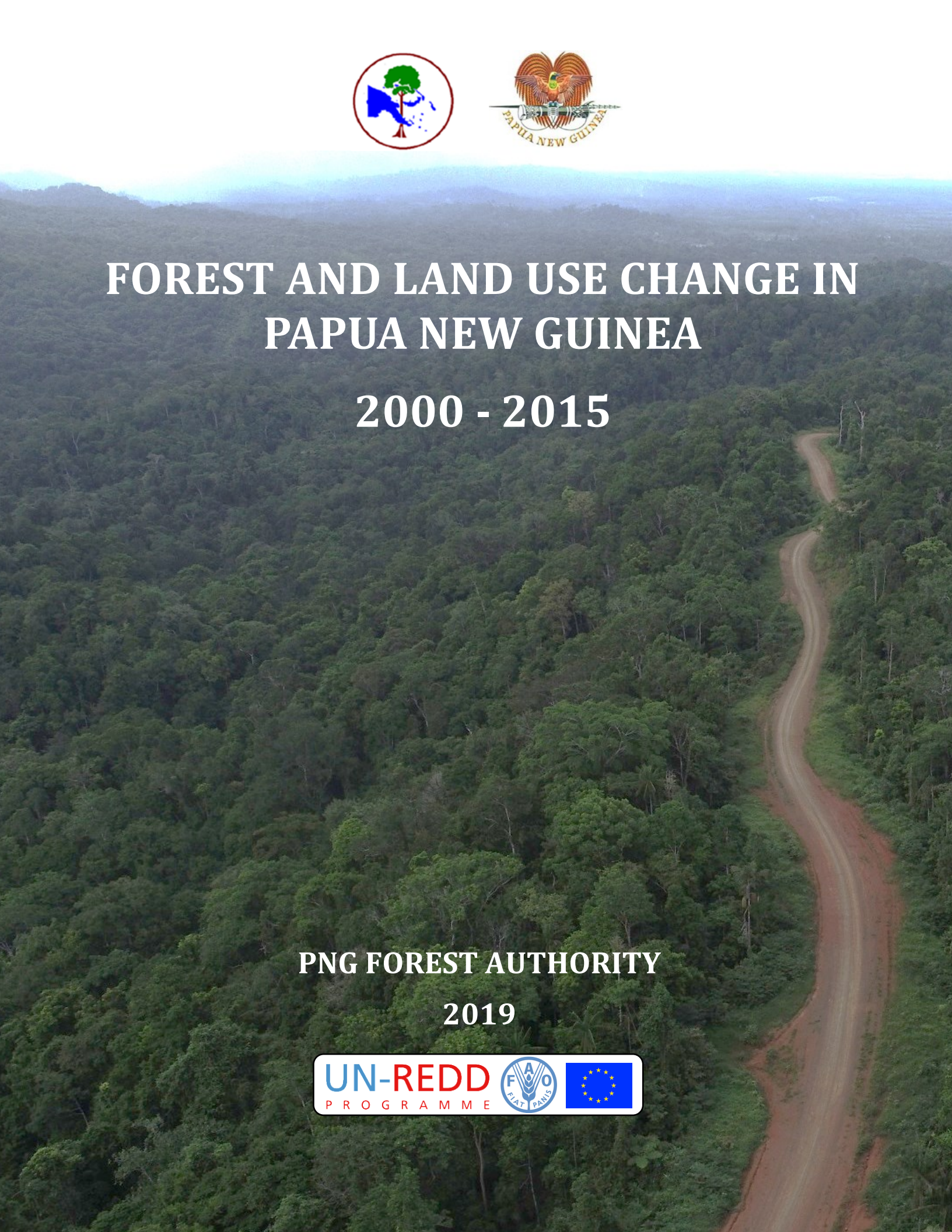

FOREST AND LAND USE CHANGE IN PAPUA NEW GUINEA

2000 - 2015

PNG FOREST AUTHORITY

2019

UN-REDD PROGRAMME

FOREST AND LAND USE CHANGE IN PAPUA NEW GUINEA

2000 - 2015

PNG FOREST AUTHORITY

2019

Aerial image of 'lowland altitude forests on plains and fans' in Lako forests, inland Aroma, Central Province (2019).

Forest and Land Use Change in Papua New Guinea 2000 - 2015

- The findings of Collect Earth assessment -

Compiled and published by Papua New Guinea Forest Authority and Food and Agriculture Organization of the United Nations

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Cover page image: Aerial view of Lako forest area, Inland Aroma, Central, PNG. Coutesy of FAO-NFI Project

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Aerial image of 'lowland altitude forests on plains and fans' in Upulima, inland Aroma, Central Province (2019).

Disclaimer

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Minister's Foreword

Hon. Solan Mirisim, MP

With the heightened concerns about global warming, Papua New Guinea (PNG) as a high forest cover country has and continues to engage in dialogues relating to appropriate actions that may contribute to the reduction of global warming. These dialogues include engaging with other partners (international and local) in undertaking specific project activities and in particular the implementation of a multi-purpose national forest inventory (better known as the National Forest inventory-NFI). The NFI for PNG started as part of the UN-REDD Program to PNG and is being supported under the European Union (EU) and implemented by the Food and Agriculture Organizations (FAO) with the Papua New Guinea Forest Authority (PNGFA) as the main local partner in overseeing the project implementation.

As part of the NFI project, a number of scholarships were awarded to PNG nationals to conduct specific studies into understanding the complex nature of the forest ecosystem in PNG. One of such studies was to get an update of the forest and land use change. It is crucial to have a good understanding of current status and trend of forest and land use change for sustainable management and development of the relevant sectors. This Report details the changes as assessed from 2000 to 2015 using the Open Foris Collect Earth approach through point sampling. Such information is vital for formulating of national policies and plans on forestry, agriculture, land, climate change and also for other sectors.

The data in this report was the primary source of information for PNG National REDD+ Strategy (2017-2027) and National Forest Reference Level (2018), which was submitted to United Nations Framework Convention on Climate Change (UNFCCC) in 2017 and the first Biennial Update Report (BUR) and REDD+ results report (BUR Technical Annex), which the estimation of the emissions from Land Use, Land Use Change and Forestry (LULUCF) sector is calculated using the information provided in this report. So in effect the data as contained in this report has significantly contributed to the formulation of national policies and other reports as mentioned above.

PNGFA is proud to disseminate the detail information on forest and land use change to the people of PNG and international community through this report. We will ensure periodic updates of the forest and land use changes in PNG and disseminate the information as it occurs.

Hon. Solan Mirisim, MP
Minister for Forestry

Acknowledgement

Many hours of hard work had gone into preparing the assessments and the resultant Report demonstrates 3 particular outcomes: (1) there are new technologies that can be applied to assist parties (countries) update their forest and land cover change at minimal cost; (2) engaging with international collaborators builds and enhance national human resources capacity; and (3) adequate financial support (both domestic and international) is paramount to a party fulfilling its obligations under an international convention – in this case, the Climate Change Framework Convention on Climate Change (UNFCCC).

With the funding support of the EU and the UN-REDD and the guidance of the FAO, PNG has conducted its Forest and Land Use Assessment as from 2000 to 2015. The assessments have shown that PNG has 78 % forest cover based on an agreed forest definition. This means that PNG has sufficient forest cover to enable it to engage more on how it can contribute at the global level in mitigating against global warming by applying the appropriate REDD+ activity without compromising the daily sustenance of its indigenous citizens and the sustainable development of the country. Printing of this publication was made possible by Global Environment Facility (GEF) – Capacity-building Initiative for Transparency (CBIT) project.

This publication is a contribution from PNGFA Policy and Planning Directorate and FAO-NFI project team, namely: Gewa Gamoga, Elizabeth Kaidong, Ruth Turia, Rabbie Lalo, Oala Iuda (FAO), Masamichi Haraguchi (FAO) and Hitofumi Abe (FAO). The team would like to thank Alfonso Sánchez-Paus Díaz (FAO-Rome) and Danilo Molicone (FAO-Rome) for technical guidance on Collect Earth tool. The data in this report also benefited from the assessment work that was conducted by other PNGFA officers (36 altogether) whose names appear in Appendix 12 and Appendix 13.

Google Earth Image with Collect Earth sampling plots around Garu Oil Palm plantations area, West New Britain Provine, PNG.

Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
ASTER	Advanced Space borne Thermal Emission and Reflection Radiometer
CO_2	Carbon Dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organization
ETM+	Enhanced Thematic Mapper Plus
EU	European Union
FAO	Food and Agriculture Organization of United Nations
FCA	Forest Clearance Authority
FIMS	Forest Information Management System
FMA	Forest Management Area
FOSS	Free Open Source Software
GEE	Google Earth Engine
GHG	Greenhouse Gas
GIS	Geographic Information System
GPG	Good Practice Guidelines
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LFA	Local Forest Area
LUCAS	Land Use Land Cover Area-frame Survey
LULUCF	Land Use and Land Use Change and Forestry
MODIS	Moderate Resolution Imaging Spectro-radiometer
NDA	National Designated Authority
NDC	National Determined Contribution
NEC	National Executive Council
NFMS	National Forest Monitoring System
NGO	Non- Government Organization
OLI	Operational Land Imager
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
PNGRIS	Papua New Guinea Resource Information System
REDD+	Reducing Emissions from Deforestation and forest Degradation, plus the sustainable management of forests, and the conservation and enhancement of the forest carbon stocks
RS	Remote Sensing
SPOT	Satellite Pour l'Observation de la Terre (Satellite for observation of Earth)
TA	Timber Authority
TM	Thematic Mapper
TOR	Top of Atmosphere Reflectance
TRP	Timber Rights Permit
UNFCCC	United Nations Framework Convention on Climate Change

UNREDD	United Nations Reduce Emissions from Deforestation and forest Degradation Program
UMD	University of Maryland
USA	United States of America
VHR	Very High Resolution

Aerial image of disturbed 'mangrove forest' near Lea Lea, Hiri, Central Province (2019).

Executive Summary

Papua New Guinea (PNG) shares the eastern portion of the island of New Guinea with West Papua – a Province of Indonesia covering the western portion. The island is said to embrace the third largest tropical rainforest after the Amazon and Congo Basin and is well-known for its biological endemism and species diversification. Despite their extent, size and rich diversity, PNG forests are poorly known scientifically.

About 97% of land in PNG is under customary tenure. Forests belong to the people and the majority of population rely directly on forest for their living in many ways. Forestry is one of the major industries in the country and contributing significantly to national economy and formal employment. Accurate information of the forest status and change is essential for sustainable management of the nation's forest. Forest also plays important roles for addressing climate change both in mitigation and adaptation. PNG's Nationally Determined Contribution (2015) states that primary mitigation effort lies in reducing emissions from land use change and forestry by reducing deforestation and promoting forest conservation. Effective forest monitoring is crucial for realizing it.

This publication reports the outcomes of the study assessing the current forest status and land use, their annual change between 2000 and 2015 in national scale with great detail. This is the first report providing annual forest and land use change in the country. Taking full recognition of the PNG forest definition, the systematic point-based sampling approach was applied with Collect Earth, a free open source GIS software including freely available satellite images were used. For the entire PNG landmass, this involved a sampling intensity of 0.04 x 0.04 degree grid (4.44 km x 4.44 km) and 0.02 x 0.02 degree grid (2.22 km x 2.22 km) for provinces having less than 500,000 hectares of landmass. A total of 25,279 sample points were assessed.

The assessment has shown that PNG is still extensively covered by forest than previously estimated. In 2015 there was 77.97% forest land followed by cropland (11.18%), grassland (5.27%), settlement (0.84%), wetland (4.61%) and other land covering only 0.13%. Table ES-1 shows the composition of land use category areas for the country in hectares.

Table ES-1: PNG Land Use Composition in 2015.

Land use category	Area (ha)	%
1. Forest Land	35,963,273	77.97
2. Cropland	5,158,633	11.18
3. Grassland	2,442,680	5.27
4. Wetlands	2,126,505	4.61
5. Settlements	388,495	0.84
6. Other Land	59,277	0.13
Total:	**46,138,863**	**100.00**

PNG's forest is dominated by three forest types which are *low altitude forest on uplands, low altitude forest on plains and fans*, and *lower montane forest* (Table ES-2). According to this study, 76.3% of the forest is still intact or not been disturbed by anthropogenic activities (human induced activities). Most of the forest disturbance or forest degradation (Figure ES-1) is caused by commercial logging (10.8%) followed by gardening (8.3%), fire (3.1%) and others 1.3%. Commercial logging is common in *low attitude forest on plains and fans* and *low altitude forest on uplands*. About 80% of commercial logging occur in Western, Gulf, WNB, ENB and West Sepik Provinces. Gardening occur throughout and are dominant in the three major forest types. The occurrences of fire are also common in all forest types however they are prevalent in savanna, woodland and scrub forests.

Table ES-2: Forest types and area in hectares.

Forest types	Area (ha)	%
Low altitude forest on plains and fans	8,927,359	24.82
Low altitude forest on uplands	11,127,733	30.94
Lower montane forest	8,005,831	22.26
Montane forest	390,815	1.09
Dry seasonal forest	2,351,310	6.54
Littoral forest	146,226	0.41
Seral forest	320,540	0.89
Swamp forest	2,462,788	6.85
Savanna	623,889	1.73
Woodland	1,055,764	2.94
Scrub	220,161	0.61
Mangrove	281,850	0.78
Eucalyptus Plantation	17,637	0.05
Balsa Plantation	3,922	0.01
Araucaria Plantation	9,764	0.03
Pinus Plantation	7,809	0.02
Acacia Plantation	5,964	0.02
Terminalia Plantation	3,913	0.01
	35,963,273	100.00

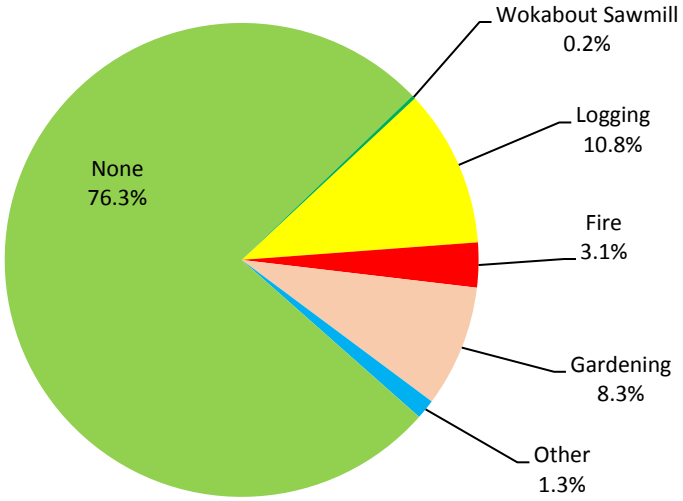


Figure ES-1: Human impact on forest land.

Majority of PNG's cropland is subsistence agriculture which consist of both permanent and shifting cultivation covering about 88.8% of the total cropland area. The commercial agriculture include tea, cocoa, oil palm, cocoa, coconut, sugarcane and rubber. comprises 11.2% of cropland. The most dominant commercial agriculture is oil palm plantation, which comprises 6.3% of cropland followed by coconut plantation (2.8%), coconut intercropped with cocoa (0.8%) and coffee plantation (0.5%) (Table ES-3).

Monoculture plantations are not common major land use in PNG except oil palm and coconut plantations. Table ES-3 shows the composition of cropland, settlement, grassland, wet land and other land.

Table ES-3: Land use composition of cropland, grassland , settlement, wetland and other land.

Land use	Subtype	Subdivision	Area (ha)	%
Cropland	Subsistence agriculture	Permanent	1,109,668	21.51
		Shifting	3,423,186	66.36
	Commercial agriculture	Tea	2,955	0.06
		Coffee	29,472	0.57
		Oil palm	325,896	6.32
		Cocoa	13,796	0.27
		Coconut	143,789	2.79
		Cocoa/Coconut	43,267	0.84
		Rubber	11,697	0.23
		Sugar	7,881	0.15
	Not identified	Other	17,606	0.34
		Not Sure	29,419	0.57
		Total:	***5,158,633***	***100.00***
Settlement		Village	233,492	60.10
		hamlet	48,018	12.36
		Large Settlement	54,013	13.90
		Infrastructure	52,972	13.64
		Total:	***388,495***	***100.00***
Grassland		Herb land	1,894,376	77.55
		Rangeland	111,188	4.55
		Others	437,116	17.89
		Total:	***2,442,680***	***100.00***
Wetland		River	444,102	20.88
		Lake	253,541	11.92
		Dam	3,901	0.18
		Nipa Swamp	190,817	8.97
		Other Swamp	1,234,144	58.04
		Total:	***2,126,505***	***100.00***
Other land		Bare	20,560	0.41
		Sand	7,882	0.16
		Rock	30,836	0.61
		Total:	***59,277***	***100.00***
			5,016,957	

Between 2000 and 2015, a total of about 253,847 hectares or 0.71% of the total forest area was deforested. Almost all deforestation (99.5%) was forest converted to cropland. Subsistence agriculture was the most significant driver causing 63.6% (154,145 hectares) of deforestation

followed by oil palm (32.0%, 81,201 hectares). All other agriculture plantations caused very minor portion of deforestation (3.1%) (Figure ES-4). Deforestation was increasing in recent years (Figure ES-5). Average annual deforestation rate between 2000 and 2010 was 0.03% but this was significantly increased to 0.08% between 2011 and 2015 (Appendix 3). Highest rate of deforestation occurred in West Sepik province, which recorded more than double of deforestation in any other province in the country (Figure ES-4). Most of oil palm plantation development occurred in three provinces (West Sepik, West New Britain and East New Britain).

During the same period a total of 2.3 million hectares or 6.6% of the total forest area was disturbed by antholopogenic activities. Logging was far most dominant (92%) cause of forest disturbance. Forest disturbance was not an increasing trend in recent years (Figure ES-6) but occurring much larger when compared to deforestation.

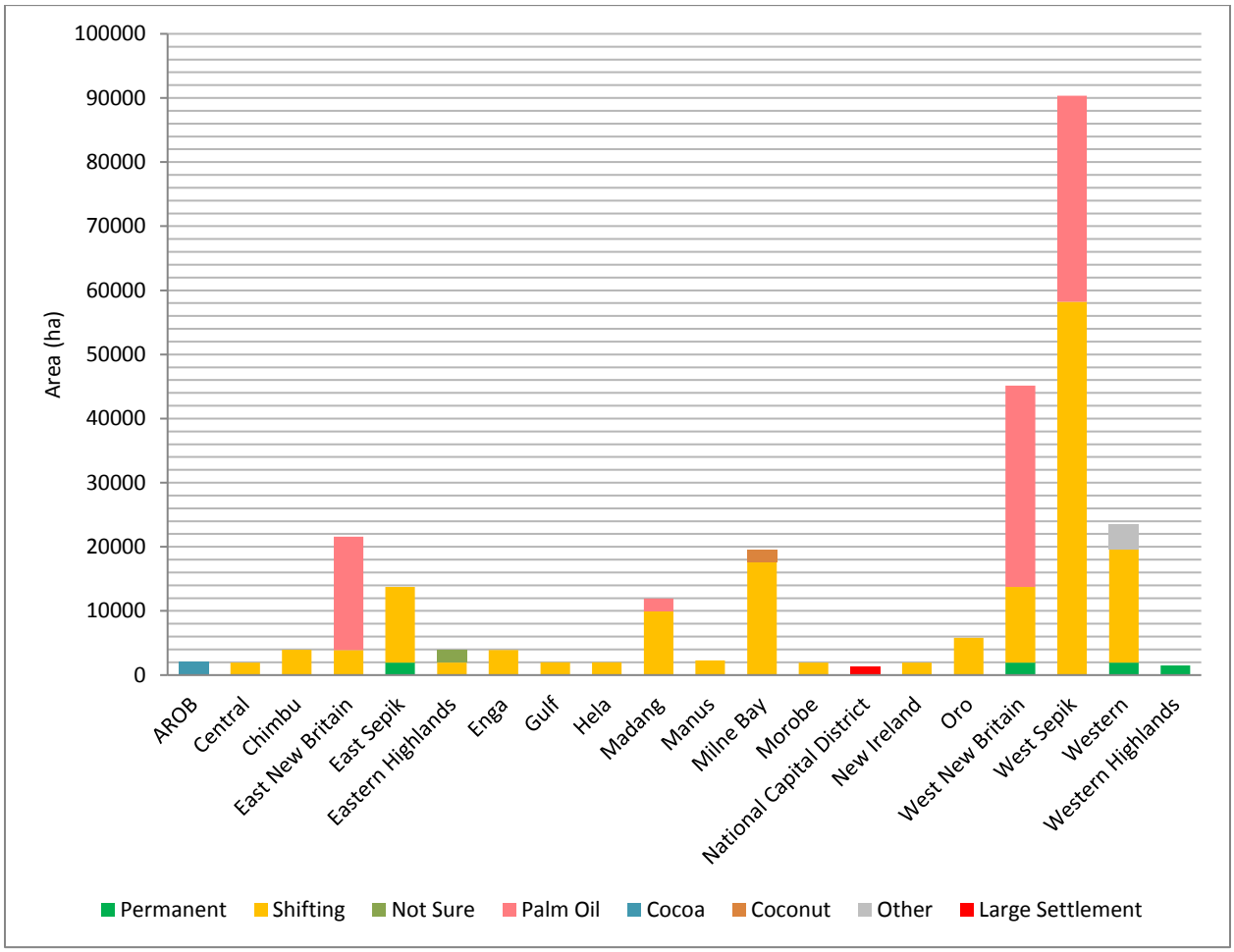


Figure ES-4: Forest converted to cropland types in Provinces between 2000 and 2015.

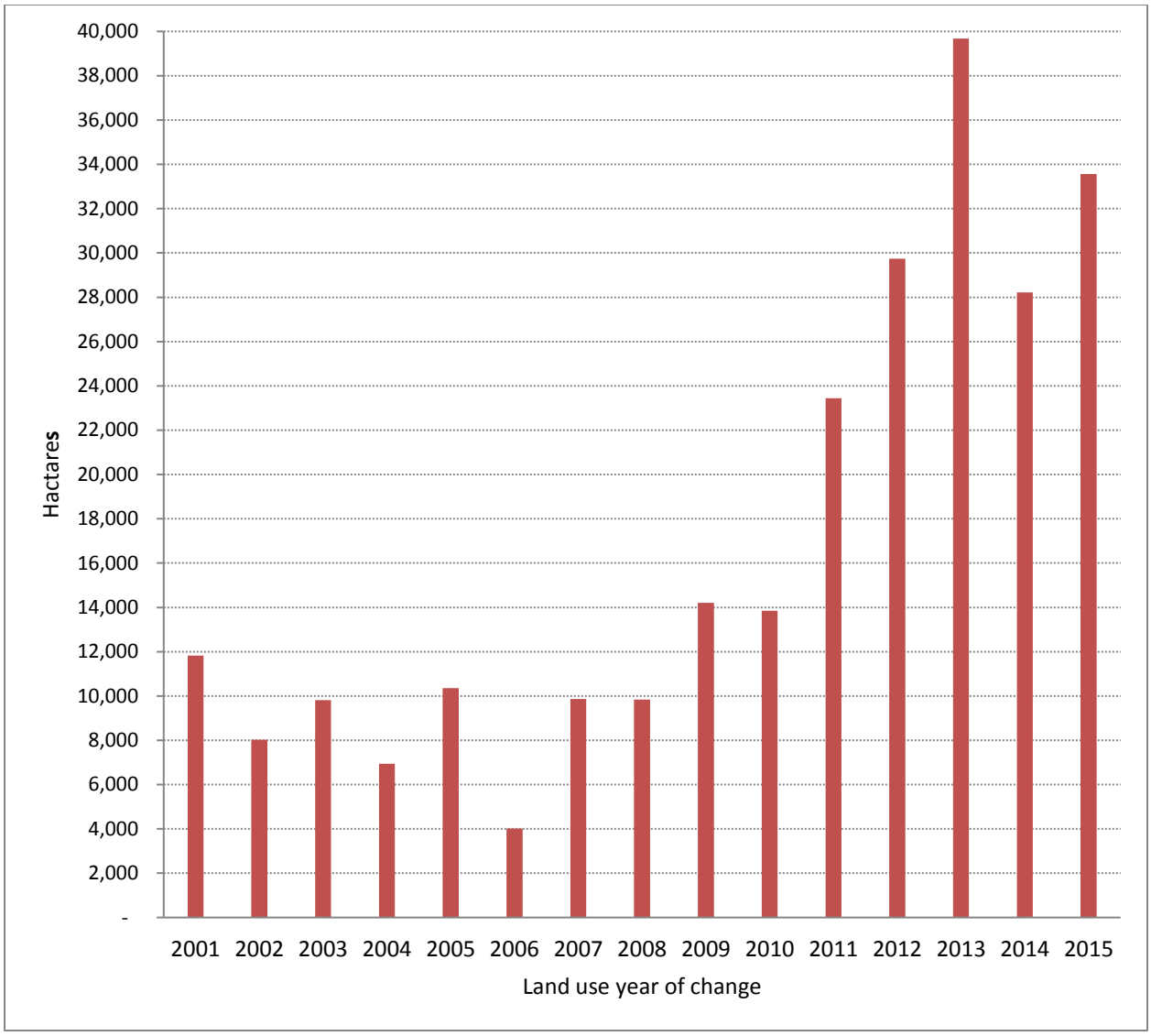


Figure ES-5: Annual deforestation from 2000 – 2015. Year 2000 is time zero.

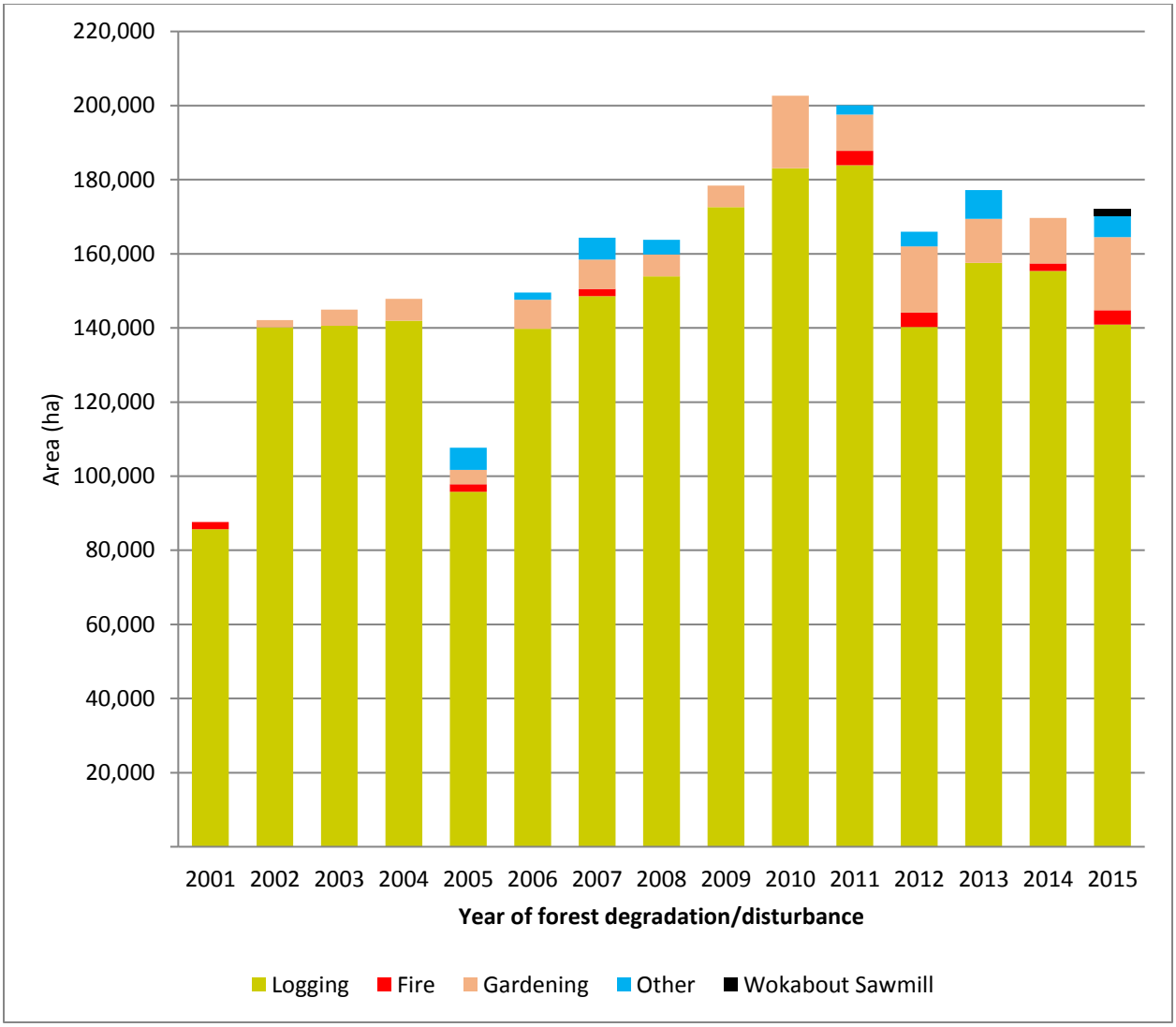


Figure ES-6: Annual forest degradation by human impact type from 2000 to 2015.

Forest definition has an influence on the forest extent and the rate of forest change. Definitions with high threshold values can exclude some important forest areas that have significant ecological values and carbon stocks. In the context of climate change, these forests have both carbon sequestration and greenhouse gas (CO_2) emission potential and therefore these potentials can either be under or over-estimated. Harmonization of the forest definitions in the country is not only necessary for consistent national and international reporting but its potential to mitigate climate change and its ecological functions. The national forest definition of PNG has low threshold values meaning that some areas of woodlands and savanna including degraded forest areas can be accounted for.

We now have information on PNG's forest land use status based on the broad IPCC land use categories and the national forest definition with detail sub-categories based on the country circumstances thus providing a broad overview and perspective of the country's land use at the national scale. This study filled the critical information gap on forest and land use of the country and it will significantly contribute for national planning and policy formation for sustainable development of the country.

PNGFA Provincial officers assessing sampling plots from the Highlands Region, NFI Lab, PNGFA HQ, Port Moresby, PNG (2016).

1. Introduction

1.1. Background

PNG Forest and Land Use

Papua New Guinea (PNG) shares the eastern portion of the island of New Guinea with West Papua – a Province of Indonesia covering the western portion. The island is said to embrace the third largest tropical rainforest after the Amazon and Congo Basin and is well-known for its biological endemism and species diversification. About 97% of land in PNG is under customary tenure. Forests belong to the people and the majority of population rely directly on forest for their living in many ways. Forestry is one of the major industries in the country and contributing significantly to national economy and formal employment.

PNG has high forest cover and is relatively well conserved and can play a significantly important role as the main carbon dioxide plus other greenhouse gases (GHG) sequester at the domestic, national, regional and global scale.

PNG's forest and land use is complex and is undergoing transitional change. These transitional changes are caused by human activities such as logging, agriculture, infrastructure expansions, fire and mining. Natural phenomena such as cyclones, earthquakes and landslides are also the causes of transitional change; however, these are not covered under this report. Some of these transitional changes especially the changes caused by humans are apparently becoming permanent and are challenging to detect due to the vastness of the topographical landscapes, including the lack of technology and human capacity in the country to measure and monitor these changes.

Globally, remote sensing (RS) and Geographical Information System (GIS) technology have been applied to measure and monitor changes and these has proven to be successful and useful. A number of studies (Filer *et al*., 2009; Shearman *et al.*, 2010) have been conducted in PNG which has provided useful information on PNG's forest cover and land use changes. These studies indicate that there is a general decline in the forest cover and the rate at which it is declining has been the subject of debate among academics and other stakeholders.

Apart from the RS and GIS wall to wall studies conducted in the past in PNG for land cover and land use assessments, this recent report used the new RS and GIS point sampling method to collect land cover and land use data using the open source Collect Earth (CE) software and medium to high resolution satellite imageries. The assessment was based on PNG's national forest definition and the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidelines (GPG) 2006.

PNG has taken actions in compliance with certain frameworks as established by the United Nations Framework Convention on Climate Change (UNFCCC) and these are outlined below;

(a) Climate Change and REDD+

Global warming is evident. Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have developed mitigation and adaptation measures to address these impacts and are required to report these measures to the UNFCCC. PNG is signatory to this convention, with the Climate Change Development Authority (CCDA) as the National Designated Authority (NDA) and is responsible to report on the country's progress on these measures as per the UNFCCC requirements. PNG has reported GHG inventory, mitigation actions and effects, and adaptation measures through its submissions of National Communication to UNFCCC (NC1 in 2002 and NC2 in 2015).

At COP 21 in 2015, Parties to the UNFCCC reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and on their implementation efforts.

Developing countries (non-Annex I Parties) are required to submit Biennial Update Report (BUR) containing updates of national Greenhouse Gas (GHG) inventories, including a national inventory report and information on mitigation actions, needs and support received. PNG ratified Paris Agreement in 2016 and submitted its Nationally Determined Contribution (NDC) in 2017 and the first BUR in April 2019. Agriculture, Forestry and Other Land Use (AFOLU), especially Land Use, Land Use Change and Forestry (LULUCF) sector is the most significant sector in PNG in terms of both sink and source of GHG. GHG in LULUCF sector reported in BUR was estimated using the data of the study reported in this publication.

PNG's NDC states that the primary mitigation effort of PNG lies in reducing emissions from land use change and forestry. PNG can contribute to addressing the global mitigation gap by reducing deforestation and promoting forest conservation and sustainable management of its forests. The main forestry effort will be coordinated though the existing REDD+ initiative. The progress and short summary of four design elements (National Strategy or Action Plan, National Forest Monitoring System, Safeguards Information System and Forest Reference Level/Forest Reference Emission Level) which are required for the countries to participate REDD+ results based payment mechanism in accordance with COP decisions, are provided below.

(b) National REDD+ Strategy

PNG has a National REDD+ Strategy (2017-2027) endorsed by the National Executive Council (NEC) in May 2017; decision number 126/2017 and was launched in October 2017. The strategy outlines activities that were identified by government departments/authorities and agencies as priorities that needed to be addressed which were lacking or non-existent and required to be enforced or established as shown in Table 1-1. The analysis on the drivers of deforestation and forest degradation in the strategy was conducted using the assessment data reported in this publication.

Table 1-1: Outline of the different components of the National REDD+ strategy

Component 1: REDD+ Actions- Policies and Measures		
Action Areas	**Specific Activity**	**Responsible Government Agency**
Strengthening land use and development planning	Strengthened and Coordinated National Level Development and Land Use Planning	Department of National Planning and Monitoring (DNPM), Department of Lands and Physical Planning (DLPP)
	Integrated subnational Planning	Department of Provincial and Local Government Affairs (DPLGA), Department of National Planning and Monitoring (DNPM)
Stronger environmental management, protection and enforcement	Strengthened climate change legislation, financing	Climate Change and Development Authority (CCDA)
	Strengthening forest management and enforcement practice	Papua New Guinea Forest Authority (PNGFA)
	Strengthening environmental management, enforcement and protection	Conservation, Environment and Protection Authority (CEPA)
Enhanced economic productivity and sustainable livelihoods	Development of sustainable commercial agriculture sector	Department of Agriculture and Livestock (DAL) Fresh Produce Development Agency (FPDA)
	Strengthened food security and increased productivity of family agriculture	
Component 2: REDD+ Coordination and Reporting- mainly covers the institutional and technical elements (four elements) to be reported to the UNFCCC overview of financing by CCDA.		

(c) National Forest Monitoring system (NFMS)

According to the COP decisions, national forest monitoring systems (NFMS) should be flexible, allow for improvement and build upon existing systems, as appropriate. They should enable the assessment of different types of forest in the country according to national definitions, including natural forest. They may also provide relevant information to the safeguards information systems.

The data and information provided by NFMS should be transparent, consistent over time, and suitable for measuring, reporting and verifying (MRV), taking into account national capabilities and capacities. In order to achieve this, the systems should also use a combination of remote sensing and ground-based forest carbon inventory approaches for estimating anthropogenic

forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes.

For assessing Activity Data for REDD+ MRV, PNG uses RS/GIS point sampling method (this study) to assess annual forest and land use change. PNG also produces forest and land use maps for improving the accuracy of the Activity Data, spatial analysis, planning, monitoring and management purposes (PNG Forest Authority 2014, Climate Change and Development Authority 2017).

For establishment of country specific Emission Factor, PNG has been implementing National Forest Inventory since 2016 (PNG Forest Authority 2018). Extensive range of spatial information on PNG forest and land use change including the above mentioned assessment and maps are accessible to general public through PNG REDD+ and Forest Monitoring Web-Portal (http://png-nfms.org/portal/) for enhancing the transparency of REDD+ process in PNG. The web-portal enables the user to conduct land use assessment by overlaying different land use information including logging concessions, protected area, oil palm plantation, vegetation type, census and census data (Climate Change and Development Authority 2017). Figure 1-1 shows the outline of REDD+ MRV system in PNG.

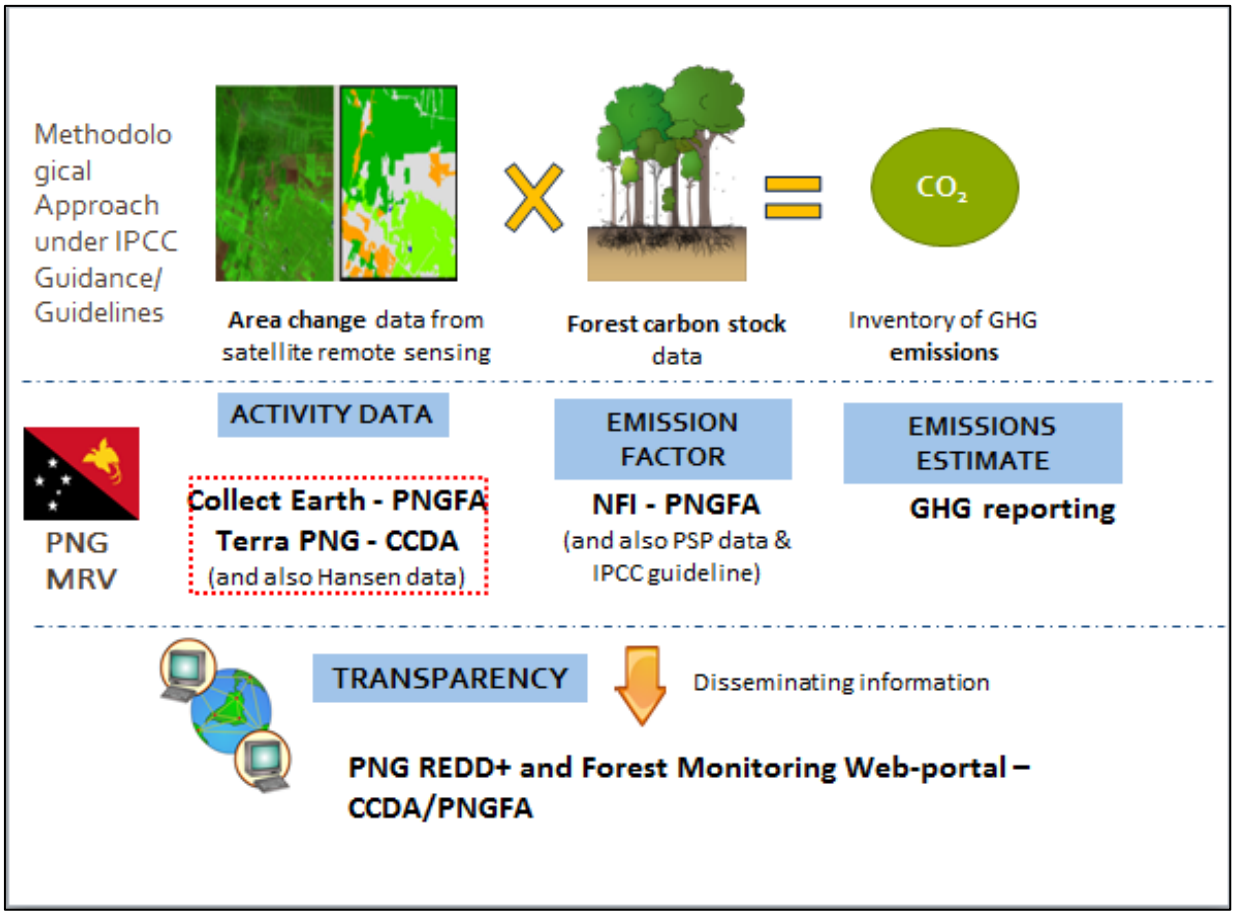


Figure 1-1: Overview of PNG's MRV system.

