PAPUA NEW GUINEA FOREST AUTHORITY
NATIONAL FOREST SERVICE

FOREST AND LAND USE CHANGE IN PAPUA NEW GUINEA 2000 - 2019

PAPUA NEW GUINEA FOREST AUTHORITY
2023

PAPUA NEW GUINEA

FOREST AND LAND USE

CHANGE BETWEEN 2000 and 2019

- The findings of Collect Earth assessment –

Supported by Food and Agriculture Organisation of the United Nations (UN FAO) and Global Green Growth Institute (GGGi)

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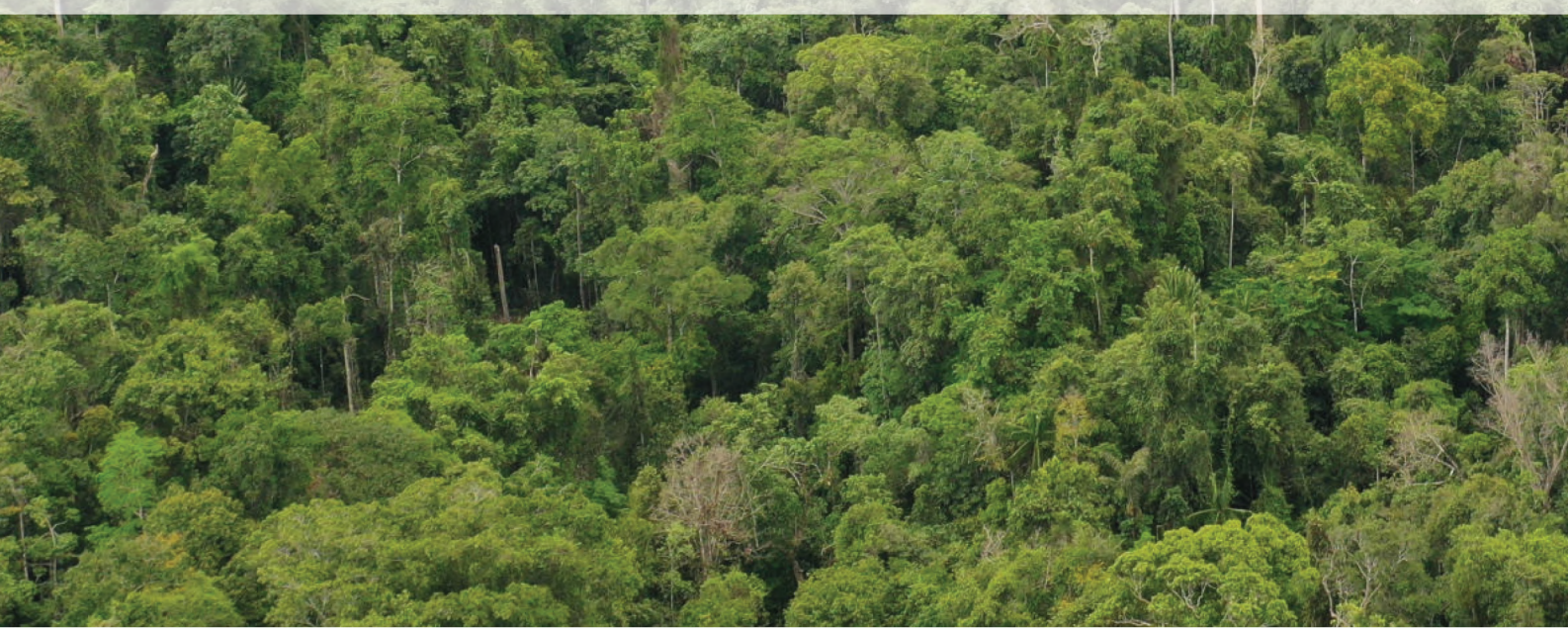

FOREST AND LAND USE CHANGE IN PAPUA NEW GUINEA
2000 - 2019

PAPUA NEW GUINEA FOREST AUTHORITY

2023

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Minister's Foreword

Hon. Salio Waipo, MP
Minister for Forests

As the Minister for Forest, it gives me great pleasure to present the report on the current status of Forest and Land Use Change in Papua New Guinea for the periods 2000-2019. It is crucial to have such information to enable policy makers to legislate and regulate activities relating to forestry, agriculture, mining, and other land use sectors to minimise deforestation and degradation thus, promoting sustainable management and development. PNG's forest together with the forest of West Papua (on the Island of New Guinea), represent the third largest tracts of tropical rainforest in the world after the Amazon and the Congo Basin.

Our forest plays a significant role in the livelihood of our rural people and the socio-economic development of this nation. The country's forest resources play an important part in regulating climate and other environmental factors as it is vital in the emission reduction of Greenhouse Gases (GHG) in particular carbon dioxide.

However, PNG's forests are under threat with the increasing expansion of industrial development, agriculture, extraction of natural resources and other activities which have led to the destruction of our forests. Deforestation by shifting cultivation and commercial agriculture is increasing annually and forest is being degraded through commercial logging as the main driver.

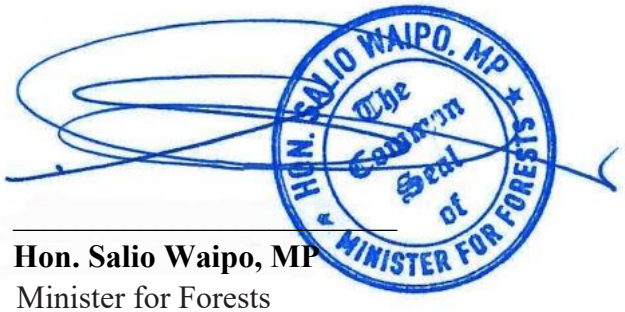
The government of Papua New Guinea has ratified a number of environmental conventions which includes the Paris Agreement and hence responsible actions are being undertaken by the government to address environmental concerns and sustainable management of forest and related resources.

I acknowledge the support of development partners such as the European Union (EU) through the Food and Agriculture Organization (FAO) who had assisted the PNGFA to conduct its first multi-purpose National Forest Inventory (NFI) and established the laboratory within the NFI building in conducting such assessment as the forest and land use change. The first report of the Forest & Land Use of PNG (2000-2015) was launched in 2019. This is the second report on the Forest & Land Use Change for PNG 2000 – 2019. I also acknowledge the Global Green Growth Institute (GGGI) and FAO with the funding from the Global Environment Facility-Capacity Building Initiative for Transparency (GEF-CBIT) and NDC Partnership/ Climate Action Enhancement Package (NDC-CAEP) towards this assessment (2000-2019), and JICA (1st Project) which supported PNGFA in the development of the Forest Basemap which was used as one of the supplementary data sources in the national level assessment of forest and land use of PNG.

The data from these reports were the primary source in the development of PNG's National REDD+ Strategy, the Forest Reference Level (FRL1 and FRL2), the Biennial Update Report (BUR1) and the REDD+ Technical Annex submitted to the United Nations Framework Convention on Climate Change (UNFCCC), in particular for the LULUCF sector. The data was also used for the reporting to the FAO on the Global Forest Resources Assessment Report

was also used for the reporting to the FAO on the Global Forest Resources Assessment Report (FRA). Furthermore, this data has been certified as one of the information sources of the ongoing NFI for the whole country.

PNG Forest Authority once again is proud to disseminate the second Forest and Land Use Change for PNG 2000 – 2019 report both locally and internationally. As a government agency, we will continue to ensure periodic assessment of the forest and land use changes in PNG and disseminate the information on a timely manner.



Hon. Salio Waipo, MP
Minister for Forests

Acknowledgement

PNG Forest Authority conducted the second Forest and Land Use Change Assessment of PNG for the period 2016-2019 between 2019 and 2020. The Global Environment Facility, Green Climate Fund, NDC Partnership, and the Government of Australia provided funding support. The Global Green Growth Institute (GGGI) and Food and Agriculture Organization of the United Nations (FAO) provided technical support.

This report is a contribution from the PNG Forest Authority and FAO. The PNGFA team include; Gewa Gamoga, Oala Iuda, Elizabeth Kaidong, Stanley Pundiye, Claude Saliau and Jehu Antiko, while the FAO and GGGI team include; Masamichi Haraguchi, Hitofumi Abe, Joshua Turia and Dika Davai. Finally, contributions from Dambis Kaip, Margaret Tongo, Alois Jenkihau and Fay Duega are acknowledged. Thank you all.

Acronyms

AGB	Above Ground Biomass
BGB	Below Ground Biomass
AFOLU	Agriculture, Forestry and Other Land Use
BTR	Biennial Transparency Report
BUR	Biennial Update Report
CO_2	Carbon Dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organization
CBIT	Capacity-building Initiative for Transparency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCA	Forest Clearance Authority
FIMS	Forest Information Management System
FMA	Forest Management Area
GEE	Google Earth Engine
GEF	Global Environment Facility
GFOI	Global Forest Observations Initiative
GHG	Greenhouse Gas
GoPNG	Government of Papua New Guinea
GIS	Geographic Information System
GPG	Good Practice Guidelines
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
LEAF	Lowering Emissions by Accelerating Forest finance
LFA	Local Forest Area
LULUCF	Land Use, Land Use Change and Forestry
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NEC	National Executive Council
NFMS	National Forest Monitoring System
NGO	Non- Government Organization
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 (+) includes the sustainable management of forests, and the conservation and enhancement of the forest carbon stocks
TOR	Top of Atmosphere Reflectance
TRP	Timber Rights Permit
UNFCCC	United Nations Framework Convention on Climate Change
UMD	University of Maryland

Executive Summary

This report provides national level forest cover and the changes within a 19-year period between 2000 and 2019 including the very details of deforestation and forest degradation drivers' assessment. It provides the land use status of PNG in 2019 including the status of forest and the annual forest and land use changes between 2000 and 2019. The methodological approaches undertaken were similar to the first publication (Government of PNG, 2019).

The assessment has shown that PNG is still extensively covered by forest than previously estimated or reported. In 2019 there was 77.9% forest land followed by cropland (11.2%), grassland (5.3%), settlement (0.9%), wetland (4.6%) and other land covering only 0.1%. PNG is mainly dominated by three (3) forest types and these are *low altitude forest on uplands, low altitude forest on plains and fans*, and *lower montane forest* (Table ES-1).

Table ES-1: PNG forest types and area in hectares (2019).

Forest types	Area (ha)	%
Low altitude forest on plains and fans	8,907,510	24.8%
Low altitude forest on uplands	11,121,353	31%
Lower montane forest	8,009,029	22%
Montane forest	390,631	1%
Dry seasonal forest	2,353,272	6%
Littoral forest	148,102	0.4%
Seral forest	320,382	0.9%
Swamp forest	2,462,395	7%
Savanna	619,922	1.7%
Woodland	1,059,481	3%
Scrub	220,106	0.6%
Mangrove	285,971	0.8%
Planted forest	52,823	0.2%
Total:	**35,950,979**	**100.0%**

Approximately 75.2% of the forest is still intact or not disturbed by anthropogenic activities. Most of the forest disturbance or forest degradation (Figure ES-1) is caused by; commercial logging (11.47%) followed by gardening (8.77%), fire (3.1%) and others at 1.2%. Commercial logging is common in *low altitude forest on plains and fans* and *low altitude forest on uplands*. About 80% of commercial logging occur in Western, Gulf, West New Britain, East New Britain and West Sepik Provinces. Gardening occurs throughout and is 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.

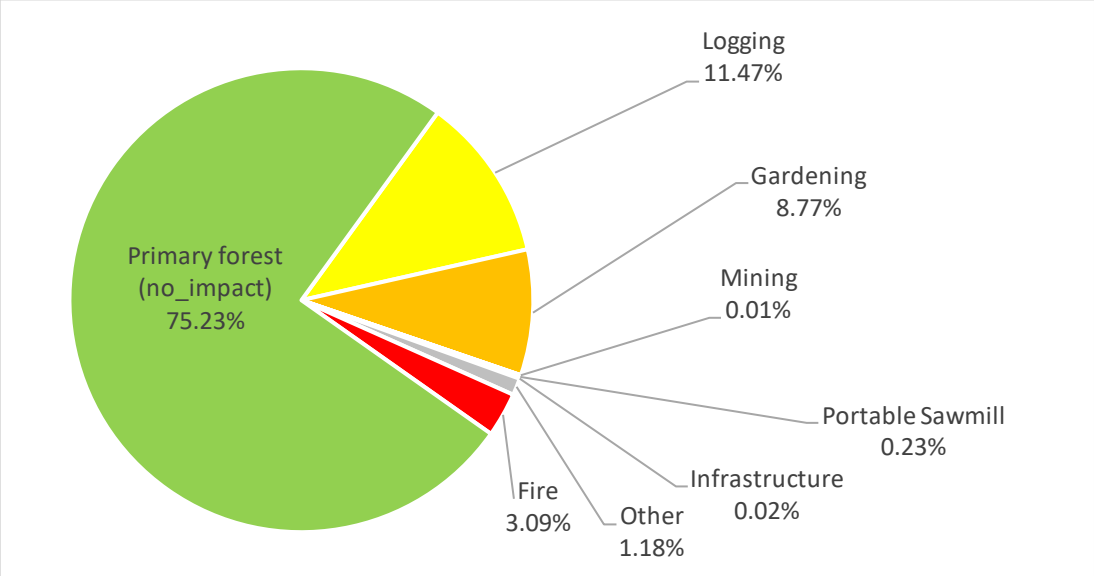


Figure ES-1: Human impact on forest land.

PNG has a total cropland area of about 5.1 million hectares, which occupies 11.2% of its land mass. The cropland is sub-divided into two categories (subsistence agriculture and commercial agriculture). These two categories are further classified into different types of activities that are commonly practiced. Subsistence agriculture (permanent and shifting cultivation) accounts for 88.2% of the total cropland area, while for the commercial agriculture: oil palm plantation (6.6%), coconut plantation (2.7%), intercropping of coconut and cocoa (0.8%) and coffee plantation (0.6%) (Table ES-2**)**. Large-scale monoculture commercial plantations are minor land use in PNG, with the exception of oil palm and coconut plantations. Table ES-2 shows the composition of cropland, settlement, grassland, wet land and other land.

Table ES-2: Land use composition of cropland, grassland, settlement, wetland and other land.

Land Use	Subdivision	Area (ha)	%
Cropland	Permanent cultivation	1,109,848.03	21.46%
	Shifting cultivation	3,424,191.16	66.19%
	Tea	2,954.99	0.06%
	Coffee	29,409.89	0.57%
	Palm Oil	343,288.09	6.63%
	Cocoa	13,779.24	0.27%
	Coconut	137,666.29	2.66%
	Other	19,606.68	0.38%
	Cocoa/Coconut	43,163.97	0.84%
	Sugar	7,867.71	0.15%
	Rubber	11,689.03	0.23%
	Sub-total:	**5,172,870.88**	**100.00%**
Settlements	Village	239,148.33	59.23%
	Hamlet	53,861.48	13.33%
	Large Settlement	57,925.33	13.85%
	Infrastructure	54,868.17	13.59%
	Sub-total:	**405,803.31**	**100.00%**
Grassland	Herbland	1,886,798.14	77.61%
	Rangeland	110,989.73	4.57%
	Others	432,908.08	17.82%
	Sub-total:	**2,430,695.95**	**100.00%**
Wetlands	River	443,947.50	20.85%
	Lake	257,488.51	11.91%
	Dam	3,890.77	0.18%
	Nipa Swamp	190,814.08	8.96%
	Other Swamp	1,237,061.19	58.10%
	Sub-total:	**2,133,202.06**	**100.00%**
Other Land	Bare	22,526.51	34.68%
	Sand	7,852.64	13.30%
	Rock	30,835.59	52.02%
	Sub-total:	**61,214.75**	**100.00%**
	Total:	**5,024,168.13**	

Between 2000 and 2019, a total of about 352,804 hectares or 0.98% of the total forest area was deforested. Almost all deforestation (99.5%) was forest converted to cropland. Subsistence agriculture was the most significant driver with 66.5% (233,396 hectares) of deforestation followed by oil palm with 28.7%, (100,831 hectares). All other agriculture plantations only accounts for 7.9% of deforestation (Figure ES-2). Average annual deforestation rate between 2000 and 2010 was 0.03% but this has significantly increased to 0.08% between 2011 and 2015. The average annual deforestation between 2016 and 2019 has decreased to 0.07%.

