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

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Papua New Guinea Forest Authority (PNGFA)

Japan International Cooperation Agency (JICA) Project

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PNG Forest Authority (JICA Project)

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

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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

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The JICA Project Casuals:

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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.

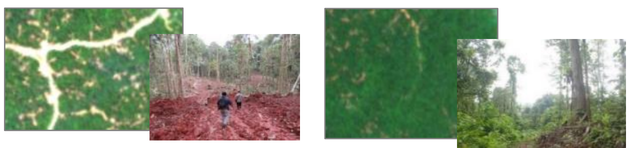
JICA-PNGFA Project 2011 – 2014 (Phase1):

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.

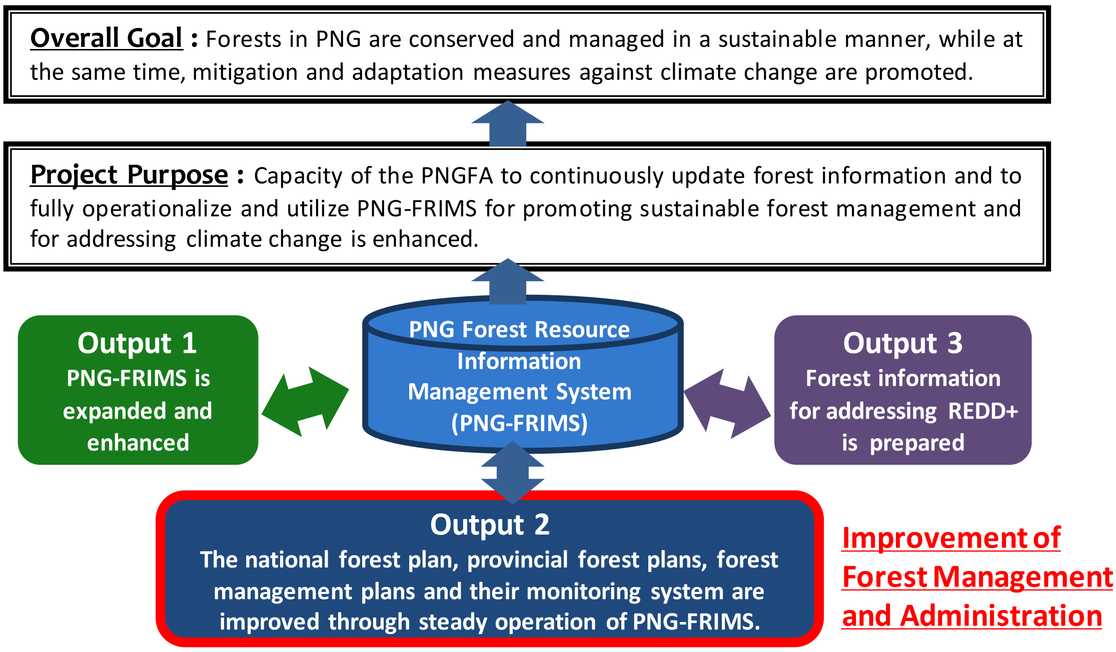


Figure 1.2.1: Overview of the Project

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

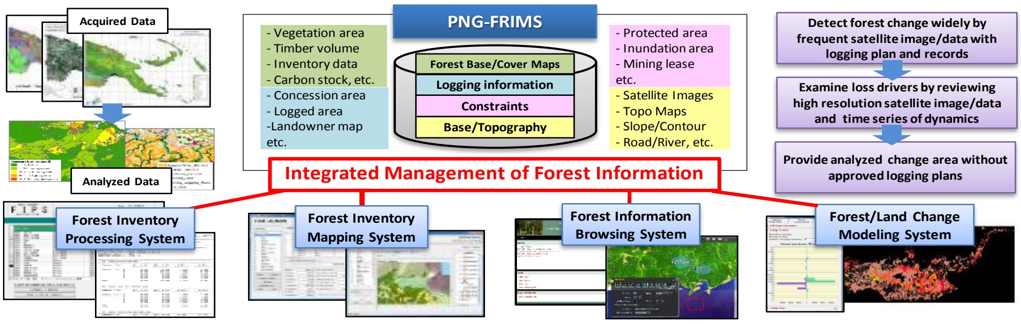


Figure 1.2.2: Overview of the Output 1

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+

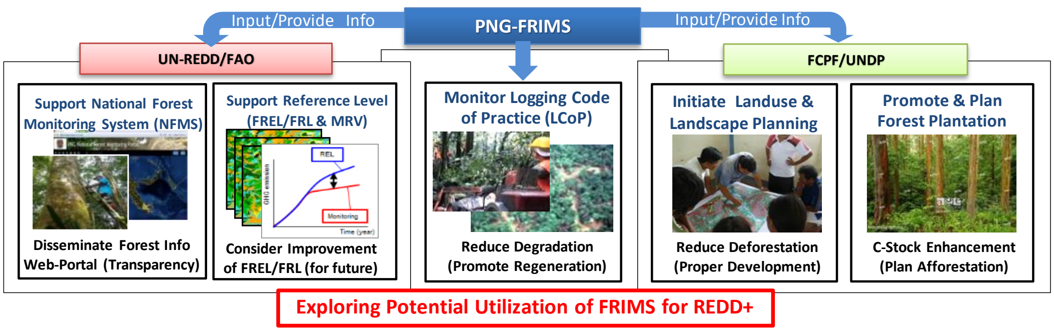


Figure 1.2.4: Overview of the Output 3

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

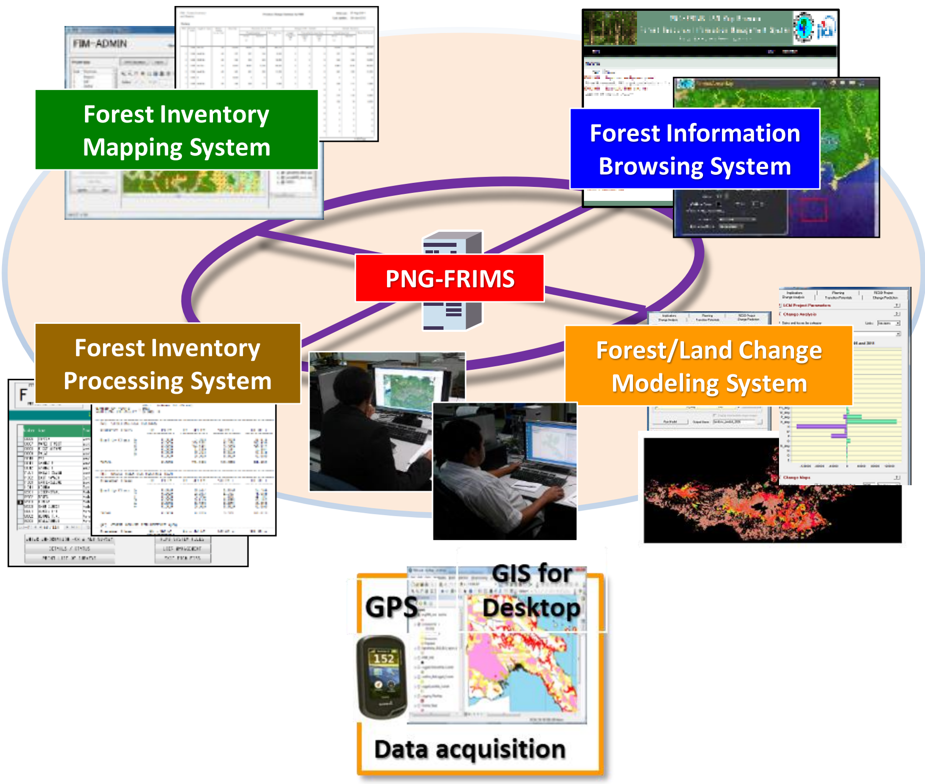


Figure 1.3.1: Overview of the PNG-FRIMS

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.

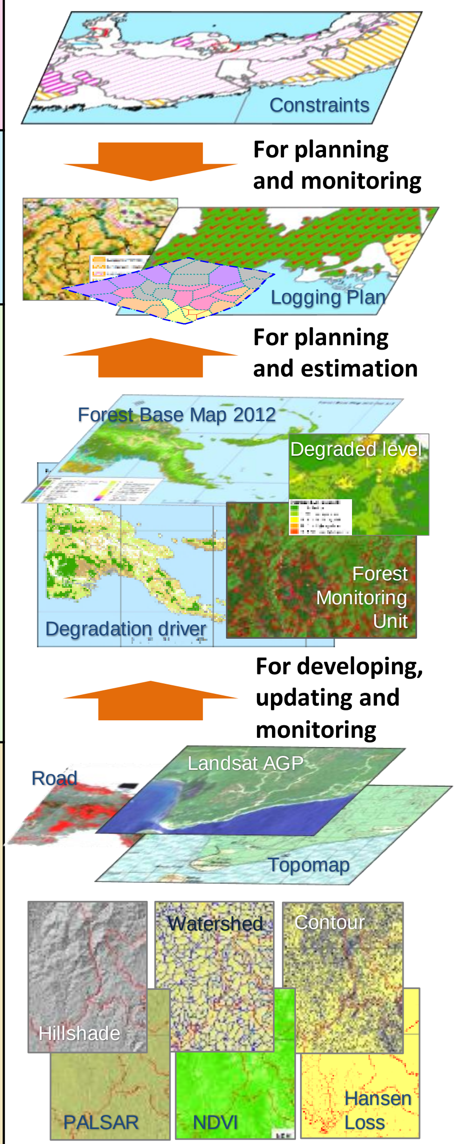


Figure 1.3.2: Information in PNG-FRIMS

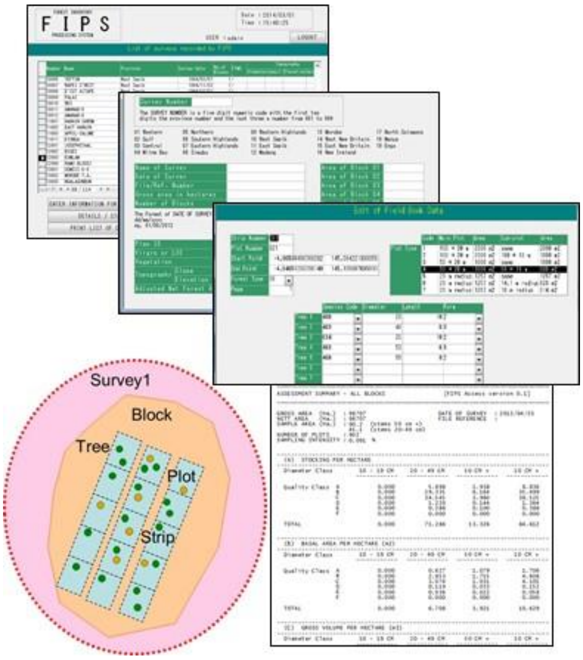
Database stores not only PNGFA data but also global dataset and the information from other organizations, which are updated and kept fresh periodically.

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)



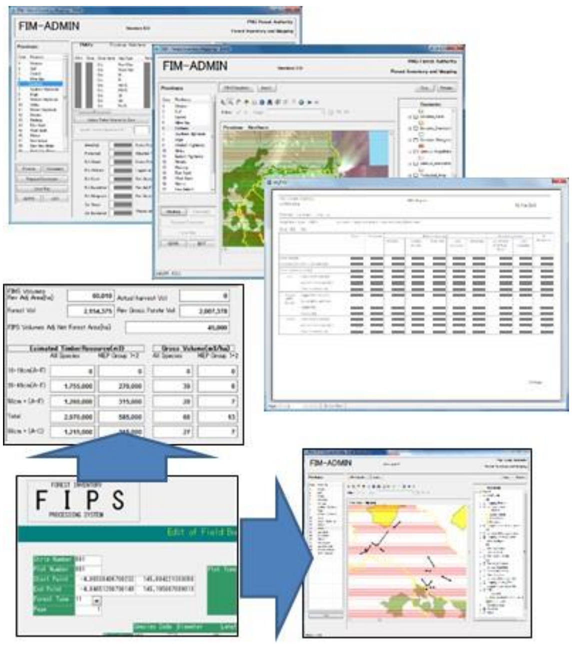
Overview

- 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

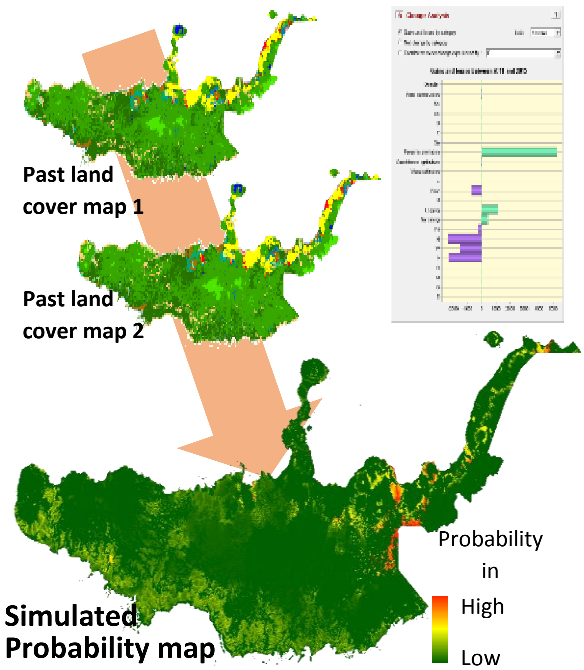
Overview

- 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

Procedure

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.

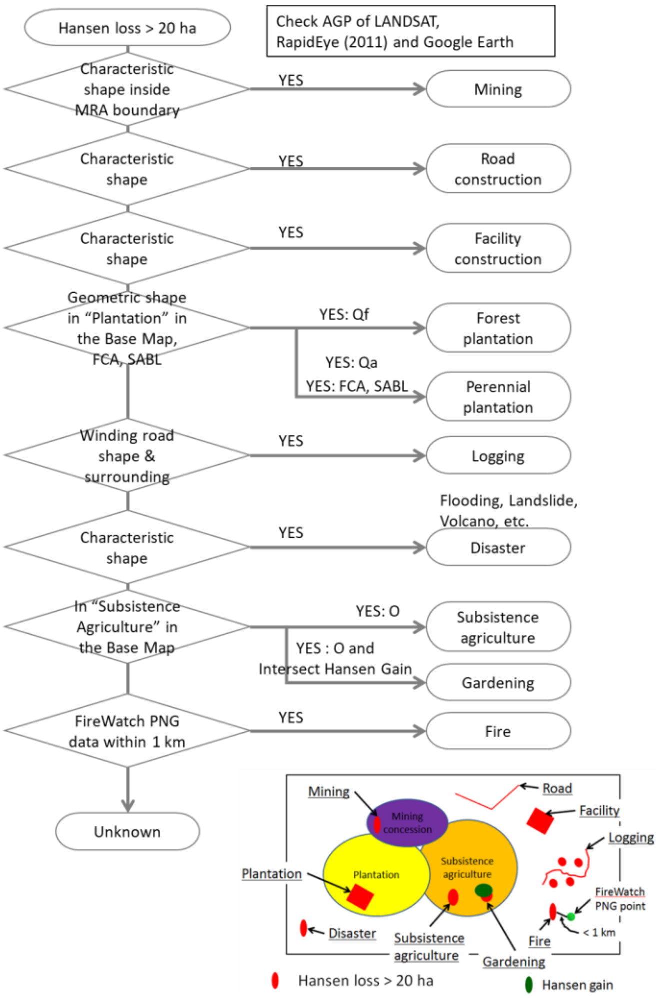


Figure 2.1.1: Flow of Driver analysis for Hansen loss-year polygons larger than 20 ha.

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.

