounted neither in deforestation (because not visible from RS) nor in degradation (because FCA decided to be integrated in deforestation). So total extracted timber, and total carbon emission, will be underestimated because it will not include FCA degradation. But at least this approach does not lead to overestimation and so it is considered as a conservative approach of carbon estimation
- Deforestation or degradation for timber issued from TA, the question remains here also clearance is allowed although restricted to 50 ha. However, TA represents only less than 0.5% of total volume extracted so it could be conservatively omitted.

Based on this description, *Table* 2.3.17 gives an example of Activity Data for PNG (nationwide).

Table 2.3.17: AD for the Volume method (total extraction FCA excluded). Source: FSD

Simulated AD based on extraction 2010-17
(FCA excluded). Source: FSD

Year	Activity Data (Mm3)
2010	3.11
2011	2.65
2012	2.6
2013	2.79
2014	3.29
2015	3.64
2016	2.28
2017	3.45

PNGFA-FSD data can be compared with harvested volumes recorded in logging companies; with exported volumes (considering FCA and time lag); or with areas of degradation determined by Remote Sensing, as established in the first FRL (Collect Earth software and using Hansen data).

To develop a logging EF, field parameters can be measured from two methods: information from Setup logbook (when available) or from sampling approach. A sampling plan should clarify sample plots, items, and number of repetitions. *Table* 2.3.18 proposes a simulation of such a sampling plan.

Table 2.3.18: Indicative sampling plan to develop logging EF (from examples of other FRL)

Sampling Units	Repetition	Examples of Choice
Concessions	4	- 2 intensive: WNB, WS, W or Gulf - 1 moderate: NI, ENB, MA, MO, CE - 1 low: MA, Northern or MB
Felling gaps	200	50/concession
Skidding gaps	100	25/concession
Log landings	40	10/concession
Roads	Exhaustive	All roads of active setups (about 40 km)
Ponds	Exhaustive	All super deck of active (about 3)

Obviously, the zones with data already available are preferred. For instance, it could be advantageous to use PNGFA Permanent Sampling Plots and project pilot areas. On the examples of Suriname and Congo, concessions can be selected according to extraction rates. Because in PNG there are no certified concessions, this approach could provide a good option to differentiate concessions. An example of activities to sample field parameters is shown *Figure* 2.3.9.

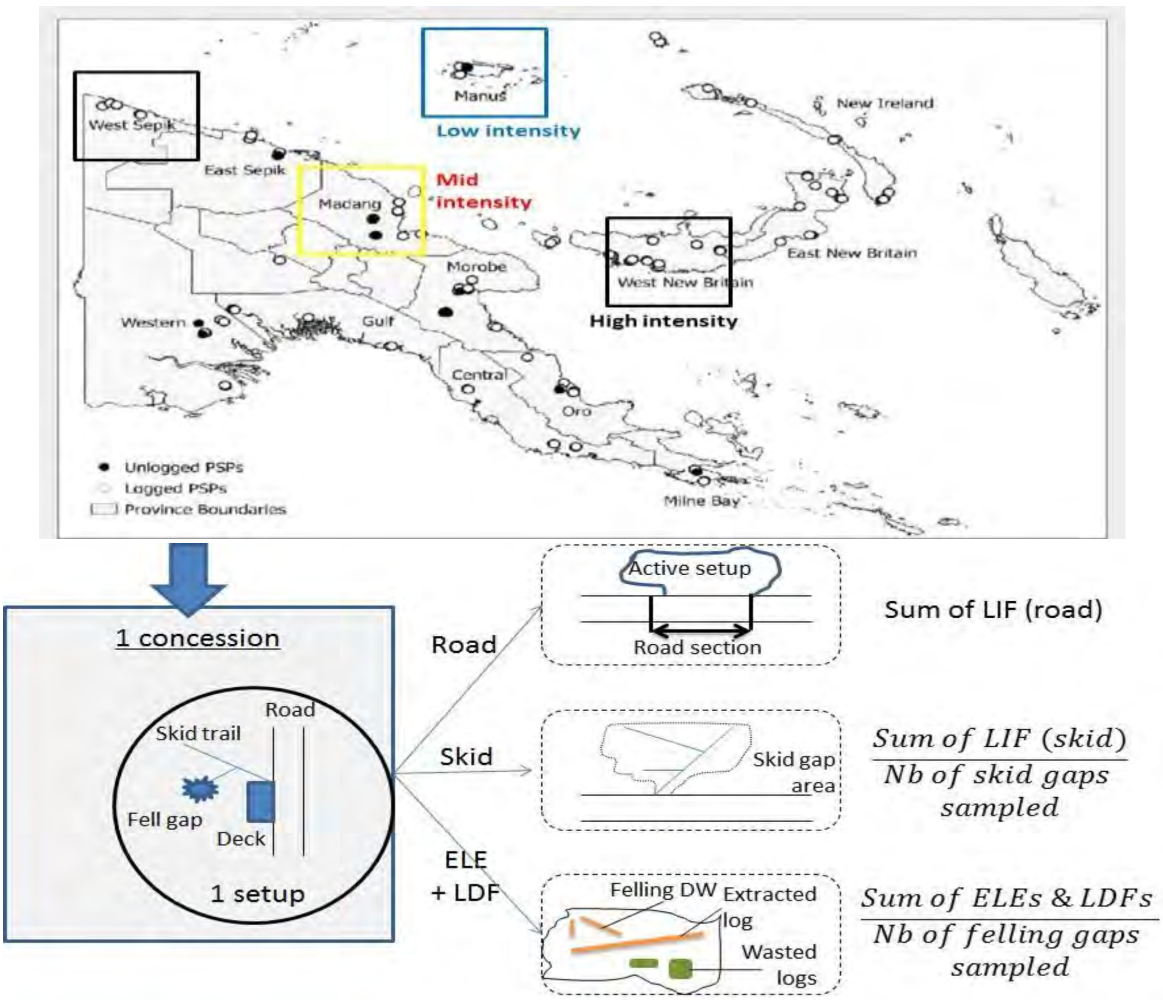


Figure 2.3.9: Proposition of plan for sampling field parameters to calculate total EF

TEF calculated based on existing data in FSD and based on this sampling plan can be compared with the Damage Factor of Congo (considering that it does not include road and infrastructure) or with the EF of PNG as found in FRI study on export volume (PNGFA, 2015).

To calculate total emissions, mean values of ELE, LDF and LIF are summed to get a value of total EF. EF is a constant. TEF is then multiplied by annual timber production to calculate total emissions. *Table* 2.3.19 shows a simulation by using EF from Congo and 3.6 to convert tC into tCO_2e.

Table 2.3.19: Matrix simulating total emissions from logging in PNG (EF assumed = 1 tC/m^3)

Year	AD (Mm^3)	Total EF (tC/m^3)	Total logging carbon loss (MtC)	Total logging emssions ($MtCO_2e$)
2010	3.1	1	3.1	11.2
2011	2.7	1	2.7	9.5
2012	2.6	1	2.6	9.4
2013	2.8	1	2.8	10.0
2014	3.3	1	3.3	11.8
2015	3.6	1	3.6	13.1
2016	2.3	1	2.3	8.2
2017	2.5	1	3.5	12.4

Total country emission in the Forestry sector is the logging emission added to emission from deforestation. Total emission obtained from two methods (RS for deforestation and Volume for degradation) can be compared with the RS method for deforestation and degradation (current FRL).

5.4. Input to carbon MRV (Monitoring, Measuring, Reporting and Verification) system

Technical framework

Improvement of existing monitoring activities and innovations can be integrated into ordinary activities of forest monitoring to monitor carbon. See an option of carbon monitoring plan (*Figure* 2.3.10).

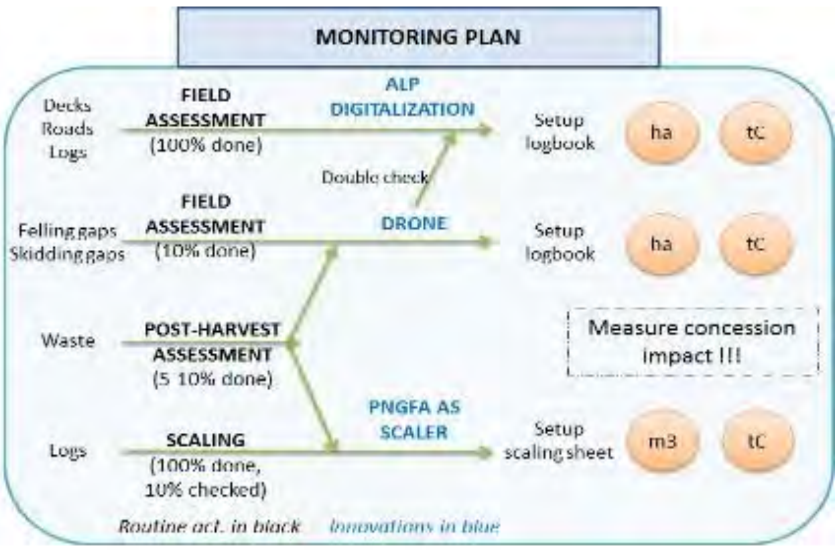


Figure 2.3.10: Carbon monitoring plan building on routine monitoring activities

Monitoring the indicators of carbon impact during routine assessment will foster following activities:

- Realization of log scaling by PNGFA officers
- Activation of post-harvest waste assessment
- Integration of field measurement of felling and skidding gaps in Setup logbooks
- Improvement of the accuracy of logging road and infrastructure areas.

Stakeholders

Logs could be scaled by PNGFA project supervisors and diameters double-checked by logging companies. This can increase reliability of volume data. Paper ALPs from operators could be digitized by cartographers in the Inventory and Mapping branch of FPPD. This could provide the position or location of Road and Infrastructure with the information on size already available. Knowing the position facilitates associating to a road section (or a log deck) a value of timber extraction. The objective is also to record their dimensions in numeric format to facilitate storage and reporting to regional and national databases. Annual emissions resulting from these different sources could be calculated by the REDD and Climate Change branch of FPPD. Emissions in each project every year would be available and could be reported to UNFCCC as requested in Biennial Update Report (BUR). See *Figure* 2.3.11.

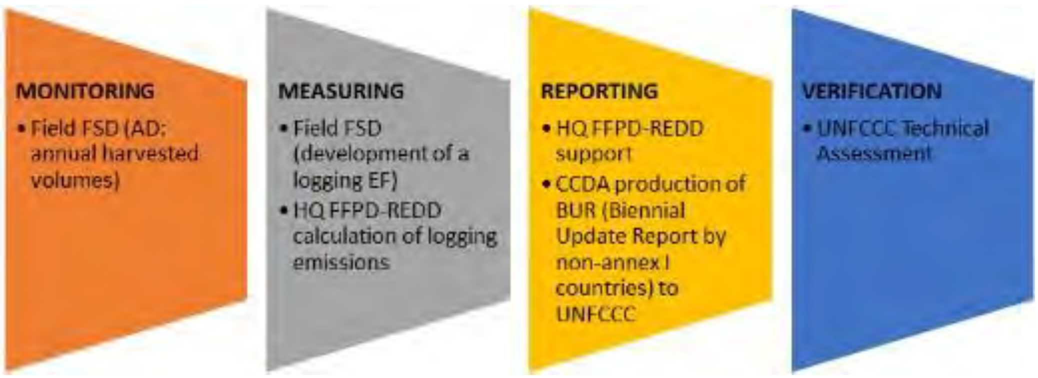


Figure 2.3.11: Possible Monitoring, Measuring, Reporting and Verification of logging

6. Utilization of outcomes from the Volume method for Forest management purposes

The Volume method allows providing a value of emissions corresponding to the climate impact of field operations. This estimation is the central objective but in addition procedures necessary to develop this method produce different outcomes which can be key indicators for decisions on forest policy. The best example is the acquisition of a strong dataset of extracted volumes. Also, Emission Factor, as it corresponds to a quantification of environmental impact of operations, can be useful to compare the quality of harvesting practices in different countries, or within a country in different logging projects. *Figure* 2.3.12 gives a representation of main outcomes.

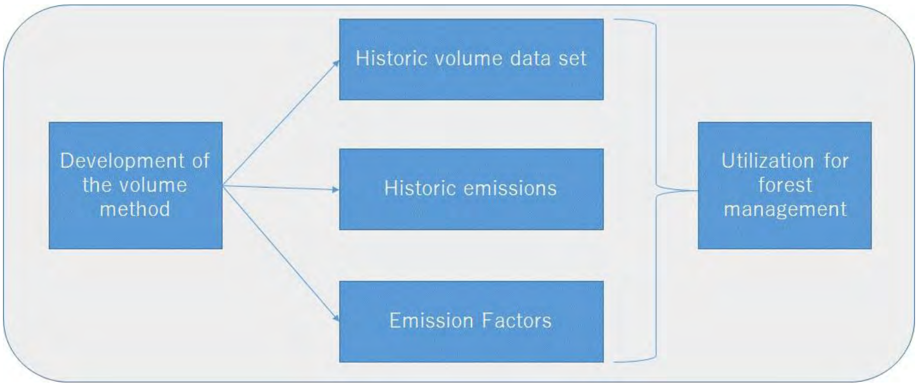


Figure 2.3.12: Main outcomes produced from the development of the Volume method

6.1. Utilization of the values of Emission

Applying the Volume Method requires a lot of resources. This section studies the main contexts where VM can directly be utilized. For instance, this method provides a good proxy of forest degradation such as harvested volumes, practical examples of method for measuring impacts on the field, or adapted equation and calculation procedures for initiatives that need to assess historic degradation (ex-ante emissions) and measure improvement after policies/measures application (ex-post emissions). So, this method can be useful in initiatives based on ER performances at country level (REDD+) as well as at project level (carbon initiatives) and, in a certain measure, for sustainable Forestry standards. This section details these three areas of possible utilization which are summarized in *Figure* 2.3.13.

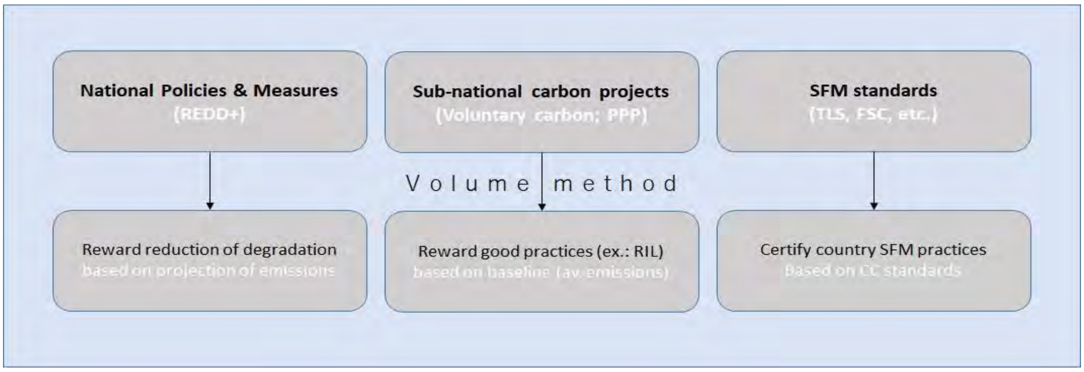


Figure 2.3.13: Contexts where and why it is needed to evaluate carbon impact of logging

1- In the context of REDD+, the Volume method allows rewarding specific efforts in reducing forest degradation caused by logging. Efforts developed by REDD+ countries are mainly involving the preparation and implementation of different Policies, Actions and Measures (PaMs) aligned on the same objective of sustaining forest resources in production sites. The volume method allows producing figures required in ER Result Based Payment (RBP) systems: make a baseline of past emissions (historic trend), a projection of future emissions (Forest Reference Level) and a measurement of actual annual emissions (MRV). This potential is particularly important in PNG because logging is a central element of the National REDD+ Strategy and PNG enters into REDD+ Implementation Phase. Besides, the determination of logging emissions is a good way to show the weight/share of the sector among total forest degradation and total emissions (degradation plus deforestation). This can show or confirm priorities to abate emissions from the Land and Logging sectors.

2- **In carbon projects** developed by private operators or PPP (Public Private Partnerships), the Volume method can be useful to calculate the baseline of emissions and measure ex-post emissions. While developing a carbon project, operators need to choose a registered methodology for example in Verified Carbon Standards (VCS). Ideally, the project scale corresponds to one logging concession and project activities an improvement of practices such as Reduced Impact Logging (directional felling, introduction of improve chainsaws, etc.). PNG is engaged in the REDD+ process and as such the national or province level is pinnacle for these actions. However, specific opportunities of such has led by political pressure and from landowners for developing activities relevant with land use based which climate change mitigation may be considered by the government of PNG, possibly through nesting carbon projects to a province or national strategy.

3- **Sustainable Forest Management (SFM) standards** are more and more including a Climate Change component. SFM certification generally needs to show that timber production is mainstreamed with different objectives notably related to land tenure, social welfare or environment conditions (soil, watershed, biodiversity). Because of the tight link existing between the storage of carbon stocks in forest and climate change, levels of carbon emissions associated to productions are also part of main standards. In this sense, SFM standards and criteria can have verifier parameters corresponding to elements that can indicate biomass loss occurring during logging. The Volume method is a method based on proxy and field parameters directly assessable on the field. So relevant examples of carbon verifiers can be provided by the Volume method.

6.2. Interpretation of timber volume figures

The unique outcome of having improved volume dataset is already a critical asset for forest management in itself. Examples of utilization of volume figures are shown below for a period of 8 years (2010-17) but as previously stated data can be accessed from 2000. Pre-requisite for analysis is to transform FSD raw database into format easy to manipulate in statistical software. Based on such a matrix, different analyses can be conducted. Note that this section has four objectives to show the potential i.e. what is possible to do from this method, it does not intend to include neither policy analysis nor propositions. First, complete dataset allows following total timber production over the time (*Figure* 2.3.14).

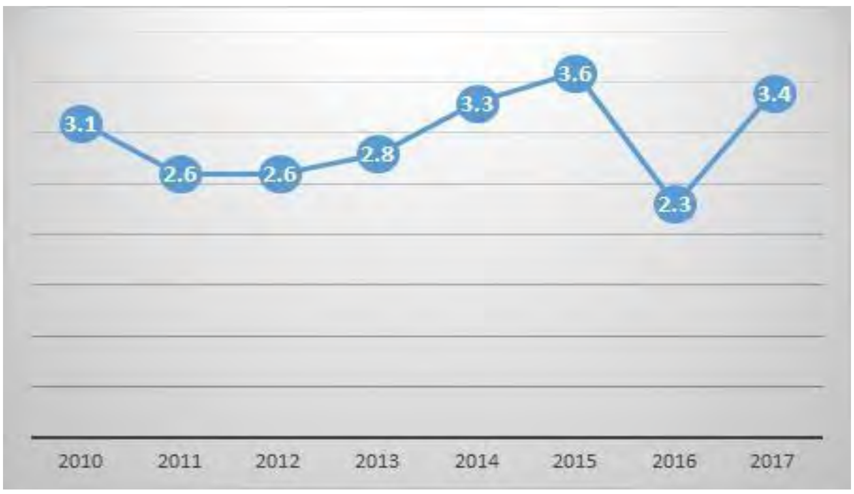


Figure 2.3.14: PNG total Forest production from 2010-17 (M m^3) (FCA excluded)

Actual harvested volumes (from FSD) can be compared with key policy figures such as AAC Permitted Cut (issued in Project Allocation Directorate) or AAC calculated by PNG-FRIMS. And this comparison can be at different levels namely project, province and/or national.

It can also be interesting to view the evolution of timber extraction according to cutting authorizations as shown *Figure* 2.3.15.

Figure 2.3.15: Evolution of timber production per cutting permit for period 2010-17 (M m^3)

These figures can be used for adjusting policies or regulations according to main trends identified. For example, the trend shows here a dominance of permits existing before 1991 (TP and LFA) and FCA. On the contrary, production in TA are insignificant (less than 0.5%). TA includes many types delivered for clearing specific zones such as road. Such elements can be considered for future decisions.

Then, productions in each type of permit can be reported to the number of projects. This provides an average value of extraction in projects for each permit type (*Figure* 2.3.16).

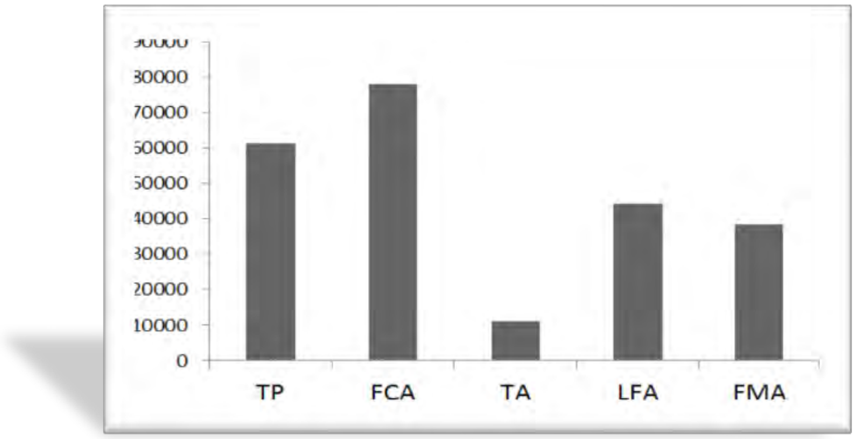


Figure 2.3.16: Mean project production for each permit type (m^3/project)

In addition, national data can be broken down to provincial and district levels. For instance, timber produced every year in average can be calculated for each province. See *Figure* 2.3.17.

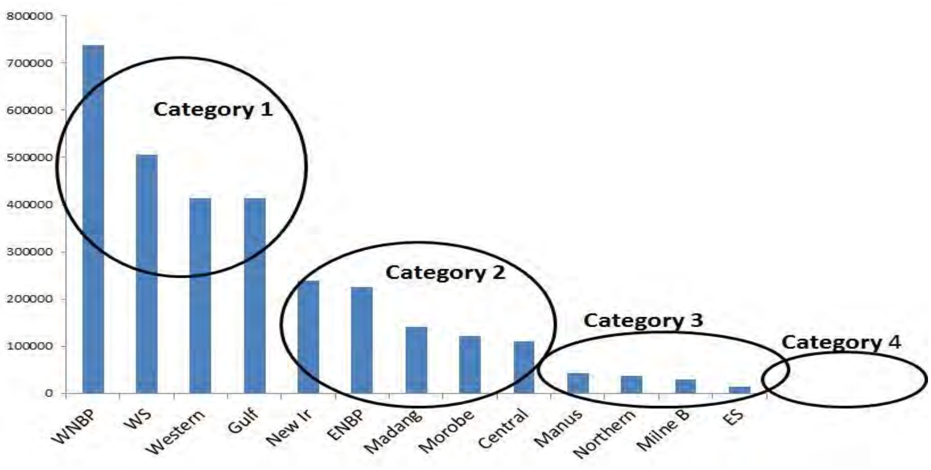


Figure 2.3.17: Mean annual (2010-17) production per province in m^3

This figure allows categorizing provinces according to their production rate: 1- intensive, 2- moderate, 3- low, and 4- no extraction. Specific policies could be discussed accordingly.

6.3. Utilizations of values of Emission Factor

Relative magnitude of each emission source indicates where are priorities to curve damage collaterally produced during harvesting. For example, Pearson *et al*. (2014) found in several countries that LDF is greater than LIF which is greater than ELE.

LDF (felling) > LIF (Road/Infra) > ELE (log extraction)

Based on that, priorities can be chosen to reduce the damage specifically on felling. Examples of measures are to increase the number of felled trees in one felling gap, promote/develop directional felling techniques or other techniques of Reduced Impact Logging (RIL).

PNG's logging EF can be used to compare average sustainability of practices in PNG concessions with other countries. More sustainable practices are, lower is EF. In Congo DR whose timber production is comparable with PNG (around 4 million m^3), EF is equivalent to Congo Rep. (1 tC/m^3) while EF in Indonesia and Brazil is 1.5 tC/m^3 and Guyana 2.3 tC/m^3 (Pearson *et al*., 2014).

Logging Emission Factor

RoC/DRC > Indonesia/Brazil > Guyana

(1 tC/m3) (1.5 tC/m3) (2.3 tC/m3)

Similarly, EF can be developed then compared within PNG either by provinces or concessions. But limitations to methodology implementation need to be taken into account.

Development of one EF can facilitate the development of further EFs because methodologies are well comprehended and developers (institutions) trained. The need to develop EF for both conventional and improved logging will be particularly important for rewarding countries 'efforts to implement sustainable forest management under REDD+ (Pearson *et al*., 2014). Only one EF would not be able to differentiate the policies that reduced extracted volumes to the policies that improved carbon efficiency of the extraction. In some studies, EF for conventional logging was estimated as double than certified concessions (FAO, 2003 and Billand *et al.*, 2008). This shows that the work of sampling (to calculate EF) does not need to be done twice. EF can be developed in only one type of concession (CVN or SFM) and the EF corresponding to the other type is estimated by using this assumption. Nevertheless, this assumption is only possible for countries which have a reliable way to differentiate concessions such as provided by certification schemes (e.g..: FSC). If there is no objective way to differentiate concessions, like in PNG (no selective logging project under certification), EF need to be developed for different concessions at different times in one concession. This comparison within and between projects is shown *Figure* 2.3.18.

Figure 2.3.18: EFs and carbon efficiency compared within and between projects

EF becomes a tool to (quantitatively) appreciate the sustainability of practices. In this sense, logging EFs can be helpful in the development of systems to push operators for improving practices. Usual regulations set low levies for certified concessions and high ones for non-certified (the case of all concessions in PNG). One original system could set a levy (named Carbon or Environmental tax) and release it for concessions once they got certified (e.g..: 50% release during the process of certification and 100% once fully certified). Taxing project operators as well as landowners could be considered. For example, to introduce index levy to the cost of certification by FSC. Practically, it will be like project developers have the choice in paying 10 000 USD to be certified by FSC or paying 10 000 USD over 10 or 20 years to PNG as Carbon tax. The first option will certainly be preferred by most of operators because of new market opportunities created and by landowners because of a possible quicker recovery of their cutting rights (as regeneration period is reduced). New levy currently in discussion within PNGFA to be operable in 2019 could consider this system. To promote new tax as a system for PNG production sites to attract more foreign buyers. Current operators may accept more easily the idea of a new levy if their awareness is raised on such potential benefits.

Conclusions

Key findings

- The Volume Method (VM) is specific to forest degradation (method different than for deforestation) and specific to logging (not including other drivers in logged areas)
- VM is an in-house method as the determination of Activity Data is based on data and EF on information ordinarily collected by the National Forest Service
- Most of data required to use VM is available in PNG Forest Authority (at least not less than in the four FRL countries cited in this report)
- The determination of AD requires historic dataset of volumes while the calculation of EF needs a sampling approach to inventory impact parameters
- Harvested volume data in PNG are stored in central database since 2000 and information on field parameters is available but not stored in database
- Challenging information types are deadwood from felling and skid track areas. They could be apprehended through field inventory or new technologies such as drones
- VM can directly be used in FRL calculation but also in carbon projects (baseline) and Forestry standards (indicators of impact)
- Outcomes from developing VM (values of Emission, EFs and volume datasets) can be useful for forest management
- Existing guidance are well developed for conducting the Volume method (IPCC and Pearson) and field inventories (Standard Operating Procedures, Winrock International).

Key advantages

- Logging emissions as calculated from VM can improve current PNG Forest reference Level
- Emissions can be broken down at province and district levels
- Information on deadwood (in concession areas) needs to be provided. This helps promoting the consideration of carbon pools other than AGB[9] and BGB[10]
- Possibility in the future to integrate SFM in the scope of REDD+ activities (by developing two EFs)
- Efforts to improve volume dataset and information on impact parameters can lever a long-term improvement in forest monitoring
- Awareness raised on requirements for carbon monitoring can be considered for adjusting routine activities of forest monitoring (log measurement, road assessment, etc.)
- The development of VM allows building experience and capacities to estimate logging emissions and calculate logging EF using the VM

Main constraints

- The Volume method does not cover important sources of GHG emissions and removals such as regrowth, post-logging degradation (illegal logging, gardening, fire…) and degradation from other drivers
- Capacity and availability of technical experts for using VM for logging EF may be limited
- Technical support may be insufficient because scientific of limited scientific background (articles, guidelines, etc.) to evaluate carbon losses from felling, skidding and hauling

---

[9] AGB: Above Ground Biomass

[10] BGB: Below Ground Biomass

- Options to financially support the development of an additional method for FRL may be limited by uncertain schedule of activities of main REDD+ donors in the country
- Rewards for creating additional methods are uncertain in future REDD+ RBP (Result Based Payment) schemes.

Next steps

- Complementary review of international guidance and FRLs to evaluate methods to consider regrowth, post-logging degradation, and degradation from other drivers
- Compare total emissions and accuracy using both ‘Remote Sensing’ and ‘RS-Volume’ methods for strategic decisions in the construction of future FRLs
- Develop opportunities of technical support by promoting Research studies in PNG (links with Pearson’s team notably)
- Develop opportunities of financial support by highlighting future initiatives that will benefit from field estimation of logging emissions such as national/sub-national ER-Programmes, carbon projects or standards of Sustainable Forest Management
- Develop methods of measurement and monitoring especially for missing emission sources (felling and skidding gaps) that can help in the short-term for calculating EF and in the long-term for daily forest monitoring (notably drones)
- Rapid operationalization of DSS to improve management of actual harvested volume.

References

Billand, A. Gourlet-Fleury, S. Sarrailh, J-M. 2008. Variation des paramètres carbone selon différentes contextes d'exploitation. Atelier COMIFAC, Paris.

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

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

CCDA. 2018. GCF concept note. Implementation of PNG's REDD+ Finance and Investment Plan.

Chave, J. Andalo, C. Brown, S. *et al*. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145, 87–99.

Congo. 2017. FCCC/TAR/2016/COG, NERF de la Republique du Congo. Improved version.

FAO. 2003. Code régional d'exploitation forestière à faible impact dans les forêts denses tropicales humides d'Afrique centrale et de l'Ouest.

FAO. 2015. Global Forest Resources Assessment 2015, Desk reference.

FAO. 2018. From reference levels to results reporting: REDD+ under UNFCCC. 2018 update. Rome.

FAO. 2019. NFI. http://www.fao.org/in-action/png-multipurpose-national-forest-inventory/en/ - Ghana. 2017. FCCC/TAR/2017/GHA, Ghana's National Forest Reference Level.

Gambella *et al*. 2016. *Forest and UAV: A bibliometric review*. Contemporary Engineering Sciences, Vol. 9, 2016, no. 28, 1359-1370.

GOFC-GOLD. 2016. A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation Report Version COP19-1. www.gofcgold.wur.nl/redd/sourcebook /GOFC-GOLD Sourcebook.pdf

GoPNG 2017. Papua New Guinea National REDD+ Strategy 2017 – 2027.

GoPNG 2017. *Papua New Guinea's National REDD+ Forest Reference Level*. Modified Submission for UNFCCC Technical Assessment in 2017

Guyana. 2015. FCCC/TAR/2015/GUY, The Reference Level for Guyana's REDD+ program.

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

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use; Prepared by the National Greenhouse Gas Inventories Programme ed H S Eggleston, L Buendia, K Miwa, T Ngara and K Tanabe (Japan: IGES)

ITTO 2015. *Voluntary guidelines for the sustainable management of natural tropical forests*. ITTO Policy Development Series No. 20 Yokohama, Japan.

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

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

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

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

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

Kislik *et al*. 2018. *UAVs in support of algal bloom research: a review of current applications and future opportunities*. Drones, 2018, 2, 35; doi: 10.3390.

Kongsager, R. Napier, J. Mertz, O. 2011. The breakeven price of REDD-credits: a case study from Kade, Ghana. Environmental Management

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

McIntosh P.D. 2013. *Review of soil and water provisions in the Papua New Guinea Logging Code of Practice and related codes in the tropics*. Project GCP/PNG/003/AUL.

Medjibe, V. P. Putz, F. E. Starkey, M. P. Ndouna, A. A. and Memiaghe, H. R. 2011. Impacts of selective logging on above-ground forest biomass in the Monts de Cristal in Gabon. For. Ecol. Manag.

Munks S.A *et al*. 2013. *A review of information on the impact of forestry operations on the biodiversity of PNG's forests*. Project GCP/PNG/003/AUL

Munks S.A. 2013. *A review of the approach to biodiversity conservation in PNG's wood production forests and recommendations relevant to the PMC procedures and Logging Code of Practice*. Project GCP/PNG/003/AUL.

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

Pearson, T. R. H. Brown, S. and Casarim, F. M. 2014. Carbon emissions from tropical forest degradation caused by logging. Winrock International. Environ. Res. Lett. 9 (2014) 034017 (11pp).

PNG. 2017. FCCC/TAR/2017/PNG. PNG’s national REDD+ Forest Reference Level.

PNGFA. 2012. Business analysis of PNGFA's existing information systems.

PNGFA. 2015. Progress of work on Estimating Degradation from Selective Timber Harvesting in PNG using historical data on Log Extraction: Proxy Approach. FAO and FRI.