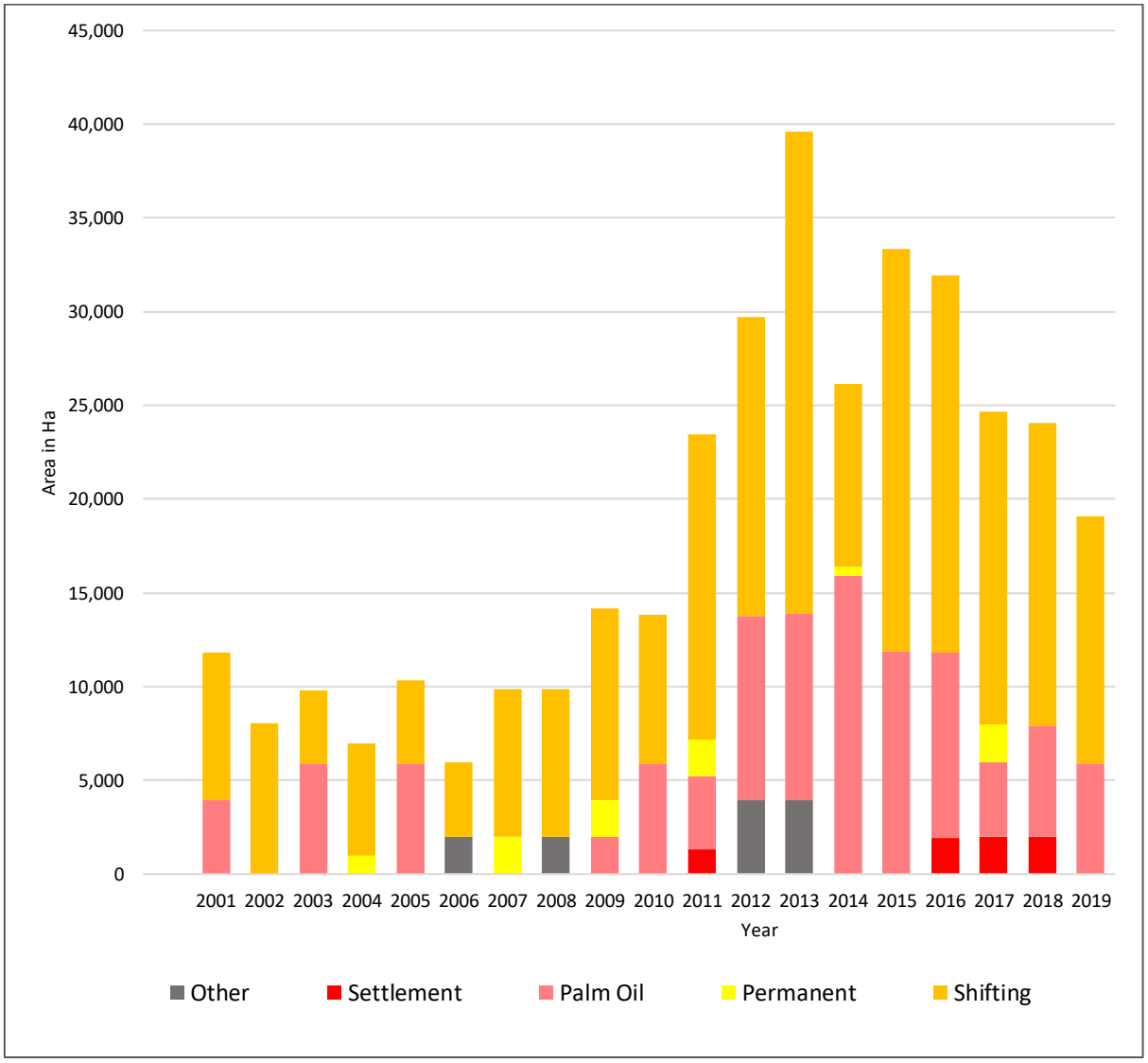


Figure ES-2: Annual deforestation from 2000 – 2019. Year 2000 is time zero.

Highest rate of deforestation occurred in West Sepik province, which doubled compared to any other provinces in the country (Figure ES-3). Most of the oil palm plantation development occurred in three provinces (West Sepik, West New Britain and East New Britain).

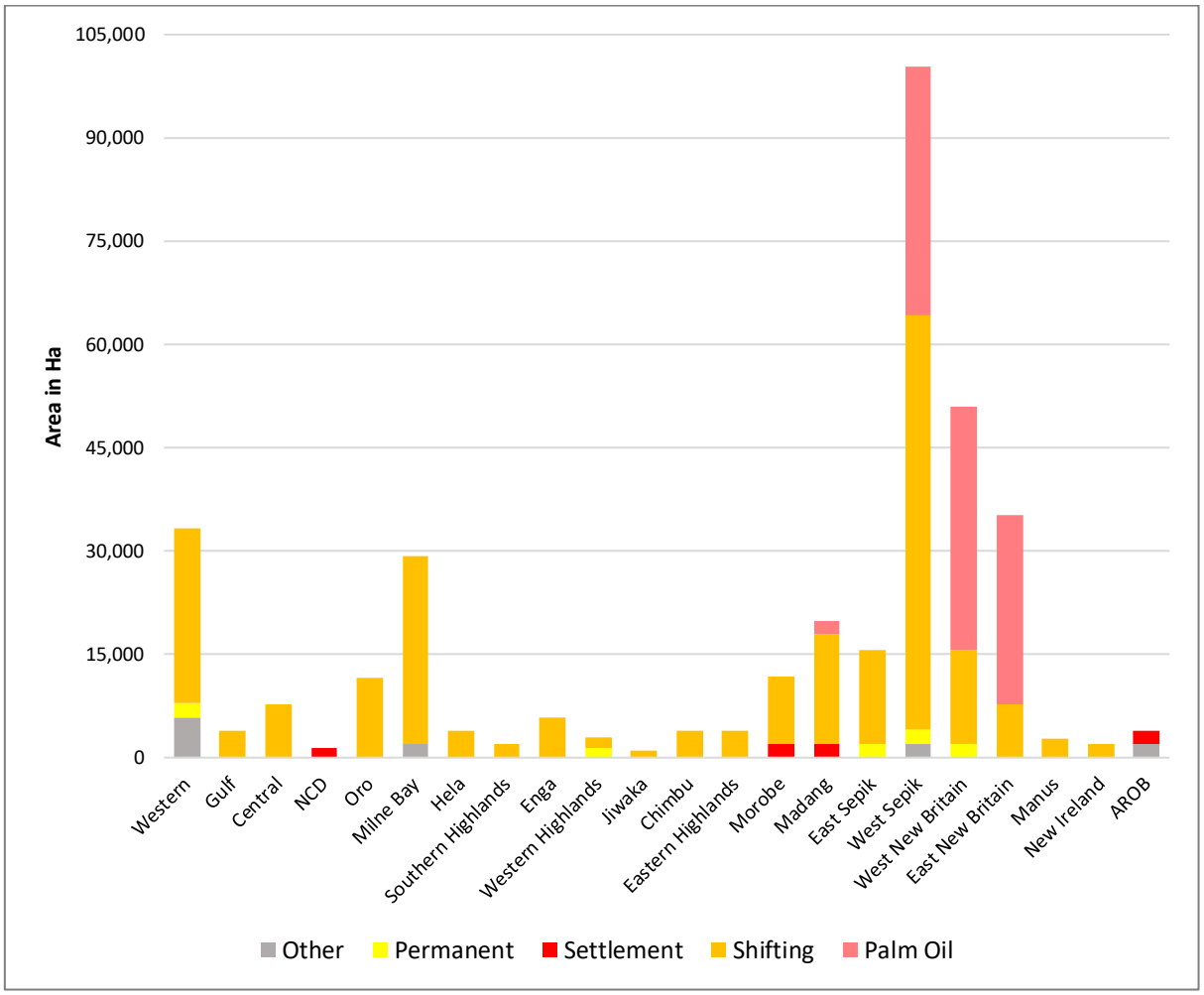


Figure ES-3: Forest converted to other land use types in Provinces between 2000 and 2019.

During the same period a total of 8.88 million hectares (7.94 %) of the total forest area was disturbed by anthropogenic activities. Logging was far most dominant (46%) cause of forest disturbance. Forest disturbance was not an increasing trend in recent years (Figure ES-4) but occurring much larger when compared to deforestation.

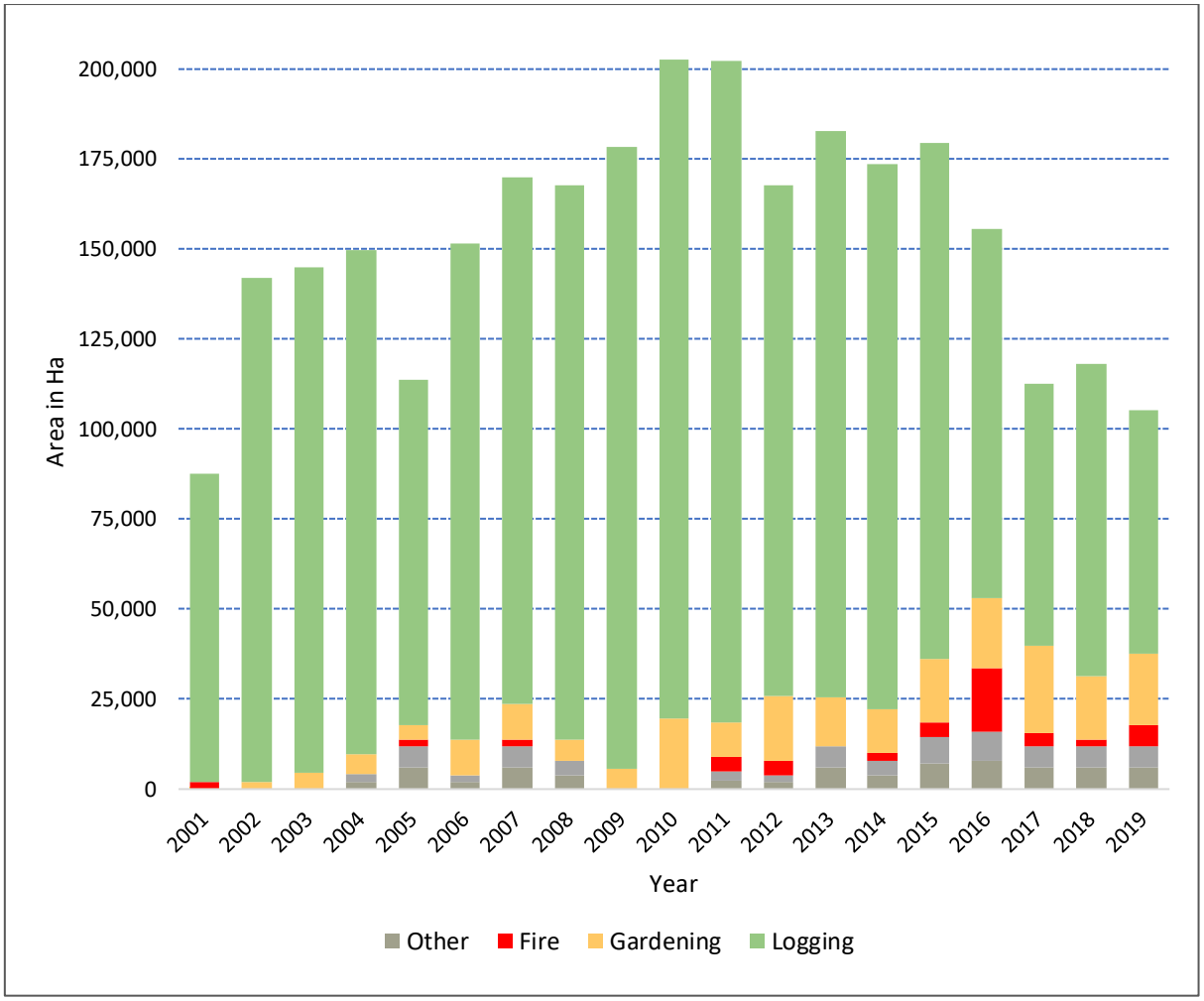


Figure ES-4: Annual forest degradation by human impact type from 2000 to 2019.

This study has addressed the critical information gap on forest and land use of the country. It will significantly contribute towards national planning and policy formation for the sustainable development of the country.

1 Introduction

1.1 Background

Agriculture and other land use are responsible for the reduction of the global forest since 1990 (EU Science Hub-JRC, 2020). About 7% - 14% of the total CO_2 emissions come from anthropogenic deforestation and forest degradation (Joint Research Centre, 2014). With effective management, forest could potentially mitigate climate change cost-effectively (Gibs, Harris, & Seymour, 2018). For example, restoring of 350 million hectares of degraded land could sequester about 1.7 $GtCO_2e$ (IUCN, 2021). Forest therefore is one of the key aspects of international climate change agreement (UNFCCC, n.d.).

PNG reported about 78% of forest, covering 12 forest types in 2015 and the total area deforested and forest degraded between 2000 and 2015 are 0.66% of forest land and 6.6% of primary forest respectively (PNG Forest Authority, 2019). With regards to emissions from Land Use, Land-Use Change and Forestry (LULUCF) sector, PNG accounted for a net emission of -21,654 Gg CO_2 eq in 2000 and 1,716 Gg CO_2 eq in 2015 (Government of PNG, 2018) (The Government of PNG, 2020).

This report documents the status of forest and land use status in 2019 and the forest land use change between 2000 and 2019, highlighting the drivers of forest change. This information has been used in the development of the PNG Nationally Determined Contribution (NDC) Implementation Plan Roadmap, 2021 – 2030, the Lowering Emissions by Accelerating Forest finance (LEAF) proposal and the second Biennial Update Report (2nd BUR). Furthermore, it is expected that the data and information will be used in the second PNG Forest Reference Level (FRL 2).

1.2. Objectives

The three (3) main objectives of this report are;

i. Addressing policies relating to sustainable forest management and other land use planning for general public consumption and 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.

The data in this report was the primary source of information for REDD+ Technical Annex of the 2nd BUR which was submitted to the UNFCCC in early 2022.

2 Forest and Land Use in 2019

2.1 National and provincial land use status in 2019

PNG has a total land area of about 46.15 million hectares. Of this, 35.95 million (77.9%) are forestland, and the remaining 10.2 million (22%) are for cropland, grassland, settlement, wetland and other land uses (Figure 2-1). Cropland is the second major land use, with 5.2 million hectares (11.2%), followed by grassland with 2.4 million hectares (5.3%), wetland with 2.1 million hectares (4.6%), settlement with 0.4 million hectares (0.9%), and other with 0.06 million hectares (0.1%).