(d) Safeguards Information System (SIS)

Under the Cancun REDD+ Agreement there are seven (7) safeguards and how these can be addressed in a country's context or circumstances (Box 1-1). PNG has developed a roadmap for the establishment of Safeguards Information System (SIS) based on a comprehensive assessment of PNG's safeguards including environmental regulations. PNG is currently working on the development of Summary of Information for submission to UNFCCC. The outline of PNG's approach on safeguards is shown in Figure 1-2.

Box 1-1: Safeguards for REDD+ activities.

The following safeguards should be promoted supported when conducting REDD+ activities;

- That actions complement or are consistent with the objectives of national forest programmes and relevant international conventions and agreements;
- Transparent and effective national forest governance structures, taking into account national legislation and sovereignty;
- Respect for the knowledge and rights of indigenous peoples and members of local communities;
- The full and effective participation of relevant stakeholders, in particular indigenous peoples and local communities;
- That actions are consistent with the conservation of natural forests and biological diversity, ensuring that the actions are note used for the conversion of natural forests, but are instead used to incentivize the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits;
- Actions to address the risks of reversals;
- Actions to reduce displacement of emissions.

Source; Handbook on Measurement, Reporting and Verification for Developing Country Parties, pg.51, (2014)

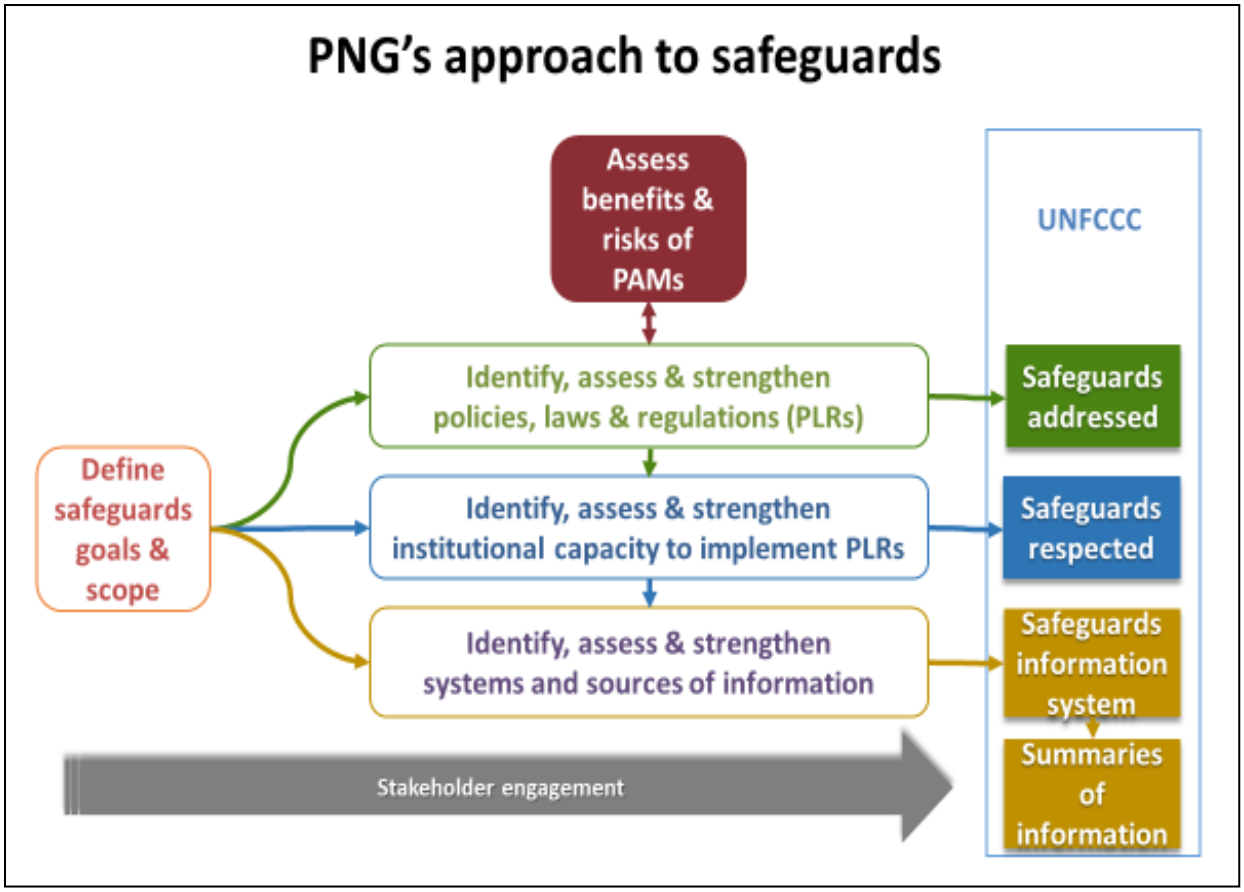


Figure 1-2: PNG's approach to safeguards.

(e) Forest Reference Level/Forest Reference Emission Level (FRL/FREL)

UNFCCC COP decision (12/CP.17) defines that forest reference emission levels and/or Forest Reference Levels (FREL/FRL) are "benchmarks for assessing each country's performance in implementing REDD+ activities". Developing countries aiming to implement REDD+ activities are invited to submit a reference level to the secretariat, on a voluntary basis and when deemed appropriate. The information contained in the submission should be transparent, complete, consistent with guidance agreed by the COP and accurate. Each submission of a proposed reference level, in the context of results-based payments, shall be subject to a technical assessment. Each submission is technically assessed by an assessment team in accordance with the procedures and time frames established by the COP. Having an assessed national reference level or, as an interim measure, subnational reference levels in place is one of the requirements in order to be eligible for results-based payments in accordance with decision 9/CP.19.

PNG has submitted its Forest Reference Level (FRL) in 2017 which was developed using the assessment data of this study and it was published on the UNFCCC website (https://unfccc.int/documents/65143) in 2018. In the FRL, PNG has reported on a national scale,

covering three (3) REDD+ activities; deforestation, forest degradation and forest carbon enhancement and covering two carbon pools; above ground biomass (AGB) and below ground biomass (BGB) with the historical reference period from 2001-2013.

GHG emissions during the historical reference period were increasing as the area of annual deforestation and forest degradation increased. Linear regression was best fitted to the trend during the historical reference period and the equation "1,679,607 x year – 3,339,358,085" was applied to estimate the business as usual annual GHG emissions during the reference period between 2014 and 2018 (Government of Papua New Guinea 2017).

1.2. Objectives

This report is to document forest and land use status in 2015 and the forest land use change between 2000 and 2015. This report is intended to focus on three (3) main objectives, which include;

i. Assessing the forest and land use in 2015 and forest land use change between 2000 and 2015 for sustainable forest management and other land use planning for general public consumption with hope that it can be used to influence decision-making.

ii. Disseminating and sharing of information to the general public, stakeholders, policy makers and international community and also strengthening of partnerships for implementation of initiatives at the national, sub-national and community level.

iii. Providing forest and land use information for formulating national policies on climate change and REDD+ initiatives at national, sub-national, community and even global level.

This report uncovers national level forest cover and the changes within a 15 year period between 2000 and 2015 including the very details of deforestation and forest degradation driver analysis. Such information is vital for formulating of national policies and plans on forestry, agriculture, land, climate change and also for other sectors. The data in this report was the primary source of information for PNG National REDD+ Strategy (2017), National Forest Reference Level, which was submitted to UNFCCC in 2017 and the REDD+ Technical Annex of the Biennial Update Report (BUR) which was submitted to the UNFCCC in 2019

2. Methodology

2.1. Forest and land use definitions

Deforestation, afforestation or reforestation is occurring it is important to define the areas within which these activities are occurring or may occur. It is therefore paramount that the forest has to be defined first.

Under the IPCC Good Practice Guidelines 2003 the 'forest' includes "all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory; subdivided into managed and unmanaged, and also by ecosystem type as specified in the IPCC (2003) Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category." The 2006 IPCC make reference to threshold values for the forestland definition. This indicates that the 2006 IPCC guidelines anticipates countries to define their forest with quantitative thresholds. By the Decision 11/CP.7 of the Marrakesh Accord, the definitions of forests, afforestation and reforestation were adopted (UNFCCC, 2002), which were later extended to land use, land-use change and forestry activities carried out under the Clean Development Mechanism (CDM) of the Kyoto Protocol by Decision 19/CP.9 adopted at Milan (UNFCCC, 2004).

The Kyoto Protocol sets three (3) parameters with a threshold range for participating countries to define forest. The parameters include area in hectares with a range from 0.5-1.0 hectares, tree height from 2-5 metres and canopy cover ranging from 10-30 percent (Table 2-1). PNG's national forest definition is "land spanning more than 1 hectare, with trees higher than 3 metres and the canopy cover of more than 10 percent". This excludes land that is predominantly under agricultural or urban land use. This national definition was endorsed by the PNG National Executive Council (NEC) in Decision #256 of Meeting #07/2014. The threshold values of the parameters chosen for the definition play a crucial role in legal interpretation of land use, assessment of forest area and its resources, development of policy frame work and planning by a country for conservation and sustainable forest management activities.

This national forest definition differs from the forest definition reported to FAO's Forest Resource Assessment (FRA) Report 2015, which defined forests as "Land spanning more than 0.5 hectares with trees higher than 5 meters" whilst "canopy cover of more than 10 percent", was maintained (Table 2-1). There was no national forest definition used in PNG prior to 2014, therefore, all default definitions under the IPCC 2006 were observed as reflected in all past GHG inventories carried out by the respective government authorities.

Table 2-1: Kyoto Protocol, PNG NEC and FRA forest definition.

Elements	Range in Kyoto Protocol	PNG NEC approved (2014)	FRA 2015
Minimum Land Area	0.05 to 1.0 ha	1.0 ha	0.5 ha
Minimum Tree Height	2 to 5 m	3 m	5 m
Minimum Canopy Cover Rate	10 to 30%	10 %	10 %

Definition of Deforestation and Forest Degradation

- Deforestation is the conversion from forest land to any non-forest land. The time for clearing may occur separately from the time the conversion process occurs. In most instances the year when the forest is cleared is used as the reference for year of change. For instance, a sampling plot is on a forest land which is cleared in 2003 and in 2008 is planted with oil palm. This is an example of deforestation or forest land conversion to cropland.
- Forest degradation is the conversion from primary forest to disturbed forest. An example of a degraded forest is a forest area impacted by selective logging activity.

Other IPCC Land Use Categories and Subdivisions Definitions

The six (6) IPCC land use categories were used as the main land classes or level 1. The 6 IPCC land use categories are Forestland; Settlement; Cropland; Grassland; Wetland and Other land. The country specific second and third level classes are subtype and subdivision. These are used for the country specific sub-categories under this study as shown in Table 2-2. Forest land and cropland are the only land use categories with subtype classes whilst the other 4 land use categories only have subdivisions (Table 2-2). All PNG land is classified into 46 land use subdivision categories. Below are the list of the land use categories, their sub-type categories and their subdivisions. The descriptions of subdivision categories are briefly defined in Appendix 11.

Table 2-2: IPCC Land Use Categories, PNG Sub-type Category and Sub-division category

IPCC Land use Category	Sub-type Category	Sub-division category
Forestland	Natural Forest	Low altitude forest on plains and fans, Low altitude forest on uplands, Lower montane forest, Montane forest, Dry seasonal forest, Littoral forest, Seral forest, Swamp forest, Savanna, Woodland, Scrub, Mangrove
	Plantation Forest	Eucalyptus, Araucaria, Pinus, Acacia, Terminalia, Teak, Other Forest Plantation
Cropland	Subsistence Agriculture	Shifting, Permanent, not sure
	Commercial Agriculture	Tea, Sugar, Coffee, Oil palm, Cocoa, Coconut, Cocoa/Coconut, Rubber Other
Grassland		Herb land, Rangeland, Other

Wetland		River, Lake, Dam, Nipa Swamp[1], Other Swamp
Settlement		Village, Hamlet, Large settlement, Infrastructure
Other land		Bare soil, Sand, Rock

**This is an additional option apart from the six IPCC land use categories.*

(a) Forest land

Forest land has been classified into land use subdivision based on the natural vegetation types and man-made plantations. Vegetation types have been classified based on the structural formation and described in Papua New Guinea Resource Information System (PNGRIS) Publication No.4. There are 12 vegetation types in PNG forests (Table 2-3). The brief description of the 12 vegetation types are provided in Appendix 11 and the full description of all PNG vegetation types are available in Hammermaster & Saunders (1995).

Moreover, natural forest types are divided into primary forest and disturbed forest as per the following definitions:

- **Primary forests** are densely populated old or matured native tree species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed.
- **Disturbed forests** are naturally regenerated forest where there are clearly visible indications of human activities (FRA, 2015). The disturbance are further subdivided into the following;
    - **Commercial logging** – refers to a large scale logging activity to harvest timber with the intent of selling (internationally or domestically). There are two types of logging activities; clear felling and selective logging. For PNG case, selective logging is practiced only for harvesting timber at a certain diameter. For commercial logging, a permit or license has to be obtained for a defined boundary under an FMA, TRP, FCA, LFA, and TA of a forest area for a longer term of a contract.
    - **Gardening** – refers to a patch of forest land cleared in preparation for shifting or permanent cultivation. They appear in satellite images as isolated and unevenly distributed patches of temporary forest clearings.
    - **Fire** – refers to an action of setting alight (human impact) which results in burning within a forest area for instance slash and burn for gardening or hunting.
    - **Portable sawmill** – refers to a small scale activity of harvesting timber for domestic use within a forest area using a Lucas mill or chain saw.

[1] If the canopy cover of trees exceeds 10%, they are considered swamp forest.
Nipa swamps don't have trees but are dominated by Nipa palms which are classified under wetland

- **Other** – refers to other activities (mining, trees cut for local uses, such as firewood etc.) which impacts a forest area.

Table 2-3: Forest classification in PNG and short description.

(a) Natural Forest	**Short description**
1.Low Altitude Forest on Plains and Fans	Elevations below 1000 m with gentle slopes
2.Low Altitude Forest on Uplands	Elevations below 1000 m with rough terrain
3.Lower Montane Forest	Between elevation from 1000 – 3000 m
4.Montane Forest	Elevations above 3000 m
5.Dry Seasonal Forest	Restricted to southwest PNG in a low-rainfall area (1800-2500 mm)
6.Littoral Forest	Dry or inundated beach forest
7.Seral Forest	River line, upper stream, river plains and volcano blast area
8.Swamp Forest	Forest area inundated with freshwater either permanent or seasonal
9.Woodland	Low and open tree layer
10.Savanna	Low (< 6m) and open tree layer in low rainfall area with a marked dry season
11.Scrub	Community of dense shrubs up to 6 m
12.Mangrove	Along coastline and in the deltas of large rivers
(b) Plantation Forest	
13.Forest Plantations	Planted forests are composed of trees established through planting or seeding by human intervention.

The breakdown of forest into management and designation (production forest, reserve forest, potential production forest area, timber concessions, etc.) based on the management regimes are elaborated in the Forest Base Map - The Big Book and the National Forest Plan.

The forest and land use change area were constructed to reflect only anthropogenic activities. This is true for both deforestation and forest degradation. This distinction between managed and unmanaged land was made due to certain factors; presence of logging roads, permanent roads and bridges, forest cover losses within proximity to villages and accessibility in terms of the topography. Where the forest cover loss was observed in inaccessible areas or far from villages/settlements and roads, these losses were not recorded or reported. Such observations were assumed to be due to natural disturbances (e.g. volcanic activities, landslides, cyclones). In summary, the deforestation and forest degradation emissions reflect anthropogenic emissions only.

(b) Cropland

The IPCC define cropland as arable and tillage land, and agro-forestry systems where vegetation falls below the threshold used for the forest land category, consistent with the selection of national definitions. The cropland category in PNG have been categorized into two types; subsistence and commercial agriculture.

(i) Subsistence Agriculture

The subsistence agriculture is a farming method where a family or a household produce enough food for own consumption. In areas where the market is accessible the surplus is sometimes sold. The subsistence agriculture for the purpose of this report is divided into shifting and permanent.

Shifting refers to a temporary cultivation of land in a rotational basis where the cultivated land is abandoned for a few years then re-cultivated once the land naturally restores its fertility.

Permanent refers to cultivation which is long term gardening without moving to a new piece of land. For PNG, this activity (Figure 2-1) differs for the lowlands and highlands regions; as for the latter is a dominant practice due to land sensitivity and it is very close to the individual household or family unit/clan boundary.

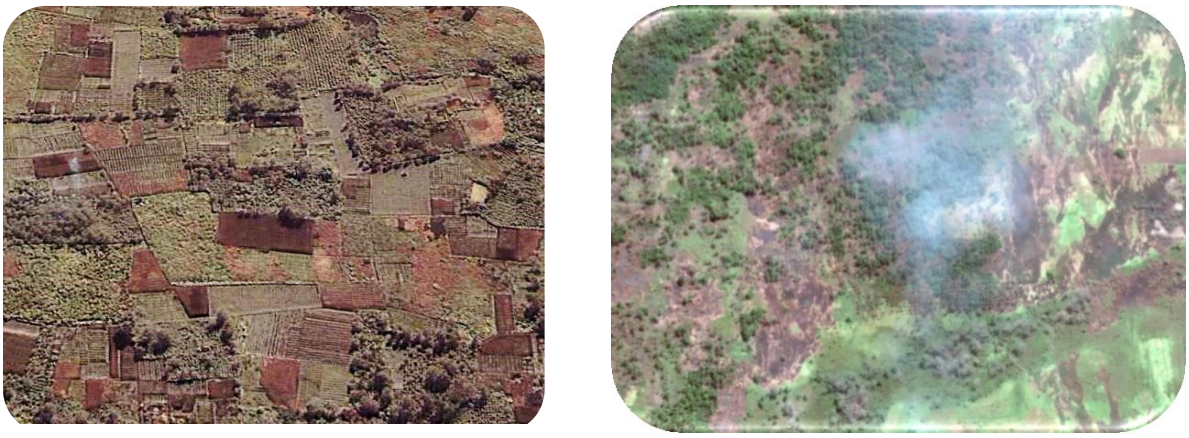


Figure 2-1: Example of permanent garden in the Highlands region (left) and lowlands (coastal).

(ii) Commercial Agriculture

Commercial agriculture includes large scale agricultural activities such as oil palm, coconut, coffee, cocoa, tea, rubber and sugar plantations. The activities are defined by boundaries under a management regime or small holders (village) on communal land.

(c) Settlement

Settlement under the 2006 IPCC guideline includes all developed land, including transportation infrastructure and human settlements of any size, unless these are already included under other categories and should be consistent with the selection of national definitions. In the PNG context the settlement category is divided into, hamlet, villages, large settlement and infrastructure.

(i) Hamlet

Hamlet refers to a cluster of permanent or semi-permanent houses usually between 3 - 5 houses scattered broadly over the landscape or the area of interest (a family or 1 clan). Usually the

hamlet inhabitants belong to the main community or a village located within the proximity of the hamlets. Hamlet is difficult to detect in low to medium resolution satellite images.

(ii) Village

Refers to a permanent human settlement comprising of a community with more than 1 clan or tribe located in a rural area. The houses are densely distributed than the hamlets. Usually marked subsistence agriculture is evident in the surroundings.

(iii) Large settlements

Refers to well-organized cities, towns and district centers. Includes mining townships that are located away/far from the mining sites.

(vi) Infrastructure

This refers to permanent structure such as road (paved or unpaved), bridges, airstrips/airports, clinic, schools and playing fields which is located outside of a village or large settlement or in remote areas.

(d) Grassland

Under the IPCC GPG 2006, the grassland includes rangelands and pasture land that is not considered as cropland. It also includes systems with vegetation that fall below the threshold used in the forest land category and is not expected to exceed, without human intervention, the thresholds used in the forest land category. This category also includes all grassland from wild lands to recreational areas as well as agricultural and silvo-pastural systems. The grassland is divided into herb land, rangeland and others.

(e) Wetlands

The land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the other five (5) IPCC land use categories are considered wetland under the IPCC GPG 2006. This category can be further subdivided into managed (reservoirs) and unmanaged (natural rivers and lakes) according to national definitions. PNG does not have a national definition, but in this report the wetland is divided into the following subdivisions; rivers, lake, dams, swamps, Nipa swamps and other swamps.

(f) Other land

Land that is not covered by forest, cropland, grassland, and settlement or wet land is classified as other land. These include bare soil, sand, and rock.

2.2. Tool and data sources

What is Open Foris and Collect Earth Tool?

This study was conducted by applying remote sensing point-sampling method using Open Foris Collect Earth tool. Open Foris is an initiative by FAO with a collaborative effort of numerous public and private institutions to develop, share and support specialized software tools meant for use by countries and institutions to implement environment and land use monitoring. Full description of Open Foris suite of tools (Table 2-4) can be found on this website: *http://www.openforis.org/home.html.*

Table 2-4: Open Foris tools and their purpose.

Open Foris Tool	**Purpose**	**Application to this study**
Collect	Develop survey design	Designing of forms
Collect Earth	Desktop data collection	Assessment
Collect Mobile	Field data collection using tablet and smart phones	Not used
Calc	For processing and analysing field inventory data	Not used
SEPAL	System for earth observation, data access, processing and analysis, accuracy assessment	Not used

Collect Earth tool is a software that enables data collection through Google Earth software. This can be undertaken in conjunction with Google Earth, Bing Maps and Google Earth Engine (Figure 2-2) where users can interpret satellite imagery for a wide variety of purposes, including:

- Supporting multi-phase National Forest Inventories
- Land Use, Land Use Change and Forestry (LULUCF) assessments
- Monitoring agricultural land and urban areas
- Validation of existing maps
- Collection of spatially explicit socio-economic data
- Quantifying deforestation, reforestation and desertification

Its user friendliness and smooth learning curve makes it a perfect tool for performing fast, accurate and cost-effective assessments. It is highly customizable for the specific data collection needs and methodologies. The data gathered through Collect Earth is exportable to commonly used formats and can also be exported to Saiku, a tool that facilitates data analysis (See Section 2.3).

PNG customized the Collect Earth IPCC LULUCF survey design template to accommodate the country's needs, requirements and environment. This was applied for the first assessment in the year 2013. Most of the customization were performed by experts from the FAO Head Quarters using Open Foris Collect tool. The customized survey design was reconfigured in 2016 by PNGFA and FAO-NFI officers locally and applied for the Forest and Land Use Change Assessment for 2000 to 2015 reporting. The Collect Earth survey template was edited time-to-time based on user needs.

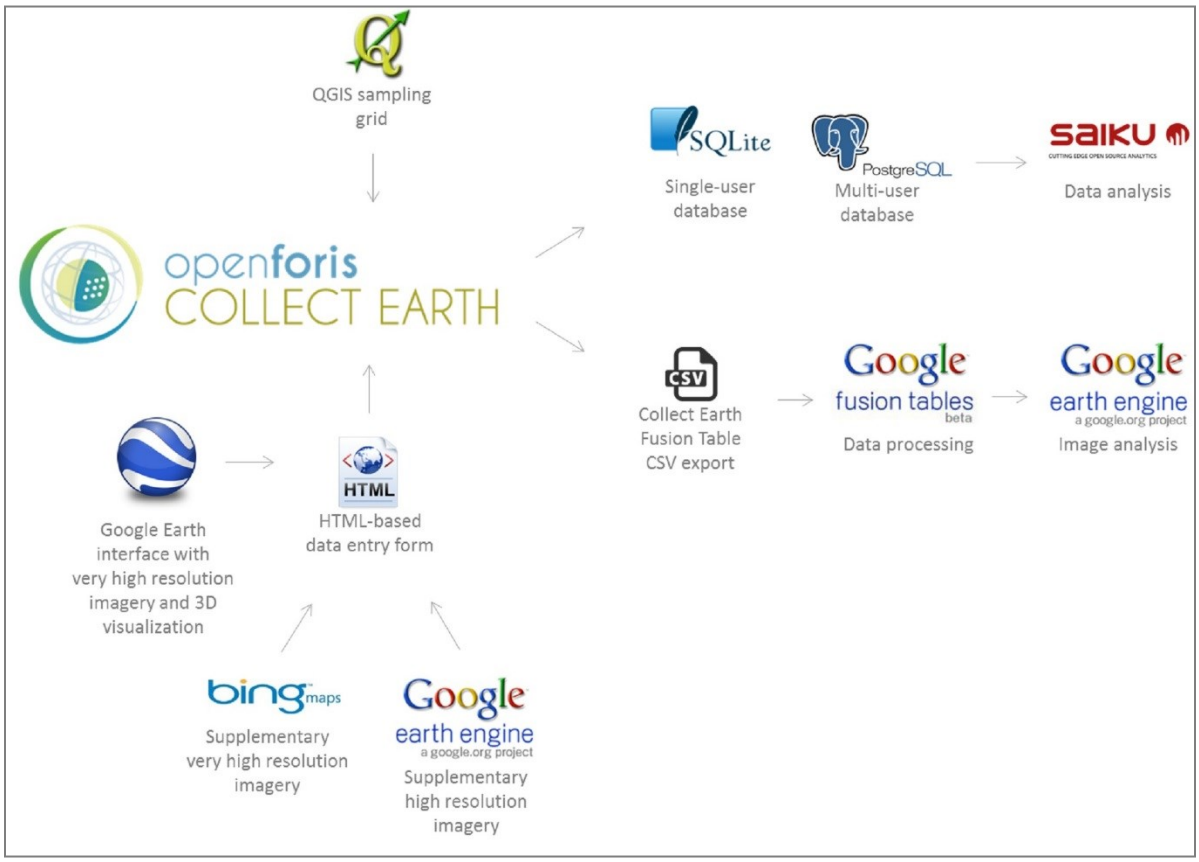


Figure 2-2: Collect Earth architecture. This shows the Collect Earth's link to other software's.

Following are the input parameters used for Collect Earth: data collection form, sampling design, plot file, project properties and area attributes. The input parameters used for PNG are further described below:

a) Data collection form

The data collection form (Figure 2-3) is a series of multiple-choice prompts and text entry fields that guide a Collect Earth user to record information on specific land attributes. Several default data collection forms are available online, however, users can also design their own forms in any language using Open Foris Collect.

PNG started with the LULUCF sample template data collection forms and customized some forms and also added new additional forms. The Collect Earth operator record information on the land use characteristics and elements in a systematic and structured approach as they are visualized on the satellite imageries by answering the question/selection provided in the forms. The format and sequence of the forms are shown in Figure 2-3. After selecting the land use category and land use conversion the operator is then guided to the sub-forms containing the question/selection for the particular land use. This workflow diagram is shown in Figure 2-14.

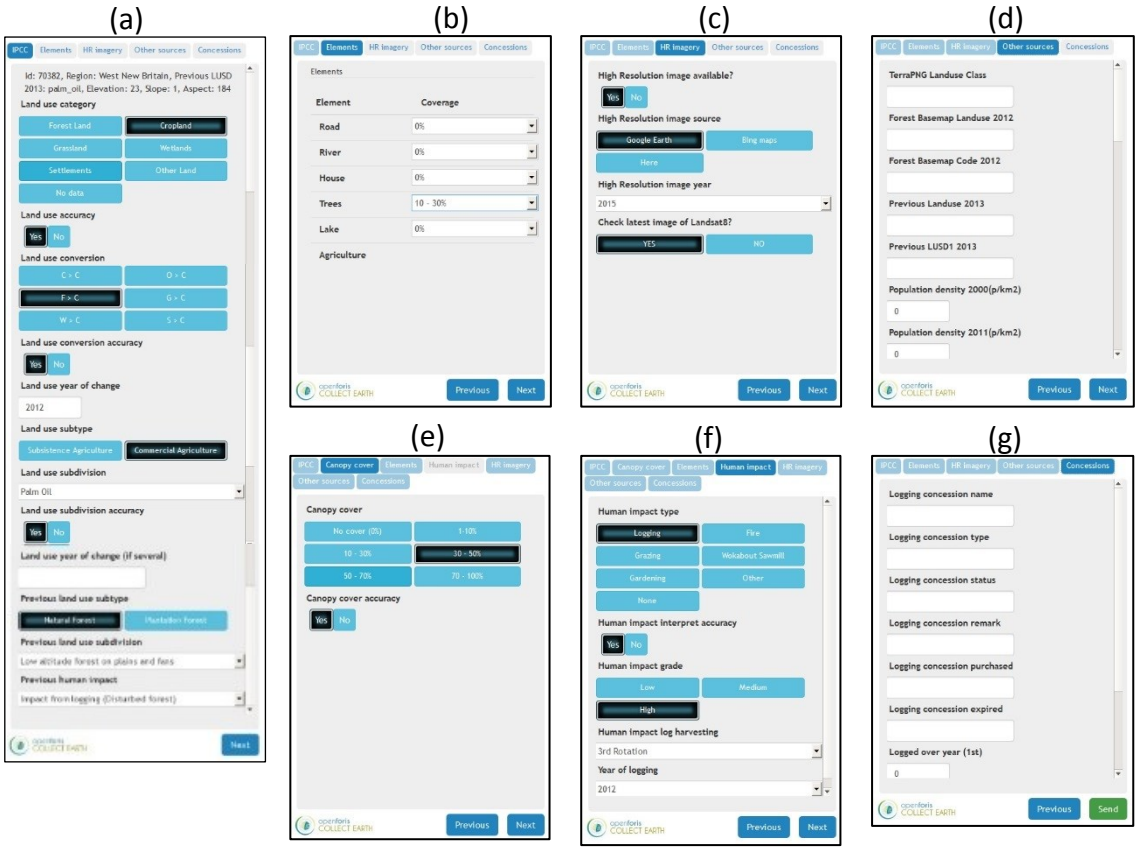


Figure 2-3: Illustration of the seven (7) PNG Collect Earth data collection forms (a) to (g).

Figure 2-3 shows form *(a)* for recording information on the IPCC Land Use and Land Use Change and country specific sub-categories; form *(b)* the land cover elements to be measured; form *(c)* information on high resolution imagery; form *(d)* other sources of information used to support assessment; form *(e)* canopy cover measurement if land use is forest land; form *(f)* assessment of human impact type and year in a forest land category; form *(g)* information on logging concession if sampling plot falls within a boundary of a logging concession.

b) Sampling design

This involved a probabilistic stratified-systematic sampling design created in GIS to facilitate area estimation and proportional land compositions. For the larger size provinces in PNG, a sampling

intensity of 0.04 x 0.04 degree grid (4.44 x 4.44 km) was applied while 0.02 x 0.02 degree grid (2.22 x 2.22 km) was applied for the three smaller provinces (Western Highlands, Jiwaka and Manus) having less than 500,000 hectares of landmass. All these were overlaid on the PNG map creating a total of 25,279 sampling plots. The shape of the sampling plot is a 100 metre by 100 metre square (1ha) which is consistent with the minimum mapping area required to apply PNG's national forest definition.

Within each sampling square plots, there are 25 dots and each dot is equivalent to 4% (Figure 2-4). These sampling dots help quantify and characterize land use within the sampling plot..

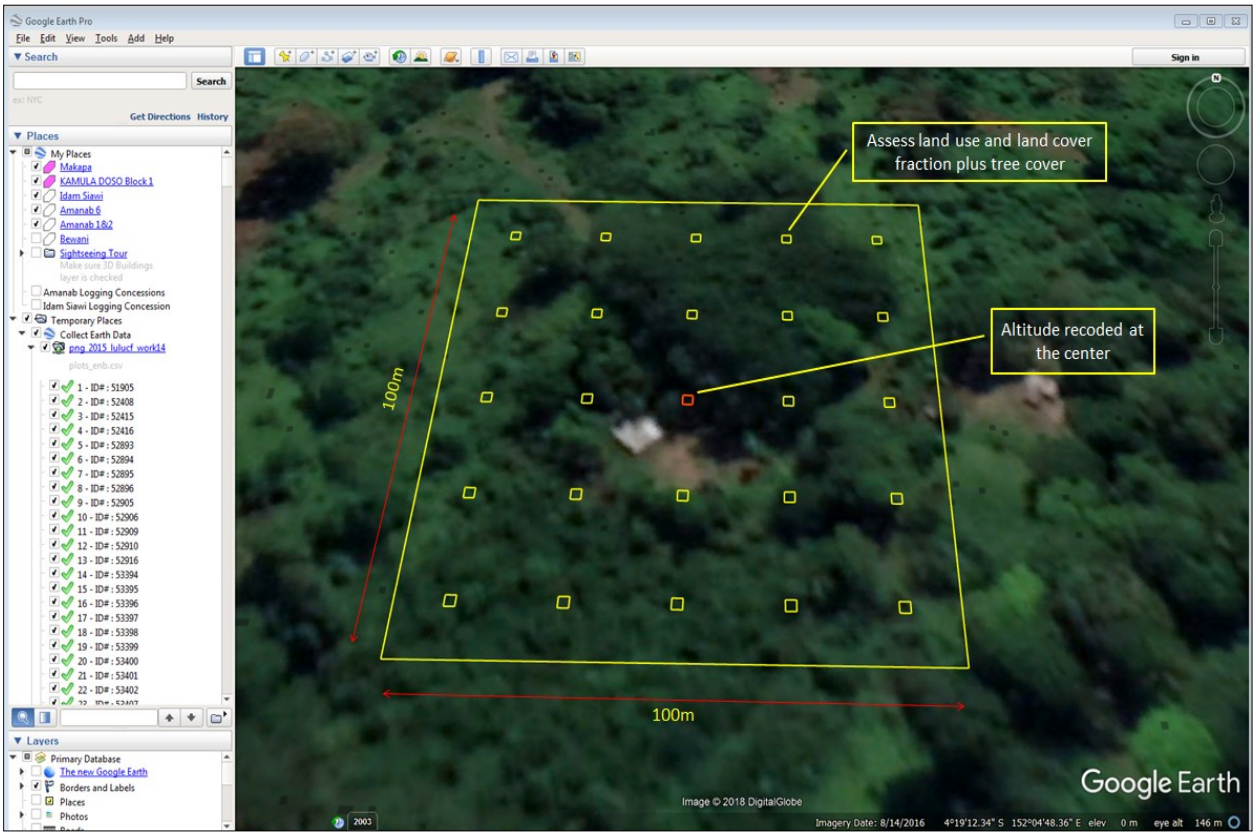


Figure 2-4: A 5x5 control point square sampling plot for PNG Collect Earth assessment.

c) Plot file

The plot file is a comma separated value (CSV) file containing geographic coordinates and the unique identifier of each plot, along with any supplementary data that may be useful for analysis, but is not manually entered by the user (e.g., elevation, climate, soil data, etc.). Supplementary data can be prepared in GEE Code Editor or any GIS software and added to the plot file CSV that is imported into Collect Earth.

The size and shape of plots and the number of sampling points within each plot can be specified in the project properties CSV file. The coverage of topographical elements within each plot (e.g.,

tree cover, roads, agricultural land, etc.) is estimated via proportions. Each plot contains a certain number of sample points, each presenting a discrete percentage of the total area within the plot. The percentage of the plot covered by a topographic element is the ratio of (a) the number of points overlaying the element being measured over (b) the total number of points. Area estimates for each land use or land cover class are obtained by multiplying the proportion of each class by the total area. Users can also indicate which imagery archives should be launched during the assessment. Project properties can be defined using any word processing software or with Open Foris Collect. These inputs comprise the Collect Earth Project (CEP) file that defines the data collection framework for land assessment through augmented visual interpretation.

d) Area attributes

Collect Earth is designed to exploit the benefits of probability sampling by facilitating area estimations and proportional land compositions (Table 2-5). When using a systematic sampling design, the area attributes CSV file enables Collect Earth to calculate the area represented by each plot. When more complex probabilistic sampling designs are used, such as random restricted sampling, the area attributes file adjusts the weighting of each plot and automatically calculates plot expansion factors and the spatial extent of each attribute.

Table 2-5: Regional and Provincial plot and area information used for the assessment.

Region Name	No.	Province Code	Province Name	Total sampling plots	Area (Ha)	Plot Weight
Southern	1	WES	Western Province	4,993	9,797,778	1
	2	GUL	Gulf Province	1,755	3,471,860	1
	3	CEN	Central Province	1,525	2,955,783	1
	4	ORO	Oro (Northern) Province	1,167	2,263,371	1
	5	MIL	Milne Bay Province	735	1,416,666	1
	6	NCD	National Capital District	15	19,720	1
			Total Southern Region:	***10,190***		
Highlands	7	SHY	Southern Highlands	779	1,504,751	1
	8	HLA	Hela	531	1,055,593	1
	9	ENG	Enga	604	1,173,438	1
	10	WHY	Western Highlands	878	432,998	0.25
	11	JIW	Jiwaka	977	480,522	0.25
	12	SIM	Chimbu	312	613,341	1
	13	EHY	Eastern Highlands	572	1,114,676	1
			Total Highlands Region:	***4,653***		
Momase	14	MOR	Morobe	1,725	3,368,621	1
	15	MAD	Madang	1,460	2,890,325	1
	16	ESK	East Sepik	2,230	4,368,599	1
	17	WSK	West Sepik	1,790	3,592,766	
			Total Momase Region:	***7,205***		
New Guinea Islands	18	WNB	West New Britain	1,042	2,034,000	1
	19	ENB	East New Britain	782	1,529,425	1
	20	NIR	New Ireland	495	939,696	1
	21	ARB	Autonomous Region of Bougainville	480	937,760	1
	22	MAN	Manus	432	193,077	0.25
			Total NGI Region:	***3,231***		
			Total for Country:	**25,279**	**46,154,766**	

Satellite Imageries

Satellite imagery also known as Earth observation imagery or space borne photography are images of Earth collected by imaging satellites operated by governments and large commercial companies around the world. The archived satellite imagery used for the assessment were accessed through web mapping services such as Google Earth, Google Earth Engine and Bing Map. RapidEye is sourced locally from PNGFA. Table 2-6 shows information about the satellite imagery.

Table 2-6: Satellite imagery, source, type, year and purpose.

Source	Imagery type	Resolution	Acquisition Year	Purpose
Google Earth	World-View, QuickBird, Ikonos, SPOT, Landsat etc.	High (0.5-2.5m) Low (30m)*	2000-2015 (to date)	Land use and disturbance
Bing Maps	World-View, QuickBird, Ikonos, SPOT, Landsat etc.	High (0.5-2.5m) Low (30m)*	2000-2005, 2007-2015 (to date)	Land use and disturbance
Google Earth Engine	Landsat 7 (Annual Greenest Pixel)	Low (30m)	1999-2013	Historical land use change
	Landsat 8 (Annual Greenest Pixel)		2014 -2018	Check Current Situation
Other	RapidEye	Medium (5.0m)	2010-2011	Reference Information

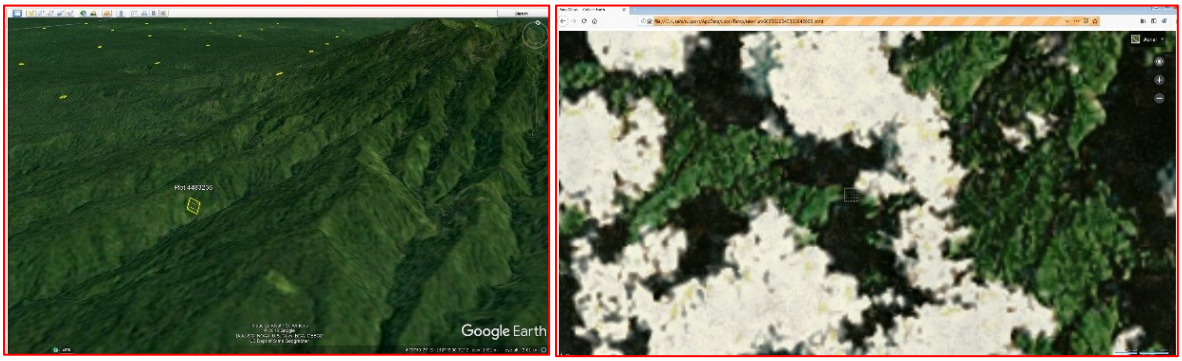
* High resolution images are available for city and town areas but often only low resolution images are available at isolated forest.

a) Google Earth

Google Earth is widely used web mapping application that shows a 3D representation of Earth based on satellite imagery. The archived satellite imageries used mostly are from the following companies/agencies; NASA, GeoEye, Digital Globe (WorldView and QuickBird), Spot Image, ASTER, BlackBridge (RapidEye), ImageSat International and Meteosat. The high resolution imagery resolutions range from 0.5 m to 2.5 m.

b) Bing Maps

Bing Maps is a web mapping service provided by Microsoft's Bing. The images include World-View, QuickBird, IKONOS, SPOT, etc. The resolution ranges from 0.5 m to 2.5 m. A substantial area in PNG is not covered by high resolution images either in Google Earth or Bing Maps. Area coverage of high resolution imageries vary. In some cases especially in the remote parts of PNG Bing Map did not provide good images (Figure 2-5).