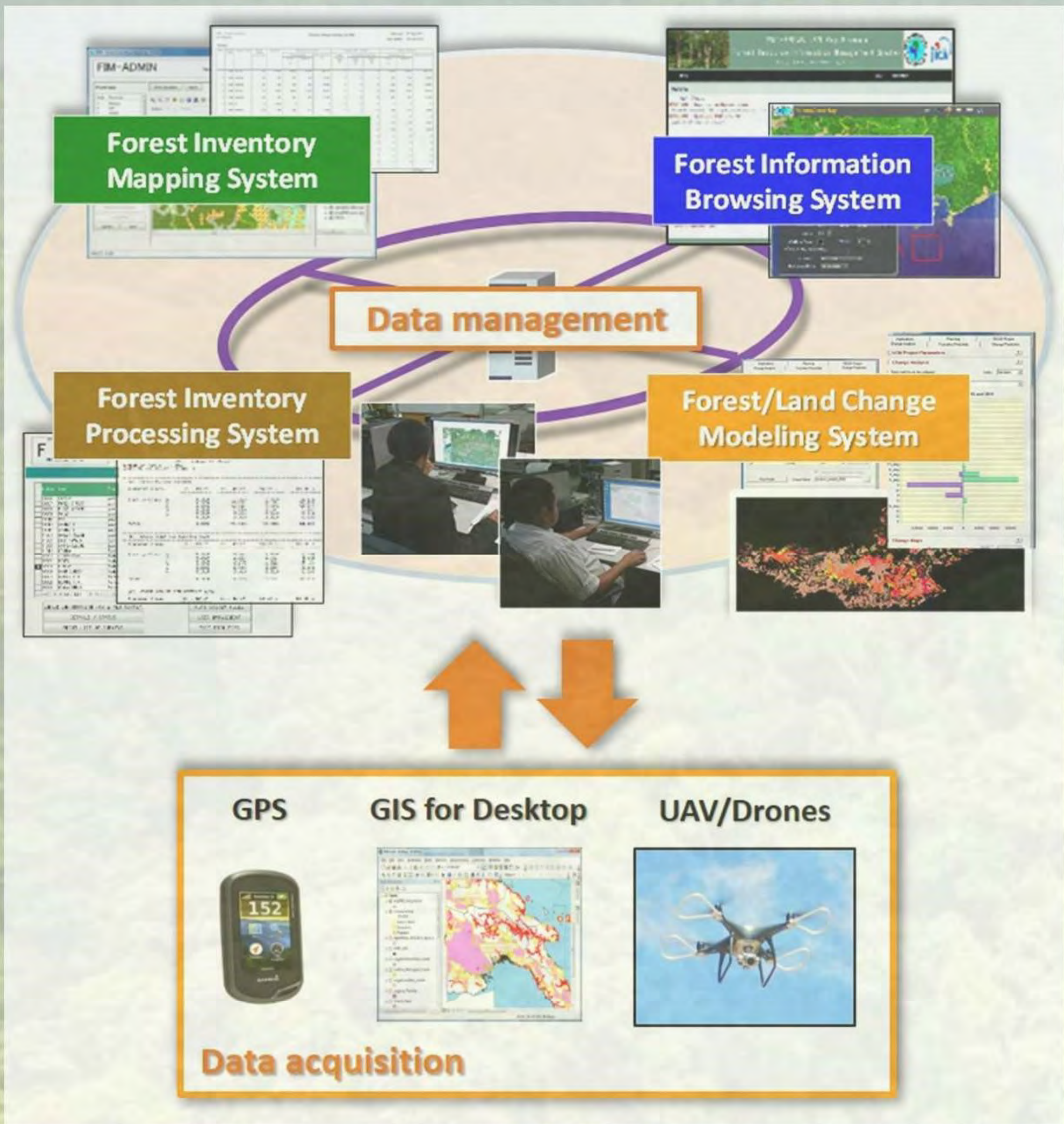
PNGFA/JICA project. 2018. GPS/GIS training report under PNGFA/JICA project. Intern document.

Suriname. 2018. FREL for Suriname REDD+'s programme.

TFF 2018. *Technical procedures for topographic forest surveys and tree position mapping*. AP/RAFT/TFF 03012016 TLVS website. http://www.euflegt.efi.int/what-is-flegt

Turia R.C.H. 2010. *Forest law enforcement and governance in Papua New Guinea*. Asia-Pacific Forestry Commission. FAO, Bangkok, Thailand.

Wilkinson G. 2013. *Background report on forests and forestry in Papua New Guinea with reference to the implementation of the Logging Code of Practice*. Project GCP/PNG/003/AUL



ISBN 9789980908766

Papua New Guinea Forest Resource Information Management System (PNG-FRIMS)

- Appendix -

Papua New Guinea Forest Authority (PNGFA)

Japan International Cooperation Agency (JICA) Project

Papua New Guinea

Forest Resource Information Management System

(PNG-FRIMS)

- Appendix -

Papua New Guinea Forest Authority (PNGFA)

Japan International Cooperation Agency (JICA) Project

The information in this document is subject to change without notice

1st Edition published August 2, 2019

PNG Forest Authority (JICA Project)

Address: P.O.Box 5055, Boroko, National Capital District, Papua New Guinea

JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html

Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/

Table of Contents

List of Figures

List of Tables

3. Appendix

Output 1

Enhanced PNG Forest Resource Information Management System (PNG-FRIMS)

Table 3-1-1: List of Thematic Products in PNG-FRIMS (under Output 1)

	Map/Layers	Target Area	Status
	Forest Base Map 2012 (Revised)	National	Main Report
	Forest Degradation Drivers Map	National	Appendix
	Forest Timber Volume Map (Draft)	National	Appendix
	Forest Cover Map 2015 (Updated)	National	Main Report
	Past Forest Cover Maps 2000/2005	WNB, WSP	Appendix
	Future Forest Change Modeling	WNB	Appendix
	Other Thematic Layers in FRIMS		
	- Forest Monitoring Unit (FMU)	National	Main Report
	- Updated Constraints Data	National	Main Report
	- Watershed (Catchment) Data	National	Main Report
	- Digitized Logging Road Data	National	Main Report
	- Forest Concession/Land Management	National	Main Report

Note: All the information can be viewed through LAN Map Browser of PNG-FRIMS

Forest Base Map 2012 (Revised)

	VEG	VEGNAME	CEN	NCD	ORO	MIL	GUL	WES
	P	Low Altitude Forest on Plains & Fans	292,663	86	365,484	209,994	1,037,694	3,219,756
	H	Low Altitude Forest on Uplands	1,101,655	32	728,478	616,187	1,200,039	629,928
	L	Lower Montane Forest	680,095		485,745	129,735	149,739	290,126
	Mo	Montane Forest	39,006		30,097	647		2,661
	D	Dry Seasonal Forest						935,368
	B	Littoral Forest	12,076		894	4,379	1,023	37,194
	Fri	Seral Forest	6,762		26,476	1,166	356	9,833
	Fsw	Swamp Forest	9,065		18,202	1,118	465,646	684,614
	M	Mangrove Forest	52,658	305	15,267	46,700	241,240	111,843
	W	Woodland	172,725	1,071	177,622	12,001	136,701	1,574,990
	Sa	Savanna	113,592	9,970	23,732	35	14,486	478,122
	Sc	Scrub	6,673	978	1,631	1,332		374,163
	G	Grassland and Herbland	241,325	6	139,929	120,098	72,942	1,009,672
	Ga	Grassland (Alpine)	19,612		8,379	2,148		941
	Gi	Grassland (Subalpine)	11,580		6,562	426		344
	O	Cropland/Agriculture land	151,455	1,012	133,601	240,870	107,317	186,534
	Qa	Plantation other than Qf	6,440		78,527	22,874	1,069	
	Qf	Forest Plantation	18,179			1,214		
	Z	Bare areas	152		412	50		27
	U	Larger Urban Centres	692	6,095	1,025	772	202	727
	E	Lake & Larger Rivers	19,378	165	21,308	4,921	43,404	250,937
		SUM	2,955,783	19,720	2,263,371	1,416,666	3,471,860	9,797,778

	Forest Cover Area						
	Forest	2,212,157	423	1,670,643	1,011,138	3,095,737	5,921,322
	Forest&Woodland	2,384,882	1,494	1,848,265	1,023,139	3,232,438	7,496,312
*	Forest&Woodland&Scrub&Savanna	2,505,147	12,442	1,873,627	1,024,507	3,246,924	8,348,597

	Forest Cover Rate						
	Forest	74.8%	2.1%	73.8%	71.4%	89.2%	60.4%
	Forest&Woodland	80.7%	7.6%	81.7%	72.2%	93.1%	76.5%
*	Forest&Woodland&Scrub&Savanna	84.8%	63.1%	82.8%	72.3%	93.5%	85.2%

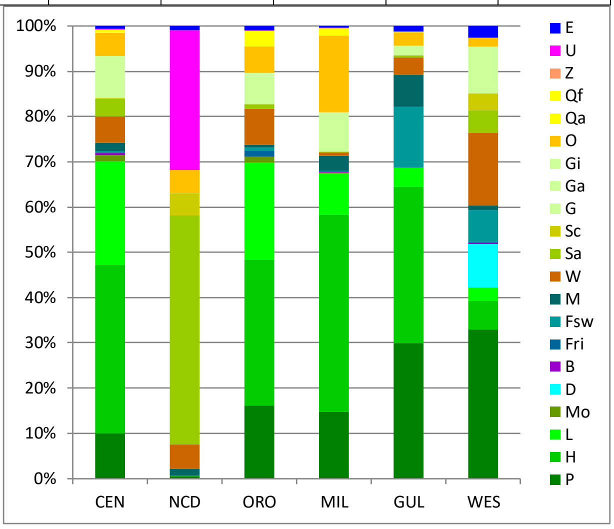


Figure 3-1-1: Forest Base Map 2012 Vegetation Type Area: Southern Region

	VEG	VEGNAME	MOR	MAD	ESP	WSP
	P	Low Altitude Forest on Plains & Fans	92,047	487,379	678,469	1,031,108
	H	Low Altitude Forest on Uplands	845,576	921,766	1,011,379	1,436,375
	L	Lower Montane Forest	1,421,949	482,384	229,009	611,335
	Mo	Montane Forest	39,179	21,849	4,055	18,002
	D	Dry Seasonal Forest				
	B	Littoral Forest	1,103	1,059	2,077	2,265
	Fri	Seral Forest	3,705	5,801	24,439	2,976
	Fsw	Swamp Forest	20,519	95,286	508,138	137,879
	M	Mangrove Forest	3,150	277	17,783	669
	W	Woodland	52,079	98,179	680,002	66,858
	Sa	Savanna				
	Sc	Scrub	11			282
	G	Grassland and Herbland	295,741	163,740	615,054	106,321
	Ga	Grassland (Alpine)	10,955	2,246	446	1,802
	Gi	Grassland (Subalpine)	18,207	6,827	183	2,550
	O	Cropland/Agriculture land	470,069	540,450	477,416	141,174
	Qa	Plantation other than Qf	35,048	23,639	1,338	1,479
	Qf	Forest Plantation	17,719	4,893		
	Z	Bare areas	9,001	2,890		1,984
	U	Larger Urban Centres	7,361	1,497	752	318
	E	Lake & Larger Rivers	25,206	30,164	118,060	29,389
		SUM	3,368,621	2,890,325	4,368,599	3,592,766

	Forest Cover Area				
	Forest	2,444,946	2,020,694	2,475,349	3,240,610
	Forest&Woodland	2,497,024	2,118,872	3,155,350	3,307,467
*	Forest&Woodland&Scrub&Savanna	2,497,035	2,118,872	3,155,350	3,307,749

	Forest Cover Rate				
	Forest	72.6%	69.9%	56.7%	90.2%
	Forest&Woodland	74.1%	73.3%	72.2%	92.1%
*	Forest&Woodland&Scrub&Savanna	74.1%	73.3%	72.2%	92.1%

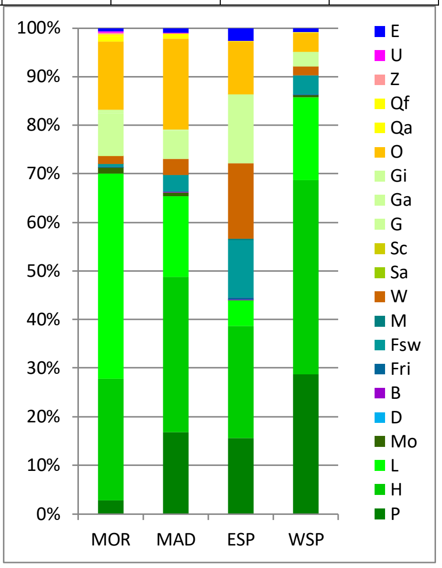


Figure 3-1-2: Forest Base Map 2012 Vegetation Type Area: Momase Region

	VEG	VEGNAME	SIM	ENG	EHP	SHP	HLA	WHP	JIW
	P	Low Altitude Forest on Plains & Fans	8,251	2,720	2,073	153,026	22,282	9,485	9,220
	H	Low Altitude Forest on Uplands	117,027	63,505	56,316	436,709	117,054	21,954	70,752
	L	Lower Montane Forest	283,511	606,659	597,381	565,842	657,590	132,980	201,434
	Mo	Montane Forest	15,852	108,371	13,368	9,163	19,510	15,086	18,668
	D	Dry Seasonal Forest							
	B	Littoral Forest							
	Fri	Seral Forest							
	Fsw	Swamp Forest		377		15,516	244	80	46
	M	Mangrove Forest							
	W	Woodland				14,375	380		
	Sa	Savanna		32					
	Sc	Scrub					111		
	G	Grassland and Herbland	30,188	21,432	193,577	49,985	28,771	12,784	8,748
	Ga	Grassland (Alpine)	752	40,796	763	2,265	17,778	1,601	100
	Gi	Grassland (Subalpine)	6,167	7,600	643	12,666	751	8,379	4,095
	O	Cropland/Agriculture land	147,357	319,520	236,001	231,061	187,341	218,349	159,904
	Qa	Plantation other than Qf	169	126	4,592	23		9,639	5,978
	Qf	Forest Plantation		25	4,911	319		1,474	
	Z	Bare areas		19	171	1,498	205	338	256
	U	Larger Urban Centres	600		837	182			
	E	Lake & Larger Rivers	3,467	2,257	4,043	12,121	3,575	849	1,320
		SUM	613,341	1,173,438	1,114,676	1,504,751	1,055,593	432,998	480,522

	Forest Cover Area							
	Forest	424,640	781,657	674,049	1,180,575	816,680	181,059	300,120
	Forest&Woodland	424,640	781,657	674,049	1,194,950	817,060	181,059	300,120
*	Forest&Woodland&Scrub&Savanna	424,640	781,688	674,049	1,194,950	817,171	181,059	300,120

	Forest Cover Rate							
	Forest	69.2%	66.6%	60.5%	78.5%	77.4%	41.8%	62.5%
	Forest&Woodland	69.2%	66.6%	60.5%	79.4%	77.4%	41.8%	62.5%
*	Forest&Woodland&Scrub&Savanna	69.2%	66.6%	60.5%	79.4%	77.4%	41.8%	62.5%

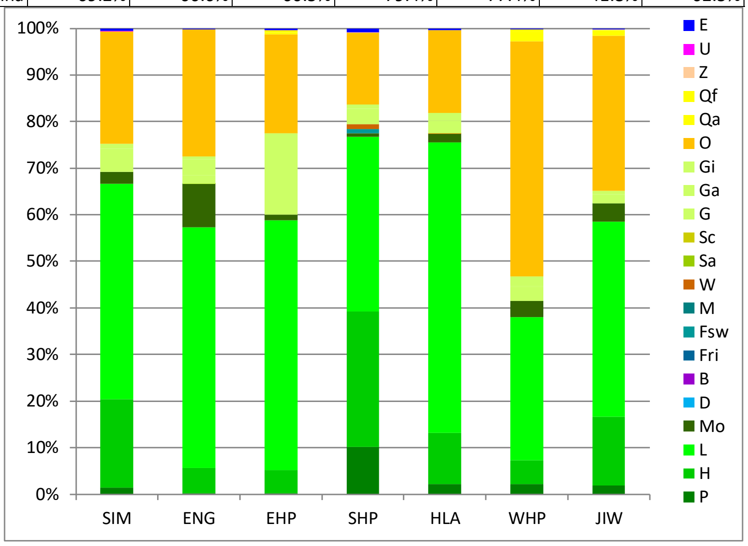


Figure 3-1-3: Forest Base Map 2012 Vegetation Type Area: Highlands Region

	VEG	VEGNAME	WNB	ENB	MAN	NIL	ARB
	P	Low Altitude Forest on Plains & Fans	508,762	135,360	67,533	138,886	235,116
	H	Low Altitude Forest on Uplands	1,050,299	831,846	107,118	531,003	369,036
	L	Lower Montane Forest	66,313	269,688		103,008	77,478
	Mo	Montane Forest					
	D	Dry Seasonal Forest					
	B	Littoral Forest	1,111	2,458	20	1	4,700
	Fri	Seral Forest	20,373	18,427		6,910	31,493
	Fsw	Swamp Forest	24,365	58		644	53,636
	M	Mangrove Forest	8,299	2,636	3,755	14,622	2,730
	W	Woodland	33,882	2,311		20,193	19,382
	Sa	Savanna					
	Sc	Scrub	112	27			6,759
	G	Grassland and Herbland	32,069	17,537	5,790	24,994	41,230
	Ga	Grassland (Alpine)					16
	Gi	Grassland (Subalpine)					
	O	Cropland/Agriculture land	125,999	201,665	6,160	78,911	51,377
	Qa	Plantation other than Qf	146,980	21,552	750	16,412	34,981
	Qf	Forest Plantation		17,931			7
	Z	Bare areas	1,137	1,286	1,018	656	2,774
	U	Larger Urban Centres	185	619	514	359	1,158
	E	Lake & Larger Rivers	14,114	6,025	418	3,095	5,886
		SUM	2,034,000	1,529,425	193,077	939,696	937,760

	Forest Cover Area					
	Forest	1,679,523	1,278,404	178,426	795,076	774,196
	Forest&Woodland	1,713,405	1,280,715	178,426	815,269	793,578
*	Forest&Woodland&Scrub&Savanna	1,713,517	1,280,741	178,426	815,269	800,337

	Forest Cover Rate					
	Forest	82.6%	83.6%	92.4%	84.6%	82.6%
	Forest&Woodland	84.2%	83.7%	92.4%	86.8%	84.6%
*	Forest&Woodland&Scrub&Savanna	84.2%	83.7%	92.4%	86.8%	85.3%

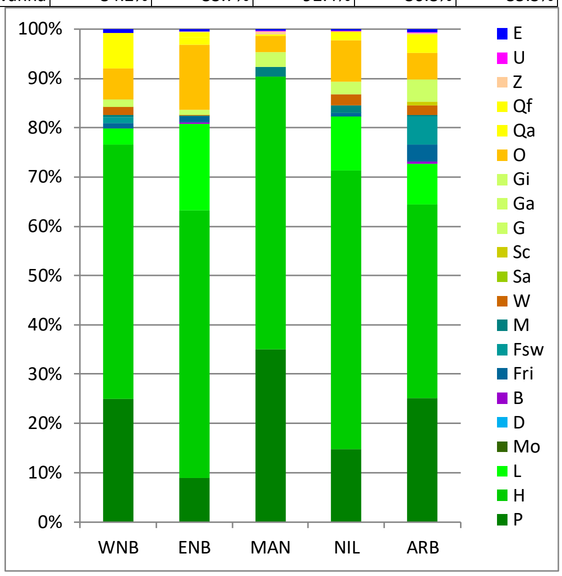


Figure 3-1-4: Forest Base Map 2012 Vegetation Type Area: Islands Region

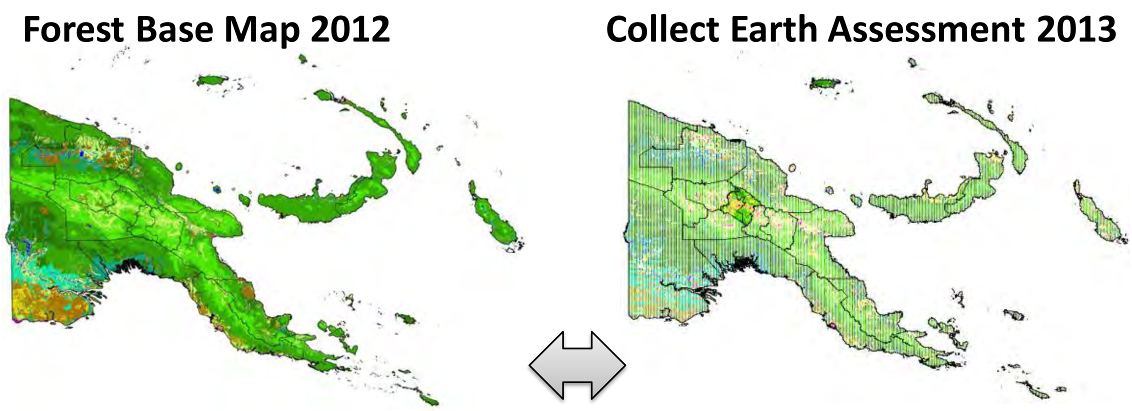
Accuracy Assessment

The Forest Base Map ver. 1.0 was updated into ver. 1.1 after improvement of the issues above. The quality and accuracy of the Forest Base Map ver. 1.1 was assessed comparing data of NFI Pre-Inventory (Collect Earth) supported by UN-REDD / FAO.

The purposes of the assessment are as follows:

- Check whether there are big issues on the results of the classification of the Forest Base Map and methodologies to develop it.
- Grasp the characteristic of the Forest Base Map and status of the classification. These kinds of information are useful to find issues on the Base Map and to consider how to modify it, if there was such a need.

The accuracy assessment was implemented comparing the land use class in the Forest Base Map and the corresponding points of Collect Earth. Figure 3-1-5 shows the characteristics of the Forest Base Map ver. 1.1 and the result of Collect Earth. The correspondence of land use classes in the Forest Base Map and Collect Earth are show in Table 3-1-2 with Intergovernmental Panel on Climate Change (IPCC) land categories.



	Basemap	Point Sampling
Spatial Coverage	**Wall-to-Wall by Polygons** Segmentation: minimum mapping unit 1ha (100x100m)	**Systematic sampling point** Points every 4x4km (2x 2km for 2 provinces) 1ha unit with 25 check points
Satellite	RapidEye (ALOS/PALSAR)	LANDSAT, Digital Globe, RapidEye, SPOT, etc.
Land cover class	21 classes based on PNGRIS including agricultural land and plantations (referring to IPCC category)	6 IPCC categories (Forest, Grassland, Cropland, Wetland, Settlement, Other), with 54 detailed subdivision (including disturbance)

Figure 3-1-5: Characteristics of the Forest Base Map and the result of Collect Earth

Table 3-1-2: Correspondence of land use classes in the Forest Base Map and Collect Earth

IPCC Category	Forest Base Map			Collect Earth Assessment
	No	Code	Class	Land use class
Forest	1	P	Low Altitude Forest on Plains and Fans	low_altitude_forest_on_plains and
	2	H	Low Altitude Forest on Upland	low_altitude_forest_on_upland
	3	L	Lower Montane Forest	lower_montane_forest
	4	Mo	Montane Forest	montane_forest
	4	Mo	Montane Forest	montane_coniferous_forest
	5	D	Dry Seasonal Forest	dry_seasonal_forest
	6	B	Littoral Forest	littoral_forest
	7	Fri	Seral Forest	seral_forest
	8	Fsw	Swamp Forest	swamp_forest
	15	M	Mangrove	mangrove
	20	Qf	Forest Plantation	acacia_plantation
				balsa_plantation
				eucalyptus_plantation
				hoop_plantation
				klinki_plantation
				pine_plantation
				rubber_plantation
				teak_plantation
				terminalia_plantation
				undetermined_plantation
Woodland	9	W	Woodland	woodland
Savanna	10	Sa	Savanna	savanna
Scrub	11	Sc	Scrub	scrub
Grassland	12	G	Grassland and Herbland	herbland
				meadows
	13	Ga	Alpine grassland	alpine_grassland
	14	Gi	Subalpine grassland	-

IPCC Category	Forest Base Map			Collect Earth Assessment
	No	Code	Class	Land use class
Cropland	16	O	Agricultural Land Use	irrigated_perennial_crops
				non_irrigated_perennial_crops
				other_crop
				subsistence_agriculture
				subsistence_agriculture_not_sure
				subsistence_agriculture_permanen
				subsistence_agriculture_shifting
	21	Qa	Plantation other than forest plantation	palm_oil
				cocoa
				coconut
				coffee
				tea
Wetlands	-	-	-	freshwater_swamp
				lowland_freshwater_swamp
				montane_swamp
				saline_brackish_swamp
	17	E	Lakes and larger rivers	lake
				river
Other land	18	Z	Bare areas	barrein_soil
				land_slides
				rock
				sand_soil
Settlements	19	U	Larger urban centres	large_settlement
				infrastructure
				village
-	22	Es	Sea	sea
	-	-	-	clouds
	-	-	-	other_reason

Comparing land use composition in Papua New Guinea between the Forest Base Map and Collect Earth showed in Table 3-1-2, their forest proportions are about the same, though Collect Earth has a high ratio of wetlands, other land and settlements to grassland and cropland (Figure 3-1-6).

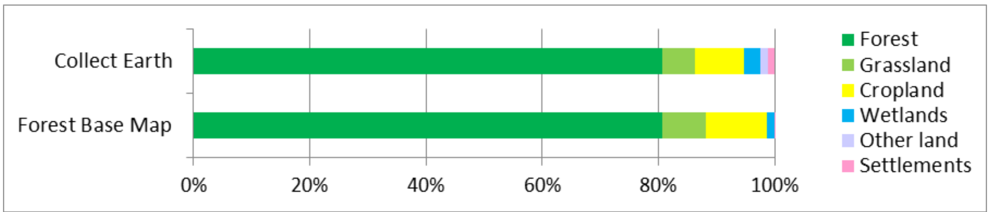


Figure 3-1-6: Comparison between Forest Base Map and Collect Earth on PNG Land use

Overall accuracy of the error matrix classified with Forest/Non-forest is 87% (Table 3-1-3). Overall accuracy of the error matrix classified with 6 land use categories is 83% Table 3-1-4). User's accuracy of Wetlands is 73% while producer's accuracy is 21%. It means accuracy of Wetlands categorized in the Base Map is good, but many Wetlands picked out in Collect Earth study could not be picked out in the Base Map. This is largely due to that only lakes and rivers are classified as Wetland and vegetated swamp are classified as Forest either as Swamp forest or Woodland in the Base Map while Collect Earth includes vegetated swamp other than forests as Wetland. Nipa palm dominant vegetation is classified as Mangrove forest in the Base Map while Nipa palm is classified as swamp (Wetland) in Collect Earth. The producer's accuracy of Settlements is 5% while user's accuracy is 88%. This is also largely attributed to the difference of classification between the two studies. While the Base Map only focuses on Larger urban centres, Collect Earth identifies small villages as well. The comparison of the two studies clarifies that high reliability of the forest and land use information derived from both studies and also the necessity of careful interpretation of the information due to the differences of definitions of land use categories.

Table 3-1-3: Error Matrix (Forest, Non-forest)

		Collect Earth			
		Forest	Non-forest	Total	User's Accuracy
Forest Base Map	Forest	18,333	1,545	19,878	92%
	Non-forest	1,612	3,606	5,218	69%
	Total	19,945	5,151	25,096	
	Producer's Accuracy	92%	70%		
	Overall Accuracy	87%			

Table 3-1-4: Error Matrix (6 land use categories)

			Collect Earth							
			Forest	Non-forest						
			Forest	Grassland	Cropland	Wetlands	Other land	Settlements	Total	User's Accuracy
Forest Base Map	Forest	Forest	18,333	323	719	415	6	82	19,878	92%
	Non-forest	Grassland	491	802	179	303	7	20	1,802	45%
		Cropland	1,063	273	1,541	47	2	174	3,100	50%
		Wetlands	53	19	2	209		2	285	73%
		Other land	5	4		3	2	1	15	13%
		Settlements		1	1			14	16	88%
		Total	19,945	1,422	2,442	977	17	293	25,096	
		Producer's Accuracy	92%	56%	63%	21%	12%	5%		
		Overall Accuracy	83%							

Table 3-1-5: The result of the Quality and Accuracy Assessment of Forest Base Map

				Collect Earth Assessment																					
				Forest													Grassland		Cropland		Wetlands	Other land	Settlements	Total	**U.A.**
														Wooc	Savanna/Sc										
				P	H	L	Mo	D	B	Fri	Fsw	M	Qf	W	Sa	Sc	G	Ga/G	O	Qa	E	Z	U		
Forest Base Map	Forest	P	Low Altitude Forest on Plai	2446	1138	4		40	21	70	309	31	16	65	9	18	41		184	26	80		31	4529	54%
		H	Low Altitude Forest on Upl	1122	4820	109			9	47	18		4	17	6	17	41		225	21	23	4	22	6505	74%
		L	Lower Montane Forest		58	4208	74						2			16	56	18	165	7	6	1	13	4624	91%
		Mo	Montane Forest			19	186									6	2	26						239	78%
		D	Dry Seasonal Forest	121	8			207	1	5	47			65	3	3	13				7			480	43%
		B	Littoral Forest	8					6		3	1		7			1			1				27	22%
		Fri	Seral Forest	17	18	11			1	4	11	1		5			3		2	3	6			82	5%
		Fsw	Swamp Forest	297	38			48	6	22	314	11		90	15	11	33		13	1	116		6	1021	31%
		M	Mangrove	17				2	11	2	34	104		5	2		1		3	2	62		2	247	42%
		Qf	Forest Plantation	3	3	1			1				7	1		2	1	1	11	2				33	21%
	Woodland	W	Woodland	267	33	1		326	5	16	247	7		307	115	40	51		36	5	104		2	1562	20%
	Savanna /Scrub	Sa	Savanna	5	1	1		34			8	3		77	132	8	27		11		9	1	6	323	41%
		Sc	Scrub	2	1	1	1	33			3			58	85	11	8		1		2			206	5%
	Grassland	G	Grassland and Herbland	83	44	45		53	3	7	72	4	1	98	24	36	689	20	162	15	303	7	19	1685	41%
		Ga/G	Alpine grassland/Subalpine			7	12									2	23	70	2				1	117	60%
	Cropland	O	Agricultural Land Use	225	299	363	4	7	12	16	45	6	7	21	9	24	233	30	1211	132	47	2	165	2858	42%
		Qa	Plantation other than forest	13	6				1		1		2			2	10		66	132			9	242	55%
	Wetlands	E	Lakes and larger rivers	13	18	3		2		4	6	3		1	2	1	19		2		209		2	285	73%
	Other land	Z	Bare areas	2	1	1										1	4				3	2	1	15	13%
	Settlements	U	Larger urban centres														1		1				14	16	88%
			Total	4641	6486	4774	277	752	77	193	1118	171	39	817	402	198	1257	165	2095	347	977	17	293	25096	
			P.A.	53%	74%	88%	67%	28%	8%	2%	28%	61%	18%	38%	33%	6%	55%	42%	58%	38%	21%	12%	5%		

O.A.	60%

Forest Degradation Drivers Map

Introduction

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[1]) 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 and lessons learned.

Methods

(1) Definition of Deforestation/Degradation Drivers

<u>Definitions of Land Use (LU) classes</u>

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

[1] *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

Table 3-1-6: Difinitions of Land Use (LU) classes

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

Table 3-1-7: Definitions of deforestation drivers

Initial LU class/ strata	Driver	Final LU class/ strata
Forest land/ whichever strata	Subsistence agriculture	Cropland/ Annual crops
		Grassland/ Shrub
		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

Table 3-1-8: Definitions of degradation drivers

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

Table 3-1-9: Definitions of regenration drivers

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

Table 3-1-10: Definitions of reforestation drivers

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.

Table 3-1-11: Assumed scale of events and disturbances for Hansen loss data analysis

Objects	Assumed scale	Explanation (and further useful information)
Mining / Extractive industry	Usually > 50 ha Sometimes > 30 ha	There are some deforestation caused for making the pipeline of oil and gas. Clearance of forest areas for facility constructions includes township with workers compounds, schools, hospitals, administrative centers and recreational areas.
Road construction	Normal size is 40 ~ 60 ha	Normal width: 40 m road line corridor (20 m on either sides) Normal distance: 10,000 ~ 15,000 m 40x (10,000 ~ 15,000) = 400,000 ~ 600,000 m^2 per annum
Facility construction (ex. School)	Normal size is 2 ha	Normal size of schools and logging camps are about 2 ha. However, because schools are constructed in the village, most of schools might not be detected as Hansen Loss. Facility constructions normally appear along the road and grassland, namely non-forest lands.
Plantation associated with FCA	Usually > 50 ha	The most of Forest Clearance Authority (FCA)[2] is larger than 50 ha. Developer can clear forest up to 1,000 ha a year.

[2] Authority of forest clearance by developers within SABL boundaries. The authority fixes the boundaries.