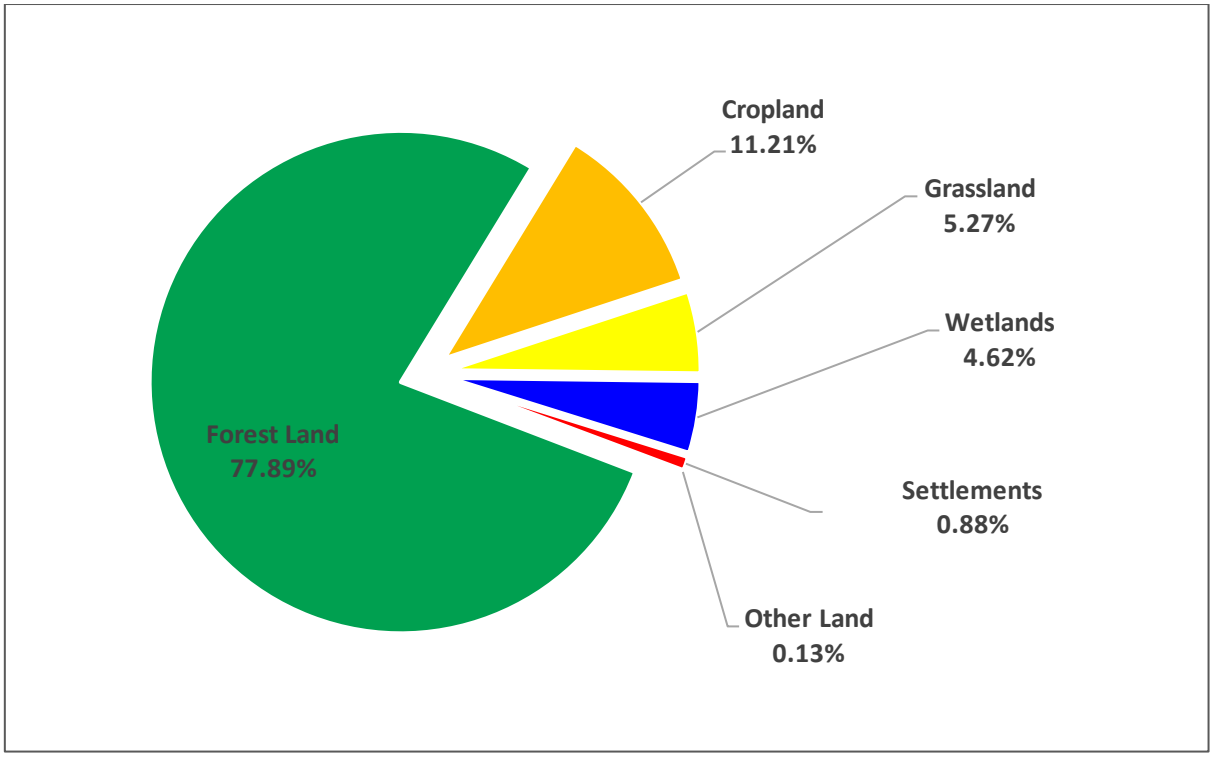


Figure 2-1: Proportion of land use in PNG in 2019.

The six provinces with the highest proportion of forest areas are Gulf (91.4%), West Sepik (90.3%), West New Britain (85%), Western (84.4%), Central (82.3%) and East New Britain (81.3%). Provinces with higher intensity of cropland are Western Highlands (43.7%), Autonomous Region of Bougainville (40.7%), Jiwaka (30.7%) and Eastern Highlands Province (28.6%) than the other provinces (Figure 2-2). In general, provinces with higher population density have a higher proportion of cropland, hence, a lower proportion of forest land.

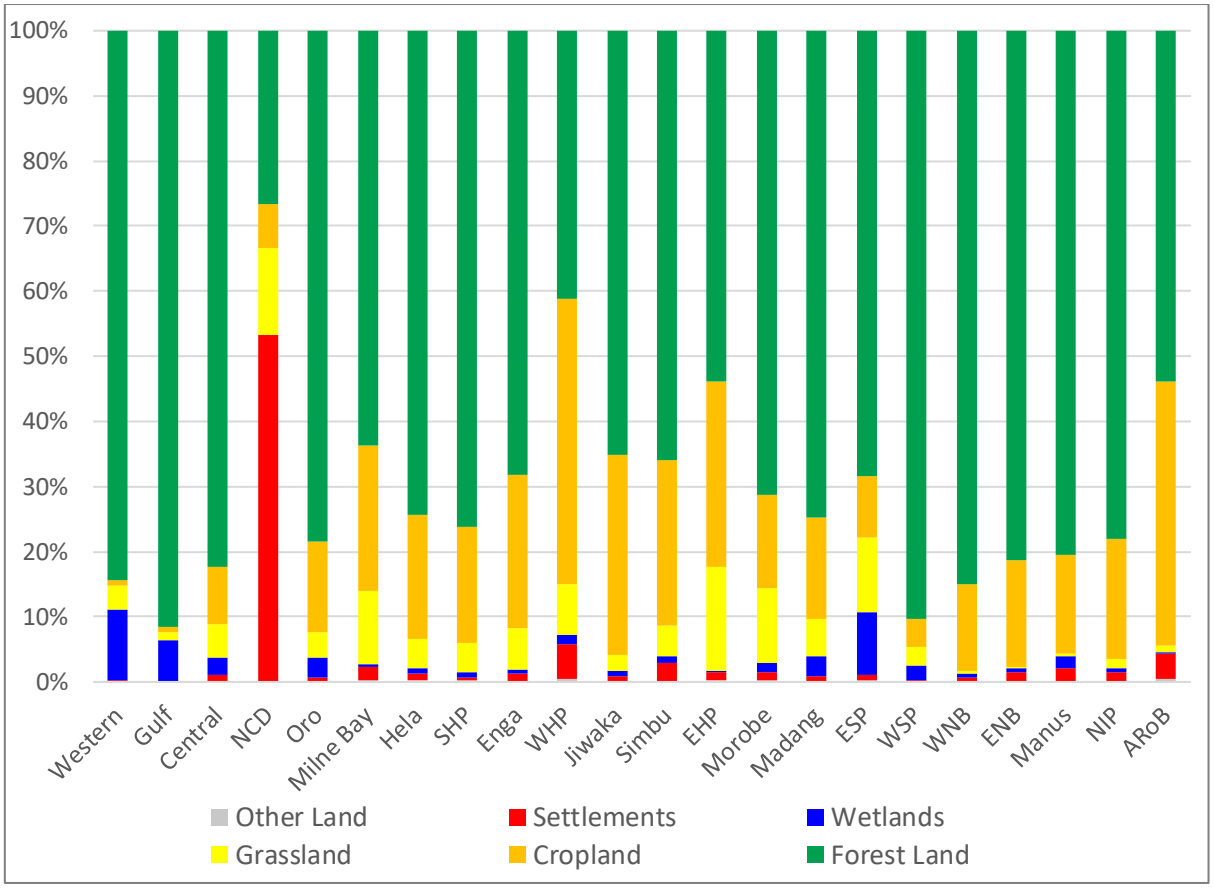


Figure 2-2: Provincial level land use proportions.

2.2 Land use and altitude

There is a distinct relationship between land use and altitude in PNG (Figure 2-3). Forest occurs from the sea level up to 3,800 metres above sea level. Above 3,200 metres, the proportion of forest diminishes with stunted trees as elevation increases and other vegetation type (alpine grassland, etc.) becomes evident. Grassland is dominant between 3,500 metres and 3,800 metres, while other land (rock and bare soil) become dominant above 3,800 metres. PNG's highest peak (Mount Wilhelm) is 4,509 metres. Agricultural activities[1] are more concentrated between 1,500 metres and 1,900 metres and prevalent in the hinterland highlands mainly: Goroka (Eastern Highlands), Kundiawa (Simbu), Banz (Jiwaka), Mount Hagen (Western Highlands) and Mendi (Southern Highlands). Agriculture activities are rarely seen above 2,800 metres. Almost all wetland is found below 100 metres.

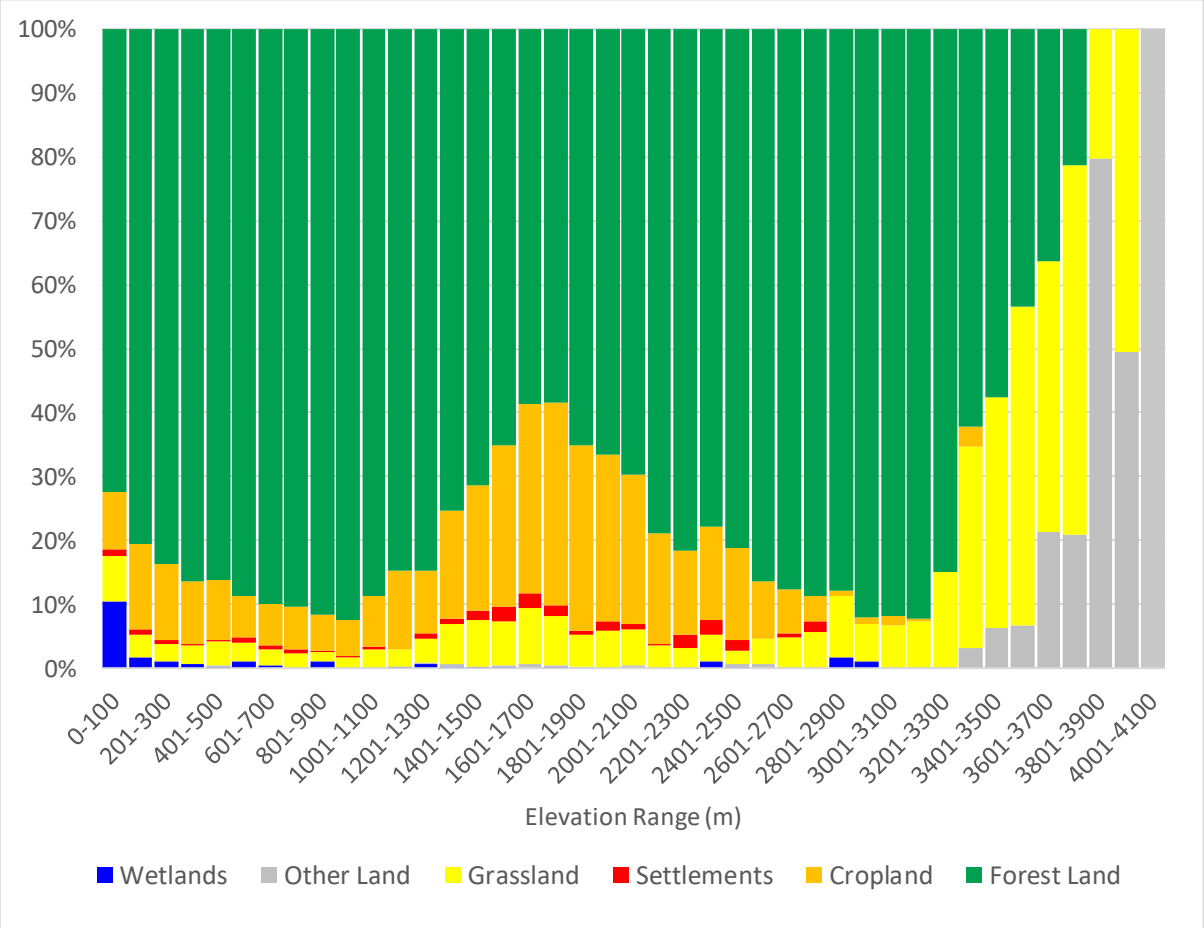


Figure 2-3: Land use at elevation range.

[1] These are combination of activities of growing, harvesting of crops, raising livestock and soil cultivation. The results or data are more towards crop raising and management.

2 Forest and Land Use in 2019

2.3.1 Forest Composition

PNG has about 35.95 million hectares of forest, covering approximately 77.89% of the total land mass (Table 2-1). More than 75.13% of the forest has not been disturbed by anthropogenic activities (Figure 2-6). The three most dominant forest types — low altitude forest on uplands (30.91%), low-altitude forest on plains and fans (24.77%), and lower montane forest (22.29%) — comprise more than three-quarters of the country. Table 2-1 shows areas of all forest types in the country (see Annex 2.4 for province-level forest areas). For more information on forest classifications, see Annex 2.1.

Table 2-1: Forest types and areas in hectares.

Forest types	Area (ha)	%
Low altitude forest on plains and fans	8,907,510	24.8%
Low altitude forest on uplands	11,121,353	30.9%
Lower montane forest	8,009,029	22.3%
Montane forest	390,631	1.1%
Dry seasonal forest	2,353,272	6.6%
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Savanna	619,922	1.7%
Woodland	1,059,481	3.0%
Scrub	220,106	0.6%
Mangrove	285,971	0.8%
Planted forest[2]	52,823	0.2%
Total:	**35,950,979**	**100.0%**

2.3.2 Distribution of forest types

PNG's major vegetation classification is based on altitude. For example, three of its most dominant forest types are clearly classified by elevation range. Low altitude forest on plains and fans and low altitude forest on uplands are below 1,000 metres, while lower montane forest is between 1,000 metres and 3,000 metres. The minor forest types are either confined to a certain altitudinal range or sparsely distributed throughout. Mangrove, dry seasonal forest and littoral forest occur from the seashore up to 100 metres above sea level, while swamp forests are found up to 700 metres, woodland occurs only below 800 metres, while montane forest is found between 3,000 metres and 3,800 metres. Scrub, although concentrated from sea level up

[2] Planted forest covers Eucalyptus, Balsa, Araucaria, Pinus, Acacia, Terminalia and Rain tree.

to 200 metres, is also sparsely distributed up to 3,500 metres above sea level. See Annex 2.5 for more information on forest type by altitude range.

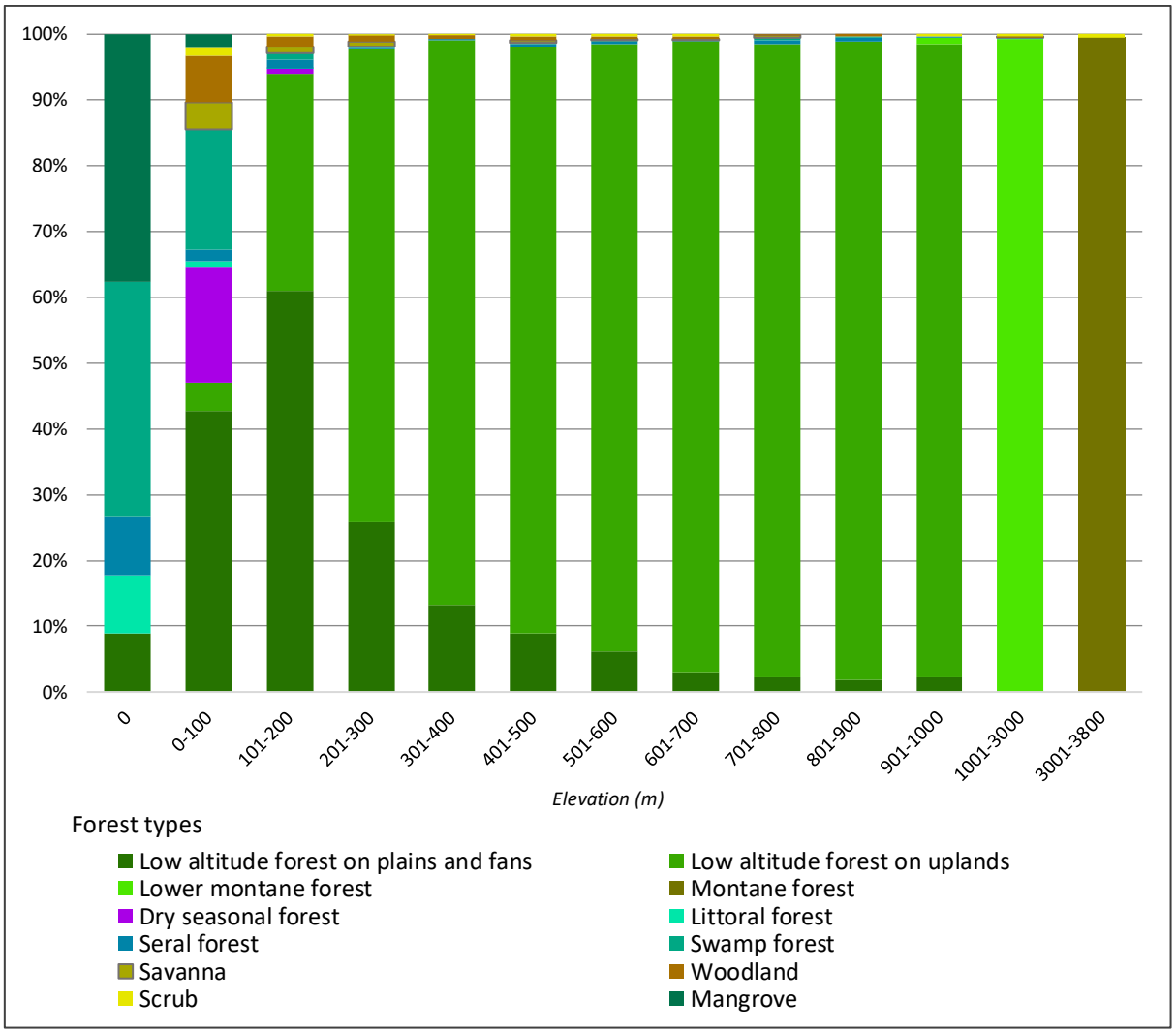

Figure 2-4: Percentage of forest types and elevation range.