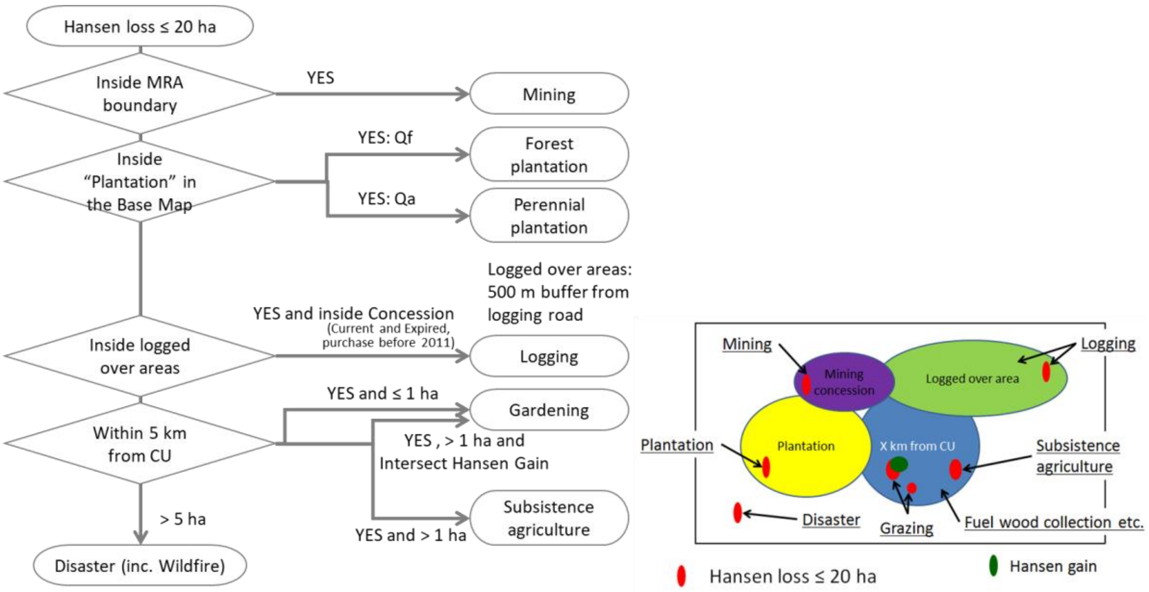


Figure 2.1.2: Flow of Driver analysis for Hansen loss-year polygons 20 ha and smaller

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.

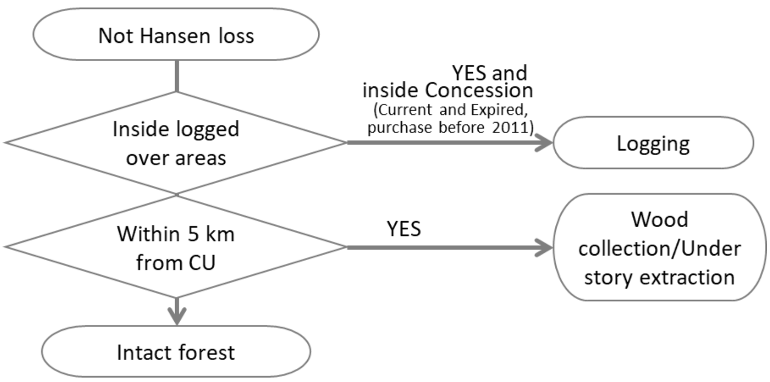


Figure 2.1.3: Flow of Driver analysis for Map polygons which do not intersect Hansen loss

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

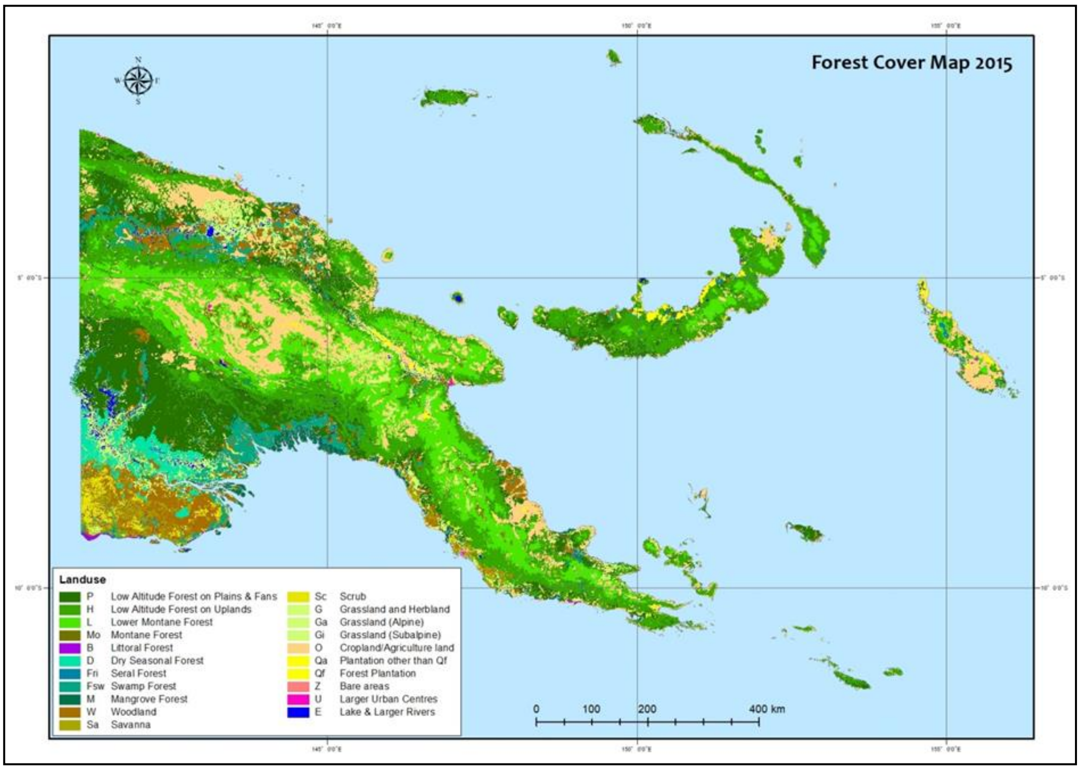


Figure 2.1.4: Forest Cover Map 2015 showing different landuse

	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

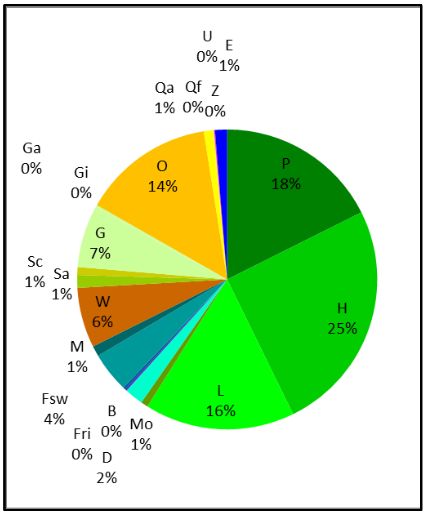


Figure 2.1.5: Vegetation cover with corresponding areas for the Forest Cover Map 2015

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.

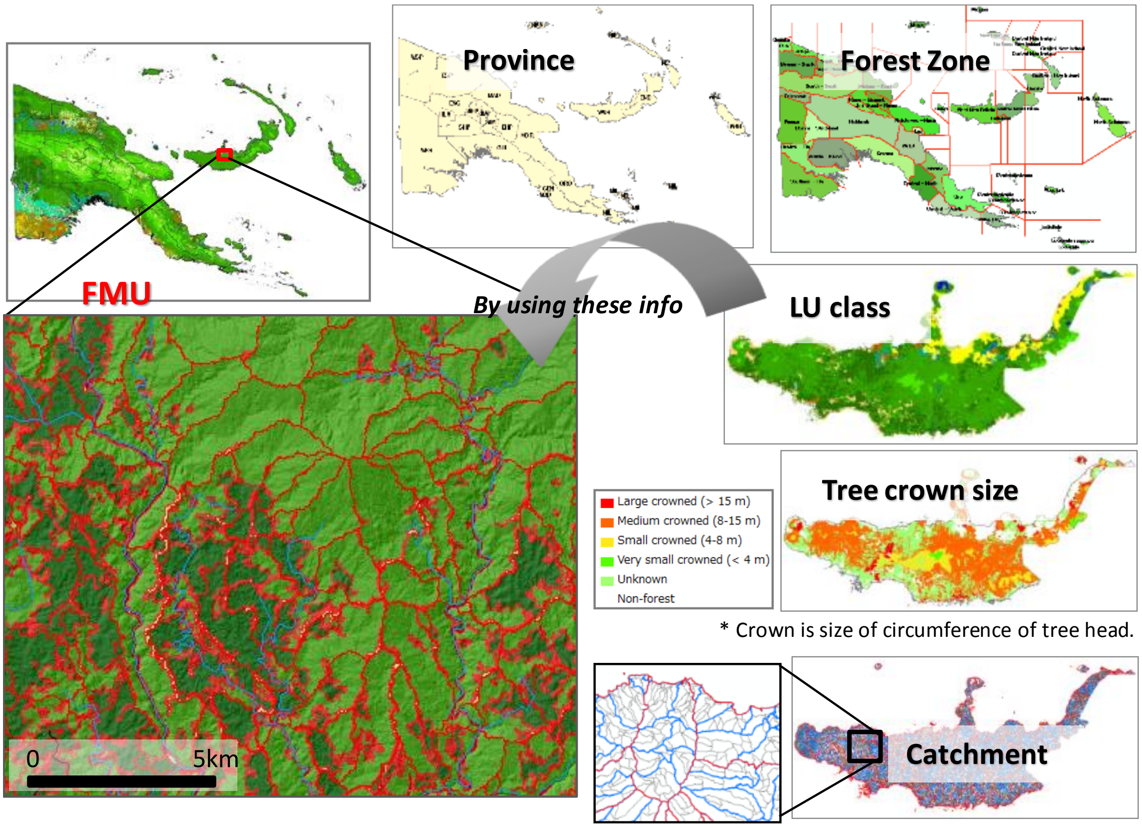


Figure 2.1.6: Development of Forest Monitoring Unit (FMU)

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

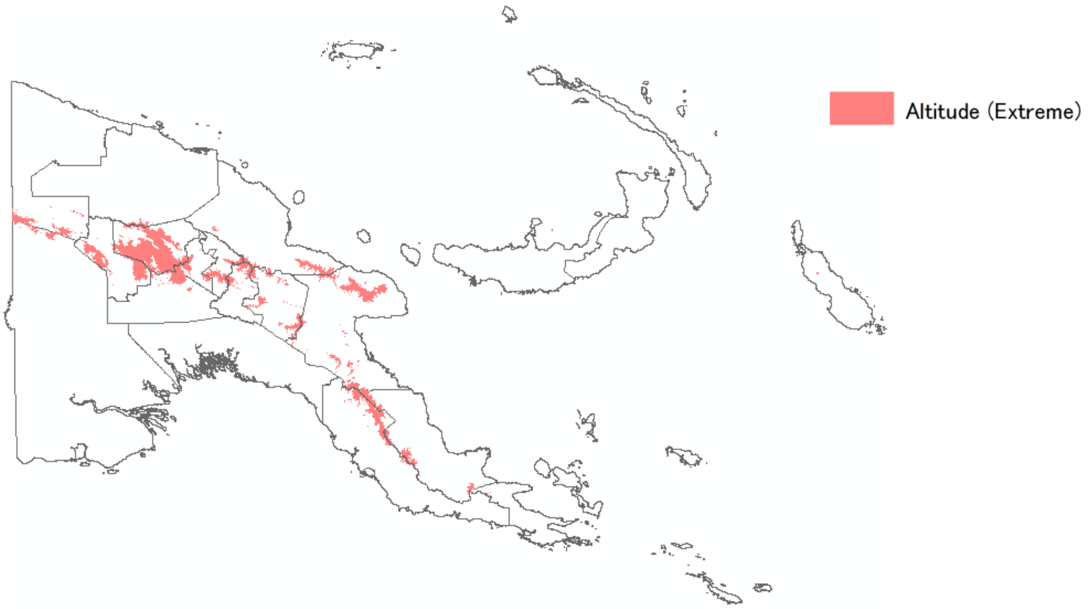


Figure 2.1.7: Data Comparison of Altitude (Extreme)

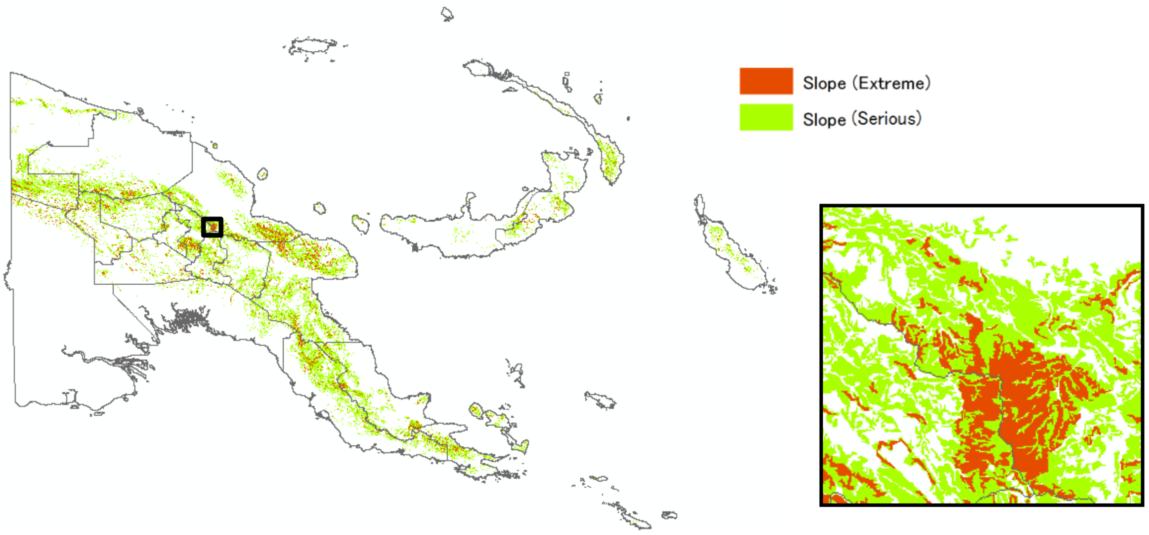


Figure 2.1.8: Data Comparison of Slope (Extreme and Serious)

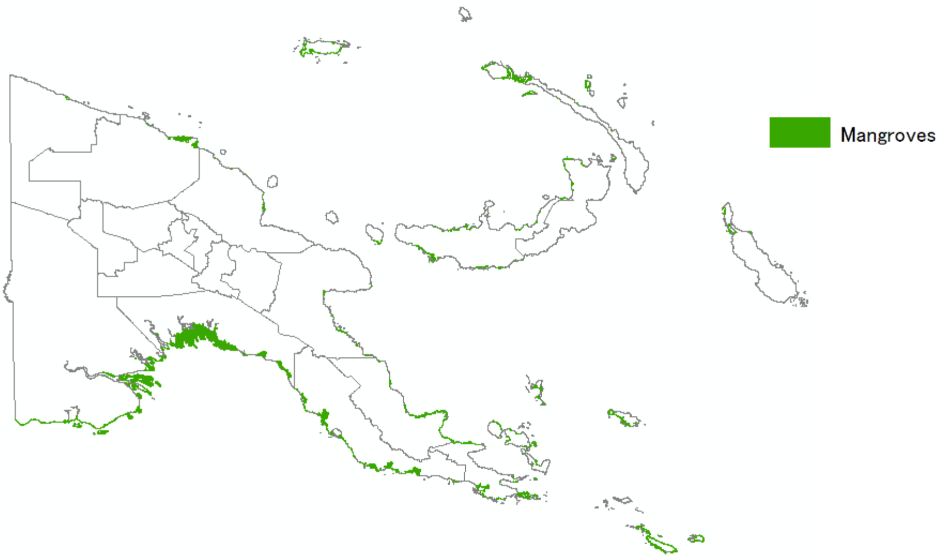


Figure 2.1.9: Data Comparison of Mangroves

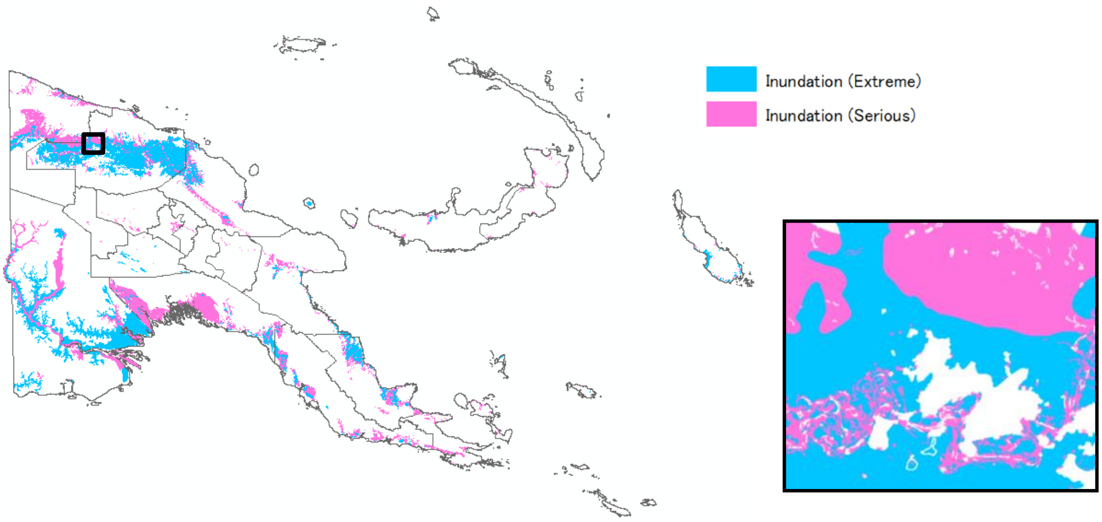


Figure 2.1.10: Data Comparison of Inundation (Extreme and Serious)