Logging (especially logging roads)	Normal size is 20 ~ 40 ha	The maximum width allowed for main logging roads, where logging trucks and other vehicles will be using, is 40 m. Spur roads are also considered to be logging roads but are not commonly used by vehicles. Normal distance: Average main road construction per annum is 5 ~ 10 km. 40 x (5,000 ~ 10,000) = 200,000 ~ 400,000 m2
Disaster	Normal size is 5 ha	Main disaster in PNG is landslide originated from flood and soil erosion especially along the Highlands Highway or earthquake (in ENB). It could happen in natural forest but hard to be identified.
Subsistence agriculture	Normal size is 1 ~ 5 ha	Definition: shifting and permanent agriculture cultivation and gardening. Within **5 ~10 km** from Census Unit (CU)[3].
	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 (ex. Cocoa, cacao and etc.) is 5 ha. The 2010 Census Information is available from National Statistics Office. Some of the information is already stored in FRIMS.
Fire	1 ~ 5 ha	Difficult to obtain realistic information from the Natural Disaster Office. Natural fires are rare in PNG and it normally happens artificially. Major causes of fire: ➢ Preparation for gardening (1ha ~ 5ha) ➢ Hunting fire in grassland (1ha ~ 5ha) to chase animals ➢ Accidental or careless fire (1ha ~ 5ha) by cigarette and 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 Fire Watch.
- 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:

Table 3-1-12: Clues to identify other disturbance signs in Hansen loss data analysis

Object	Information for analysis

[3] Point of national census operated every 5 years and location of villages

Plantations	Replanting periods for each species type are useful in identifying plantations. Forest plantations: 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 Plantations other than forest plantations: 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 area 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:

Table 3-1-13: Other activities causing forest degradation and their characteristics

Object	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. Small logging could be operated with chainsaws and portable sawmills.
Building materials collection	People cut down and collect living tree for building materials.

<u>Notes on Subsistence Agriculture</u>

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

Means to identify small agriculture patches

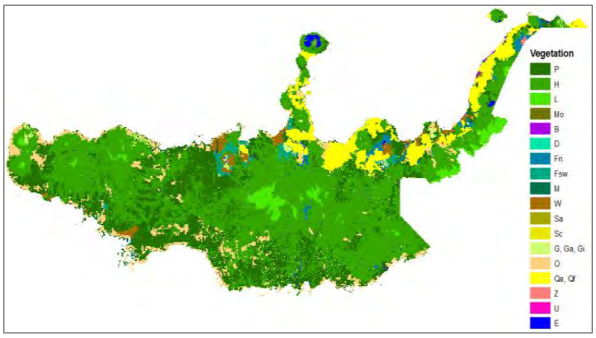
- Hansen Loss larger than 1 to 5 ha, that is adjacent to the Forest Base Map LU class "Cropland/Agriculture land" but not in characteristic shapes of mining, road, other facilities, plantation, or logging.
- A set of expedient criteria for classifying Hansen Loss data is shown below.

Table 3-1-14: Expedient criteria for classifying Hansen Loss data

Distance from CU	Size of Hansen loss data	Class
No longer than 5 to 10 km	5 ~ 20 ha	Commercial agriculture
	Up to 1 ~ 5 ha	Small agriculture patches
	Less than 1 ha	Other disturbance

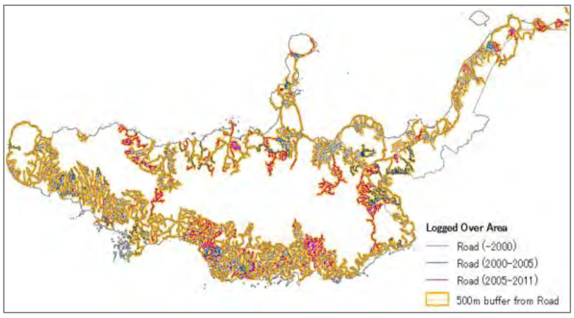
(2) Information used for Driver Identification

The following information was used for the driver identification.

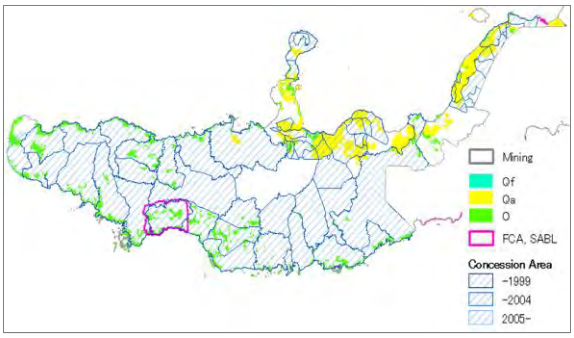


Forest Base/Cover Maps: Forest cover information in PNG. Driver information was added to each of the Forest Monitoring Unit (FMU) of the Forest Base/Cover Maps.

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.

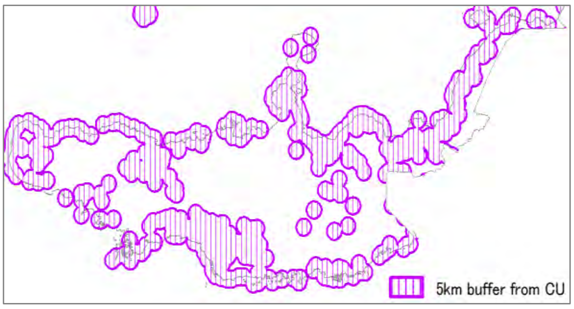
Plantation: Plantation data (Qf/Qa) from the Forest Base Map.

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



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

Fire-Watch PNG: Data obtained from a web site (http://fire.pngsdf.com/home.php) developed by the University of Papua New

(3) Detection of Forest Area Changes and their Drivers

(a) Hansen Loss Polygon 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.

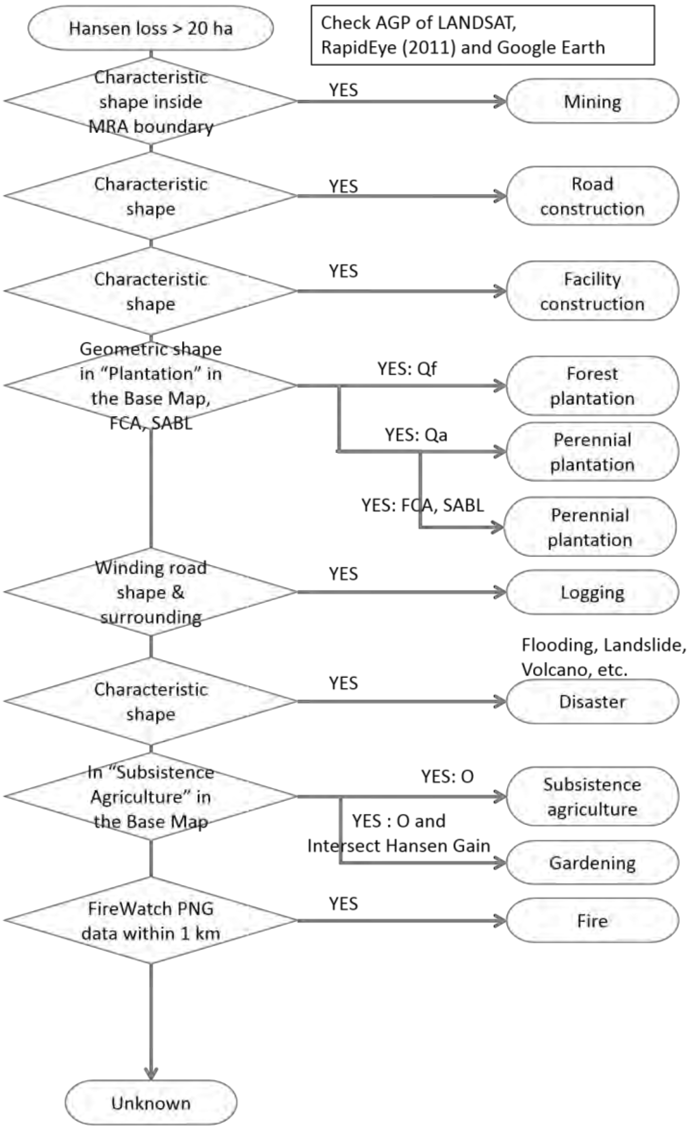
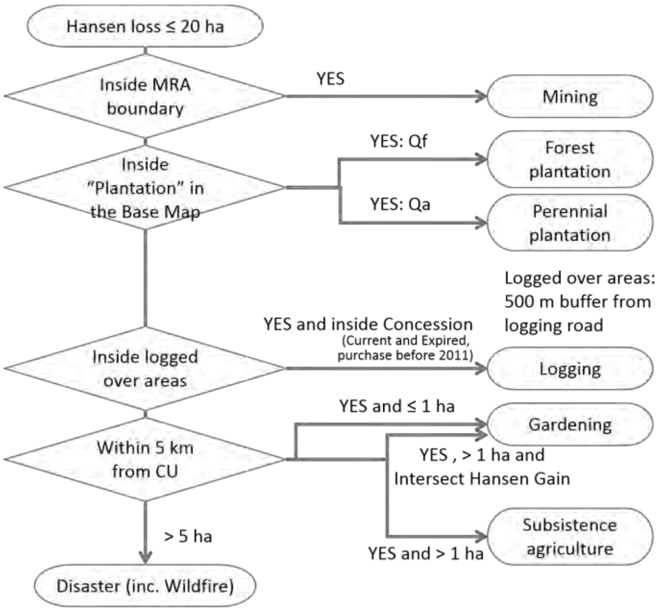


Figure 3-1-7: Driver information in WNB province for year 2000

(b) Hansen Loss polygons 20 ha and smaller

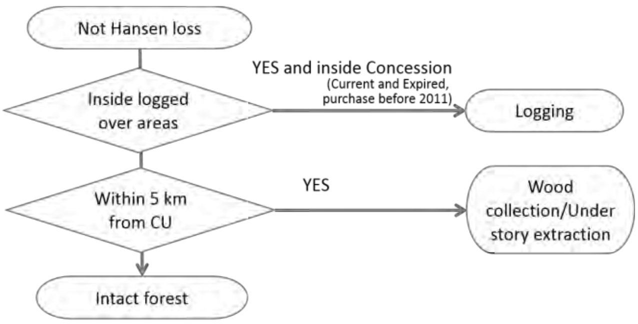
The Hansen Loss polygons 20 ha or smaller in targeted years 2001-2010 were automatically classified to DD driver using GIS data and GIS process. The drivers were identified according to the rules shown in the flowchart (right).

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) Hansen Loss polygon 20 ha and smaller

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.

<u>Data used for the Forest Cover Map 2005:</u>

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.

<u>Data used for the Forest Cover Map 2000:</u>

Logging road data before 2000 and concession purchase before 1999.

Results

National Level

Deforestation and forest Degradation 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).

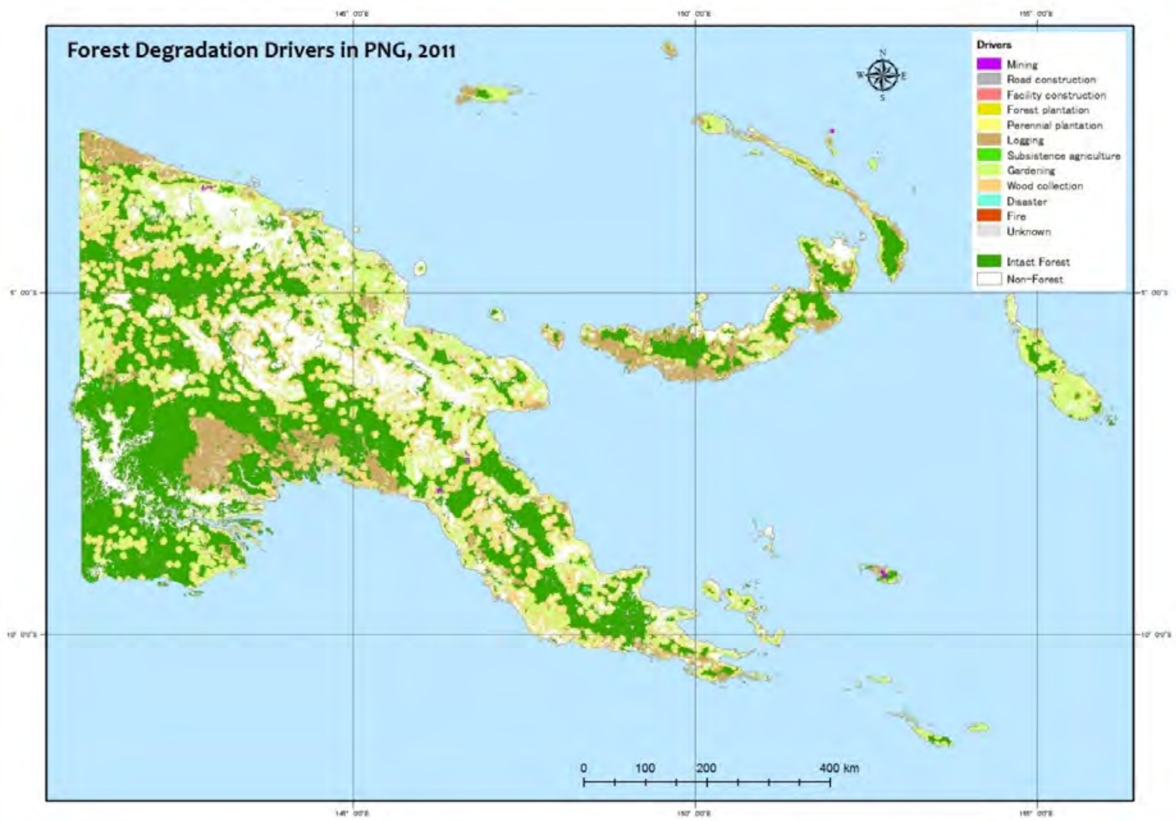


Figure 3-1-8: Driver information in PNG for year 2011

	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

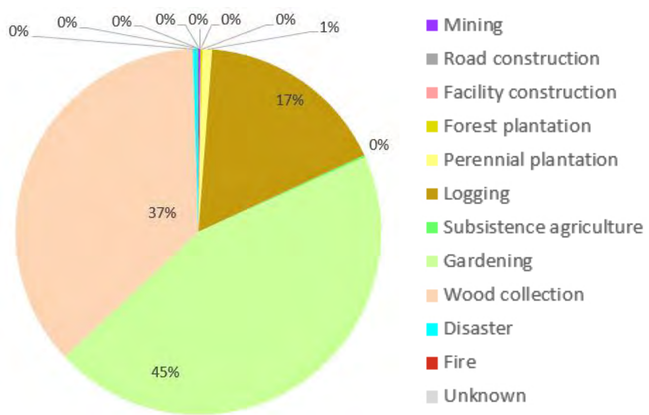


Figure 3-1-9: Area and area ratio of each forest degradation drivers of PNG (2011).

Provincial Level: West New Britain

For West New Britain province and West Sepik province, deforestation and forest degradation 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 the drivers for 2011.

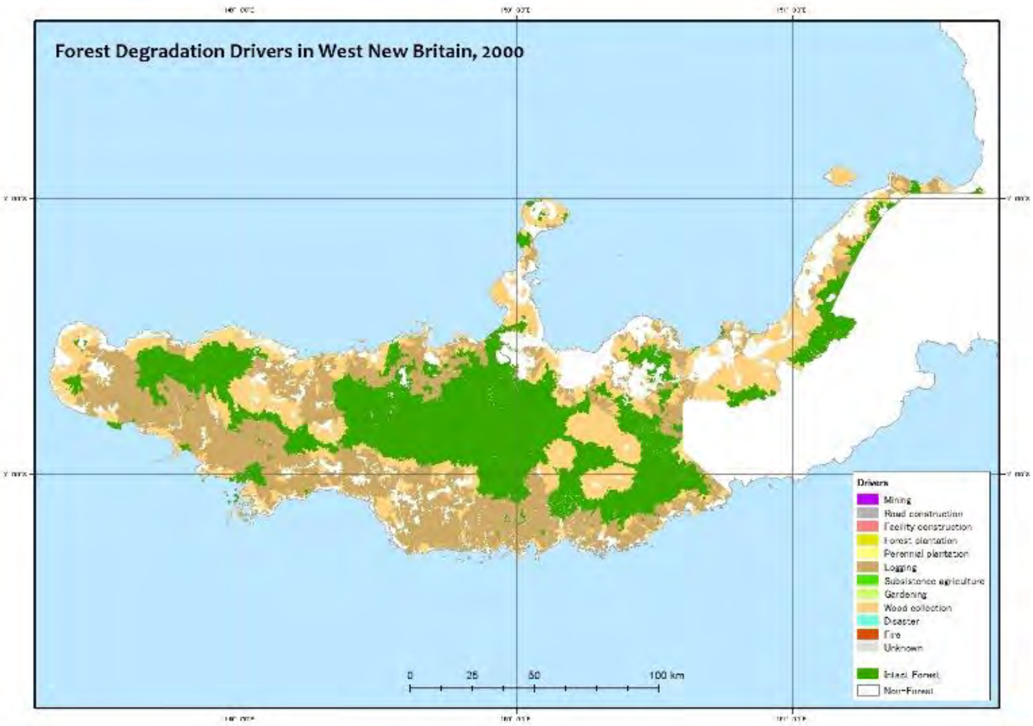


Figure 3-1-10: Driver information in WNB province for year 2000

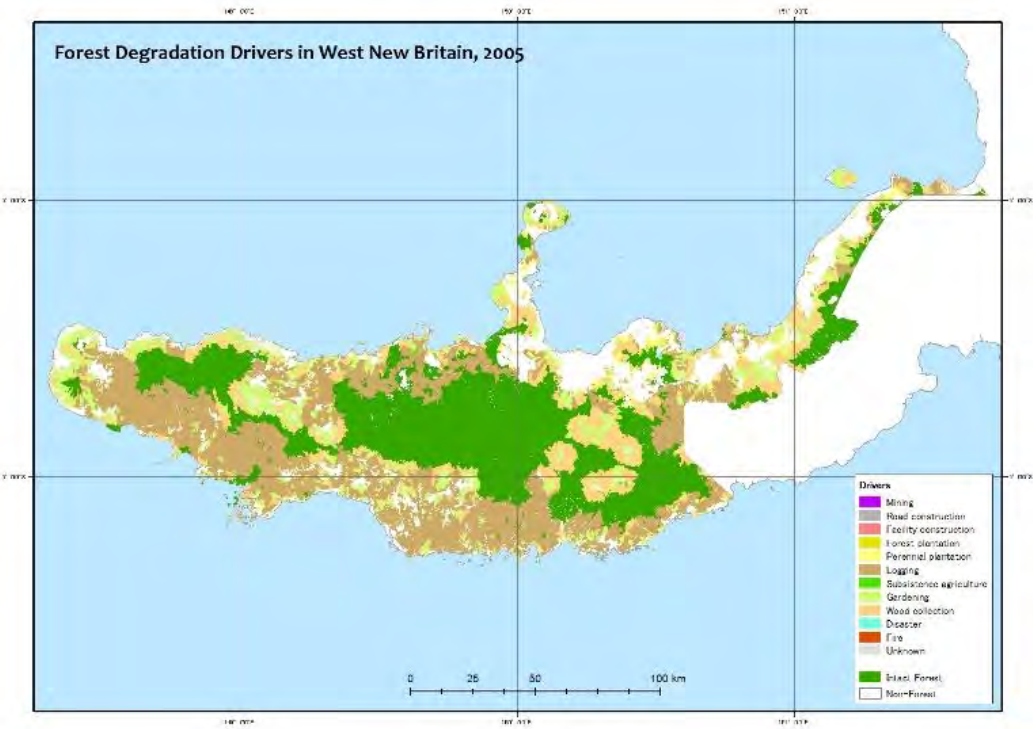


Figure 3-1-11: Driver information in WNB province for year 2005

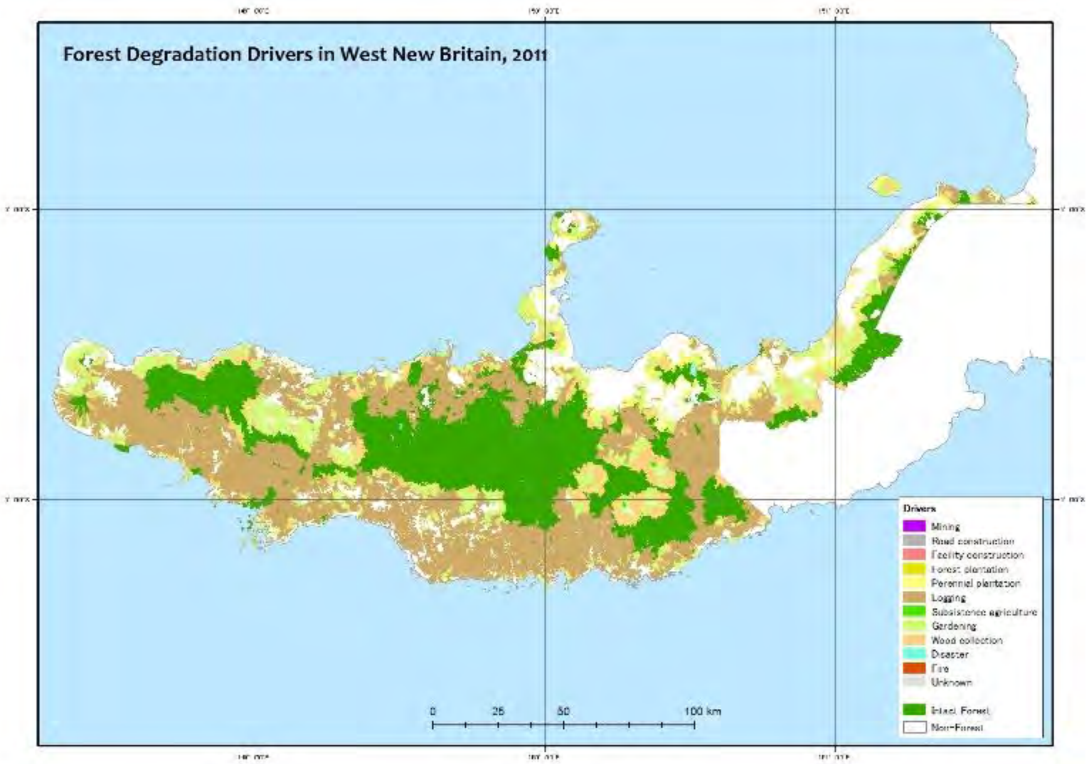


Figure 3-1-12: Driver information in WNB province for year 2011

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

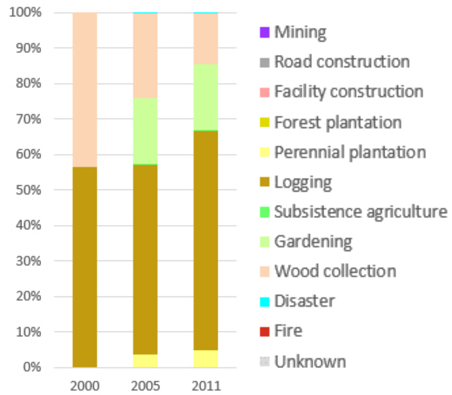


Figure 3-1-13: Area and ratio of degradation drivers of WNB in year 2000, 2005 and 2011

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.

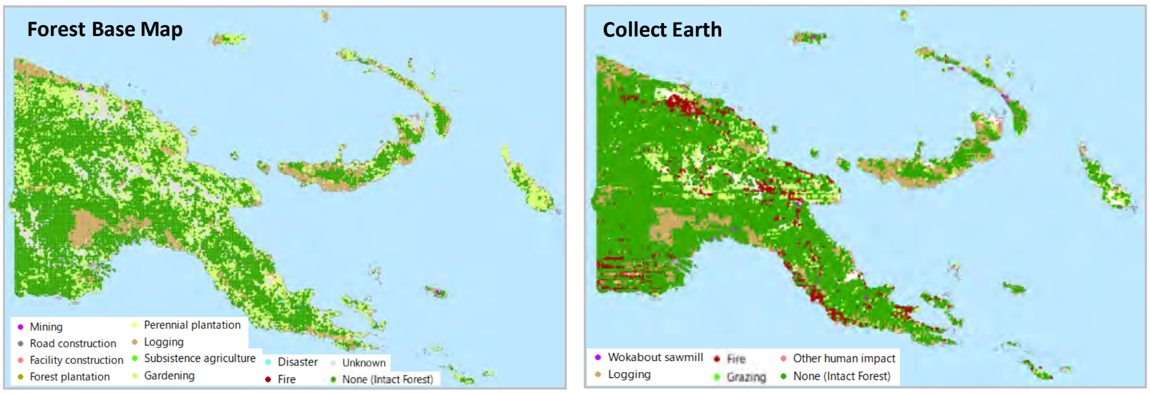


Figure 3-1-14: DD Driver and impact type distribution: PNG

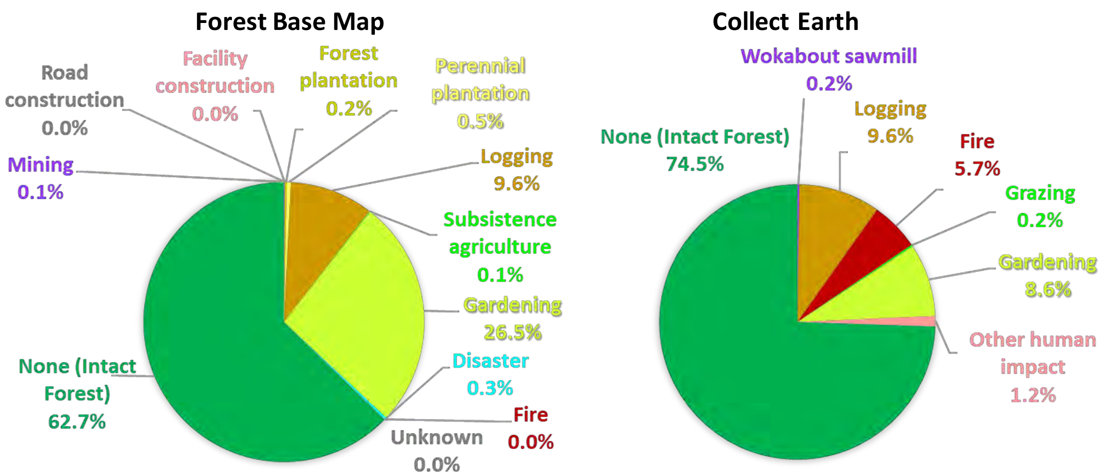


Figure 3-1-15: DD Driver and impact type composition: PNG

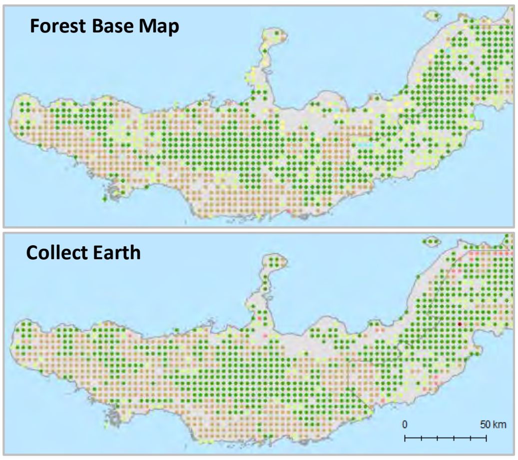


Figure 3-1-16: DD Driver and impact type distribution: WNB

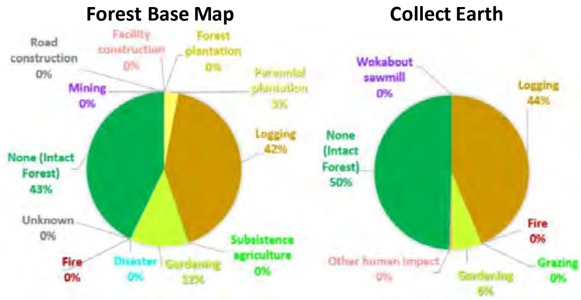
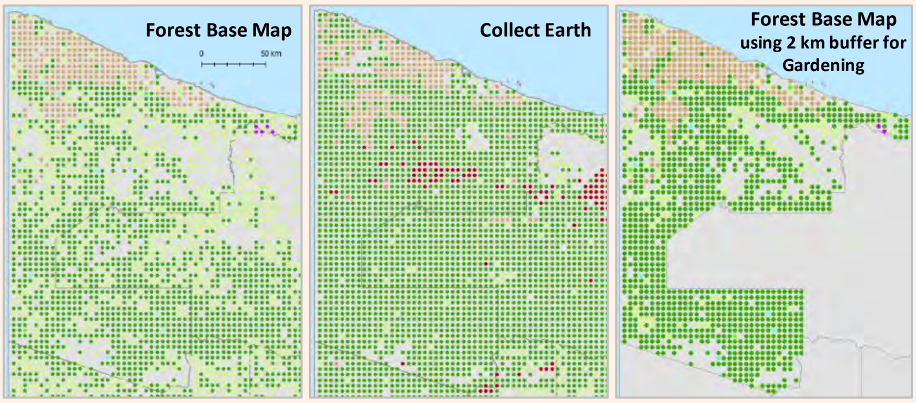


Figure 3-1-17: DD Driver and impact type composition: WNB

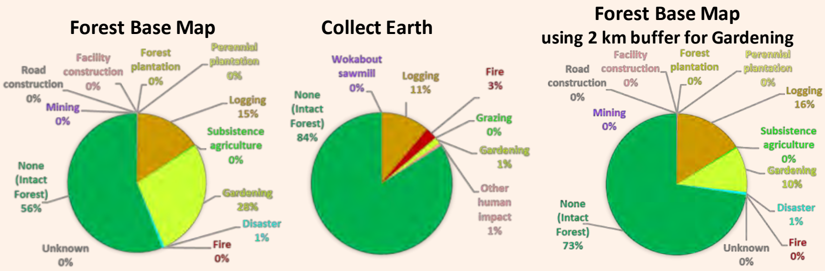
Box: Trial-basis adjustment in Garden driver parameters using WSP data

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

Discussions

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.

References

Government of Papua New Guinea, 2017, Papua New Guinea's National REDD+ Forest Reference Level

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

PNG Forest Authority (2015) Forest and land use in Papua New Guinea 2013. FAO.

Cuthbert, R.J., Bush, G., Chapman, M., Ken, B., Neale, E. and Whitmore, N. (2016). Analysis of National Circumstances in the Context of REDD+ and Identification of REDD+ Abatement Levers in Papua New Guinea. Report produced by the Wildlife Conservation Society (Goroka, Papua New Guinea), for Papua New Guinea's UN-REDD National Programme.

de Lamo, X., Arnell, A., Pollini, B., Salvaterra, T., Gosling, J., Ravilious, C. and Miles, L. (2018) Using spatial analysis to support REDD+ land-use planning in Papua New Guinea: Strengthening benefits for biodiversity, ecosystem services and livelihoods. Prepared on behalf of the UN-REDD Programme, Cambridge, UK: UNEP-WCMC

Giancarlo et al., Future Deforestation Modeling and Land Suitability Assessment for Oil palm: Agricultural Mapping Assessment in Papua New Guinea, Forest Carbon Partnership Facility (FCPF)

Roy Banka, Sarah Stocks, Peter Stephen, Kevin Brown, 2015, Low Emission Land Use Planning for Madang Province: Options and Opportunities, USAID Lowering Emissions in Asia's Forests (USAID LEAF)

Shearman, P.L., Bryan, J.E., Ash, J., Hunnam, P., Mackey, B. & Lokes, B. (2008) The state of the forest of Papua New Guinea. Mapping the extent and condition of forest cover and measuring the drivers of forest change in the period 1972-2002. University of Papua New Guinea.

Hansen et al., Science 2013, 'High-Resolution Global Maps of 21st-Century Forest Cover Change, University of Maryland (Hansen/UMD/Google/USGS/NASA)

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

Forest Timber Volume Map (Revised)

Introduction

Although Forest Base Map vegetation type and boundaries were updated, the timber volume information used in FIMS were not updated yet. The timber volume information will be the base for forest management. Therefore, the project team tried to input existing information in PNGFA into a database to integrate them.

Method

Regarding forest stock, the project team tried to input existing information in PNGFA into a database to integrate them. The following data were used as the target information: PNGRIS, which integrates timber volume information obtained between the 1950's and mid 1990's; FIPS, which is based on pre-surveys for setting new logging concessions by PNGFA implemented mostly between the 1980's to the present time; and PSP, which is the result of inventory survey in PSP implemented by FRI between the 1990's and 2000's.

PNGRIS data is paper- based information integrating various timber volume information obtained by PNGFA and the other organizations between 1950's and mid 1990's. This data set is the fundamental information to calculate timber volume in current FIMS. In this dataset, the volumes of all trees, both merchantable and non-merchantable, which have DBH of > 50 cm are recorded. Because of various sources of the data, the procedures of the surveys are not unified (unknown in a lot of cases) and the detailed site locations are missing. How to calculate the timber volume is also unknown.