Altitude is one of the primary indices for vegetation classification in PNG, hence, forest composition in the provinces is related to the altitude. Provinces in the Highlands Region, for example, has a higher portion of high-altitude forest types (Figure 2-5), while drier forest types (woodland, dry seasonal forest, savanna and scrub) are distributed in the southern part of the country, especially in Western Province, and at lower altitudes (Figure 2-5).

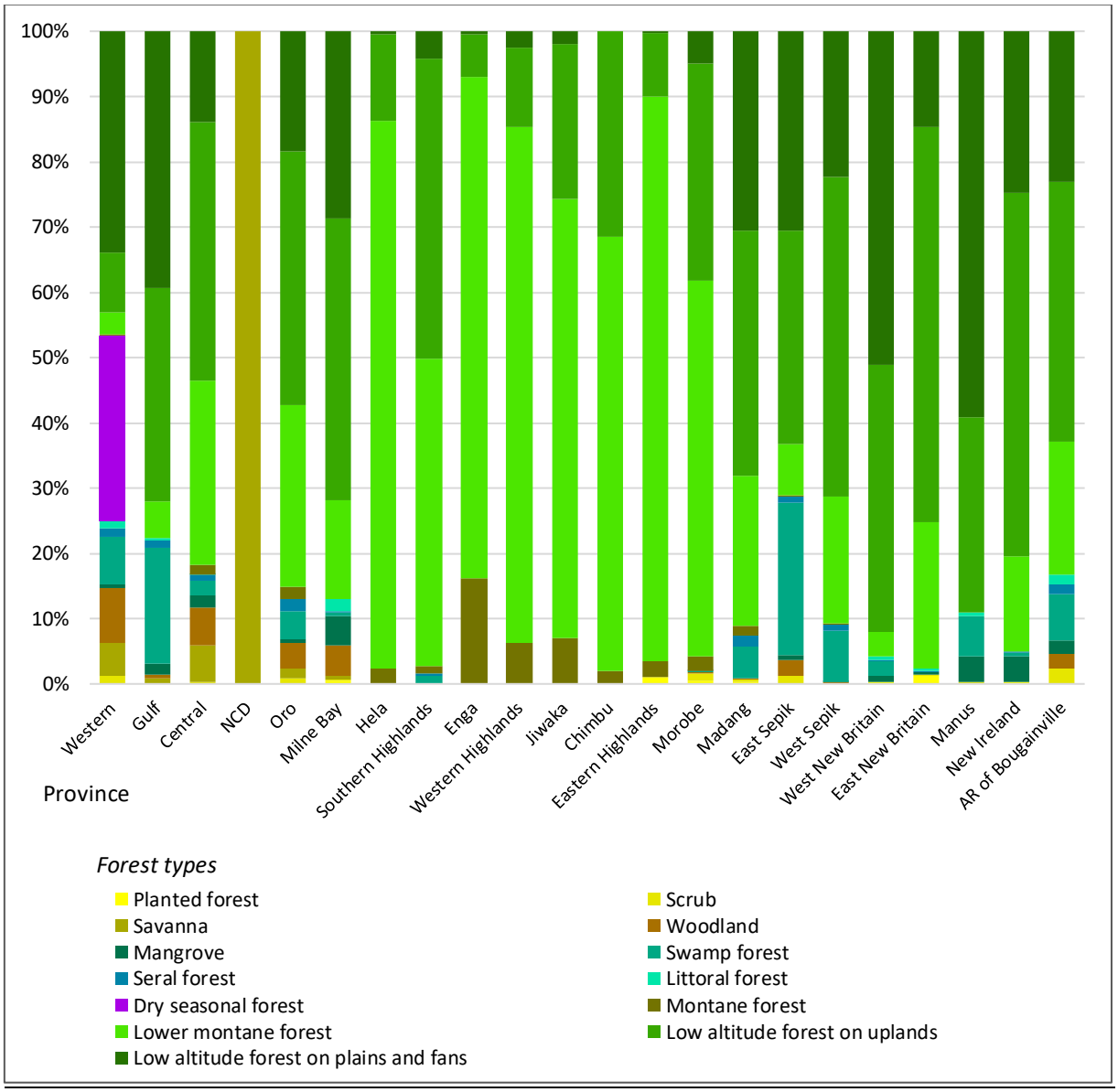

Figure 2-5: Proportion of forest types in the provinces.

2.3.3 Forest Disturbances

As of 2019, about 75.13% of PNG's total forest was undisturbed; 24.74% was disturbed through commercial logging, gardening, fire and other[3] activities. Thus, most of the disturbances are from commercial logging and gardening[4] (Figure 2-6). In the three most dominant forest types, the disturbed ratio varies. It is significantly higher (36.8%) than the national average (23.7%) in *low altitude forest on plains and fans* due to commercial logging, while *low altitude forest on uplands* and *lower montane forest areas* (Figure 2-7) are less disturbed than the national average (21.5% and 16.6%, respectively). The disturbed ratio is also higher than the average for *savanna* and *woodland*, due to forest fire (Figure 2-7).

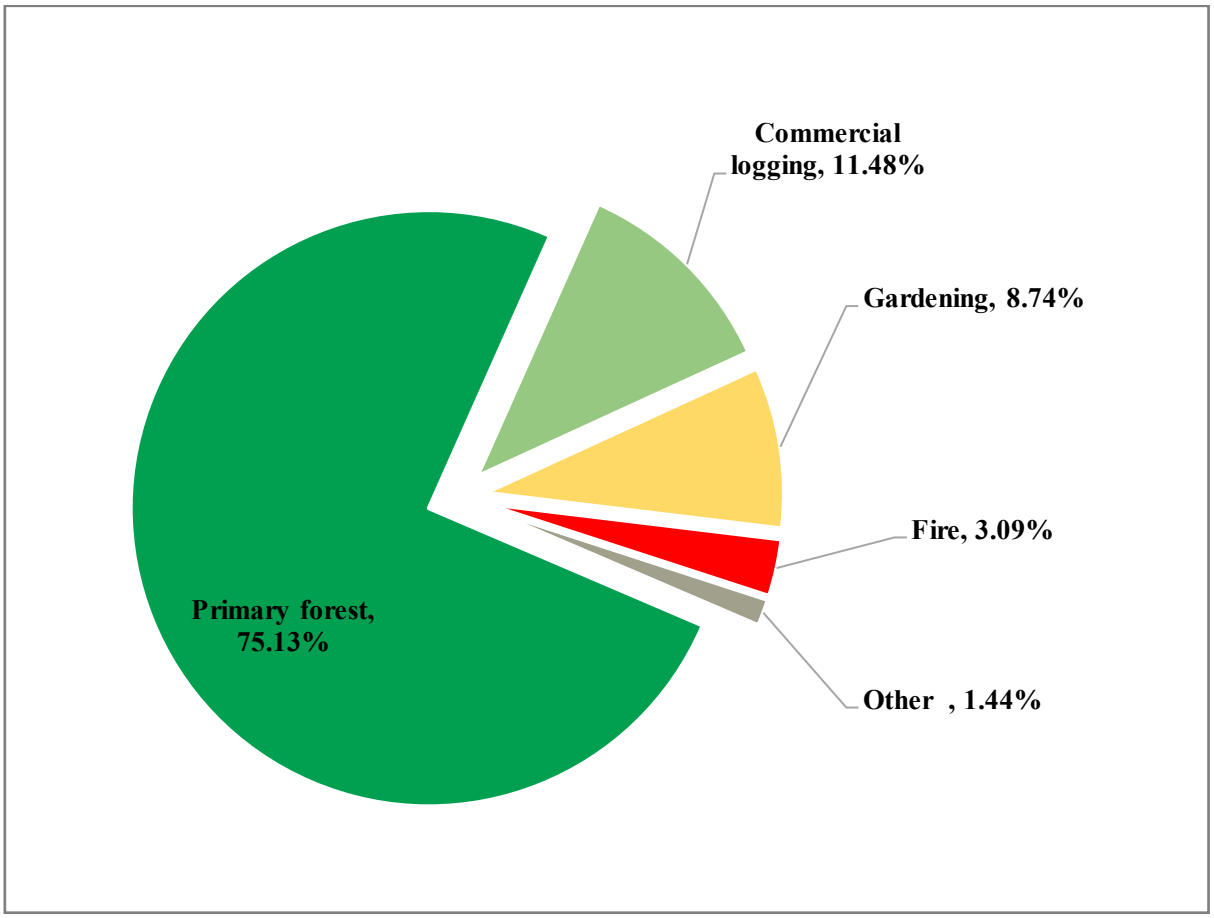

Figure 2-6: Man-made disturbances on forest land.

Generally, logging mostly occurs in the *low altitude forest on plains and fans*, and *low altitude forest on uplands*, particularly in the latter. Fire is prevalent in *savanna*, *woodland* and *scrub* forests. Gardening areas are isolated patches of temporary forest clearings. While gardening activities occur in all forest types, they are dominant in *lower montane*, *low altitude forests on uplands* and *low altitude forests on plains and fans* in order of abundance (Figure 2-7). See Annex 2.6 for more information on how forest types are impacted by anthropogenic activities.

[3] Other refers to portable sawmill, mining, and infrastructure
[4] Gardening under forest degradation/disturbance is an example of temporary shifting cultivation.

Elevation has a distinct relationship with anthropogenic activities on forest land (Figure 2-8). Although logging occurs from the seashore up to an elevation of 1,100 metres, it is more concentrated between 0 and 500 metres. Gardening activities occur across all elevations, is more concentrated between 1,000 metres and 2,800 metres. Fire also occurs in all elevations but is prevalent between 2,700 metres and 3,400 metres. The dominance of grassland starts at 2,700 metres (Figure 2-3) and the occurrence of fire also seems to follow this pattern (Figure 2-8).

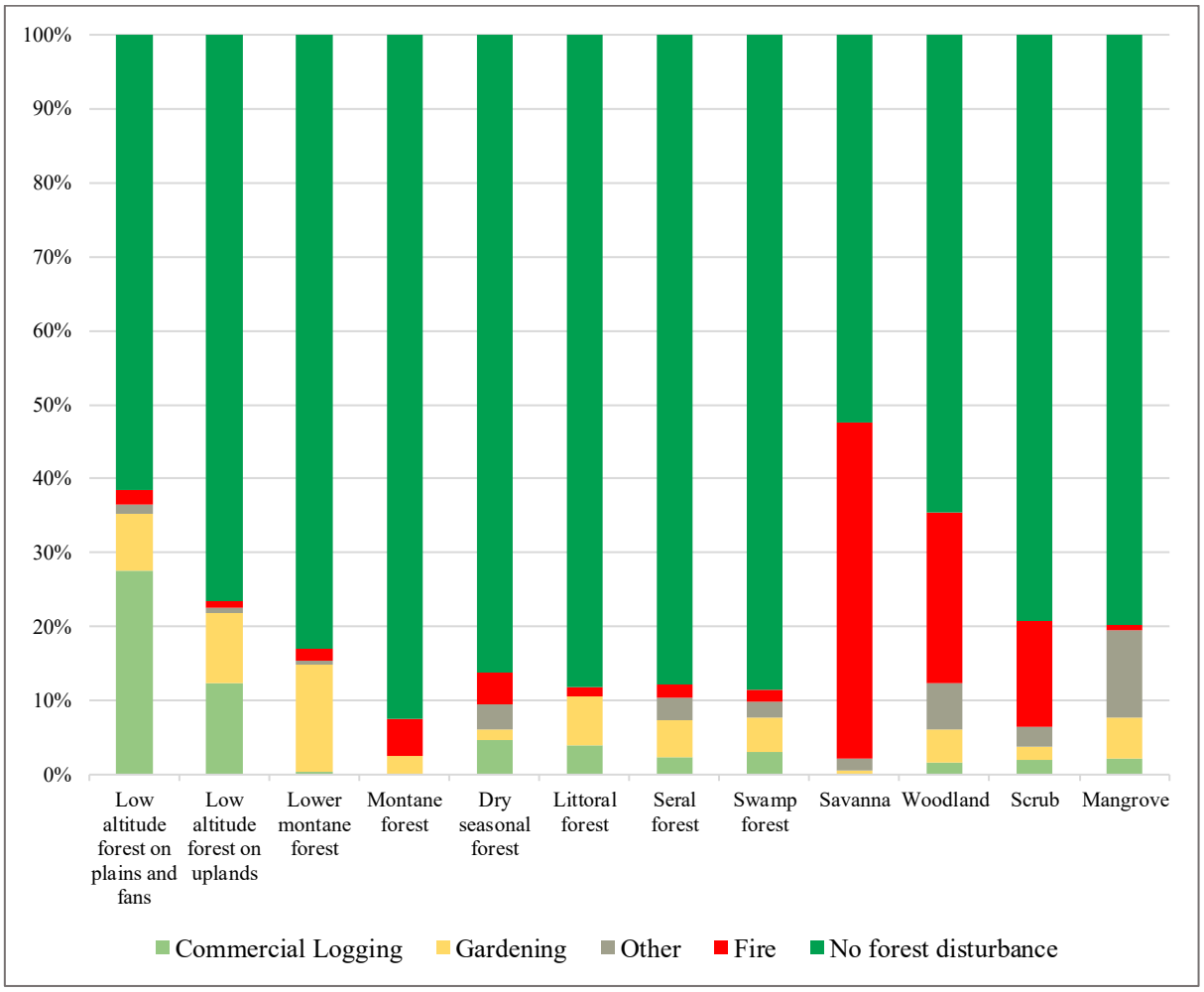

Figure 2-7: Man-made disturbance on forest types in 2019.

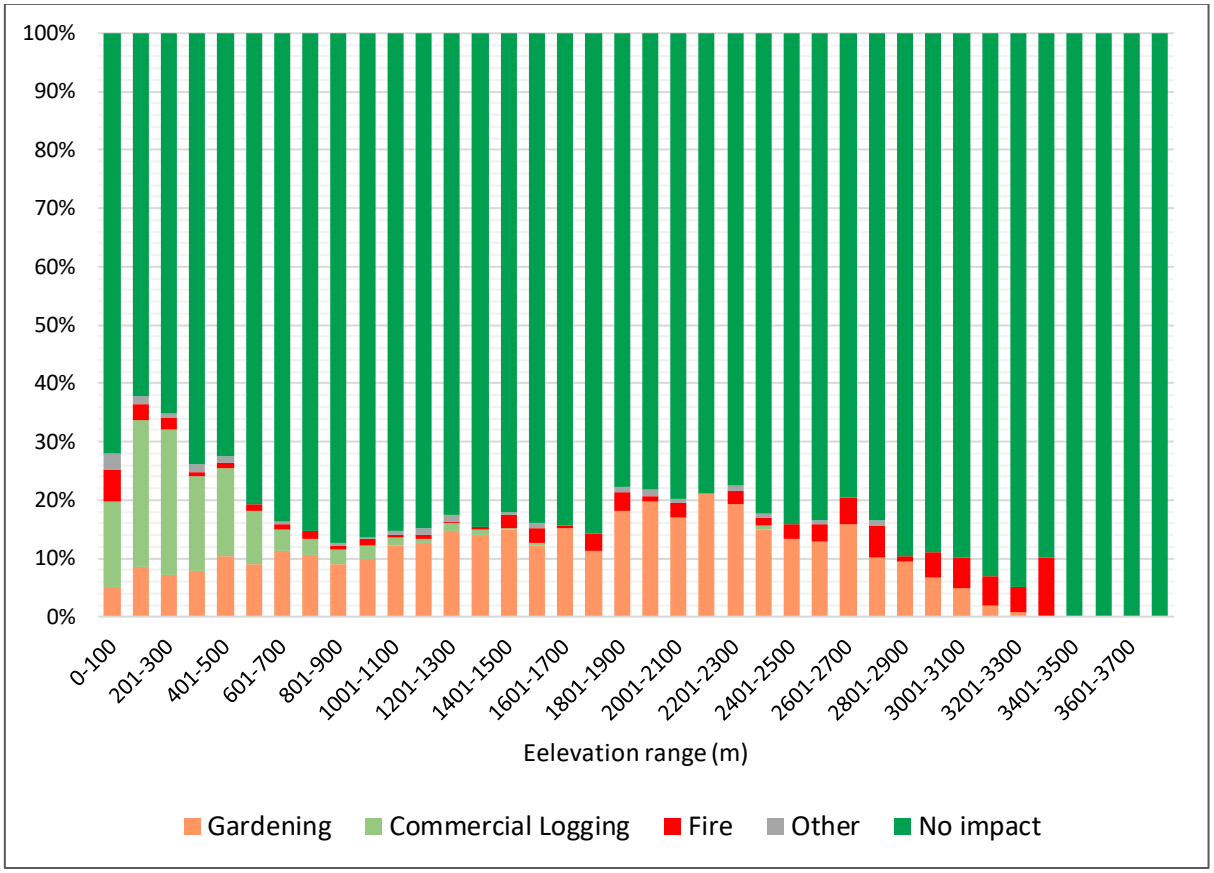

Figure 2-8: Forest disturbance at elevation ranges in 2019.