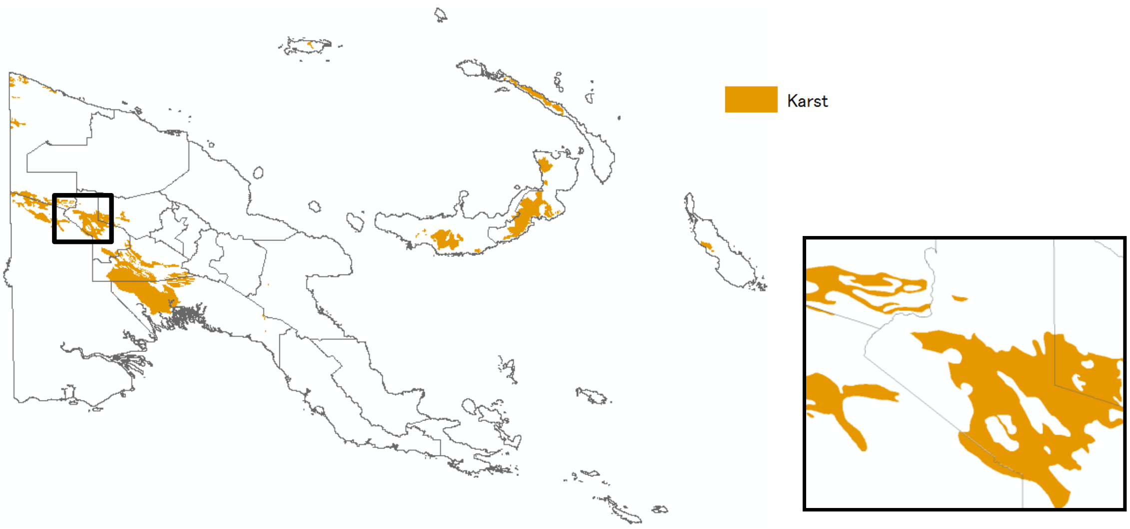


Figure 2.1.11: Data Comparison of Karst

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)

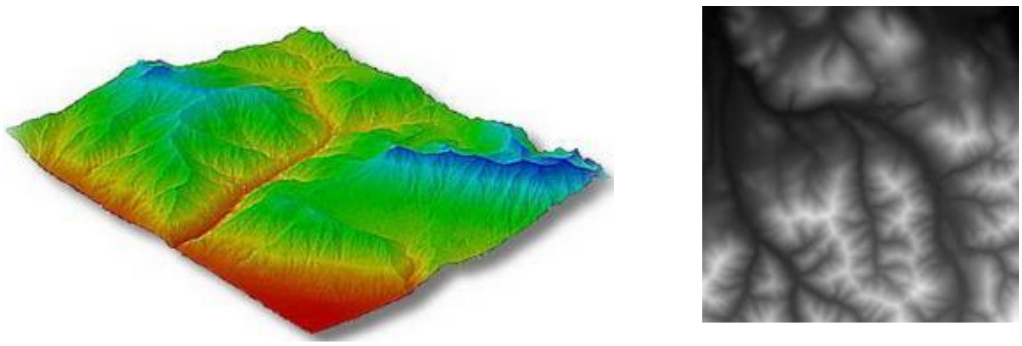


Figure 2.1.12: 3D and 2D representatives of DEM

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.

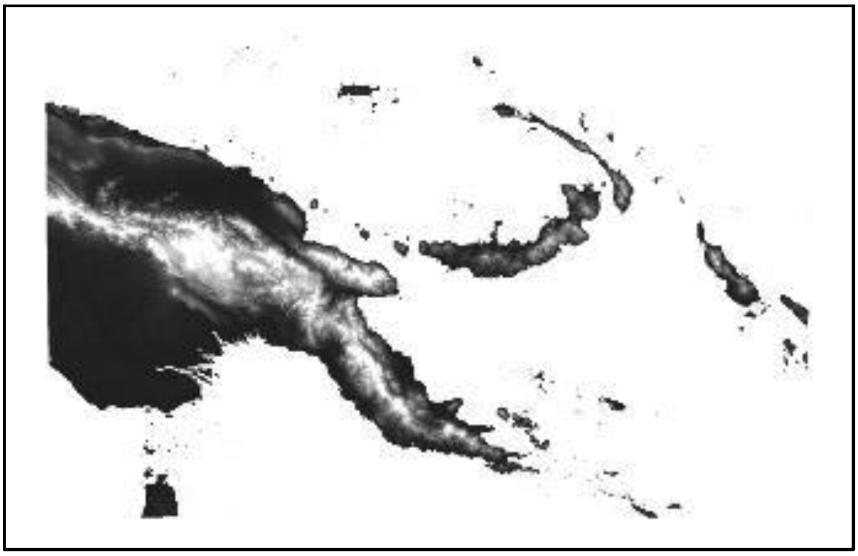


Figure 2.1.13: SRTM 90 meter resolution DEM data covering the whole land area of PNG

<u>Procedure</u>

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.

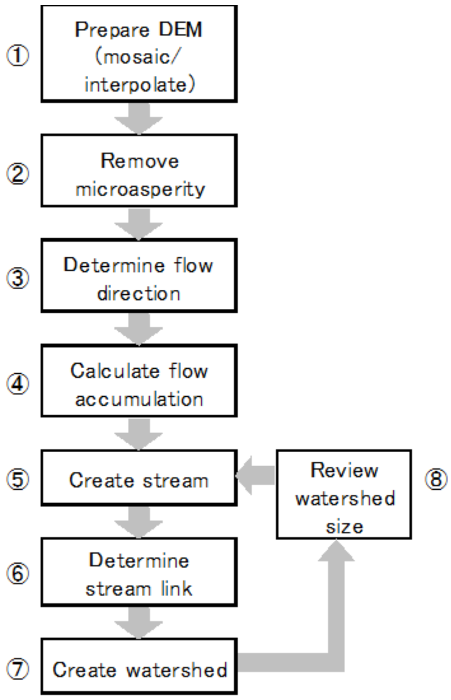


Figure 2.1.14: Work-flow involved in generating Watershed data from DEM

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.

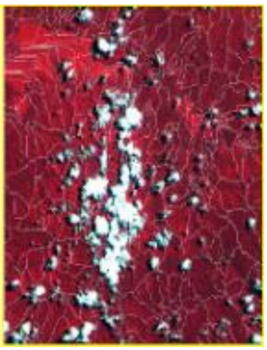
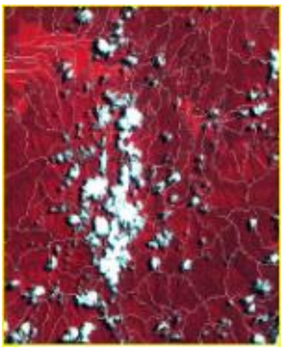
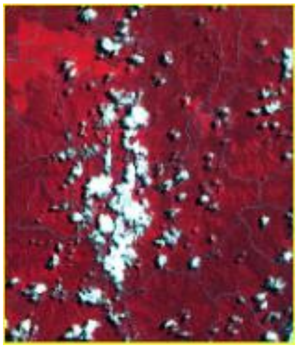
Watershed Boundary > 50,000	Watershed Boundary > 100,000	Watershed Boundary > 500, 000
		
❖ Preferred for Watershed Analysis	❖ Less preferred for watershed analysis	❖ Not preferred for watershed analysis
❖ Excellent indicator for vegetation & forest classification especially at high altitude	❖ Good indicator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

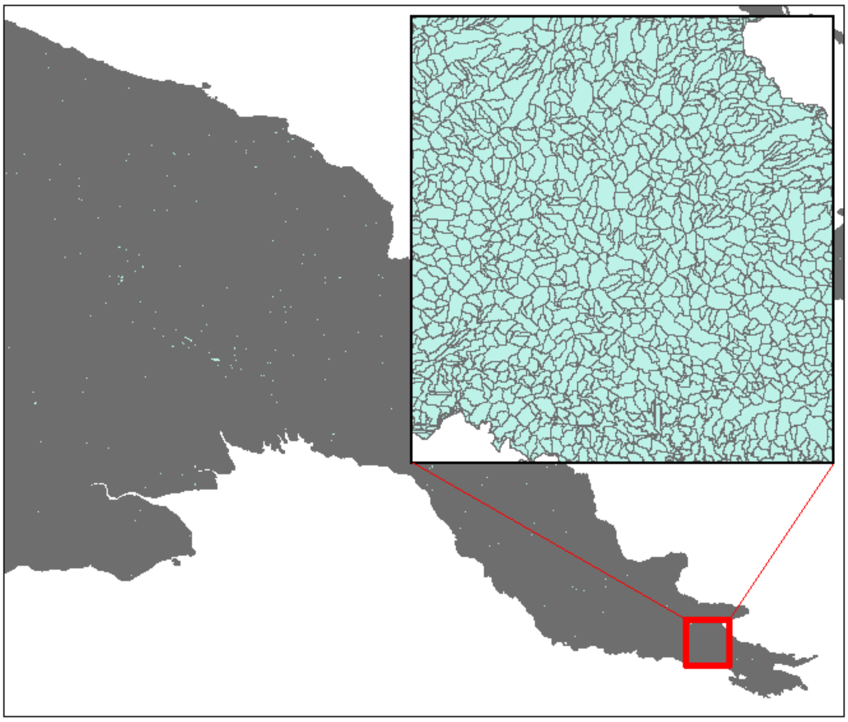


Figure 2.1.16: Sample of PNG Watershed Boundaries shapefile created with DEM Analysis

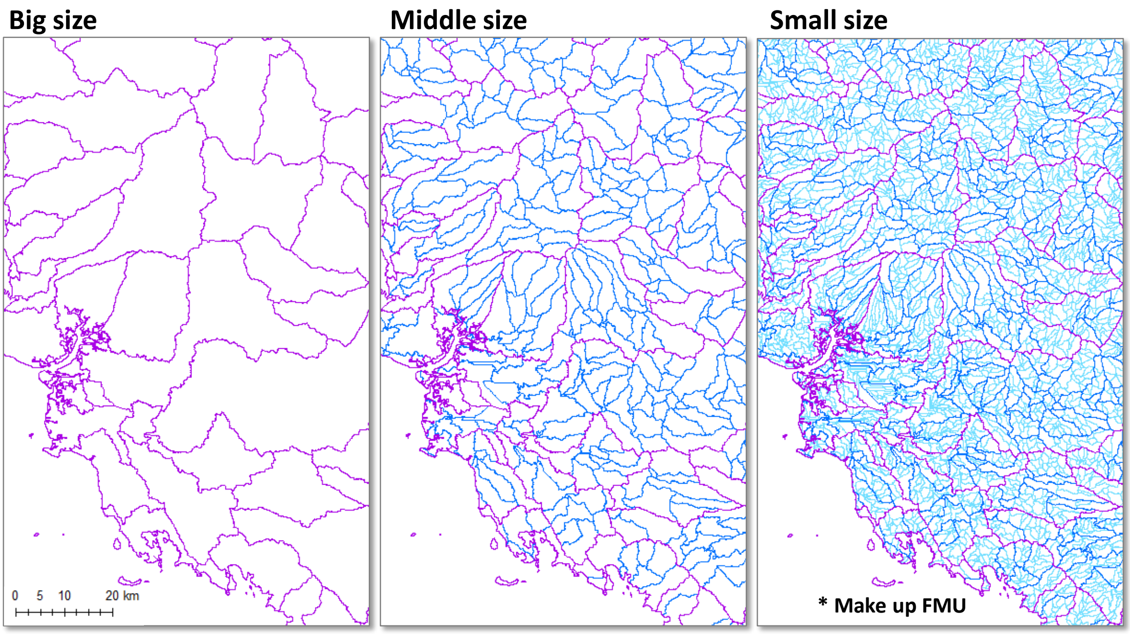


Figure 2.1.17: Three level of Watershed Data of PNG

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

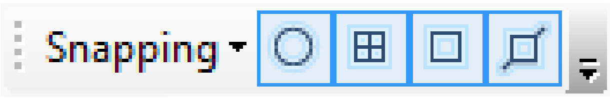
1. National Roads – Roads that are recognized as under the care and management of the National Government. These roads are the major highways and roads that connect the main centres and regions throughout the country.
2. Provincial Level Roads – Roads that are recognized as under the care and management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

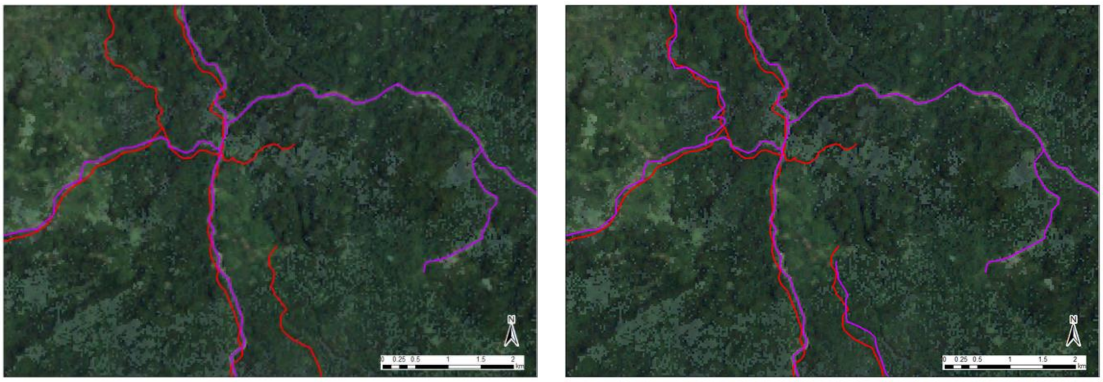
1. Road network of year 2000 was developed as the basis of the information mentioned in the data acquisition above.

A. Digitize road referring LANDSAT AGP 2000 directly

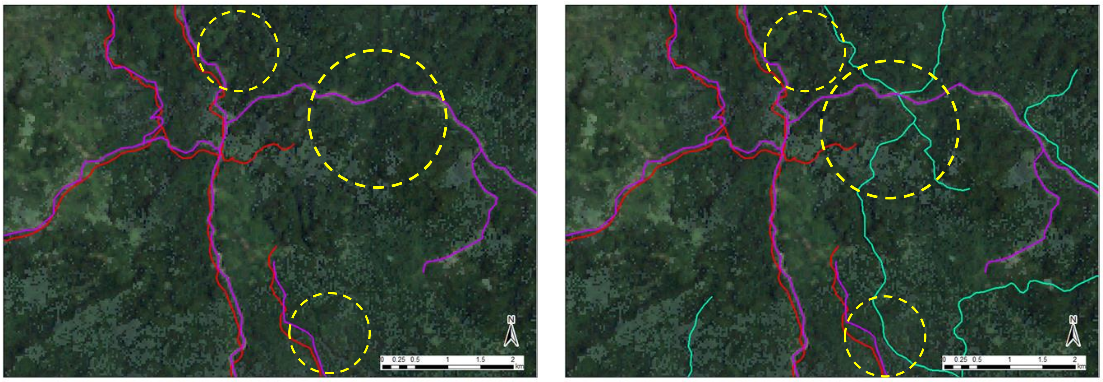
Use "Snapping" tool (from ArcGIS/ArcMap Toolbars) to connect line features.