FIPS data is information from timber volume survey which PNGFA is implementing before establishing Forest Management Area (FMA) for setting new logging concession mainly from the 1980's to present. In this survey, basically only species which have high values as exporting timber in a particular list (the list of Species Groups and Species Codes for Log Exports in Procedures for Exporting Logs published by PNGFA; Annex 27) are measured (only DBH > 20 cm). Additionally, trees which have bad shapes as timber are removed from the samples. To calculate timber volume of each tree, the following common equations are used applying DBH and merchantable height of each tree:

If there was no height data: $V = 0.00000515025*(3.14159*D)^{2.4762}$

DBH ≥ 50 cm:

$$V=0.189523+0.0000547982*(D-2.4)^2-0.0089213*H+0.0000528219*(D-2.4)^2*H$$

DBH = 20 – 50 cm:

$$V=-0.001508+0.000044658*D^2+0.00005310227*D^2*H-0.00000061883*D^2*H^2$$

Where V is timber volume (m^3), D is DBH (cm), H is merchantable height (m).

The PSP data obtained by Forest Research Institute (FRI) is mainly from the 1990's. In this survey, all trees (DBH ≥ 10 cm) including every species and every shape, were measured and recorded. To calculate timber volume of each tree, the following equations are used:

Merchantable height (m): $H_m = (D*a)/(b+D)$
Merchantable volume (m^3): $V_m = 0.5*(3.14159*(D/200)^2)*H_m$
Where D is DBH (cm), a and b are species specific coefficients developed by Fox et al. (2010).

The target of each survey is summarized in Figure 3-1-18. PSP survey is measuring all trees with a DBH of 10 cm or more, PNGRIS focuses on all trees with a DBH of 50 cm or more and FIPS survey is measuring only merchantable trees with a DBH of 20 cm or more.

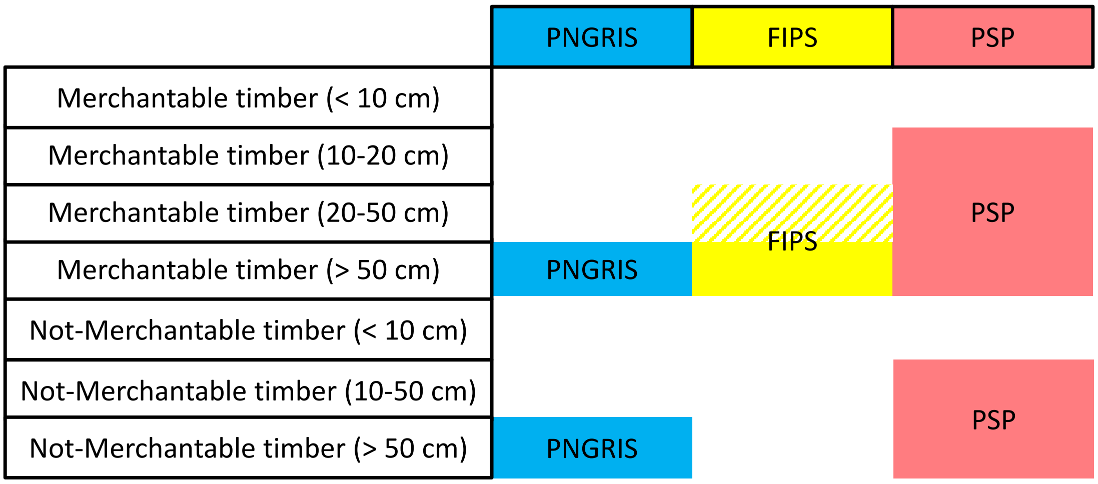


Figure 3-1-18: Targets of PNGRIS, FIPS, PSP surveys

The project team first made a database of PNGRIS paper- based data. The data in each survey were then standardized and compared. The timber volume in FIPS is recalculated using the equation for PSP data. Figure 3-1-19 shows ratios of the merchantable timber volume to total volume (DBH ≥ 50 cm) of FIPS, PNGRIS and PSP, respectively. As merchantable timber volume, species in Group 1-3 in the list of Species Groups, which are regarded as valuable as exporting timber, were counted. The ratios in FIPS, PNGRIS and PSP (average ± s.e.) were 0.70± 0.02, 0.62 ± 0.01 and 0.56 ± 0.07, respectively. The difference in averages between FIPS and PNGRIS indicates a possibility that un-merchantable trees were not counted in FIPS survey. Otherwise, there were some biases in methodologies to choose sampling sites between FIPS survey and PNGRIS survey series although it was not possible to verify this because of too many unclear points in PNGRIS surveys. On the other hand, the averages in FIPS and PSP and those in PNGRIS and PSP were not significantly different. Although this might be due to the small numbers of the PSP sites (n =12), it can be considered that the results in FIPS survey and PINGRIS surveys were not completely different from the truth. Although there is a possibility that PSP survey points themselves also had some bias such as the accessibility of the sites, the project team assumed that the merchantable volumes of the trees with a DBH of 50 cm or more in FIPS survey and PNGRIS surveys are reliable.

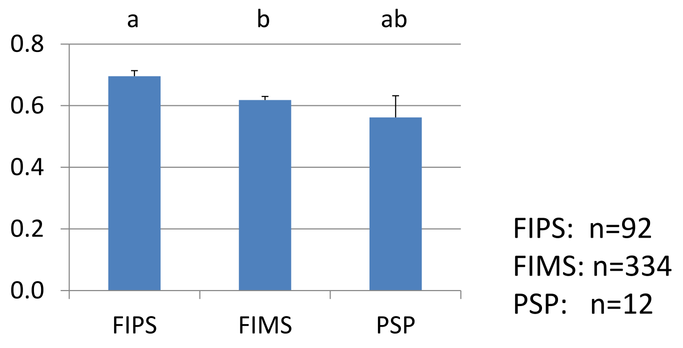


Figure 3-1-19: Ratio of merchantable timber volume to total volume in FIPS, PNGRIS & PSP

The error bars are indicating the standard errors. The difference in the small letters indicate the significance between the averages (P < 0.05, Tuekey's test).

Figure 3-1-20 shows the ratio of the timber volume of the trees with DBH ≥ 50 cm to those with DBH 20 – 50 cm in FIPS data and PSP data. The ratios in FIPS and PSP (average ± s.e.) were 0.75± 0.01 and 0.52 ± 0.04, respectively, suggesting significant difference between the averages in FIPS and PSP. Considering this with the result that showed no significant difference in the averages in ratios of the merchantable timber volume to total volume (DBH ≥ 50 cm) of FIPS and PSP, it seemed that a large part of the trunks whose DBH were less than 50 cm were not counted in FIPS survey. PNGFA targets only trees which have 50 cm or larger DBH for commercial logging, so the reason why the trees with 20 – 50 cm DBH are also measured in FIPS is likely to obtain data for future logging, as it were a kind of preliminary survey. So, the results in this range may be not so accurate; in some sites the results are completely missing. These results suggest that the data in FIPS are reliable when merchantable timber volume was estimated though it is difficult to use it to estimate total forest carbon stock to contribute REDD+ activities in the future.

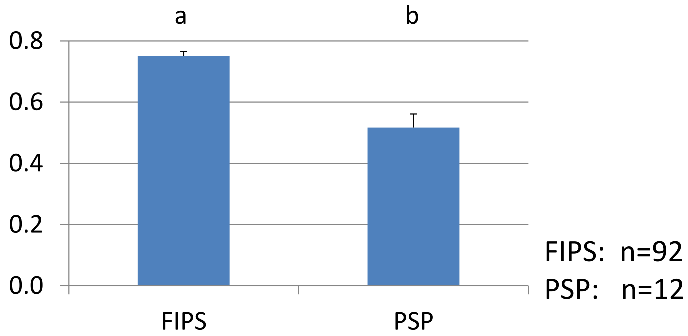


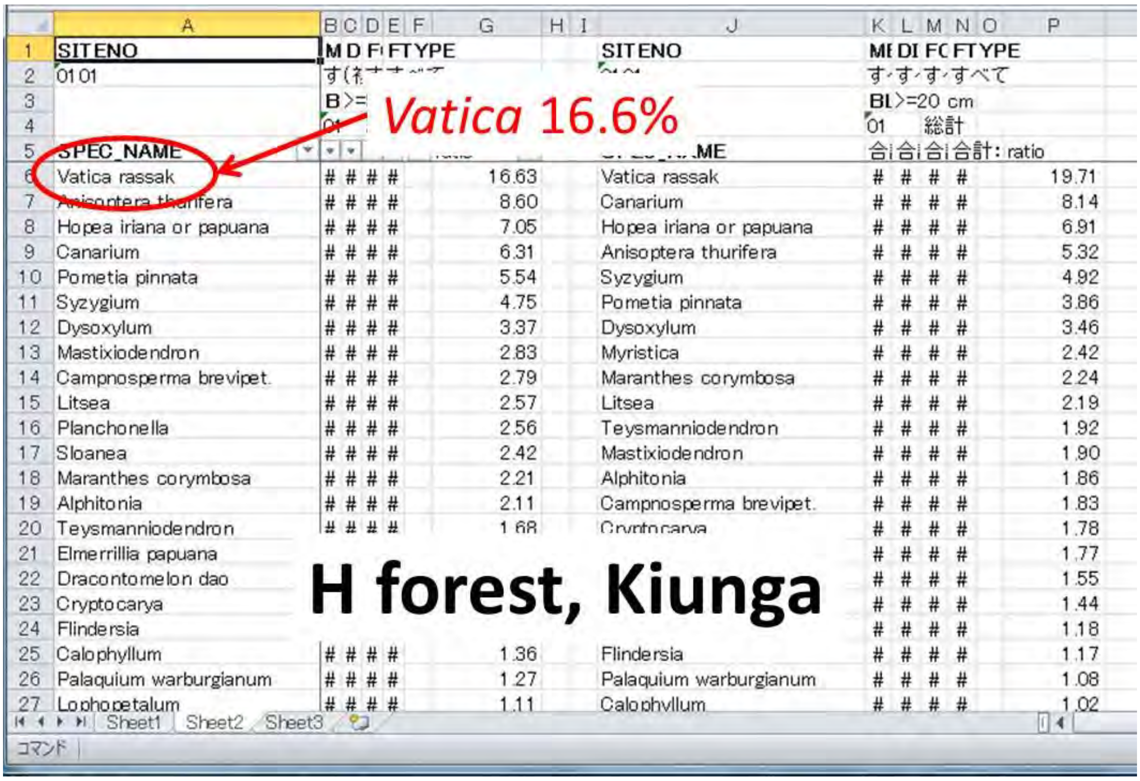
Figure 3-1-20: Ratio of timber volume of trees with DB ≥50cm to 20–50cm in FIPS and PSP

The error bars indicate the standard errors. The difference in the small letters indicates the significance between the averages ($P < 0.05$, t- test).

The project team made a database of PNGRIS paper-based data. The data in PNGRIS, FIPS and PSP survey were then standardized extracting merchantable timber volume (DBH ≥ 50 cm). As merchantable timber volume, species in Group 1-3 in the list of Species Groups were counted.

As forest zone and vegetation type of each site of FIPS survey and vegetation type of each site of PSP survey were unknown, these were estimated from lists of existing tree species and those volume ratios of each site. It was not possible to specify small classifications of vegetation type, only large classifications such as “P” or “H” were applied for each site. In some sites, forest zones could not be estimated so a list of possible forest zones was made. In this case, the figure of the site was weighted to calculate the average timber volumes of the forest zones.

The average timber volumes of each forest zone and each vegetation type were calculated from the extracted information from PNGRIS, FIPS and PSP dataset and a timber volume list was prepared (refer to Annex 28). Average timber volumes of each large classification of vegetation type were calculated, as well as those of each small classification, for filling the volume information into a classification of vegetation type which is not specified (for example, a location with a small vegetation classification subscripted with the letter “x”, indicating the large classification is different between the Forest Base Map and PNGRIS). When timber volume at a certain point with some vegetation type was not shown in the list, average timber volume of all forest zones and all vegetation types was assigned.



	A	B C D E F	G	J	K L M N O	P
1	SITENO	M D F FTYPE		SITENO	ME DI FC FTYPE	
2	0101					
3		B>=			BL>=20 cm	
4					01 総計	
5	SPEC_NAME			ME	合 合 合 合計: ratio	
6	Vatica rassak	# # # #	16.63	Vatica rassak	# # # #	19.71
7	Anisoptera thurifera	# # # #	8.60	Canarium	# # # #	8.14
8	Hopea iriana or papuana	# # # #	7.05	Hopea iriana or papuana	# # # #	6.91
9	Canarium	# # # #	6.31	Anisoptera thurifera	# # # #	5.32
10	Pometia pinnata	# # # #	5.54	Syzygium	# # # #	4.92
11	Syzygium	# # # #	4.75	Pometia pinnata	# # # #	3.86
12	Dysoxylum	# # # #	3.37	Dysoxylum	# # # #	3.46
13	Mastixiodendron	# # # #	2.83	Myristica	# # # #	2.42
14	Campnosperma brevipet.	# # # #	2.79	Maranthes corymbosa	# # # #	2.24
15	Litsea	# # # #	2.57	Litsea	# # # #	2.19
16	Planchonella	# # # #	2.56	Teysmanniodendron	# # # #	1.92
17	Sloanea	# # # #	2.42	Mastixiodendron	# # # #	1.90
18	Maranthes corymbosa	# # # #	2.21	Alphitonia	# # # #	1.86
19	Alphitonia	# # # #	2.11	Campnosperma brevipet.	# # # #	1.83
20	Teysmanniodendron	# # # #	1.68	Cryptocarya	# # # #	1.78
21	Elmerrillia papuana				# # # #	1.77
22	Dracontomelon dao				# # # #	1.55
23	Cryptocarya				# # # #	1.44
24	Flindersia				# # # #	1.18
25	Calophyllum	# # # #	1.36	Flindersia	# # # #	1.17
26	Palaquium warburgianum	# # # #	1.27	Palaquium warburgianum	# # # #	1.08
27	Lophopetalum	# # # #	1.11	Calophyllum	# # # #	1.02

Figure 3-1-21: Example of tree species compotion (Site No. 101 (Agrim Ext., WES) in FIPS)

Table 3-1-15: Example of timber volume table (FIMS: n=339, FIPS: n=97, PSP: n=13)

ID	Code	Province	Zone	Type	Volume (DBH ≥ 50 cm, Group 1-3)	Source	No. of Possible Zones
384	1003	WSP	Aitape	H	32.32	FIPS	1
387	1008	WSP	Aitape	H	27.10	FIPS	2
183	AIT01	WSP	Aitape	Hm	18.25	FIMS	1
184	AIT04	WSP	Aitape	Hm	27.45	FIMS	1
348	0203	GUL	Aramia-Kikori	H	49.47	FIPS	1
150	ARK01	GUL	Aramia-Kikori	Po	33.15	FIMS	1
-	0104	WES	Aramia-Kikori	D	45.25	FIPS	2
163	ARK08	WES	Aramia-Kikori	D	61.38	FIMS	1
-	0105	WES	Aramia-Kikori	H	22.06	FIPS	5
346	0108	WES	Aramia-Kikori	H	20.49	FIPS	1
443	SASER03	WES	Aramia-Kikori	H	56.18	PSP	1

Results

Table 3-1-16: Timber Volume (DBH>5 cm) given into Forest Base Map (m3 ha-1) 1

Province	Zone	Pl	Ps	Po	P_general	Hl	Hm	HmAr	Hmd	Hme	Hs	H_general
ARB	North Solomons			14	14		23	23	23	23		24
CEN	Central North	56			48		38	38	38	38	12	20
CEN	Central South	38	11	10	25		13	13	13	13	19	17
EHP	Highland				33							50
ENB	Central New Britain				59	25	29	29	29	29		34
ENB	Gazelle			26	25		29	29	29	29		32
ENG	Jimi				33			18				18
ENG	Highlands				33							36
ESP	Bewani-Sepik				29							33
ESP	Sepik-Costal			49	46		65	65	36	65		50
ESP	Sepik-South				40							48
GUL	Aramia-Kikori			33	33							49
GUL	Kerema	23	33		30		29	29	29	29		30
MAD	Finisterre-Huon				12		29	29	29	29		30
MAD	Gogol-Ramu		37	47	42		24	24	33	24		34
MAD	Madang-Bogia				37		39	39	50	39		40
MAD	Ramu-Bismark	28		19	25		39	41	22	39		35
MAN	Manus				33					25		76
MIL	D'Entrecasteaux		24		24						30	28
MIL	Louisiade				30						15	19
MIL	Milne Bay	8	8		31		33	33	33	33	37	33
MIL	Oro	15			35							30
MIL	Woodlark		29		31						34	34
MOR	Finisterre-Huon	12			12		33	33	33	33		33
MOR	Lae	34			34		32	32	32	32		32
MOR	Morobe				33		39	39	39	39		42
MOR	Umboi			10	10		22	22	22	22		22
MOR	Watut	38		55	40		25	25	25	25		29
NIP	Central New Ireland				33		32	32	32	32		33
NIP	Mussau				33		34	34	34	34		55
NIP	New Hanover				33		30	30	30	30		35
NIP	Northern New Ireland				33		19	19	19	19	31	28
NIP	Southern New Ireland				33		20	20	20	20		26
ORO	Morobe	37		30	33		19	19	19	19	18	25
ORO	Oro	24		21	35		29	29	29	29		30
SHP	Bosavi-Strickland				33	31						55
SHP	Highland				33							40
SIM	Highland				33		49	49	49	49		45
WES	Aramia-Kikori				33		42	42	42	42		43
WES	Bosavi-Strickland				33		24	24	24	24		33
WES	Central - Fly				33							22
WES	Kiunga				33		16	16	16	16		20
WES	South Fly				33							22
WHP	Highland				33							44
WHP	Jimi				33			27				62
WNB	Central New Britain				59	17	55	55	55	55		42
WNB	West New Britain	56		29	39		25	25	25	25		34
WSP	Aitape				27		26	26	26	26		23
WSP	Bewani-Sepik				31		31	31	31	31		33
WSP	Oenake				33		15	15	15	15		15
WSP	Pual River				27		36	36	36	36		36
WSP	Sepik Plains				27							57
WSP	Sepik-Costal				27							27
WSP	Sepik-South				27		55	55	55	55		55
WSP	Telefomin				27		54	54	54	54		54

Table 3-1-17: Timber Volume (DBH>50cm) given into Forest Base Map (m3 ha-1) 2

Province	Zone	L	LN	Lc	Ls	L_general	D	FriK	Fsw	FswTb	M	W	Wsw	Wx	Others
ARB	North Solomons					36				8					34
CEN	Central North					36									34
CEN	Central South					36									34
EHP	Highland		32	23		29									34
ENB	Central New Britain	37	37	37		28									34
ENB	Gazelle					20		18							34
ENG	Jimi					10									34
ENG	Highlands	26	42	29		35									34
ESP	Bewani-Sepik					36									34
ESP	Sepik-Costal					36									34
ESP	Sepik-South					36									34
GUL	Aramia-Kikori					36									34
GUL	Kerema					36			17		24				34
MAD	Finisterre-Huon					28									34
MAD	Gogol-Ramu					36									34
MAD	Madang-Bogia					36									34
MAD	Ramu-Bismark					36									34
MAN	Manus					36									34
MIL	D'Entrecasteaux					36									34
MIL	Louisiade					36									34
MIL	Milne Bay					36									34
MIL	Oro					36									34
MIL	Woodlark					36									34
MOR	Finisterre-Huon	29	29	29	25	28									34
MOR	Lae					44									34
MOR	Morobe					44			29				13	13	34
MOR	Umboi					44									34
MOR	Watut	43	53	43		52									34
NIP	Central New Ireland					36									34
NIP	Mussau					36									34
NIP	New Hanover					36									34
NIP	Northern New Ireland					36									34
NIP	Southern New Ireland					36									34
ORO	Morobe					36									34
ORO	Oro					36									34
SHP	Bosavi-Strickland					30									34
SHP	Highland	31	31	43		30									34
SIM	Highland	17	50	17		28									34
WES	Aramia-Kikori					36	56								34
WES	Bosavi-Strickland					36									34
WES	Central - Fly					36	45								34
WES	Kiunga					36									34
WES	South Fly					36						29		27	34
WHP	Highland		81	8		52									34
WHP	Jimi					10									34
WNB	Central New Britain					28									34
WNB	West New Britain					36									34
WSP	Aitape					36									34
WSP	Bewani-Sepik					36									34
WSP	Oenake					36									34
WSP	Pual River					36									34
WSP	Sepik Plains					36									34
WSP	Sepik-Costal					36									34
WSP	Sepik-South					36									34
WSP	Telefomin					36									34

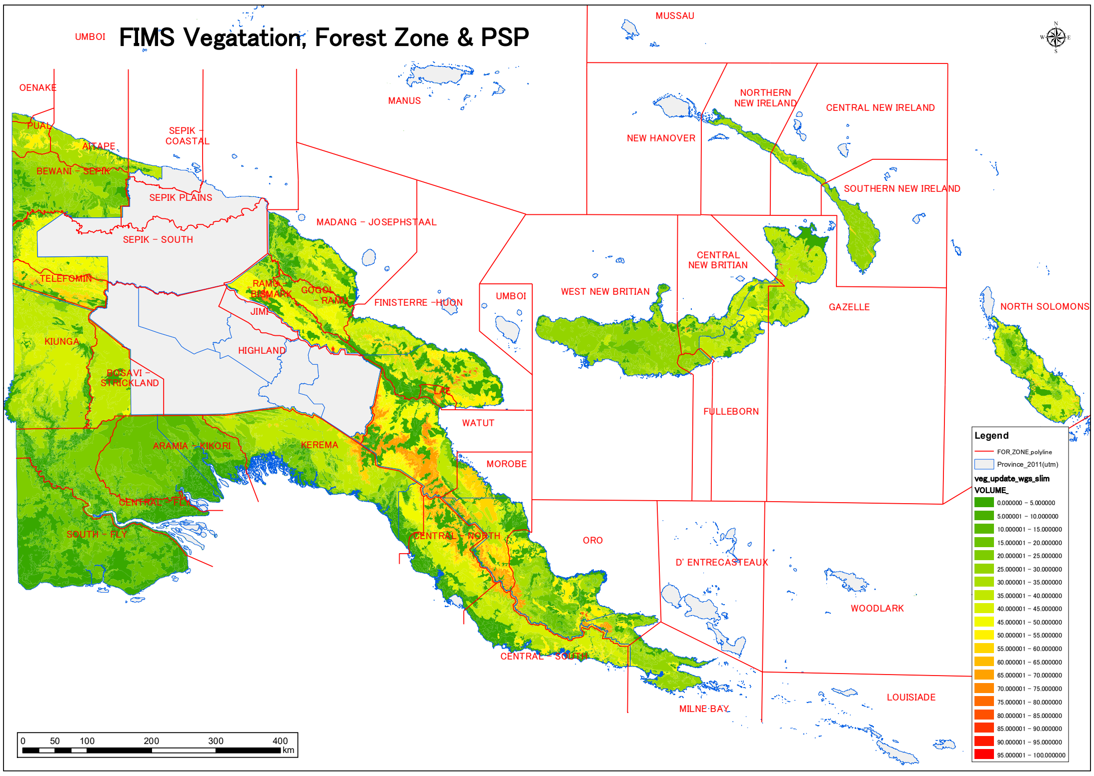


Figure 3-1-22: National FIMS Timber Volume Map (For Each Forest Zone / Vegetation Type)

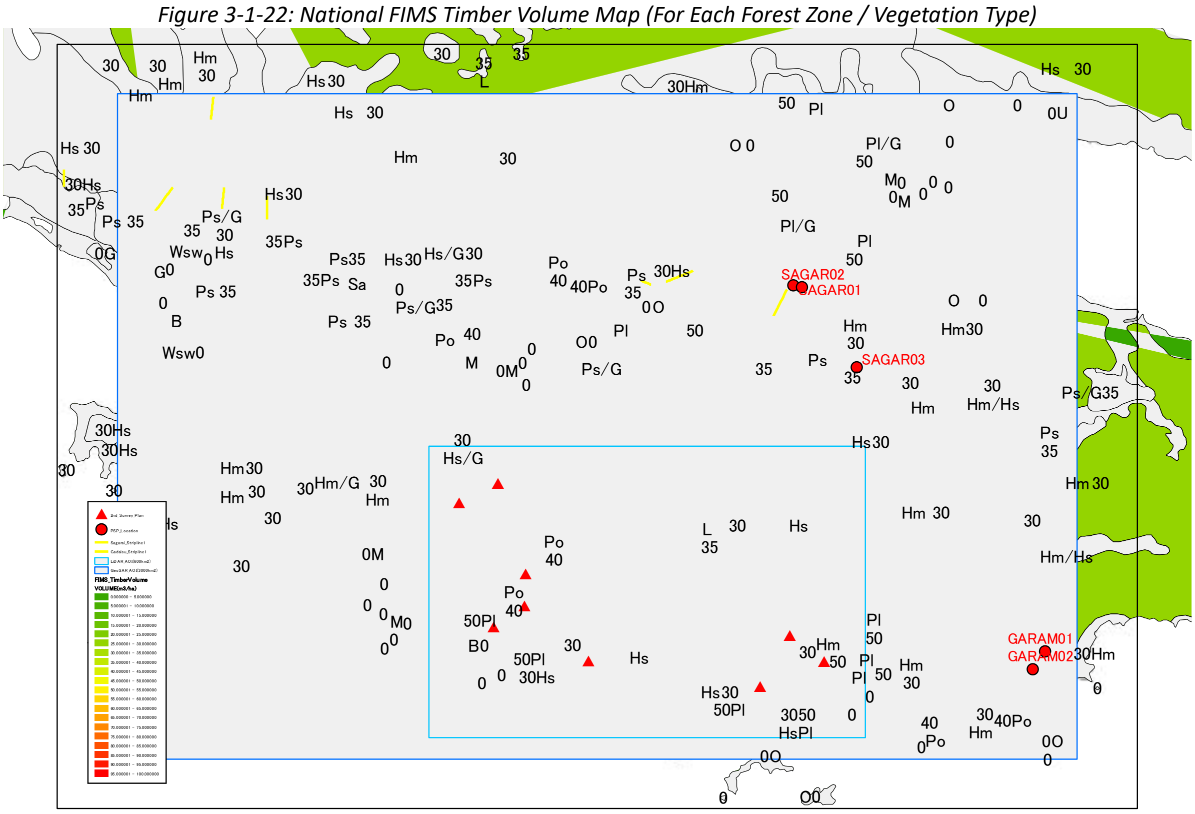


Figure 3-1-23: FIMS Timber Volume Map in Central Suau Area (For Each Vegetation Type)

Discussions

The estimated timber volumes were reviewed and approved by the officers of PNGFA after a modification on an extremely large number in a forest zone utilizing average values in forest zones nearby the forest zone. The approved timber volumes are attached into the Forest Base Map. Because the Forest Base Map contains timber volume information originated by FIMS as well, it has two kinds of timber volume information (originated from FIMS and approved in this time) at this moment. As the newly approved information refers more data than FIMS information, the accuracy is probably better in the new information.

The estimated figures obtained here are only tentative because the data collection was not implemented in a consistent way. These values are prepared to be replaced by results from the NFI survey operated by the FAO (Food and Agriculture Organization of the United Nations) project in the future.

References

Julian C. Fox et al. (2010). Assessment of Aboveground Carbon in Primary and Selectively Harvested Tropical Forest in Papua New Guinea. BIOTROPICA 42(4): 410–419.

PNG Forest Authority (1991). FIPS - Forest Inventory Processing System, Version 3.01 USER MANUAL.

PNG Forest Research Institute (1994). A Data Management System for Permanent Sample Plots in Natural Forest: USER MANUAL

Past Forest Cover Maps 2000/2005

Introduction

It is important to figure out where and how much forest resources are for a sustainable forest management. To get handle on the behavior of the forest is useful for a better forestry planning, monitoring and management. In this project, we will create past forest cover maps (2005, 2000) for pilot provinces to look into forest situation, say (a) where intact forest is, (b) how degraded forest has recovered, (c) how deforestation or forest degradation has expanded, and (d) if people run cyclic subsistence agriculture or not. Those data also can be useful information for addressing REDD+.

In this operation, past forest cover maps (2005, 2000) of WNB province will be created in order to compare the changes in forest cover over years. However, while reviewing the Forest Base Map with new reference data, we found some misclassifications in the Base Map, and it turned out that it will be difficult to make comparisons over years using the current Base Map.

Therefore, while creating the past forest cover map of 2005, the Base Map should be revised. After completion of the Base Map and forest cover map of 2005, forest cover map of 2000 will be created.

Methods

Vegetation and landuse code:
2011 (revised), 2005, 2000

Vegetation and landuse code:
2 pilots: WNB and WSP

Available data to be referred and used for analysis:

- The Forest Base Map 2012
- LANDSAT / LANDSAT AGP: 1990, 2000, 2005, 2010, 2011, 2014
- Hansen gain / loss / lossyear data 2001-2014
- Old FIMS vegetation
- Logged over area
- Mining, Google Earth, etc.
- SRTM 30 (Slope)

Vegetation and landuse code:

Code	Vegetation and landuse
P	Low Altitude Forest on Plains & Fans
H	Low Altitude Forest on Uplands
L	Lower Montane Forest
Mo	Montane Forest
B	Littoral Forest
D	Dry Seasonal Forest
Fri	Seral Forest
Fsw	Swamp Forest
M	Mangrove Forest
W	Woodland
Sa	Savanna
Sc	Scrub
G	Grassland and Herbland
Ga	Grassland (Alpine)
Gi	Grassland (Subalpine)
O	Cropland/Agriculture land
Qa	Forest Plantation
Qf	Plantation other than Qf
Z	Bare areas
U	Larger Urban Centres
E	Lake & Larger Rivers
Es	Sea (Outside land)

Table 3-1-18: Vegetation and landuse code

Procedure:

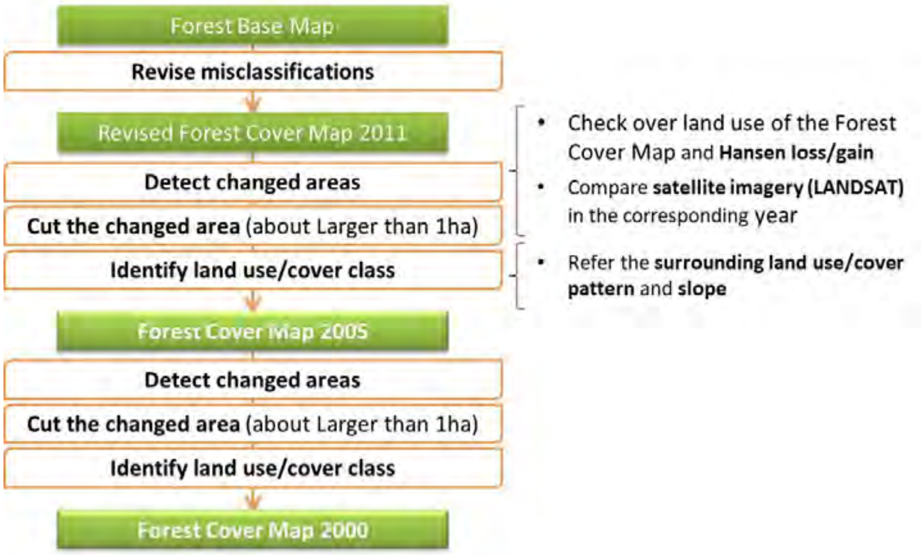


Figure 3-1-24: Work-flow of creation of past forest cover maps

1. Data preparation
   - ➢ In ArcCatalog, copy the Forest Base Map file geodatabase (21_WNB.gdb in 7_Bmapv11_fmu) in the work folder.
     This will be used for creating past forest cover maps.
   - ➢ Copy the Forest Base Map feature class (WNB_ForestBaseMap) in the copied Forest Base Map file geodatabase (21_WNB.gdb), and rename it as "WNB_ForestCover_2005_00_11".
2. Preparation in ArcMap
   - ➢ Open ArcMap, and add the following data.

     - The copied Forest Base Map (WNB_ForestBaseMap)
     - The past forest cover map to be edited (WNB_ForestCover_2005_00_11)
     - LANDSAT AGP in 1990, 2000, 2005, 2011, and the latest year for the target area
     - LANDSAT imagery in 1990, 2000, 2005, 2011, and the latest year for the target area
     - Hansen loss year, loss and gain
     - Old FIMS vegetation target area (All_PNG_Veg_region)
     - Concession (LandUse_NotLogged_Current, Logged_LandUse_Current, Logged_NotLandUse_Current, and ConcessionArea)
     - Slope (Slope_strm30_z55.tif)
     - Driver related data such as mining, road, etc.
     - Province (Province_2014_single)
   - ➢ Set symbols of each layer. Suggested settings of symbols are listed below.

     - For "WNB_ForestCover_2005_00_11", import symbol from layer (ForestBaseMap_ver1.1_code.lyr)
     - Loss from 2001 to 2005, loss from 2006 to 2011 and loss after 2012 by using Hansen loss-year
     - Only land use area (O, Qa, Qf, Z and U) and grassland area (G, Ga and Gi) by using the Forest Base Map

- Add Three fields for past land-use and revised land-use 2011 in the attribute table of the past forest cover map (WNB_ForestCover_2005_00_11).