2.3.4 Forest Regrowth

The regrowth of a forest is an ecological process (natural) that occurs in a forest to recover or through human interventions (natural regeneration) over a period of time. The regrowth or recovery rate is dependent on the level/nature of disturbance (human induced activities or natural) in the forest.

Forest plantation or planted forest contributed 0.15% (52,823 ha) of the forest cover as of year 2019. These forest plantations are established on grassland areas and new areas identified to be for plantation expansion or development. Most of these plantations are mono-type which few are mixed species. With forest plantations, the period of time is determined on the type of tree species as it varies from species to species. In terms of forest cover or recovery, the rate is much faster than natural forest.

2.3.5 Forest Carbon Stock in 2019

As of 2019, PNG's total forest carbon stock was estimated to be 3,982 million tonnes (Mt). This is composed of primary forest carbon stock with 3,245 million tonnes (81.5%) followed by degraded forest carbon stock with 731 million tonnes (18.4%) and plantation forest carbon stock (0.13%) (Figure 2-9). The forest carbon stock per province is provided in Annex 2.11.

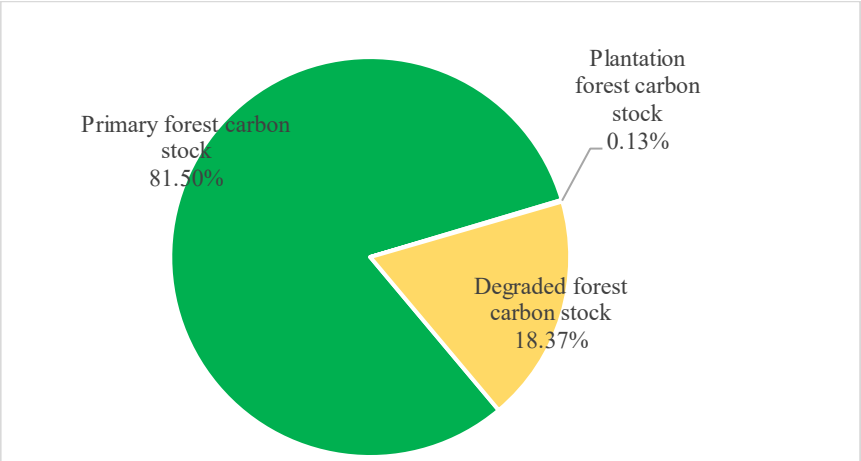

Figure 2-9: Composition of forest carbon stock in PNG at 2019.

The four forest types with large proportions of primary forest carbon stock as of 2019 are *low altitude forest on uplands* with 30.7% followed by *low altitude forest on plains and fans* 19.8%, *lower montane forest* with 13.9% and *swamp forest* with 7.8%. See Table 2-2 and Figure 2-10 for more details.

Whilst forest with large proportions of degraded forest carbon stock as of 2019 are *low altitude forest on plains and fans* with 8.1%, *low altitude forest on uplands* with 6.1% followed by *lower montane forest* with 1.9% and swamp forest with 0.7%. See Table 2-2 and Figure 2-10 below for more details.

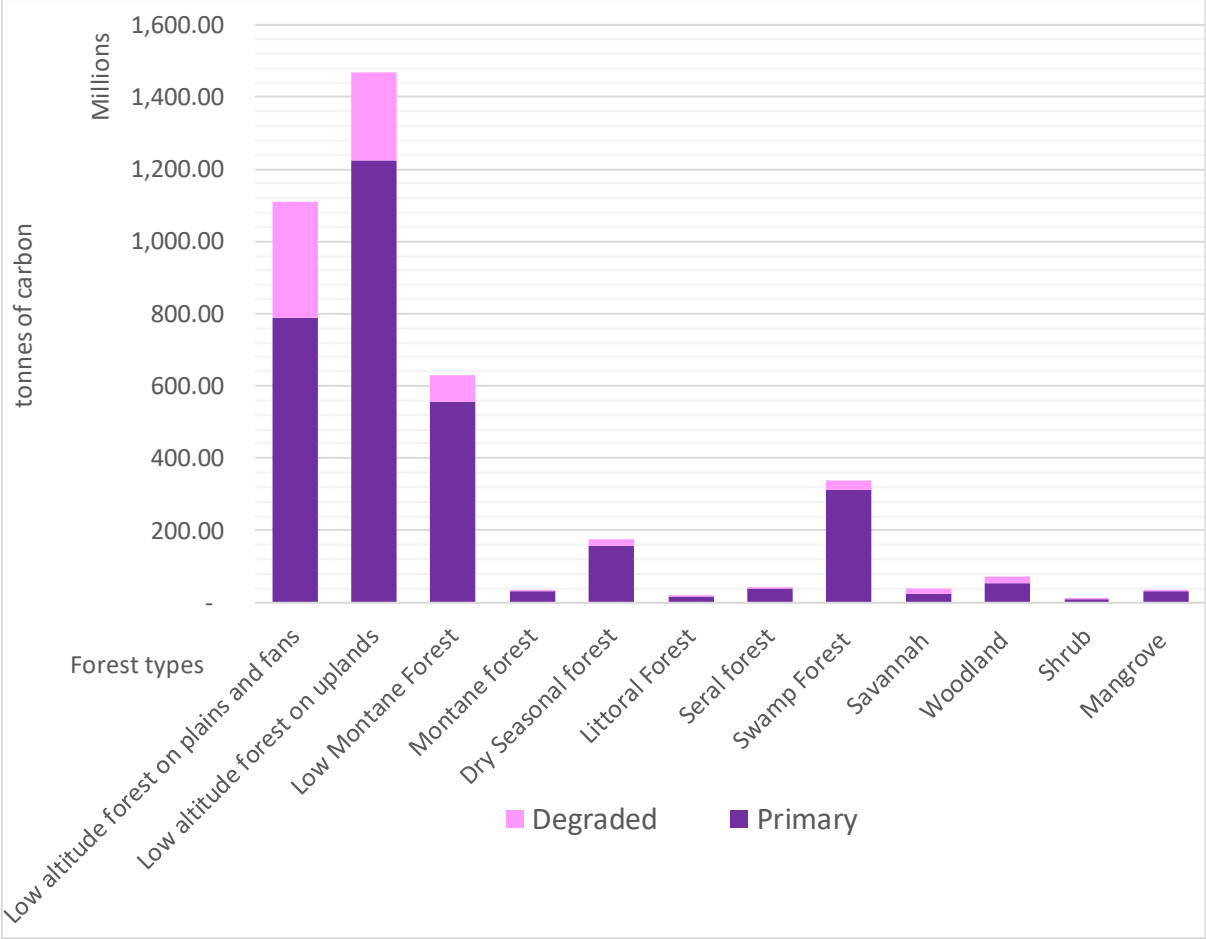

Figure 2-10: Distribution of primary and degraded forest carbon stock in PNG (2019).

Picture: Bewani FCA, West Sepik Province

Table 2-2: Forest types, status and the carbon stock in 2019.

Forest type	Forest status	Area (ha)	Above & Below Ground Biomass (t.d.m)	Carbon in above & below ground biomass (t)	Carbon in above & below ground biomass (t)
Low altitude forest on plains and fans	Primary	5,482,352	1,674,913,436	787,209,315	19.8%
	Degraded	3,425,157	685,099,892	321,996,949	8.1%
Low altitude forest on uplands	Primary	8,524,631	2,604,360,094	1,224,049,244	30.7%
	Degraded	2,596,722	519,396,382	244,116,300	6.1%
Low Montane Forest	Primary	6,642,757	1,181,082,216	555,108,641	13.9%
	Degraded	1,366,272	159,635,216	75,028,552	1.9%
Montane forest	Primary	360,947	64,176,391	30,162,904	0.8%
	Degraded	29,684	3,468,247	1,630,076	0.0%
Dry Seasonal forest	Primary	2,029,428	337,696,750	158,717,473	4.0%
	Degraded	323,845	35,234,317	16,560,129	0.4%
Littoral Forest	Primary	130,471	39,860,085	18,734,240	0.5%
	Degraded	17,632	3,526,675	1,657,537	0.0%
Seral forest	Primary	281,266	85,929,553	40,386,890	1.0%
	Degraded	39,117	7,824,116	3,677,334	0.1%
Swamp Forest	Primary	2,181,730	666,540,260	313,273,922	7.9%
	Degraded	280,665	56,138,713	26,385,195	0.7%
Savannah	Primary	325,483	54,160,439	25,455,406	0.6%
	Degraded	294,439	32,034,942	15,056,423	0.4%
Woodland	Primary	683,973	113,813,167	53,492,188	1.3%
	Degraded	373,566	40,643,938	19,102,651	0.5%
Shrub	Primary	174,549	17,105,802	8,039,727	0.2%
	Degraded	45,557	2,933,871	1,378,919	0.0%
Mangrove	Primary	229,219	65,575,096	30,820,295	0.8%
	Degraded	56,752	10,654,605	5,007,664	0.1%
Plantation Forest	n.a	54,765	11,254,277	5,289,510	0.1%
	Total:	**35,950,979**	**8,473,058,479**	**3,982,337,485**	

2.4 Status of Cropland in 2019

PNG has a total cropland area of about 5.1 million hectares, which occupies 11.2% of its land mass. Subsistence agriculture comprises of both permanent cultivation and shifting cultivation and accounts for 88.2% of the total cropland area, followed by oil palm plantation (6.63%), coconut plantation (2.66%), coconut intercropped with cocoa (0.84%) and coffee plantation (0.57%) for commercial agriculture activities (Table 2-3). Large-scale monoculture commercial plantations are minor land use in PNG, with the exception of oil palm and coconut plantations (Figure 2-11).

Western Highlands Province has the highest proportion of cropland (43.7%), followed by the Autonomous Region of Bougainville (40.7%), Jiwaka (30.7%), Eastern Highlands (28.6%), Chimbu (25.3%) and Enga (23.5%). There are more croplands between elevations 1,000 metres and 2,500 metres (Figure 2-11) — these are mostly subsistence agriculture and are common in all provinces, except for the National Capital District (NCD). Large extents of oil palm plantations are recorded for West New Britain, West Sepik, Oro, Milne Bay, Morobe, Madang and East New Britain (Figure 2-11; Annex 2.2). New oil palm plantations have emerged in other provinces after 2019.

Table 2-3: Cropland land use subtypes and subdivisions with area in hectares as at 2019.

Subtype	Subdivision	Area (HA)	%
Subsistence Agriculture	Permanent cultivation	1,109,848	21.5%
	Shifting cultivation	3,453,597	66.8%
Commercial Agriculture	Tea	2,955	0.1%
	Coffee	29,410	0.6%
	Oil palm	343,288	6.6%
	Cocoa	13,779	0.3%
	Coconut	137,666	2.7%
	Other	19,607	0.4%
	Cocoa/Coconut	43,164	0.8%
	Sugar	7,868	0.2%
	Rubber	11,689	0.2%
		5,172,871	**100.0%**

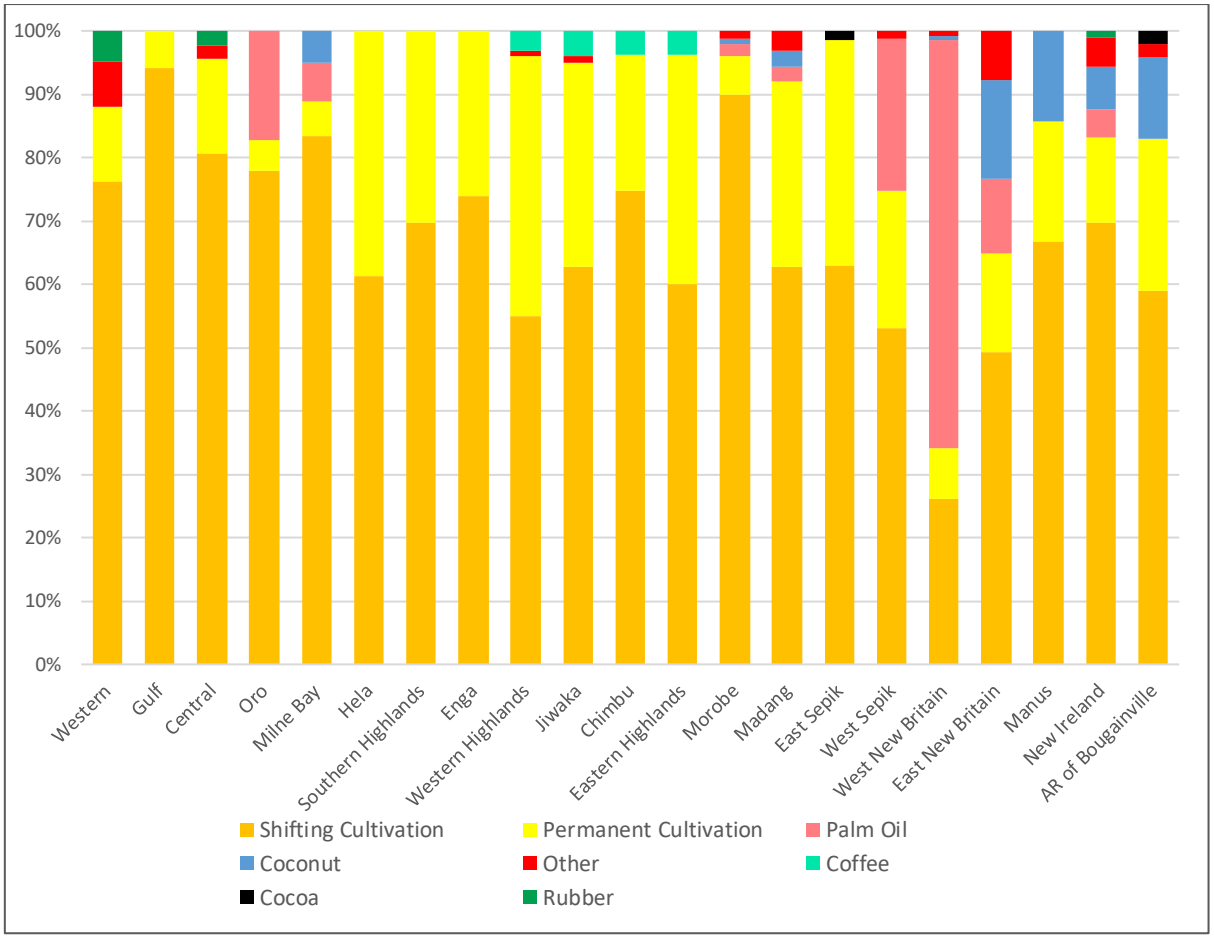

Figure 2-11: Proportion of cropland types in the Provinces.

2.5 Status of other land use categories other than forest and cropland – 2019

The other land use categories include: settlement, grassland, wetland and other land (Table 2-4) and comprises about 10.91% of PNG's total land mass. Settlements cover about 0.88% of total land area; villages are the most dominant followed, by large settlements and infrastructure. Grasslands cover about 5.28% of the country's total land area. Herb land is mostly dominant, comprising about 77.6% of total grassland area. Wetlands cover about 4.62% of PNG's total land area. Other swamps include low-lying seasonal inundated areas comprising shrubby or vegetated areas, and are the most dominant wetland areas in PNG, followed by rivers. Other land — mainly rock, but also bare land and sand — is not significant in PNG, comprising just 0.13% of its total land area.