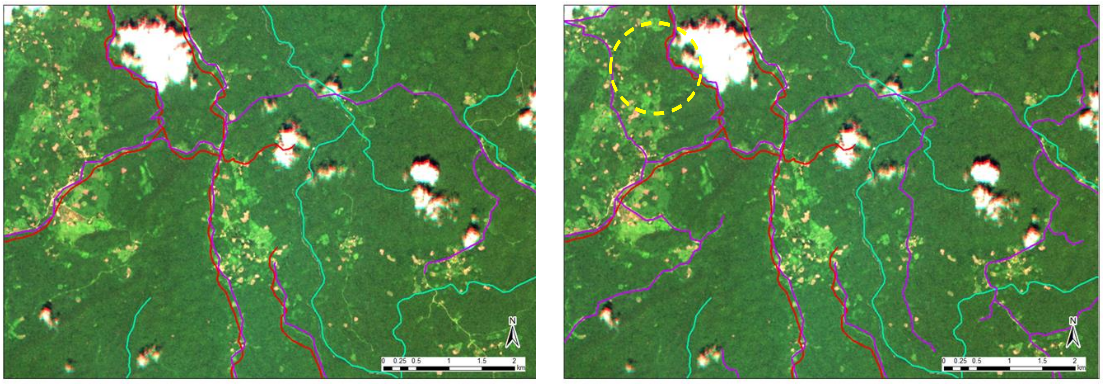
B. Road information of GeoBook is a good reference to digitize unclear roads on LANDSAT AGP.



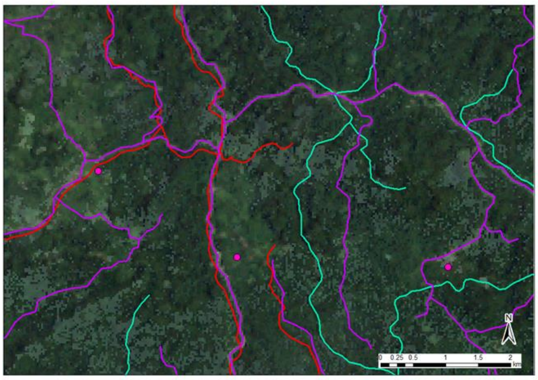
C. To avoid digitize rivers as roads, refer the river GIS information

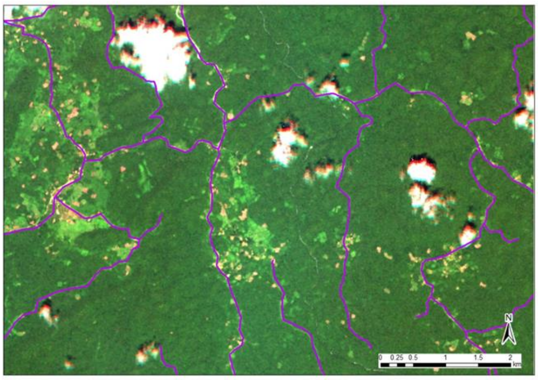


D. Comparing LANDSAT imagery and RapidEye imagery, digitize unclear roads.

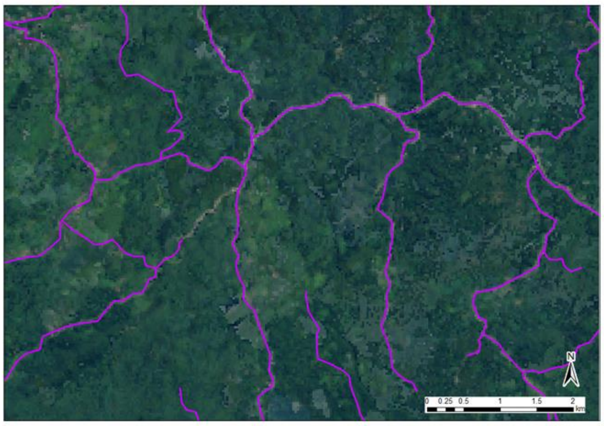


E. Census Unit information is also useful to estimate intensity of human activities. In the following image (top), the pink circles are Census Unit information. The color spotting around the points indicate existing of agricultural fields there.



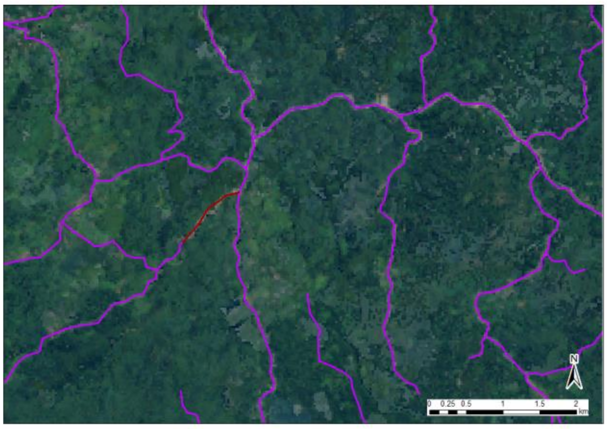


2. Road network of year 2005, 2011 and 2015 were digitized in order from the oldest year adding line features on the road network feature on the older year.



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

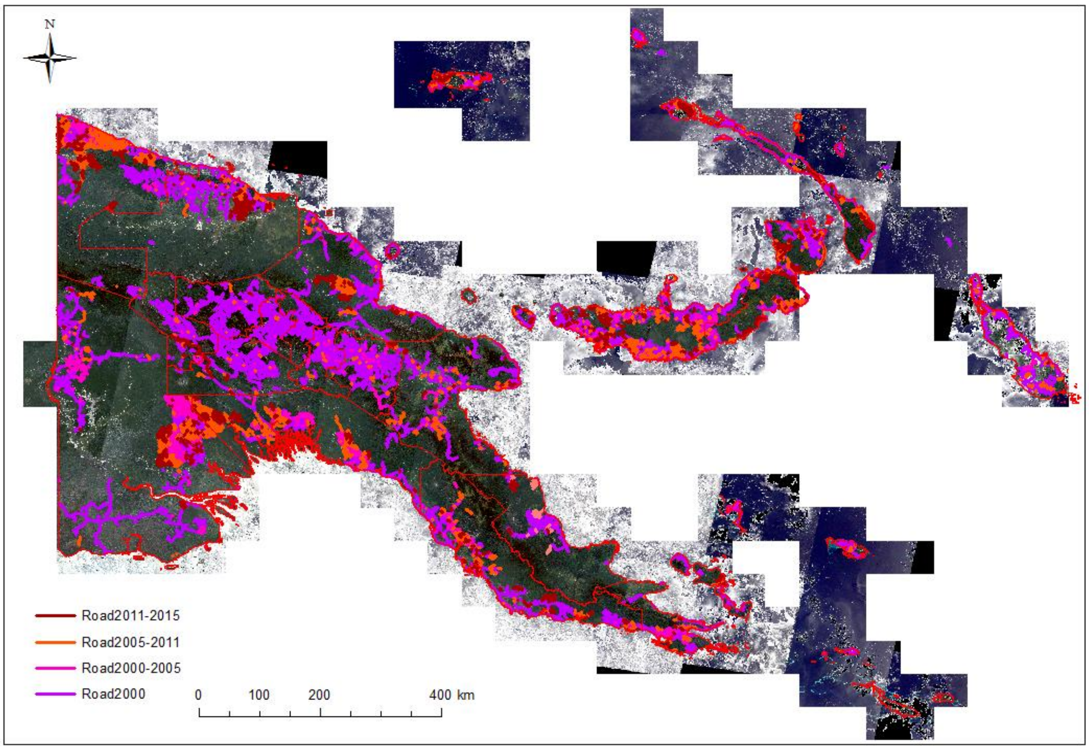


Figure 2.1.18: Map of completed road GIS information

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.

<u>Method</u>

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.

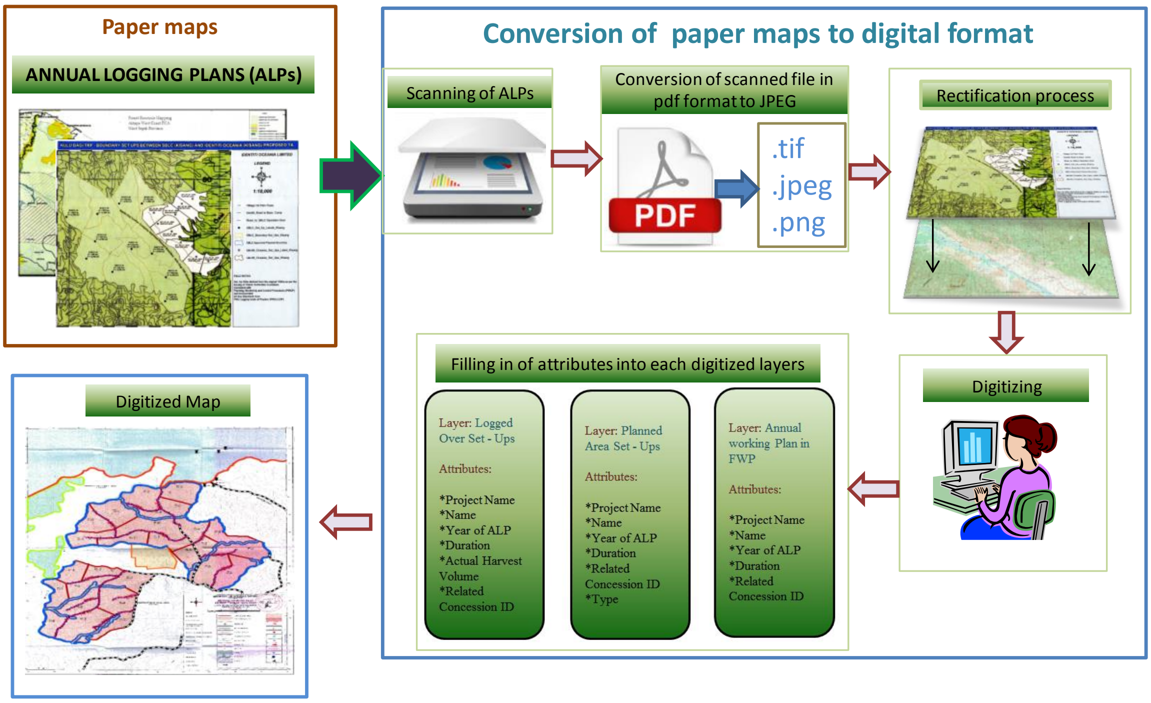


Figure 2.1.19: Process involved in digitizing the ALP's

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.

<u>Basic Steps to Digitization</u>

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.

<u>Attributes</u>

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.

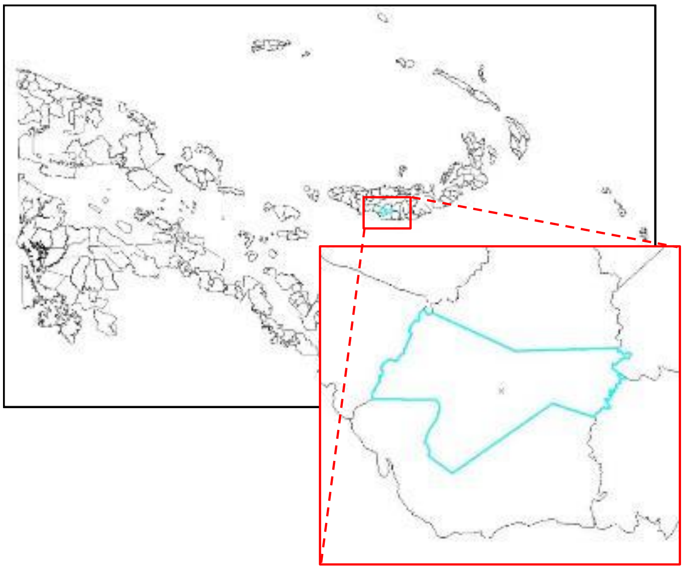
Table 2.1.7: Attributes of Forest Concession / Land Management Layers

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.



Attributes

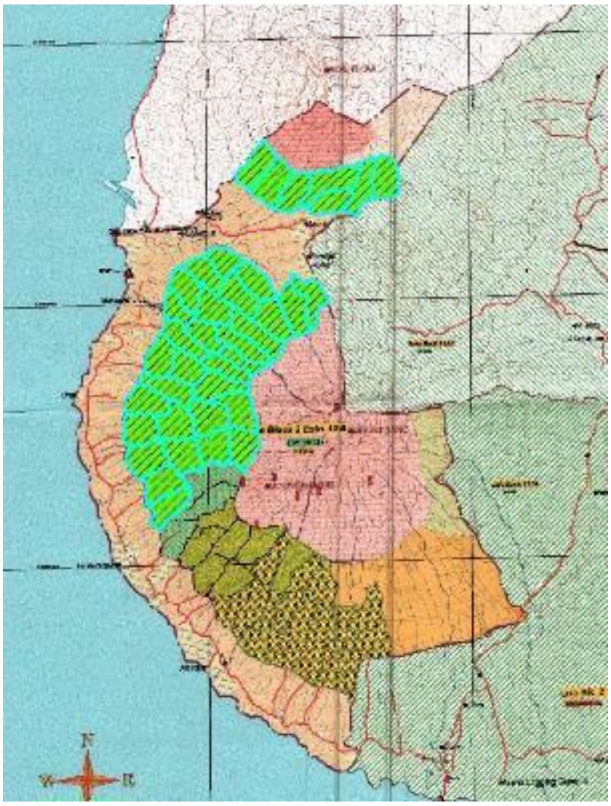
ConcessionArea_update_rev
Passismanua Inland

FID	24
PLAN_ID	1952
NAME	Passismanua Inland
AREA	39886.560734
PURCHASE	26/02/1992
EXP	25/02/2002
CONSTYPE	LFA
STATUS	Concession
SCALE	
PROVINCE	19

- **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]



Identify

Identify from: <Top-most layer>

Polygon

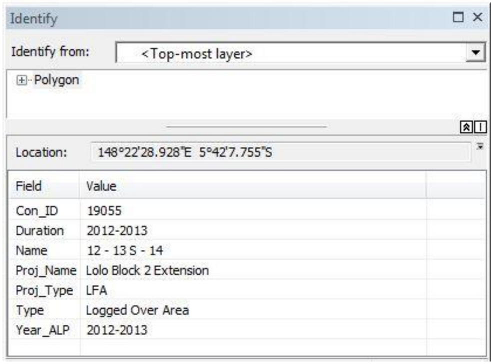
Location: 148°21'53.12"E 5°36'17.728"S

Field	Value
Con_ID	19055
Duration	2013 - 2014
Name	13 - 14 S - 24
Proj_Name	Lolo Block 2 Extension
Proj_Type	LFA
Type	Planned
Year_ALP	2013 - 2014

- **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]


Identify

Identify from: <Top-most layer>

Polygon

Location: 148°22'28.928"E 5°42'7.755"S

Field	Value
Con_ID	19055
Duration	2012-2013
Name	12 - 13 S - 14
Proj_Name	Lolo Block 2 Extension
Proj_Type	LFA
Type	Logged Over Area
Year_ALP	2012-2013

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 demarcation of forest areas		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		WNB ・Less interests among stakeholders ・Low level of ownership of Provincial Government on PFP ・Infrequent updating of geographical and resource information	WNB ・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	MLB ・Checking the License、Timber Permit、Minimum and Maximum Annual Allowable Cut(AAC)、facility construction WNB ・Checking the location of strip inventory line on site	WNB ・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	WNB ・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	MLB ・Comparing ALP with 5 year plan and Timber Permit WNB ・Checking the consistency between ALP and 5 Year Plan ・Verifying the positional relationship between maps and actual sites	WNB ・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)	WNB ・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	MLB ・Checking the marked trees and set-up boundaries in the field (selection of tree and felling direction) ・Checking the skidding track location	MLB ・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) WNB ・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 WSP ・Lack of resources (finance (vehicle, laptops and GPS) and manpower) and skill (GIS)	WNB ・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.