  Field name: lu11, lu05, lu00

  Field type: Text

  Field length: 12

- Copy records of original land-use in 2011 from "Land-use" field into "lu11" and "lu05" field.
- Fix the move tolerance to avoid moving the existing polygon (Tip 1).
- Fix the visible fields to show only the fields to be edited (Tip 2).

3. Editing
   - Refer to 2005 LANDSAT imagery, and cut the polygon at the area of changes bigger than about 1ha, and add its attribute (land-use code) in the "lu05" field. For detecting changes, also refer to the imagery of other years, Hansen loss-year, and concession layer, etc.
   - If any obvious misclassification is found for 2011 Forest Base Map, edit "lu11" field.
   - Typical changes are changes from forest (P~Sc) and grassland (G~Gi) to Cropland (O), Plantation (Qa, Qf) and other land used (Z, U), and from forest (P~Sc) to grassland (G~Gi). You can edit for the changes from glass land to forest if there are any, but this is expected to be rare. That is to say, you will look at the whole area, but should especially pay attention to the cropland, plantation, and other land use area (O~U) in the Base Map, and confirm how it was used in the past.
   - Hansen data can be useful to find the changed area, although note that the loss and gain is also repeated inside the plantation.
   - For the land-use classification, refer to the texture of land-use at the surrounding area. However, since "H" and "P" cannot be classified based on the texture, refer to the slope data. If a range of area with slope steeper than 6 is large within the target polygon, it should be "H", and if it is most of the area is slope 6 or less, it should be "P" (also refer to the classification of surroundings).
   - After completing 2011 base map and 2005 cover map, copy records of land use in 2005 from "lu05" field into "lu00" field. Create 2000 cover map by adding attributes to "lu00" field.

Matters to consider:

- ✓ Changes that are obvious in 1:50,000 scale is targeted.
- ✓ Zoom in when cutting or editing the polygons, because shape of some polygons is sometimes unexpected.
- ✓ If the shape of changed area is similar to FMU boundary, just add past land-use code since many tiny polygons are not preferable. Do not mind the slight difference in shapes.
- ✓ Do not change the "lu11" field, unless the existing classification is obviously wrong.
- ✓ Some area is hardly visible. Ignore the area you are not sure about.
- ✓ Keep the consistence over year (ex. changes like "crop land → forest → crop land" is unlikely to happen).
- ✓ Logging road and forest degradation can be ignored. They will be edited in another layer.
- ✓ NEVER merge polygons. Each polygon has their own ID and consistency will be lost by merging them.

Results

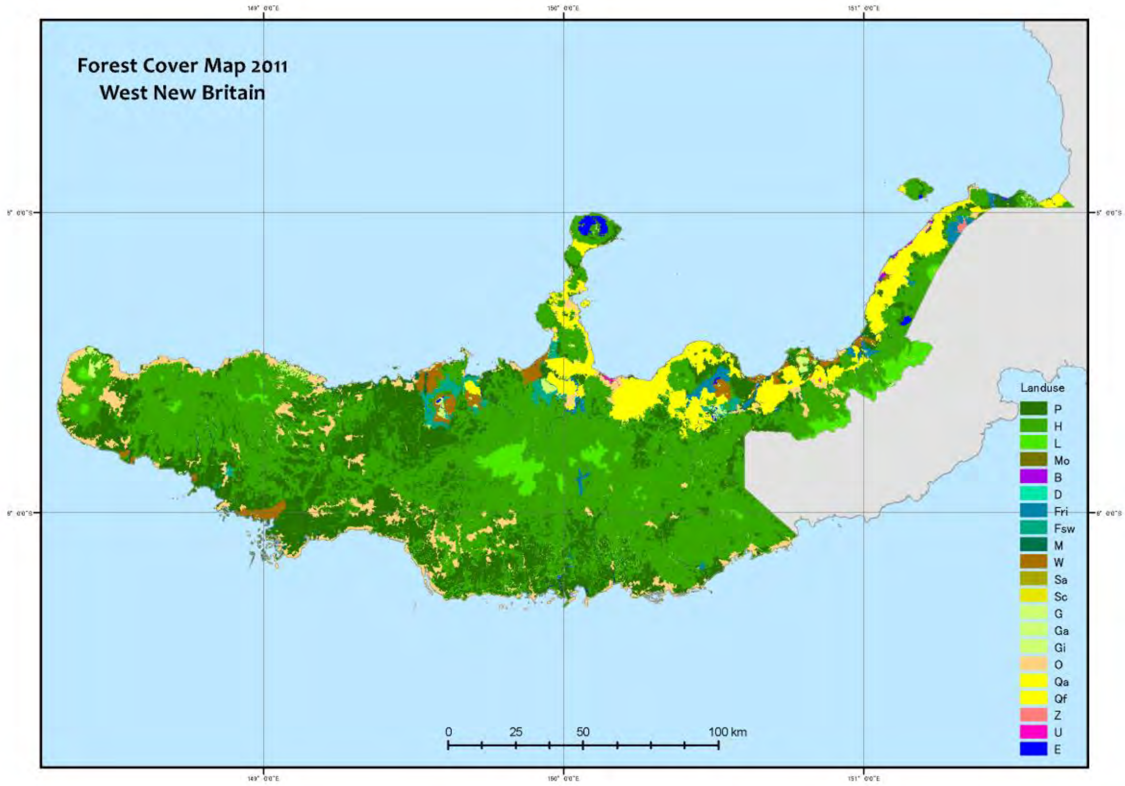


Figure 3-1-25: Forest Cover Map 2011 (WNB)

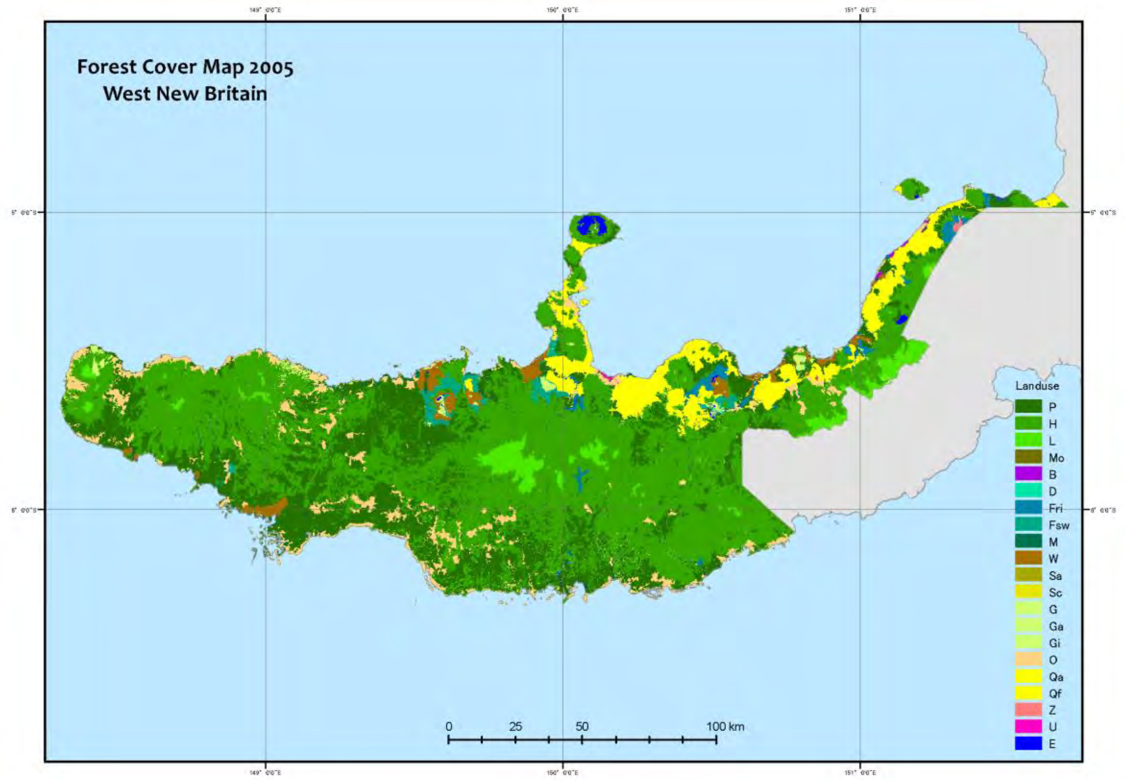


Figure 3-1-26: Forest Cover Map 2005 (WNB)

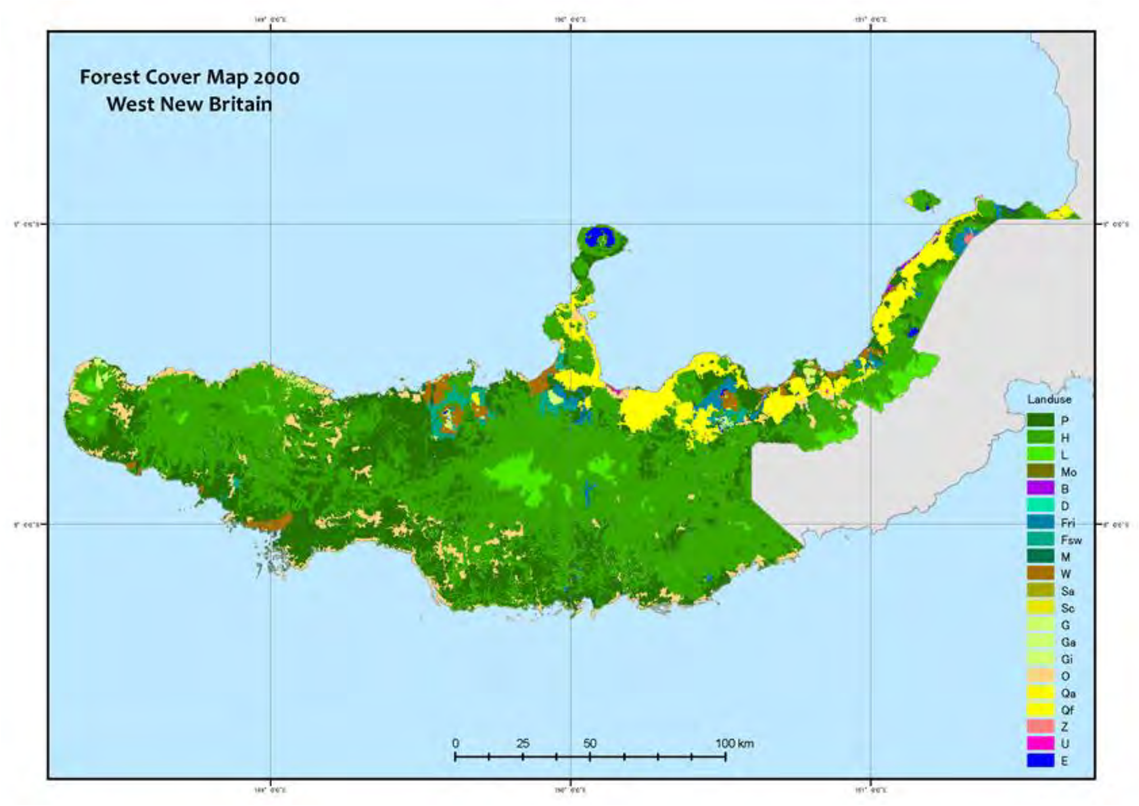


Figure 3-1-27: Forest Cover Map 2000 (WNB)

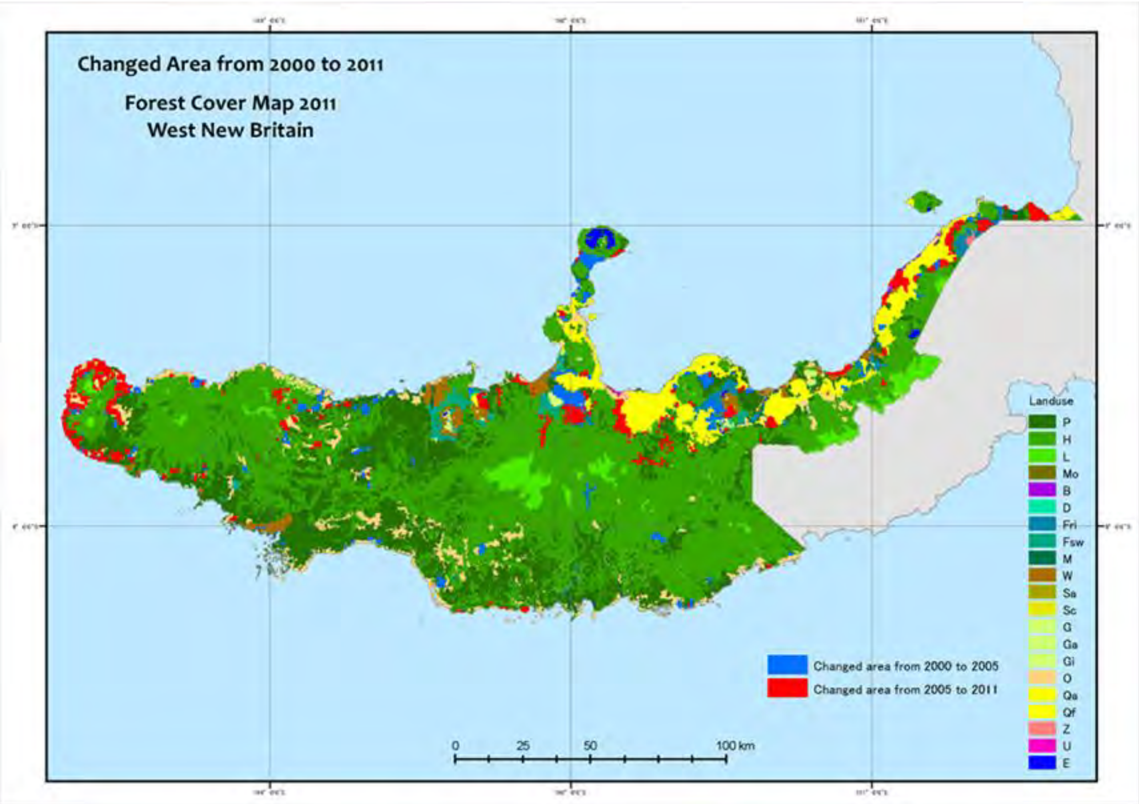


Figure 3-1-28: Changed Area 2000-2011 (WNB)

Forest Cover Map of WNB: Vegetation Type Area (ha) x Year

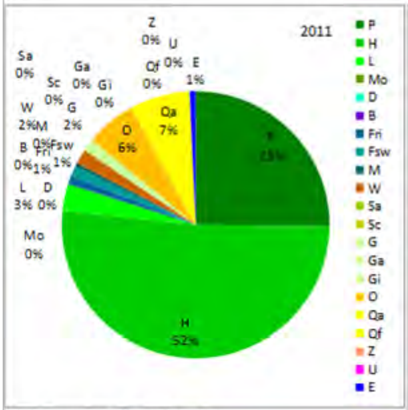
	VEG	VEGNAME	2000	2005	2011	FBM
	P	Low Altitude Forest on Plains & Fans	535,769	524,515	511,652	508,762
	H	Low Altitude Forest on Uplands	1,056,131	1,053,508	1,048,040	1,050,299
	L	Lower Montane Forest	66,383	66,383	66,313	66,313
	Mo	Montane Forest				
	D	Dry Seasonal Forest				
	B	Littoral Forest	1,392	1,222	1,111	1,111
	Fri	Seral Forest	25,263	20,605	20,366	20,373
	Fsw	Swamp Forest	26,076	26,029	24,208	24,365
	M	Mangrove Forest	9,667	9,667	9,553	8,299
	W	Woodland	37,156	36,803	36,203	33,882
	Sa	Savanna				
	Sc	Scrub	112	112	112	112
	G	Grassland and Herbland	29,015	29,121	30,721	32,069
	Ga	Grassland (Alpine)				
	Gi	Grassland (Subalpine)				
	O	Cropland/Agriculture land	106,022	112,050	122,038	125,999
	Qa	Plantation other than Qf	125,378	138,350	147,766	146,980
	Qf	Forest Plantation				
	Z	Bare areas	1,137	1,137	1,137	1,137
	U	Larger Urban Centres	651	651	651	185
	E	Lake & Larger Rivers	14,130	14,130	14,130	14,114
		SUM	2,034,281	2,034,281	2,034,000	2,034,000

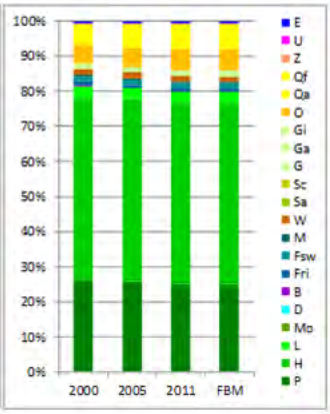
	Forest Cover Area				
	Forest	1,720,681	1,701,927	1,681,243	1,679,523
	Forest & Woodland	1,757,837	1,738,730	1,717,446	1,713,405
*	Forest & Woodland & Scrub & Savanna	1,757,949	1,738,842	1,717,558	1,713,517

	Forest Cover Rate				
	Forest	84.6%	83.7%	82.7%	82.6%
	Forest & Woodland	86.4%	85.5%	84.4%	84.2%
*	Forest & Woodland & Scrub & Savanna	86.4%	85.5%	84.4%	84.2%

Forest Cover Map of WNB: Changed Area (ha) x Year

	VEG	2000->2005	2005->2011	Sum
	P	-11,254	-12,863	-24,117
	H	-2,623	-5,468	-8,092
	L	0	-70	-70
	Mo	0	0	0
	D	0	0	0
	B	-171	-111	-281
	Fri	-4,658	-238	-4,896
	Fsw	-47	-1,820	-1,868
	M	0	-114	-114
	W	-354	-600	-954
	Sa	0	0	0
	Sc	0	0	0
	G	106	1,600	1,706
	Ga	0	0	0
	Gi	0	0	0
	O	6,028	9,988	16,016
	Qa	12,972	9,416	22,388
	Qf	0	0	0
	Z	0	0	0
	U	0	0	0
	E	0	0	0





*FBM: Forest Base Map 2012 (ver.1.1)

Forest Cover Map of WNB: Changed Area (ha) x Year

	VEG	2000->2005	2005->2011	Sum
	P	-11,254	-12,863	-24,117
	H	-2,623	-5,468	-8,092
	L	0	-70	-70
	B	-171	-111	-281
	Fri	-4,658	-238	-4,896
	Fsw	-47	-1,820	-1,868
	M	0	-114	-114
	W	-354	-600	-954
	G	106	1,600	1,706
	O	6,028	9,988	16,016
	Qa	12,972	9,416	22,388

Figure 3-1-29: Vegetation Type Area x Year (WNB)

Discussions

Difficulties / challenges clarified in the examination:

- LANDSAT 2005 imagery has scanning line errors -> difficult to interpret
- Absence of Hansen data before 2000

  -> Difficult to know changed area before 2000
- Hansen loss-year data, which shows loss year in mesh, can only show one loss year in each mesh; data shows first change year only

  -> Disable to detect repeated changed area
- Hansen gain data does not have year information

  -> Disable to know gain year
- LANDSAT image resolution is 30m

  -> Difficult to find small change and forest degradation such as selective logging and sustainable agriculture, and vegetation type
- The Forest Base Map has some misclassifications

  -> Need to revise land use/cover class in 2011

Future Forest Change Modeling

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.

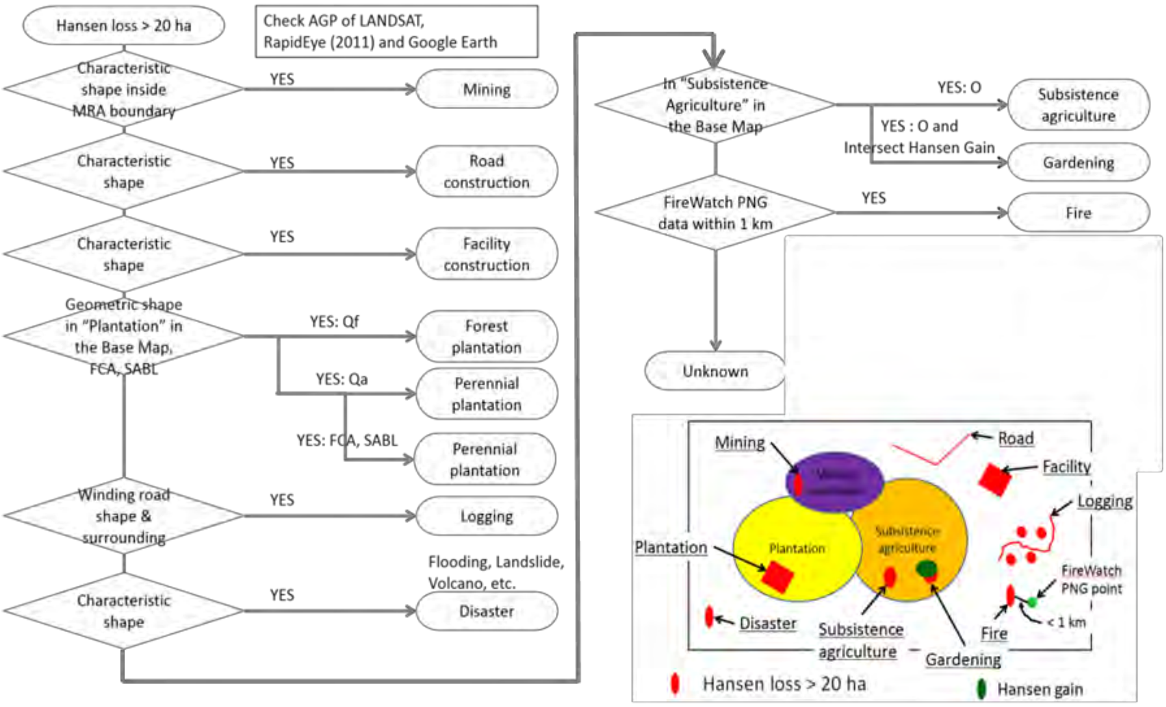


Figure 3-1-30: An example of flow chart of deforestation/degradation driver analysis

Methods

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)

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 3-1-31).

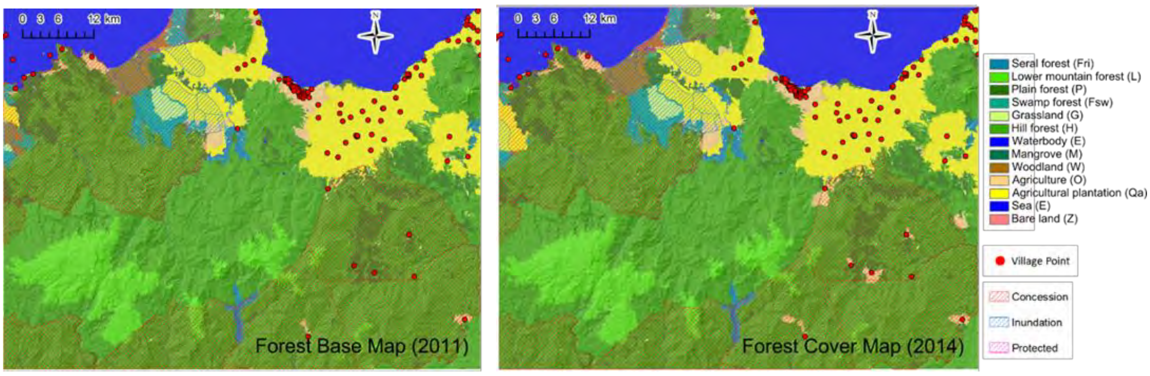


Figure 3-1-31: Forest maps of two points used in simulation with Land Change Modeler

In the beginning, the maps of 2011 and 2014 were compared to elucidate what types of land use increased and what types of land use decreased between 2011 and 2014 (Figure 3-1-32). 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 use boundaries in 2011 were used as the model parameters.

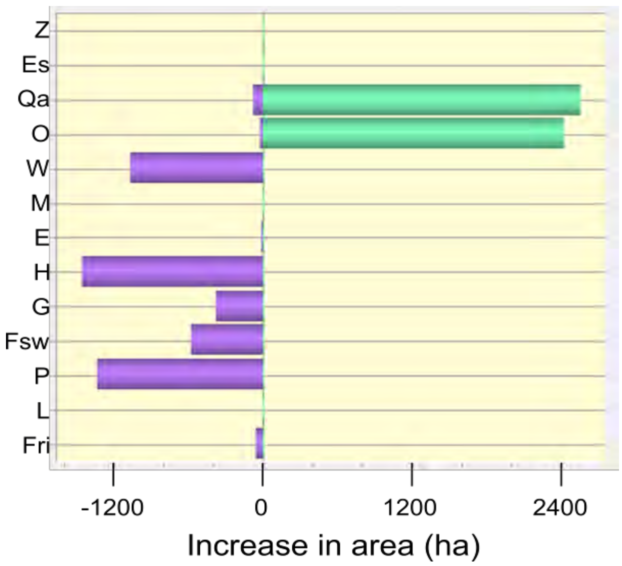


Figure 3-1-32: Changes in the land use between the two points in time

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 3-1-19). 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 use 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 3-1-19: 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

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 (approx. 20,340 km^2) was used in the simulation. A 2011 forest base map and a 2005 forest cover map were used as the land use 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 3-1-33).

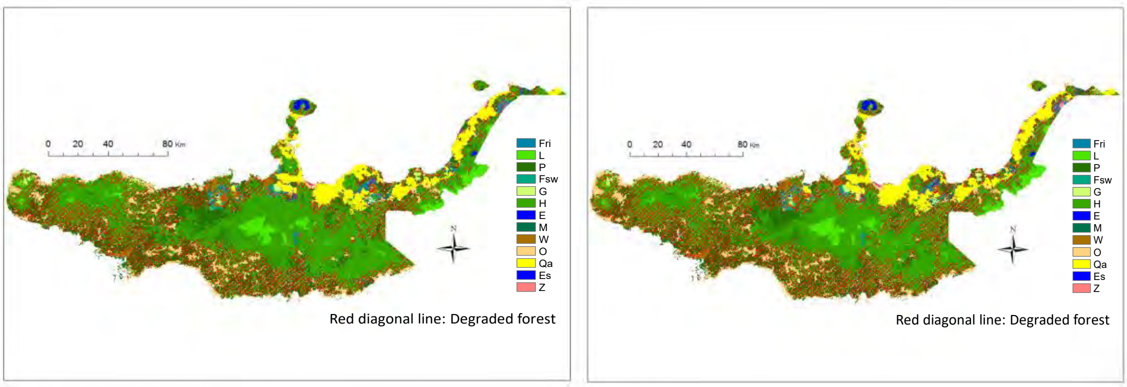


Figure 3-1-33: Forest Cover Map in 2005 (left) and Forest Base Map in 2011 (right)

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 3-1-20). 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 3-1-20: 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 3-1-21). 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 3-1-21: 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 use	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 use"	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)

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 3-1-34 and Figure 3-1-35). These two maps were utilized for the analysis.

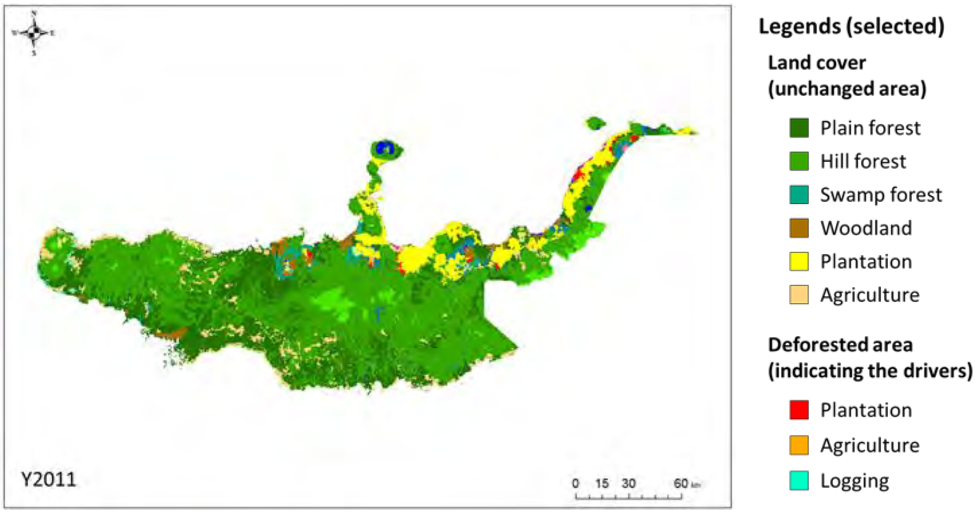


Figure 3-1-34: Forest Base Map with deforestation info. in year 2011

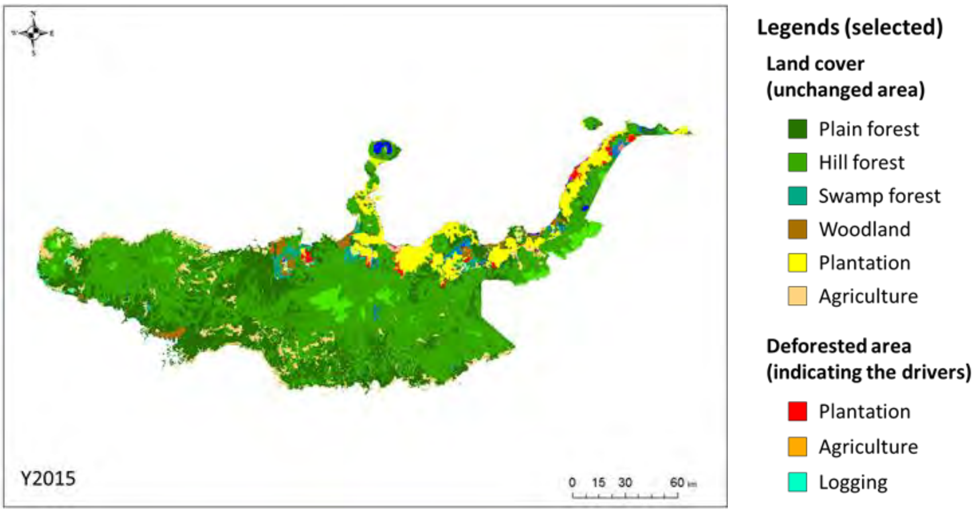


Figure 3-1-35: Forest Base Map with deforestation info. in year 2015

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 3-1-22.

Table 3-1-22: Seven major types of deforestation between 2011 & 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 3-1-23. 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 3-1-23: 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 3-1-36 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.

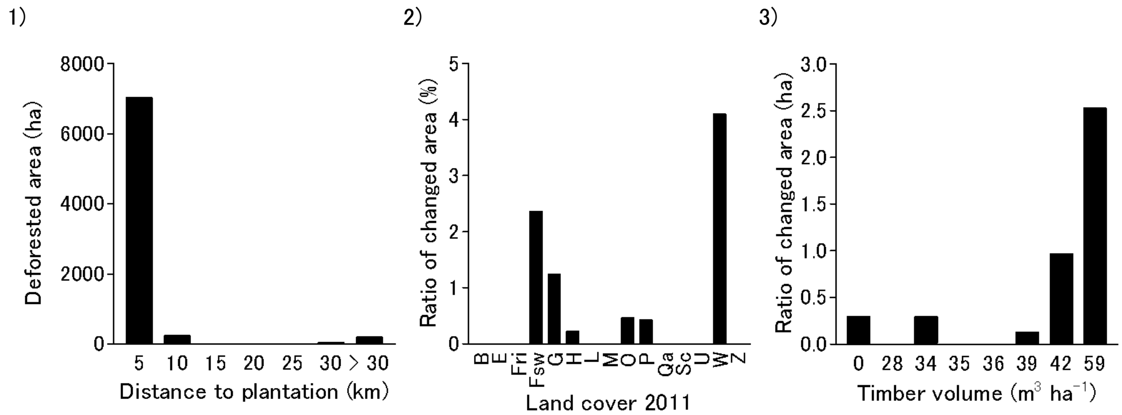


Figure 3-1-36: Relation between deforested area, distance, land cover and timber volume

Results

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

A forest cover map of 2030 was created in the simulation using these models (Figure 3-1-37). 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 3-1-24). This map is considered representative of the land use pattern in 2030 if the current trend in deforestation and forest degradation (BAU) continues till 2030.