Table 2-4: Land use subdivision of land use other than forest and cropland.

Land Use	Subdivision	Area (ha)	%
Settlements	Village	239,148	59%
	hamlet	53,861	13%
	Large Settlement	57,925	14%
	Infrastructure	54,868	14%
	Sub-total:	**405,803**	**100.0%**
Grassland	Herbland	1,886,798	78%
	Rangeland	110,990	4%
	Others	432,908	18%
	Sub-total:	**2,430,696**	**100.0%**
Wetlands	River	443,947	21%
	Lake	257,488	12%
	Dam	3,891	0.2%
	Nipa Swamp	190,814	9%
	Other Swamp	1,237,061	58%
	Sub-total:	**2,133,202**	**100.0%**
Other Land	Bare	22,526	35%
	Sand	7,853	13%
	Rock	30,835	52%
	Sub-total:	**61,214**	**100.0%**
	Total:	**5,024,168**	

3 Forest and land use change between 2000 and 2019

3.1 Deforestation during 2000-2019

A total of 352,804 ha of forest was deforested between 2000 and 2019. This is about 0.98% deforestation in 19 years. Between 2000 and 2010 about 100,662 ha (0.28%) was deforested. Deforestation increased rapidly between 2011 and 2015 where about 154,361 ha (0.42%) of forestland was converted to other land use. From 2016 to 2019, deforestation decreased where about 99,780 ha (0.28%) of total forest land was converted to other land use (Figure 3-1 and Annex 2.3).

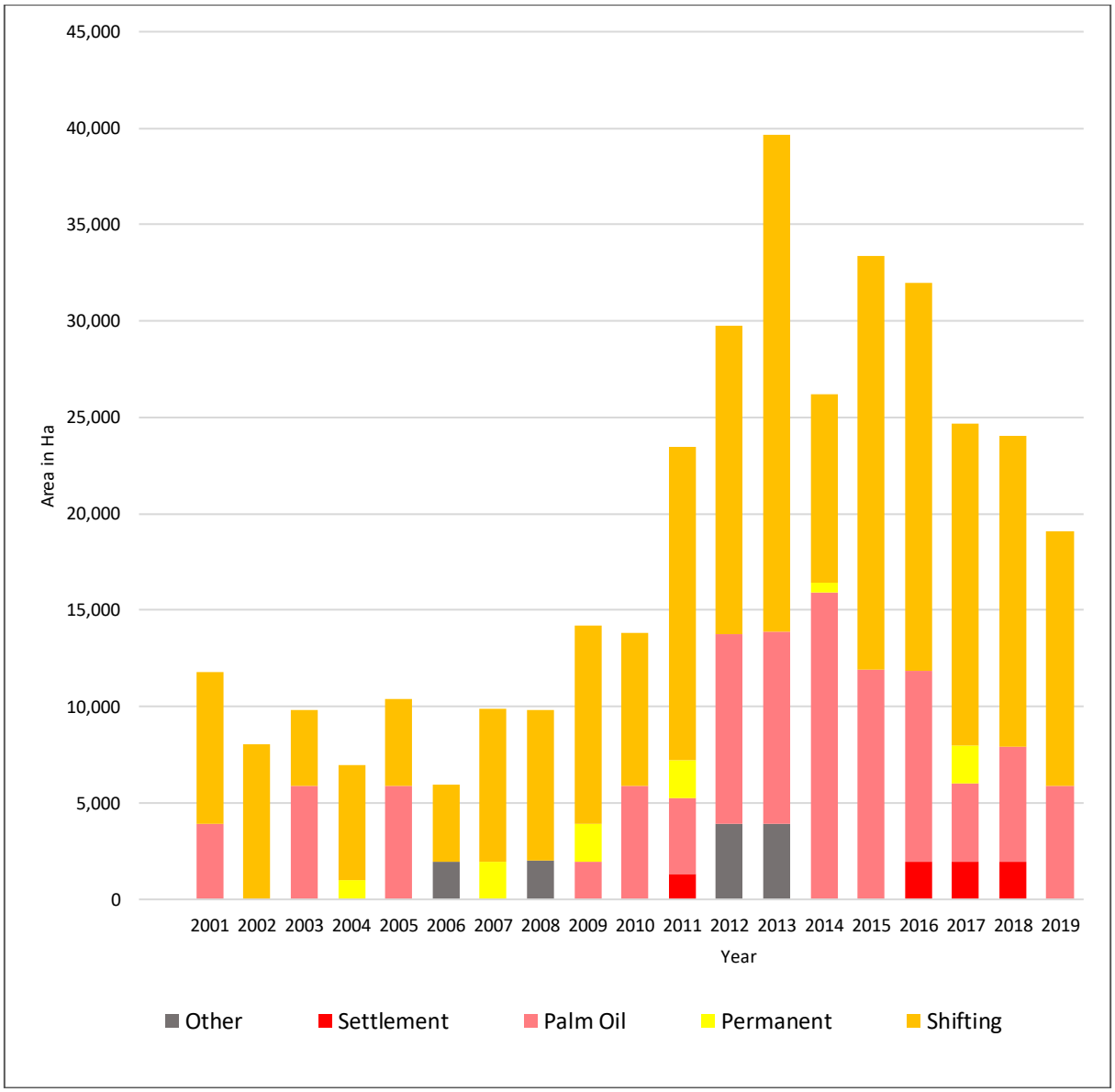

Figure 3-1: Annual deforestation between 2000 and 2019. (Note: Disaggregated data is provided in Annex 2.3)

Subsistence agriculture and oil palm development continue to be the major drivers of deforestation. (Table 3-1). Subsistence agriculture and oil palm increased by 3.08% and 5.56% (19,630ha) respectively from 2015.

The highest rate of deforestation was faced in West Sepik province, recording more than double of deforestation compared to other provinces in the country (Figure 3-2). Most of the major oil palm plantation development occurred in three provinces (West Sepik, West New Britain and East New Britain (Figure 3-2). Information on annual deforestation rates can be found in Annex 2.3 and all province deforestation composition can be found in Annex 2.7.

Table 3-1: Forest types converted to other land use between 2000 and 2019.

	Cropland				**Settlements[5]**	**Total deforested (ha)**	**Percentage (%) against the total area deforested**
	Subsistence agriculture		**Commercial agriculture**				
	Permanent	**Shifting**	**Oil palm**	**Other[6]**			
Low altitude forest on plains and fans	5,885	85,418	83,057	7,893	1,981	184,234	**52.4%**
Low altitude forest on uplands	0	62,037	17,774	1,963	1,974	83,748	**23.8%**
Lower montane forest	1,479	62,783		0	1,953	66,216	**18.8%**
Dry seasonal forest		3,925		0	0	3,925	**1.1%**
Swamp forest	2,007	5,949		0	0	7,957	**2.3%**
Savannah		0		0	1,314	1,314	**0.4%**
Woodland		3,911		0	0	3,911	**1.1%**
Total:	9,371	224,025	100,831	9,855	7,223		
%	**2.7%**	**64%**	**29%**	**3%**	**2%**		

[5] Settlement includes village, hamlet and large settlements.
[6] Other includes specific commercial agriculture activities such as coconut, cocoa, tea, coffee

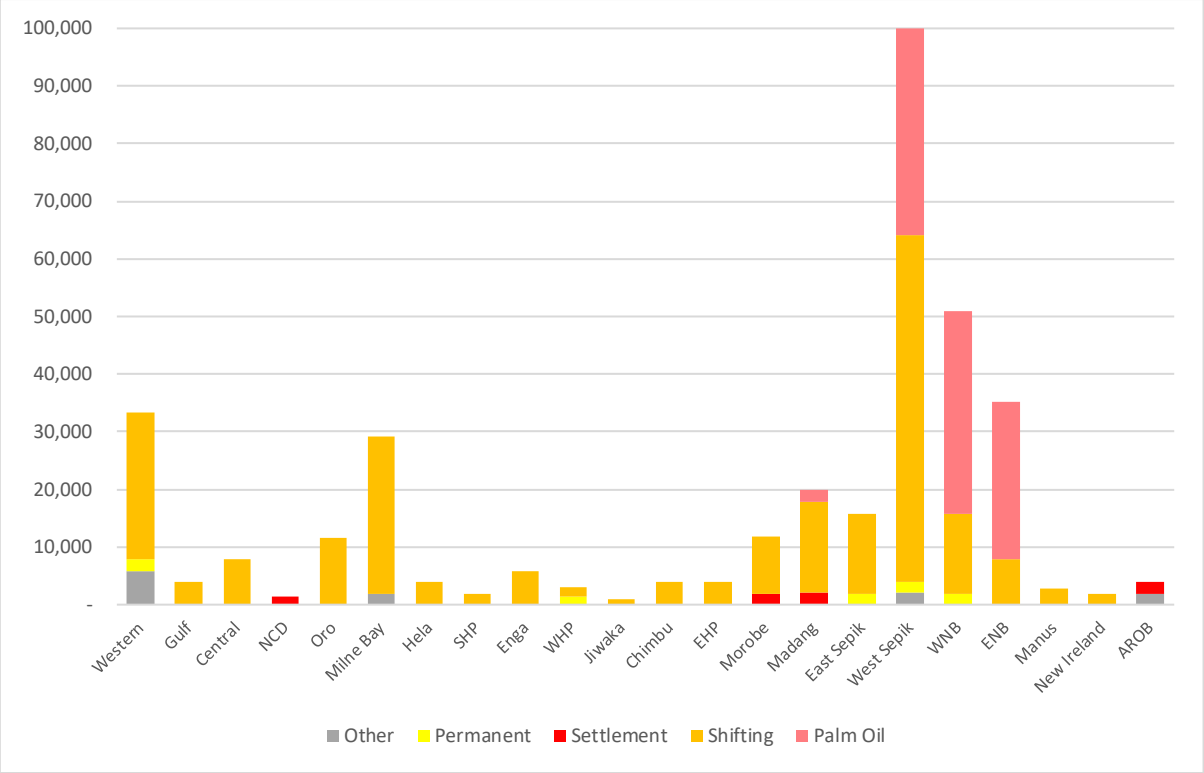

Figure 3-2: Forest converted to other land use types in Provinces between 2000 and 2019.

3.2 Forest Degradation during 2000-2019

About 7.94% (8.884 million hectares) of forest in 2019 was degraded in 19 years (Table 3-2). Forest degradation has been increasing steadily since 2000 and reached its peak in 2010 and 2011 (Figure 3-3). Between 2015 and 2019 forest degradation steadily decreased (Figure 3-3). The country's 19-year period forest disturbance is shown in Annex 2.9.

Table 3-2: Forest area disturbed or degraded by human activities between 2000 and 2019.

Forest disturbance status	Human impact (ha)					Total disturbed	Forest in 2019	
	Logging	Gardening	Portable Sawmill	Other [7]	Fire		Intact (ha)	Total (ha)
1999 or before	1,605,458	2,924,227	77,538	373,411	1,058,978	6,039,613	27,009,227	35,950,979
2000-2015	2,191,887	136,554	1,961	37,701	21,562	2,389,665		
2016-2019	329,132	81,643	1,961	23,572	29,394	465,702		
Total forest disturbed	4,124,247	3,133,554	81,551	434,932	1,110,565	8,884,850		
% Disturbed in 15 years (2000-2015)	6.09%	0.38%	0.01%	0.10%	0.06%	6.64%		
% Disturbed in 4 years (2016-2019)	0.92%	0.23%	0.01%	0.07%	0.08%	1.30%		
% Disturbed in 19 years (2000-2019)	7.01%	0.61%	0.01%	0.17%	0.14%	7.94%		
Annual Rate of disturbance (%)	0.37%	0.03%	0.00%	0.01%	0.01%	0.42%		

[7]Other in forest disturbance covers infrastructure, mining and others (other=activities not listed under man-made disturbance type). Full descriptions can be found in Annex 2.1.

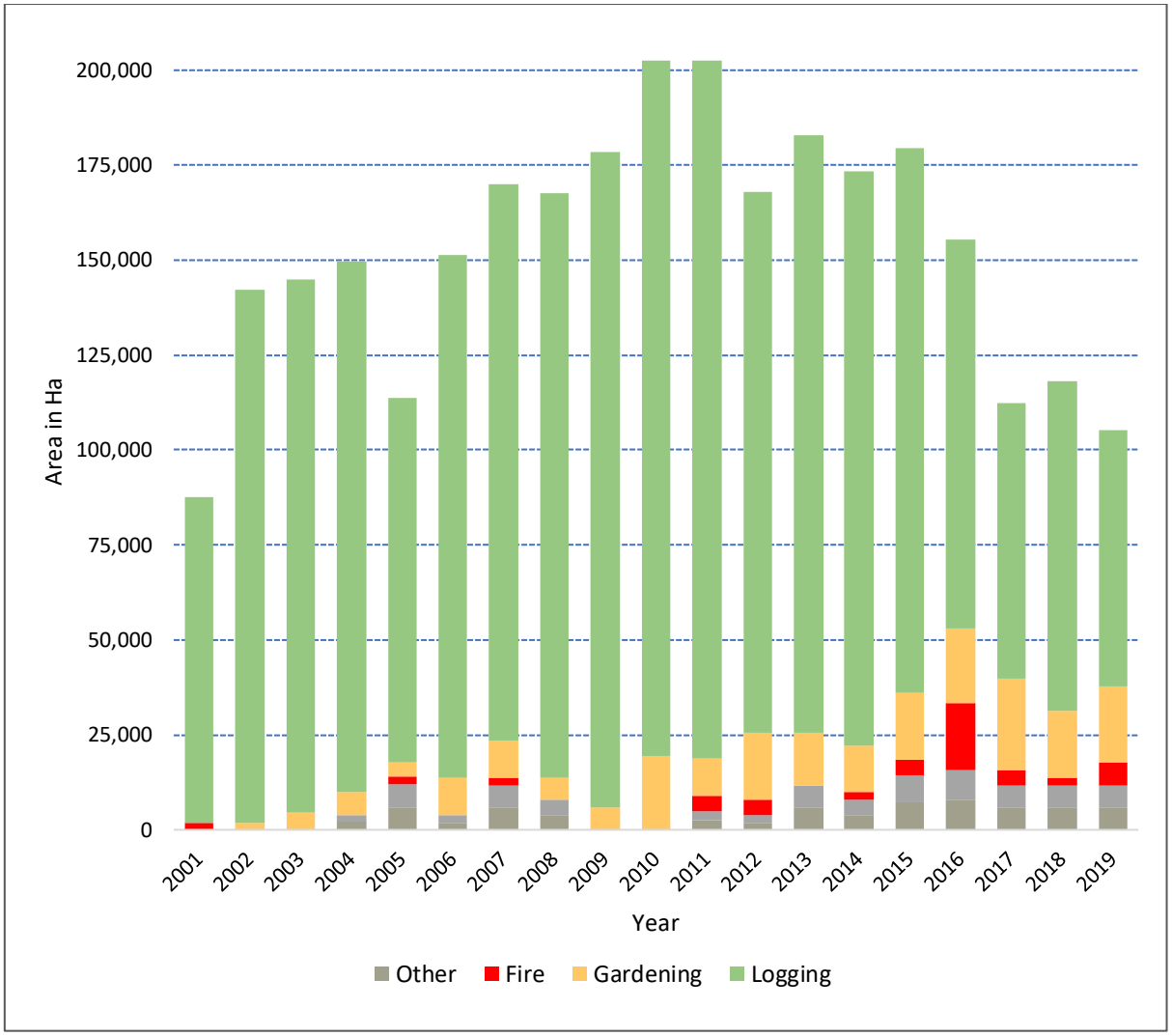

Figure 3-3: Annual Forest degradation by human impact type.

Commercial logging was the major driver in forest degradation or disturbance where about 7.01% of the total forest in 2019 was degraded/disturbed (Table 3-2). Commercial logging degraded or disturbed about 46.31% of the total degraded/disturbed forest between 2000 and 2019 (Figure 3-4). Commercial logging occurred mostly in low altitude forest on plains and fans, and low altitude forest on uplands (Annex 2.6).