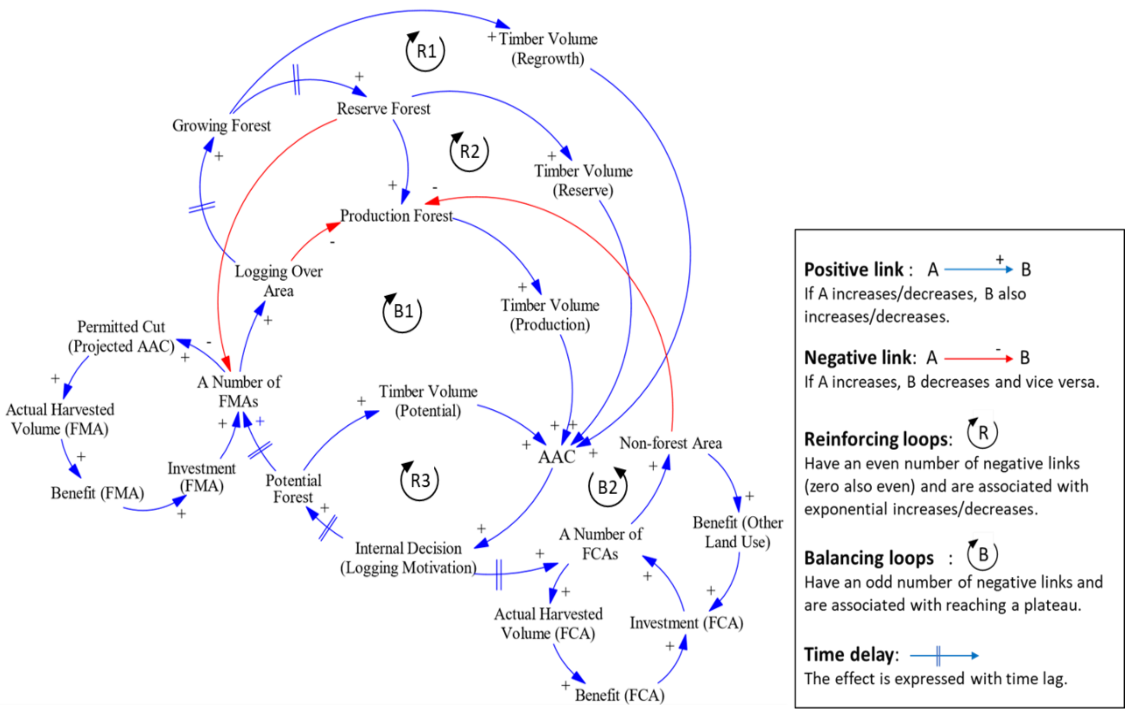


Figure 2.2.2: Causal loop diagram of the forest management cycle in PNG

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.

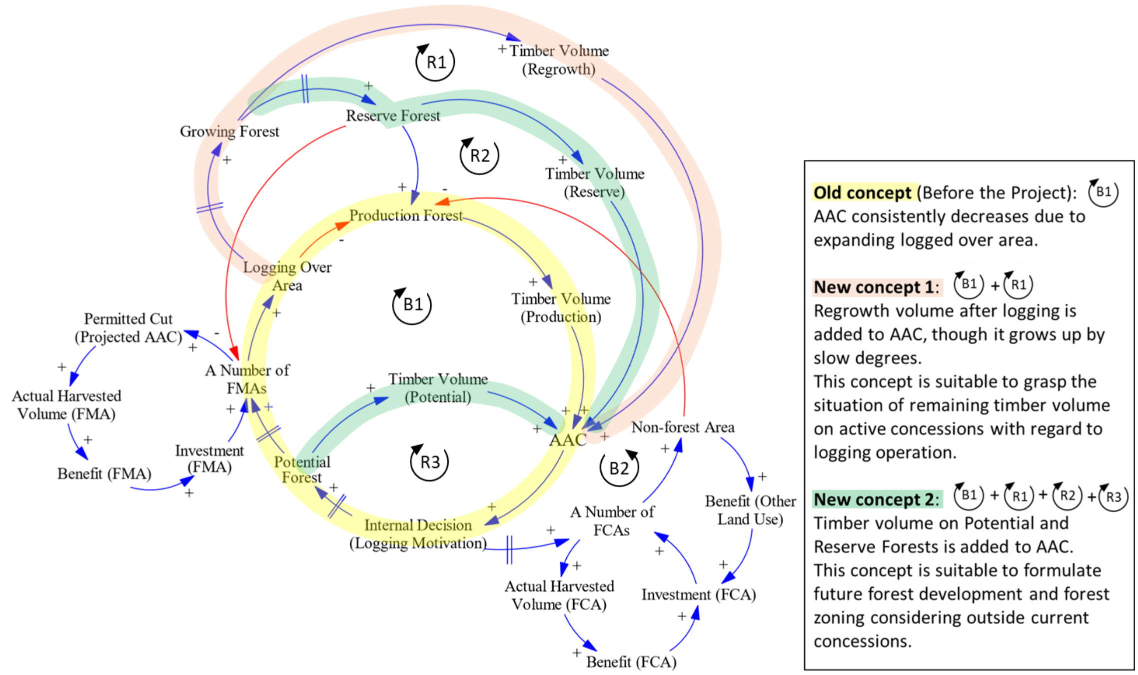


Figure 2.2.3: Before-after of the AAC calculation concept

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)

$$AAC = (Atotal - Alogged) * Vstandard \quad / 35 * 0.4$$

Adjusting index

New concept (The Project's output)

$$AAC = \{(Anet - Alogged) * Vstandard + Vregrowth\} / 35$$

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

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 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 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 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).

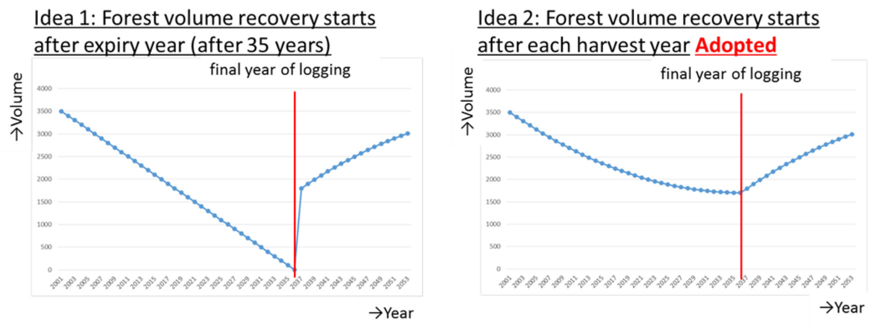


Figure 2.2.6: Timing of adding growing stock counting on AAC

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

Item			Description	Calculation Order
a	Total Land Area		The total area of Forest Base Map other than "Sea (code = Es)" by province. (b)+(h)+(i)	1
b	Gross Forest area		(c)+(d)+(e)+(g)	9
c	Production Forest		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>	6
	Total	Un-logged area	The total forest area in the operational concession areas that have not been harvested.	

<table>
<tr><th colspan="3">Item</th><th>Description</th><th>Calculation Order</th></tr>
<tr><td rowspan="8"></td><td></td><td>Logged-over area</td><td>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’.</td><td rowspan="8"></td></tr>
<tr><td rowspan="2">FMA</td><td>Un-logged area</td><td>The total forest area in the operational FMAs not covered by Logged Over Area.</td></tr>
<tr><td>Logged-over area</td><td>The total forest area in operational FMAs overlapping with Logged Over Area.</td></tr>
<tr><td rowspan="2">TRP</td><td>Un-logged area</td><td>The total forest area in the operational TRPs not covered by Logged Over Area.</td></tr>
<tr><td>Logged-over area</td><td>The total forest area in the operational TRPs overlapping with Logged Over Area.</td></tr>
<tr><td rowspan="2">LFA</td><td>Un-logged area</td><td>The total forest area in the operational LFAs not covered by Logged Over Area.</td></tr>
<tr><td>Logged-over area</td><td>The total forest area in the operational LFAs overlapping with Logged Over Area.</td></tr>
<tr><td>TA01</td><td>Logged-over area</td><td>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.</td></tr>
<tr><td rowspan="3">d</td><td colspan="2">Potential Production Forest</td><td>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".</td><td rowspan="3">7</td></tr>
<tr><td></td><td>Un-logged area</td><td>The total forest area in the proposed concession areas not covered by Logged Over Area</td></tr>
<tr><td></td><td>Logged-over area</td><td>The total forest area in the proposed concession areas overlapping with Logged Over Area</td></tr>
</table>

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 (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	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.

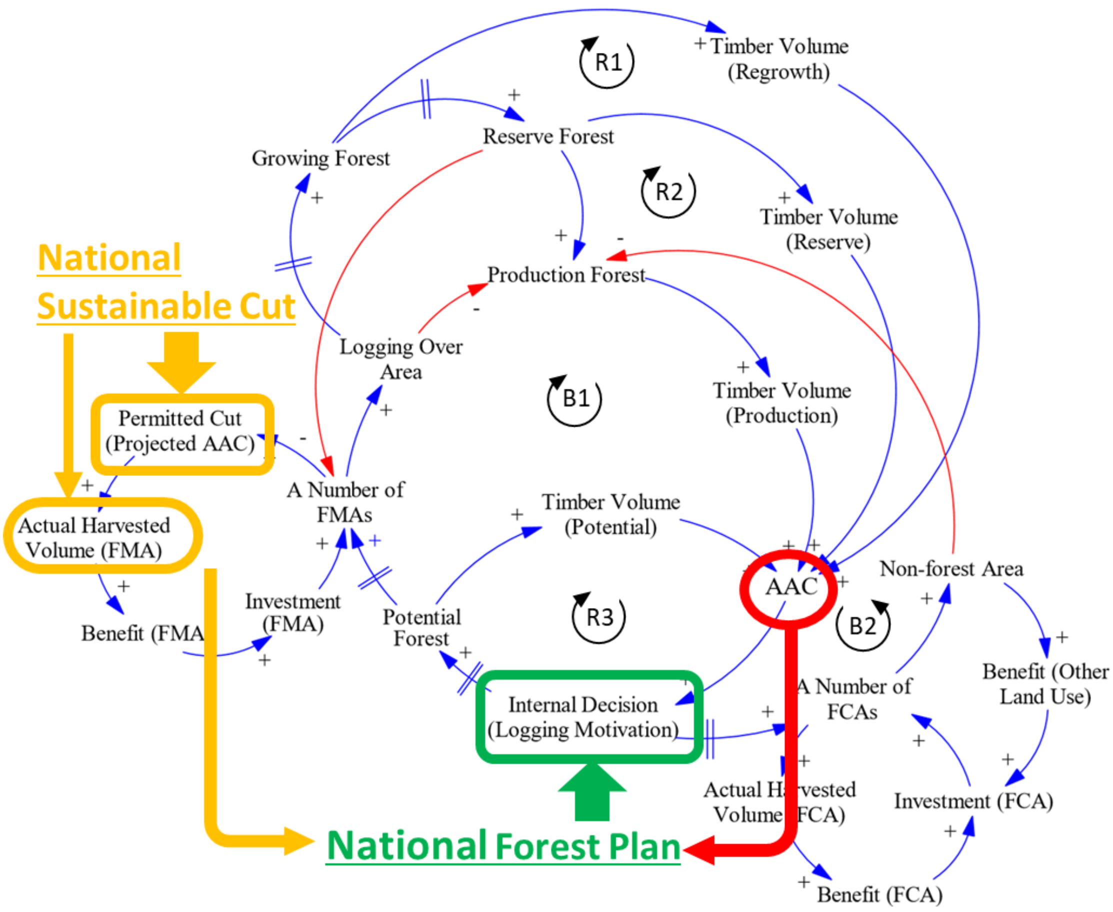


Figure 2.2.7: Role of AAC and Permitted Cut for the forest plannning

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.

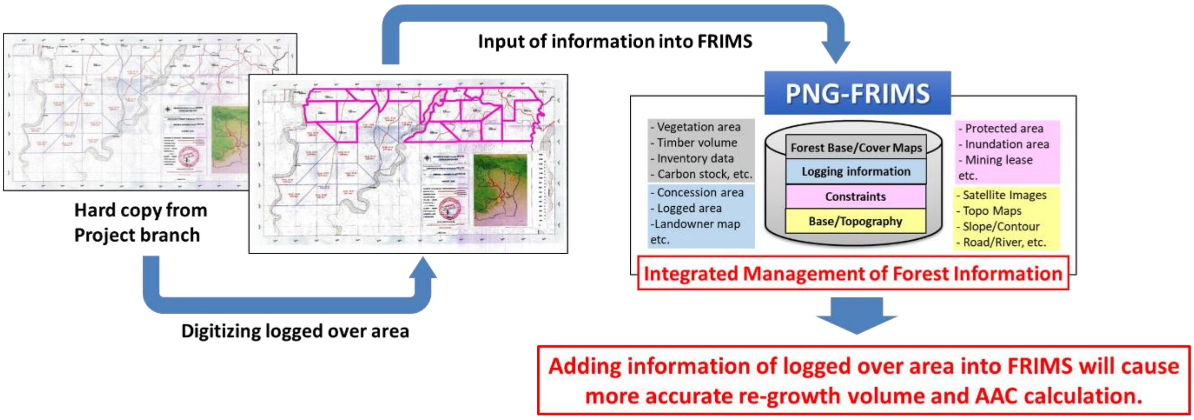


Figure 2.2.8: Digitizing logged over areas and stored it into PNG-FRIMS

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).

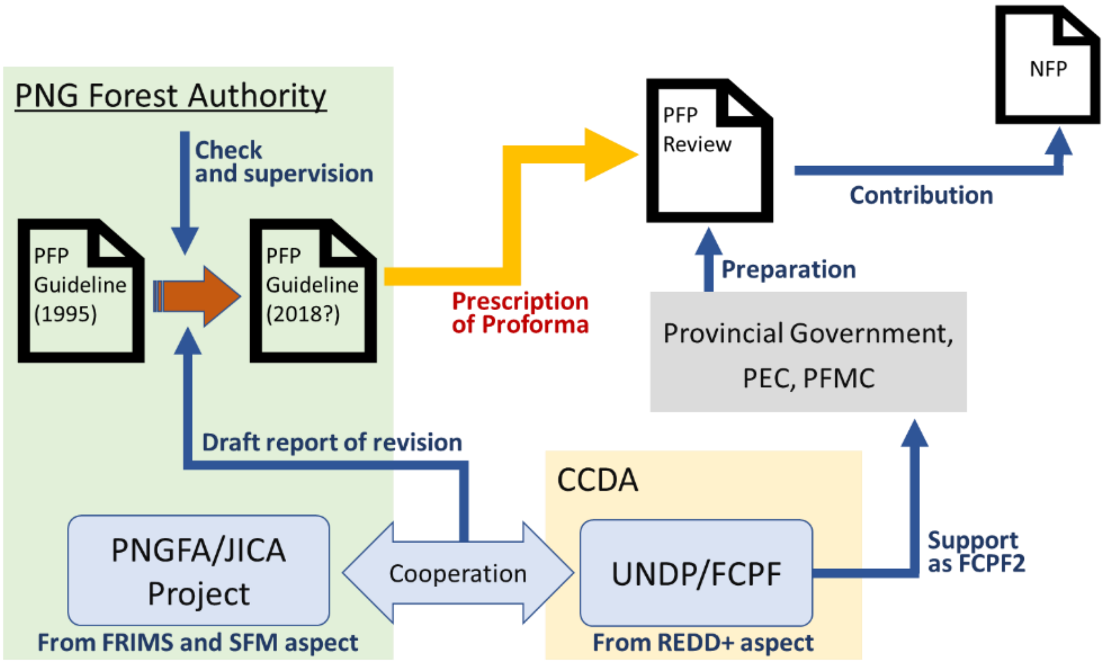


Figure 2.2.9: Scheme to support PNGFA in harmony with UNDP/FCPF Project

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.

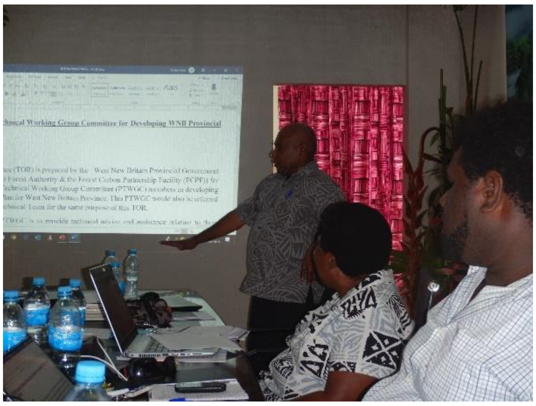
- **AAC**
  As mentioned above, AAC calculation method in PNG-FRIMS was updated. The more administrative information such as logging activities including logged over area are updated, the more its output in enhancing the credibility of AAC is improved. AAC by each province and by each project (or concession) 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.