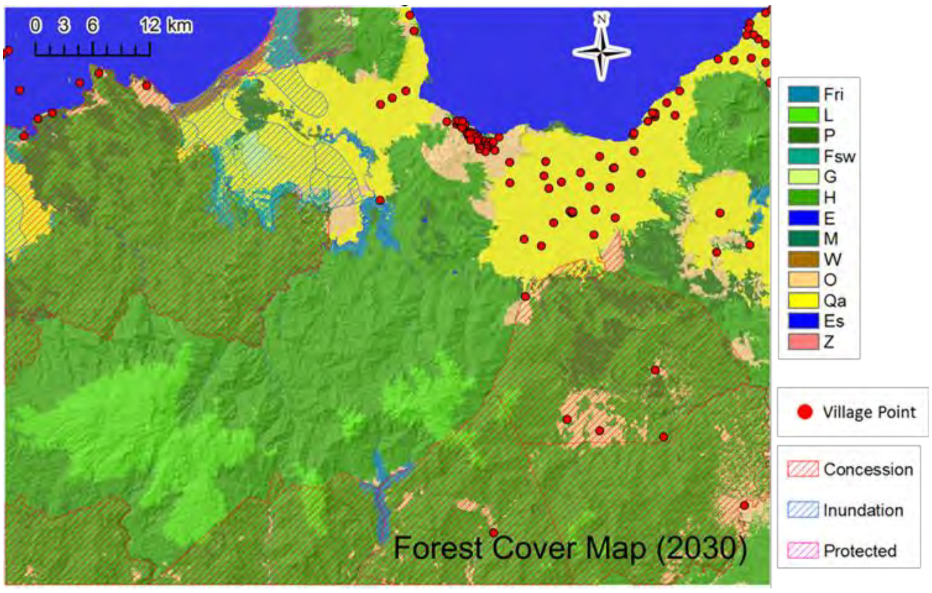


Figure 3-1-37: Forest cover map of 2030 simulated with Land Change Modeler
Table 3-1-24: Influence of parameter with accuracy of model for subsistence farmland

Land use	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 3-1-25). 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 assumption that 1t CO_2-eq is worth US$ 5.

Table 3-1-25: Comparison between the biomass in 2014 and the estimated biomass in 2030

Land use	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 (4) and its price is assumed at US$ 562 t-1 (5), 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

[4] http://www.soyatech.com/Palm_Oil_Facts.htm (accessed on 03 April 2017)
[5] http://www.indexmundi.com/commodities/?commodity=palm-oil&months =300 (accessed on 09 June 2016)

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 (6), 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 3-1-26).

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 use 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 3-1-26: 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

2) Simulation on distribution of deforestation and forest degradation

A forest cover map of 2026 was created in the simulation using this model (Figure 3-1-38). 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 3-1-27). This map is considered representative of the land use pattern in 2026 if the current trend in deforestation and forest degradation (BAU) continues till 2026.

[6] 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)

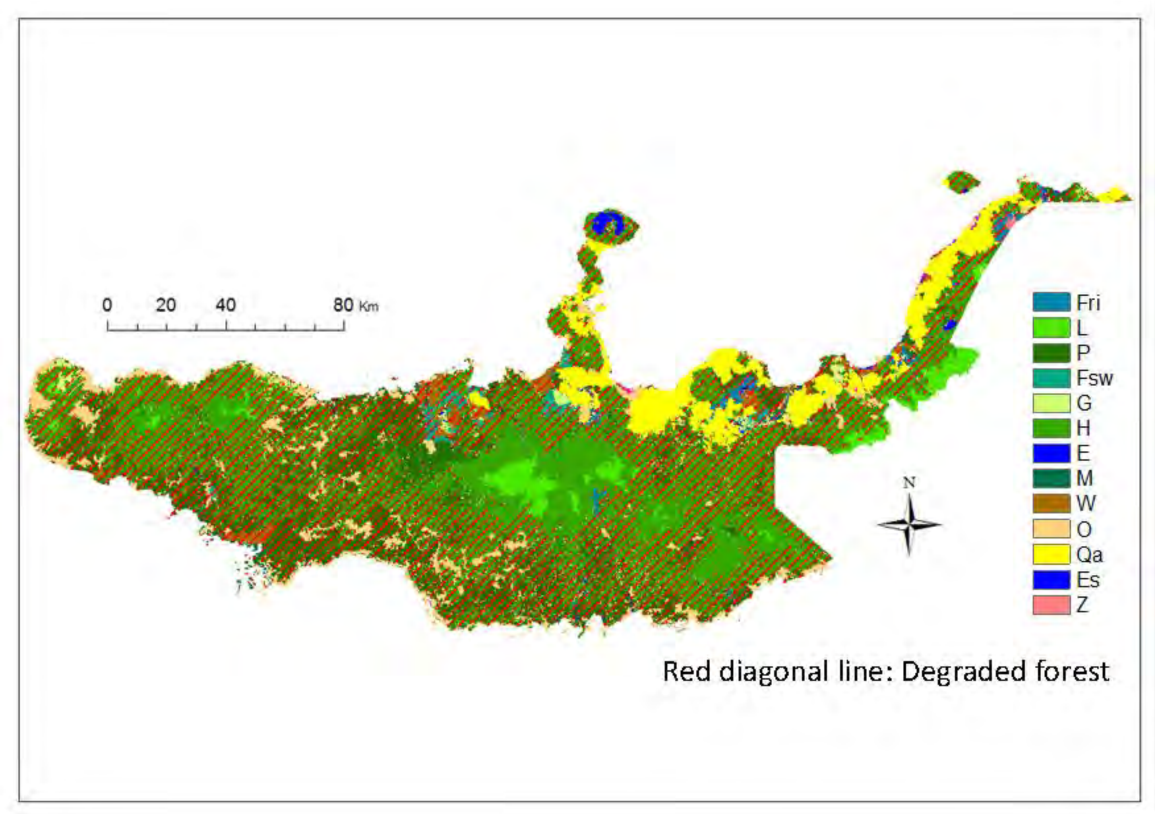


Figure 3-1-38: Simulated Forest cover map of 2026

Table 3-1-27: Changes in areas of each land cover

Change in area of Land cover other than degraded forest				Change in area of degraded forest			
Land cover	Area in year 2011 (ha)	Aria in year 2026 (ha)	Change ratio	Land cover	Area in year 2011 (ha)	Aria in year 2026 (ha)	Change ratio
B	250	249	-0.40%	B_deg	861	863	0.20%
Fri	5000	5004	0.10%	Fri_deg	15366	15361	0.00%
Fsw	5587	5584	-0.10%	Fsw_deg	18622	18606	-0.10%
H	414485	200291	-51.70%	H_deg	633555	847772	33.80%
L	62089	62109	0.00%	L_deg	4224	4224	0.00%
M	4910	4905	-0.10%	M_deg	4643	4642	0.00%
P	103129	47430	-54.00%	P_deg	408523	438148	7.30%
Sc	112	113	0.50%	Sc_deg	0	0	0.00%
W	16732	7458	-55.40%	W_deg	19471	28760	47.70%
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%				

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

Utilizing the simulated model, probability of land cover change in each location was estimated in the entire West New Britain Province. Figure 3-1-39 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 3-1-40, 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.

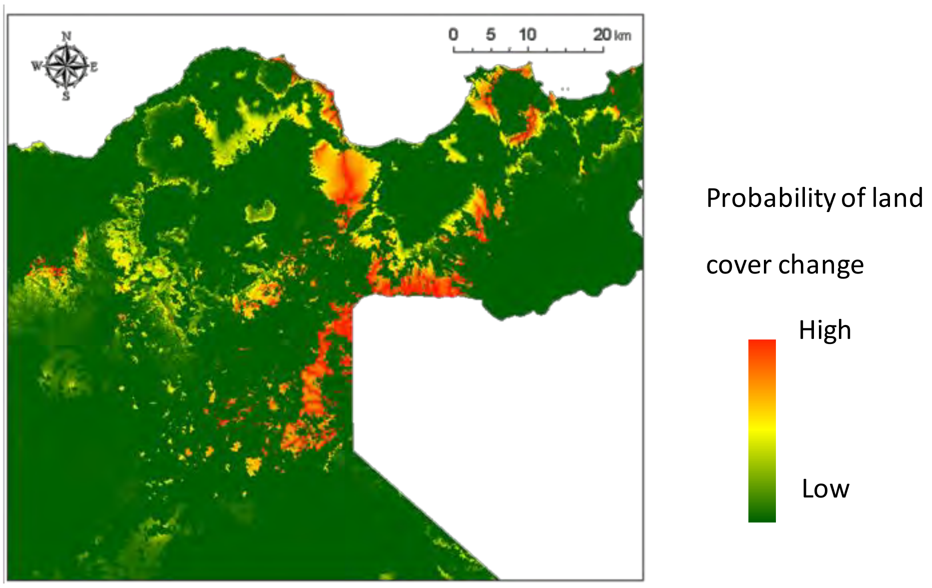


Figure 3-1-39: Probability of land cover change in western part of West New Britain Province

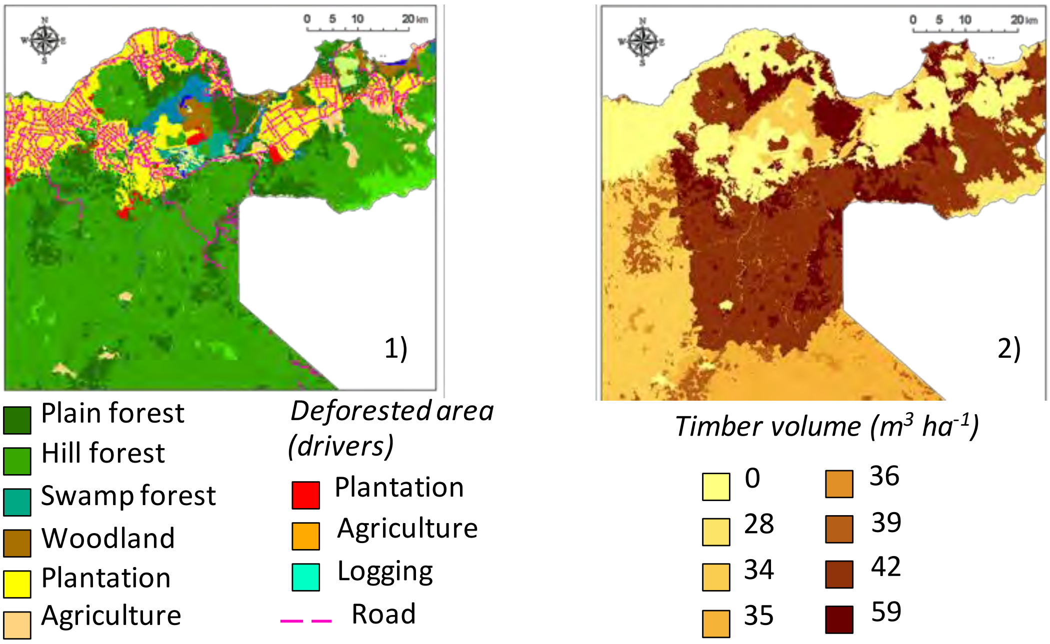


Figure 3-1-40: Land cover and road (1) and timber volume distribution (2)

Discussions

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 (Brown et al. 2013). 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.

Reference

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.

Output 2

Utilization of AAC derived from PNG-FRIMS for forest planning

Table 3-2-1: Output AAC within concession areas

2019/6/17

Provinces	Net Production Area(ha) (j)	Logged Over Area in Net Production Area (ha) (k)	Un-logged Area in Net Production Area (ha) (l) ((j)-(k))	Regrowth Volume in Logged Over Area(m^3) (m)	Volume in Un-Logged Area(m^3) (n)*1	Gross Merchantable Volume(m^3) (o) ((m)+(n))	AAC(m^3) (p) ((o)/35)
Western	1,044,498	467,937	576,561	7,014,736	18,116,357	25,131,093	718,031
Gulf	1,203,287	430,864	772,423	5,085,260	22,152,619	27,237,879	778,225
Central	321,928	89,367	232,561	1,106,542	4,879,271	5,985,813	171,023
Milne Bay	71,405	9,046	62,359	80,221	1,987,692	2,067,913	59,083
Northern (ORO)	147,183	14,276	132,907	73	3,412,403	3,412,476	97,499
Southern Highlands	87,510	0	87,510	0	3,028,881	3,028,881	86,539
Eastern Highlands	0	0	0	0	0	0	0
Simbu	296	0	296	0	14,486	14,486	414
Western Highlands	0	0	0	0	0	0	0
West Sepik	888,338	103,276	785,071	573,402	23,520,193	24,093,595	688,388
East Sepik	252,101	27,783	224,318	0	10,119,570	10,119,570	289,131
Madang	290,726	81,112	209,614	1,187,675	7,581,379	8,769,054	250,544
Morobe	159,559	46,008	113,551	528,141	3,687,920	4,216,061	120,459
West New Britain	955,127	539,423	415,704	4,616,085	12,709,873	17,325,958	495,027
East New Britain	18,629	10,182	8,447	120,728	244,942	365,670	10,448
New Ireland	103,591	73,111	30,480	1,395,694	666,078	2,061,772	58,908
Autonomous Bougainville Government (ABG)	38,871	0	38,871	0	779,391	779,391	22,268
Manus	38,943	25,531	13,412	250,431	460,907	711,338	20,324
Enga	0	0	0	0	0	0	0
National Capital District	0	0	0	0	0	0	0
Hela	0	0	0	0	0	0	0
Jiwaka	0	0	0	0	0	0	0
Total	**5,621,992**	**1,917,916**	**3,704,085**	**21,958,988**	**113,361,962**	**135,320,950**	**3,866,311**

*1: Volume is calculated by Forest Monitoring Unit of Forest Basemap 1.2 and its tentative volume

*2: Net Production Area=Production Forest

Table 3-2-2: Output AAC in concession areas, reserve forest and potential forest

2019/6/17

Provinces	Net Production Area(ha) (j)	Logged Over Area in Net Production Area (ha) (k)	Un-logged Area in Net Production Area (ha) (l) ((j)-(k))	Regrowth Volume in Logged Over Area(m^3) (m)	Volume in Un-Logged Area(m^3) (n)*1	Gross Merchantable Volume(m^3) (o) ((m)+(n))	AAC(m^3) (p) ((o)/35)
Western	6,669,860	817,030	5,852,830	7,516,904	169,917,727	177,434,631	5,069,561
Gulf	2,170,919	509,025	1,661,894	6,438,603	48,652,821	55,091,424	1,574,041
Central	2,085,878	286,365	1,799,513	2,581,064	45,927,677	48,508,741	1,385,964
Milne Bay	904,292	176,394	727,898	3,070,497	21,679,027	24,749,524	707,129
Northern (ORO)	1,546,215	101,633	1,444,582	1,095,049	41,934,479	43,029,528	1,229,415
Southern Highlands	647,529	13,374	634,155	333,505	22,926,011	23,259,516	664,558
Eastern Highlands	484,995	8,938	476,057	0	15,486,371	15,486,371	442,468
Simbu	258,266	0	258,266	0	8,697,756	8,697,756	248,507
Western Highlands	99,665	22,007	77,658	600,091	4,753,673	5,353,764	152,965
West Sepik	2,874,210	377,882	2,496,328	6,743,936	89,179,000	95,922,936	2,740,655
East Sepik	1,813,436	70,649	1,742,787	509,530	73,366,369	73,875,899	2,110,740
Madang	1,737,962	181,414	1,556,548	3,564,013	53,751,140	57,315,153	1,637,576
Morobe	1,918,799	177,859	1,740,940	1,132,216	66,043,919	67,176,135	1,919,318
West New Britain	1,464,855	909,974	554,881	15,629,287	17,386,992	33,016,279	943,322
East New Britain	811,472	412,115	399,357	4,695,714	11,514,601	16,210,315	463,152
New Ireland	663,801	391,805	271,996	4,850,891	7,525,085	12,375,976	353,599
Autonomous Bougainville Government (ABG)	713,663	41,129	672,534	711,660	14,440,789	15,152,449	432,927
Manus	156,806	36,569	120,237	346,518	5,374,614	5,721,132	163,461
Enga	324,420	32,804	291,616	450,165	9,108,849	9,559,014	273,115
National Capital District	7,192	0	7,192	0	23,822	23,822	681
Hela	477,546	0	477,546	0	16,285,644	16,285,644	465,304
Jiwaka	211,932	48,621	163,311	1,257,153	7,562,556	8,819,709	251,992
Total	**28,043,713**	**4,615,587**	**23,428,126**	**61,526,796**	**751,538,922**	**813,065,718**	**23,230,450**

***1: Volume is calculated by Forest Monitoring Unit of Forest Basemap 1.2 and its tentative volume**

***2: Net Production Area=Production Forest + Potential Production Forest + Reserve Forest**

Table 3-2-3: Permitted Cut, Actual Harvested Volume and National Sustainable Cut

Provinces	AAC (Production)	AAC (Production + Potential + Reserve)	Permitted Cut (2017) (Production)	Actual Harvested Volume (2017) (Production)	National Sustainable Cut
Western	718,031	5,069,561	1,209,918	389,604	-
Gulf	778,225	1,574,041	1,441,941	349,742	-
Central	171,023	1,385,964	341,535	125,230	-
Milne Bay	59,083	707,129	85,223	20,570	-
Northern (ORO)	97,499	1,229,415	85,930	49,571	-
Southern Highlands	86,539	664,558	74,062	-	-
Eastern Highlands	0	442,468	-	-	-
Simbu	414	248,507	-	-	-
Western Highlands	0	152,965	-	-	-
West Sepik	688,388	2,740,655	886,208	415,993	-
East Sepik	289,131	2,110,740	561,500	-	-
Madang	250,544	1,637,576	279,427	201,289	-
Morobe	120,459	1,919,318	163,475	260,605	-
West New Britain	495,027	943,322	1,355,743	753,123	-
East New Britain	10,448	463,152	191,771	101,666	-
New Ireland	58,908	353,599	183,065	250,981	-
Autonomous Bougainville Government (ABG)	22,268	432,927	46,720	-	-
Manus	20,324	163,461	51,734	18,120	-
Enga	0	273,115	-	-	-
National Capital District	0	681	-	-	-
Hela	0	465,304	-	-	-
Jiwaka	0	251,992	-	-	-
Total	**3,866,311**	**23,230,450**	**6,958,252**	**2,936,494**	**3,500,000**

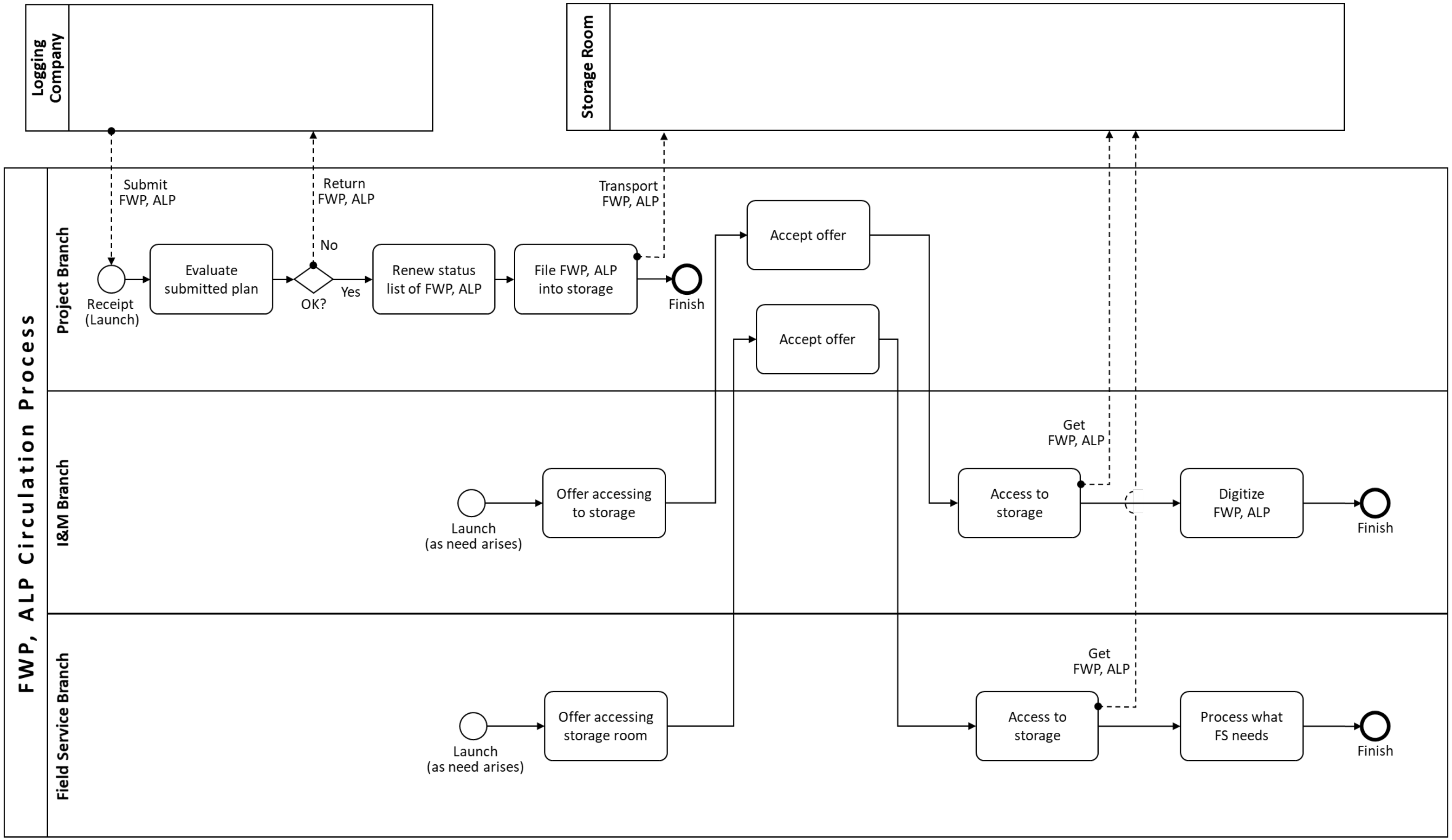


Figure 3-2-1: Work flow diagram of ALPs and other forest working plans circulation (As-Is)

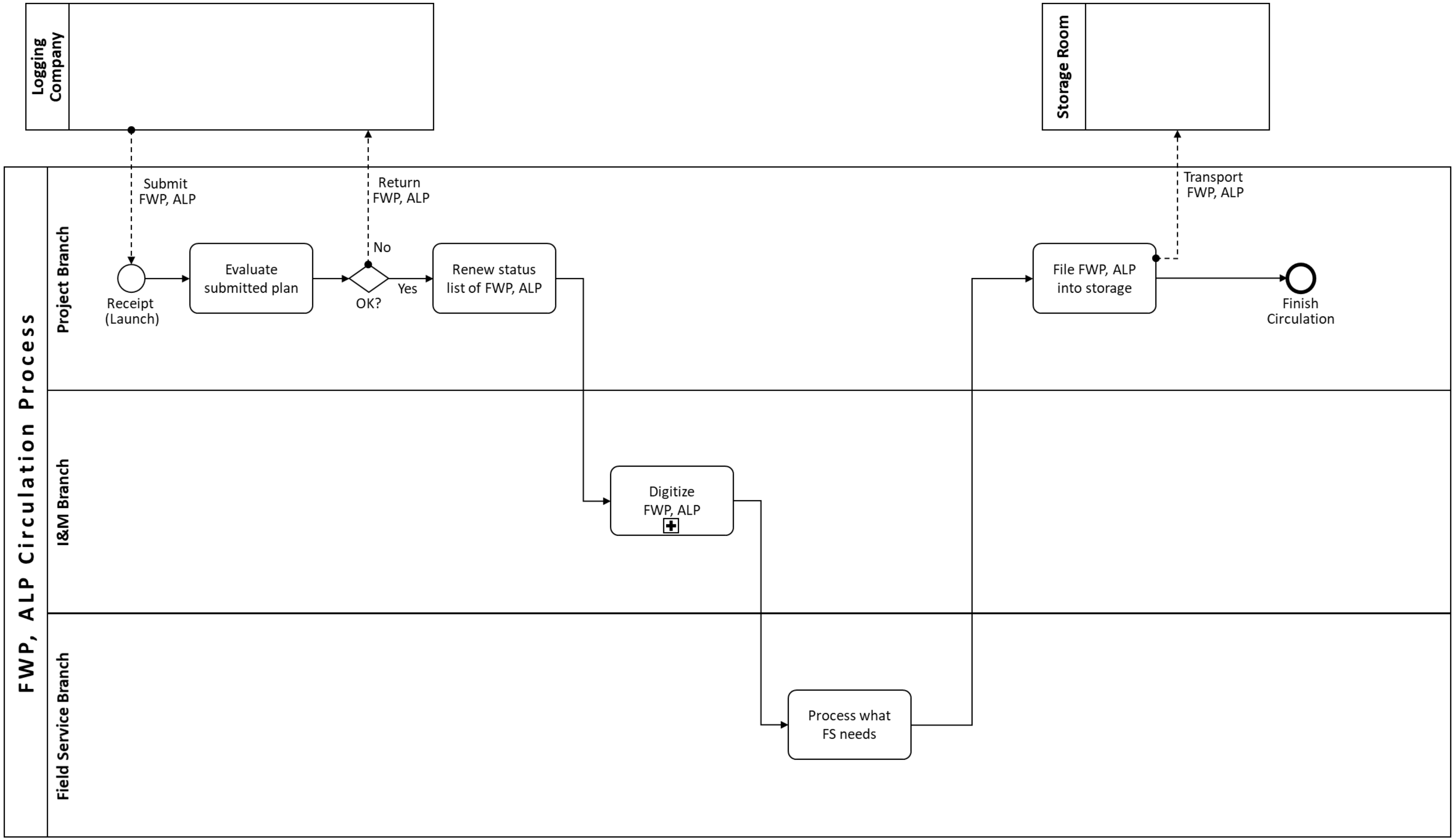


Figure 3-2-2: Work flow diagram of ALPs and other forest working plans circulation To-Be)

Output 3

Policies, Actions, and Measures for SFM

Introduction

Forests in Papua New Guinea (PNG) represent more than 37 M ha (80% of the country's area) and 5% of the world's biodiversity with a high endemism (JICA, 2014). Resources are essential for local livelihoods, national economy, global climate and ecological equilibrium. However this resource is threatening, already 25% of forests are degraded and half from logging. Logging impact is caused by timber extraction as well as collateral damages. Consequences can be significant on biodiversity, watersheds and carbon emissions.

PNG's REDD+ Strategy logically identified sustainable timber production as priority for reducing forest carbon emissions (CCDA, 2017). The Green Climate Fund (GCF) is solicited to "improve the management of production forests" through the development of SFM capacities, forest plantations and alternative production/processing systems. The first priority deals with logging in natural forests and systems for monitoring and law enforcement. In this context, JICA-PNGFA project (referred as "the Project" hereafter) is developing capacities for promoting sustainable forest management and addressing climate change issues. The project targets the Forest Authority of Papua New Guinea as it oversees the planning, monitoring and control of operations in natural forest.

The enhancement of forest data in PNG Forest Resource Information Management System (PNG-FRIMS) is expected to facilitate forest management and REDD+. The design (or adjustment) and implementation of relevant Policies, Actions and Measures (PAM) can be facilitated by a better understanding of forest resources and their evolution. The stakes are very high because SFM approaches can have wide benefits. At the national/provincial level, logging regulations can be strengthened. And at the field level, reduced-impact logging (RIL) practices can improve post-harvest environmental and carbon conditions. For instance, the adoption of RIL methods could reduce CO_2 emissions by 30-50% (Ellis et al, 2013).

So what we need to detail next is some examples of PAM promoting SFM approaches and facilitating the dissemination of RIL methods. Another question is to understand the contribution that PNG-FRIMS and the Project can bring to facilitate the identification and implementation of relevant PAM. These two questions can help clarifying remaining needs for forest management and related PAM expected to be developed in future REDD+ activities. As such, the first section provides a literature review on PAMs that promote sustainability in Planning, Monitoring and Control of logging. The second section describes main potentialities in PNG (including from the project) for implementing PAM conducive to sustainable management. The last part shows supports expected from future REDD+ activities to fill remaining challenges in achieving SFM.

Methodology

Section 1: components of sustainable forest management

The international literature provides recommendations for a sustainable management of production forests. The first objective is to strengthen institutional capacities to organize logging. The second objective is to generalize good practices among logging operators. This section shows recommendations for planning, implementing, monitoring, controlling and valorizing harvest operations (Figure 3-3-1).

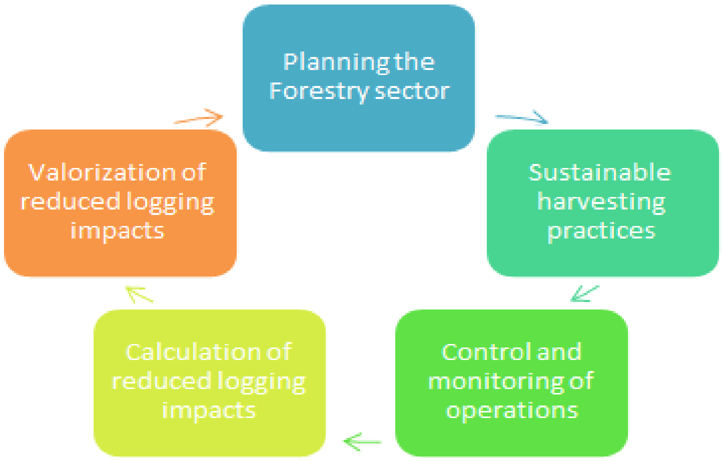


Figure 3-3-1: Components of sustainable forest management

1-1: Planning of the Forestry sector

Institutional management of forest generally follows a top-down approach. The application of good practices on the field is pre-determined by realistic yet ambitious functioning rules established at national and/or provincial level. This part summarizes main recommendations for geographical and regulatory planning of the logging sector (Figure 3-3-2).

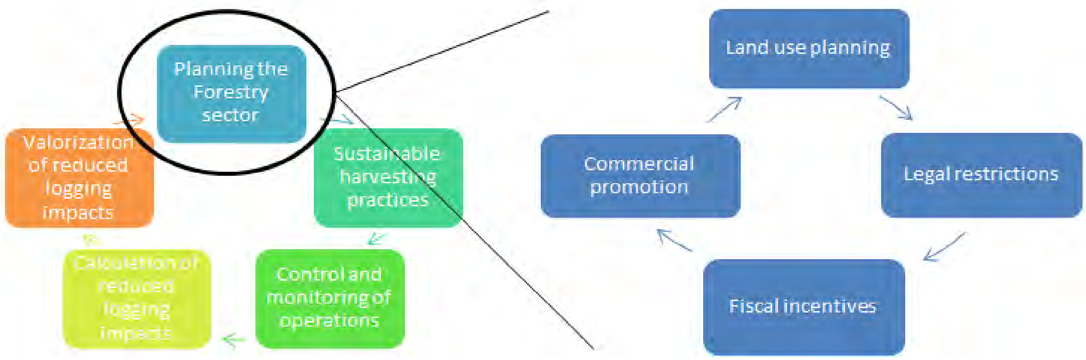


Figure 3-3-2: Regulatory and geographical organization of Forestry activities.

Land use plans should include a careful consideration of land potentialities and risks as they determine the spatial repartition of human activities and their effects on landscapes. Multi-sector approaches are recommended to limit the encroachment of land uses such as agriculture and mining in forests. In the Forestry sector, national and provincial management plans are key elements to explicit planning. CIFOR (2009) showed that management plans should take into serious consideration the natural resources to avoid any overlaps between production and protected areas. Furthermore, forest mapping and data management systems are critical assets to organize the activities and minimize the impacts.

Legal restrictions are the first PAM option to limit impacts from logging. One of the most utilized harvesting quotas is the Annual Allowable Cut (AAC). AAC enables a limitation of volumes harvested at the level of the country, province or concession. Also the Minimum Merchantable Diameter (MMD) limits exploitable trees to facilitate regeneration. Constraint areas (buffer, sloppy, erodible and inundation areas) are determined to restrain zones of exploitation. Furthermore, specific PAM can promote SFM approaches such as the ones which attempt to make RIL practices, wood certification, training of forest workers or fire control systems, mandatory or at least highly recommended.

Incentive systems from fiscal PAM can play an important role in urging logging operators to comply with national standards. The following examples are adapted to different contexts:

- Reduction of export taxes for compliant projects;
- Application of fines for non-compliant projects;
- Calculation of royalties based on standing instead of exported volumes to avoid waste;
- Performance bonds deposited in a government account at the beginning of the concession period and gradually returned when good practices are reported

Commercial standards can complement further PAMs by fostering or rewarding SFM/RIL practices. The objective is to secure an access to premium prices and preferential buyers to cover possible loss from efforts. The Forest Stewardship Council (FSC) is the first standard for certifying tropical forest management. FSC principles (2015) urge for respecting laws, forest groups (workers, communities and indigenous peoples) and the multiple benefits of forest such as environmental services and biodiversity. They guarantee good practices in planning, implementation but also assessment of operations. Sustainable Forestry Initiative (SFI) and Tree Farm System are other famous standards although less relevant in tropics. Timber Legality Traceability Verification standards from the EU FLEGT initiative (European Union Forest Law Enforcement Governance and Trade) are basically design to address illegal logging. But these standards can be useful to demonstrate compliance of operations (another form of legality).

1-2: Planning and implementation of harvest

A sound spatial and regulative organization of the Forestry sector facilitates the application of good practices on the ground. Most of the tropical countries integrate Reduced Impact Logging (RIL) standards in their guidelines or codes. RIL practices are described by ITTO (ITTO website) and FAO (Killmann, FAO website) as an intensively planned and carefully controlled implementation of timber harvesting to minimize waste and the environmental impact on trees and soils. This part provides a summary of recommendations [Sist et al. (1998), IUCN/ITTO (2009) and Applegate et al. (2001)].