Between 2016 and 2019 West Sepik Province had an area of 84,299 ha of forest disturbed by commercial logging followed by West New Britain (54,972 ha), New Ireland (44,747 ha) and Western Province (43,179 ha). Area information on disturbance type (man-made) by province from 2000 and 2019 are shown in Annex 2.9.

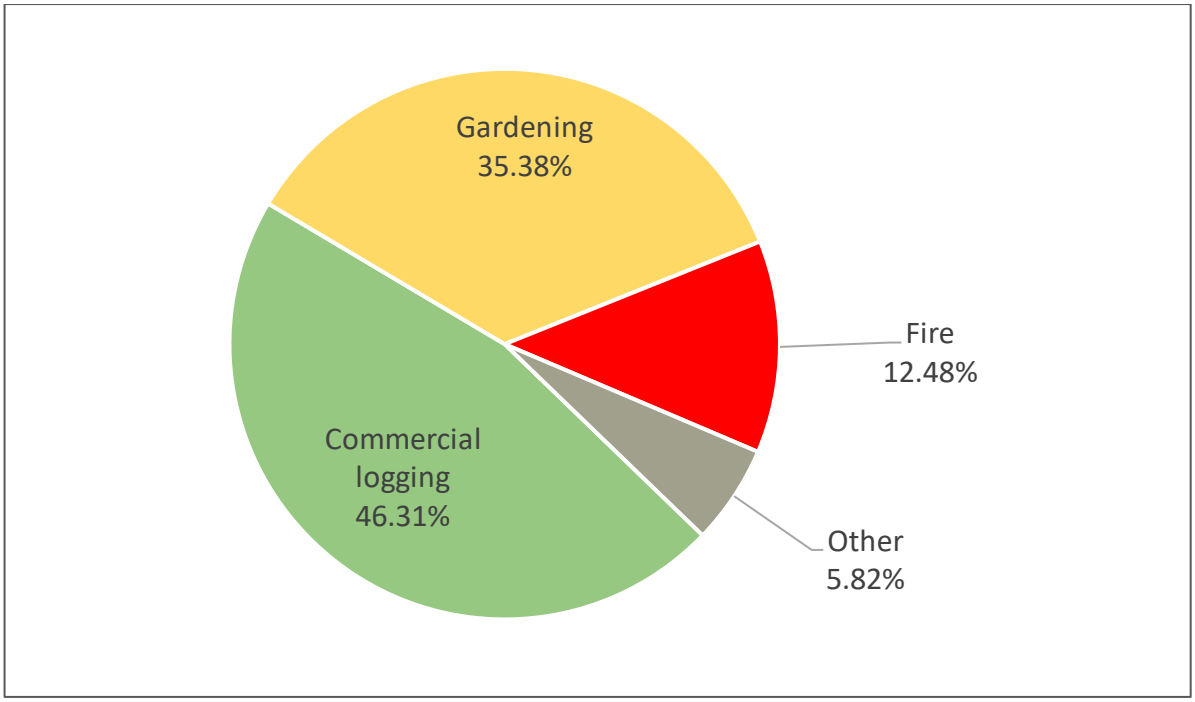

Figure 3-4: Percentage of man-made disturbance on the forest land.

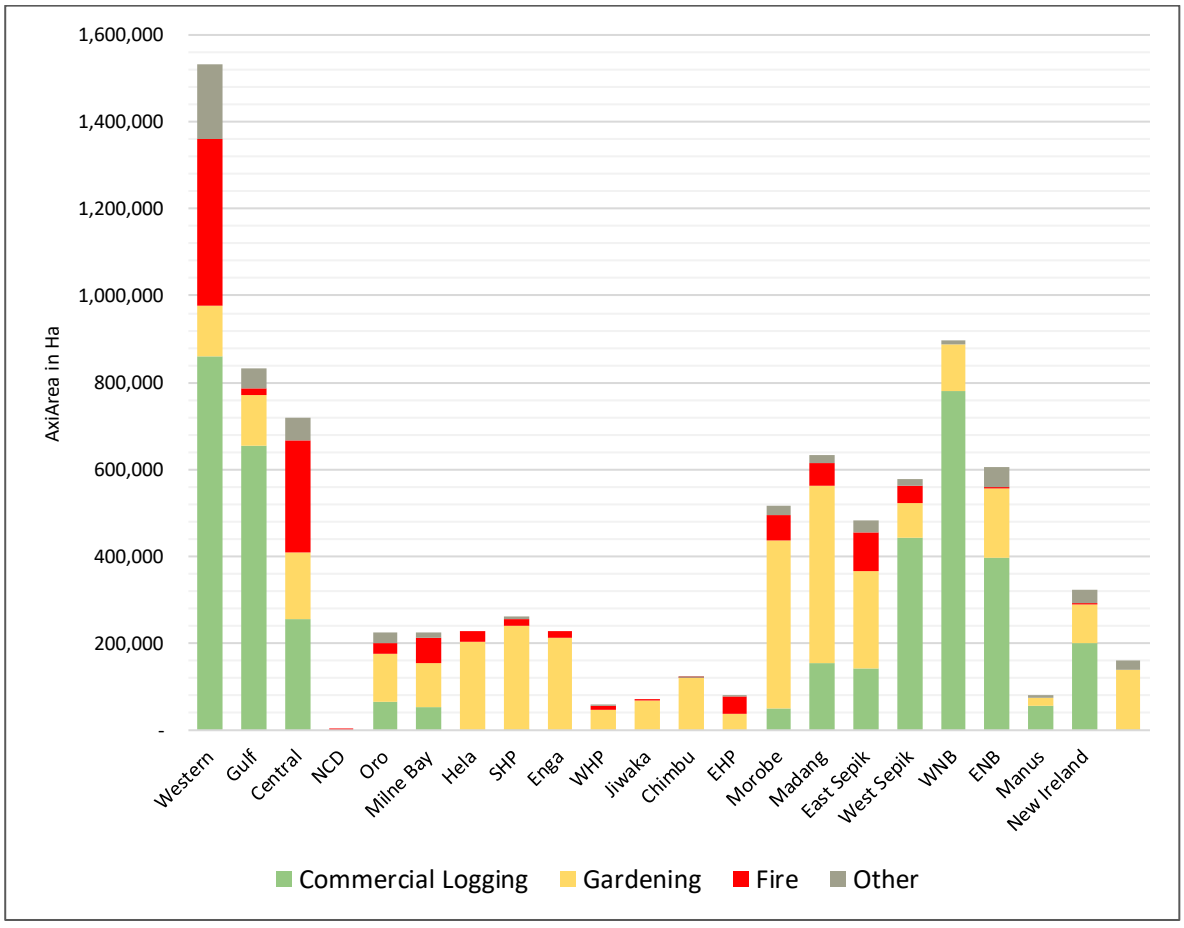

Figure 3-5: Forest disturbed by man-made activities in Provinces between 2000 and 2019.

4 Uncertainty of Area Estimates

4.1 Overview of sampling

Table 4-1 shows the sampling plot count and the estimated area of each land use category of Initial land use (2000) and Current land use (2019), respectively. A total of 25,279 plots were planned to be assessed however, only 25,226 were assessed. Fifty-three (53) plots were identified on the sea and cloud, hence recorded as 'no data'.

Table 4-1: Initial and Current Land Use (2000 to 2019)

	Initial Land Use		**Current Land Use**	
IPCC Land Use Category	**Plot Count**	**Area (ha)**	**Plot Count**	**Area (ha)**
Forest	19,503	36,304,248	19,313	35,950,979
Cropland	3,029	4,849,689	3,202	5,172,871
Grassland	1,313	2,432,661	1,312	2,430,696
Otherland	33	57,289	35	61,215
Wetland	1,110	2,139,151	1,107	2,133,202
Settlement	238	371,728	257	405,803
All	**25,226**	**46,154,766**	**25,226**	**46,154,766**

4.2 Quantitative analysis

Table 4-2 to Table 4-5 show sampling errors and the uncertainty of area estimates of each land use category and conversion during 2000-2019, using the spreadsheet developed by the FAO based on the equation shown in Annex 1, section 5.1 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 quite 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. However, the estimation of the uncertainties will be improved in next assessment reporting by considering ground-truth data from PNG NFI and from PNGFA field activities that are conducted on our sampling plots geographic positions.

Table 4-2: Sampling error and uncertainty of area estimate of each land use category – Initial land use (2000)

Initial Land Category	Sample Size	Area	pi	Area [Ai] (ha)	Standard Error (proportion)	Standard Error (mil. ha)	Confidence Intervals (ha)	Uncertainty %
Forest	19,503	36,304,248	0.773130897	35,683,675.54	0.00263693	121,706.89	± 238,545.5	± 0.66%
Cropland	3,029	4,849,689	0.120074526	5,542,011.65	0.002046599	94,460.31	± 185,142.2	± 3.82%
Grassland	1,313	2,432,661	0.052049473	2,402,331.23	0.001398574	64,550.85	± 126,519.7	± 5.20%
Otherland	33	57,289	0.001308174	60,378.47	0.000227579	10,503.87	± 20,587.6	± 35.94%
Wetland	1,110	2,139,151	0.04400222	2,030,912.16	0.001291368	59,602.81	± 116,821.5	± 5.46%
Settlement	238	371,728	0.00943471	435,456.84	0.000608682	28,093.56	± 55,063.4	± 14.81%
All	**25,226**	**46,154,766**						

Table 4-3: Sampling error and uncertainty of area estimate of each land use category – Current land use (2019)

Current Land Category	Sample Size	Area	pi	Area [Ai] (ha)	Standard Error (proportion)	Standard Error (mil. ha)	Confidence Intervals (ha)	Uncertainty %
Forest	19,313	35,950,979	0.765598985	35,336,042	0.002667257	123,107	± 241,289	± 0.67%
Cropland	3,202	5,172,871	0.12693253	5,858,541	0.002096017	96,741	± 189,613	± 3.67%
Grassland	1,312	2,430,696	0.052009831	2,400,502	0.00139807	64,528	± 126,474	± 5.20%
Otherland	35	61,215	0.001387457	64,038	0.000234365	10,817	± 21,201	± 34.63%
Wetland	1,107	2,133,202	0.043883295	2,025,423	0.001289702	59,526	± 116,671	± 5.47%
Settlement	257	405,803	0.010187901	470,220	0.000632271	29,182	± 57,197	± 14.09%
All	**25,226**	**46,154,766**						

Table 4-4: Land use data without verification – Initial and Current land use (2000 and 2019)

Land Category	Sample Size	Area	pi	Area [Ai] (ha)	Standard Error (proportion)	Standard Error (mil. ha)	Confidence Intervals (ha)	Uncertainty %
Initial Forest Land	19,503	36,304,248	0.773	35,683,676	0.002637	121,707	± 238,545.5	± 0.66%
Initial non-Forest Land	5,723	9,850,518	0.227	10,471,090	0.002637	121,707	± 238,545.5	± 2.42%
Current Forest Land	19,313	35,950,979	0.766	35,336,042	0.002667	123,107	± 241,289.0	± 0.67%
Current non-Forest Land	5,913	10,203,787	0.234	10,818,724	0.002667	123,107	± 241,289.0	± 2.36%
Total	**25,226**	**46,154,766**						

Table 4-5: Land use and land use change data without verification – Forest to non –forest (2000 to 2019)

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	19,313	35,950,979	0.766	35,336,042	0.002667	123,107	± 241,289.0	± 0.67%
non-Forest land converted to Forest land	-	-	0.000	0	0.000000	0	± 0.0	#DIV/0!
Forest land converted to non-Forest land	190	353,269	0.008	347,634	0.000544	25,125	± 49,245.7	± 13.94%
non-Forest land remaining non-Forest land	5,723	9,850,518	0.227	10,471,090	0.002637	121,707	± 238,545.5	± 2.42%
Total	**25,226**	**46,154,766**						

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ANNEXES

Annex 1: Methodology

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Annex 1

Methodology

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1. Introduction

The methodology PNG used in the 2020 survey is fully compliant with the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (2006 IPCC guidelines) [8] and consistency with the previous survey is important to ensure that key information is comparable. So the basic methodology is maintained in the 2020 survey design. Annex 1 of this report presents the main methods used, covering survey design, sampling design, assessment approach, data preparation, uncertainty analysis and forest carbon estimation.

1.1. Forest and land use

For national-level reporting, information must be transparent, accurate and consistent. Providing detailed classification and land definition descriptions must therefore be specific (accuracy) and reported over time (maintaining consistency). With deforestation, afforestation or reforestation all taking place in PNG, it is also important to start with defining the areas within which these activities occur or may occur in the forest.

1.1.1. Forest

The IPCC Good Practice Guidelines 2003 terms 'forest' as "all land with woody vegetation consistent with thresholds used to define forest land in the national greenhouse gas (GHG) inventory; subdivided into managed and unmanaged, and also by ecosystem type as specified in the 2003 IPCC guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category" (IPCC 2003)[9].

The 2006 IPCC guidelines define forestland by threshold values, indicating an anticipation that countries will define their forest with quantitative thresholds (IPCC 2006). Decision 11/CP.7 of the Marrakesh Accord adopted definitions for forests, afforestation and reforestation (UNFCCC 2002)[10]. These were later extended to LULUCF activities carried out under the Clean Development Mechanism of the Kyoto Protocol by Decision 19/CP.9 adopted at Milan (UNFCCC 2004)[11].

The Kyoto Protocol sets three parameters with a threshold range for participating countries to define forest: area in hectares ranging from 0.5–1.0 hectares; tree height from 2–5 metres; and canopy cover from 10–30% (Table 1-1).

PNG defines its national forest as "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)[12] in Decision #256 of meeting #07/2014 (GoPNG 2014). The threshold values of the parameters chosen for the definition play a crucial role in legally interpreting land use, assessing forest areas and resources, developing policy frameworks, and planning conservation and sustainable forest management activities.

[8] https://www.ipcc-nggip.iges.or.jp/public/2006gl/
[9] https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html
[10] https://unfccc.int/files/meetings/workshops/other_meetings/application/pdf/11cp7.pdf
[11] https://unfccc.int/resource/docs/cop9/06a02.pdf#page=13
[12] The NEC is an important arm of the PNG government in terms of its review and endorsement of national policies, legislation.

This national forest definition differs from the FAO's definition, as reported in the Forest Resource Assessment (FRA) Report 2015[13], which is "land spanning more than 0.5 hectares with trees higher than 5 metres" and "canopy cover of more than 10 percent" (Table 1-1). Before 2014, PNG had no national forest definition, so all default definitions under the IPCC 2006 were observed as reflected in all past GHG inventories carried out by government authorities.

Table 1-1. Definitions of 'forest'

Elements	Kyoto Protocol	GoPNG (NEC) 2014	FRA 2015
Minimum land area (hectares)	0.05–1.0	1.0	0.5
Minimum tree height (metres)	2–5	3	5
Minimum canopy cover (%)	10–30	10	10

1.1.2. Deforestation and forest degradation

Deforestation is the conversion of forest land to any non-forest land. The time for clearing may be different from the time conversion occurs. In most instances, the year the forest is cleared is used as the reference for year of change. For example, for a sampling plot on forest land that was cleared in 2003 and planted with oil palm in 2008, the year of change is recorded as 2003. This is an example of deforestation or forest land conversion to cropland.

Forest degradation is the conversion of primary forest into disturbed forest — for example, a forest area impacted by selective logging activity.

1.1.3. Other IPCC land use categories and subdivisions

This assessment uses the six IPCC land use categories — forest land; settlement; cropland; grassland; wetland and other land — as the main or Level 1 land classes. Country-specific Level 2 and 3 classes are subtype and subdivision. These are used for the country-specific subcategories under this study as shown in Table 1-2. .

Forest land and cropland are the only categories with Level 2 subtype classes, while the other four categories only have Level 3 subdivisions. All PNG land is classified into 46 land use subdivision categories. This section explores the land use categories, subtypes and subdivisions (Table 1-2). For more detailed subdivision category definitions, see Annex 2.1.