(a) Google Earth (b) Bing map

Figure 2-5: Example of a clean Landsat imagery (a) shown in Google Earth (dated 2015) and a low resolution cloudy imagery (b) of the same site shown in Bing Map dated 2012. Plot ID-4483236, situated on south-west gulleys of Mt. Bosavi, Southern Highalnds, PNG.

c) Landsat 7 and 8

Landsat 7 was launched in 1999 and imageries from 1999 to 2013 are available and were used in the PNG assessment. Landsat 8 was launched in 2013 and imageries are available from 2014 to current year. Landsat 7 and 8 Annual Greenest-Pixel are satellite images that are accessed through Google Earth Engine. Most areas in PNG is mostly covered by cloud all year around. This is one of the major challenges for optical based imagery assessment in PNG. The United States Geological Survey (USGS) composites the best Landsat images taken in each year to make cloud free images. Those images are freely available through Google Earth Engine.

Landsat images are used for land use change detection. There are three tabs within the Google Earth Engine window i.e. home, data catalogue and workspace. The long list of available satellite images is located on the data catalogue tab. Upon selecting Landsat 7 and 8 Annual Greenest Pixel Top of Atmosphere (TOA) reflectance composite. These images are displayed on the workspace.

Landsat 7 and 8 (Figure 2-6) there are assigned three band colors of red, green and blue (RGB) which are used to give the image a false colors for enhancing imagery. Landsat 7 was assigned band 4, band 5, band 3 and Landsat 8 the band 5, band 6, and band 4. This gives the image both from Landsat 7 and 8 the same false color composite (orange color). Orange tone color indicate healthy vegetation whilst non-orange colors indicate shadows or non-vegetation such as water, bare soil or human activities. The changes are detected using the slider to move between the years.

d) RapidEye

RapidEye images (Figure 2-7) are at five-metre resolution and contain about one thousand tiles that cover the whole country. The RapidEye images taken in 2011 were made available through the first PNGFA/JICA Project where one of the major outcomes was the development of the Forest BaseMap (see more details in Section 5). The images were converted to KMZ (Keyhole Mark-up language Zipped) which were only used when there were no available images on Google Earth and Bing Maps to determine the type of land use category. Upon displaying these images, one would have to add one tile at a time as too many tiles would slow the loading of these images onto Google Earth. The tiles cover at least three to four sampling plots in a tile which was vital in the assessment.

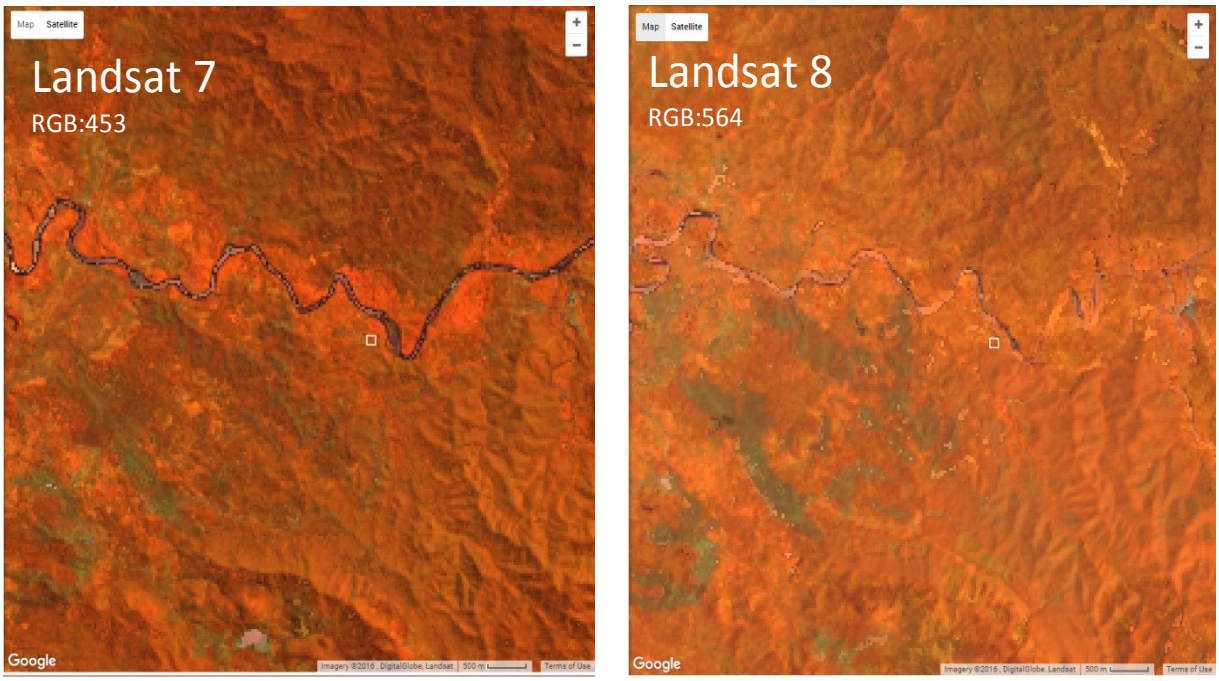


Figure 2-6: Example of Landsat 7 and Landsat 8 image with Collect Earth sampling plot (white square).

Figure 2-7: Example of RapidEye image (right image) showing Collect Earth plot. Google Earth image on the left.

Other Information

The assessment also used additional information to assist the operators to make precise judgement on the type of land use activity. Table 2-7 shows the list of additional information used during the assessment. Additional data used for the data analysis are also listed. This additional information is a combination of internationally and nationally developed datasets.

Table 2-7: List of additional Information used in the Collect Earth assessment and data analysis.

	Information	Source	Purpose
CE Assessment	Forest Base Map 2012	PNGFA/JICA Project	Reference for Forest and Vegetation Type
	Logging Concession Information	PNGFA (JICA support)	Reference for Human Impact Type (Logging)
	Logged over Area	PNGFA (JICA support)	Reference for Human Impact Type (Logging)
	Forest Information Mapping System (FIMS)	PNGFA	Reference in General
	Global Forest Cover Change (Hansen data)	University of Maryland	Quality Assurance and Quality Control
CE data Analysis	Population Density (Census)	Census 2011 (NSO)	Analysis for Correlation with Forest Change
	Annual Precipitation (Rainfall)	PNGRIS 3rd Edition (UNPG)	Analysis for Vegetation and Ecological Type
	Digital elevation model (DEM)	SRTM	Correlation with land use type
	Logging Constraints Information	PNGFA/JICA	Reference in General
	Soil/Geological Information	PNGRIS 3rd Edition (UNPG)	Reference in General
	Terra PNG 2015	CCDA/UN-REDD/FAO	Reference in General
	Protected Area (existing)	CEPA	Reference in General
	Biodiversity Priority Area	CEPA	Reference in General

a) Forest Base Map 2012

This was developed under the JICA/PNGFA phase 1 project[2] (2011-2014) using RapidEye satellite images. The Base Map covers 12 forest types and 7 non-forest classes (grassland, bare areas, large urban centers, lakes and large rivers, forest plantations, agriculture plantations and agricultural land use). Figure 2-8 shows forest base map KML format displayed on Google Earth.

[2] Capacity Development Project for Operationalization of PNG Forest Resource Information Management System for Addressing Climate Change (2014-2019)

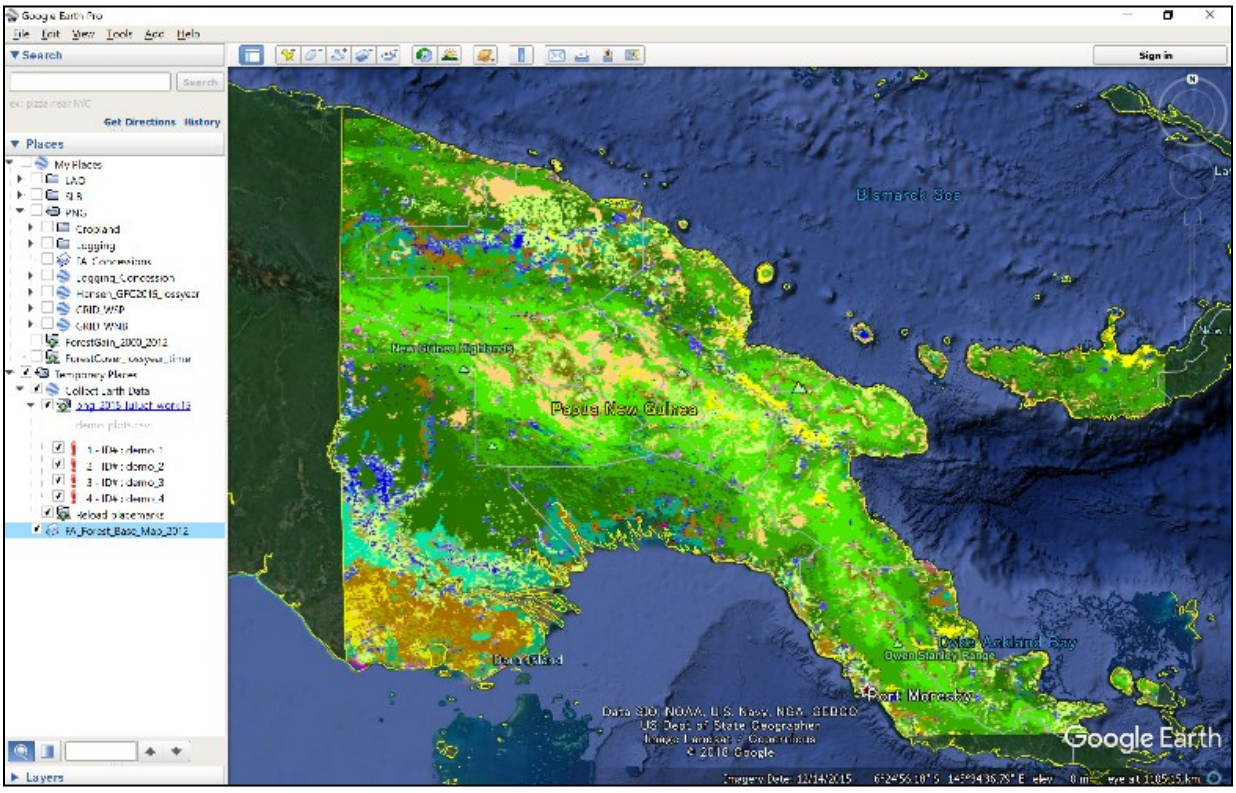


Figure 2-8: Example of Forest Basemap projected in Google Earth map along with Collect Earth tools.

b) Logging Concession information

This information was used during the assessment when there was an indication of logging activities detected on Landsat 7/8 or uncertainty for further clarification. The logging concession information appear as green boundaries that depicts the total area or size of the concession area either, current, proposed and expired areas (Figure 2-9).

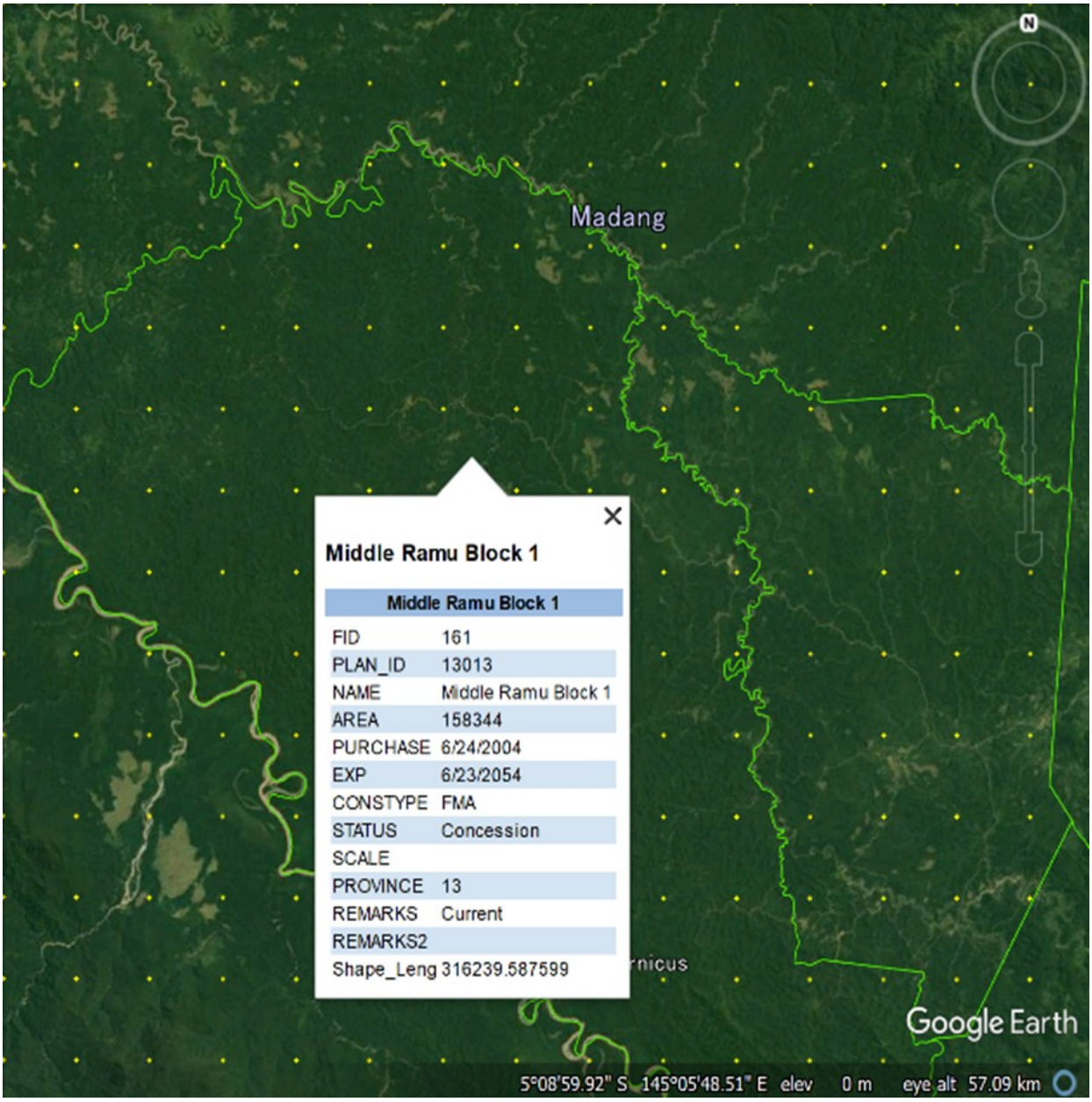


Figure 2-9: Example of logging concession boundary projected on Collect Earth / Google Earth interface.

c) Forest Inventory Mapping System (FIMS)

This information was produced in 1996 funded by the Australian government as a component of PNG's National Forestry and Conservation Action Programme (NFCAP) 1991-1995 (Filer & Sekhran, 1998). and is housed in Papua New Guinea Forest Authority (PNGFA). The information from this system has been used for Forest Resource Assessment (FRA) reporting. This system was basically designed to capture data on the timber resource by PNGFA and include timber concessions, vegetation types and areas logged (
Figure 2-10).

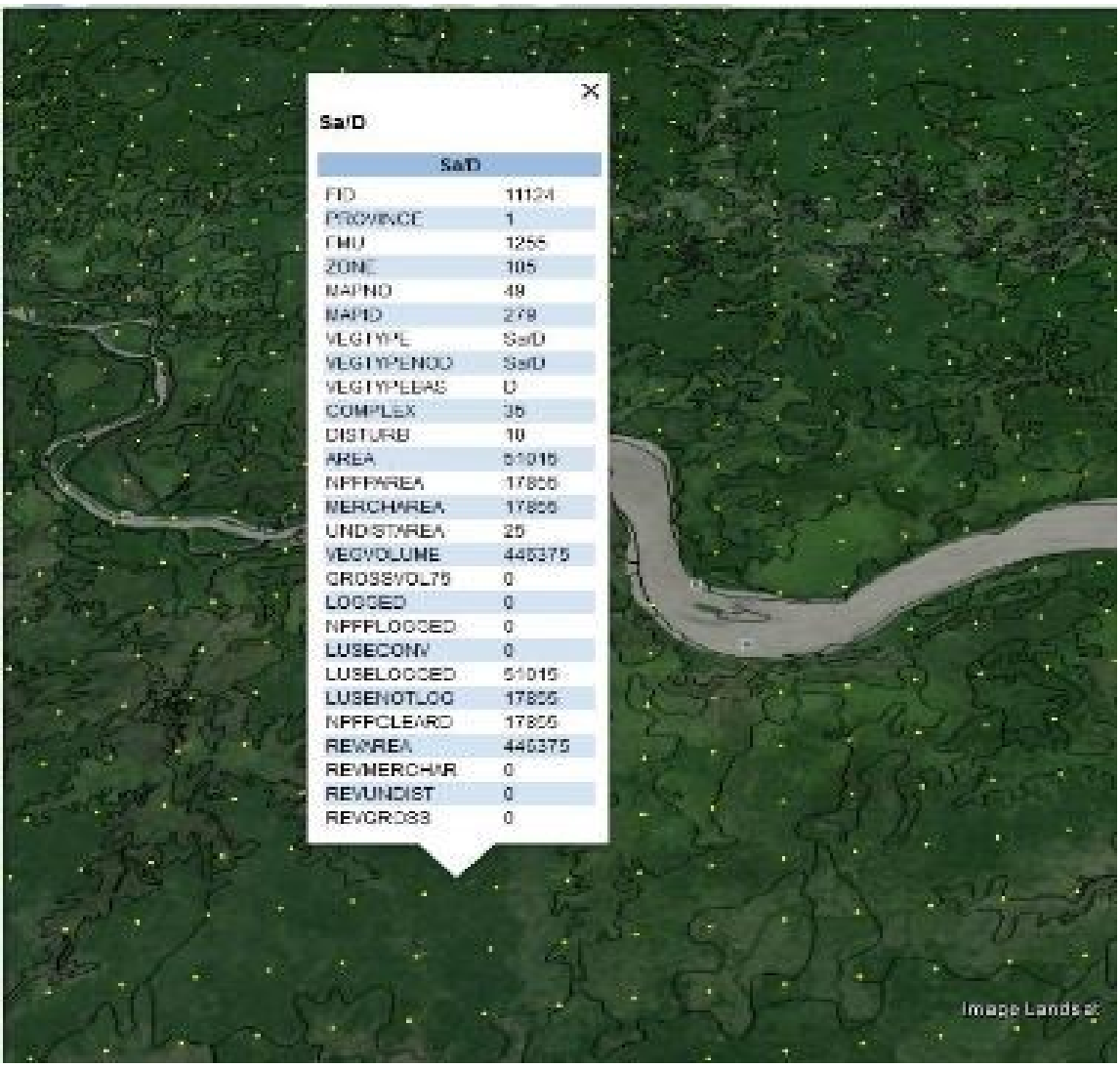


Figure 2-10: Example of FIMS GIS dataset (shapefile) showing vegetation polygons (black lines) converted to KMZ file and projected on Google Earth and Collect Earth map frame.

d) Global Forest Cover Change (Hansen Data)

The Global Forest Cover Change provides annual gross forest loss from 2000 to 2014. The data was used as a reference GIS layer to assist the operator to see and know where the forest cover loss occur (Figure 2-11).

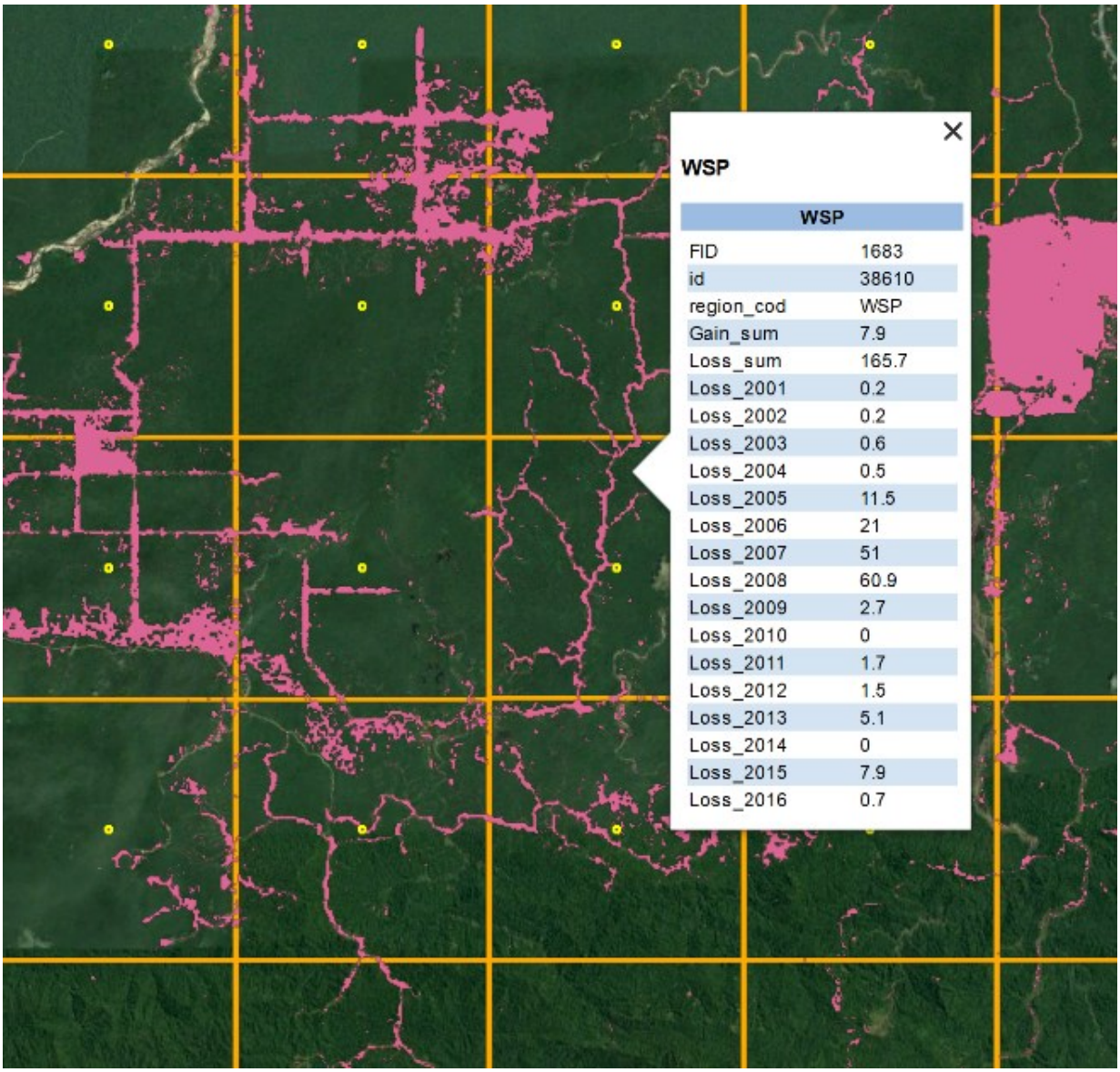


Figure 2-11: Example of Global Forest Change loss data (pink colored areas) integrated into the Google Earth interface for Collect Earth assessment.

2.3. Assessment and Analysis Methodology

The assessment and analysis methods include assessment methodology, working environment setup, QAQC, data analysis and uncertainty analysis. These five (5) parts are described in the following sections:

i. Assessment Methodology

Overview of the Assessment

The Collect Earth assessment was done with the aid of an operator to conduct a detailed land use assessment for Papua New Guinea. In the initial phase a total of 25,279 sampling plots were assessed. Each officer was assigned to one desktop and registered as an operator (or an assessor). The operator had to view the different sampling plots following assigned plot identification numbers in a day depending on his/her best judgement to assess the sampling plot with the available imagery on Google Earth, Bing and Google Earth Engine (Figure 2-12).

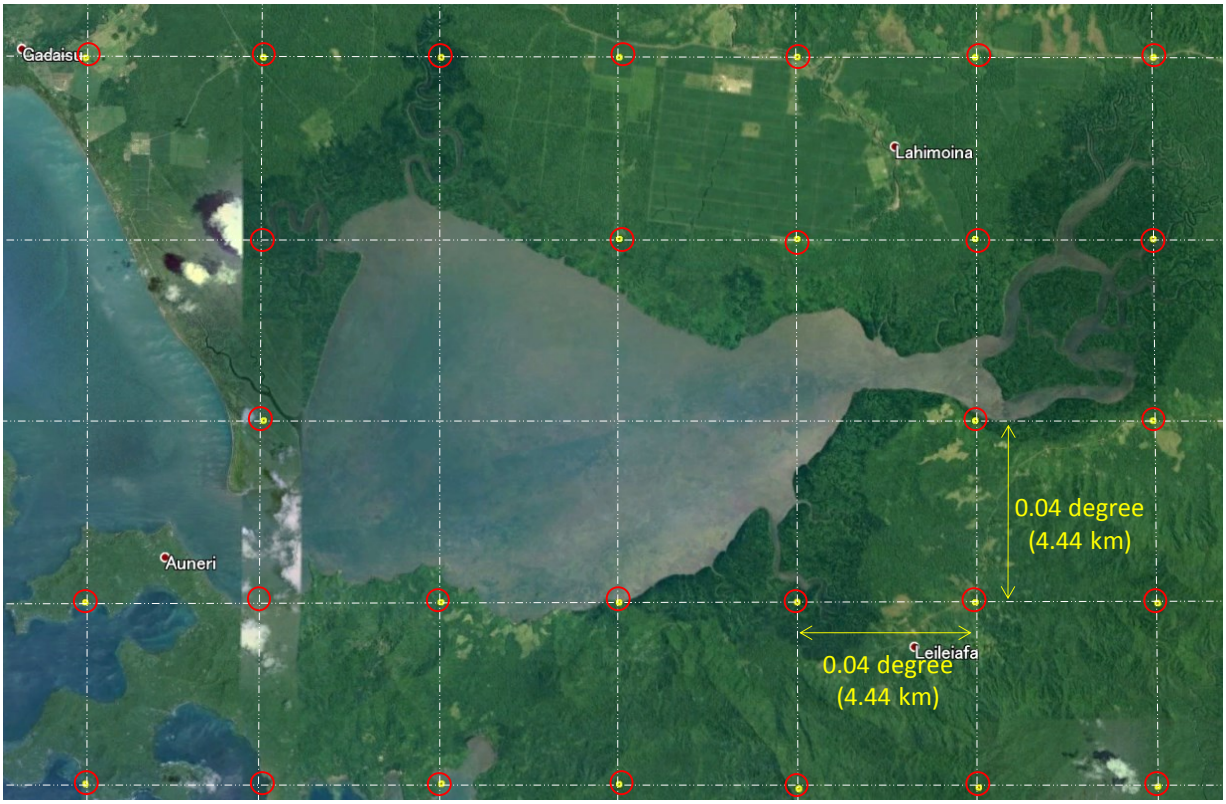


Figure 2-12: Collect Earth sampling points with the grid lines integrated in Google Earth interface.

When initiating the Collect Earth software, it starts up the Google Earth Engine and Bing Maps simultaneously which are executed by web-browsers (Google Chrome or Mozilla Firefox) where new windows appear displaying those images. There were other digital maps used such as the RapidEye 2012 images, logging concession maps, FIMS forest types, and local knowledge of the operators (Figure 2-13).

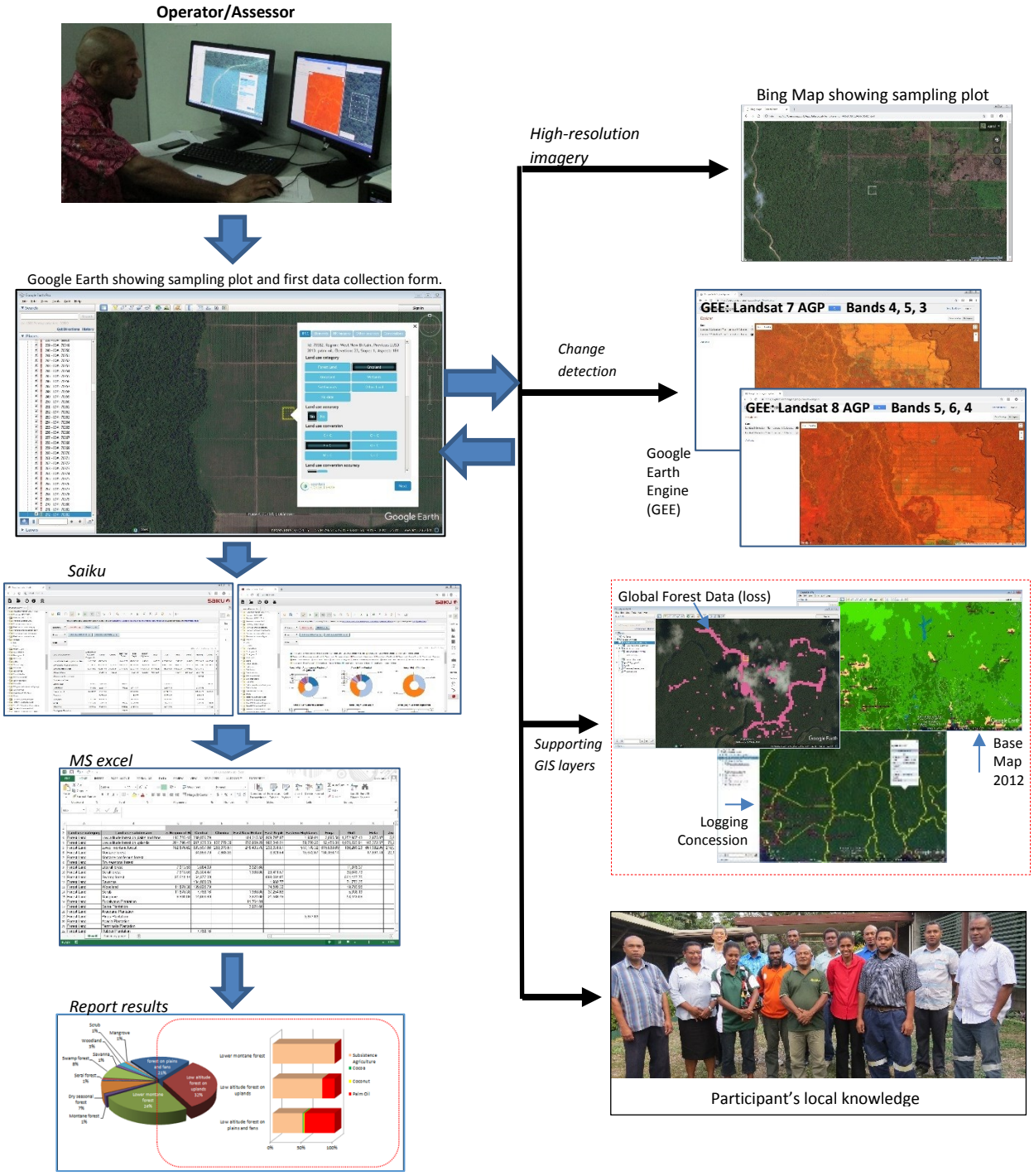


Figure 2-13: Illustration of the Collect Earth assessment.

Procedure of the Assessment

Data collection in this study is assessing the land use using the tools and materials described in Figure 2-13. The data collection process starts with the installation of the PNG customized Collect Earth on desktop computers with internet connections. Starting the Collect Earth software

simultaneously launches the Google Earth with CE data recording dialog, Google Earth Engine and Bing Map (Figure 2-13). This enables the systematic review of satellite images to assess land use and forest land use change. The step by step process of the CE installation and setup is fully described in the Collect Earth 1.1.1 User Manual (Bey *et al*., 2015). In short, these entails;

(a) The Collect Earth software is opened thus enabling the Google Earth to be automatically launched.

(b) The plot ID numbers located at the right-side pane in Google Earth interface when double clicked automatically directs the screen to the sampling plot (Yellow Square) and the area of interest to be assessed. This sampling plot assist to quantify and characterize land cover within the plot. For example, canopy cover percentage within the plot can be measured to apply the canopy cover threshold of the national forest definition.

(c) The cursor was then placed inside the square plot and single-clicked, enabling the field form to appear and at the same time activating Google Earth Engine and Bing Map. Landsat 7 and 8 Annual Greenest Pixel are accessed through Google Earth Engine simultaneously.

(d) At the area of interest, the operator then record information on the land characteristics and elements in a systematic and structured approach as they were visualized on the satellite imagery. Once the assessment of the area of interest was done, the 'ok' button at the end of the field form (Figure 2-3) was clicked which automatically directs the assessor to the next plot which is 4.4km away from plot that was assessed. This was repeated until all the 25,279 sampling plots were assessed.

Land Use and Land Use Change Assessment

Initial step was to detect 'key land elements' using medium to very high-resolution images. The key land elements are defined as a physical component of the land that characterizes one or more land cover classes and/or land use categories (Table 2-8).

Table 2-8: List of key land elements subdivided by land classes

IPCC Land Use Category	Land Key Elements
1. Forest land	Tree crown cover
2. Settlement	Building, paved roads and bridges
3. Cropland	Food crops
4. Wetland	Water, rivers, swamp, dam, lake
5. Grassland	Grasses, scrubs
6. Other Land	Rocky outcrop, barren land, sand

The second step was to determine the land use function of the land based on the spatial distribution of the key land elements and classify the land use. If the land class was complex (less than one land class in the area of interest) the hierarchical threshold criteria.

The final step was to determine if there was a land use change in the area of interest. The land use change was detected using Landsat 7 and 8 using Google Earth Engine. The operator determines the actual year of change from one land use conversion to another by visually going through the Landsat 7 and Landsat 8 imagery in GEE.

Forest Disturbance by Human Impact Assessment

If the land use was classified as forest land, the next step was to assess this particular forest land if it had been disturbed and identify the key features that causes this change as shown in Table 2-9. The detail steps or work-flow of the assessment is illustrated in Figure 2-13 and Figure 2-14.

Table 2-9: Forest Disturbance key features

Disturbed forest	Key features	Remarks
Logged forest	Logging roads,	Easy to see
Gardening	Isolated patches of temporary clearings at the edge of cropland areas	Challenging to see in Landsat 8 & 7 images
Fire	Burnt forest	Challenging to detect on Landsat images
Portable sawmill	Based on local knowledge	As above
Others	Mining clearings & those not identified	As above

Terminalia woodlots in Milne Bay

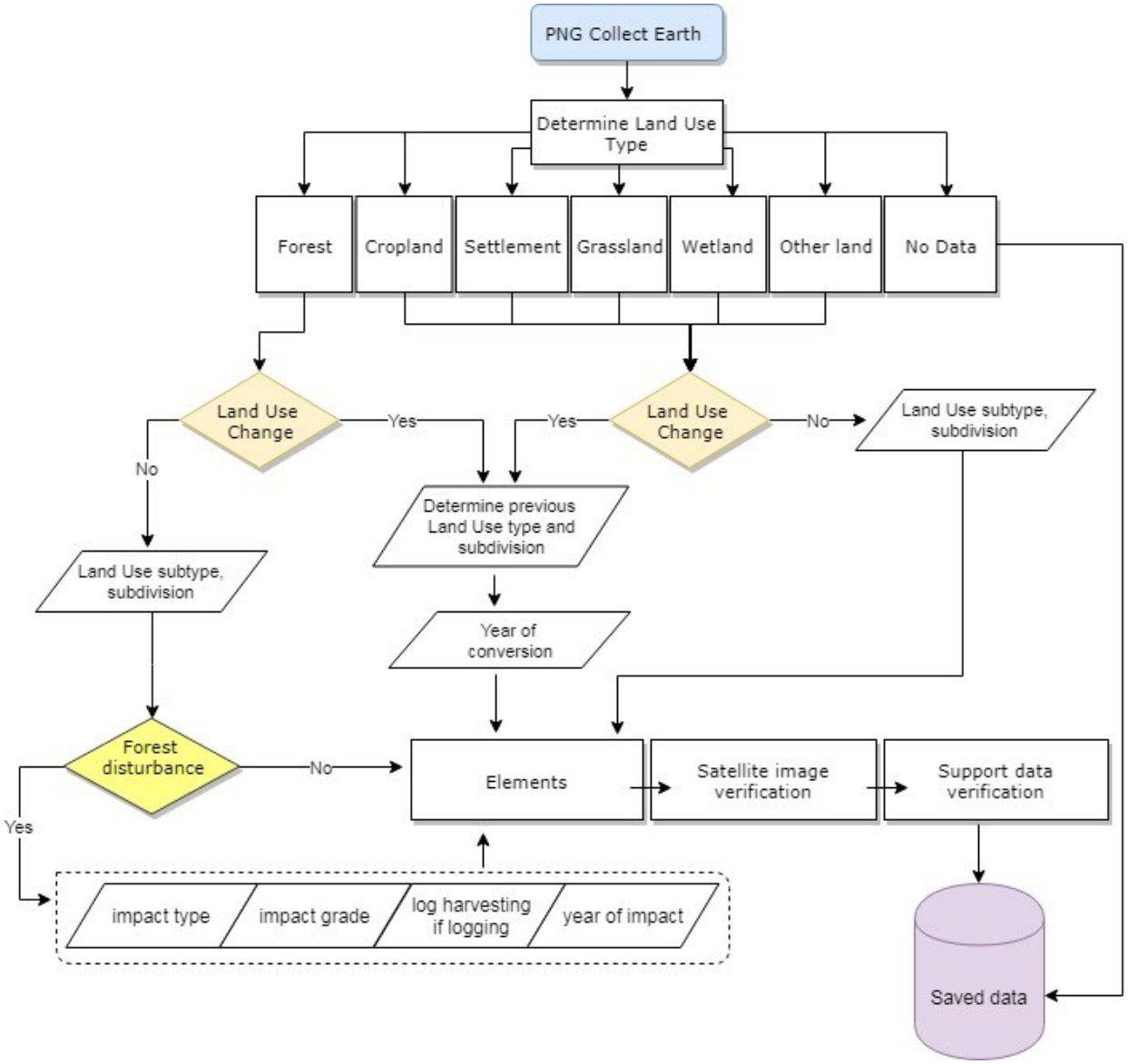


Figure 2-14: Overall steps of the land use and land use change assessment.

Hierarchical rules for Land Use Determination

The land class was evaluated and visually interpreted by recognizing the land key elements; the assessment of their socio-economic functions and the adoption of the 'predominant land use' criteria in the classification scheme settled by rules. The notion is that the land use function of land can be expressed through hierarchical relationships among key land elements, and that these functional relationships are based on thresholds (Table 2-10) reflecting the relevance and predominance of key land elements in the observed area.

Table 2-10: Land use Hierarchical Rules threshold for the assessment.