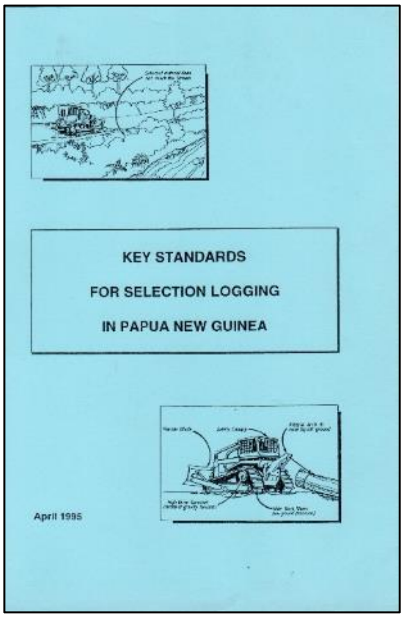
2.2.3 Systematic scheme of field monitoring/inspection for SFM

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

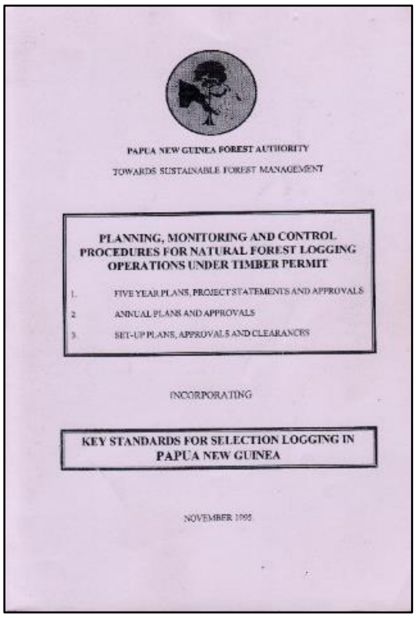


Key Standards, or Key Standards for selection logging in Papua New Guinea was published in collaboration with PNGFA and the department of environment and conservation (reorganized to CEPA in the present day) in April, 1995. Total of 24 standards which direct how logging operation should be conducted 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

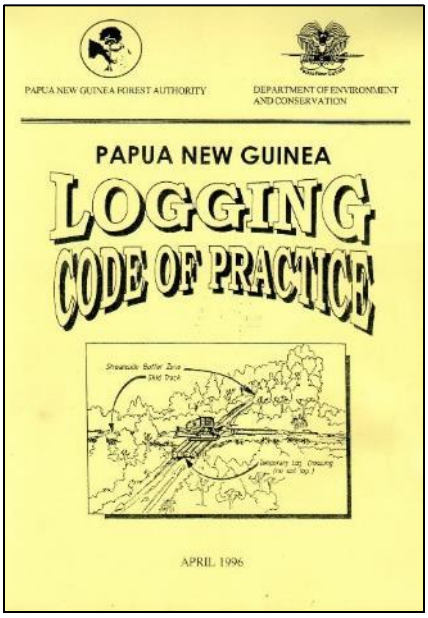


PMCP, or Planning, Monitoring and Control Procedures for natural forest logging operations under timber permit was issued in order to assist timber permit holders (or their logging contractors) and officers in PNGFA in November, 1995, because the responsibility for the management of the forestry sector 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.

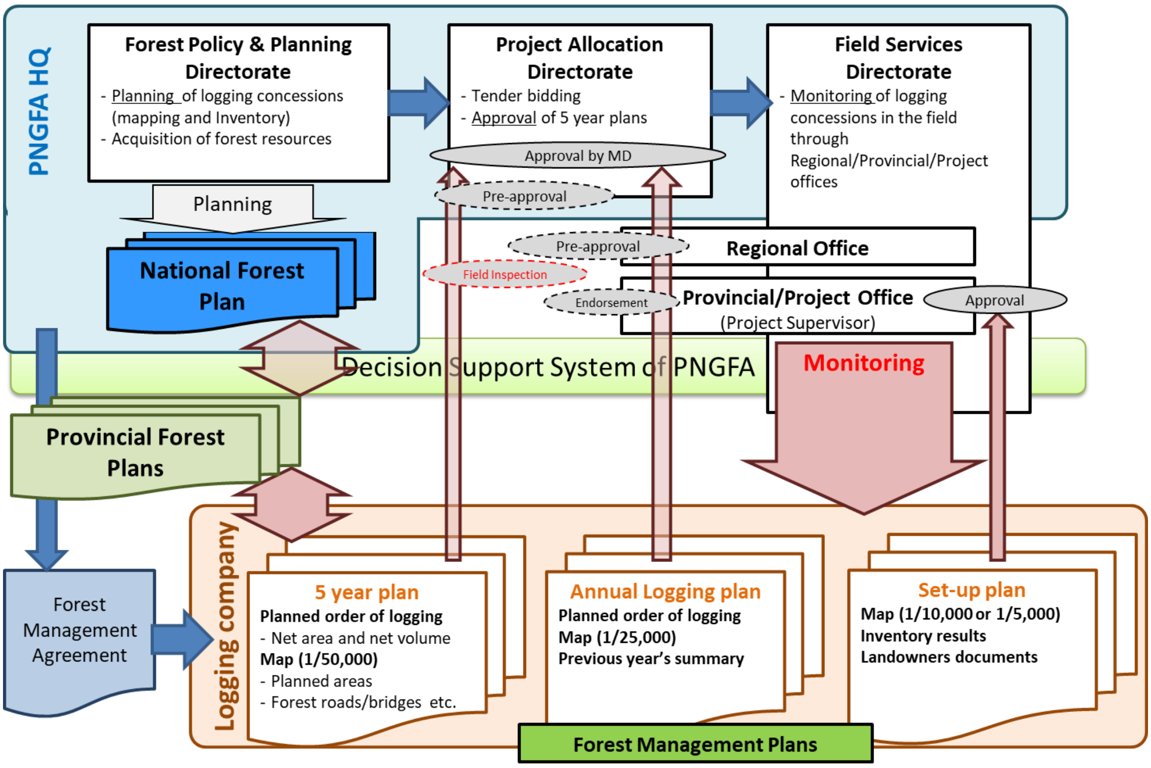


Figure 2.2.10: Procedure to approve forest management plans

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.*

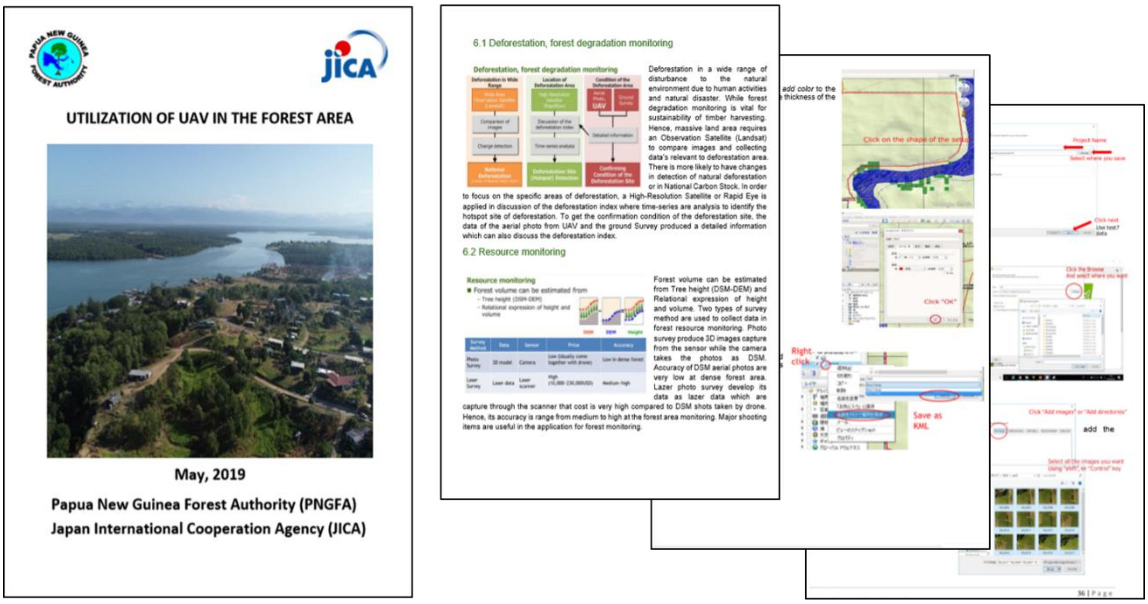
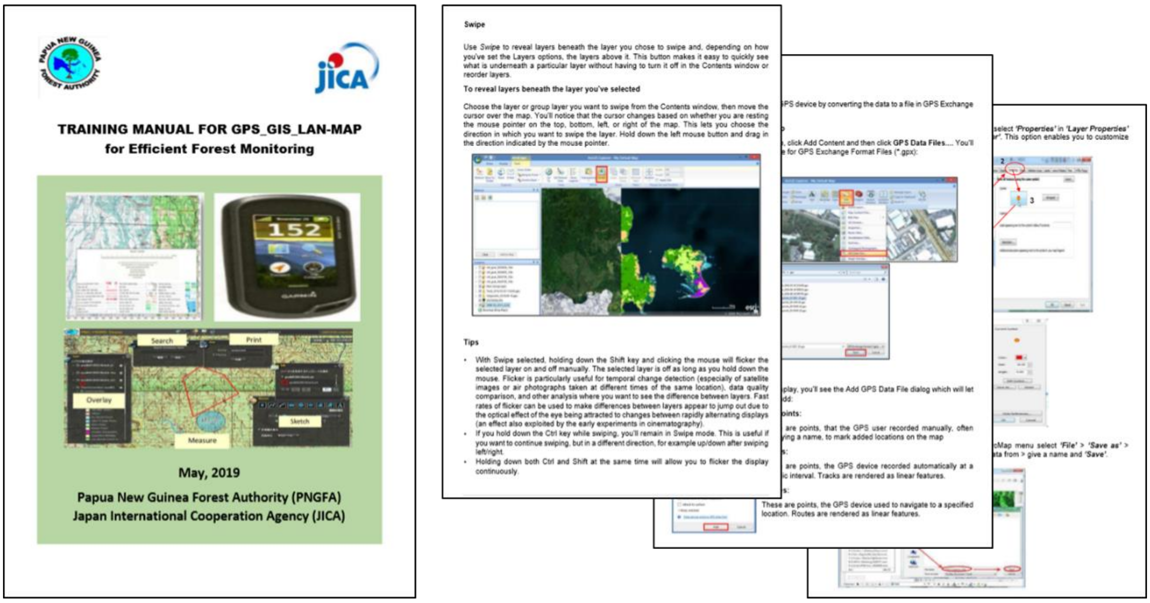


Figure 2.2.11: Manuals for GPS/GIS and drones (UAV)



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.

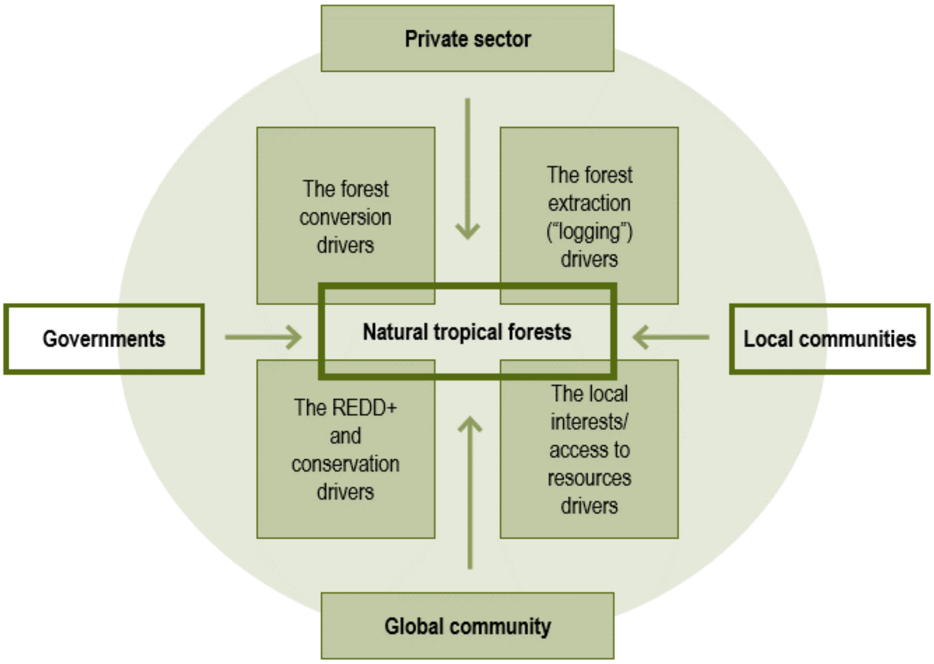


Figure 2.2.12: Various sectors with direct influence on sustainable management of forest

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	Drone s
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.

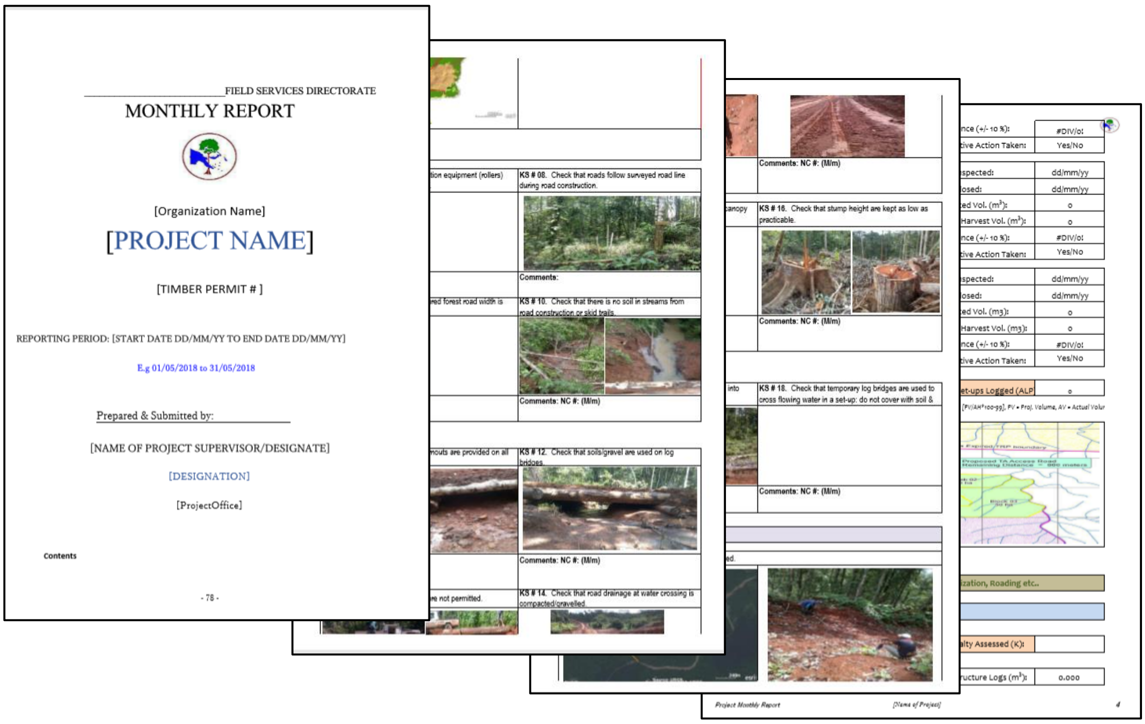


Figure 2.2.13: Reporting format to feedback the field inspection/monitoring result

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.