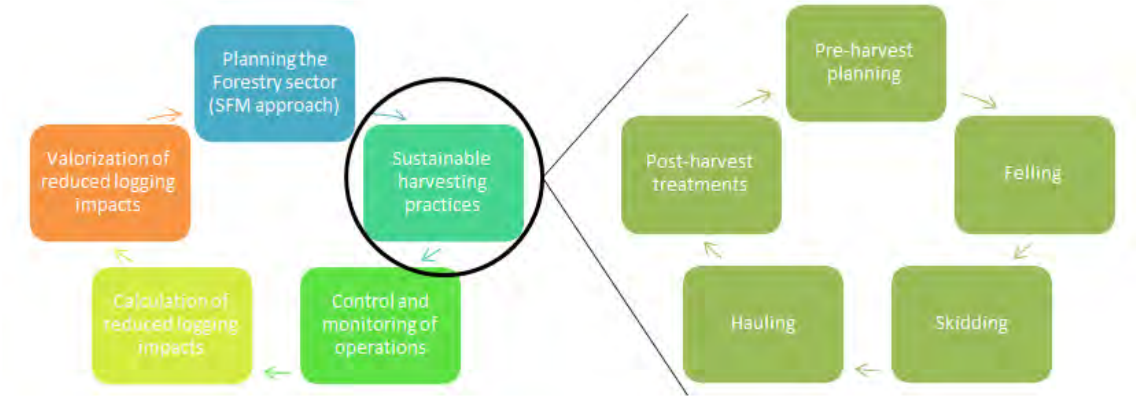


Figure 3-3-3: Harvesting steps

Pre-harvest planning should include:

- Long term plans (> 10 years; 1/50000) that identify protection and production areas;
- Mid-term plans (3-10 years; 1/25 000) that delimit coupes and estimate volumes;
- Annual plans (1/1-5000) that map units (streams, roads, landing areas and skid trails) and plan inventories of sound, inaccessible and protected trees, the cutting of vines and the detection of hollow trees (to avoid felling defective trees).

Felling recommendations are as follow:

- Directional felling to minimize gaps and protect future harvest trees (Figure 3-3-4 and Figure 3-3-5);
- Improvement of bucking to recover all commercial round wood; and
- Cutting of stumps low to the ground to avoid waste.

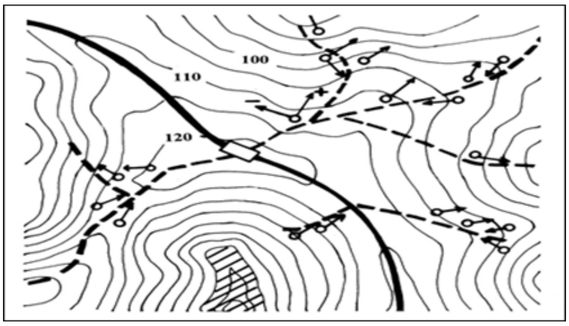


Figure 3-3-4: Directional felling planning. arrows: felling, solid line; roads, dashed line: trails

Figure 3-3-5: Harvesting neck used to facilitate directional felling (Tiger Cat website)

Skidding (felling sites to trucks) should:

- Minimize skid length by planning bulldozer trails;
- Ensure dozers remain on skid trails/roads all time;
- Use long line winching in sloppy fields (Figure 3-3-6).

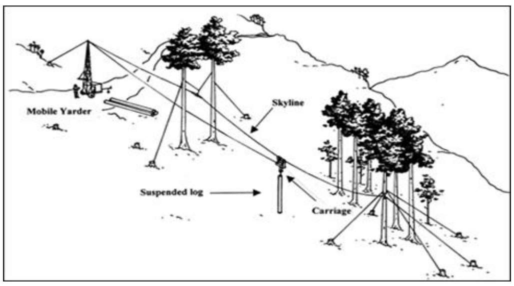


Figure 3-3-6: Skidding by log line winching (Sist, 1998)

Hauling (trucks to ports) should narrow width of road corridors and limit number and area of log landings.

Post-harvest treatment is highly recommended by taking into consideration the following:

- Areas to treat: landing areas and further gaps;
- Techniques of planting (gap or line) according to the area to treat (Maswar, 2001);
- Spacing types and fertilizer dosages as appropriate (Widiyatno, 2013);
- Role of assisted natural regeneration (native species), fast growing plantation (exotic species) and agro-forestry (mixed trees/crops).

1-3: Control operations and monitor forest degradation

Policies promoting a strengthening of monitoring capacities are also very relevant PAM for SFM. The variation of carbon stocks from logging is due to (1) wood extraction (for timber) and (2) damages collaterally caused by this extraction. Wood extraction is usually assessed by actual harvested or exported volumes. Collateral damage is due to log roads, landings, trails and tree damages. Monitoring is more challenging. IPCC (2006) suggest three methods:

1. Field inventory from a whole inventory (for limited areas) or sampling;
2. The utilization of proxy and indicators;
3. Forest cover assessment from Remote Sensing technologies.

Field inventory

- Scale: local (the scale of logging setups).
- Accuracy in determining collateral damage: high as even damaged trees are assessable.
- Challenges: consuming in time and manpower so that the generalization is difficult.
- Parameters to monitor collateral damages such as suggested in guidelines and codes:

✧ Felled trees abandoned (number, H and DBH)
✧ Logs abandoned excluding entire trees felled and abandoned (number, H and DBH)
✧ Stumps wasted, greater than 30cm above fluting (number, H and DBH)
✧ Trees (DBH> 20 cm) damaged by skidding, dead trees only (number, H and DBH)
✧ Average width of roads (m)
✧ Length of roads (m)
✧ Total landings area (m2).

Proxy method

- Scale: local (records in setups) to provincial or national (province/country statistics).
- Accuracy in determining collateral damage: medium as it corresponds to an evaluation
- Challenges: find relevant or reliable indicators.

There is only one carbon methodology in the Land sector dealing with RIL and collateral damage, from VCS (Verified Carbon standards) using a mix proxy-inventory method (Table 3-3-1).

Table 3-3-1: Logging impact parameters used in the carbon methodology "VM0035:

Logging impact parameters = Proxies	Baseline (Borneo)	Target
- Av % of felled trees abandoned	25%	5%
- Av. % of trees where vines were cut 3 - 6 months before harvesting	10%	100%
- Av. number of trees (DBH > 20 cm) destroyed by skidding per	20 trees/ha	5 trees/ha

ha		
- Av. % of bulldozer skidding area employing planning standards	5%	100%
- Av. % of concession area logged with long line system	< 5%	15 to 50%
- Mean width of haul road corridors (m)	40m	20m
- Mean size of log landings (m2 / ha of setup)	100-900 m2/ha	30 m2/ha

Reduced Impact Logging that reduce carbon emissions" (Terra Carbon/TNC, 2016). In blue, no inventory is needed.

<u>Remote Sensing (RS) method</u>

- Scale: national to local according to sensors resolution;
- Accuracy in determining collateral damage: low to medium (tree damage not detectable);
- Challenges: availability (and price) of high resolution images and time series.

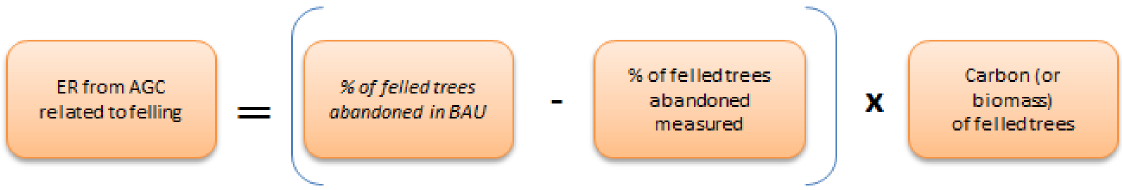
RS detection of forest degradation is possible from sampling, wall-to-wall mapping or a combination of the two methods (IPCC, 2006). Medium (30m) or better spatial resolution is preferential. Therefore wall-to-wall approaches could be onerous. Because of that plus the practicability (for statistical analysis), sampling methods are preferred (cf details in sec. 2).

1-4: Measuring and valorizing reduced logging impacts

<u>Measuring emission reductions achieved through RIL.</u> Carbon is an interesting factor to appraise the state of forests as it federates (i.e. it has a strong correlation with) several key environmental parameters such as biomass, biodiversity, forest cover, shadow, water services, etc. According to IPCC (2006), carbon performances can be calculated as follow: Emission Reductions = AD x EF.

- *AD (Activity Data) corresponds to the area of land transition. It can be determined through Remote Sensing or proxy methods;*
- *EF (Emission Factor) that corresponds to the carbon content in converted lands. It is determined by following the calculation steps below:*
    - Step 1: measure tree height and diameter at breast height (dendrometric measure);
    - Step 2: calculate biomass from diameter and/or height (allometric equations);
    - Step 3: calculate carbon content from biomass (conversion)
    - Step 4: calculate Below (BGC) from Above Ground Carbon (AGC) (Root/Shoot ratio).

One example of measurement of Emission Reductions (ER) is provided below (VCS, 2016). It shows the reduction in emissions from improved felling. The same methodology can be applied for ERs from AGC or BGC due to an improvement of skidding or hauling.



<u>Possible valorization</u> of forest management and practices improvement are shown below (Table 3-3-2).

Table 3-3-2: Means to valorize Forestry/Climate benefits from SFM/RIL

Elements valorized	*Place*	*Benefits*	*Beneficiaries*

Forest management practices, compared with FSC standards	Wood SEM	Wood certification	Logging operators (private companies or communities)
Emission reductions, compared to a project scale baseline (VCS project covering one or several logging sites)	Carbon markets (Voluntary)	Carbon credits	Carbon project developers and indirectly communities *in situ*
Emission reductions, compared to a jurisdiction baseline (VCS Jurisdictional Nested REDD or WB Carbon Fund)	Carbon markets or fund	Carbon credits	Carbon project developers and indirectly communities within the sub-national jurisdiction
Emission reductions, compared to a national (or provincial) FRL	UNFCCC (fund or market)	REDD+ finance	Stakeholders of forest management and utilization, at the national or province scale

One of the main challenges for valorizing PAM promoting sustainable forest management may lie in quantifying sustainability. This appears particularly important in the context of REDD+ Result Based Payments. Deforestation, Forest degradation or Carbon stock enhancement can be defined based on a rate. At contrary, to define SFM based on a rate, threshold or point is difficult. In reality, the definition of the level of sustainability in forest management is closer to a combination of relative parameters or a grey zone. One suited approach could be to attribute to each Planning, Monitoring, Control component an indication of sustainability based on indicators. For example: has the "land use planning" activity been carried out in a concerted manner? Are harvesting quotas strict compared to international values? Etc. Figure 3-3-7 is an attempt to summarize the concept.

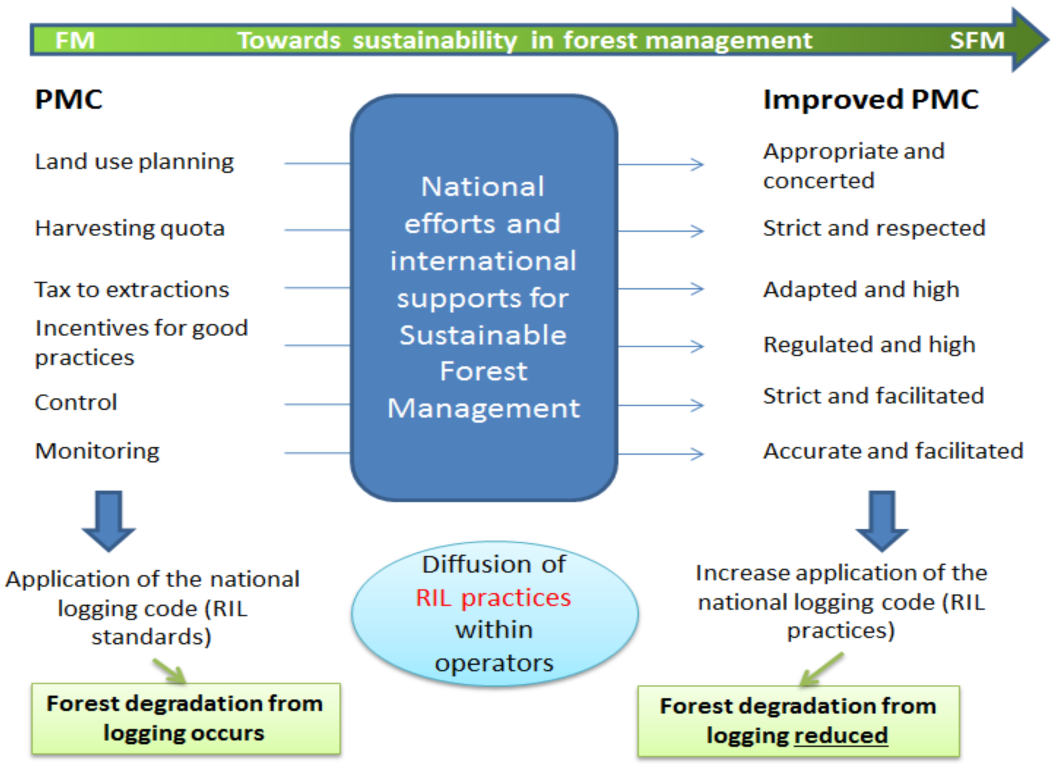


Figure 3-3-7: Improvement process of sustainability in forest management

Section 2: Potentialities from PNG-FRIMS for supporting SFM policies

Planning, Monitoring and Control activities conducted by the Forest Authority in Papua New Guinea are summarized in Figure 3-3-8. PNG potentialities, including from JICA/PNGFA project support and PNG-FRIMS, are shown for each component of forest management.

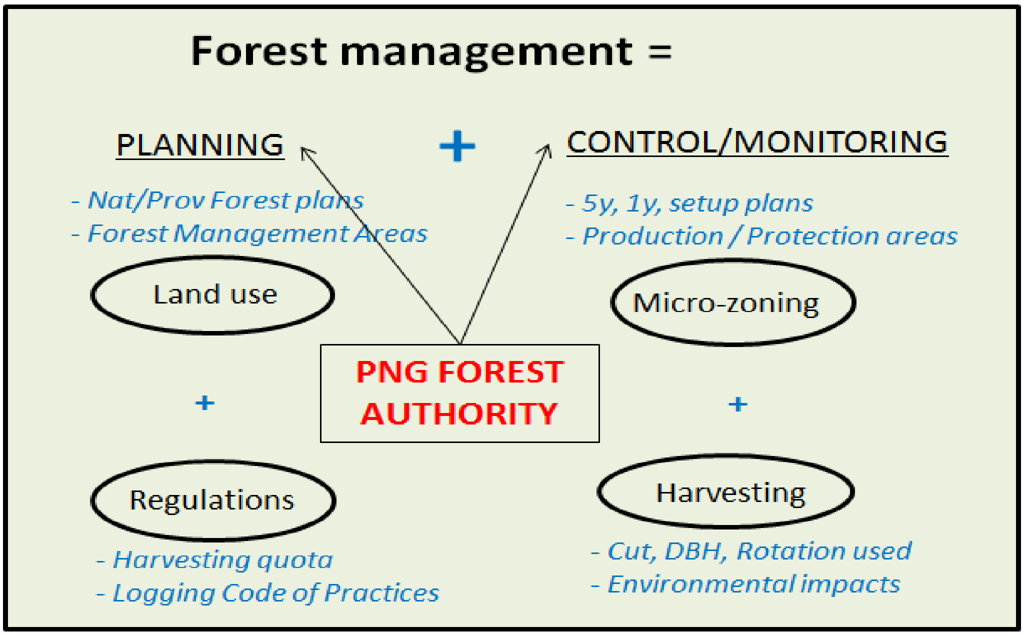


Figure 3-3-8: Components of forest management led by PNGFA

2-1: Potentialities to support land use planning

<u>Forest plans.</u> Geographical repartition of activities is explicit in PNG's national forest plan, provincial forest plans and forest management plans. To improve suitability of production areas, both national and provincial plans are currently under review, along with the support from the Project. This review is based on improved decision-making tools detailed below.

<u>Forest cover mapping system</u>

- Based on the Forest Map 1996 and FIMS (Forest Inventory Mapping System) that provides an estimate and cartography of timber volumes; and
- Developed in the 2012 Forest Base Map (FBM) that offers a benchmark of land covers with detail on forest strata. Two JICA projects (from 2011 and 2014) enhance PNGFA capacities to create, update and utilize FBM.

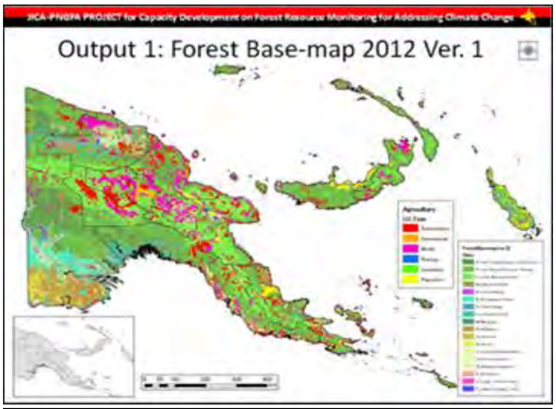


Figure 3-3-9: Forest Base Map as a new key planning tool in Papua New Guinea.

<u>Management systems of forest data (and logging data in particular)</u>

- Based on the PNG FIPS (Forest Inventory Processing System) that reports timber volumes from field surveys (without mapping info); and
- Developed in the PNG-FRIMS (Forest Resources Information Management System) which is the main outcome of the Project. It integrates pre-existing applications (FIMS and FIPS) and new functions for editing (ArcGIS) and sharing (LAN Map) forest information.

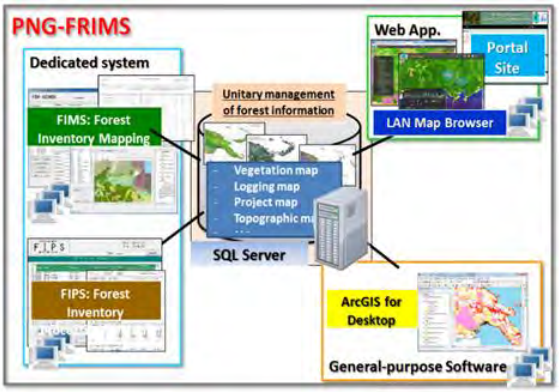


Figure 3-3-10: PNG-FRIMS components

<u>Possible support from Forest Base Map and PNG-FRIMS in land use planning:</u>

N.B: this aspect is detailed in further documents from the project

i- Facilitate proposing new logging concessions at the national or provincial scale by integrating information on land potentialities and risks such as:

- Vegetation maps and information: timber volumes, carbon stocks and regrowth
- Information on constraint areas: FCA, plantation, wildlife management, mining areas

ii- Facilitate planning logging activities within concessions by integrating such information;

- "Topography" information as roads, rivers, villages, slopes and hill shapes;
- Information on logged-over areas, current concessions and planned areas;
- Degradation thanks to three time series of forest cover maps (2000, 2005 and 2011).

2-2: Potentialities for PAM promoting Reduced Impact Logging

<u>Quotas</u> used in PNG to limit wood extraction are presented in Table 3-3-3.

Table 3-3-3: Harvesting quota in PNG and related decision documents and makers

Regulations	*Related policy documents; Decision makers*
AAC (Annual Allowable Cut)	National and provincial forest plans; PNGFA Forest Policy and Planning directorate, Forest Inventory & Mapping Branch, National Forest Board
Number of permit	Provincial Forest Management Committee; National Forest Board
Volume allocated	FMA (Forest Management Agreement) and 5-year plan; PNGFA
Constraint areas	FMA, Logging Code of practices (LCoP), should appear in the 5y plan; PNGFA
MMD	LCoP (new version only) and 5-year plan; PNGFA
Rotation cycles	FMA; PNGFA

Possible needs in amending quotas are currently being reviewed, in particular the method to determine AAC used in forest plans. The process may be coming with the review of LCoP.

The project is expected to raise awareness and knowledge on deforestation, degradation and climate change issues. This should strongly influence decision makers so then decisions. Ex.: the selection of bidder companies from Province Forest Management Committees.

<u>PNG fiscal PAM to incentivize good practices:</u>

- Table 3-3-4 sets out what modalities would be operated and what institutions involved if fiscal PAM options as recommended in section 1 were implemented in PNG.

Table 3-3-4: Tentative fiscal policies, modalities for RIL and non-RIL concessions

Policy types	For **low impact** logging projects	For **high impact** logging projects	Possible institutions involved in PNG
Fiscal	Subsidies / rewards	No	PNGFA
	Income tax reduced	Income tax not reduced	Budget, Finance
	Export tax reduced	Export tax not reduced	Commerce
	No fine	Fine	Forest, Justice
	Performance bonds returned	Bonds not returned	Forest, Finance
Commercial	Premium price	Regular/low price	Stock Exchange Market, FSC
	Preferred buyers	Buyers/traders uncertain	

- The table above can be a good basis for examining the feasibility of fiscal options. The priority is for policies that directly relate to the Forestry sector (subsidies and rewards). Exploring other options is beyond the scope of the Project and sometimes beyond the scope of PNGFA as it is shown. Multi-sector approach like REDD+ can be supportive (see Section 3).

<u>Commercial PAM to promote RIL practices in PNG</u>

- FSC has established an office in PNG. Voluntary certification is now recognized (EU-FLEGT, 2016). Three concessions are currently under FSC certification:

- 10 000 ha in Eastern New Britain (Open bay timber, Japan, Sumitomo group);
- 20 000 ha in West New Britain (Stetin Bay Lumber Company, Malaysia); and
- 5000 ha developed by a national company (3 A Composite PNG Ltd).

ENB and WNB concessions are plantations of Camarere (Eucalyptus deglupta).

Also, standards under the Decision Support System (DSS) are tested in two concessions. Consultations are on-going regarding the application of Timber Legality Standards (regrouping FSC and EU-TLTV standards) to decide whether they will be voluntary or mandatory. In relation with this, RAFT-2 project (2012-15) realized capacity building on RIL techniques. RAFT-3 project is currently under consideration (EU-FLEGT, 2016).

The collaboration (or at least relationship) existing with private loggers in the Project pilot provinces is a good opportunity to heed their interests and challenges in certification. The Project may also participate in facilitating inputs from the PNG FSC office in the LCoP update process. FSC input can be critical to ensure PNG standards are compatible with the most recent recommendations and to accelerate leverage of green investments.

2-3: Systems and capacities to control logging activities

<u>Assessment of the zoning in Forest Management Agreements (FMA)</u>

- Forest Management Plans (FMP) are reviewed and approved by PNGFA 'Forest Policy and Planning' directorate (FPPD), five-year and one-year plans by the 'Project Allocation' Directorate (PAD) and setups plans by project supervisors.

- Main challenges identified in the Project when reviewing FMPs are as follow:

- Maps provided by logging managers are often in analog format. This issue may have consequences on the uncertainty of boundaries and time for analysis;
- Reference maps used for review may be outdated and/or imprecise (contours) and the scale of the maps too small.

- The Project may facilitate assessing the impact of the FMA zoning by:

- Identifying potential overlapping of logging projects' boundaries;
- Identifying potential encroachment of production with protection areas;
- Validating road alignment and overlapping with the help of field records of boundary.

New PNG-FRIMS functions are expected to facilitate this assessment through the following:

- Manage PNG-FRIMS and FBM data and maps thanks to FBM Portal site;
- Update information in PNGFA headquarter thanks to Web GIS function;
- View information in field offices thanks to Lan Map (Web browser map);
- Detail and validate information based on field observation thanks to GPS.

Control of the actual application of Logging Code of Practice in PNG

- PNGFA is decentralized in areas (area managers) and provinces (project supervisors and inspectors) to respond to the important number of logging business projects (more than four concessions per province in average). The application of logging standards is controlled by local officers supposedly before, during and after operations.

- Table 3-3-5 regroups challenges in control as shown in discussion with local officers. It is noteworthy that a further in-depth gap analysis is needed for more accurate conclusions.

Table 3-3-5: Examples of identified challenge in the control of logging operations in PNG

Examples of challenge	*Possible reasons*
Resources (man / day)	Time (several set-ups can be opened at the same time), distance between sites, availability of vehicles, monitoring tools and technical capacities.
Independence of supervisors	Logging companies in some cases provide logistics including accommodation to supervisors.
Capacity of operators to apply recommendations	Regular re-affectation of logging managers and not systematic training of logging companies' workers
Follow-up of recommendations	Supervisor recommendations are often limited to oral suggestions (rare penalties). Follow-up application of recommendations is time consuming
Stopping operations in case of non-respect	Consequences for local economy i.e. for companies, landowners and/or local communities (when employed in logging sites)
Realization of post-harvest control	Time consuming and not priority when new setups open in the same time (or further reasons leading to over workload)

2-4: Capacities for monitoring forest degradation

Field monitoring of the logging impact in PNG

- PNG standards are described in the 1996 Logging Code of Practices (PNGFA & DEC, 1996) annexed to "Planning, Monitoring and Control procedures for natural forest logging operations under timber permit". They integrate international RIL recommendations. Many standards relate to pure environmental criteria such as soil, water and disposal. Some standards specifically concern the degradation of trees or vegetation and thus have a direct relation with carbon stocks. Based on LCoP standards, project supervisors have practically to report in "Field assessment sheets" whether the following conditions are met.

- Wasted logs < 3% of total extracted logs;
- Number of stumps above 50cm is not important;
- Number of trees not felled into gaps created by harvesting is not important;
- Roads width < 40m;
- Roads area < 10% of setup area; and
- Number of landings < 3 and area < 2500 m2 (0.25ha).

As a result, field assessments collect a lot of useful information for evaluating the impact of logging on forest carbon.

- Main challenge for carbon monitoring is that field assessment method is qualitative. Field assessment sheets are often filled with Yes or No and not with numerical values. This certainly provides a good ratio of "time spent for assessment" versus "indication on compliance". In other words, this information is sufficient to determine whether or not the operations comply with threshold values fixed in the LCoP and can be approved. However, it is difficult to exploit such information for measuring carbon loss and providing a consistent basis to performance-based payments. But the quantitative methods (providing numerical values) may also suffer from challenges, such as set out below:

1. Demanding time and human resources to:
   - Count/measure H and DBH of wasted logs, trees felled and stumps above 50cm;
   - Measure roads width in several points (to get mean values);
   - Measure landings' length and width.
2. Demanding in capacities to apply certain rules specific to carbon assessment that may differ from forestry methods (ex.: determine carbon pools or impact parameters).

- The Project does not directly support field carbon monitoring. But PNG-FRIMS include functions such as GPS, GIS and Lan Map that can enable identifying positions and calculating distances. This support can be useful in estimating the length of logging roads and size of landings, locating damaged trees and checking if boundaries overlap. REDD+ may be critical to provide complementary supports to this issue (section 3).

<u>Methods using Remote Sensing</u>

- Several activities in the Project participate in improving PNGFA capacities to analyze forest degradation through RS analyses:

i. Integration into PNG-FRIMS of spatial parameters (indicated in carbon methodologies) required to determine boundaries, forest stratification, DD location and drivers;
ii. Consensus within PNGFA on forest definitions and categories useful for analyses;
iii. Training on the delimitation of logged-over areas and logging history;
iv. Evaluation of different types of sensor and resolution to detect degradation spots and drivers. Medium and high resolution images are used in the Project: Rapid Eye (5m pixels), Hansen data (30m, loss of forest covers) and Collect Earth (Figure 3-3-11); and
v. Dissemination of RS and GIS tools in PNGFA local offices (Figure 3-3-12):
   - Provision of material (PC and GPS) and software to Area and Province offices; and

- Development of capacities to analyze degradation from RS and GIS analyses.

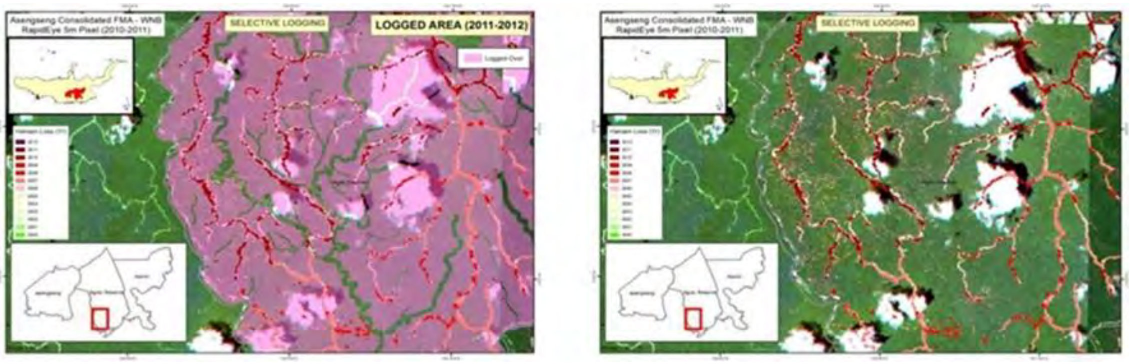


Figure 3-3-11: Examples of RS analyses conducted in the Project

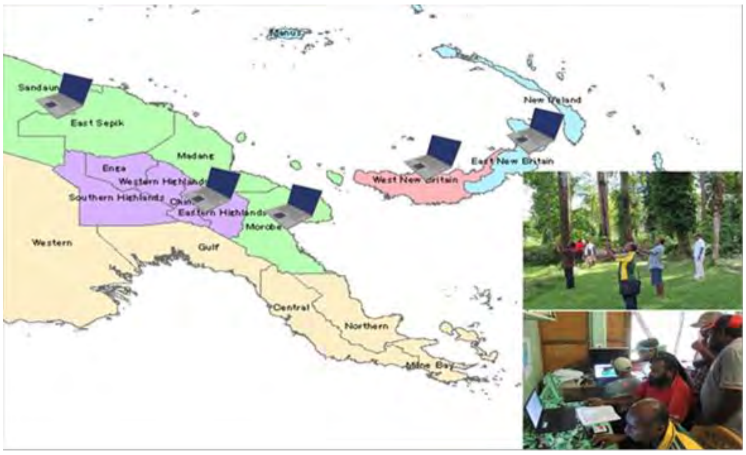


Figure 3-3-12: RS/GIS trainings conducted by the Project in several locations in 2016

To conclude this section, PNG fills many conditions that are required to efficiently plan land uses, set up adapted regulations, control operations and monitor forest degradation. Forest plans, harvesting standards and decentralized offices are important assets to achieve SFM. The Project is expected to bring an improvement in forest information, data management and mapping systems. The objective is to support PNGFA in planning the logging sector at provincial and national levels, and in controlling the planning and execution of local operations. Nevertheless there remain several challenges in forest management such as a multi-sector planning of land uses, amendment of harvest quota or activation of fiscal levers. One further critical challenge is the monitoring of logging impacts.

SECTION 3: Expected support from future REDD+ activities

REDD+ aims at identifying, and facilitating the implementation of, low emission development options in land sectors. One objective is to attract investments for sustainable businesses. In the Forestry sector, SFM corresponds to a critical approach of low carbon activities because integrated approaches in the organization of logging seem to have the potential to lower impacts. Therefore, PAMs conducive to SFM appear very relevant targets for REDD+ support. Figure 3-3-13 highlights close ties between SFM and REDD+ and the virtuous cycle allowed by performance-based supports.

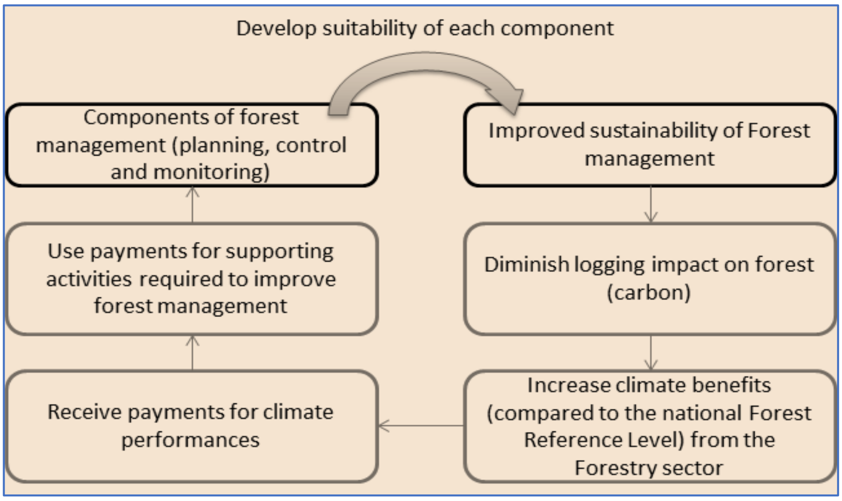


Figure 3-3-13: Virtuous cycle of improvement in forest management by performance-based

3-1: PAMs to address remaining challenges in planning

Land use planning

First target is to develop land use planning in a development strategy that is common to all land sectors and that promotes carbon neutrality. Factors to consider are as follows.

- Ensure political engagement to avoid overlapping between sector activities;
- Facilitate pluri-disciplinary dialogue between main agencies (PNGFA, DAL, DEC, etc.)
- Exchange consistent data between sectors like during the preparation of FBM and Terra PNG (defined below).