Priority	Land class	Threshold in % Cover
1	Settlement	10
2	Cropland	20
3	Forestland	30
4	Grassland	30
5	Wetland	30

The single land class or land use is simple to assess but becomes difficult when there is multiple classes. In this situation hierarchical sequence of *settlement > cropland > forestland > grassland > wetland > other land* was applied with the thresholds being: settlement 10%; cropland 20%; forestland 30%; grassland 30%; wetland 30%; other land 30% to express their pre-dominance. In Figure 2-15 image A2, settlement is 8%, cropland 44%, forest land 48%, grassland 0%, and 0% of wetland. Cropland is the predominant land use of the observed area. However, if the settlement area was more than 10%, the predominant land use of the observed area will be considered as settlement because settlement is the first preference in the hierarchical sequence. The objective was to provide a systematic approach for the representation of land use that is consistent with the concepts and methodologies developed by the IPCC.

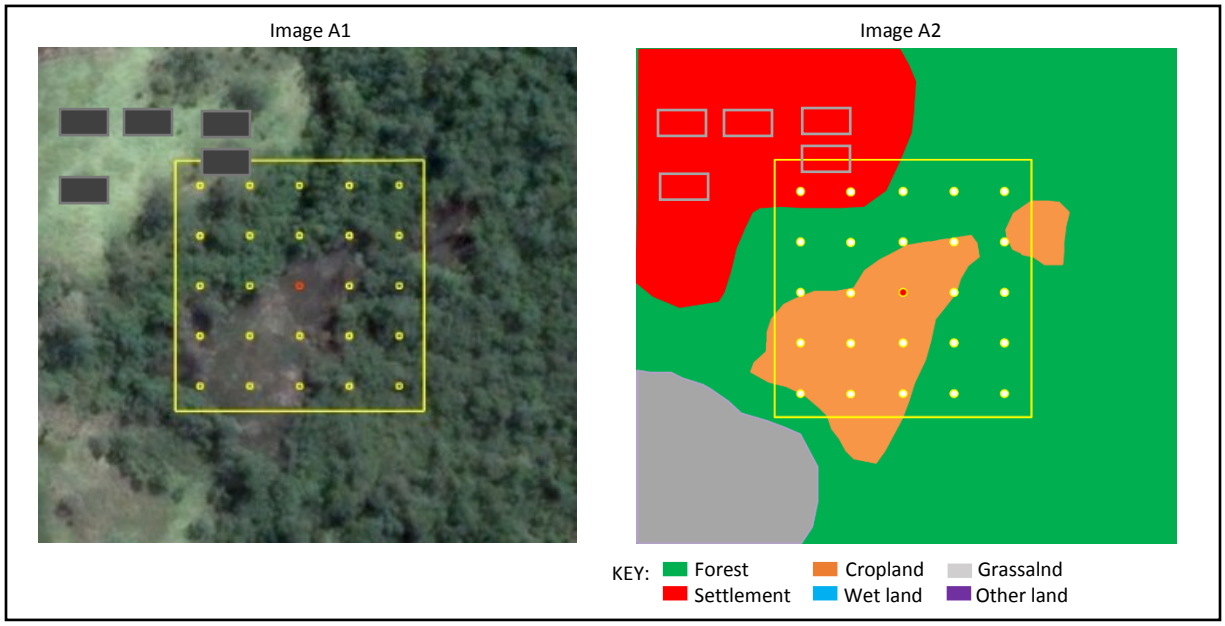


Figure 2-15: High resolution image A1 shows a zoomed-in Collect Earth 100 m x 100 m plot with 25 dots. A dot is 4%. The plot consist of multiple land use. In image A2 the idea of hierarchical rules is applied by imagining to demarcate land use type over the plot to distinguish the land use types. In image A2, three land use types are intersected by the plot. These are; settlement which contains 2 dots i.e. 8%, cropland contains 11 dots i.e. 44%, forest 12 dots i.e. 48% and grassland zero percent. The dominant land use is forest but cropland with 44% is the second preference and is over the threshold value of 20%. Therefore, the plot is represented as a Cropland land use type.

For the historical assessment, the level of disturbance is associated with the different land use categories as a result of human impact, i.e., logging, fire, gardening, 'wokabout' sawmill (portable sawmill) and others. The degree of human impact is determined by the operator's own judgement and his\her local knowledge (field experience) of the area. As for the land use change, the operator has to use Google Earth Engine with the different time series on Landsat 7 and Landsat 8.

ii. Working Environment Set-up

PNG Forest Authority local field officers from Provincial and Area offices were invited to be operators to undertake the actual assessment (Figure 2-16). These officers have obtained qualifications with a diploma or degree in Forest Management or Forest Science and are employed by the PNGFA. They perform various field tasks in the provinces and project sites. Other officers from PNGFA Policy and Planning Directorate also assisted in this assessment.

The first assessment included New Guinea Islands and the Highlands Region that was conducted from 25 April to 13 May 2016. The second assessment for Momase Region conducted was from 4 to 22 July 2016. The final assessment was conducted for Southern Region from 30 May to 18 June 2016. Initial QAQC work commenced with checking and cleaning conducted from July to December 2016. The checking and cleaning resumed in February and ended in May 2017.

Initial exercise was to train officers on how to conduct the assessment. Under the training exercise, overview presentations were given to make the participants understand the land use and land use change in forestry. The second aspect of the training was the hands-on practical using Collect Earth, Google Earth, Google Earth Engine and how to apply the hierarchical rules. The assessment took 3 weeks per region (4 regions) with selected PNGFA officers.

During the training exercises important presentations were made on Land Use and Land Use Change (LULUCF) by IPCC Guidelines and Open Foris Collect Earth. Critical interpretation skills were presented for land use conversion and forest disturbance. Examples of land use such as forest remaining forest but detection of a disturbance was also explained graphically through power-point presentations. Demonstrations on how to operate Google Earth, Google Earth Engine and Bing Map were also taught briefly.

Figure 2-16: Working Environment of Collect Earth Assessment.

A total of sixteen (16) desktops with dual 22-inch screens were set-up with fast internet connectivity. The internet service was a direct router connection to Telikom PNG. This enabled the PCs to utilize full capabilities of the web mapping tools such as Google Earth, Google Earth Engine and Bing Map. The only interruptions faced were power disruption and internet disconnection at times which caused delays to the assessment.

iii. Quality-Assurance / Quality-Control

PNG is the first country which utilized the Collect Earth for the national level forest and land use change assessment and the tool had been developed and improved through utilization in PNG. In the initial assessment, we found several data errors to be corrected caused by customization of the tool. In addition, since the Collect Earth is a user friendly tool that require minimum GIS and Remote Sensing skills but requires good understanding of the land, the Collect Earth assessment had been conducted by many local area officers, mainly from the PNG Forest Authority. Therefore it is important to have quality-assurance and quality control process and system in place to ensure the results are standardized and consistent with the various assessment by the officers. The same quality-assurance and quality-control process were applied for all the data during assessment period. There were three (3) sessions of data checking and cleaning were conducted from September 2016 to May 2017. Figure 2-17 shows the general process applied to conduct the whole QAQC process.

Figure 2-17: Data checking and cleaning general workflow.

The first session included addressing 7,501 sampling plots with data integrity issues. Out of this the issues were due to non-corresponding land use classes with Forest Basemap 2012 vegetation classes to double check the assessment. For the first session some of these issues were resolved (40%) included correction of integrity errors such as missing or blank records, odd values, typing errors or incorrect input values. After cleansing of these errors a group of operators were invited to perform sessions 2 and 3 of data cleansing.

On the second session, data was compared with Global Forest Change (GFC or Hansen data). Using sampling plot of 4 km by 4 km grid, GFC tree cover loss information was integrated. Sampling plots containing more than 200 hectares of GFC tree cover loss since 2001 to 2015 were aggregated (Figure 2-18) with a total of 921 sampling plots were identified as potential missing change plots. These sampling plots were re-assessed and modified to contain a land use conversion or allocated a human impact. Sampling plots were unchanged if GFC tree cover was incorrect due to some image processing and analysis error.

During the second session it was found that deforestation and forest disturbance can be overestimated. To overcome this, sampling plots with less than or equal to 20 ha of GFC tree cover loss since 2001 to 2015 were selected as potential over estimated plots, a total of 921 plots were identified. All these 921 sampling plots were re-checked for land use change. Figure 2-18 shows the general process of identifying and modifying the sampling plots. These also required the use of Landsat 7 and 8 time series imageries in Google Earth Engine to confirm and verify these changes.

The third session included re-checking of 738 sampling plots that had GFC tree cover loss greater than 20 ha neither having a land use ‘year of change’ nor a ‘year of forest disturbance’. If GFC tree cover loss was true for a land use change the whole sampling plot information was edited and new information entered. This was same for forest disturbance. After the final cleaning process it was confirmed that a total of 70 sampled plots were recorded as ‘No data’. A summary of the total number of sampling plots before and after the data cleaning process are shown in Table 2-11.

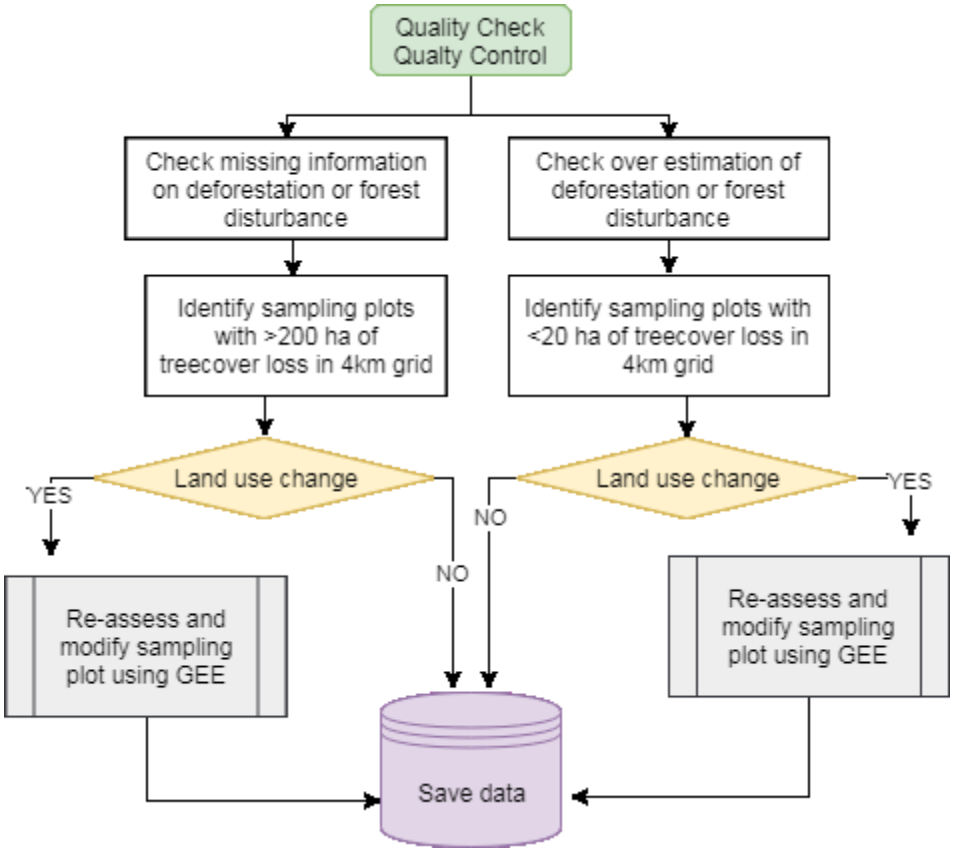


Figure 2-18: Flow chart showing re-assessment of sampling plots with missing information and over estimation of deforestation/forest disturbance.

Table 2-11. Plots per land use category totals before and after the data checking and cleaning process.

Land use category	No. of plots Before cleaning	No. of plots After cleaning	Difference
Forest land	19,976	19,327	-649
Cropland	2,492	3,187	695
Grassland	1,350	1,306	-44
Wet land	1,097	1,106	9
Settlement	234	251	17
Other land	53	32	-21
Total:	**25,202**	**25,209**	
No data	77	70	-7
Total:	**25,279**	**25,279**	**0**

iv. Data Analysis

The data collected through this assessment was analyzed in Saiku. Saiku is an analysis software linked to Collect Earth that uses a familiar drag-and-drop interface to perform queries. Saiku offers a user friendly, web-browser based analytics solution that lets users, quickly and easily analyze data and create and share reports (Barber, 2017). The solution connects to a range of Online Analytical Processing or OLAP Servers including Mondrian, Microsoft Analysis Services, Systems, Applications and Products (SAP) Business Warehouse (BW) and Oracle Hyperion and can be deployed rapidly and cost effectively to allow users to explore data in real time (Barber, 2017).

Saiku has made it very easy for the analysis to be conducted with drag-and-drop function. For example to determine areas in hectares of only forest land subdivisions for year 2015 a simple query is developed by drag-and-drop of the 'Area (Ha)' measure to COLUMNS and 'Land use subdivision' dimension to ROWS. To get only the subdivision for forest land the filter function is applied. This requires drag-and-drop of 'Land use category' dimension to FILTER. Once done the 'land use category' is double-clicked and the filter dialogue appears to choose the forest land category. Figure 2-19 shows an example described above.

A key function of Saiku is exporting the results in tables or in graphics to other file formats such as PDF, JPEG and Comma Separate Value (CSV). The commonly used Saiku export function in this assessment is exporting to CSV file format. This allowed analysis to be performed in Microsoft Excel using analysis functions that are not available in Saiku. In MS excel data was re-analyzed to develop charts and graphs to present various information relevant to the objective of the assessment. All derived information are presented in the results section of this report.

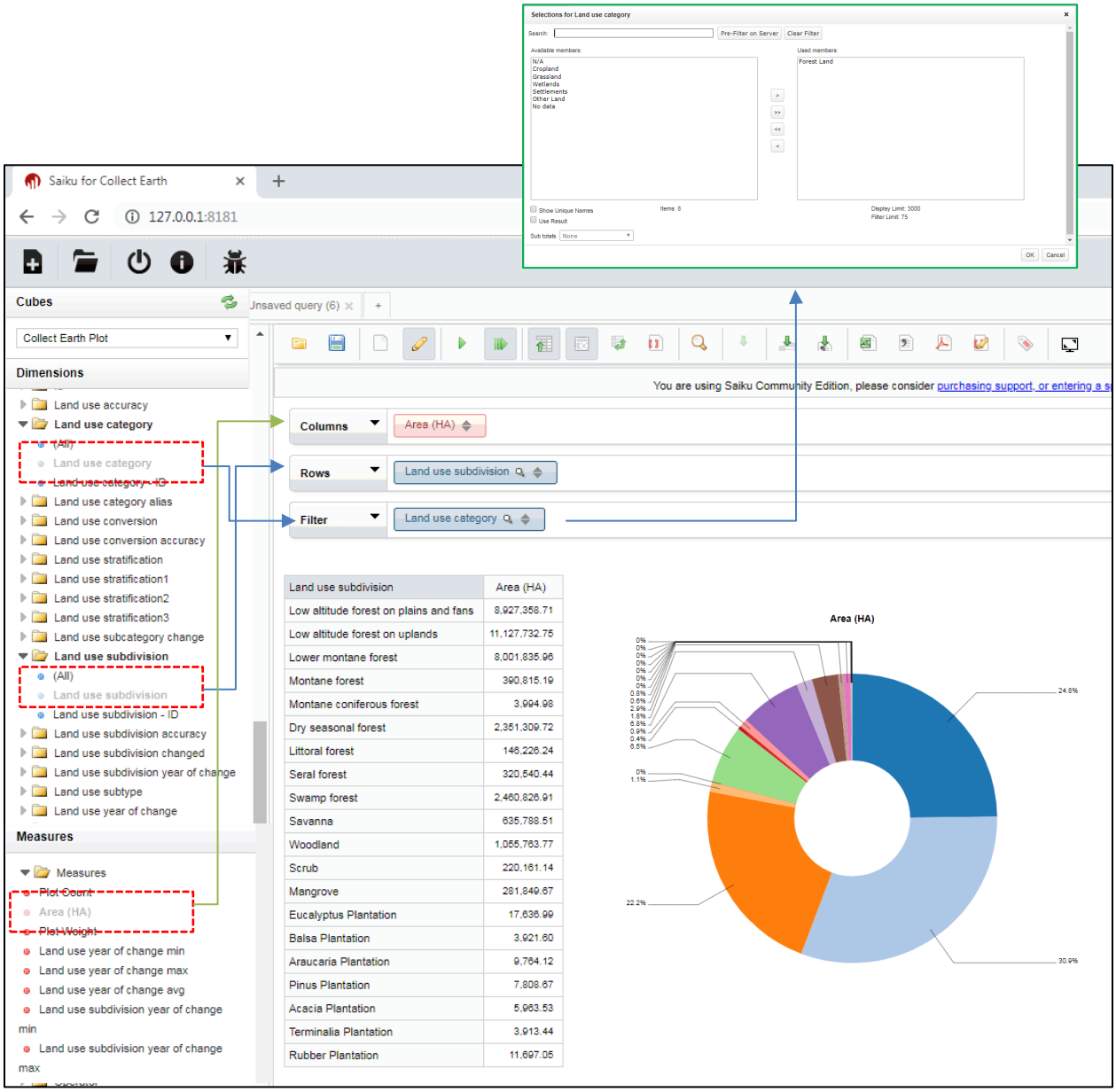


Figure 2-19: Showing how the drag-and-drop query is developed in Saiku. The example shown is how to get information on forest land subdivisions areas in hectares.

v. Uncertainty Analysis

A qualitative and quantitative uncertainty analysis was undertaken. In elaborating the forest and land use change area and forest carbon stock per unit area that underlie it, the analysis of uncertainties makes it possible to identify opportunities for improvement.

Qualitative analysis

In terms of area change in forest and land use, several major sources of error in estimating past land-use trends from the Collect Earth exercise are expected.

- Classification error (random and systematic error)
- Sampling error (random error)

To reduce the uncertainty of classification error, PNG defines the land use subdivision based on the existing classification system described in Section 2.1 and Section 4. The stratification based on the carbon stock amount will be considered in future based on the progress and result of current ongoing national forest inventory.

The potential sources of error contributing to uncertainty of the sampling assessment includes sampling error and human error. Sampling error arises from unrepresentative samples and variability resulting from the use of samples. Human error on the other hand arises from misinterpretation of historical land use and land use change and forest (Potapov, Hansen, Stehman, Loveland, & Pittman, 2008).

In terms of forest carbon stock per unit area, there are also several most important error sources to be considered in estimating carbon stocks for PNG's land-use types. The set of forest carbon stock values used is taken from literature and only little direct information is available on the error. Nonetheless, PNG expects a set of typical errors to occur for the carbon stock value:

- Measurement error (random and systematic error) since the literature values were all derived from primary measurements, usually plot-based measurements where measurements can have error.
- Sampling error (random error) since the plot-based measurements that underlie estimates reported in literature and in the IPCC guidelines only sample the forests.
- There is representation error from using IPCC default values that might be imperfectly suitable for PNG's forests (systematic error).
- There is a representation error from approximating forest carbon stocks in all of PNG's forest types from literature values that were developed only for the most abundant types of forests (systematic error).
- There is model error from inferring on forest degradation carbon stocks from measurements in one type of forest only (systematic error).

Quantitative analysis

Implementation of statistically valid ground truth survey is not practical considering the fact that most part of PNG is not accessible hence estimation of the uncertainties of forest and land use change area is purely statistical with no ground truth. The uncertainty analysis is based on IPCC 2006 GPG, complemented by GFOI (Global Forest Observations Initiative) Methodological Guidance on estimating uncertainties of land areas estimated by proportion without verification (it is always good practice to verify a land classification).

The area estimate of each land use category is calculated by multiplying the total area A and by the proportion of sample plots in the specific land category. The percentage uncertainty associated with the area estimate is calculated as ±1.96 times the standard error of Ai divided by Ai.

The standard error[3] of an area estimate is obtained as $A * \sqrt{\frac{p_i(1-p_i)}{n-1}}$

Where:

p_i is the proportion of points in the particular land-use category (stratum) i; $p_i = \frac{n_i}{n}$

A is the total area of PNG,

n the total number of sample points,

n_i is the number of point under a particular land-use category.

[3] *Standard error is the standard deviation of the sampling distribution*

3. PNG Forest and Land Use in 2015

3.1. National and provincial land use status in 2015

PNG has a total land area of about 46.1 million hectares of which 77.97% is forested followed by cropland (11.81%), grassland (5.27%), Wetland (4.61) settlement (0.84%), and other land covering only 0.13% (Table 3-1). Land use population in all provinces is provided in Table 3-2. The top six provinces with high proportion of forest areas are Gulf (91.2%), West Sepik (90.6%), West New Britain (85.3%), Western (84.5%), Central (82.5%) and East New Britain (81.3%). Higher proportion of cropland are found in Western Highlands Province (43.6%), Autonomous Region of Bougainville (40.7%), Jiwaka (30.5%) and Eastern Highland Province (28.6%) have more cropland compared to other provinces (Figure 3-1). In general, provinces with higher population density have higher proportion of cropland, thus less proportion of forest land (Table 3-2).

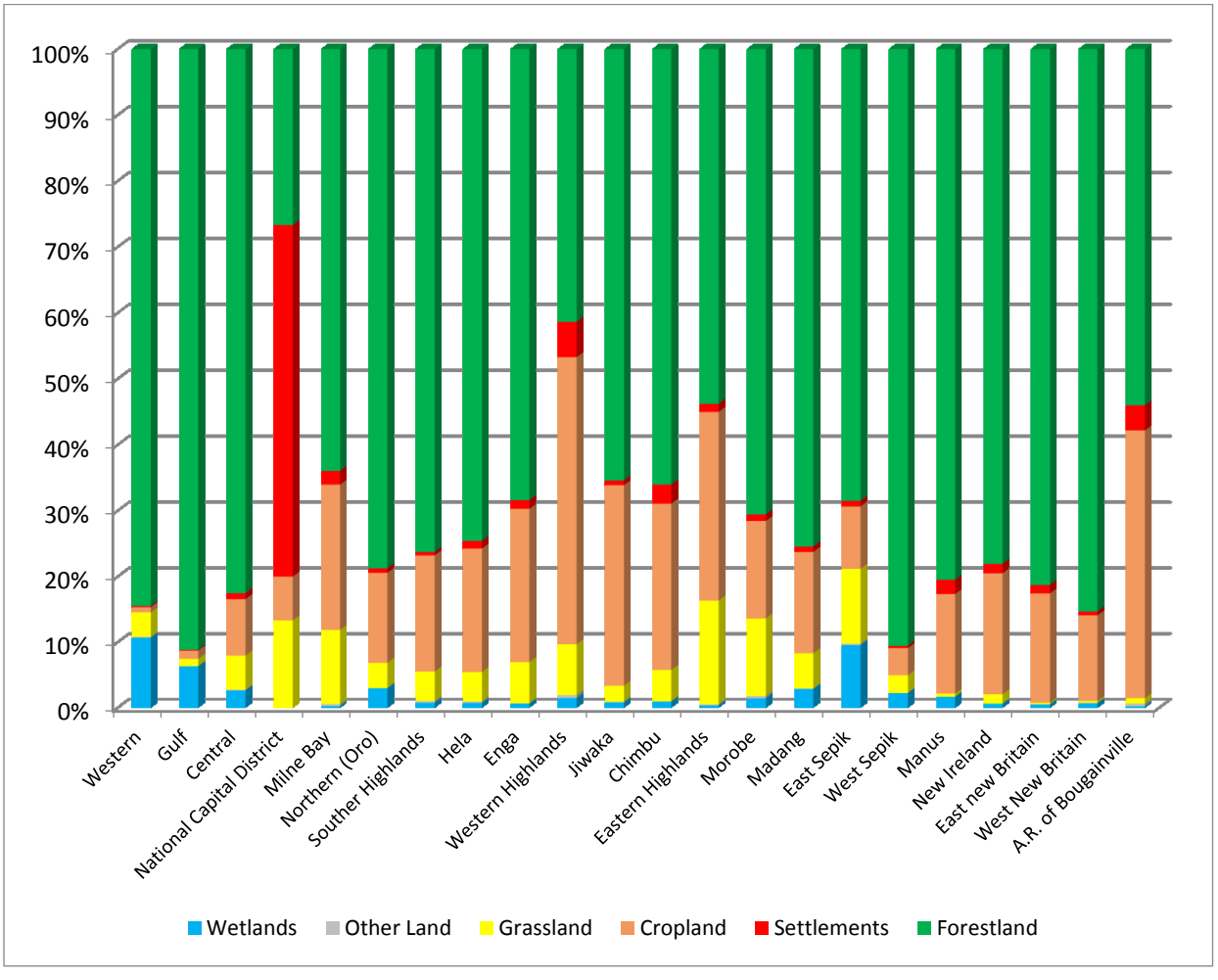


Figure 3-1: Proportion of land use in Provinces

Table 3-1: PNG Land Use Composition in 2015.

Land use category	Area (ha)	%
Forest Land	35,963,273	77.97
Cropland	5,158,633	11.18
Grassland	2,442,680	5.27
Wetlands	2,126,505	4.61
Settlements	388,495	0.84
Other Land	59,277	0.13
Total:	**46,138,863**	**100.00**

Table 3-2: Land use and population in provinces.

Province	Population*	Pop. density (p/sq.km)	Area (Ha)	Forest land (Ha)	Cropland (Ha)	Grassland (Ha)	Wetlands (Ha)	Settlements (Ha)	Other land (Ha)
Western	201,351	2.06	9,797,778.05	8,276,688.71	76,545.14	367,024.14	1,048,079.62	17,664.26	11,776.18
Gulf	158,197	4.56	3,471,859.93	3,165,053.61	43,546.70	39,587.91	219,712.91	3,958.79	-
Central	269,756	9.13	2,955,783.08	2,439,200.76	254,407.09	153,421.07	77,681.55	27,188.54	3,884.08
NCD	364,125	1,846.48	19,720.00	5,258.67	1,314.67	2,629.33	-	10,517.33	-
Milne Bay	276,512	19.52	1,416,665.97	905,961.80	313,075.35	160,451.12	3,913.44	29,350.81	3,913.44
Northern	186,309	8.23	2,263,371.00	1,782,380.42	310,316.50	87,276.52	67,881.74	15,515.83	-
Southern Highlands	510,245	33.91	1,504,750.99	1,147,396.78	266,566.93	67,607.55	11,589.87	7,726.58	3,863.29
Hela	249,449	23.63	1,055,593.00	787,221.90	198,793.41	47,710.42	7,951.74	11,927.60	1,987.93
Enga	432,045	36.82	1,173,438.03	802,367.40	273,931.73	73,825.57	7,771.11	15,542.23	-
Western Highlands	362,850	83.80	432,997.99	179,018.53	188,881.81	33,535.15	6,411.13	23,178.71	1,972.66
Jiwaka	343,987	71.59	480,522.01	314,282.05	146,566.59	11,804.02	3,934.67	3,442.84	491.83
Chimbu	376,473	61.38	613,341.00	404,962.33	155,301.09	29,487.55	5,897.51	17,692.53	-
Eastern Highlands	579,825	52.02	1,114,676.00	599,456.69	319,318.43	176,310.79	3,918.02	13,713.06	1,959.01
Morobe	674,810	20.03	3,368,620.94	2,376,586.48	499,922.88	398,376.04	48,820.59	33,198.00	11,716.94
Madang	493,906	17.16	2,878,073.81	2,170,563.45	444,202.08	155,051.82	82,414.49	23,854.13	1,987.84
East Sepik	450,530	10.31	4,368,598.87	2,992,137.29	413,722.78	498,035.96	417,644.33	37,254.66	9,803.86
West Sepik	248,411	6.91	3,592,765.99	3,253,560.71	148,527.76	98,349.46	80,285.27	12,042.79	-
Manus	60,485	31.93	189,425.43	152,453.23	28,756.15	912.89	3,195.13	4,108.02	-
NewIreland	194,067	20.65	939,696.02	733,468.73	173,153.10	13,618.78	5,836.62	13,618.78	-
East New Britain	328,369	21.47	1,529,424.99	1,243,148.00	254,904.17	3,921.60	7,843.21	19,608.01	-
West New Britain	264,264	12.99	2,033,999.97	1,735,575.26	265,048.26	5,889.96	13,743.24	11,779.92	1,963.32
AROB	249,358	26.59	937,759.99	506,469.53	381,830.55	7,913.59	1,978.40	35,611.14	3,956.79
PNG or Total	**7,275,324**	**15.77**	**46,138,863.06**	**35,973,212.32**	**5,158,633.14**	**2,432,741.25**	**2,126,504.59**	**388,494.57**	**59,277.17**

*PNG Census 2011 (NSO)

3.2. Land use and altitude

Land use dominancy according to the elevation range is shown in Figure 3-2 below. There is a distinct relationship between land use and altitude in PNG. Forest occurs from the sea level up to 3,800 m above sea level. Above 3,200 m, proportion of forest become smaller as elevation increase. Grassland is dominant at elevation between 3,500 and 3,800 m and other land (rock and bare soil) become dominant at elevation higher than 3,800 m. Highest peak of PNG is 4,509 m (Mt. Wilhelm). Agricultural activities are denser at the elevation range between 1,500 m and 1,900 m. These are prevalent in the hinterland Highlands of PNG; Goroka (Eastern Highlands), Kundiawa (Simbu), Banz (Jiwaka), Mt. Hagen (Western Highlands) and Mendi (Southern

Highlands) are all located in this elevation range. Agriculture activities are rarely seen at elevation above 2,800 m. Almost all Wetland is found at elevation below 100 m. Table on the area of each six land use in elevation range are in Appendix 1.

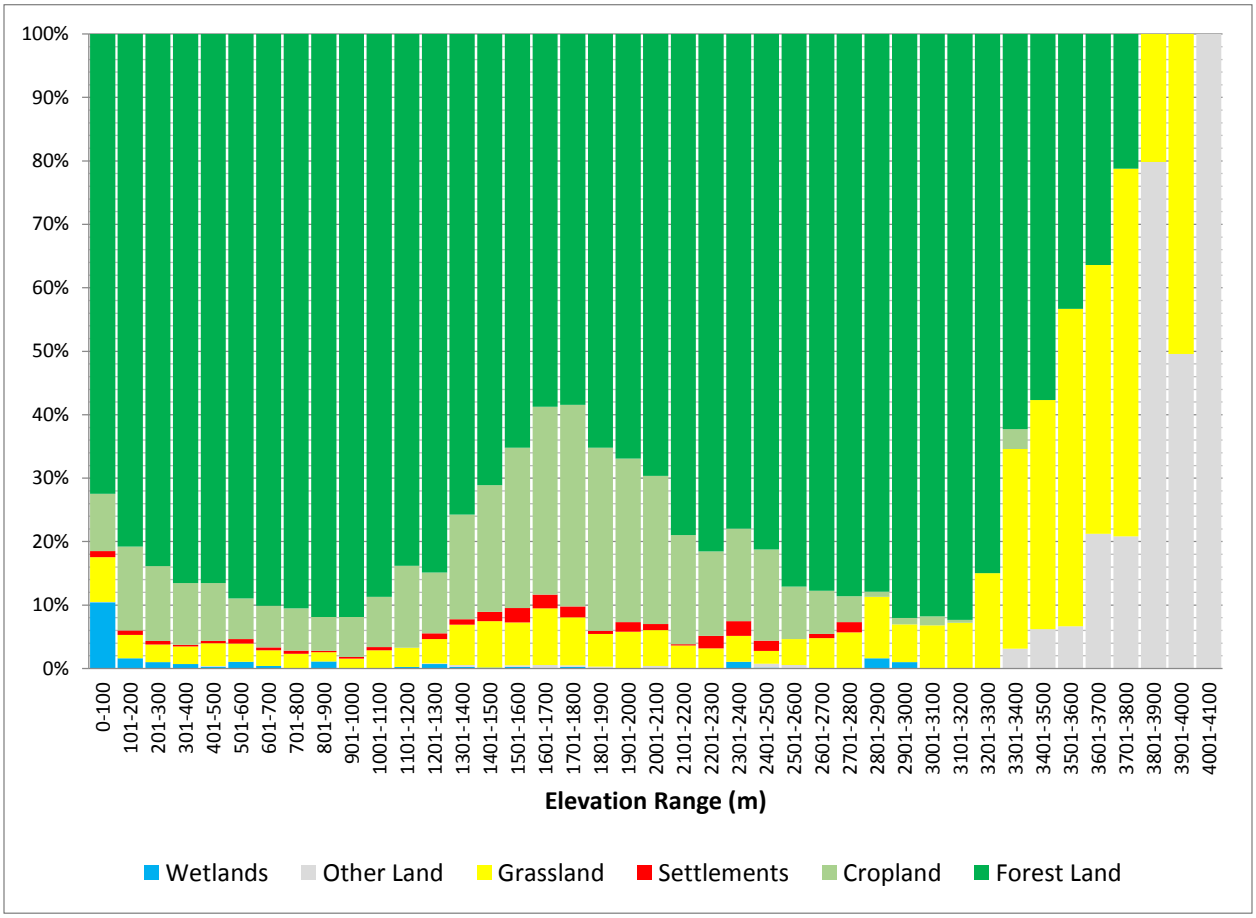


Figure 3-2: Land use at elevation range

3.3. Land Use and Population

There is a distinct correlation between the proportions of land use and the 2011 population density (Figure 3-3). With increase of population density, the proportion of forest decrease and cropland and settlement increase. There are a few settlement plots with zero population density (Table 3-2). This is due to the 4 km (or 2 km) grid polygons having no village census units. The village census units are just points from the NSO dataset.

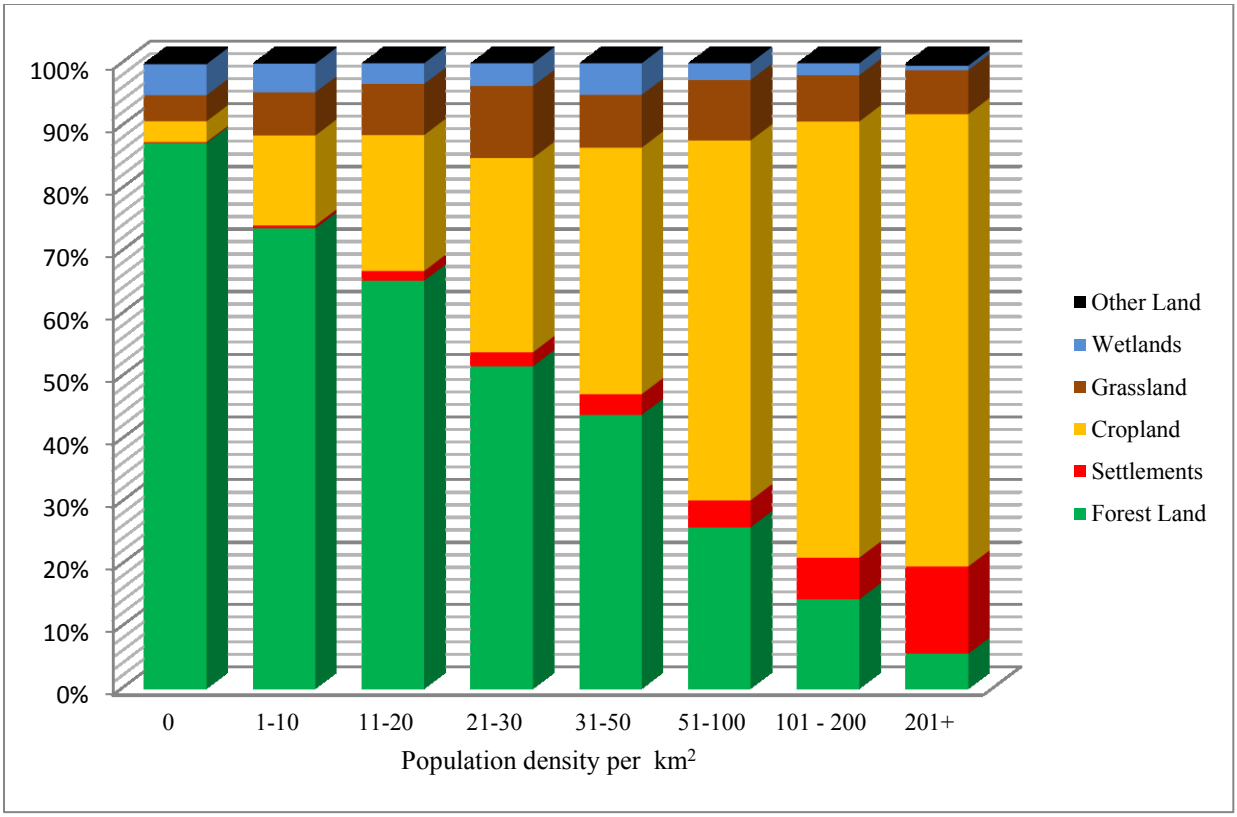


Figure 3-3: Land use composition in different population density range. Population density of each sampling points was calculated from Census 2011 data (NSO 2015).

3.4. Status of Forest in 2015

Forest composition and distribution

The total forest in PNG is about 35.9 million hectares covering approximately 78% of the total land mass (Table 3-3) and more than 76.3% of forest has not been disturbed by anthropogenic activities (Figure 3-6). The three most dominant forest types comprise more than three quarters of the country. They are *low altitude forest on uplands* (30.9%), *low altitude forest on plains and fans* (24.8%), and *lower montane forest* (22.3%) in order of abundance. Areas of all forest types in the country are provided in Table 3-3 and the same for provincial level is provided in Appendix 4. For more information on the forest classifications, refer to Chapter 2.1 and Appendix 11.

Table 3-3: Forest types and area in hectares

Forest types	Area (ha)	%
Low altitude forest on plains and fans	8,927,359	24.82
Low altitude forest on uplands	11,127,733	30.94
Lower montane forest	8,005,831	22.26
Montane forest	390,815	1.09
Dry seasonal forest	2,351,310	6.54
Littoral forest	146,226	0.41
Seral forest	320,540	0.89
Swamp forest	2,462,788	6.85
Savanna	623,889	1.73
Woodland	1,055,764	2.94
Scrub	220,161	0.61
Mangrove	281,850	0.78
Eucalyptus Plantation	17,637	0.05
Balsa Plantation	3,922	0.01
Araucaria Plantation	9,764	0.03
Pinus Plantation	7,809	0.02
Acacia Plantation	5,964	0.02
Terminalia Plantation	3,913	0.01
	35,963,273	100.00

Distribution of forest type

PNG's major vegetation classification is based on altitude (Table 2-3). For example, the distribution of three most dominant forest types (Table 3-2) in the country clearly classified by elevational range; *low altitude forest on plains and fans* and *low altitude forest on uplands* are among the forests distributed below 1,000 m in altitude while *lower montane forest* is among the forests distributed between elevation 1,000 and 3,000 m. The minor forest types are either confined to certain altitudinal range or sparsely distributed throughout. *Mangrove, dry seasonal forest* and *littoral forest* occurs from the sea shore up to 100 m asl while *swamp forests* are found to be occurring up to 700 m asl. woodland occurs only below 800 m asl. Montane forest occurs between 3000 m and 3800 m asl. Scrub although is concentrated from the sea level up to 200 m above sea level, it is also sparsely distributed throughout from the 200 m up to 3,500 m above sea level. Full information on forest type distribution in altitude range is provided in Appendix 5.

Since altitude is one of the primary indices for vegetation classification in PNG, altitude of provinces is related to the forest compositions of provinces. Provinces in Highlands Region contain higher portion of high-altitude forest types (Figure 3-4 and Appendix 5). Dryer forest types (Woodland, Dry seasonal forest, Savanna and Scrub) distributes southern part of the country especially in Western Province (Figure 3-4 and Figure 3-5).