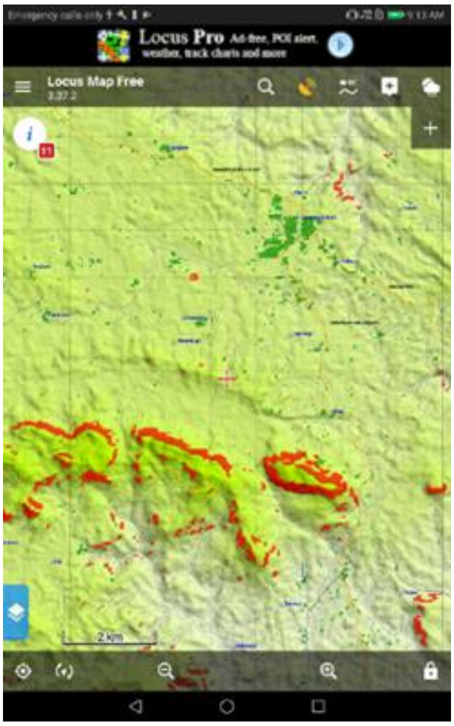


Figure 2.2.14: Locus map (Free version)

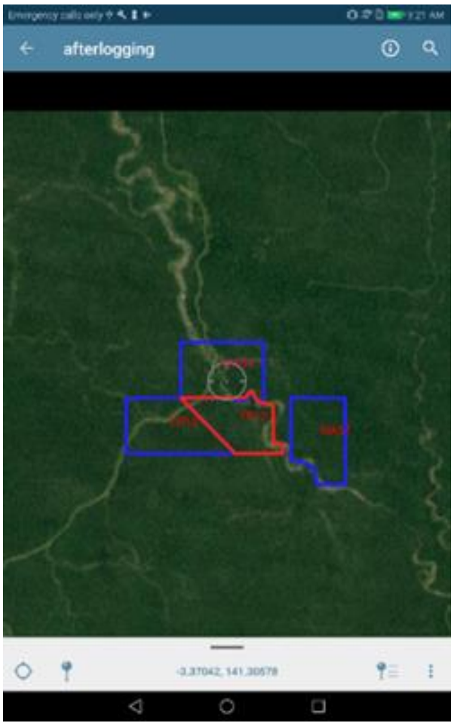


Figure 2.2.15: Avenza map (Free version)

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.

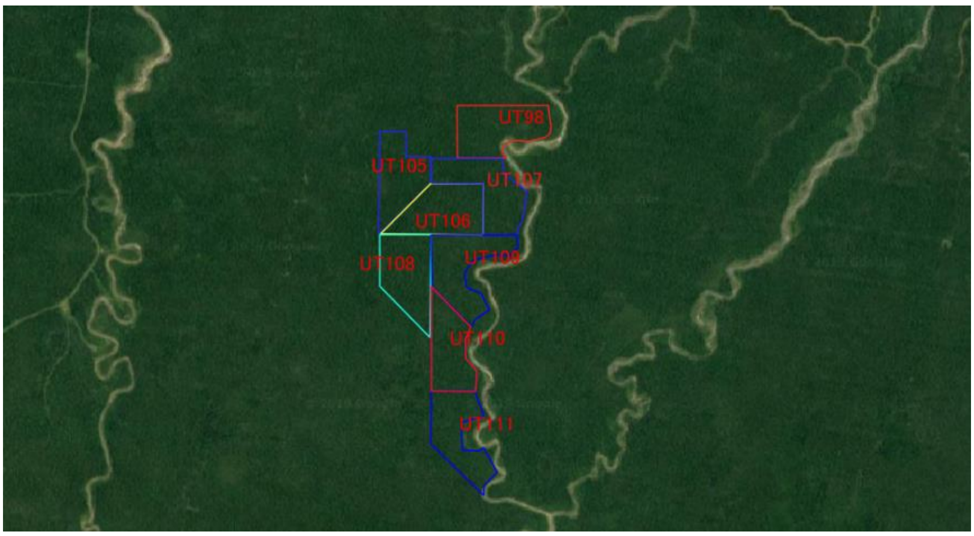


Figure 2.2.16: GeoTIFF data image used at this forest monitoring.

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.

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[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.

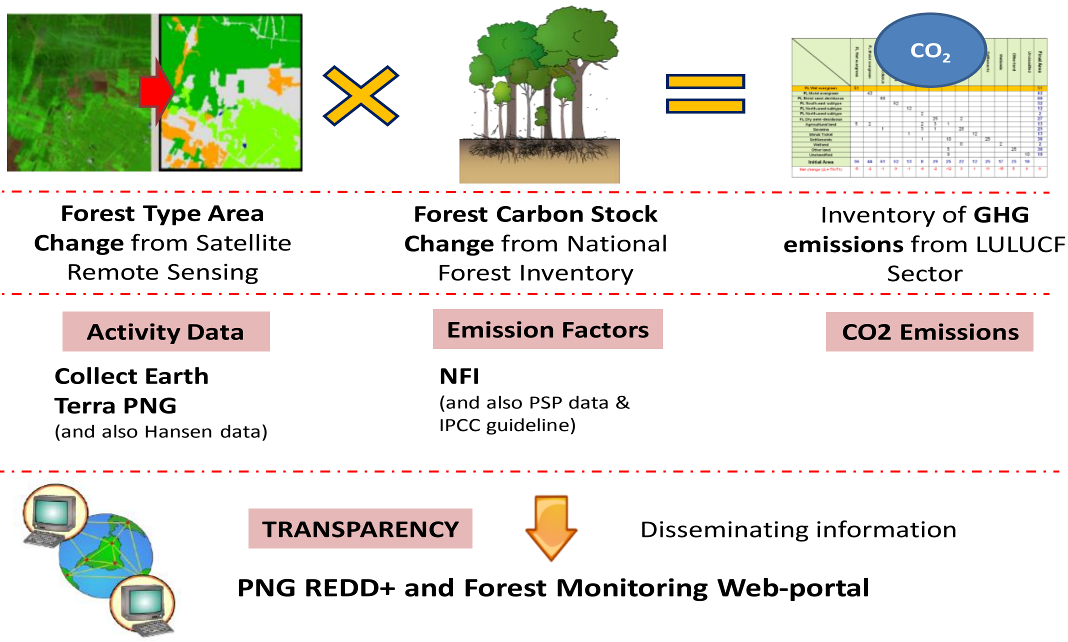

Figure 2.3.1: Calculation of emissions in the Forest reference Level of Papua New Guinea

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).

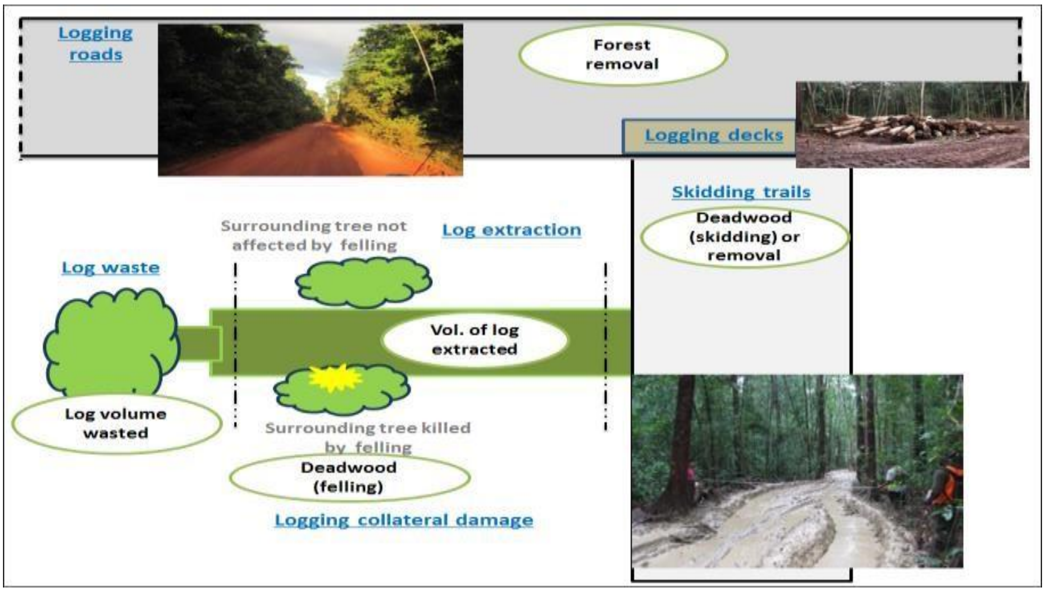

Figure 2.3.2: Main sources of emission from commercial logging

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.

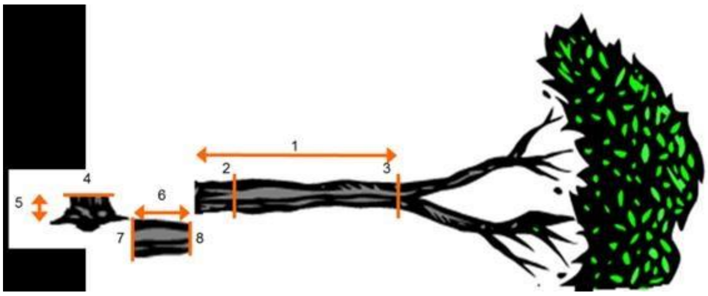

Figure 2.3.3: Inventory method to estimate extracted and wasted volumes

2- Felling deadwood: 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).

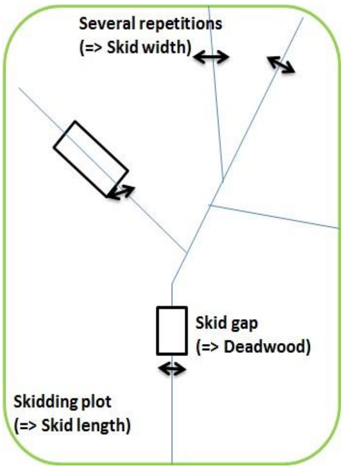

Figure 2.3.4: Sampling of skid trails

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

<u>Calculation</u>: *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).

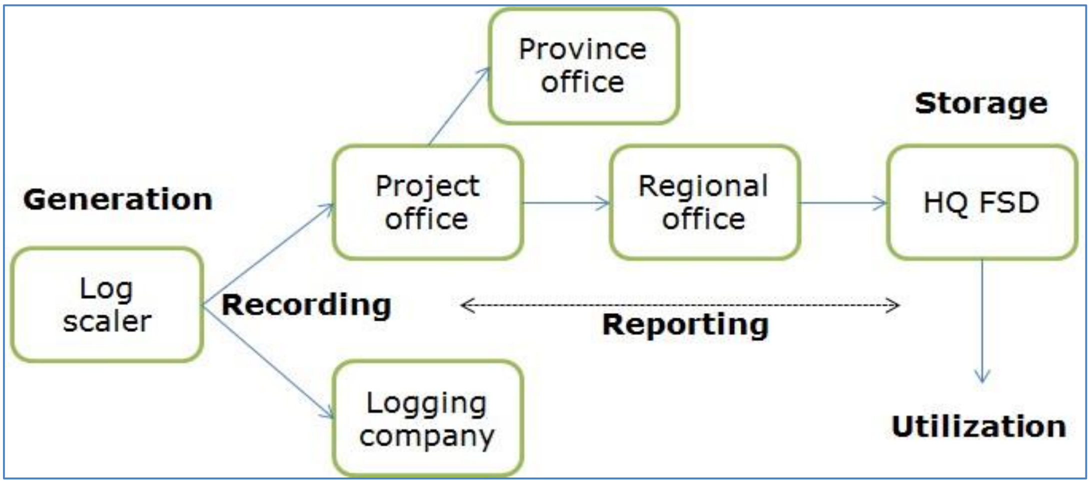

Figure 2.3.5: Flow of harvested volume data in PNGFA from scaler to central database

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	66904.831	45613.798	73028.000	49862.948	37812.894	
	TA 02-09	Eia River	340.618	264.610							

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	
1 Felling gap	Wasted logs	Log volume extracted from 1 gap
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).

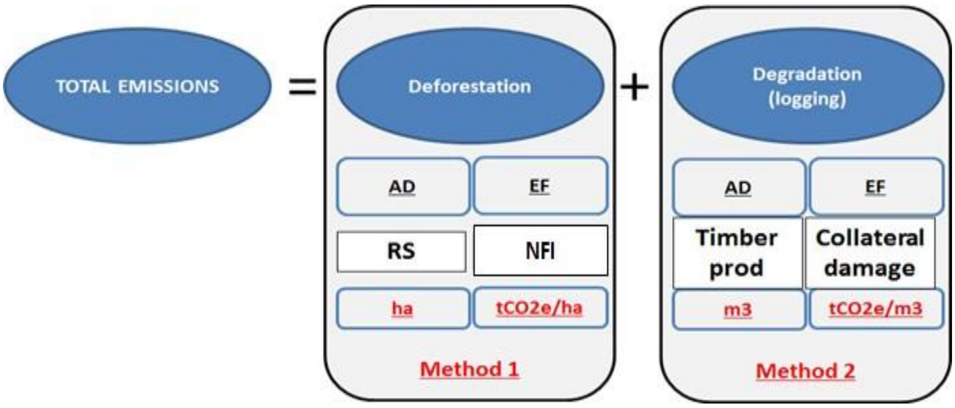

Figure 2.3.7: Estimation of emissions based on 2 distinct and complementary methods

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.

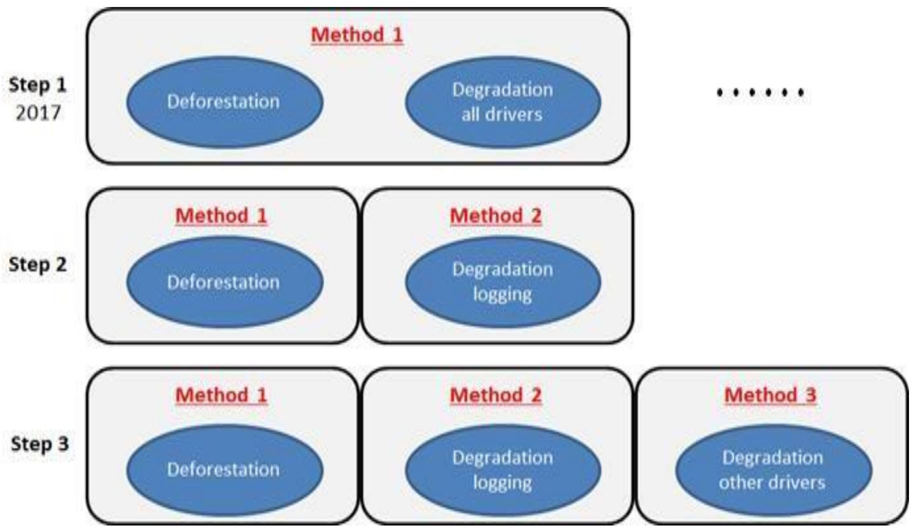

Figure 2.3.8: Possible step wise approach in FRL construction in PNG

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.

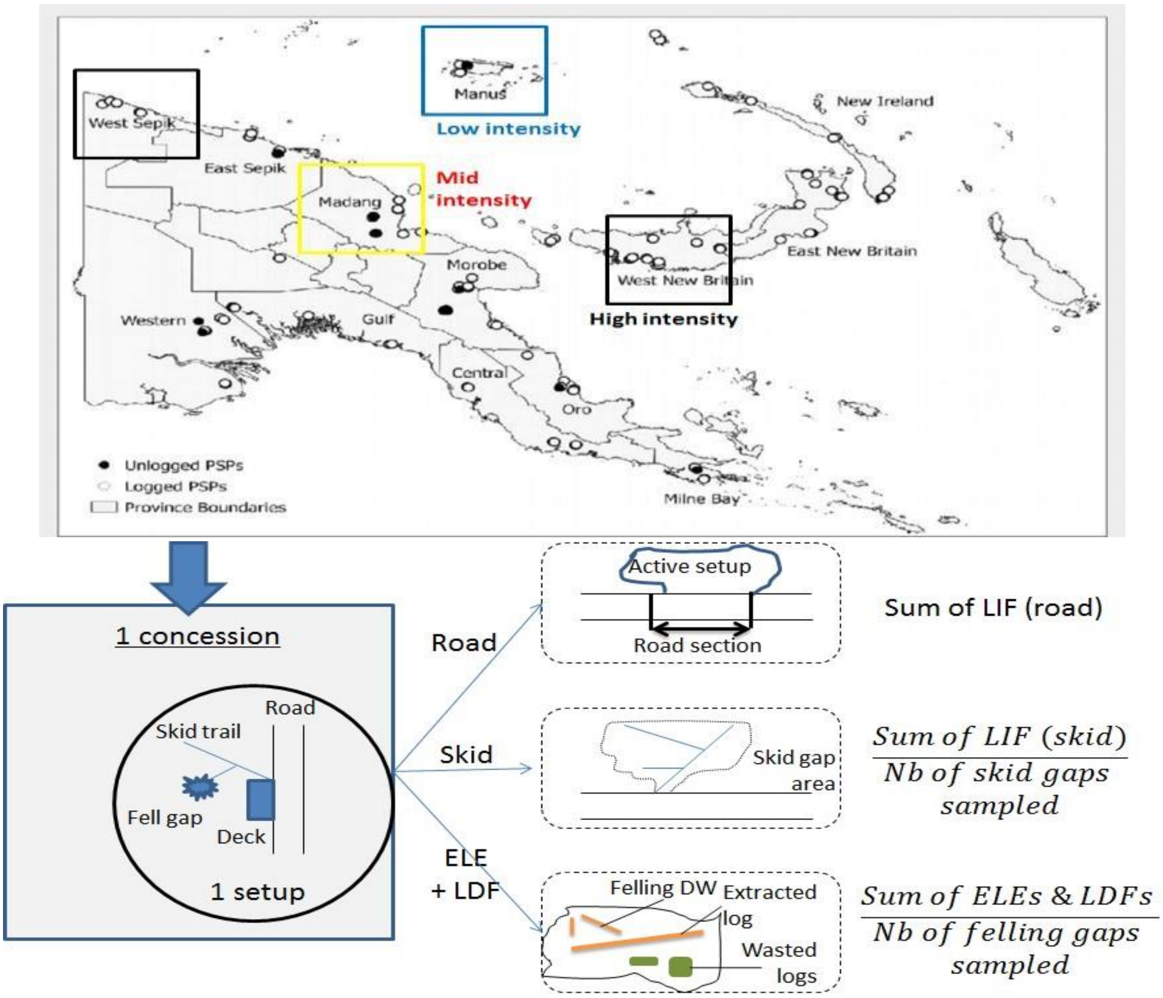

Figure 2.3.9: Proposition of plan for sampling field parameters to calculate total EF

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).