Second target is to mainstream SFM principles into national and provincial forest plans. The planning of initiatives relevant for SFM can be facilitated by the utilization of FBM and Terra PNG. Terra PNG is displayed in the REDD+ Web portal and regroups simple but time series wall-to-wall maps, sector activity data and land cover changes. Main initiatives are.

- Initiatives supporting RIL and regeneration in the logging and logged-over areas;
- Conservation initiatives in the high-value areas (notably high spots of biodiversity);
- Agro- and forest plantations valorizing grasslands and heavily disturbed forest areas.

Forestry regulatory framework

A holistic approach expected to bring a global impact in limiting degradation can consist in:

- Restrictive approach supported by legal PAMs that limit extracted volumes;
- Incentive approach supported by fiscal/commercial PAMs that foster good practices;
- Advisory/advocacy approach supported by PAMs that facilitate the implementation of good practices (ex.: guidelines, trainings and awareness rising). See Figure 3-3-14.

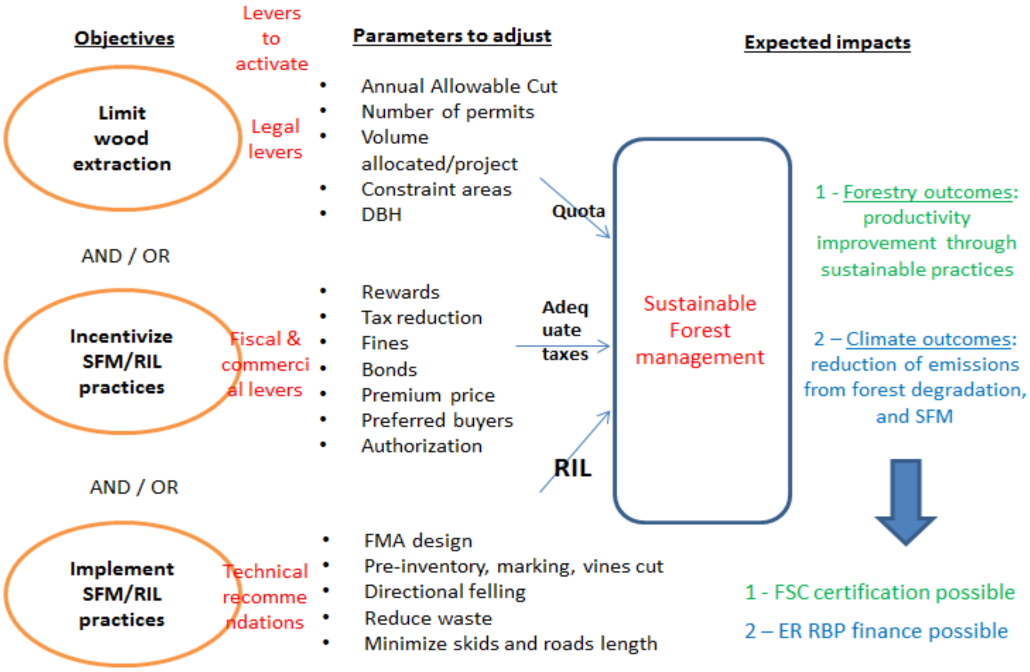


Figure 3-3-14: Levers to activate for reducing degradation from logging (holistic approach)

Significant changes in legal, fiscal or commercial policies cannot be processed without prior feasibility studies that discuss the following in detail:

- Involved stakeholders by mapping and identifying their role and capacities;
- Opportunity costs for each policy option by modeling changes in both economic and ecological aspects. For instance, reducing export taxes for compliant concessions may cause a direct loss in the country's budget. Such opportunity costs can be evaluated and a covering (compensation) system can be elaborated accordingly.

3-2: PAMs to address remaining challenges in control and monitoring

Control of logging

PAM with a high potential for improving the quality of control are presented here (Table 3-3-6). To increase the efficiency of future supports, realistic interventions must be designed. Feasibility studies are thus necessary notably to determine the associated risks, costs, practicality and potential benefits for each option.

Table 3-3-6: PAMs to overcome challenges in the control of logging

Challenges	*PAM options (expected to have a high potential of change)*
Independence of supervisors	- PNGFA facility (supervisor housing/office) in each logging concession - Regular re-affectation of PNGFA project supervisors (every 3/5 years)
Efficiency of forest workers	- Nomination by logging companies of one focal point for the whole project duration - Regular trainings to field workers with possible external support (funds, trainers)
Post-harvest control	Operator contribution for post-logging inventory (compulsory in LCoP) and relevant treatments such as assisted regeneration or agroforestry (voluntary)
Consideration of	Standardized response to non-compliance based on three levels (tentative): 1. Notice to field managers

PNGFA supervisor recommendations by operators	2. Notice to permit holders and fines 3. Temporary then definitive suspension of the permit
Cover impact of punitive measures	System of subsidy to provinces to compensate their income losses (taxes, royalties, local community employments, etc.) associated with operation stopping

Carbon monitoring

The first target is to quantify collateral damage. Figure 3-3-15 shows how to monitor carbon by adding few (but resource-demanding) activities to routine assessments done by supervisors.).

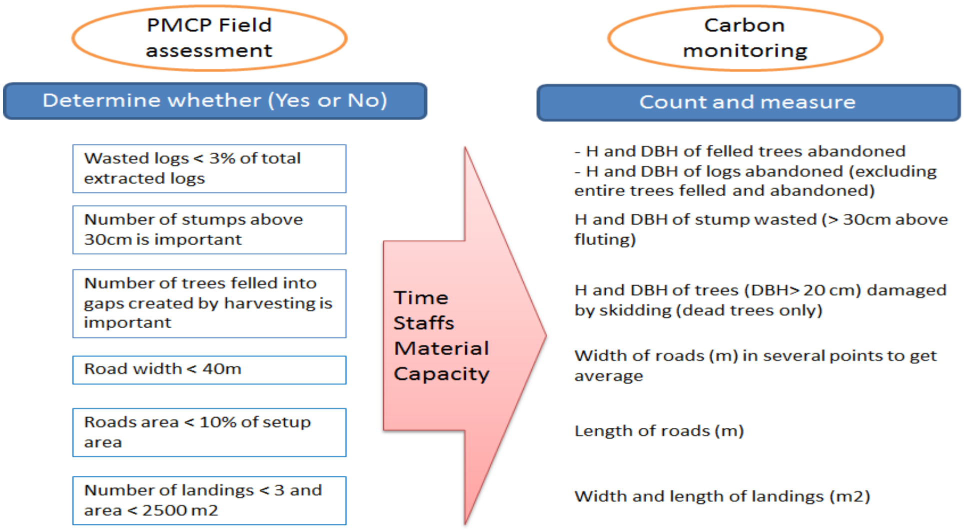


Figure 3-3-15: Additional activities to include carbon monitoring into routine assessment.

The potential parties to carry out carbon monitoring are presented below:

- PNGFA project supervisors (in supervision and/or inventory tasks);
- Logging company workers (inventory tasks); and/or
- Local communities living and/or working in concessions (participatory monitoring).

Main needs are as follow:

- Funds to cover the costs from additional staffs;
- Materials for instance: information (maps and forest data) and technologies (GPS, etc.);
- Capacities and training on carbon monitoring and specific carbon parameters;
- Regulations by integrating a climate component into PMCP documents:
    - ➢ Additional module in PMCP related to the carbon monitoring procedure;
    - ➢ Additional parameters in the checked items list (PMCP field assessment sheet).

The second target is to determine forest degradation at the scale of a province or the country. As such, setup data need to be scaled up and data issued from different scales and methods homogenized.

The scale for measuring the performance of interventions is the province or the country because the benchmark of emissions is a provincial or the national Forest Reference Level (UNFCCC). Thus, collateral damage data recorded in setups cannot be directly used to calculate Emission

Reduction performances. Nevertheless, if data are systematically monitored in setups, they can be "accumulated" at the concession level, assuming there is no degradation in the concession other than in setups. Then, concessions' values can be accumulated to get degradation values in each province, assuming there is no degradation in the province other than in concessions. Both assumptions are logical because the objective here is to evaluate the degradation from commercial logging rather than from other drivers. Eventually, provincial or national data on collateral damage (field methods) can be added to data on exported volumes (proxy) and observed logged-over areas (RS).

Then at the national (or provincial) scale, RS data can be used to determine the extent of logged areas (Activity Data). Data of collateral damage and proxy of export volumes can be used to determine the carbon content of logged forests (Emission Factors). As such, the emissions from forest degradation due to registered logging can be appraised, and the effect from interventions measured. See Figure 3-3-16.

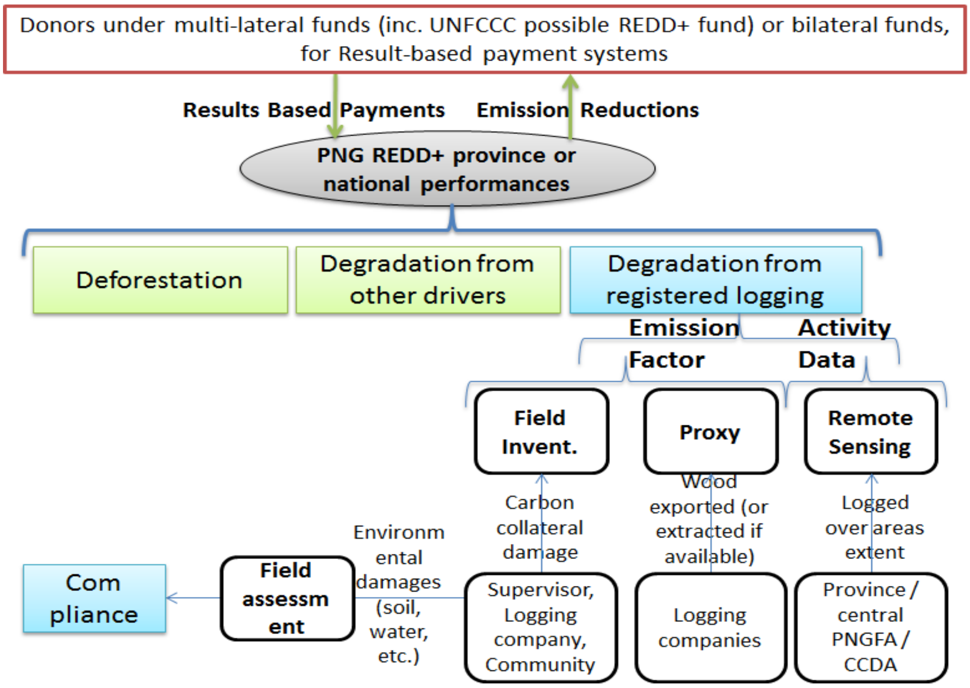


Figure 3-3-16: Collateral damage integrated in calculation of climate performance

3-3: PAM to valorize ERs and share benefits

There are two levers to reduce forest degradation from logging: to improve forestland use (referring to institutional organization and policy regulations) and to improve field harvesting practices. Valorization systems should reward both types of effort. The costs to fill institutional gaps are due to the design and implementation of PAMs while the costs to follow good practices are mainly due to additional materials and resources. This part discusses REDD+ Benefit Sharing and Distribution systems to promote SFM/RIL efficiently and fairly. Prior to it, this part shows the prerequisites for REDD+ support (Forest degradation / SFM should be in REDD+ scope and interventions respect safeguards).

SFM is not one of the 5 REDD+ activities selected by PNG. But the activity "reduction of forest degradation" is selected, and SFM can have for effect to reduce degradation. So SFM efforts could be actually accounted and rewarded. CCDA (2016) highlights the importance to address commercial logging as the first driver of emissions. PAMs prioritized in PNG are in line with the promotion of SFM and RIL:

- The prescribed "clarification of forest legislation" can indeed contribute to strengthen forest management components (notably regulations and land use planning);
- The prescribed "strengthening of applications" can step up the implementation of logging standards.

SFM approaches (including RIL practices) are respecting REDD+ safeguards, notably the standards related to:

- The Environment by limiting the erosion of biodiversity, soils and hydrologic services;
- Stakeholders by enhancing worker safety, land tenure and conflict regulation;
- National regulations by promoting a reinforcement of forest standards and laws.

Key factors to be considered while designing Benefits Sharing and Distribution Systems are discussed below. Figure 3-3-17shows benefits that the interventions addressing logging issues could receive. For practicality, the representation is provincial. The price of the carbon ton does not intend to suggest market approach. It only aims to estimate the financial benefit.

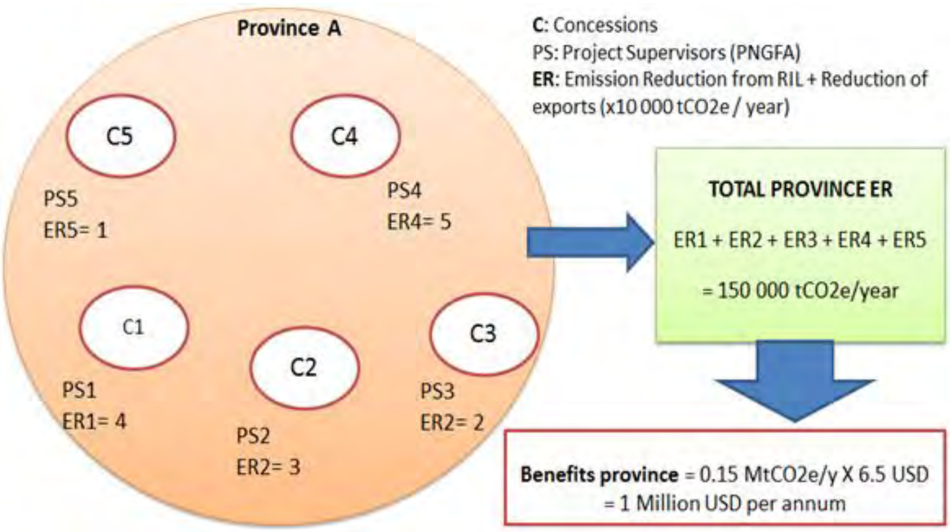


Figure 3-3-17: Factors for consideration in Benefit systems in a province program

Figure 3-3-18 indicates the arrangements of benefit sharing to support key components of forest management as identified along this paper.

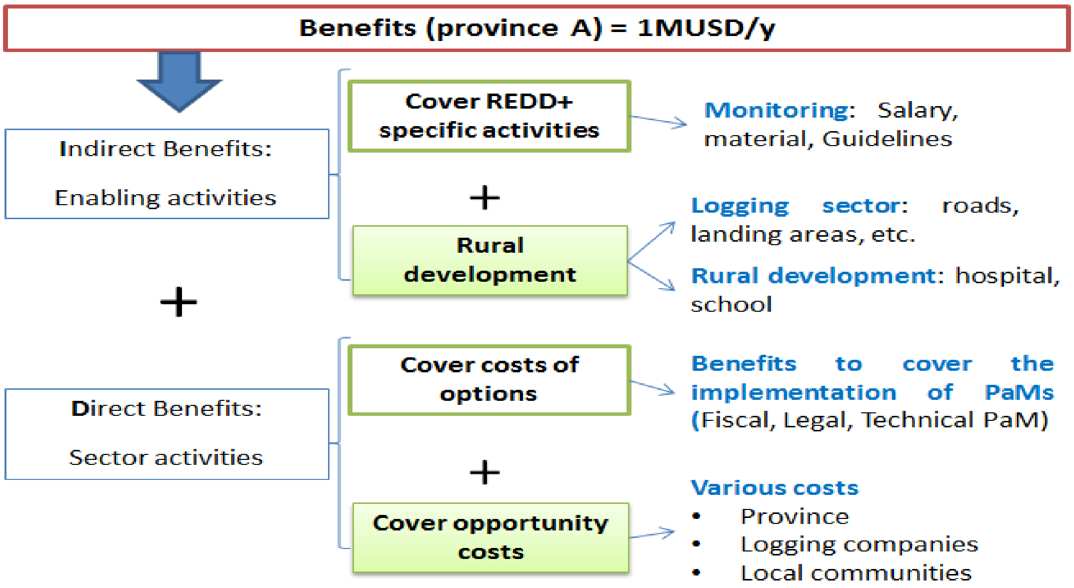


Figure 3-3-18: Factors for consideration in Benefit Sharing systems

Figure 3-3-19 describes the costs related to policy implementation and opportunity costs.

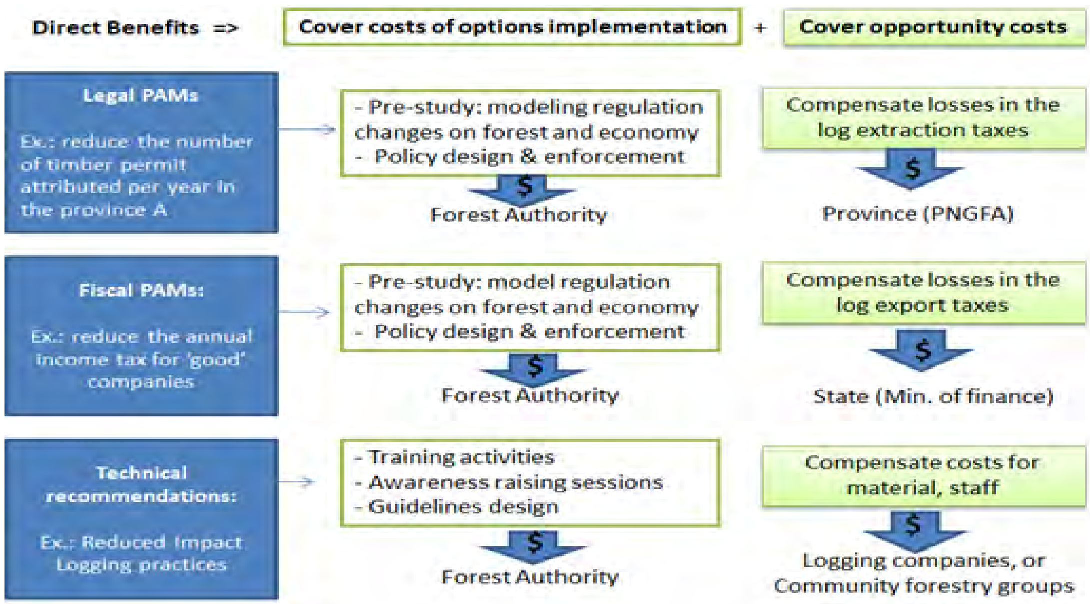


Figure 3-3-19: Factors for consideration in Distribution systems. $ = Financial support.

Figure 3-3-20 shows rewarding systems that REDD+ can activate to cover both costs to institutions for policy implementation and costs to logging operators for new practices.

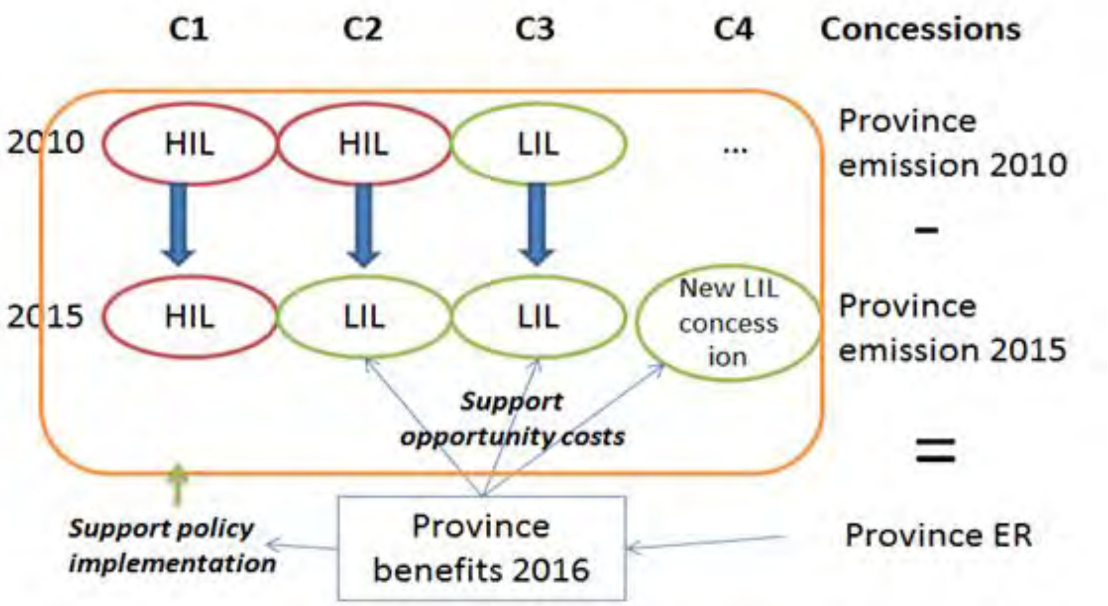


Figure 3-3-20: Factors for consideration in rewarding systems to foster SFM and RIL practice

C: Concessions; HIL: High Impact Logging; LIL: Low Impact Logging; ER: Emission Reductions.

In conclusion, REDD+ seems particularly relevant to support the following components:

- Parts of the forest management components that are still considered challenging such as the planning and control of operations, carbon monitoring and reporting;
- Activities that involve different land sectors (ex.: land use planning) or institutions (ex.: fiscal and commercial policies) because of their multi-sector dimension;
- Activities that are particularly relevant in a programmatic or pilot approach such as feasibility studies, legislation amendments' test, trainings and awareness raising.

However, REDD+ is not an ultimate response. The proposed supports must be inserted in suitable arrangements. The promotion of SFM and RIL should be included into the country's scope of REDD+ activities, respect strict Safeguards and be associated with adapted benefit sharing and rewarding systems. SFM approaches can allow aligning forest activities (and timber businesses) with social and environmental considerations. This perspective can produce a leverage in other land sectors (which depend strongly on forest) to facilitate a sustainable and climate compatible development of the economy and the country.

Conclusion

This section presents a summary of opportunities, challenges and recommendations highlighted in the paper. The lists are not exhaustive but try to show the main elements.

Opportunities for achieving SFM in PNG:

1. A strong institutional background with national standards that incorporate international recommendations and the decentralized institutions of PNGFA;
2. A number of international literature proposing guidelines in SFM and RIL practices as well as specialists in South-east Asia and the Pacific region;

3. The capacities related to the National Forest Monitoring System (NFMS);
4. Past relevant initiatives such as land use planning in the Madang province (USAID) or training sessions on RIL practices (Australia cooperation);
5. The FSC office in the country, and potential rewards for the good management of forests, in complement (no double counting) of REDD+ funds rewarding carbon benefits; and
6. The support to the Forestry sector from the international organizations, initiatives and frameworks such as EU-FLEGT, REDD+, etc.

Challenges for SFM in PNG

1. The logistic and financial supports for integrating carbon components in the routine assessment of logging setups;
2. The combination of different scales and methods of forest monitoring to be able to integrate local information on collateral damage into the calculation of FRLs and the performance of interventions;
3. The availability and collection of consistent and homogeneous information on the activities and boundaries of different land sectors in order to develop the national and provincial land use planning with a multi-sector approach;
4. The complexity (and the demand in resources) of the feasibility studies necessary to model changes from policy amendment; and
5. The design and implementation of policies involving different land sectors (Forestry, Agriculture, etc.) or different economic sectors such as Economy, Finance or Justice.

Recommendations for additional PAMs:

1. To involve the private sector (and logging operators in particular) in discussions, training and awareness-raising activities as a key factor to tackle degradation;
2. To gather in a national workshop stakeholders of the logging sector (companies, land owners, communities, institutions and international organizations) to evaluate the needs, and share knowledge on practice details and Climate benefits;
3. To study feasibility to add a module of carbon assessment in the PMC procedures;
4. To develop guidelines for monitoring carbon in logging setups, for different parties such as PNGFA supervisors, logging companies and community groups;
5. To provide training for trainers (project supervisors) and project operators on RIL practices;
6. To consider the potential support from the improved conditions and management tools for further Forestry options that can reduce logging impact; for instance, forest plantations (that allow to move logging out from natural forests) or the reforestation of logged over areas (that facilitates regeneration);
7. To conduct Research experiments on PNGFA or private sites to test harvesting practices and use these sites as demonstration sites to logging companies and actors of the development in PNG or in the neighboring countries;
8. To evaluate solutions for increasing the actual application of the "procedures for assessing post-logging waste in set-ups" (in PMCP) to improve the recording of collateral damage; and
9. To foster post-harvest treatments such as assisted natural regeneration, plantation, agroforestry or agro-ecology from institutions, communities and logging companies.

Reference

Abe, Hitofumi, 2016. Emission Factor for PNG REDD+ Forest Reference Level (FRL). Third National REDD+ FRL Consultation Workshop Port Moresby, 27-28 October 2016.

Applegate, G., and Kartawinata, K. 2001. Reduced Impact Logging guidelines for Indonesia. CIFOR. 28p.

European Union FLEGT programme. 2016. Multi-stakeholder workshop on the EU Forest Law Enforcement Governance and Trade (FLEGT) initiative in Papua New Guinea and its possible implementation. Historic overview of FLEGT related initiatives in PNG.

FCPF. 2013. Papua New Guinea's REDD+ Readiness Preparation Proposal (R-PP). 148p.

Forest Stewardship Council (FSC). 2015. FSC Principles and Criteria for Forest Stewardship.

Intergovernmental Panel on Climate Change (IPCC). 2006. Guidelines for National Greenhouse Gas Inventories Volume 4. Agriculture, Forestry and Other Land Use.

ITTO/IUCN. 2009. Guidelines for the conservation and sustainable use of biodiversity in tropical timber production forests. A joint publication of the International Tropical Timber Organization and the International Union for the Conservation of Nature. 120p.

JICA office in Papua New Guinea. 2014. Environment is JICA's priority. Pacific Business Review.

https://www.jica.go.jp/png/english/office/topics/c8h0vm000092px0m-att/150315.pdf

Killmann, W, et. al. No date, currently on the FAO website. Reduced impact logging: does it cost or does it pay? http://www.fao.org/docrep/005/AC805E/ac805e0f.htm#TopOfPage

Maswar, M, et. al. 2001. Evaluation of methods for rehabilitation of logged-over lowland forest in Pasoh, Negeri Sembilan, Malaysia. CIFOR, Bogor, Indonesia.

Papua New Guinea Climate Change Development Authority (CCDA). 2016. Issues and Options for Papua New Guinea's National REDD+ Strategy. UN-REDD, FCPF programme.

Papua New Guinea Climate Change and Development Authority (CCDA). 2017. Papua New Guinea’s National REDD+ Forest Reference Level. Submission for UNFCCC Technical Assessment.

National Parks Act. 1984. Planning, Monitoring and Control Procedures for Natural Forest Logging Operations under Timber Permit: November 1995.

Papua New Guinea Forest Authority and the Department of Environment and Conservation (PNGFA & DEC). 1996. Papua New Guinea Logging Code of Practice.

Program for the Endorsement of Forest Certification schemes (PEFC). 2010. PEFC STANDARD 1003:2010. Chap. 5: Sustainable Forest Management – Requirements. pp 8-13.

Sist, P., Dykstra, D. & Fimbel, R. 1998. Reduced impact logging guidelines for lowland and hill dipterocarp forests in Indonesia. Occasional Paper No. 15. Bogor, Center for International Forestry Research.

TerraCarbon LLC and The Nature Conservancy. 2016. Reduced impact logging practices that reduce carbon emissions (RIL-C) methodology. Verified Carbon Standards (VCS). 20p.

The Nature Conservancy. 2016. RAFT 3 partnership PNG programme inception report

Widiyatno, S. 2013. The growth of selected Shorea spp in secondary tropical rain forest: the effect of silviculture treatment to improve growth quality of Shorea spp. Environmental Sciences 17. pp. 160 – 166.

- Wilkinson, G, and Putz, F. 2012. Report on the Asia-Pacific workshop: Reduced-Impact Logging: challenges, opportunities and strategies in the Emerging Forest Carbon Economy. sansiri.visarutwongse@fao.org.

Appendix: Supporting to Forest Plantation

Overview of possible PNG-FRIMS support to forest plantation development programs and REDD+ potential (drafted in June 2016).

Introduction

Current situation of plantation in the country was analyzed as follows

- Managing authority of forest plantations in Papua New Guinea (PNG): Forest authority (PNGFA), Forest Development Directorate, Plantation Development and Management team. Reference for this paper: PWP presentation of Mr Francis Vilamur, 2015.
- General remarks from the managing authority: state owned plantations are declining; development should be scheduled in the provincial forest plan
- Forest plantations managed by PNGFA: 11 projects in 25 000 ha
- Private projects: one area, several projects in 25 000 ha (data needs to be checked)
- Total forest plantation area = 50 000ha.
- Main species: Eucalyptus 50%, Acacia: 20, Araucaria: 20, Pinus: 10, Teak: 5.

Methodology

Country Target

- Vision 2050: calls for forest plantations development
- National target:
  - ➢ 250 000 ha by 2025
  - ➢ 800 000 ha by 2050
- Provincial target:
  - ➢ 1000 ha per year
  - ➢ 40 000 ha/province by 2050

To reach its national target in terms of planted area, PNG must quintuple existing plantations (50 000 ha) in less than 10 years.

Issues forest plantation development faces

- ✓ Few support from government; development strategies not clear (national / provincial forest plan)
- ✓ Lack of resources for management and update plantation information
- ✓ Land tenure: acquisition (competing land use options) and disputes between landowners
- ✓ Monoculture not attractive economically
- ✓ Fires, amongst else.

Objective

General Objective

Increase the planted area in PNG and the utilization of existing forest plantations for two main purposes: economical (state/province revenues from timber) and ecological (rehabilitation of degraded zones and utilization of unused lands).

Specific Objectives

(1) Create conditions to facilitate operations in existing plantations by improving land tenure clarification, boundary definition regularly and general maintenance.
(2) Facilitate the installation of new development areas by providing tools and resources for planning (zoning suitable areas) and installing (GPS) plantations.

Required activities supported by the JICA-PNGFA project

Examine the potential support from new tools and capacities within Forest Authority brought by the JICA-PNGFA project (PNGFA officers training, PNG-FRIMS, Forest Base Map, Lan map, GPS, and GIS and Remote Sensing analytical tools) for;

(1) Updating forest plantations data: during the work of PNG-FRIMS update
(2) Updating forest plantation boundaries: during GPS training include forest plantation officers (Forest Development Directorate)
(3) Planning new forest plantations: land suitability analysis (from RS and GIS) prioritizing Logged Over and savanna areas: during the design of national & provincial forest management plan insert consideration of forest plantations
(4) Managing and maintenance of (existing and new) forest plantations: during trainings for utilizing Forest Base map and Lan Map include forest plantations officers
(5) Designing measures that ensure a monitoring and control of fires: during trainings on GIS and RS utilization insert a component related fires and include officers managing forest plantations
(6) Raising awareness on plantation leases and their benefits to landowners: thanks to knowledge increase of field officers concerning plantations benefits for Forestry but also for Climate Change (REDD+, PES)
(7) Gathering and recording information on economic and ecological value of different timber species including mixture and new Agroforestry concepts: during the process of updating PNG-FRIMS content include data on plantations and species of interest

Besides, an update of the interest of the government will be necessary: Vision 2050, Forest Year, and Declaration of New York.

Conclusion

Stakes of forest plantation development are organized as follows

Economic benefits

- Increase companies, province and state revenues from timber
- Facilitate new businesses development for local communities (Community forestry component) or logging enterprises (private sector component)
- Attract timber and carbon investors into the country by improving conditions enabling the development of forest plantations.

Climate benefits

- Reduce emissions from forest degradation by displacing logging from primary forests to existing or new plantation sites
- Enhance forest carbon stocks by extending the planted area
- Reduce deforestation that could happen in logged over areas (after logging projects) by providing a source of income by planting new trees (regeneration instead of degradation)
- Reduce deforestation by providing an income alternative (from wood sale and crops setup between planted trees) to slash and burn farmers
- Provide REDD+ implementation options at the national or provincial scale.

Other benefits

- High benefits for biodiversity and watersheds in particular by forest plantations contributing for landslide-caused disasters risks reduction

- Test Agroforestry approaches (ex.: intercropping in Acacia / Teak) for rural development benefits.

Discussions

Data currently available on Forest Plantations established in PNG in the past (updating data now). Ownership: half state half (company name)

Province	**Plantation**	**Start**	**Area (ha)**	**Species**	**Ownership**
Central	Brown River Kuriva	1955 1985	1266 1440	Teak Teak	State State
Milne Bay	Ulabo	1985	1500	Kamarere	State
Morobe	Bulolo/Wau Umi	1985 1990	12,000 764	Hoop,Klinki, Pinus Pinus/Eucalytus	State State
Madang	Gogol North Coast	1975 1985	12,375 1,748	A.Mangium E.deglapta	(JANT) State
New Irel.	Kaut	1986	570	E.deglapta	Community
WNB	SBLC	1972	12,000	E.Deglapta	(SBLC)
East New Britain	- Kerevat - Open Bay	1950 1972	- 2,385 - 14,000	Teak Kamarere	State (OBT)
West High.	Waghi	1962	2100	E.grandis, robusta	State
South Hig.	Lalibu	1972	440	P.patula	State