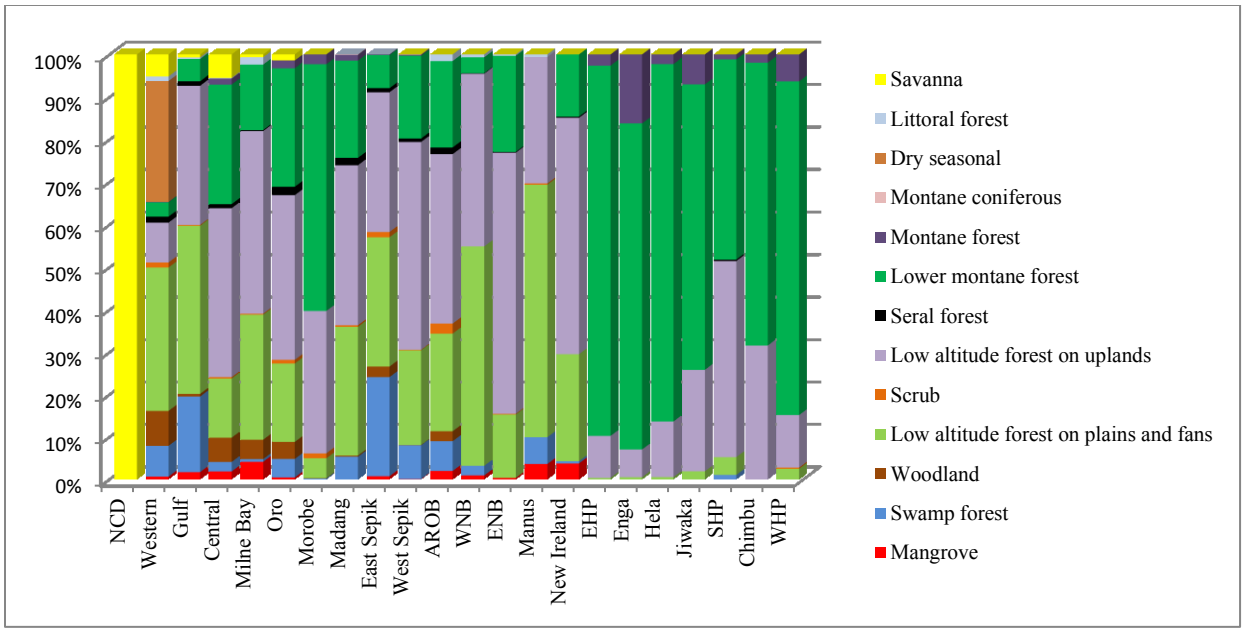


Figure 3-4: Proportion of forest types in Provinces.

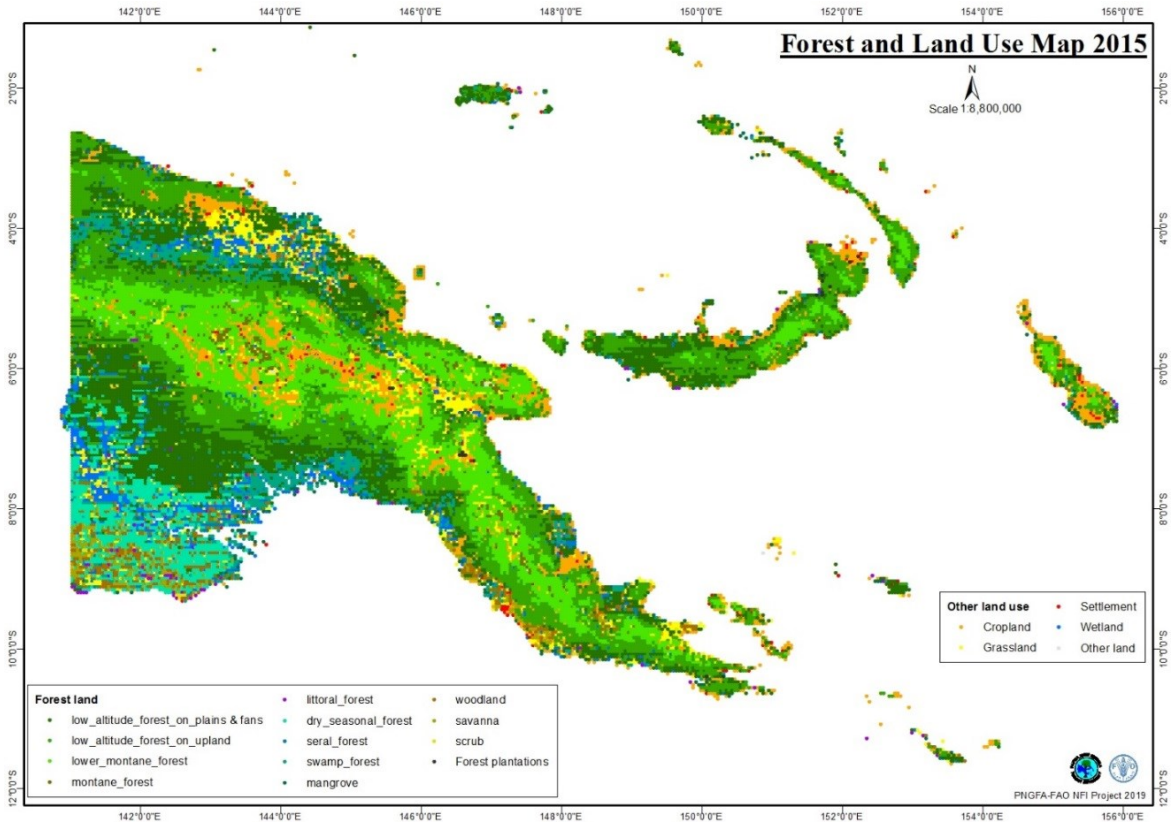


Figure 3-5: Collect Earth point-sampling forest and land use type distribution map.

Forest Disturbances

As at 2015 about 76.3% of the total forest in PNG was undisturbed and 23.7% was disturbed through commercial logging, gardening fire, portable sawmill and others. Most of the disturbance was caused by commercial logging and temporary agriculture (Figure 3-6). For the three most dominant forest types , the disturbed ratio in *Low altitude forest on plains and fans* is 36.8% and significantly higher than national average due to commercial logging while *Low altitude forest on uplands* (21.5% disturbed) and *Lower montane forest* (16.6% disturbed) (Figure 3-7) are less disturbed than national average (23.7%). Savanna and woodland are also disturbed higher ration than national average due to forest fire (Figure 3-7).

Human impacts are distinct on the type of forest. Logging mostly occur *in low attitude forest on plains and fans* and *low altitude forest on uplands* although the latter is more profound. Fire is prevalent in savanna, woodland and scrub forests. Gardening areas are isolated patches of temporary forest clearings. While gardening activities occurs throughout they are dominant in *lower montane*, *low altitude forest on uplands* and *low altitude forest on plains and fans* in order of abundance (Figure 3-7). Area of each forest type impacted by anthropogenic activities can be found in Appendix 6.

Elevation has a distinct relationship with anthropogenic activities on the forest land (Figure 3-8). Logging occurs from the seashore up to 1,100 m asl but is more concentrated between 0 – 500 m. Gardening activities occurs throughout but becoming denser between 1,000 m and 2,800 m. Fire also occur throughout but prevalent between the elevation 2,700 m and 3,400 m. The dominancy of grassland starts at elevation 2700m (Figure 3-8) and the occurrence of fire seems to follow this pattern (Figure 3-8). See Appendix 7 for details.

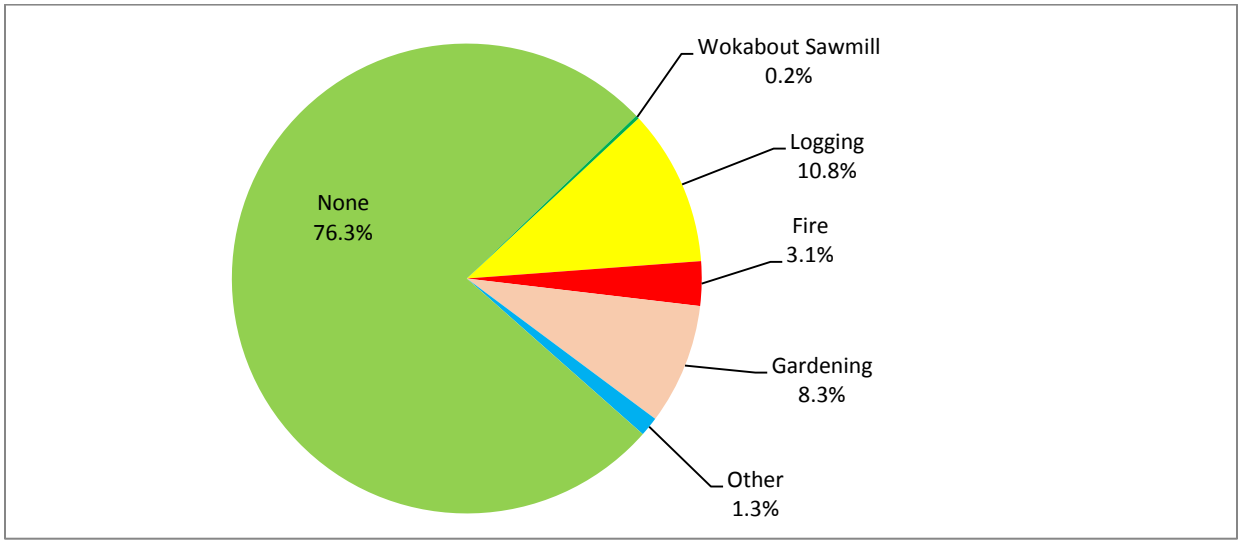


Figure 3-6: Human impact on forest land.

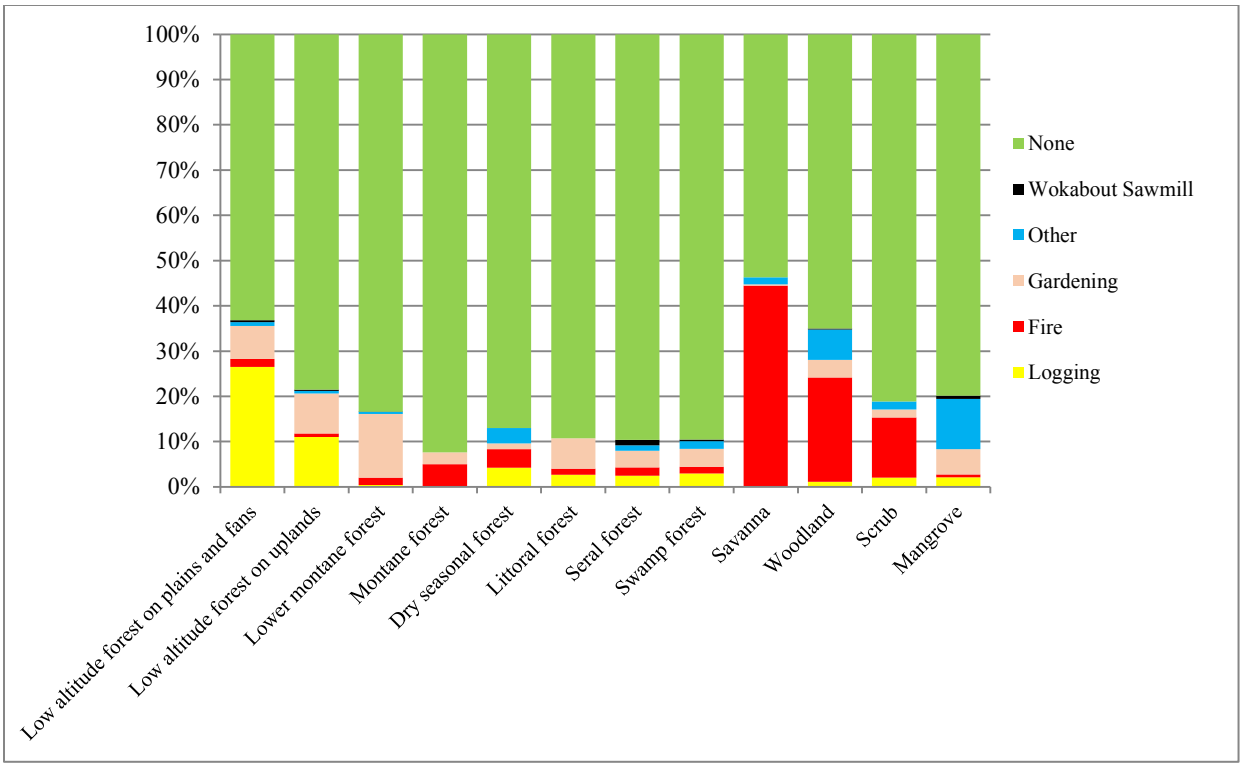


Figure 3-7: Human impact on forest types in 2015.

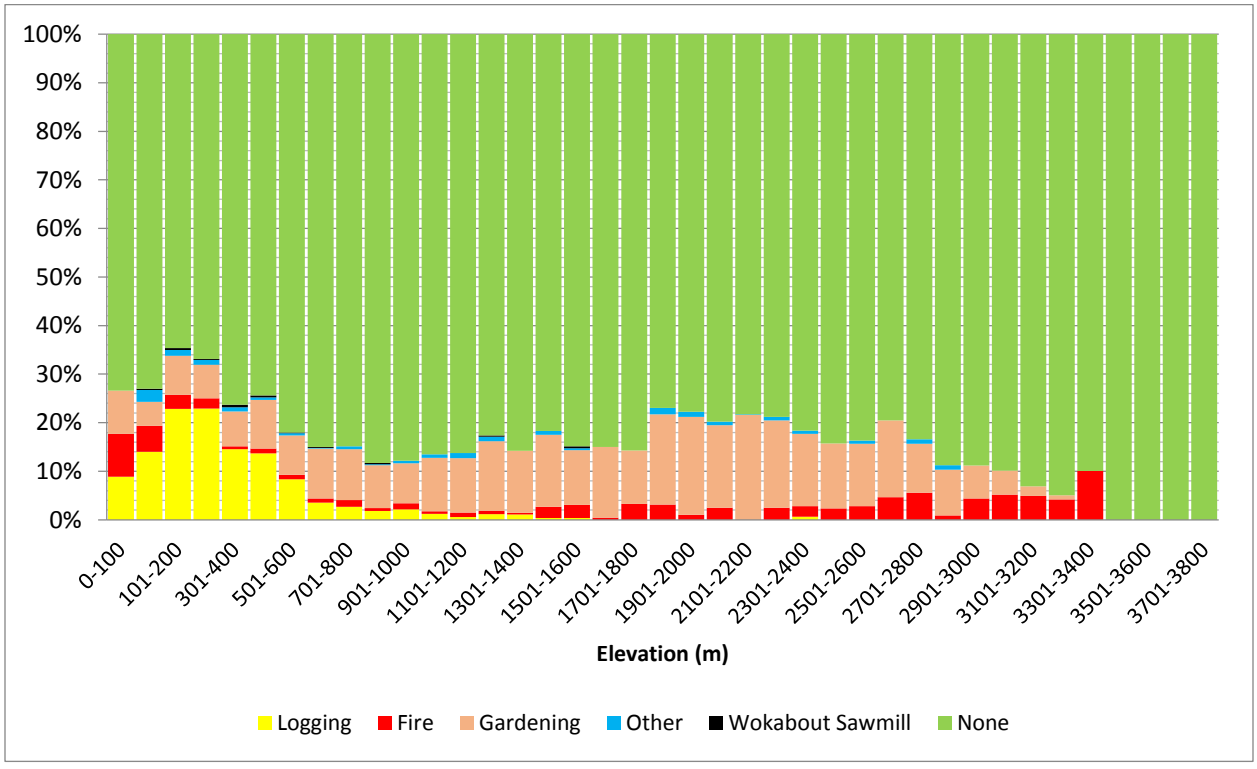


Figure 3-8: Forest disturbance at elevation range in 2015.

3.5. Status of Cropland in 2015

Total area of cropland in PNG is about 5.1 million ha and occupy 11.18% of PNG land mass. The subsistence agriculture comprised of both Permanent and Shifting and account for more than 88.8% of the total cropland area followed by oil palm plantation (6.32%), coconut plantation (2.79%), coconut intercropped with cocoa (0.84%) and Coffee plantation (0.57%) (Table 3-4). Large scale monoculture commercial plantations are minor land use in PNG except oil palm and coconut plantations (Table 3-4).

The proportion of cropland is high in Western Highlands Province (43.6%) followed by Autonomous Region of Bougainville (40.7%), Jiwaka (30.5%), Eastern Highlands (28.6%), Chimbu (25.3%) and Enga (23.3%). There are more croplands between elevations 1000 m to 2500 m (Figure 3-2). Most of these cropland are subsistence agriculture and which are common in all the provinces except NCD. Oil palm plantations are specific to West New Britain, West Sepik, Oro, Milne Bay, Morobe, Madang and East New Britain (Figure 3-9). The detail information are in Appendix 2.

Table 3-4: Cropland land use type subtypes and subdivisions with area in hectares as at 2015.

Subtype	Subdivision	Area (ha)	%
Subsistence Agriculture	Permanent	1,109,668	21.51
	Shifting	3,423,186	66.36
Commercial Agriculture	Tea	2,955	0.06
	Coffee	29,472	0.57
	Oil palm	325,896	6.32
	Cocoa	13,796	0.27
	Coconut	143,789	2.79
	Cocoa/Coconut	43,267	0.84
	Rubber	11,697	0.23
	Sugar	7,881	0.15
Not identified	Other	17,606	0.34
	Not Sure	29,419	0.57
		5,158,633	100.00

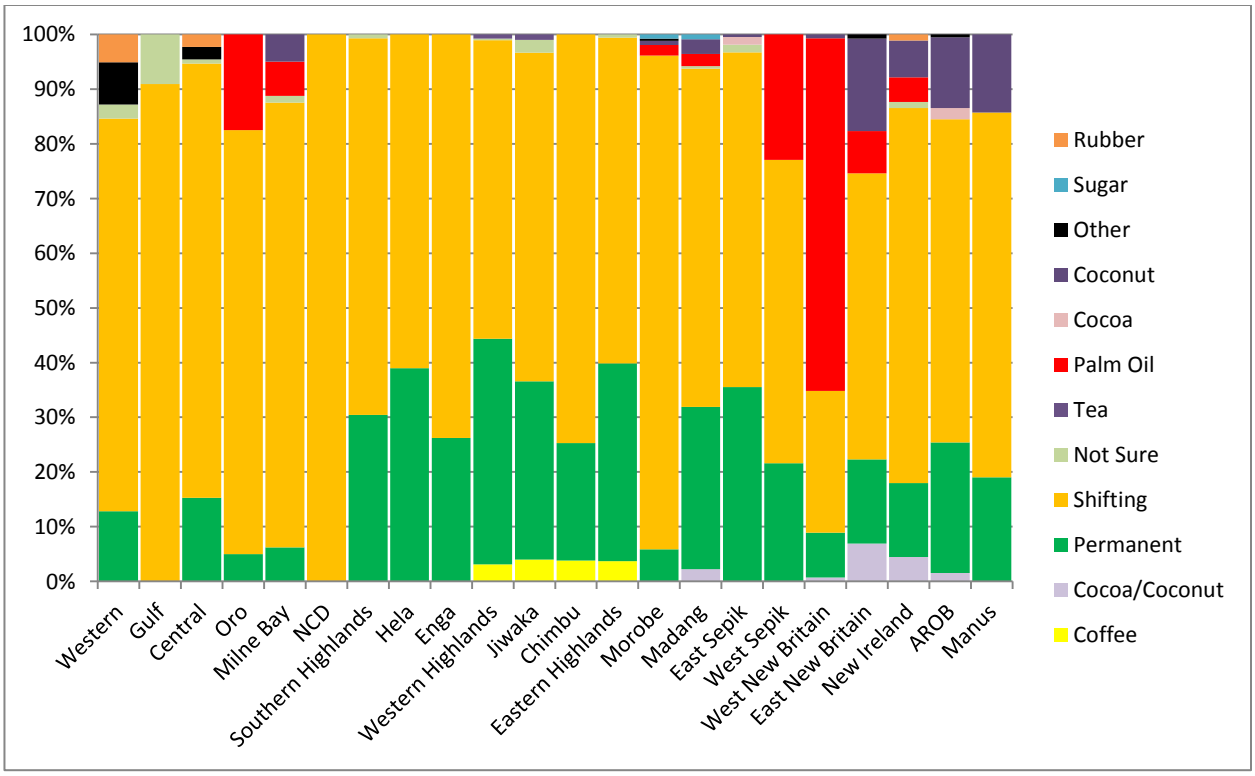


Figure 3-9: Proportion of Cropland types in Provinces.

3.6. Status of land use other than forest and cropland

The land use other than Forest and Cropland comprised of Settlement, Grassland, Wetland and Other land (Table 3-5). They comprised about 10.9% of the total PNG land mass. Settlement covers about 0.8% of the total land area and villages are most dominant followed by large settlements and infrastructure. Grassland cover about 5.3% of the total land area. Herb land is most dominant in PNG and comprised about 77% of the total grassland area. Wetland cover about 4.6% of the total land area. Other swamps include low laying seasonal inundated areas comprising of shrubby or vegetated areas and which are most dominant wetland areas in PNG followed by rivers. Other land is not significant in PNG and are comprised of 0.1% of the total land area of PNG. The dominant subcategory of other land are rocks followed by bare land then sand.

Table 3-5: Land use subdivision of land use other than forest and cropland.

Land use	Subdivision	Area (ha)	%
Settlement	Village	233,492	60.10
	hamlet	48,018	12.36
	Large Settlement	54,013	13.90
	Infrastructure	52,972	13.64
	Total:	***388,495***	***100.00***
Grassland	Herb land	1,894,376	77.55
	Rangeland	111,188	4.55
	Others	437,116	17.89
	Total:	***2,442,680***	***100.00***
Wetland	River	444,102	20.88
	Lake	253,541	11.92
	Dam	3,901	0.18
	Nipa Swamp	190,817	8.97
	Other Swamp	1,234,144	58.04
	Total:	***2,126,505***	***100.00***
Other land	Bare	20,560	0.41
	Sand	7,882	0.16
	Rock	30,836	0.61
	Total:	***59,277***	***100.00***
		5,016,957	

4. Forest and Land Use Change during 2000-2015

4.1. Deforestation during 2000-2015

A total of about 253,847 ha of forest was deforested between 2000 and 2015. This is about 0.71% deforestation in 15 years. Between 2000 and 2010 about 99,199 ha or 0.27% was deforested. Deforestation increased rapidly between 2010 and 2015 where about 154,648 ha or 0.43% of forestland was converted to other land use (Figure 4-1 and Appendix 8).

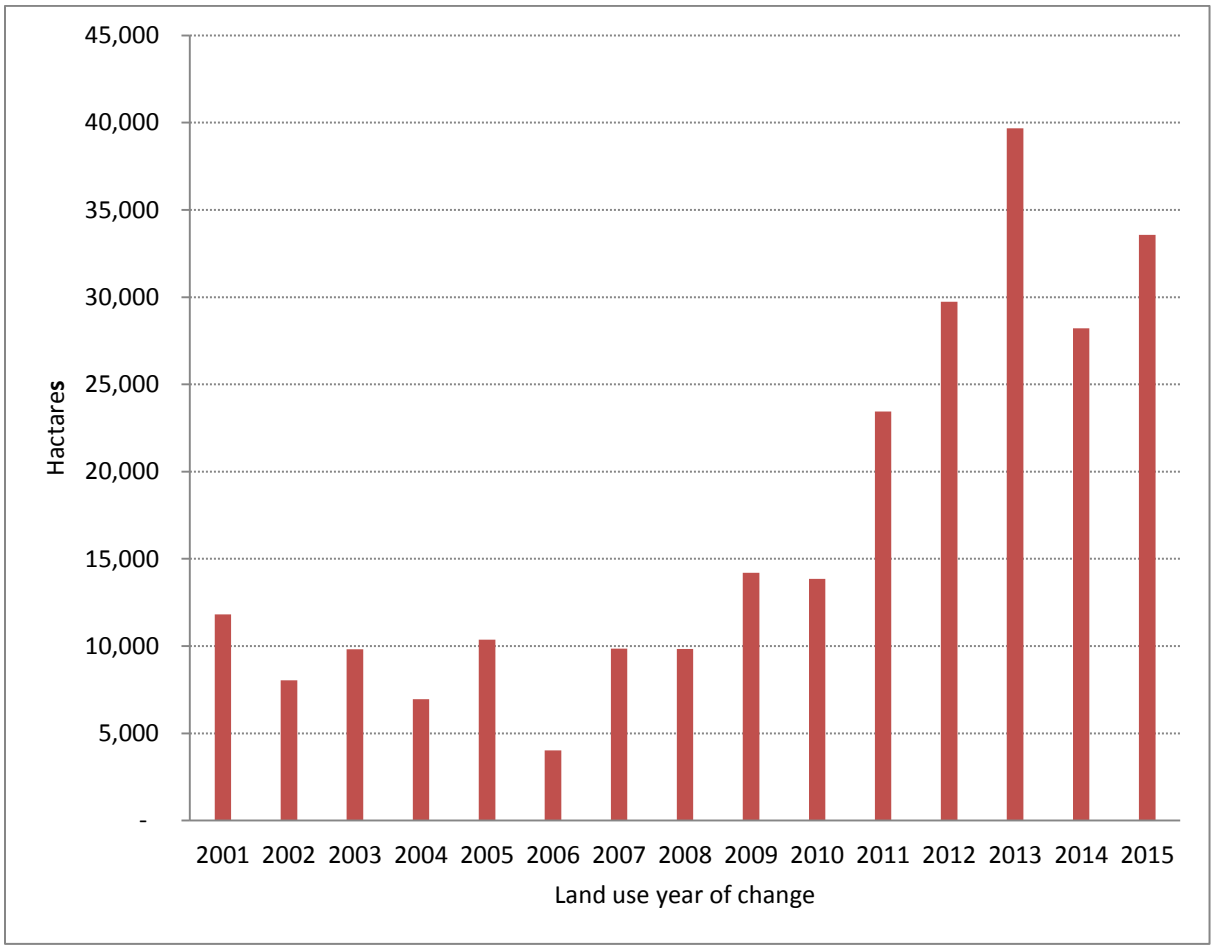


Figure 4-1: Annual deforestation.

Major driver of deforestation is shifting cultivation followed by oil palm development (Table 4-1). Of the total forest converted, over 50% of these forest conversions occurred in the *low altitude forest on plains and fans* (Figure 4-2). In this forest type, oil palm plantation development is the most significant cause of deforestation followed by shifting cultivation (Table 4-1). Highest rate of deforestation occurred in West Sepik province, which recorded more than double of deforestation in any other province in the country (Figure 4-3) . Most of oil palm plantation development occurred in three provinces (West Sepik, West New Britain and East New Britain)

(Figure 4-3). Information on annual deforestation rates can be found in Appendix 3 and all province deforestation composition can be found in Appendix 8.

Table 4-1: Forest types converted to other land use between 2000 and 2015

Forest types	Cropland (ha)							Settlement (ha)	Total	%
	Perma-nent	Shifting	Not Sure	Oil palm	Cocoa	Coconut	Other			
Low altitude forest on plains and fans	5,887	61,050	-	67,334	1,978	1,957	1,963	-	**140,169**	**55.22**
Low altitude forest on uplands	-	41,526	-	13,867	-	-	1,963	-	**57,356**	**22.59**
Lower montane forest	1,479	39,729	1,959	-	-	-	-	-	**43,167**	**17.01**
Dry seasonal forest	-	1,963	-	-	-	-	-	-	**1,963**	**0.77**
Swamp forest	-	5,958	-	-	-	-	-	-	**5,958**	**2.35**
Savanna	-	-	-	-	-	-	-	1,315	**1,315**	**0.52**
Woodland	-	3,919	-	-	-	-	-	-	**3,919**	**1.54**
Total:	**7,366**	**154,145**	**1,959**	**81,201**	**1,978**	**1,957**	**3,925**	**1,315**	**253,847**	**100**
%	**2.90**	**60.72**	**0.77**	**31.99**	**0.78**	**0.77**	**1.55**	**0.52**	**100**	

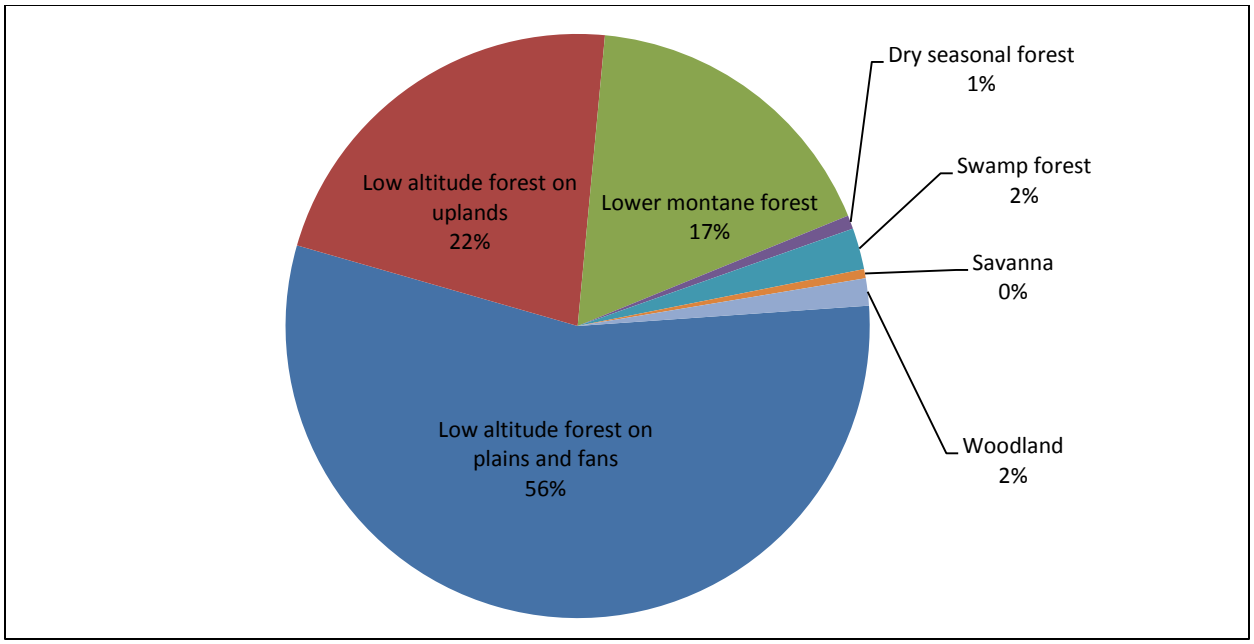


Figure 4-2: Forest types converted to cropland between 2000 and 2015.

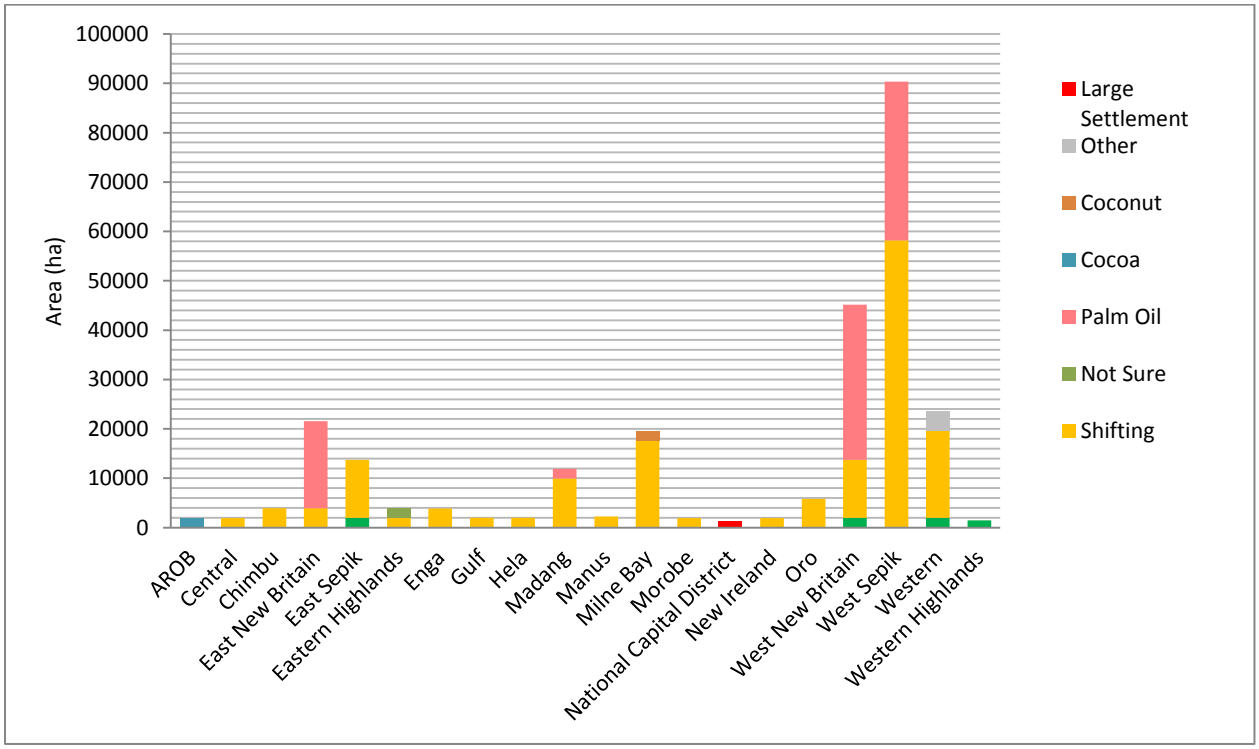


Figure 4-3: Forest converted to cropland types in Provinces between 2000 and 2015.

4.2. Forest degradation during 2000-2015

About 6.6% or 2.3 million hectares of forest in 2000 was disturbed or degraded in 15 years (Table 4-2). Forest degradation/disturbance has been increasing steadily since 2000 and reached its peak in 2010 and 2011 (Figure 4-4). The country's 15 year period forest disturbance is shown in Appendix 9.

Table 4-2: Forest area disturbed or degraded by human activities between 2000 and 2015.

Forest status (ha)	Human Impact					Total Impacted	Forest in 2015	
	Logging	Fire	Gardening	Other	W/Sawmill		Intact	Total
Disturbed before 2000	1,679,059	1,076,691	2,854,027	442,715	81,483	6,133,974	27,439,635	35,963,273
Disturbance between 2000 - 2015	2,191,887	21,562	136,554	37,701	1,961	2,389,665		
Total forest disturbed	3,870,945	1,098,253	2,990,581	480,416	83,444	8,523,639		
% disturbed in 15 years	6.1	0.1	0.4	0.1	0.0	6.6		
Annual Rate of disturbance (%)	0.41	0.00	0.03	0.01	0.00	0.44		

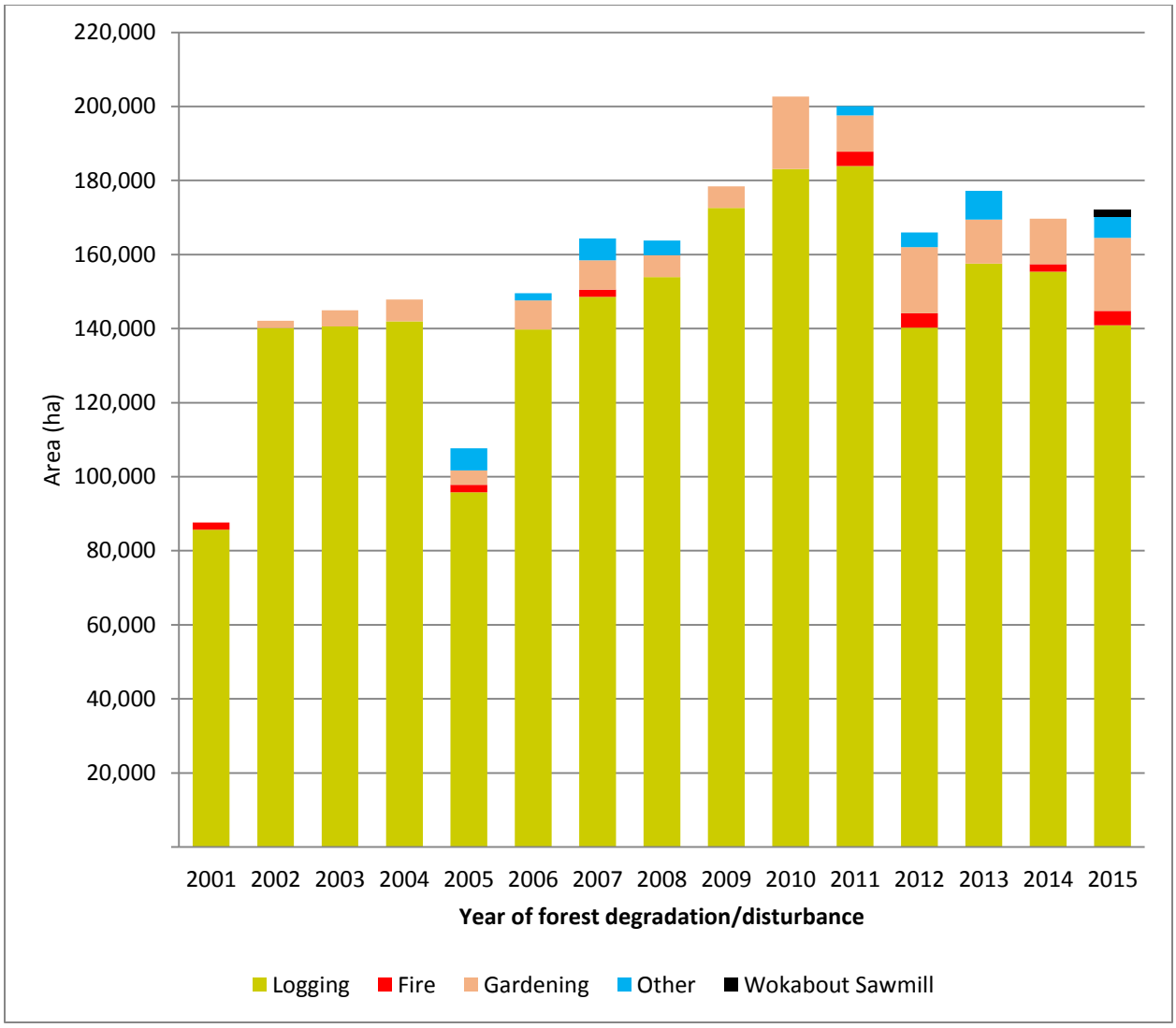


Figure 4-4: Annual forest degradation by human impact type.

Commercial logging was the major driver behind forest degradation or disturbance where about 6.1% of the total forest in 2015 was degraded/disturbed (Figure 4-4). Commercial logging degraded or disturbed about 91.7% of the total degraded/disturbed forest between 2000 and 2015 (Figure 4-5). Commercial logging occurred mostly in Low altitude forest on plains and fans and Low altitude forest on uplands (Appendix 5). The top five province with high rates of logging during the 15 year period were Western, Gulf, West Sepik, West and East New Britain (Figure 4-6). Areas information on human impact types by province from 2000 and 2015 are shown in Appendix 10.