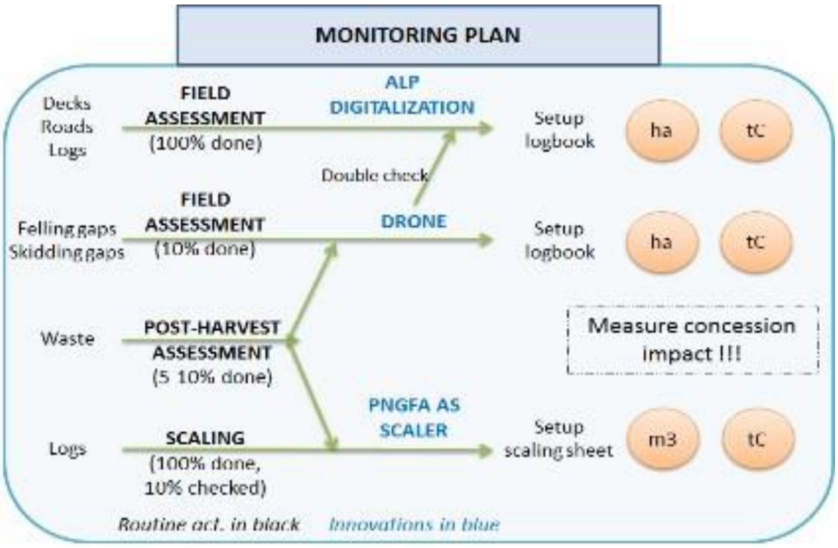

Figure 2.3.10: Carbon monitoring plan building on routine monitoring activities

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.

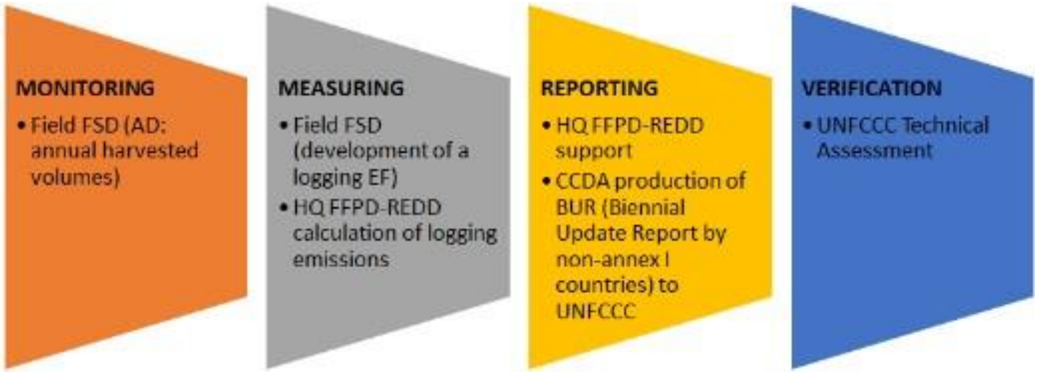

Figure 2.3.11: Possible Monitoring, Measuring, Reporting and Verification of logging

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.

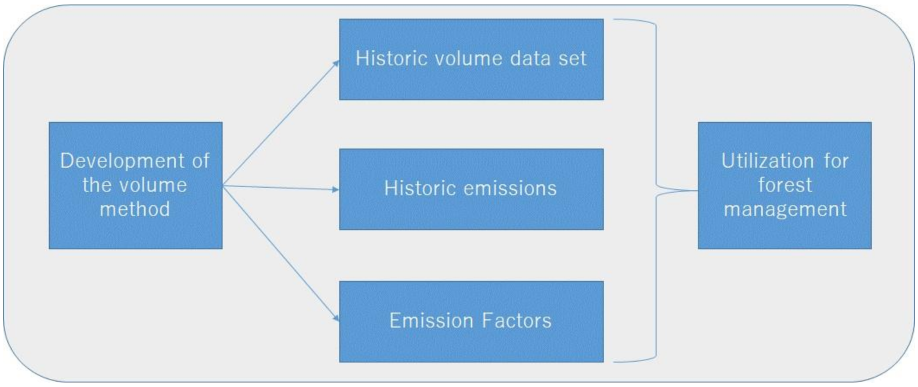

Figure 2.3.12: Main outcomes produced from the development of the Volume method

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.

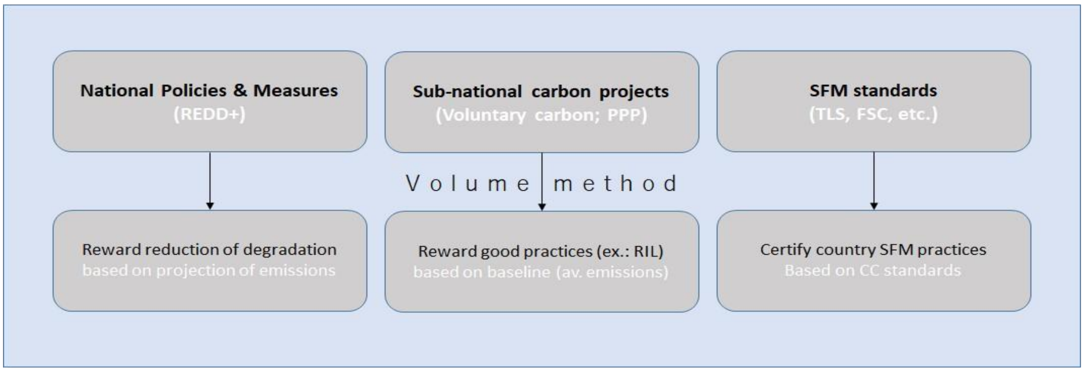

Figure 2.3.13: Contexts where and why it is needed to evaluate carbon impact of logging

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).

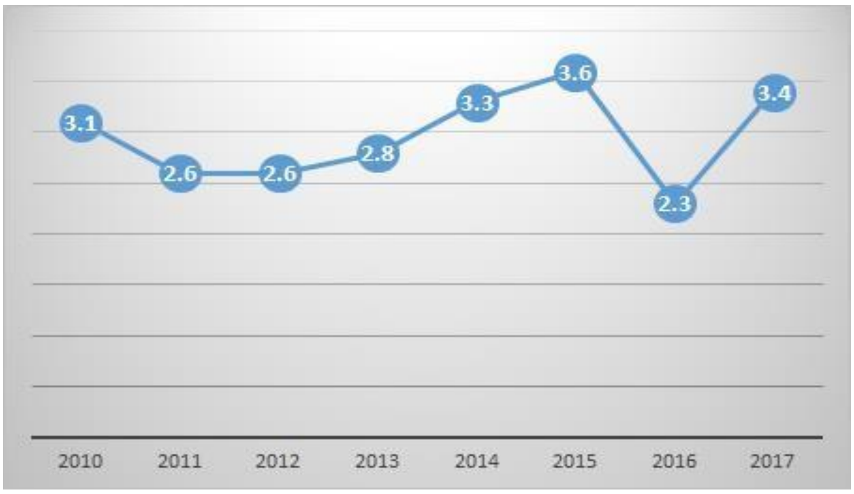

Figure 2.3.14: PNG total Forest production from 2010-17 (M m^3) (FCA excluded)

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.

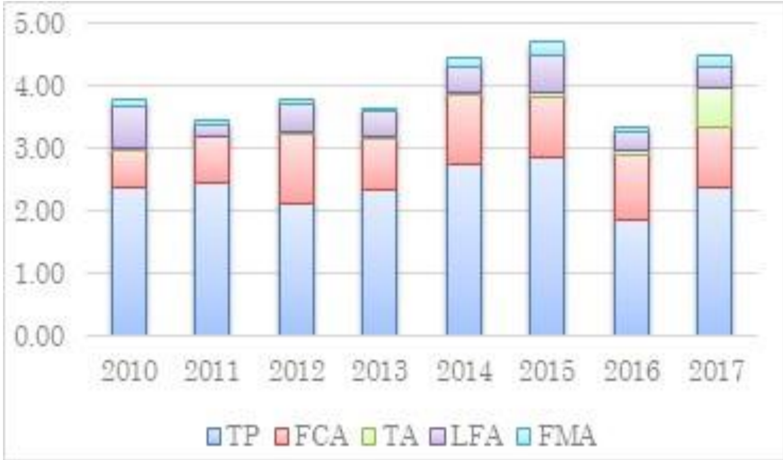

Figure 2.3.15: Evolution of timber production per cutting permit for period 2010-17 (M m^3)

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).

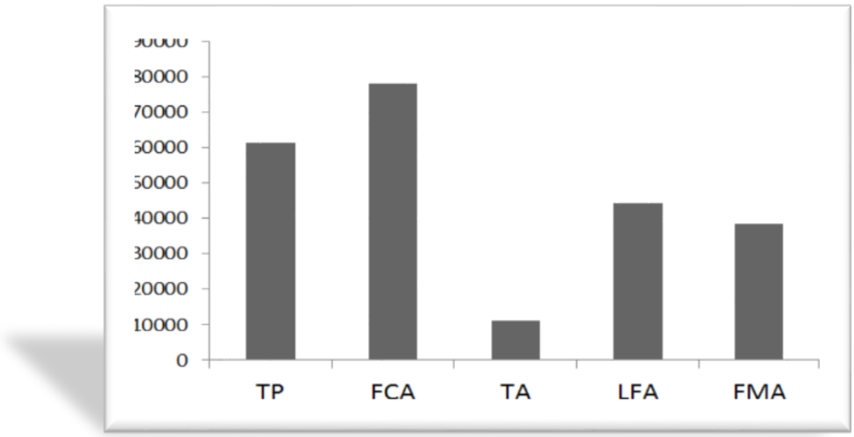

Figure 2.3.16: Mean project production for each permit type (m^3/project)

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.

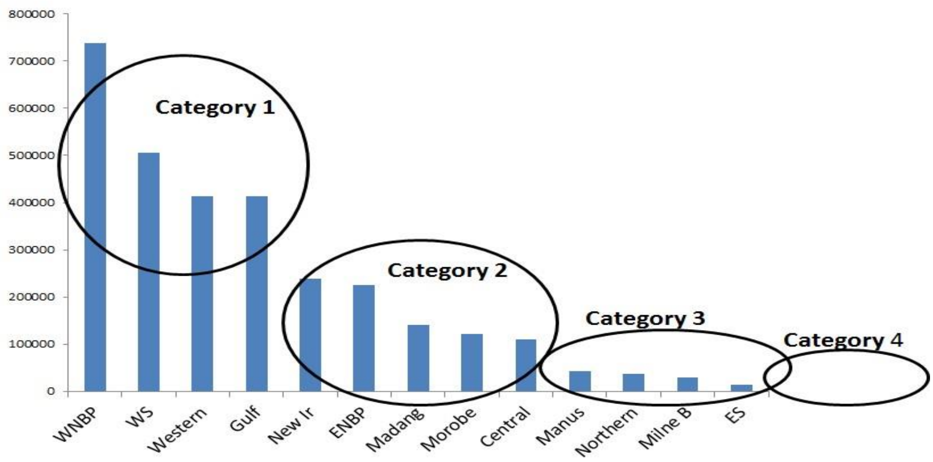

Figure 2.3.17: Mean annual (2010-17) production per province in m^3

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

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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.

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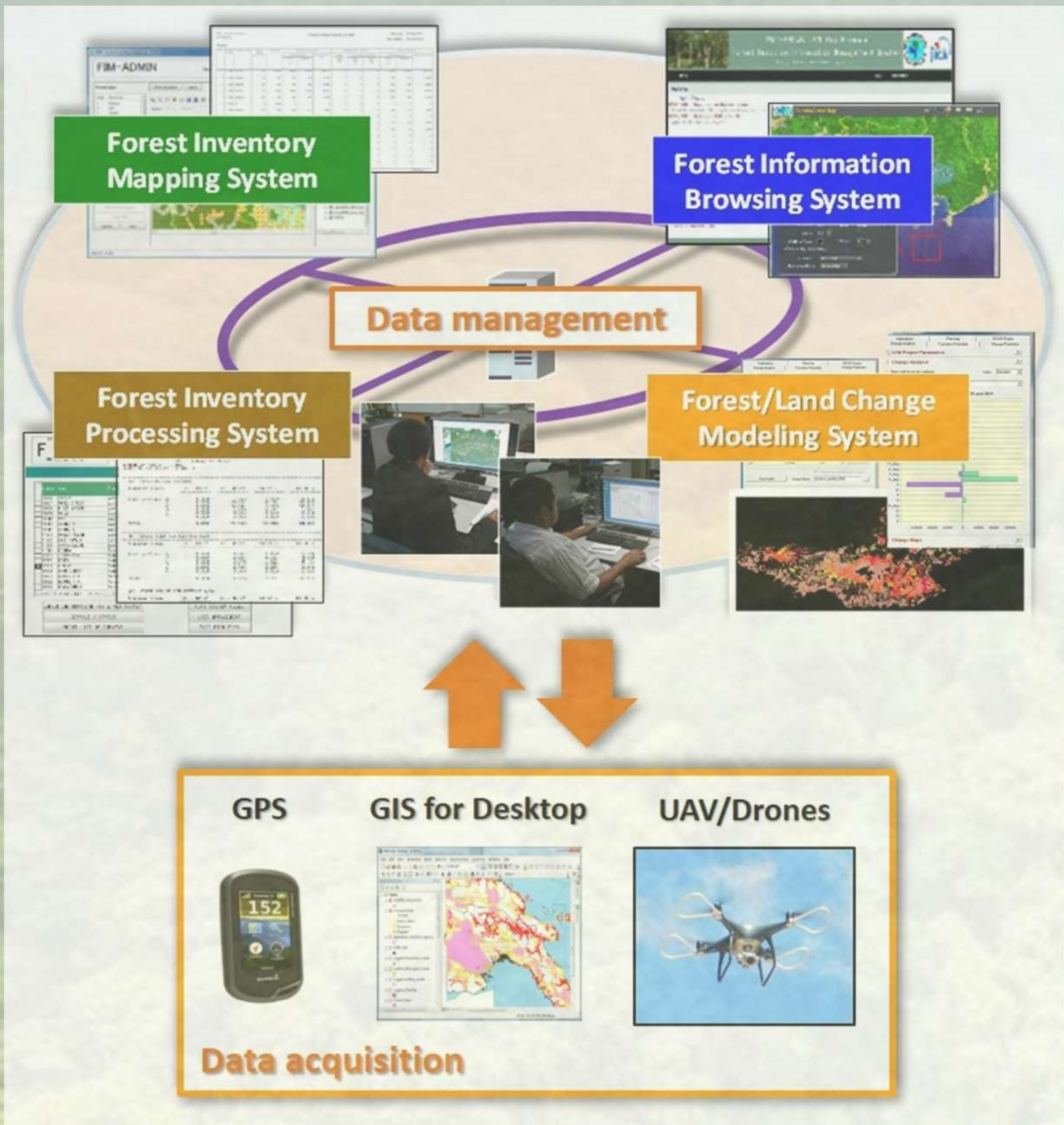

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