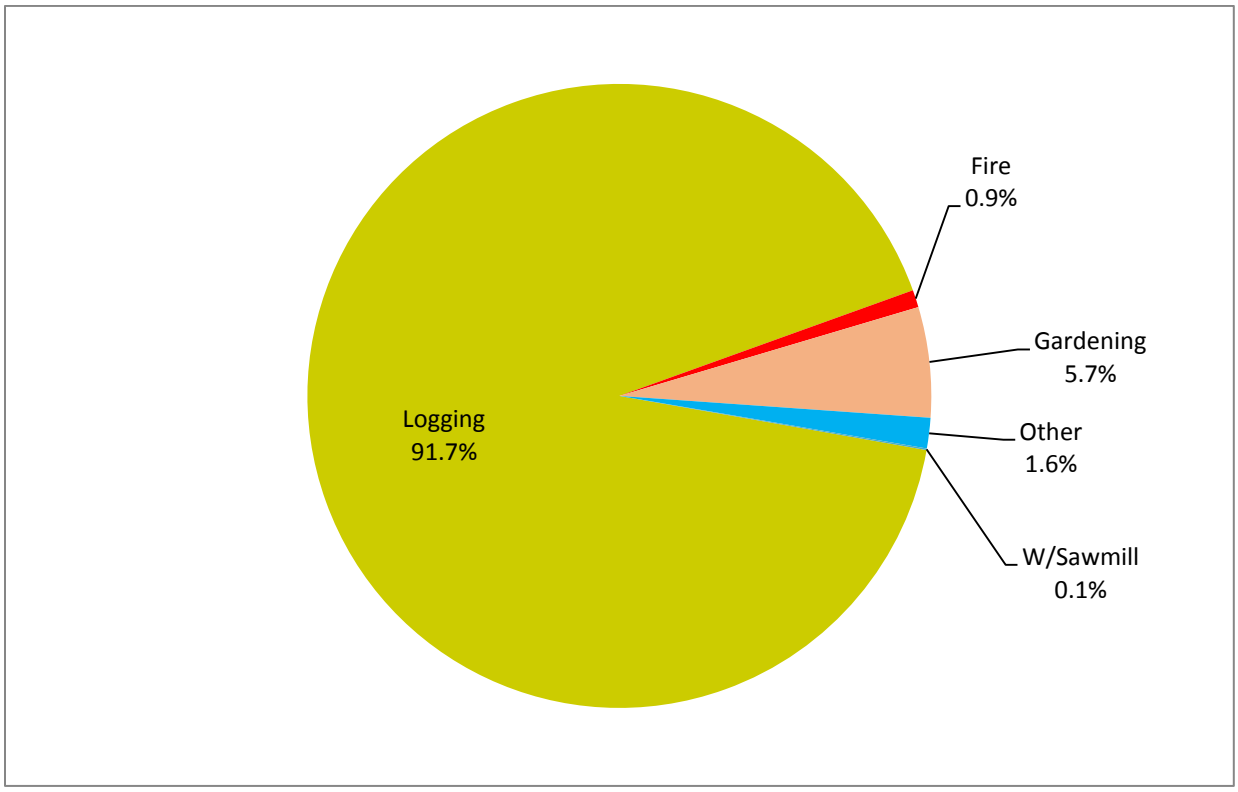


Figure 4-5: Percentage of human impact on the forest land.

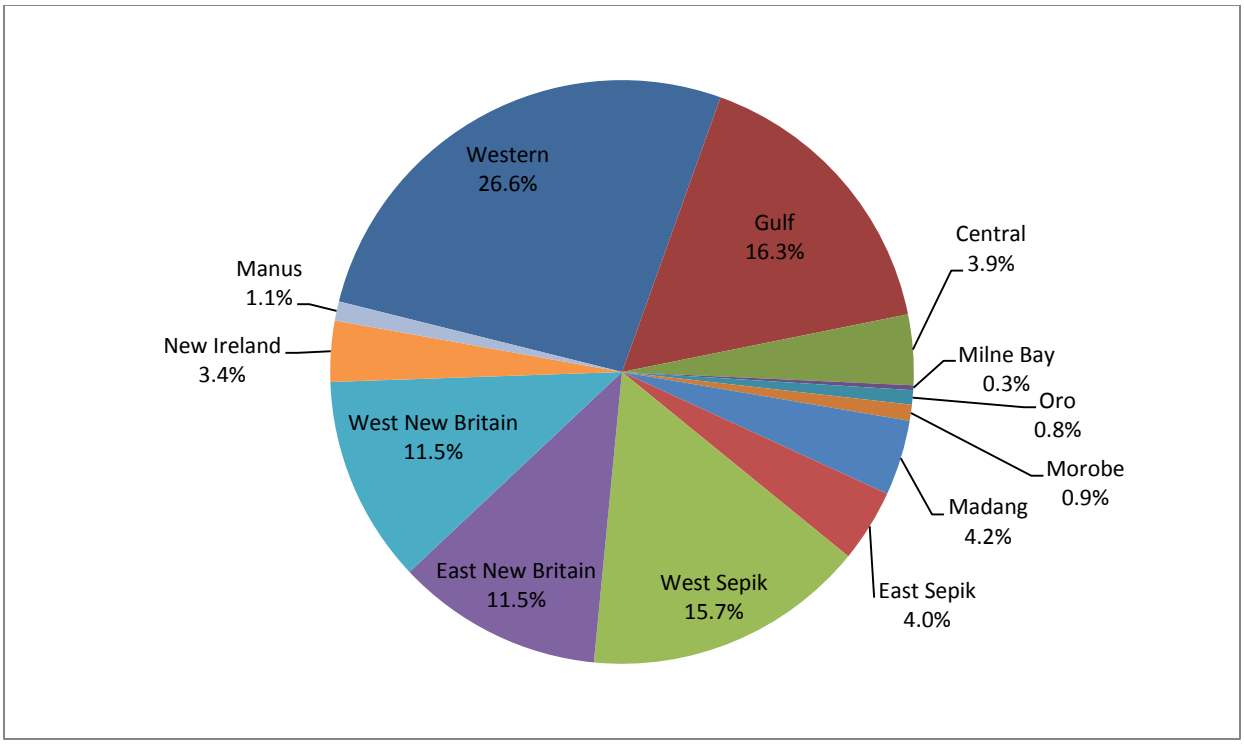


Figure 4-6: Logging intensity in the provinces between 2000 and 2015.

5. Comparison with other studies

Studies conducted in calculating forest area in PNG (Figure 5-1) used various methods using different remote sening data and techniques to calculate forest cover between 1972 and 2015. PNG' forest extent and rate of both deforestation and forest degradation reported in various studies conducted including this study are not consistent (Table 5-1). These inconsistencies are discussed in Chapter 5.

Table 5-1: Comparison of forest cover, deforestation and forest degradation

Studies in PNG	Forest Cover (%)	Deforestation (%)	Degradation (%)	Total (%)	Period
PNGRIS	69.5	*	*	*	1975
FIMS	56.3	0.2	0.3	0.5	1975-1996
State of the Forest of PNG	71.0	0.77	0.64	1.41	1972-2002
Forest Base Map 2012	80.6	*	*	*	2012
The State of Forest of PNG 2014	60.4	0.11	0.23	0.34	2002-2014
Global Forest Change (GFC)	93.0	*	*	0.15	2001-2015
FRA 2015	72.5	0.01	1.9	1.91	2010-2015
This report	78.0	0.04	0.41	0.45	2000-2015

**Not reported*

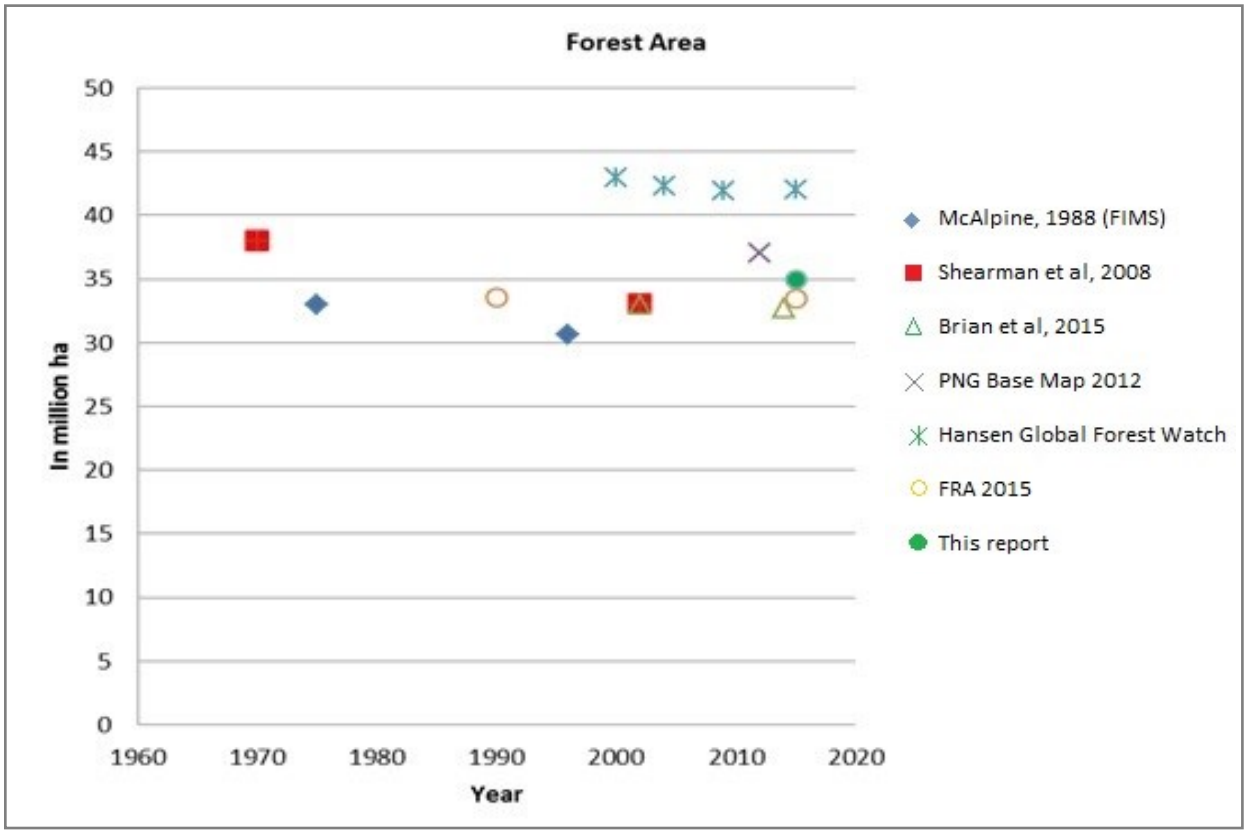


Figure 5-1: Comparing studies conducted on measuring forest cover of PNG.

5.1. PNG Resource Information System (PNGRIS) and Forest inventory Mapping System (FIMS)

In PNGRIS the land is classified into 'cultivated land (25.6%)', 'uncultivated land (4.9%)' and unused land (69.5%)'. The cultivated land comprised of existing land use and fallow land which is mostly covered with secondary vegetation at various stages of regrowth. The uncultivated land comprised of grassland, sago stands and savanna woodland. The forest is classified under unused land (Bourke & Hardwood, 2009). This means that only intact forest was considered as forestland while the disturbed forest was classified as cultivated land. If the forest was categorized as 'land use' then either disturbed or degraded forest would be included. About 7.4 % was considered as low land use intensity and 12. 5% as extremely low and very low land use intensity. Some of these areas could be assumed as disturbed or degraded forestland in the context of the land use and national forest definition. Hence if these vegetated areas were included, the forest cover (both disturbed and undisturbed) would be around 89% in 1975.

In FIMS, areas of significant disturbance (significant land use intensity) were excluded from the gross forest area in 1975 because they were misclassified as forest (Filer *et al*. 2009) resulting in the lower forest cover compared to other studies.

The total land area estimated in FIMS is about 46.4 million hectares, within which total forest area is 33.0 and 31.7 million hectares in 1975 and 1996, respectively. McAlpine & Quigley (1998) reclassified the forest as 'gross forest' thus reducing the gross forest to 29.3 million hectares in 1975 and the remaining gross forest area was 26.1 million hectares or 56% forest cover in 1996. The reclassification of the forest was based on the forest definition and that is the area of trees with "touching or overlapping crowns" (Hammermaster & Saunders, 1995). The FIMS was designed to determine potential forest areas for timber harvesting in undisturbed and well stock forest only or the area where trees had "touching or overlapping crowns". This resulted in the exclusion of about 5.8 million hectares of vegetated land classified as forest in this report. These vegetated land include 3.9 million hectares of woodlands, mangroves, savanna, some areas of swamp forest, dry seasonal, alpine, littoral, seral forests and 1.9 million ha of logged but regenerating forest (Filer *et al.*, 2009).

The annual deforestation rate was reported as 0.5%. This include 1.9 million hectares of 'logged but regenerating forests'. This is considered disturbed forest under this report therefore if the logged forest was excluded than the annual deforestation rate would be about 0.2%. The annual deforestation rate of 0.5% would therefore be considered as annual combined deforestation and forest degradation rate (Shearman *et al.*, 2008). The 0.2% however is still high compared to this report because woodlands, mangroves, savanna and some areas of swamp forest, dry seasonal,

alpine and littoral forests are included as non-forest. The forest degradation rates are similar in both FIMS (0.3%) and this study (0.4%).

5.2. State of the Forest of Papua New Guinea 2002

Shearman *et al.* (2008) reported a 71% forest cover in 2002 and very high deforestation and forest degradation rates between 1972 and 2002 compared with the past studies including this report. This generated much debate among academics and NGOs (Filer *et al*., 2009); (Shearman *et al.*, 2010).

The report indicated the total forest cover declining from 38 million hectares in 1972 to 33 million hectares in 2002 with the annual combined deforestation and forest degradation rate of 1.41% (deforestation – 0.77% and forest degradation 0.64%). The forest is defined as trees with the canopy density of more than 70% and tree height of 5m and above. This means that about 15% of the forest did not qualify under this definition. In 2002, the major broad category of rainforest was about 86% in PNG (Shearman *et al.*, 2008).

5.3. Forest Base Map 2012 (version 0) and Forest and Land Use in PNG 2013

The forest base map only updated or improved the national level forest base map (FIMS) that was developed in 1996 using high resolution satellite images such as RapidEye, Radar satellite data (ALOS-PALSAR) including the MASP dataset (PNG Forest Authority and JICA, 2012). The forest cover found was 37 million hectares or 80.7%. The national forest definition and the PNG vegetation classification (Hammermaster and Saunders 1995) was used to develop the 2012 forest base map. There was no change analysis done.

A total of 37.6 million hectares or 80.4% of forest was reported in 2013 (PNGFA, 2013). The study used the national forest definition and the vegetation classification of PNG. PNG has six "structural formation of the vegetation" under PNG Resource Information System and these are forest, woodland, savanna, scrub grassland and mangrove (Hammermaster and Saunders, 1995). The woodland, savanna, scrub and mangrove forest are classified as forest by PNGFA, 2013 and this report including the Forest Base Map 2012 resulting in similar forest cover. These vegetation types are also classified as forest in the 2012 Forest Base Map. There was no change analysis found in this report.

5.4. The State of Forest of PNG 2014

Bryan and Shearman (2015) found that 71% of PNG was covered with some form of forested landscape but when they applied the same forest definition in Shearman *et al.* (2008) the forest was reduced to 60.4% (27.8 million ha) of 'closed canopy forest' in 2014. This resulted in the

exclusion of about 8.4 million hectares of dry evergreen forest, swamp forest and mangrove forest and secondary forest. The woodland and savanna were also excluded. These vegetation types are classed as forest in this report. .

The rate of forest change therefore is based on the closed canopy forest which is referred to as rainforest in Bryan and Shearman (2015) report. In 2014 about 4.1% forest was changed over the 12 year period or 0.34% annually. The change was due to the closed canopy forest been converted to other land use (0.11%) or the forest been degraded to secondary forest (0.23%). In contrast these rates are much lower than that of Shearman *et al.* (2008) despite the same forest definition and classifications used. Bryan and Shearman (2015) deforestation and forest degradation rates although lower are slightly closer to this report. The slightly lower rates are due to forest changes that occurred in dry evergreen forest, swamp forest, woodland and savanna between 2000 and 2014 not accounted for. This report found evidences of both deforestation and forest degradation or disturbance in these forest types (Table 5-1).

5.5. Global Forest Change

The forest cover estimates in PNG is 93% in the Global dataset (Hansen *et al.,* 2014). This is much higher compared to the past studies. Hansen Global dataset refers forest as standing trees with height more than 5 meters and the canopy density of more than 50% regardless of land use. Consequently vegetated areas in cropland such as oil palm and coconuts plantations including other vegetated areas in grassland falling above the 50% threshold are considered forest by the Global Dataset hence the high forest cover.

Furthermore, the vegetation loss or 'tree cover loss' in land use other than forestland can be miss-interpreted as forest change. This is clearly demonstrated in the REDD+ and Forest Monitoring Web-portal (Climate Change and Development Authority and PNG Forest Authority, 2017). The annual tree cover loss has been increasing since 2001 and reached its peak in 2015 (Global Forest Watch, 2015). The forest cover loss is 2.11% in 14 years or 0.15% per annum. Since the forest cover loss refers to stand replacement disturbance' or forest changing to non-forest state, the loss occurring is considered to be coming from both forest disturbance and forest clearance for other land use.

Despite the high forest cover and increasing forest cover loss, the Global Dataset is reporting less tree cover loss rates compared to the past studies including this report. This is because Hansen records only actual loss/change while other studies record both actual loss/change and intact forest areas. Some points in a forest area experienced no change but considered change in earlier studies because of the application of different forest definitions and various rules to determine the land use or land cover. For instance McAlpine and Quiqley, (1998), Shearman *et al*. (2008)

and Bryan and Shearman (2015) considering some logged or secondary forest as non-forest does not mean that all the points in these areas were disturbed.

Practically some of the areas within these logged over areas remained undisturbed due to logging constraints. In this instance Hansen records only the actual forest change while in other studies both forest change and intact forest areas are recorded as change. This is similar to this study where the area of interest showing a network of logging roads are recorded as disturbed forest despite some intact forest still remaining. These intact forest areas include steep areas, buffer zones and other areas constraints to logging. In most timber concessions in PNG the PNG logging Code of Practice and the 24 Key Standards are applied.

5.6. Forest Resource Assessment (FRA) 2015

Forest Resource Assessment 2015 report for PNG was put together before year 2015 by the FAO national correspondent (PNGFA). The forest areas were projected using simple linear regression based on the Base Map 2012 and the FIMS data sets. The country's forest definition was used instead of the FAO's where some areas of vegetation types such as savanna and woodland felled into the national forest definition threshold were considered forest otherwise they were classed as 'other wooded land'.

The forest cover reported in FRA 2015 is 72.5%. This is similar to that of Shearman et al. (2008) in 2002 (71%) but much higher in more recent reports (PNGFA and JICA, 2012, PNGFA, 2013, Hansen *et al.,* 2014) and this study. FRA 2015 reported the lowest deforestation and highest forest degradation rates compared with the past studies and this study. The forest area was estimated at 33,627,000 hectares in 1990 and reduced to 33,559,000 hectares in 2015 resulting in the forest loss of 0.2% in 25 years or 0.01% per annum.

There was an exponential increase in the 'other naturally regenerated forest' in 2015. These are naturally regenerating forests disturbed by anthropogenic activities (FRA 2015). In 2015 a total of 15,960,000 ha or 47.6% (1.9% per annum) was reported as 'other naturally regenerated forest'. The exponential increase is attributed to the application of simple linear regression using four data points or years (1990, 2000, 2005, 2010) to predict 'other naturally regenerated forest' in year 2015 hence not realistic.

6. Uncertainty analysis

Overview of sampling

Table 6-1 shows the sampling plot count and the estimated area of each land use category of Initial land use and Current land use, respectively. There were a total of 25,279 plots planned to be sampled however only 25,209 were sampled. Seventy (70) plots were on the sea and hence recorded as no data.

Table 6-1: Initial and Current Land Use

	Initial Land Use		Current Land Use	
IPCC Land Use Category	**Plot Count**	**Area (ha)**	**Plot Count**	**Area (ha)**
Forest land	19,453	36,225,470	19,314	35,963,273
Cropland	3,061	4 ,910,816	3,191	5,158,633
Grassland	1,318	2 ,444,645	1,317	2,442,680
Other land	32	55,352	34	59,277
Wetland	1 ,108	2,132,460	1,105	2,126,505
Settlement	237	370,120	248	388,495
Total:	**25,209**	**46,138,863**	**25,209**	**46,138,863**

Quantitative analysis

Table 6-2 to 6-4 show sampling errors and the uncertainty of area estimates of each land use category and conversion during 2001-2015, using the spreadsheet developed by FAO based on the equation shown in Chapter 2.3(v) without ground-truth. The results suggest that the assessment work overall was exceptionally performed where the uncertainty is generally low. The higher uncertainty of 'Other land' is quiet high because only a small area was sampled.

The current estimation of the uncertainties is purely statistical with no ground truth. PNG is one of the difficult countries to implement statistically-valid ground truth survey since the country is composed of many islands and large parts of the forest area is inaccessible for ground truth. But if the national forest inventory is implemented in future, the estimation of the uncertainties using ground-truth data will be considered.

Table 6-2: Sampling error and uncertainty of area estimate of each land use category – Initial land use

Initial Land Category	Sample Size	Area	pi	Area [Ai] (ha)	Standard Error (proportion)	Standard Error (mil. ha)	Confidence Intervals (ha)	Uncertainty %
Forest	19,453	36,225,470	0.771668848	35,603,923.32	0.002643802	121,982.00	± 239,084.7	± 0.66%
Cropland	3,061	4,910,816	0.121424888	5,602,406.28	0.002057189	94,916.34	± 186,036.0	± 3.79%
Grassland	1,318	2,444,645	0.052282915	2,412,274.25	0.001402007	64,686.99	± 126,786.5	± 5.19%
Other land	32	55,352	0.001269388	58,568.12	0.00022426	10,347.11	± 20,280.3	± 36.64%
Wetland	1,108	2,132,460	0.043952557	2,027,920.99	0.001291108	59,570.26	± 116,757.7	± 5.48%
Settlement	237	370,120	0.009401404	433,770.10	0.000607821	28,044.19	± 54,966.6	± 14.85%
All	**25,209**	**46,138,863**	**-**	**-**	-	-	-	-

Table 6-3: Sampling error and uncertainty of area estimate of each land use category – Current land use

Current Land Category	Sample Size	Area	pi	Area [Ai] (ha)	Standard Error (proportion)	Standard Error (mil. ha)	Confidence Intervals (ha)	Uncertainty %
Forest	19,314	35,963,273	0.766154945	35,349,518.07	0.002665957	123,004.24	± 241,088.3	± 0.67%
Cropland	3,191	5,158,633	0.126581776	5,840,339.24	0.002094245	96,626.09	± 189,387.1	± 3.67%
Grassland	1,317	2,442,680	0.052243246	2,410,443.99	0.001401504	64,663.80	± 126,741.0	± 5.19%
Other land	34	59,277	0.001348725	62,228.62	0.000231153	10,665.13	± 20,903.7	± 35.26%
Wetland	1,105	2,126,505	0.043833552	2,022,430.23	0.001289439	59,493.26	± 116,606.8	± 5.48%
Settlement	248	388,495	0.009837756	453,902.89	0.00062163	28,681.30	± 56,215.4	± 14.47%
All	25,209	46,138,863	-	-	-	-	-	-

Table 6-4: Land use data without verification – Initial and Current land use

Land Category	Sample Size	Area	pi	Area [Ai] (ha)	Standard Error (proportion)	Standard Error (mil. ha)	Confidence Intervals (ha)	Uncertainty %
Initial Forest Land	19,453	36,225,470	0.772	35,603,923	0.002644	121,982	± 239,084.7	± 0.66%
Initial non-Forest Land	5,756	9,913,393	0.228	10,534,940	0.002644	121,982	± 239,084.7	± 2.41%
Current Forest Land	19,314	35,963,273	0.766	35,349,518	0.002666	123,004	± 241,088.3	± 0.67%
Current non-Forest Land	5,895	10,175,590	0.234	10,789,345	0.002666	123,004	± 241,088.3	± 2.37%
Total	**25,209**	**46,138,863**	-	-	-	-	-	-

Table 6-5: Land use and land use change data without verification – Forest to non -forest

Land Category	Sample Size	Area	pi	Area [Ai] (ha)	Standard Error (proportion)	Standard Error (mil.ha)	Confidence Intervals (ha)	Uncertainty %
Forest land remaining Forest land	19,314	35,963,273	0.766	35,349,518	0.002666	123,004	± 241,088.3	± 0.67%
non-Forest land converted to Forest land	0	0	0	0	0	0	0	0
Forest land converted to non-Forest land	139	262,197	0.006	254,405	0.000466	21,519	± 42,177.7	± 16.09%
non-Forest land remaining non-Forest land	5,756	9,913,393	0.228	10,534,940	0.002644	121,982	± 239,084.7	± 2.41%
Total	25,209	46,138,863	-	-	-	-	-	-

7. Forest Carbon Stock in PNG

7.1. Estimating forest carbon in PNG

Climate change is one of the most serious global challenge we are facing today. Deforestation and forest degradation account for about 12% of CO_2 emissions globally (IPCC 2014). PNG has been leading the international negotiations on reducing emissions from deforestation and forest degradation (REDD+) since PNG together with Cost Rica submitted the agenda to the UNFCCC COP in 2005. PNG's Nationally Determined Contribution (2015) states that primary mitigation effort lies in reducing emissions from land use change and forestry by reducing deforestation and promoting forest conservation. Accurate forest carbon stock estimation is crucial for climate change reporting and implementing REDD+.

For estimating the total carbon stored in living biomass in forest in PNG, following steps were taken;

1) Stratify the forest in PNG.
2) Review existing PNG data and determine if appropriate country specific forest carbon data for each forest strata is available.
3) Refer IPCC Guideline (2006) for most appropriate default value on forest carbon data for those forest strata, which country specific data is not available.
   Calculate carbon stock in each forest strata based on the total area of each forest strata.

Each of the above steps is described in the following sections.

1) Forest Carbon Stratification

There are 12 vegetation types in PNG's natural forest, which is described in PNGRIS (Hammermaster & Saunders 1995). Each forest type excluding Woodland, Savanna, Scrub and Mangrove were further stratified to three disturbance categories namely primary; logged over and forest disturbed by other than logging (e.g. fire, gardening). No commercial logging is conducted in Woodland, Savanna, Scrub and Mangrove. Consequently, these forest types were classified to only two disturbance categories namely; primary and forests disturbed by other than logging. In addition to natural forest, there are plantation forest with two disturbance categories (primary and disturbed other than logging). In total forest in PNG were stratified to 37 strata (Table 7-1).

2) Above Ground Biomass in a unit area of forest in PNG

Above ground biomass of a unit forest area of each forest type and different type of disturbance need to be identified to estimate forest carbon stock in PNG. Collecting such information is one of the major objectives of National Forest Inventory (NFI), which is currently under implementation. However it will take another 2-3 years before the full

information derived from the NFI become available. We reviewed the existing information and identified the most appropriate aboveground biomass per unit forest area. We excluded forest biomass information derived from small plots (e.g. 1 ha) in a single forest site from our assessment because of high local heterogeneity of PNG forest (Abe 2007, Vincent et al. 2015) and tropical rainforest elsewhere (Nascimento & Laurance 2002).

Fox et al. (2010) reported the average of above ground biomass of primary lowland tropical rainforest in PNG as 222.8 t/ha based on ten 1 ha permanent sample plots (PSP) managed by PNG Forest Research Institute. This is lower than any of ten lowland tropical rainforest studies (230 – 597 t/ha) in PNG summarised by Bryan et al. (2010a) and also substantially lower than averages for tropical equatorial forest (Gibbs & Brown 2007: 328 t/ha; IPCC 2006: 350 t/ha; Lewi et al. 2009: 404 t/ha). On the other hand, above ground biomass estimated for 50 ha plot at Wanang lowland tropical rainforest in Madang Province is 210.7 t/ha (Vincent et al. 2015) and estimated for 3,000 ha lowland tropical rain forest of Makapa concession in Western province is 222.7 t/ha (Bryan et al. 2010b). The both studies are in agreement with Fox et al. (2010). For above ground biomass of logged over lowland tropical rainforest in PNG, Fox et al. (2010) reported 146.0 t/ha as the average of 115 1-ha PSP plots across the country. This is also supported by Bryan et al. (2010b) reporting 152.9 t/ha at Makapa concession in Western province. Although there are some uncertainty, we concluded that it is most appropriate to apply the above ground biomass for primary and logged over lowland tropical rainforest reported in Fox et al. (2010) to Primary, Logged and Other disturbed forests in five lowland moist forest types namely Low altitude forest on plains and fans, Low altitude forest on uplands, Littoral forest, Seral forest and Swamp forest (Table 7-1).

3) IPCC Guideline

Other than five forests type discussed in the above section, no sufficient information on above ground biomass is available. IPCC Guideline (2006: Table 4.12) provides above ground biomass per unit forest area of each Global Ecological Zone described by FAO (2001). Global Ecological Zone and the PNG forest classification provided in PNGRIS (1995) correlate very well as can be seen in Figure 7-1 . It shows similar distribution of montane vegetation and dry vegetation between the PNG Forest Base Map (PNGFA, 2014) and Global Ecological zone (FAO, 2001). The description of Ecological Zone in tropical climate is summarised in Table 7-2.

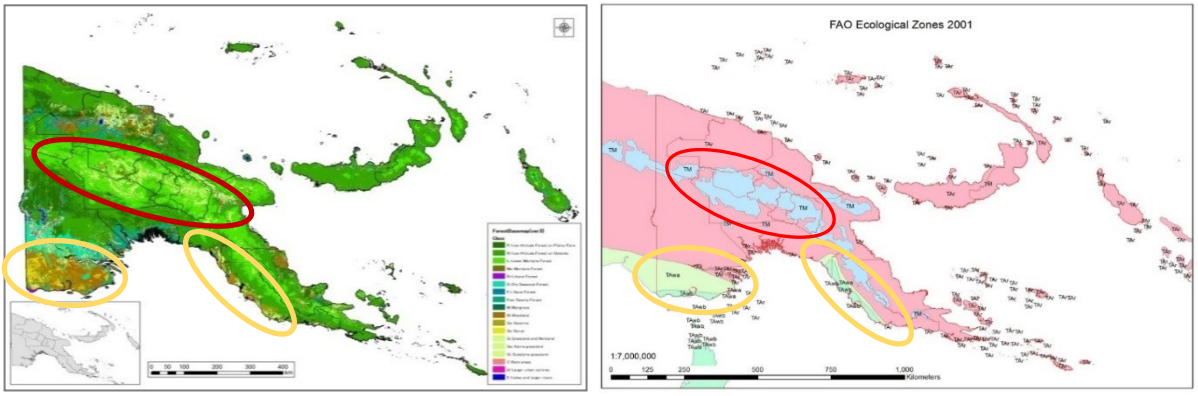


Figure 7-1: Correlation between PNG forest classification in Base Map (Left: PNGFA/JICA 2014) and Global Ecological Zone (Right: FAO 2001). The red ellipse shows the distribution of montane vegetation and the yellow ellipse shows the distribution of dry vegetation.

The default values of IPCC Guidelines for above ground biomass for associated Ecological Zone were applied to each of all forest type excluding the five forest type, which country specific value was available (Table 7-2). There is no default value for logged over or disturbed other than logging provided in IPCC Guidelines. The ratio of the biomass in logged forest against primary forest (35% smaller) in Fox et al. (2010) was applied to calculate the biomass of degraded forest against the IPCC default vale. Root to shoot ratio and carbon fraction of IPCC guidelines (2006) were also applied to estimate below ground biomass and carbon contents of above and below ground biomass (Table 7-1). Among the five carbon pools described in IPCC Guidelines (2006), the default values for Dead wood, Litter and Soil organic matter are not provided in the Guidelines. We therefore do not discuss the carbon stock in those three carbon pools. Country specific values for those three carbon pools will be generated through National Forest Inventory, which is currently under implementation.

Calculation

Carbon of each forest strata was calculated using the below formula;

$$A*[(B + (B*R))*CF]$$

Where:

A is the forest strata area in hectares

B is the unit biomass in tons per hectare

R is the Root-to-shoot ratio

CF is the Carbon fraction i.e. 0.47 from IPCC 2006

Table 7-1: Carbon stored in above and below ground biomass in PNG. Carbon of each forest strata was calculated using the following formula; A*[(B + (B*R))*CF].

Forest type	Human impact	Area (ha) (A)	Source	Forest type	Human impact	AGB[1] (t/ha) (B)	IPCC Guideline (2006)		Carbon in above and below ground biomass (tons)
							Root to shoot ratio (R)	Carbon fraction (CF)	
Low altitude forest on plains and fans	Primary	5,621,495	Fox et al. (2010)	Lowland tropical forest	Primary	223	0.37	0.47	807,188,806
	Degraded[2]	3,305,864			Logged	146	0.37	0.47	310,782,247
Low altitude forest on uplands	Primary	8,702,804			Primary	223	0.37	0.47	1,249,633,023
	Degraded[2]	2,424,929			Logged	146	0.37	0.47	227,966,091
Littoral forest	Primary	130,533			Primary	223	0.37	0.47	18,743,209
	Degraded[2]	15,693			Logged	146	0.37	0.47	1,475,302
Seral forest	Primary	287,277			Primary	223	0.37	0.47	41,250,050
	Degraded[2]	33,263			Logged	146	0.37	0.47	3,127,055
Swamp forest	Primary	2,199,666			Primary	223	0.37	0.47	315,849,450
	Degraded[2]	263,121			Logged	146	0.37	0.47	24,735,865
Lower montane forest	Primary	6,666,762	IPCC Guideline (2006) Table 4.12	Tropical mountain system	Primary	140	0.27	0.47	557,114,651
	Degraded[2]	1,339,069			Degraded[4]	92	0.27	0.47	73,262,287
Montane forest	Primary	361,131			Primary	140	0.27	0.47	30,178,312
	Degraded[2]	29,684			Degraded[4]	92	0.27	0.47	1,624,038
Dry seasonal forest	Primary	2,043,166		Tropical dry forest	Primary	130	0.28	0.47	159,791,963
	Degraded[2]	308,143			Degraded[4]	85	0.28	0.47	15,777,996
Woodland	Primary	680,067			Primary	130	0.28	0.47	53,186,656
	Degraded[2]	375,697			Degraded[4]	85	0.28	0.47	19,236,984
Savanna	Primary	329,467			Primary	130	0.28	0.47	25,766,940
	Degraded[2]	294,422			Degraded[4]	85	0.28	0.47	15,075,406
Scrub	Primary	178,511		Tropical shrubland	Primary	70	0.40	0.47	8,222,202
	Degraded[2]	41,650			Degraded[4]	46	0.40	0.47	1,256,006
Mangrove	Primary	225,044		Tropical wet Mangrove	Primary	192	0.49	0.47	30,258,869
	Degraded[2]	56,806			Degraded[4]	126	0.49	0.47	5,000,638
Forest plantation	*n.a.*[3]	49,008		Tropical rainforest (plantation)	*n.a.*[3]	150	0.37	0.47	4,733,472
Total:		**35,963,273**							**4,001,237,518**

[1] AGB: aboveground biomass [2] Combined *logged* and *disturbance other than logging* [3] *n.a.*: not applicable

[4] The ratio of the biomass in logged forest against primary forest (35% smaller) in Fox et al. (2010) was applied to calculate

7.2. Forest Carbon Stock in PNG

We estimated the forest carbon stock in PNG as 4001 million ton (Mt) (Table 7.2). This is substantially lower than the estimate by Bryan *et al*. (4770 Mt, 2010a) and lower than even the lowest forest carbon stock (4154 – 8037 Mt) estimated by Gibbs *et al.* (2007) using above

ground biomass information derived from a number of other studies. The lower estimate of this study is largely due to the lower above ground biomass per unit area applied. If we apply the default value for Tropical rain forest (300 t/ha) in IPCC Guidelines (2006) to all the forest strata come under this category instead of 223 t/ha for primary forest and 146 t/ha for disturbed forest reported by Fox et al. (2010), the forest carbon estimate would become 5509 Mt.

The major uncertainty for estimating forest carbon stock in PNG is the reliability of above ground biomass in unit forest area for each forest strata. In this study we sourced the most appropriate information currently available. National Forest Inventory, which PNGFA is currently implementing with assistance from European Union, UN-REDD and FAO will provide more reliable country specific information within a couple of years. It will enable us to estimate forest carbon stock in PNG significantly more accurate.

Table 7-2: Summary of Climate Domains and Ecological Zone (FAO 2001) relevant to PNG environment.

Climate domain		**Ecological zone**	
Domain	**Domain criteria**	**Zone**	**Zone criteria**
Tropical	all months without frost; in marine areas, temperature >18^{o}C	Tropical rain forest	wet: ≤ 3months dry, during winter
		Tropical moist deciduous forest	mainly wet: 3-5 months dry, during winter
		Tropical dry forest	mainly dry: 5-8 months dry, during winter
		Tropical shrubland	semi-arid: evaporation > precipitation
		Tropical desert	arid: all months dry
		Tropical mountain systems	altitudes approximately > 1000 m, with local variations

8. Advantages, Limitations, and Potentials of Collect Earth

8.1. Difference between Point Sampling and Wall-to-Wall Mapping

PNG was the first country to use Collect Earth for LULUCF assessment and FRL and some of the other countries followed afterwards. On the other hand, many other countries use Wall-to-Wall mapping assessment (Please refer to the FAO recent publication "From reference levels to results reporting: REDD+ under the UNFCCC 2018 update"[4], (Figure 8-1). Methods used to assess deforestation (and in some cases also afforestation). Therefore, we present here our experiences of using Collect Earth.

Based on the outcomes, challenges and lesson learnt from forest and land use change assessment in PNG 2000 - 2015, PNGFA organized the advantages and limitations of Collect Earth point sampling method compared with other method (wall-to-wall mapping, such as TerraPNG, which is the other FAO support outcome in PNG). The overview of two different methods is illustrated in Figure 8-1 and the summary is compiled in the Table 8-1. Further details are explained from the following subchapters.

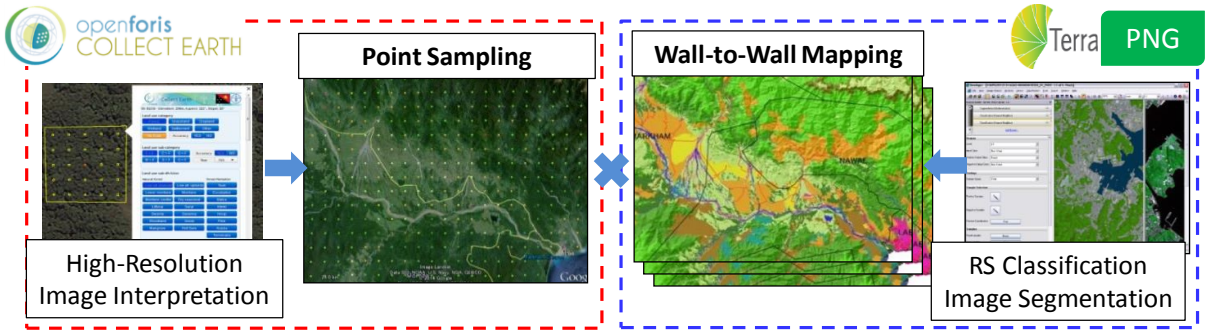


Figure 8-1: Overview Image of Collect Earth Point Sampling and Wall-to-Wall Mapping Method.

[4] http://www.fao.org/3/CA0176EN/ca0176en.pdf

8.2. Advantages and Limitations of Collect Earth Assessment

The advantage and limitations of point sampling and wall-to-wall mapping methods are described below and also summarized in Table 8-1.

Table 8-1: Summary of Advantages and Limitations of Collect Earth assessment compared with other Method. These advantages and limitations with alphabetical numbered correspond to each other.

Collect Earth (Point Sampling Method)	**Wall-to-Wall Mapping Method (e.g. TerraPNG)**
Advantages	Limitations
a) Less trainings are required (minimal GIS and remote sensing skills required) b) Annual-level historical "land-use change" assessment (flexible and simple method) c) Detail identification of land-use types and drivers of deforestation and degradation d) Statistical rapid assessment with step-wised improvement (by increasing sampling points) e) Possible to provide the confidence interval of the assessment	a) Operators needs to be trained (in GIS and remote sensing) to conduct good assessment b) Limited frequency for "land use change" assessment (due to complex data and method) c) Limited identification of land-use types and drivers of deforestation and degradation d) Not easy for rapid assessment, neither for step-wise assessment (usually full assessment) e) Not able to provide confidence interval of the assessment
Limitations	Advantage
f) Boundary is not produced through assessment (no demarcation is required) g) Area is estimated by statistical ratio using total area and number of sampling plots h) Not suitable to nest project approach (there are no boundaries for the assessment area) i) Linear type features are not detected well (if sampling plots are not enough or distributed)	f) Boundary-based "land-cover" assessment (demarcation is clear) g) Area is calculated exactly by the wall-to-wall segmented polygons h) Suitable to nest project-based approach (by excluding the project area using boundary) i) Geographically visualizing land features including linear type (such as river, coast, etc.)

One of the advantages of Collect Earth point sampling method is to annual-level "land-use" assessment by simple satellite image interpretation. This is not easy by wall-to-wall mapping method since it requires more technical capacity on GIS and Remote Sensing. In addition, Collect Earth provides the capacity of detail land-use/drivers identification with High Resolution Satellite images from Google Earth and Bing Maps and time-series cloud-free LANDSAT mosaic through Google Earth Engine. Collect Earth sampling approaches also make it possible to implement statistical rapid and step-wise assessment by starting small number of samples then increasing the number of sample points. Another advantage of sampling method is the capacity to provide confidence interval for the assessment, which is not possible by wall-to-wall mapping method.

One of the major limitations of Collect Earth point sampling method is it does not provide geographical boundary, which is the fundamental element in wall-to-wall mapping method. This is also related to the other limitation that the area is estimated by statistical ratio (number of sample plots for the total population area), not calculated based on the actual segmented polygons. The other limitation is point sampling method is not suitable to nest project-based approach for carbon registry because the nesting usually deals with the area by delineated boundaries. Another limitation of "systematic" point sampling method is this may not detect linear type features (such as river, coastal features) very well. PNG may be able to consider stratified random sampling, but the main objective of this assessment was to analyze whole country in systematic manner.

8.3. Potentials of Collect Earth

As described in advantages and limitations of Collect Earth point sampling method are closely related to the advantages and limitations of wall-to-wall mapping method such as TerraPNG. In fact, those two methods could be supplementing and verifying each other. Figure 8-2 shows the overview looking of systematic point sampling (per grid) and wall-to-wall mapping with Hansen tree-cover loss. If the number of sampling points is statistically valid enough and well distributed, then those sampling points are representing the forest and land use change with detail analysis of human impact type such as drivers of deforestation and forest degradation. It is difficult for wall-to-wall mapping to implement these detail analyses but it provides more simple classes with geographical boundaries, which is useful for land use planning.

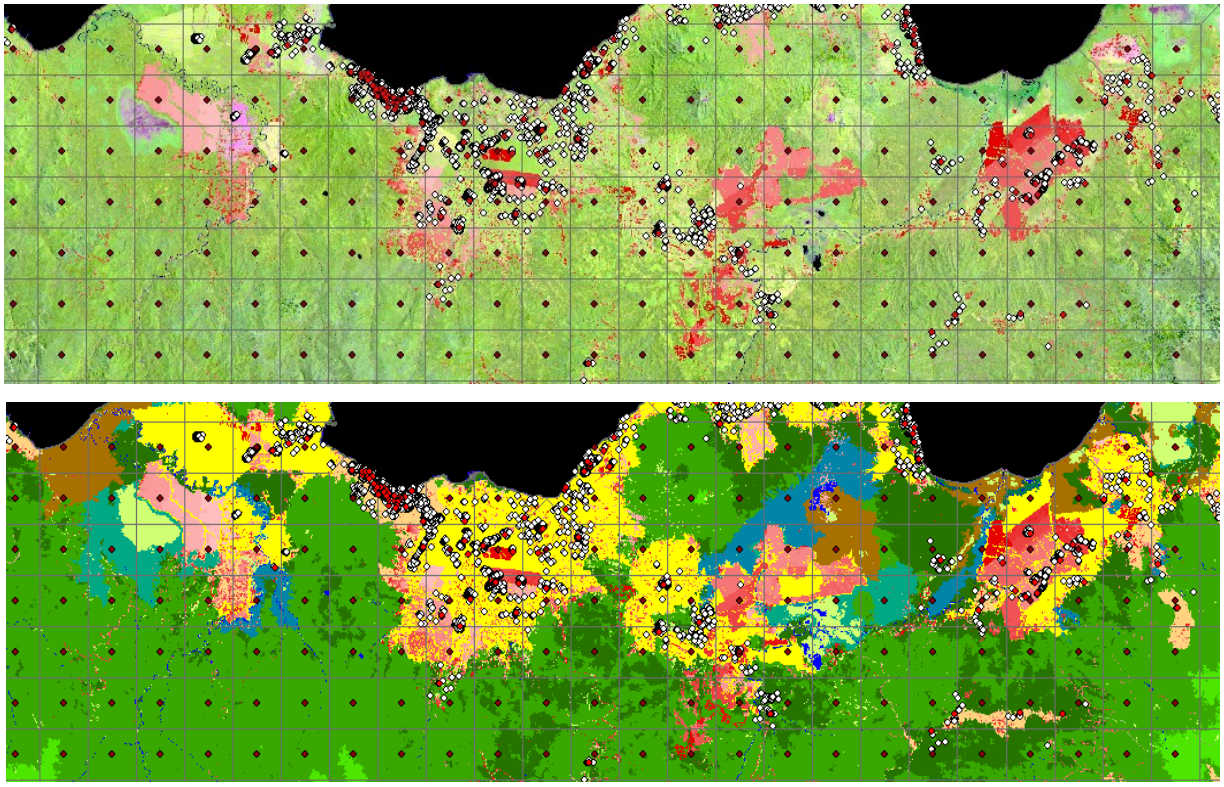


Figure 8-2: Overview Image of Systematic Point Sampling and Wall-to-Wall Mapping with Hansen tree-cover loss (Legend: red dot is systematic point sampling, pink polygon is Hansen tree cover loss and background images are Landsat and wall-to-wall mapping by Forest Basemap 2012)

One of the most potential applications of Collect Earth point sampling method in future is map accuracy assessment and stratified area estimation, which can be also used for uncertainty analysis and based on the result the assessment. Those are implemented in one of the new Open Foris Tools called SEPAL (System for Earth Observation Data Access, Processing and Analysis for Land Monitoring). Collect Earth functions are already integrated into SEPAL web-browser based module (which is called Collect Earth Online: CEO).

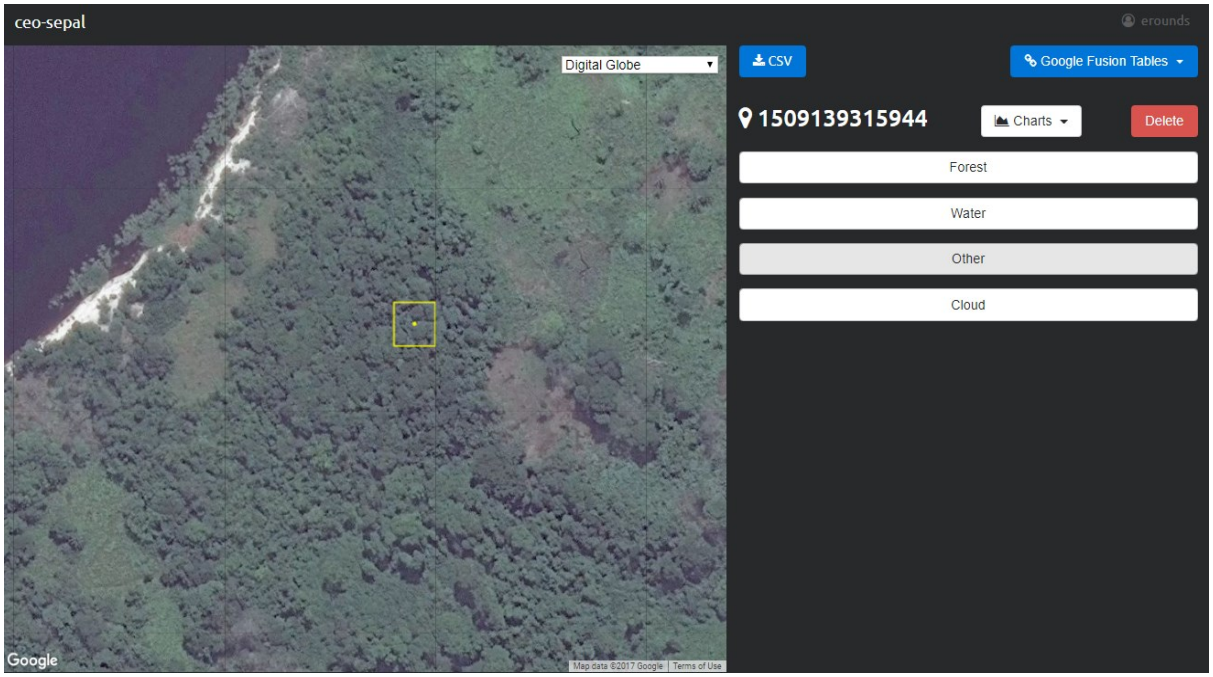
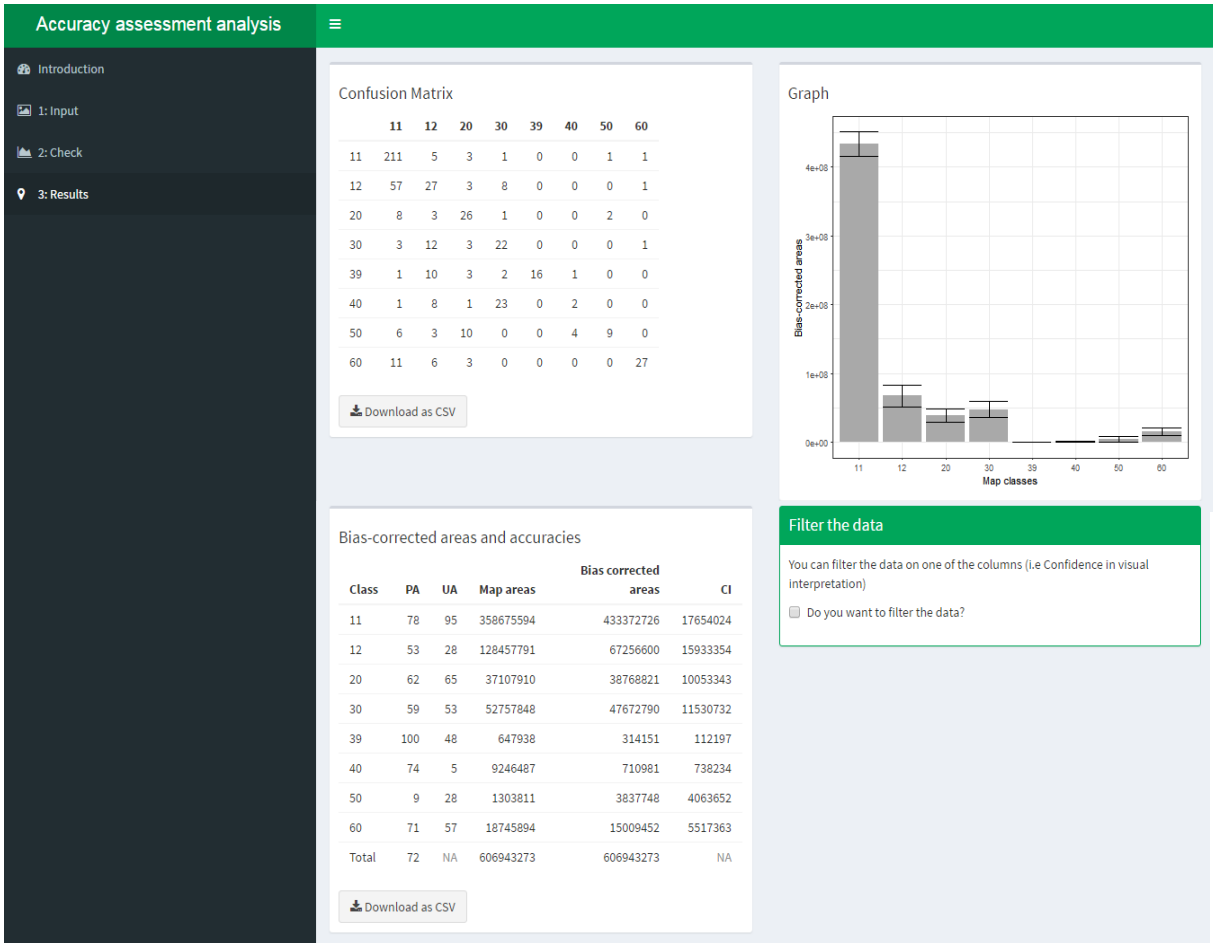


Figure 8-3: Interface of Collect Earth Online in SEPAL which can be operate within web-browser.



	11	12	20	30	39	40	50	60
11	211	5	3	1	0	0	1	1
12	57	27	3	8	0	0	0	1
20	8	3	26	1	0	0	2	0
30	3	12	3	22	0	0	0	1
39	1	10	3	2	16	1	0	0
40	1	8	1	23	0	2	0	0
50	6	3	10	0	0	4	9	0
60	11	6	3	0	0	0	0	27

Class	PA	UA	Map areas	Bias corrected areas	CI
11	78	95	358675594	433372726	17654024
12	53	28	128457791	67256600	15933354
20	62	65	37107910	38768821	10053343
30	59	53	52757848	47672790	11530732
39	100	48	647938	314151	112197
40	74	5	9246487	710981	738234
50	9	28	1303811	3837748	4063652
60	71	57	18745894	15009452	5517363
Total	72	NA	606943273	606943273	NA

Figure 8-4: Interface of Accuracy Assessment in SEPAL which can be operate within web-browser.

Collect Earth has the potentials to be used for deforestation and degradation hotspots or drivers analysis. An example would be overlaying samplings points over major tree cover loss areas (high dense Hansen loss data) to verify and justify the presence of loss before field verification. The figure below demonstrates results of deforestation/degradation hotspots driver analysis using Collect Earth.

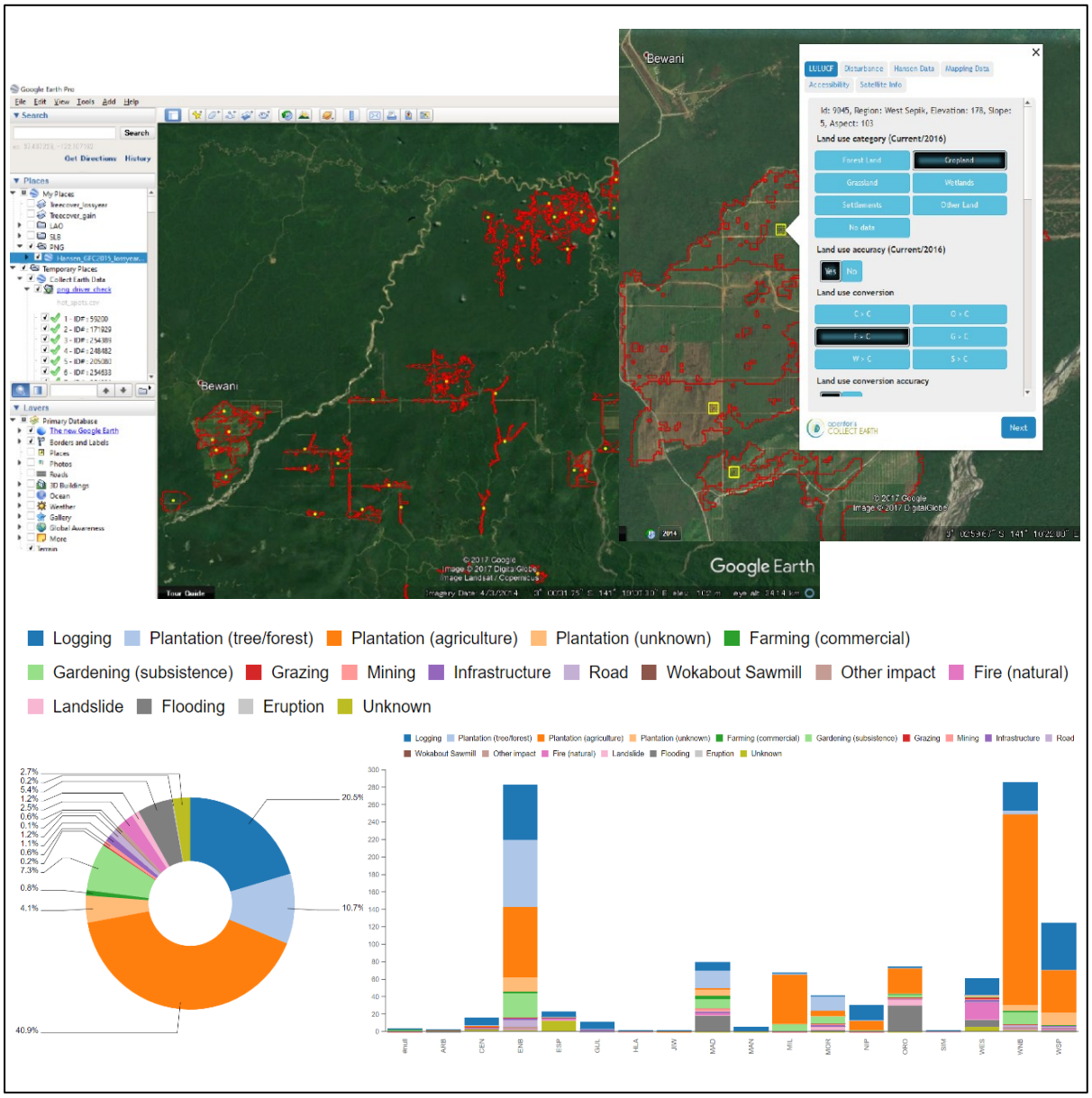


Figure 8-5: Collect Earth for deforestation/degradation hotspots drivers' analysis (demo).

9. Recommendations

Forest and land use in PNG

There is a need to harmonize the different forest definitions used in the country taking into consideration the ecological aspect of forest and its potential to mitigate climate change. Natural events/phenomena were outside the scope of this study. Further studies on the occurrences of the natural events/phenomena such as landslides, frosts, cyclone needs to be conducted to provide a complete picture of forest and land use status in PNG.

Forest Reference Level Updating

This report focuses on the results of forest and land use change from 2000 to 2015, which were used for Forest Reference Level (FRL) and Biennial Update Report (BUR): Technical Annex of REDD+ Results. Reference period of FRL is 2001-2013 and FRL period is 2014-2018 and the REDD+ Results Reporting period against FRL in BUR is 2014-2015.

PNG plans to update FRL using the data until 2018 in 2019 and submit updated FRL between 2020-21. This data and results are also planned to be used for third national communication (TNC) and BUR2 (REDD+ results reporting period will be from 2016 to 2018). Table below is the draft schedule of updating FRL and REDD+ Results Report, which will be discussed in 2019.

Table 9-1: Draft schedule of updating FRL and REDD+ Results Report

	2001				2005					2010			2013	2014	2015	2016	2017	2018				2022
Submitted Reference Period																						
Submitted FRL Period																						
Submitted Result Period																						
Updating Result Period																						
Updating Reference period																						
Updating FRL Period																						

Therefore, updating the forest and land use change assessment is being considered. For the REDD+ results reporting 2016 to 2018, the same methodology will be used for consistency, but PNG also has been considering to improve the methodology based on the lessons learnt from the assessment described in this report.

As quality assurance and quality control information, tree cover loss data from Global Forest Change / Global Forest Watch (Hansen data) and PNG log export volume data will be used for

the assessment as PNG did for the assessment in this report. The tree cover loss from Global Forest Watch until 2018 can be seen in the following Figure 9.1; that is showing decreasing trend in 2017, which will be compared in the updating assessment and report.

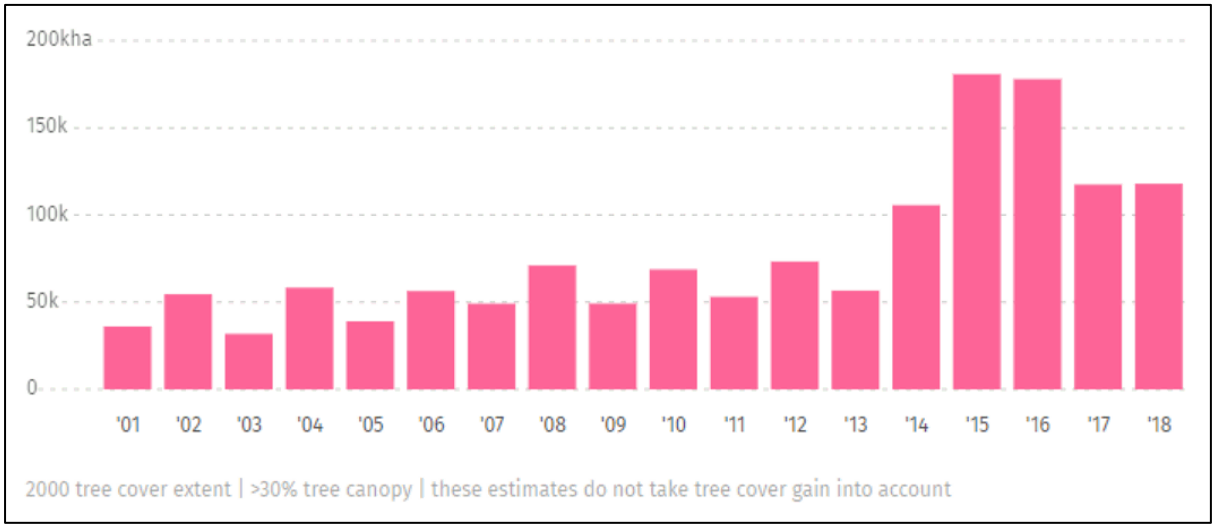


Figure 9-1: Tree cover loss trend 2001 – 2018 from Global Forest Watch.

Forest monitoring system for logging operation

Commercial logging is making a significant impact on the forest cover with an annual rate of 6%. The application of Collect Earth for site-specific forest monitoring system for logging operation is recommended for verifying legality of the operations annually. A set of targeted monitoring tracts (points or polygons) within commercially logged areas can be used to check operations periodically and regularly. Following this reports methods, logging operation sites abusing the required cut areas based on the ALPs can be assessed in Google Earth, Bing Map and Google Earth Engine (GEE). GEE allows to show historical status of the site up to recent years annually, exposing huge extents of vegetation changes which can depict selective logging footprints. Support is needed to boost the current mapping division to increase its internet usage enabling live checking directly on latest satellite imagery. Figure 9-2 shows an example of logging operation that can be monitored using Collect Earth application.

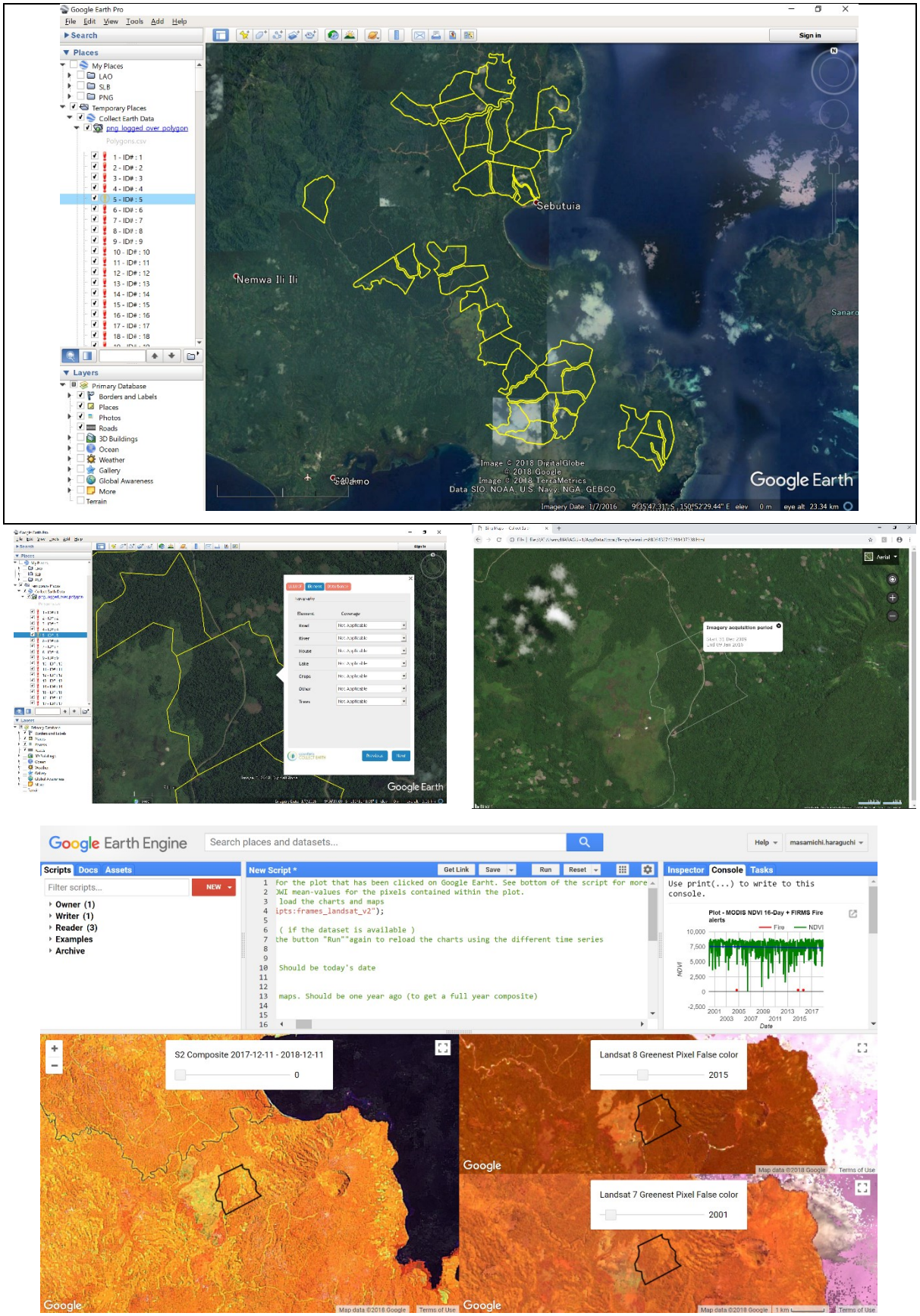


Figure 9-2: Demo of Collect Earth application for site specific logging operation monitoring.

References

Abe, H. (2007). *Forest management impacts on growth, diversity and nutrient cycling of lowland tropical rainforest and plantations, Papua New Guinea*. PhD thesis. The University of Western Australia.

Butler, R. (2015, 10 07). Tratto da Mongabay: https://news.mongabay.com/2015/10/nasa-photo-shows-new-guinea-going-up-in-flames/.

Bey, A., Sánchez-Paus Díaz, A., Maniatis, D., Marchi, G., Mollicone, D., Ricci, S., . . . Miceli, G. (2016). *Collect Earth: Land Use and Land Cover Assessment*. *Remote Sens. 2016, 8, 807; doi:10.3390/rs8100807*.

Bey, A., Sanchez-Paus Diaz, A., Pekkarinen, A., Patriarca , C., Maniatis, D., Weil, D., . . . Ricci, S. (2015). *Collect Earth Use Manual: A guide to monitoring land use change and deforestation with free and open-source software.*

Bourke, M. R., & Hardwood, T. (A cura di). (2009). *Food and Agriculture in Papua New Guinea.* Canberra: Anu Press. Australian National University.

Bryan, J., & Shearman, P. (2015). *The State of Forest of Papua New Guinea 2014: Measuring the change over the period 2002-2014.* Port Moresby: University of Papua New Guinea.

Coffey, R. (2013, January 18). Tratto da Michigan State University: http://msue.anr.msu.edu/news/the_difference_between_land_use_and_land_cover

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

Eva, H., Carboni, S., Achard, F., Stach, N., Durieux, L., Faure, F., & Mollicone, D. (2010). Monitoring forest areas from continental to territorial levels using a sample of medium spatial resolution satellite imagery. *ISPRS J. Photogram. Remote Sens., 65: 191–197*.

FAO (2001). *Global Forest Resources Assessment 2000. Main Report.* FAO Forestry Paper 140. FAO, Rome.

FAO & JRC. (2012). *Global forest land-use change 1990–2005, by E.J. Lindquist,R. D'Annunzio, A. Gerrand, K. MacDicken, F. Achard, R. Beuchle, A. Brink, H.D. Eva,P. Mayaux, J. San-Miguel-Ayanz & H-J. Stibig.FAO Forestry Paper No. 169.* Food and Agriculture Organization of the United Nations and European Commission Joint Research. Rome, FAO.

Filer, C., Keenan, R. J., Allen, B. J., & Mcalpine, J. R. (2009). Deforestation and forest degradation in Papua New Guinea. *Ann. For. Sci. 66 (2009) 813*.

Forest and Development Website. (2017, January 17). *Forest & Development Website*. Tratto da http://forestryanddevelopment.com/site/2017/01/17/png-government-debates-proposed-increase-to-log-export-tax/

Fox, J.C., Yosi, C.K., Nimiago, P., Oavika, F., Pokana, J.N., Lavong, K., & Keenan, R.J. (2010). *Assessment of aboveground carbon in primary and selectively harvested tropical forest in Papua New Guinea*. *Biotropica*, 42, 410-419.

FRA. (2015). *Country Report Papua New Guinea.* Rome: Food and Agriculture Organization of the United Nations.

Gamoga, G. (2018). *Measuring Forest Land Use in Papua New Guinea between 2000 – 2015*. Master Science Thesis Paper. Forestrty Dept. Papua New Guinea University of Technology.

Gibbs, H., Brown, S., Niles, J., & Foley, J. (2007). Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Res. Lett. 2007, 2, 045023*.

Government of Papua New Guinea (2002). National Communication 1

Government of Papua New Guinea (2015). National Communication 2

Government of Papua New Guinea (2017). National Communication 2

Government of Papua New Guinea (2017). Forest Reference Level

Government of Papua New Guinea (2017). Papua New Guinea National REDD+ Strategy for the period 2017-2027.

Government of Papua New Guinea (2019). Biennial Update Report 1

Haberle, S., Hope, G., & Kaarsa, S. D. (2001). Biomass burning in Indonesia and Papua New Guinea: natural and human induced fire events in the fossil record. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 171:259–268.

Hammermaster, E., & Saunders, J. (1995). *Forest resources and vegetation mapping of Papua New Guinea.* PNGRIS Publication No. 4. CSIRO.

Hansen, M., Potapov, P., Moore, R., Hancher, M., Turubanova, S., Tyukavina, A., . . . Kommareddy, A. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science, 2013, 342, 850-853*.

Hansen, M., Roy, D., Lindquist, E., Adusei, B., Justice, C., & Altstatt, A. (2008). A method for integrating MODIS and Landsat data for systematic monitoring of forest cover and change in the Congo Basin. *Remote Sens. of Environment, 112: 2495–2513*.

IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4 Agriculture, Forestry and Other Land Use.* IPCC. Tratto da IPCC websites.

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I. II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core writing team, R.K Pachauri, and L.A Meyer (eds.).* IPCC, Geneva, Switzerland, 151.

ITTO. (2015). *ITTO*. Tratto da ITTO: http://www.itto.int/annual_review/

Iuda, O., & Samanta, S. (2017). *Land Use and Land Cover Change Assessment from 1995 to 2015 using GIS and Remote Sensing Techniques: A case study in a Logging Concession*. Melanesia Journal of Geomatics and Property Studies. Volume 3, 2017. PNG University of Technology. 54-67.

Keenan, R., Reams, A., Archard, F., Freitas, J., Grainger, A., & Linquist, E. (2015). Dynamics of global forest area: Results from the FAO Global Forest.Resources Assessment 2015. *Forest Ecology and Management 352 (2015) 9–20.*

MacDicken, K. G. (2015). Global Forest Resources Assessment 2015: What, why and how? *Forest Ecology and Management*, 3-8.

Martínez, S., & Mollicone, D. (2012). From Land Cover to Land Use:A Methodology to Assess Land Use from Remote Sensing Data. *Remote Sens. 2012, 4, 1024-1045; doi:10.3390/rs4041024*.

Matino, L., & Fritz, M. (2008). New insight into land cover and land use in Europe. *Eurostat 33/2008*.

McAlpine, J. (1970). *Population and land use in the Goroka-Mt Hagen Area.* Canberra: CSIRO Land Research Series No. 27. CSIRO.

McAlpine, J., & Quigley, J. (1998). *Forest resources of Papua New Guinea.Summary statistics from the Forest Inventory Mapping (FIM) System.* Coffey MPW Ltd for the Australian Agency for International Development and the Papua New Guinea National Forest Service.

Montesano, P., Nelson, R., Sun, G., Margolis, H., Kerber, A., & Ranson, K. (2009). MODIS tree cover validation for the circumpolar taiga-tundra transition zone. *Remote Sens. Environ. 2009, 113, 2130-2141*.

Nascimento, H.E.M. & Laurance, W.F. (2002) Total aboveground biomass in central Amazon rainforests: a landscape—cale study. *Forest Ecology & Management*, 168, 311-321.

National Statistics Office. (2015). *National Population and Housing Census 2011. .* Port Moresby: National Statistics Office.

Papua New Guinea Forest Authority. (1996). *National Forest Plan.* Port Moresby: Unpublished.

Ploton, P., Pélissier, R., Proisy, C., Flavenot, T., Barbier, N., Rai, S., & Couteron, P. (2012). Assessing aboveground tropical forest biomass using Google Earth canopy images. *Ecol. Appl. 2012, 22, 993-1003*.

PNG Forest Authority. (2013). *Forest and Land Use in 2013.* Port Moresby: Unpublished.

PNG Forest Authority and JICA. (2012). *Forest Base Map 2012.* Port Moresby: Unpublished.

PNG Forest Authority. (nd). *Annual Log Harvest Volume.* Port Moresby: unpublished.

Potapov, P., Hansen, M., Stehman, S., Loveland, T., & Pittman, K. (2008). Combining MODIS and Landsat imagery to estimate and map boreal forest cover loss. *Remote Sens. Env., 112(9): 3708–3719.*

Romijn, E., Lantican, C., Herold, M., & Lindquist, E. (2015). Assessing change in national forest monitoring capacities of 99 tropical countries. *For. Ecol. Manage. 352, 109–123*.

Saebo, H. V. (1983). Land Use and Environmental Statistics obtained by Point Sampling. *Artikler fra Statistisk 144*.

Saunders, J. (1993). *Agricultural land use of Papua New Guinea (map with explanatory notes). PNGRIS Publication 1.* Canberra: Commonwealth Scientific and Industrial Research Organisation for Australian International Development Assistance Bureau.

Shearman, P. J., Bryan, J. B., Mackey, B., & Lokes, B. (2010). Deforestation and degradation in Papua New Guinea: a response to Filer and collegues, 2009. *For. Sci. 67 (2010) 300*.

Shearman, P., Bryan, J., Hunnam, P., Mackey, B., & Lokes, B. (2008). *The state of the Forest of Papua New Guinea. Mapping the extent and condition of forest cover and measuring the driver of forest change in period 1972-2002.* Port Moresby: University of Papua New Guinea.

Societe Generale de Surveillance (SGS). (n.d). *Annual Log Export Volume 2001-2015.* Port Moresby: Unpuplished.

Stehman, S.V; Sohl, T.L; Loveland, T.R. (2005). An evaluation of sampling strategies to improve precision of estimates of gross change in land use and land cover. *J. Remote Sens., 26: 4941–4957.*

The Government of Papua New Guinea. (2014). *Papua New Guinea National Forest Definition*. Port Moresby, PNG: National Exercutive Council.

Vincent, J.B., Henning B., Saulei, S., Sosanika, G. & Weiblen, G.D. (2015). *Forest carbon in lowland Papua New Guinea: Local variation and the importance of small trees*. *Austral Ecology*, 40, 151-159.

World Resource, I. (2017). *Climate Analysis Indicators Tool*. Tratto il giorno 11 07, 2016 da Center for Climate Change Solutions: https://www.c2es.org/content/international-emissions/

Appendix List

Appendix 1: Land use and elevation range

Elevation - ranges (m)	Area (ha)						Total (ha)
	Forest Land	Cropland	Grassland	Wetlands	Settlements	Other Land	
0-100	13,285,830	1,658173	1,292718	1,950,896	185,442	19,652	18,392,711
101-200	3,612,984	590,887	163,290	73,129	33,144	-	4,473,433
201-300	2,116,525	298,025	72,487	25,587	13,752	-	2,526,377
301-400	1,769,745	198,800	58,894	14,156	5,906	-	2,047,500
401-500	1,451,076	152,886	62,168	4,892	5,879	1,959	1,678,860
501-600	1,249,040	90,427	42,196	15,216	9,831	-	1,406,710
601-700	1,208,746	87,929	35,269	5,420	5,899	-	1,343,264
701-800	1,013,597	74,431	25,451	492	5,880	-	1,119,851
801-900	975,820	56,826	15,685	11,696	1,942	-	1,061,969
901-1000	824,481	56,866	14,207	-	1,988	-	897,541
1001-1100	782,613	70,024	25,488	-	4,423	-	882,548
1101-1200	668,146	102,957	24,015	1,959	-	-	797,076
1201-1300	677,418	76,794	30,892	5,863	6,906	493	798,366
1301-1400	540,224	117,761	45,563	1,932	5,912	1,963	713,356
1401-1500	510,633	143,400	52,766	984	10,358	-	718,141
1501-1600	504,930	195,799	52,235	1,970	17,718	1,963	774,614
1601-1700	414,751	208,768	63,126	-	15,297	3,949	705,891
1701-1800	432,157	234,781	55,723	1,953	12,790	1,961	739,365
1801-1900	434,195	192,266	34,302	-	3,431	1,953	666,147
1901-2000	372,743	143,705	32,343	-	8,372	-	557,162
2001-2100	316,521	106,036	25,505	-	4,356	1,961	454,379
2101-2200	352,739	76,715	16,160	-	986	-	446,600
2201-2300	338,365	55,179	13,170	-	8,242	-	414,957
2301-2400	295,459	55,199	15,588	3,950	8,804	-	379,001
2401-2500	269,987	47,786	6,811	493	5,410	1,963	332,450
2501-2600	295,872	28,250	13,716	-	-	1,978	339,816
2601-2700	250,766	19,447	13,630	-	1,943	-	285,786
2701-2800	212,073	9,760	13,618	-	3,886	-	239,336
2801-2900	212,751	1,943	23,477	3,931	-	-	242,101
2901-3000	180,262	1,943	11,697	1,988	-	-	195,890
3001-3100	158,213	2,435	11,720	-	-	-	172,368
3101-3200	99,086	493	7,760	-	-	-	107,339
3201-3300	58,219	-	10,299	-	-	-	68,518
3301-3400	38,658	1,943	19,536	-	-	1,953	62,089
3401-3500	18,114	-	11,331	-	-	1,953	31,398
3501-3600	12,681	-	14,637	-	--	1,953	29,270
3601-3700	5,865	-	6,827	-	-	3,422	16,114
3701-3800	1,988	-	5,429	-	-	1,953	9,369
3801-3900	-	-	984	-	-	3,895	4,879
3901-4000	-	-	1,966	-	-	1,932	3,897
4001-4100	-	-	-	-	-	2,423	2,423
Total	35,963,273	5,158,633	2,442,680	2,126,505	388,495	59,277	46,138,863

Appendix 2: Cropland types in each province

	Area in hectares												
Province	**Permanent**	**Shifting**	**Not Sure**	**Tea**	**Coffee**	**Oil palm**	**Cocoa**	**Coconut**	**Other**	**Cocoa/ Coconut**	**Sugar**	**Rubber**	**Total**
Western	9,813	54,955	1,963						5,888			3,925	**76,545**
Gulf		39,588	3,959										**43,547**
Central	38,841	201,972	1,942						5,826			5,826	**254,407**
Oro	15,516	240,495				54,305							**310,317**
Milne Bay	19,567	254,374	3,913			19,567		15,654					**313,075**
NCD		1,315											**1,315**
Southern Highlands	81,129	183,506	1,932										**266,567**
Hela	77,529	121,264											**198,793**
Enga	71,883	202,049											**273,932**
Western Highlands	77,920	103,071	493	1,479	5,918								**188,882**
Jiwaka	47,708	88,038	3,443	1,476	5,902								**146,567**
Chimbu	33,419	115,984			5,898								**155,301**
Eastern Highlands	115,582	190,024	1,959		11,754								**319,318**
Morobe	29,292	451,102				9,764		3,906	1,953		3,906		**499,923**
Madang	131,654	274,779	1,988			9,939		11,927		9,939	3,976		**444,202**
East Sepik	147,058	252,940	5,882				5,882	1,961					**413,723**
West Sepik	32,114	82,292				34,121							**148,528**
West New Britain	21,597	68,716				170,809		1,963		1,963			**265,048**
East New Britain	39,216	133,334				19,608		43,138	1,961	17,647			**254,904**
New Ireland	23,346	118,678	1,946			7,782		11,673		7,782		1,946	**173,153**
Manus	5,477	19,171						4,108					**28,756**
AROB	91,006	225,537					7,914	49,460	1,978	5,935			**381,831**
Total:	**1,109,668**	**3,423,186**	**29,419**	**2,955**	**29,472**	**325,896**	**13,796**	**143,789**	**17,606**	**43,267**	**7,881**	**11,697**	**5,158,633**

Appendix 3: Annual deforestation from 2000 to 2015

Land use year of change	Total forest area (ha)	Total deforestation (ha)	Forest types with deforestation (2000-2015)							Annual rate of deforestation
			Low altitude forest on plains and fans (ha)	Low altitude forest on uplands (ha)	Lower montane forest (ha)	Dry seasonal forest (ha)	Swamp forest (ha)	Savanna (ha)	Woodland (ha)	
2000	**36,225,470**									
2001	**36,213,650**	**11,821**	11,821	-	-	-	-	-	-	***0.03%***
2002	**36,205,621**	**8,029**	-	2,007	4,014	-	2,007	-	-	***0.02%***
2003	**36,195,808**	**9,813**	7,851	-	1,963	-	-	-	-	***0.03%***
2004	**36,188,860**	**6,947**	3,995	-	2,952	-	-	-	-	***0.02%***
2005	**36,178,500**	**10,361**	6,346	4,014	-	-	-	-	-	***0.03%***
2006	**36,174,486**	**4,014**	4,014	-	-	-	-	-	-	***0.01%***
2007	**36,164,626**	**9,859**	5,910	1,942	2,007	-	-	-	-	***0.03%***
2008	**36,154,790**	**9,837**	3,970	3,924	1,943	-	-	-	-	***0.03%***
2009	**36,140,580**	**14,209**	6,337	5,909	1,963	-	-	-	-	***0.04%***
2010	**36,126,728**	**13,853**	11,887	-	1,966	-	-	-	-	***0.04%***
2011	**36,103,284**	**23,443**	10,262	3,902	7,964	-	-	1,315	-	***0.06%***
2012	**36,073,541**	**29,744**	15,804	9,989	1,988	1,963	-	-	-	***0.08%***
2013	**36,033,864**	**39,677**	15,868	7,891	13,955	-	-	-	1,963	***0.11%***
2014	**36,005,646**	**28,218**	19,841	7,884	493	-	-	-	-	***0.08%***
2015	**35,972,079**	**33,566**	15,807	9,893	1,959	-	3,951	-	1,957	***0.09%***

Appendix 4: Area (in hectares) of forest type in each province of Papua New Guinea.

Province	Low altitude forest on plains and fans	Low altitude forest on uplands	Lower montane forest	Montane forest	Dry seasonal forest	Littoral forest	Seral forest	Swamp forest	Savanna	Wood-land	Scrub	Mangrove	Forest Plantation	Total
Western	2,794,879	775,265	276,740	7,851	2,351,310	90,284	115,799	598,622	429,830	684,981	98,135	52,993	-	***8,276,689***
Gulf	1,250,978	1,037,203	166,269		-	11,876	33,650	564,128	21,773	19,794	5,938	53,444	-	***3,165,054***
Central	341,799	969,077	683,598	34,957	-	3,884	23,304	54,377	135,943	139,827	7,768	44,667	-	***2,439,201***
Oro	329,711	690,454	496,506	32,971	-	-	34,911	77,579	25,213	71,761	15,516	7,758	-	***1,782,380***
Milne Bay	266,114	387,431	138,927		-	15,654	1,957	5,870	5,870	41,091	1,957	37,178	3,913	***905,962***
NCD*	-	-	-	-	-	-	-	-	5,259	-	-	-	-	***5,259***
Southern Highlands	48,291	529,271	538,929	13,522	-	-	3,863	11,590	-	-	-	-	1,932	***1,147,397***
Hela	3,976	103,373	661,982	17,891	-	-	-	-	-	-	-	-	-	***787,222***
Enga	3,886	52,455	615,861	130,166	-	-	-	-	-	-	-	-	-	***802,367***
Western Highlands	4,438	22,192	141,045	11,343	-	-	-	-	-	-	-	-	-	***179,019***
Jiwaka	5,902	75,251	210,997	22,133	-	-	-	-	-	-	-	-	-	***314,282***
Chimbu	-	127,779	269,320	7,863	-	-	-	-	-	-	-	-	-	***404,962***
Eastern Highlands	1,959	58,770	517,178	15,672	-	-	-	-	-	-	-	-	5,877	***599,457***
Morobe	111,311	794,799	1,372,835	54,679	-	-		3,906		1,953	27,340	-	9,764	***2,376,586***
Madang	657,814	815,016	496,961	29,818	-	-	37,769	103,368	-	5,964	7,951	-	5,964	***2,160,624***
East Sepik	913,720	982,347	233,332	3,922	-	-	29,412	696,074	-	74,509	37,255	21,568	-	***2,992,137***
West Sepik	722,567	1,595,670	632,247	8,029	-	-	26,093	258,920	-	4,014	4,014	2,007	-	***3,253,561***
West New Britain	895,274	702,869	64,790	-	-	11,780	1,963	39,266	-	-	-	15,707	3,927	***1,735,575***
East New Britain	182,355	754,908	278,434	-	-	3,922	1,961		-	-	1,961	3,922	15,686	***1,243,148***
New Ireland	184,826	406,618	107,005	-	-	-	1,946	3,891	-	-		27,238	1,946	***733,469***
Manus	90,833	45,188		-	-	913		9,585	-	-	456	5,477	-	***152,453***
AROB**	116,725	201,796	102,877	-	-	7,914	7,914	35,611	-	11,870	11,870	9,892	-	***506,470***
Total	**8,927,359**	**11,127,733**	**8,005,831**	**390,815**	**2,351,310**	**146,226**	**320,540**	**2,462,788**	**623,889**	**1,055,764**	**220,161**	**281,850**	**49,008**	**35,963,273**

Appendix 5: Forest at altitudinal ranges

Land use subdivision	Low altitude forest on plains and fans	Low altitude forest on uplands	Lower montane forest	Montane forest	Dry seasonal forest	Littoral forest	Seral forest	Swamp forest	Savanna	Woodland	Scrub	Mangrove	Eucalyptus Plantation	Balsa Plantation	Araucaria Plantation	Pinus Plantation	Acacia Plantation	Terminalia Plantation	Total (ha)
0-100	5,639,185	581,253	0	0	2,327,757	134,462	233,540	2,403,635	556,464	932,905	155,455	273,545	15,674	1,961	0	0	3,976	3,913	**13,263,725**
101-200	2,192,533	1,197,133	0	0	23,552	3,919	45,584	37,706	36,353	60,428	9,864	0	1,963	1,961	0	0	1,988	0	**3,612,984**
201-300	557,850	1,511,921	0	0	0	0	3,925	1,939	15,531	21,401	3,958	0	0	0	0	0	0	0	**2,116,525**
301-400	233,705	1,518,457	0	0	0	0	5,915	0	0	7,763	3,905	0	0	0	0	0	0	0	**1,769,745**
401-500	129,125	1,294,538	0	0	0	0	6,002	1,932	5,838	7,784	5,857	0	0	0	0	0	0	0	**1,451,076**
501-600	77,517	1,153,959	0	0	0	0	3,967	1,932	1,942	5,832	3,892	0	0	0	0	0	0	0	**1,249,040**
601-700	36,710	1,158,373	0	0	0	0	0	1,932	1,942	5,858	3,931	0	0	0	0	0	0	0	**1,208,746**
701-800	23,527	974,468	0	0	0	0	5,881	3,863	3,879	1,979	0	0	0	0	0	0	0	0	**1,013,597**
801-900	17,110	945,021	0	0	0	0	5,869	1,932	0	3,936	0	0	0	0	1,953	0	0	0	**975,820**
901-1000	18,134	792,610	5,938	0	0	0	1,939	0	0	0	1,953	0	0	0	3,906	0	0	0	**824,481**
1001-1100	0	0	766,888	0	0	1,963	1,978	0	0	3,959	7,825	0	0	0	0	0	0	0	**782,613**
1101-1200	0	0	656,349	0	0	1,963	1,988	0	0	1,963	1,978	0	0	0	3,906	0	0	0	**668,146**
1201-1300	0	0	671,538	0	0	0	1,988	0	1,939	0	1,953	0	0	0	0	0	0	0	**677,418**
1301-1400	0	0	536,309	0	0	1,963	0	0	0	0	1,953	0	0	0	0	0	0	0	**540,224**
1401-1500	0	0	508,681	0	0	0	0	0	0	0	1,953	0	0	0	0	0	0	0	**510,633**
0	0	0	502,971	0	0	0	0	0	0	0	0	0	0	0	0	1,959	0	0	**504,930**
1601-1700	0	0	412,792	0	0	0	0	0	0	0	0	0	0	0	0	1,959	0	0	**414,751**
1701-1800	0	0	430,198	0	0	0	0	0	0	0	0	0	0	0	0	1,959	0	0	**432,157**
1801-1900	0	0	426,405	0	0	0	0	0	0	0	5,858	0	0	0	0	1,932	0	0	**434,195**
1901-2000	0	0	368,834	0	0	0	0	0	0	1,957	1,953	0	0	0	0	0	0	0	**372,743**
2001-2100	0	0	316,521	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**316,521**
2101-2200	0	0	350,778	0	0	0	0	0	0	0	1,961	0	0	0	0	0	0	0	**352,739**
2201-2300	0	0	338,365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**338,365**
2301-2400	0	0	295,459	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**295,459**

2401-2500	0	0	269,987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**269,987**
2501-2600	0	0	293,919	0	0	0	0	0	0	0	1,953	0	0	0	0	0	0	**295,872**
2601-2700	0	0	248,813	0	0	0	0	0	0	0	1,953	0	0	0	0	0	0	**250,766**
2701-2800	0	0	212,073	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**212,073**
2801-2900	0	0	212,751	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**212,751**
2901-3000	0	0	180,262	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**180,262**
3001-3100	0	0	0	158,213	0	0	0	0	0	0	0	0	0	0	0	0	0	**158,213**
3101-3200	0	0	0	99,086	0	0	0	0	0	0	0	0	0	0	0	0	0	**99,086**
3201-3300	0	0	0	58,219	0	0	0	0	0	0	0	0	0	0	0	0	0	**58,219**
3301-3400	0	0	0	38,658	0	0	0	0	0	0	0	0	0	0	0	0	0	**38,658**
3401-3500	0	0	0	16,107	0	0	0	0	0	0	2,007	0	0	0	0	0	0	**18,114**
3501-3600	0	0	0	12,681	0	0	0	0	0	0	0	0	0	0	0	0	0	**12,681**
3601-3700	0	0	0	5,865	0	0	0	0	0	0	0	0	0	0	0	0	0	**5,865**
3701-3800	0	0	0	1,988	0	0	0	0	0	0	0	0	0	0	0	0	0	**1,988**
Total:	**8,927,359**	**11,127,733**	**8,005,831**	**390,815**	**2,351,310**	**146,226**	**320,540**	**2,462,788**	**623,889**	**1,055,764**	**220,161**	**281,850**	**17,637**	**3,922**	**9,764**	**7,809**	**5,964**	**3,913**	**35,963,273**

Appendix 6: Forest types impacted by anthropogenic activities from 2000 to 2015

Forest type	C-Logging	Fire	Gardening	Other	None	Wokabout Sawmill	Total (ha)
Low altitude forest on plains and fans	2,379,795	160,449	645,816	85,733	5,621,495	34,071	8,927,359
Low altitude forest on uplands	1,230,894	88,256	983,856	92,158	8,702,804	29,764	11,127,733
Lower montane forest	33,240	128,388	1,126,124	47,434	6,666,762	3,884	8,005,831
Montane forest	-	19,477	10,207	-	361,131	-	390,815
Dry seasonal forest	100,097	96,172	31,403	80,471	2,043,166	-	2,351,310
Littoral forest	3,927	1,957	9,810	-	130,533	-	146,226
Seral forest	7,814	5,888	11,761	3,879	287,277	3,921	320,540
Swamp forest	77,363	37,320	99,227	41,329	2,199,666	7,882	2,462,788
Savanna	-	276,843	3,905	13,674	329,467	-	623,889
Woodland	15,681	238,518	46,938	72,618	680,067	1,942	1,055,764
Scrub	4,424	29,384	3,918	3,925	178,511	-	220,161
Mangrove	5,890	1,942	15,628	31,367	225,044	1,979	281,850
Eucalyptus Plantation	7,846	-	-	3,906	5,885		17,637
Balsa Plantation	-	-	-	3,922	-	-	3,922
Araucaria Plantation	-	7,811	-	-	1,953	-	9,764
Pinus Plantation	-	5,850	-	-	1,959	-	7,809
Acacia Plantation	3,976	-	1,988	-	-	-	5,964
Terminalia Plantation	-	-	-	-	3,913	-	3,913
Total:	**3,870,945**	**1,098,253**	**2,990,581**	**480,416**	**27,439,635**	**83,444**	**35,963,273**
% disturbed	**10.8**	**3.1**	**8.3**	**1.3**	**76.3**	**0.2**	**100**

Appendix 7: Forest disturbance at elevation rang

Elevation Range	Forestland (ha)					
	Logging	Fire	Gardening	Other	Wokabout Sawmill	None*
0-100	1,859,729	704,526	659,252	325,531	36,199	9,678,488
101-200	824,976	105,289	289,886	42,188	16,549	2,334,095
201-300	484,991	44,862	145,761	21,596	4,351	1,414,964
301-400	257,263	10,723	126,432	15,767	9,751	1,349,807
401-500	198,876	13,709	145,265	7,907	6,372	1,078,947
501-600	104,042	12,180	100,581	5,863	1,946	1,024,428
601-700	43,171	9,819	124,291	1,961	1,946	1,027,559
701-800	27,432	13,653	106,310	5,826	-	860,377
801-900	17,649	5,837	86,444	1,961	2,446	861,484
901-1000	17,613	10,267	68,064	4,381	-	724,155
1001-1100	9,789	3,906	86,071	5,918	-	676,929
1101-1200	3,922	5,894	75,160	6,860	-	576,311
1201-1300	7,843	4,388	97,664	5,902	1,942	559,678
1301-1400	5,848	1,953	68,930	-	-	463,493
1401-1500	1,961	11,760	75,834	3,892	-	417,186
1501-1600	1,946	13,753	56,851	1,946	1,942	428,493
1601-1700	-	1,959	60,197	-	-	352,595
1701-1800	-	14,205	47,381	-	-	370,570
1801-1900	-	13,665	80,527	5,884	-	334,120
1901-2000	-	3,891	75,026	3,925	-	289,901
2001-2100	-	7,783	53,843	2,423	-	252,472
2101-2200	-	-	76,237	492	-	276,010
2201-2300	-	8,385	60,874	2,435	-	266,671
2301-2400	1,932	6,398	44,065	1,942	-	241,123
2401-2500	-	6,327	36,131	-	-	227,529
2501-2600	-	8,334	38,045	1,939	-	247,553
2601-2700	-	11,711	39,612	-	-	199,443
2701-2800	-	11,780	21,497	1,932	-	176,864
2801-2900	-	1,988	19,951	1,943	-	188,869
2901-3000	-	7,877	12,225	-	-	160,160
3001-3100	-	8,251	7,771	-	-	142,191
3101-3200	-	4,872	1,943	-	-	92,271
3201-3300	-	2,459	493	-	-	55,267
3301-3400	--	3,895	-	-	-	34,763
3401-3500	-	-	-	-	-	18,114
3501-3600	-	-	-	-	-	12,681
3601-3700	-	-	-	-	-	5,865
3701-3800	-	-	-	-	-	1,988
Total	**3,870,945**	**1,098,253**	**2,990,581**	**480,416**	**83,444**	**27,439,635**

*No disturbance or intact

Appendix 8: Forest converted to other land use in Provinces between 2000 and 2015

Province	Forest converted to cropland (ha)							Forest converted to settlement (ha)	Total	%
	Permanent	Shifting	Not Sure	Oil palm	Cocoa	Coconut	Other			
Autonomous Region of Bougainville	-	-	-	-	1,978	-	-	-	1,978	0.78
Central	-	1,942	-	-	-	-	--	-	1,942	0.77
Chimbu	-	3,932	-	-	-	-	-	-	3,932	1.55
East New Britain	-	3,922	-	15,686	-	-	-	-	19,608	7.72
East Sepik	1,961	11,765	-	-	-	-	-	-	13,725	5.41
Eastern Highlands	-	1,959	1,959	-	-	-	-	-	3,918	1.54
Enga	-	3,886	-	-	-	-	-	-	3,886	1.53
Gulf	-	1,979	-	-	-	-	-	-	1,979	0.78
Hela	-	1,988	-	-	-	-	-	-	1,988	0.78
Madang	-	9,939	-	1,988	-	-	-	-	11,927	4.70
Manus	-	1,826	-	-	-	-	-	-	1,826	0.72
Milne Bay	-	17,610	-	-	-	1,957	-	-	19,567	7.71
Morobe	-	1,953	-	-	-	-	-	-	1,953	0.77
National Capital District	-	-	-	-	-	-	-	1,315	1,315	0.52
New Ireland	-	1,946	-	-	-	-	-	-	1,946	0.77
Oro	-	5,818	-	-	-	-	-	-	5,818	2.29
West New Britain	1,963	11,780	-	31,413	-	-	-	-	45,156	17.79
West Sepik	-	56,200	-	32,114	-	-	-	-	88,314	34.79
Western	1,963	15,702	-	-	-	-	5,888	-	23,552	9.28
Western Highlands	1,479	-	-	-	-	-	-	-	1,479	0.58
	7,366	154,145	1,959	81,201	1,978	1,957	5,888	1,315	253,832	100

Appendix 9: Annual forest degradation by human impact type

Year of forest degradation/disturbance	Human Impact (Area - ha)					
	Logging	Fire	Gardening	Other	Wokabout Sawmill	Total
2000	11,834	1,946	1,946	0	0	15,725
2001	85,666	1,953	0	0	0	87,618
2002	140,152	0	1,953	0	0	142,105
2003	140,579	0	4,386	0	0	144,965
2004	141,962	0	5,854	0	0	147,816
2005	95,824	1,953	3,916	5,977	0	107,670
2006	139,751		7,840	1,963	0	149,554
2007	148,608	1,939	7,916	5,871	0	164,335
2008	153,911	0	5,909	3,947	0	163,767
2009	172,600	0	5,824	0	0	178,424
2010	183,068	0	19,573	0	0	202,641
2011	183,895	3,922	9,772	2,464	0	200,052
2012	140,221	3,941	17,866	3,923	0	165,951
2013	157,520	0	11,884	7,824	0	177,229
2014	155,402	1,988	12,249	0	0	169,640
2015	140,894	3,922	19,664	5,732	1,961	172,172
Total:	**2,191,887**	**21,562**	**136,554**	**37,701**	**1,961**	**2,389,665**

Appendix 10: Human impact in provinces between 2000 to 2015

	Human Impact (Area-ha)					Total
	Logging	Fire	Gardening	Other	W/Sawmill	
Western	582,921	-	13,739	9,813	-	606,473
Gulf	358,271	-	3,959	-	-	362,229
Central	85,450	-	7,768	1,942	-	95,160
Milne Bay	5,870	-	7,827	-	-	13,697
Oro	17,455	1,939	9,697	1,939	-	31,032
Morobe	19,528	5,858	3,906	-	-	29,292
Madang	91,441	1,988	13,915	-	-	107,344
East Sepik	88,235	7,843	9,804	-	1,961	107,842
West Sepik	343,220	-	22,078	8,029	-	373,327
East New Britain	250,983	-	1,961	9,804	-	262,747
West New Britain	251,305	-	11,780	-	-	263,085
New Ireland	73,931	1,946	23,346	3,891	-	103,114
Manus	23,279	-	913	2,282	-	26,474
Enga	-	-	1,943	-	-	1,943
Hela	-	1,988	-	-	-	1,988
Eastern Highlands	-	-	3,918	-	-	3,918
Total:	**2,191,887**	**21,562**	**136,554**	**37,701**	**1,961**	**2,389,665**

Appendix 11: Subdivision categories definitions

A. Detailed descriptions of forest types

Land Use Subtype and Subdivision		Definition
Natural forest (*Hammermaster & Saunders, 1995)*		
1	Lower altitude forest on plains and fans	Denoted in the FIMS with letter P, is also differentiated by crown size from large to medium crowned as Pl, Open forest as Po and small crowned as Ps. Pl forest is a tall forest with average canopy height of 30-35 m. Emergent trees often attain and sometimes exceed 50 m. The canopy is irregularly open and irregularly uneven in profile. These forest occurs on well to imperfectly drained alluvial plains and on gently sloping undissected fans. Flooding rarely occurs or is infrequent and of short duration. It is often found on the foot slopes of volcanoes. Po forest canopy can reach 30 m in height often with large crowned emergent to 40 m. The irregularly uneven profile canopy is composed of mainly medium and some small crowns. The open canopy has many, often large, gaps revealing a lower tree stratum. The large crowned emergent often include strangling figs, and Octomeles sumatrana in frequently flooded areas. Ps forest has a dense even canopy of small crowns 25-30 m in height with no emergent. It occurs on flat to gently undulating plains and fans where soils are often gravelly and/or poorly drained. The forest may contain mixed species similar to those of the open forest, but a single species often dominates the canopy (e.g. Intsia, dipterocarps such as Hopea, Vatica).
2	Lower altitude forest on uplands	Low altitude forest on uplands is further distinguished by crown size, canopy height, and canopy closure and species composition. However, the key factor that differentiates Upland forests is the slope. Large crowned Low altitude forest on uplands. This forest type has an uneven canopy 30-35m in height with a 60-80% closure. Emergent can reach 40m in height. Large stem diameters (70-89cm) predominant. In both structure and floristic content it is very similar to the “Large to medium crowned forest” on plains and fans. Medium crowned Low altitude forest on uplands. The canopy of this forest type is 25-30m in height, is generally only slightly uneven and has a 60-80% crown closure. Except for Araucaria emergent rarely exceed 40m in height. Very large stem diameters (90cm+) are rare except for Araucaria. Floristically the forest is very mixed. Small crowned Low altitude forest on uplands. This forest has a relatively even canopy 20-30m in height, with a 60-80% closure and no emergent. Large stem diameters (90cm+) are rare, the majority of trees falling into the medium (50-69cm) to small (30-49cm) classes. The forest may be either a mixed forest which is poorly developed due to adverse site or climatic conditions, or a forest win which a small crowned (<8m) trees predominates in the canopy.
3	Montane forest	This forest “mossy forest” has a dense, even, dark toned, almost velvety textured canopy 5-15m in height, usually without emergent. Stems are very thin and crooked.
4	Lower montane forest	Small crowned Lower montane forest (above 1000m). This forest has an even to slightly undulating canopy 20-30m in height. Canopy closure varies from dense to slightly open. The canopy height decreases with increasing altitude. Stem diameters are generally medium (50-69cm) to small (30-49cm). The forest occurs throughout the mountain ranges in the 1400-3400m altitude range. Lower montane forest: Small crowned forest with conifers. This forest has a canopy 15-25m in height with emergent conifers. Crowns are small (<8m) to very small. Although the stems of the associated broadleaf species are generally small (30-49cm) in diameter, the coniferous stems often exceed 50cm in diameter. The forest occurs in many places in the mountain ranges above 2400m altitude.

5	Montane coniferous forest (>1000m)	This forest has a canopy 15-25m in height with emergent conifers. Crowns are small (<8m) to very small. Although the stems of the associated broadleaf species are generally small (30-49cm) in diameter, the coniferous stems often exceed 50cm in diameter. The forest occurs in many places in the mountain ranges above 2400m altitude.
6	Dry seasonal forest	This forest has a fairly open canopy 20-25m in height with emergent to 30m and occasionally to 40m. Stems are often low-branched and crooked.
7	Littoral forest	Contains forest classes: Mixed forest (B) The forest has an irregularly open, irregularly uneven canopy of medium (8-15m) crowns 20-30m in height. Forest with Casuarina equisetifolia (BCe): The forest has a dense to irregularly open, more or less even canopy of small (<8m) crowns 15-30m in height. Forest with Melaeuca leucandendron (BMI): The forest has an irregularly open to sometimes almost closed, irregularly uneven canopy of medium (8-15m) to small (<8m) crowns 20-30m in height.
8	Seral forest	This forest class contains five sub-classes: Riverine mixed successions (Fri): This forest has an irregularly open to open, irregularly uneven, medium (8-15m) to small (<8m) crowned canopy up to 30m in height. Large crowned (>15m) emergent, may be present. The forest is heterogeneous, comprising many seral stages, from low forest to original levee forest, following changes in the course of a river. Riverine successions with Casuarina grandis (FriCg): This forest has a dense, even canopy of small (<8m), semi-conical crowns up to 30m in height. It is an almost pure stand of Casuarina grandis. Stem diameters are small (30-49cm). Riverine successions with Eucalyptus deglupta [commonly known in PNG as Kamarere] (FriK): This forest has a dense to open, generally even, large crowned (>15m) canopy up to 30m in height. The canopy is predominantly Kamarere which has light-toned crowns. Riverine successions with Terminalia brassii (FriTb): This forest has a dense to open, even to slightly undulating, volcanic successions (Fv): The forest is highly variable in height, crown size, canopy closure and profile, and in species composition, being a seral vegetation
9	Swamp forest	This forest class contains four sub-classes: Mixed swamp forest (Fsw): The forest has an irregularly open, almost even canopy of medium (8-15m) to very small (<8m) crowns 20-30m in height. A dense under-storey of sago palms is often visible. In some intermontane basins the forest is extremely low in height, up to 5m and can be a pure stand of Nothofagus or Poducarpus. Swamp forest with Campnosperma (FswC): The forest has a dense, even canopy of small crowns 20-30m in height. Although rarely seen under the dense canopy there is a lower layer of sago palms. Swamp forest with Melaleuca leucadendron (FswML): This forest has an open, irregularly uneven canopy of small crowns 20-30m in height. Swamp forest with terminalia brassii (FswTb): The forest has a generally dense, occasionally open, even to slightly uneven or undulating canopy of medium (8-15m) to large (>15m), woolly, light-toned crowns 20-30m in height.
10	Savanna	This class contains three sub-classes: Savannah (Sa): The tree layer is low, generally less than 6m tall, and is open. The ground layer is clearly visible and is dominated by grasses with some shrubs and herbs. Savannah with gallery forest (Saf): The type of savannah present is similar to that described above for the appropriate area. Savannah with Melaleuca leucadendron (SaMI): in southwest PNG, on periodically waterlogged terrain, the tree layer is dominated by Melaleuca.
11	Woodland	This class contains six sub-classes: Woodland (W): The tree layer is low and open but the ground layer is usually dense and may include shrubs, herbs or grasses, or any combination of these three. Riverine succession dominated by woodland (Wri): A low open tree layer of species common to its forest counterpart. Riverine successions with Casuarinas grandis woodland (WriCg): This type is a low, open version of its forested counterpart. The ground layer is generally sparse. Volcanic successions dominated by woodland (Wv): The low, open tree layer up to 8m high over a sparse to dense ground layer of grasses. Swamp woodland (Wsw): The wood land consists of an open to fairly dense upper layer of sago palms or

		pandans, with scattered trees, over a ground layer of tall sedges and ferns or Phragmites grass, or bare ground. Where trees occur, the species are similar to those of swamp forest. Swamp woodland with Melaleuca leucandendron (WswMI): This woodland is a very open variant of swamp forest with Melaleuca. The upper layer of very open Melaleuca leucandendron can attain a height of 20m over a dense ground layer of grasses and sedges.
12	Scrub	This class contains three sub-classes: Scrub (Sc): Scrub is a community of dense shrubs up to 6m in height, with or without low scattered trees. Scrub with Bambusa and Cyathea (ScBc): Occasional low trees may be present but for the most part the scrub comprises of the tree-fern Cyathea with a tangled mass of scrambling Bambusa.
13	Mangrove	Covers a wide range of communities from almost bare tidal flats with scattered halophytic herbs, to mangrove forest over 30m in height.
Plantation forest		
14	Teak	Planted forest predominantly composed of exotic Teak tree species established through planting and/or deliberate seeding. Teak is a tropical hardwood tree from the genus Tectona, endemic to Southeast Asia that is exclusively planted for the purpose of forestry management, for either commercial or ecological purposes.
15	Eucalyptus	Planted forest predominantly composed of exotic Eucalyptus tree species established through planting and/or deliberate seeding. Mostly Australian evergreen trees or rarely shrubs of the myrtle family that have rigid entire leaves and umbellate flowers and are widely cultivated for their gums, resins, oils, and woods
16	Balsa	Planted forest predominantly composed of exotic Balsa tree species established through planting and/or deliberate seeding. The PNG Balsa Company was established in 1997 and is one of the few fully integrated balsa growers and manufacturers in the world.
17	Araucaria	Planted forest predominantly composed of exotic Araucaria tree species established through planting and/or deliberate seeding. It is a very large, symmetrical tree that grow up to 90 m tall. The bole is straight, cylindrical and self-pruning up to 35 m or more and up to 300 cm in diameter.
18	Pinus	Planted forest predominantly composed of exotic Pinus tree species established through planting and/or deliberate seeding.
19	Acacia	Planted forest predominantly composed of exotic Acacia tree species established through planting and/or deliberate seeding.
20	Terminalia	Planted forest predominantly composed of exotic Terminalia tree species established through planting and/or deliberate seeding.
21	Other	Any other forest plantation composed of trees established through planting and/or deliberate seeding.

B. Detailed descriptions of human impacts applied to forest land subdivisions.

Human impact type	Definition
1. Commercial logging	Refers to a large scale logging activity to harvest timber with the intent of selling (internationally or domestically). There are two types of logging activities; clear felling and selective logging. For PNG case, selective logging is practiced only for harvesting timber at a certain diameter. For commercial logging, a permit or license has to be obtained for an acquired boundary of a forest area for a longer term of a contract.
2. Gardening	Refers to growing of food crops for domestic consumption. They appear in satellite images as isolated and unevenly distributed patches of temporary forest clearings often at the edge of cropland areas especially shifting cultivation.
3. Portable sawmill	Refers to a small scale activity of harvesting timber for domestic use within a forest area using a sawmill and chain saw.

4. Fire	Refers to an action of setting alight (human impact) which results in burning within a forest area for instance slash and burn for gardening or hunting.
5. Other	Any disturbance to the forest that is caused naturally or by humans, and that is not commercial logging, portable sawmilling or temporary gardening. This include mining, grazing and other infrastructure development.
6. None	No visible impact from the center of plot to about 1km buffer. Forest canopy 90-100%.

C. Detailed descriptions of other land use categories

Land Use	Land Use Subtype and Subdivision		Definition
Cropland	***Subsistence (Family) Agriculture***		
	1	Permanent	Permanent refers to cultivation which is long term gardening without moving to a new piece of land. For PNG, this activity differs for the lowlands and highlands regions; as for the latter is a dominant practice due to land sensitivity and close proximity to individual household or family unit/clan areas.
	2	Shifting	Shifting refers to a temporary cultivation of land in a rotational basis where the cultivated land is abandoned for a few years then re-cultivated once the land naturally restores its fertility.
	3	Not sure	Neither permanent nor shifting agriculture. Blurry or distorted image that is difficult to be classed as permanent or shifting but the plot is near or in close proximity to populated areas understood to be dwelling on subsistence agriculture esp. below 1000 m altitudinal range areas of PNG.
	Commercial Agriculture		
	4	Tea	Large-scale estate meant for farming that specializes in tea planting. Tea is an evergreen shrub or small tree which produces tea leaves and grown as a major cash crop in the Highlands of PNG.
	5	Sugar	Large-scale estate meant for farming that specializes in sugarcane planting. Sugarcane are several species of tall perennial true grasses of the genus Saccharum, tribe Andropogoneae, native to the warm temperate to tropical regions of South Asia and Melanesia, and used for sugar production.
	6	Coffee	Large-scale estate meant for farming that specializes in coffee planting. Coffee is a genus of flowering plants whose seeds, called coffee beans, are used to make various coffee beverages and products. It is a member of the family Rubiaceae. They are shrubs or small trees that can grow to 4 meters tall. It is grown as a major cash crop in the Highlands of PNG.
	7	Oil palm	Large-scale estate meant for farming that specializes in oil palm planting. Oil palm is an edible vegetable oil derived from the mesocarp (reddish pulp) of the fruit of the oil palms, primarily the African oil palm Elaeis guineensis, and to a lesser extent from the American oil palm Elaeis oleifera and the maripa palm Attalea maripa.
	8	Cocoa	Large-scale estate meant for farming that specializes in cocoa planting. Theobroma cacao, also called the cacao tree and the cocoa tree, is a small (4–8 m (13–26 ft) tall) evergreen tree in the family Malvaceae, native to the deep tropical regions of Central and South

			America. Its seeds, cocoa beans, are used to make cocoa mass, cocoa powder, confectionery, ganache and chocolate.
	9	Coconut	Large-scale estate meant for farming that specializes in coconut planting. The coconut tree (Cocos nucifera) is a member of the family Arecaceae (palm family) and the only species of the genus Cocos. Coconut is a multipurpose crop, providing copra for export, food, drink, combustible materials, raw materials for making baskets and mats, leaves for thatched roofs for houses and trunks as posts for houses and fencing.
	10	Cocoa/coconut	Large-scale estate meant for farming that specializes in cocoa/coconut planting. Coconut trees intercropped with cocoa.
	11	Rubber	Large-scale estate meant for farming that specializes in rubber tree planting. Rubber tree plants are a fast-growing species of broadleaf evergreen tree called Ficus elastica.
	12	Other	Blurry or distorted image that is difficult to classify the plot area but the plot is understood to be within or in close proximity to commercial agriculture activities.
Grassland	1	Herb land	It can be defined as unmanaged grassland areas below 1,000m a.s.l
	2	Rangeland	It can be defined as grassland area that is managed for cattle grazing in confined area (fenced)
	3	Other	It is neither rangeland nor herb land. It mainly would be for alpine grassland areas (1,000+a.s.l).
Wet land	1	River	A river is a natural flowing watercourse, usually freshwater, flowing towards an ocean, sea, lake or another river
	2	Lake	An area of variable size filled with water, localized in a basin that is surrounded by land, apart from any river or other outlet that serves to feed or drain the lake.
	3	Dam	A dam is a barrier that stops or restricts the flow of water or underground streams. Hydropower is often used in conjunction with dams to generate electricity. A dam can also be used to collect water or for storage of water which can be evenly distributed between locations.
	5	Nipa swamp	Nipa palms often intergrade with mangroves in estuarine transition zones near.
	6	Other	Neither river, lake, dam nor nipa swamp. Other wet land areas not described in this document or difficult to classify.
Settlement	1	Village	Refers to a permanent human settlement comprising of a community with more than 1 clan or tribe i.e. located in a rural area. The houses are densely distributed than the hamlets. Usually scattered subsistence agriculture is evident in the surroundings.
	2	Hamlet	Hamlet refers to a cluster of permanent or semi-permanent houses usually between 3 - 5 houses scattered broadly over the landscape or the area of interest (a family or 1 clan). Usually the hamlet inhabitants belong to the main community or a village located within the proximity of the hamlets. Hamlet is difficult to detect in low to medium resolution satellite images.
	3	Large Settlement	Refers to well-organized cities, towns and district center's. Includes mining townships that are located away/far from the mining sites.
	4	Infrastructure	This refers to permanent structure such as road (paved or unpaved), bridges, airstrips/airports, clinic, schools and playing fields which is located outside of a village/large settlement or in remote areas.

Other land	1	Bare land	Non-vegetated land either barren for long periods of time that can be caused by natural or human induced disasters.
	2	Sand	Non-vegetated land such as sandy beaches, sand banks.
	3	Rock	Non-vegetated surface mainly composed of rock materials. Highly likely to be found near volcanoes or on very high altitude mountain tops. This also depends on very high resolution images.

Appendix 12: List of operators for the Collect Earth assessments in 2016

No	Name	Designation	Division
1	Mr. Peter Lat	Inventory Officer	Area Office-West (WNB)
2	Mr. Michael Gamung	Monitoring Officer	Kavieng-East, ENB
3	Mr. Darius Kalulu	Monitoring Officer	Kerevat-East, ENB
4	Mr. Donald Tarere	Extension Officer	Area Office-East, ENB
5	Mr. Mathew Solomon	Project Supervisor	Lorengau, Manus
6	Mr. Timothy Palpali	Inventory and Mapping	Area Office
7	Mr. Sakias Aine	Nursery Extension Officer	Mt. Hagen, WHP
8	Mr. Gaima Takai	Extension Officer	Kundiawa, Simbu
9	Mr. Jim William	Land Liaison Officer	Goroka, EHP
10	Mr. Kenzele Propis	Extension Officer	Wabag, Enga
11	Mr. Stanley Pudiye	Inventory Assistant Officer	Port Moresby
12	Ms. Elizabeth Helali	Special Projects Officer	Port Moresby
13	Mr. Damien Doko	Project Supervisor, NFM,Vanimo	Forest Development Directorate, WSP
14	Mr. Conrad Kilalang	Monitoring Officer, Bewani LFA,Vanimo	Field Services Directorate
15	Ms. Priscilla Hokoi	Monitoring Officer, Hawain/Marienberg	Field Services Directorate, East Sepik
16	Mr. Philip Pomoso	Project Supervisor, MNC	Forest Development Directorate, Madang
17	Mr. Brenden Opasa	Extension Officer, MNC	Forest Development Directorate, Madang
18	Mr. Leon Jerry Laki	Monitoring Officer, Ramu Block	Field Services Directorate
19	Late Kevin Turbarat	Monitoring Officer, Lae	Field Services Directorate
20	Mr. Kunsey Lavong	Tree Growth Officer	FRI, Lae
21	Mr. Maman Tavune	Silviculturist Officer	FRI, Lae
22	Ms. Agnes Sumareke	Silviculturist Officer	FRI, Lae
23	Mr. Samuel Aloysius	Project Supervisor, Alotau, Milne Bay	
24	Ms. Brenda Kispe	Assistant Forester	Area Office, HQ
25	Mr. Henry Aopo	Monitoring Officer	Vailala Block 1 FMA, Gulf
26	Mr. Manu Wakol	Monitoring Officer	Turama TRP, Gulf
27	Mr. Bodger Auri	Monitoring Officer	Yema Gaiapa LFA, Oro
28	Mr. Rex Wunum	Monitoring Officer	Wawoi Guavi TRP, Western
29	Mr. Robin Samuel	Monitoring Officer	Makapa, Western
33	Mr. Baip Simberi	Monitoring Officer	Cloudy Bay, Central
31	Mr. Mosa Sipara	Monitoring Officer	Central
32	Mr. Ori Renagi	Inventory/Mapping	Officer, Area Office, HQ

Appendix 13: Group photographs of operators and facilitators.

Session 1: Highlands Region and NGI Region participants. PNGFA HQ, Port Moresby (2016).

Gewa Gamoga, Darius Kalulu, Timothy Palpali, Mathew Solomon, Sakias Aine, Dr. Hitofumi Abe, Donald Tarere, Kenzele Propis, Jim William, Micheal Gamung, Stanley Pundiye, Peter Lat, Gaima Takai, Oala Iuda.

Session 2: Momase Region participants. PNGFA HQ, Port Moresby (2016).

Gewa Gamoga, Agnes Sumareke, Dr. Hitofumi Abe, Priscilla Hokoi, Maman Tavune, Damien Doko, Leon Jerry Laki, Kunsey Lavong, Late Kevin Turbarat, Elizabeth Kaidong, Conrad Kilalang, Brenden Opasa, Oala Iuda, Philip Pomoso.

Session 3: Southern Region participants. PNGFA HQ, Port Moresby (2016).

Front row: Bodger Auri, Baip Simberi, Robin Samuel. Second row: Brenda Kisper, Ori Renagi, Henry Aopo, Samuel Aloysius. Back row: Dr. Hitofumi Abe, Rex Wunum, Oala Iuda, Manu Wakol, Elizabeth Kaidong and Mosa Sipara.

Collect Earth tools see website;

http://www.openforis.org

For National Forest Inventory information see website;

http://www.fao.org/in-action/png-multipurpose-national-forest-inventory/en/

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