[13] FAO. Forest Resources Assessment 2015: Country Report Papua New Guinea [https://www.fao.org/3/az303e/az303e.pdf]

Table 1-2. Land use categories, subtypes and subdivisions used in this assessment

IPCC land use category	PNG subtype	PNG subdivision
Forest land	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 (Rain trees)
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[14], other swamp
Settlement		Village, hamlet, large settlement, infrastructure
Other land		Bare soil, sand, rock

Note: These subtype and subdivision are additional options apart from the six IPCC land use categories.

1. Forest land: Forest land is classified into subdivisions, based on natural vegetation types and manmade plantations. Vegetation types are based on the structural formation and described in the Papua New Guinea Resource Information System (PNGRIS) (Hammermaster and Saunders 1995). There are 12 vegetation types in PNG forests (see Annex 2.1 for more details).

Natural forest types are further divided into primary and disturbed forests, whereby primary forests are areas of densely populated old or matured native tree species, where there are no clearly visible indications of human activities and ecological processes are not significantly disturbed, and disturbed forests are naturally regenerated forests with clearly visible indications of human activities (FAO 2015. FRA 2015). Disturbances can be natural or manmade.

Natural disturbances are caused or derived from nature — through flooding, landslide, eruption, frost, or other means. These are stored in the database under "no_impact". Manmade disturbances are made or caused by humans through:

- **Commercial logging**: Large-scale logging activity to harvest timber with the intent of selling it internationally or domestically. There are two types of commercial logging: clear felling and selective logging. In PNG, only selective logging is practiced, harvesting timber at a certain diameter. A permit or license must be obtained for a defined boundary under a forest management area, timber rights permit, forest clearance authority, local forest area, or timber authority for a longer-term contract.
- **Gardening**: A patch of forest land cleared for shifting or permanent cultivation. These appear in satellite images as isolated and unevenly distributed patches of temporary forest clearings.
- **Fire**: 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:** A small-scale activity harvesting timber for domestic use within a forest area using a Lucas mill or chain saw.
- **Other:** Other activities — including mining, trees cut for firewood and other local uses, and so on — which impacts a forest area.

[14] If the canopy cover of trees exceeds 10%, it is considered swamp forest. Nipa swamps do not have trees but are dominated by Nipa palms, which are classified under wetland.

Table 1-3. Forest classifications in PNG

Category/subdivision	Short description
Natural forest	
Low-altitude forest on plains and fans	Elevations below 1,000 metres with gentle slopes
Low-altitude forest on uplands	Elevations below 1,000 metres with rough terrain
Lower montane forest	Between elevation from 1,000–3,000 metres
Montane forest	Elevations above 3,000 metres
Dry seasonal forest	Restricted to southwest PNG in a low-rainfall area (1,800–2,500 mm)
Littoral forest	Dry or inundated beach forest
Seral forest	River line, upper stream, river plains and volcano blast area
Swamp forest	Forest area inundated with freshwater either permanently or seasonally
Woodland	Low and open tree layer
Savanna	Low (< 6-meter) and open tree layer in low rainfall area with a marked dry season
Scrub	Community of dense shrubs up to 6 metres
Mangrove	Along coastline and in the deltas of large rivers
Plantation forest	
Forest plantations	Planted forests are composed of trees established through planting or seeding by human intervention.

The Papua New Guinea Forest Basemap and Atlas (Turia et al. 2019)[15] and National Forest Plan both break down forests into management and designation — production forest, reserve forest, potential production forest area, timber concessions, and so on — based on their management regimes.

The forest and land use change areas were constructed to reflect only anthropogenic activities. This is true for both deforestation and forest degradation. The distinction between managed and unmanaged land was made by: presence of logging roads, permanent roads and bridges, forest cover losses within proximity to villages, and accessibility in terms of the topography. Where 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, such as volcanic activities, landslides and cyclones. As such emissions from deforestation and forest degradation reflect anthropogenic emissions only.

2. Cropland: The IPCC defines cropland as arable and tillage land, and agroforestry systems where vegetation falls below the forest land threshold, consistent with the selection of national definitions. Cropland in PNG is further divided into two types: subsistence and commercial agriculture.

Subsistence agriculture is a farming method where a family or a household produce enough food for their own consumption, selling any surplus in areas where the market is accessible. For the purpose of this report, subsistence agriculture is divided into shifting and permanent. Shifting subsistence agriculture is a temporary, rotational cultivation of land where the cultivated land is abandoned for a few years then recultivated once the land naturally restores its fertility. Permanent subsistence agriculture is long-term gardening without moving to a new piece of land. It is the dominant practice in highland regions, due to land sensitivity and it takes place very close to the individual household or family unit/clan boundary.

[15] https://www.jica.go.jp/png/english/activities/c8h0vm00008t2ycr-att/part_01.pdf

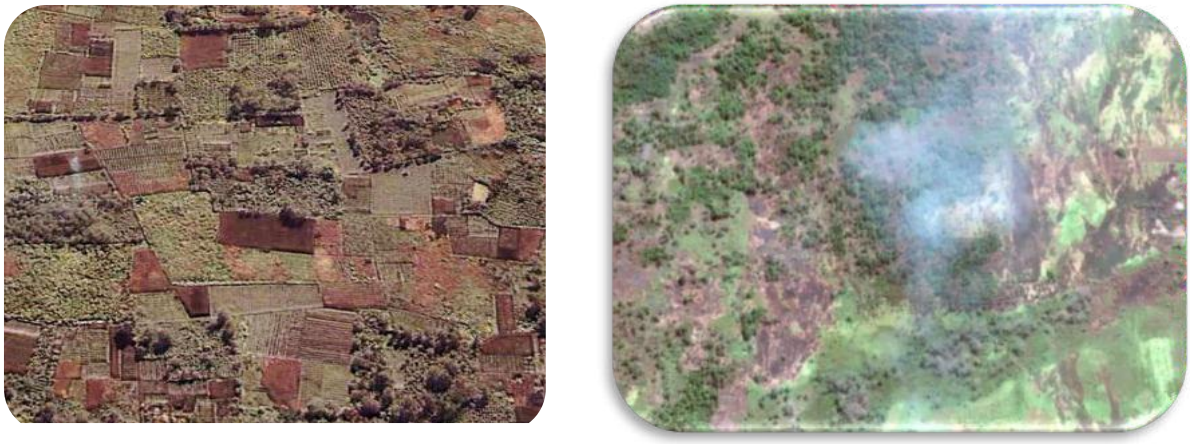

Figure 1-1. Permanent gardens in the highlands (left) and lowlands (coastal)

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 smallholders (village) on communal land.

3. Settlement: Under the 2006 IPCC guidelines, 'settlement' covers 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: A cluster of (usually three to five) permanent or semi-permanent houses scattered broadly over the landscape or area of interest (a family or one clan), with the inhabitants usually belonging to a nearby community or village. They are difficult to detect in low- to medium-resolution satellite images.
- Village: A permanent human settlement comprising a community with more than one clan or tribe in a rural area. The houses are more densely distributed than the hamlets, and marked subsistence agriculture is usually evident in the surroundings.
- Large settlements: Well-organized cities, towns and district centers, including mining townships located away/far from the mining sites.
- Infrastructure: Permanent structures including roads (paved or unpaved), bridges, airstrips/airports, clinics, schools and playing fields, located outside of a village or large settlement or in remote areas.

4. Grassland: Under the 2006 IPCC guidelines, grassland includes rangelands and pastureland that are not considered cropland. It also includes systems with vegetation that fall below the forest land threshold and is not expected to exceed, without human intervention, the thresholds used in the forest land category. This category also includes all grassland from wildlands to recreational areas and agricultural and silvopastural systems. Grassland is divided into herb land, rangeland and others.

5. Wetlands: Land that is covered or saturated by water for all or part of the year (such as peatland) and that does not fall into the other five IPCC land use categories are considered wetland under the 2006 IPCC guidelines. They can be further subdivided into managed (reservoirs) and unmanaged (natural rivers and lakes) wetlands, according to national definitions. PNG does not have a national definition, but this report uses the following subdivisions: rivers, lake, dams, swamps, Nipa swamps and other swamps.

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

2. Survey Design

The survey was prepared through Collect, an easy-to-use open-source programming tool by FAO's Open Foris that allows users to customize an existing or a default survey to suit a country's needs. A collaborative effort between FAO experts and PNGFA local experts in 2013 to 2015 had already designed a complete survey for PNG. As a result, the PNG LULUCF 2020 survey was able to replicate the PNG LULUCF 2000–2015 assessment design, with a few enhancements — outlined in the next section — based on the lessons learnt from the previous survey. Once the design was completed, the new survey was exported to Collect Earth to collect and store information interpreted from satellite imagery.

2.1. Customizing the survey

Forest degradation or disturbance form: Forest disturbance section was subdivided into four subtypes: natural disturbances, manmade disturbances, no disturbance and unknown — faced minor enhancements from the previous survey design. The term 'human impact' is now replaced with manmade, mainly to allow easy aggregation of the new information in Saiku[16] Other parts under forest disturbance were maintained to minimize further inconsistency with the previous survey.

New specific classes of natural forest and manmade disturbances were also included, following a final decision between the FAO and PNGFA teams. Natural disturbance is now subdivided into flooding, landslide, eruption, frost and other, while new manmade disturbance classes include mining, petroleum and infrastructure (Table 2-1.). Fire has been re-categorized from natural to manmade due to limited understanding of the ignition of fire in PNG's natural environment. Further understanding of the ignition of fire in the natural environment is required through study before it is included in the natural subtype category in future.

Canopy cover form: In this assessment, the canopy cover is the percent of a fixed area covered by the crown of an individual plant species or defined by the vertical projection of its outermost perimeter. Canopy cover assessment is enhanced by automating the cover percentage calculation in Collect Earth (Figure 2-1).

The previous method used a selection of percentage range values between 0 and 100 to express the canopy based on manual calculation of the 4% dots. The current protocol is the same, but the operator has to count and record the number of dots that fall onto tree canopy cover or crop cover, entering a value between 0 and 25 based on his/her count of the equally spaced out dots that fall on a tree canopy cover or crop cover in the 1-hectare plot (Figure 2-2). Collect Earth then automatically calculates the percentage tree canopy or crop cover.

[16] Saiku is a web browser-based tool that facilitates data analysis. See [http://openforis.org/tools/collect-earth/tutorials/saiku/]

Table 2-1. Forest disturbance subtypes used in this assessment

Disturbance type	Subtype	Tool tips (additional description)
Natural	Flooding	Can include vegetation die-back
	Landslide	
	Eruption	
	Frost	
	Other	manmade disturbance that is not in the current list
Manmade	Logging	
	Gardening	
	Portable sawmill	
	Mining	Applies to any temporary/permanent roads and built-up areas linked to mining activities
	Petroleum	Applies to any temporary/permanent road and built-up areas linked to oil and gas activities
	Infrastructure	Semi-permanent or temporary construction features, such as roads or cleared areas for communication or other apart activities excluding logging, mining and petroleum
	Fire	Recent occurrence
	Other	Applies to any manmade disturbance not included on this list
No disturbance		No natural or manmade impact
Unknown	Disturbance which is difficult to identify as natural or manmade	

Note: The light green shaded sections denote new subtypes in this survey.

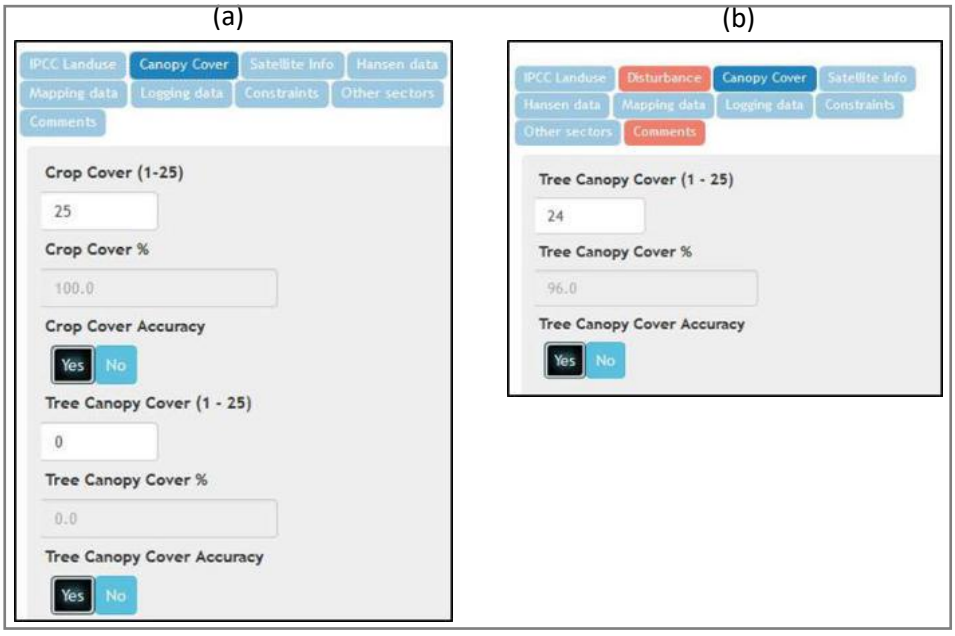

Figure 2-1: Canopy cover forms. Tab (a) shows canopy cover when land use is cropland and Tab (b) shows canopy cover when land use is forest, grassland or settlement.

The forest, grassland, wetland, settlement and other land use categories use tree canopy cover, while crop cover is applied to the cropland category. Tree canopy cover is applied to represent or capture any standing trees that may cover a certain extent of the sampling plot area. A validation rule is applied to restrict the operator entering a number beyond 25, with an error notice appearing if the value is greater than or equal to 26.

Figure 2-2. Example of measuring crop cover of a plot in a palm oil plantation

Figure 2-2 clearly shows that five dots fall on grass and 20 dots fall onto palm oil trees. Therefore, 5 x 4% is 20% and 20 x 4% is 80%, this represents crop cover as 80% and tree canopy cover as 0%.

2.2. Collect Earth inputs

Collect Earth is fully customizable and can be configured to serve a wide variety of land monitoring purposes at the global, regional, national and subnational scale. Each unique Collect Earth customization has its own Collect Earth Project (CEP) package, which contains parameters and other inputs to configure the data collection framework. The CEP inputs, described below, are:

- Data collection form (Figure 2-3)
- Sampling design
- Area attributes file
- Plot file
- Project properties file

Data collection form: Integrated with Google Earth, these are 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, but users can also design their own forms in any language using Open Foris Collect. Starting with the LULUCF sample template data collection forms, PNG customized some forms and added some new ones. Collect Earth operators record information on the land use characteristics and elements in a systematic and structured approach as they are visualized on satellite imageries by answering the questions/selections in the forms (Figure 2-3). After selecting the land use category and land use conversion, the operator is guided to the sub-forms containing the question/selection for the particular land use. This workflow diagram is shown in Figure 2-3.

Sampling design: This involved a probabilistic stratified, systematic sampling design created in GIS to facilitate area estimation and proportional land compositions. For the larger provinces in PNG, a sampling intensity of 0.04 x 0.04-degree grid (4.44 x 4.44 kilometres) was applied, while in the three smaller provinces — Western Highlands, Jiwaka and Manus — which have less than 500,000 hectares of landmass, a 0.02 x 0.02-degree grid (2.22 x 2.22 kilometres) was applied. All these were overlaid on the PNG map, creating 25,279 sampling plots. Each sampling plot is 100 x 100 square meter (1 hectare) square, which is consistent with the minimum mapping area required to apply PNG's national forest definition.

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

Plot file: These comma-separated value (CSV) files contain 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, such as elevation, climate and soil data. Supplementary data can be prepared in Google Earth Engine (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 one can be specified in the project properties CSV file. The coverage of topographical elements — tree cover, roads, agricultural land, and so on — within each plot is estimated via proportions. Every 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 the number of points overlaying the element being measured, over 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 CEP file that defines the data collection framework for land assessment through augmented visual interpretation.

Area attributes: Collect Earth is designed to exploit the benefits of probability sampling by facilitating area estimations and proportional land compositions. 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 — such as random restricted sampling — are used, the file adjusts the weighting of each plot and automatically calculates plot expansion factors and the spatial extent of each attribute.

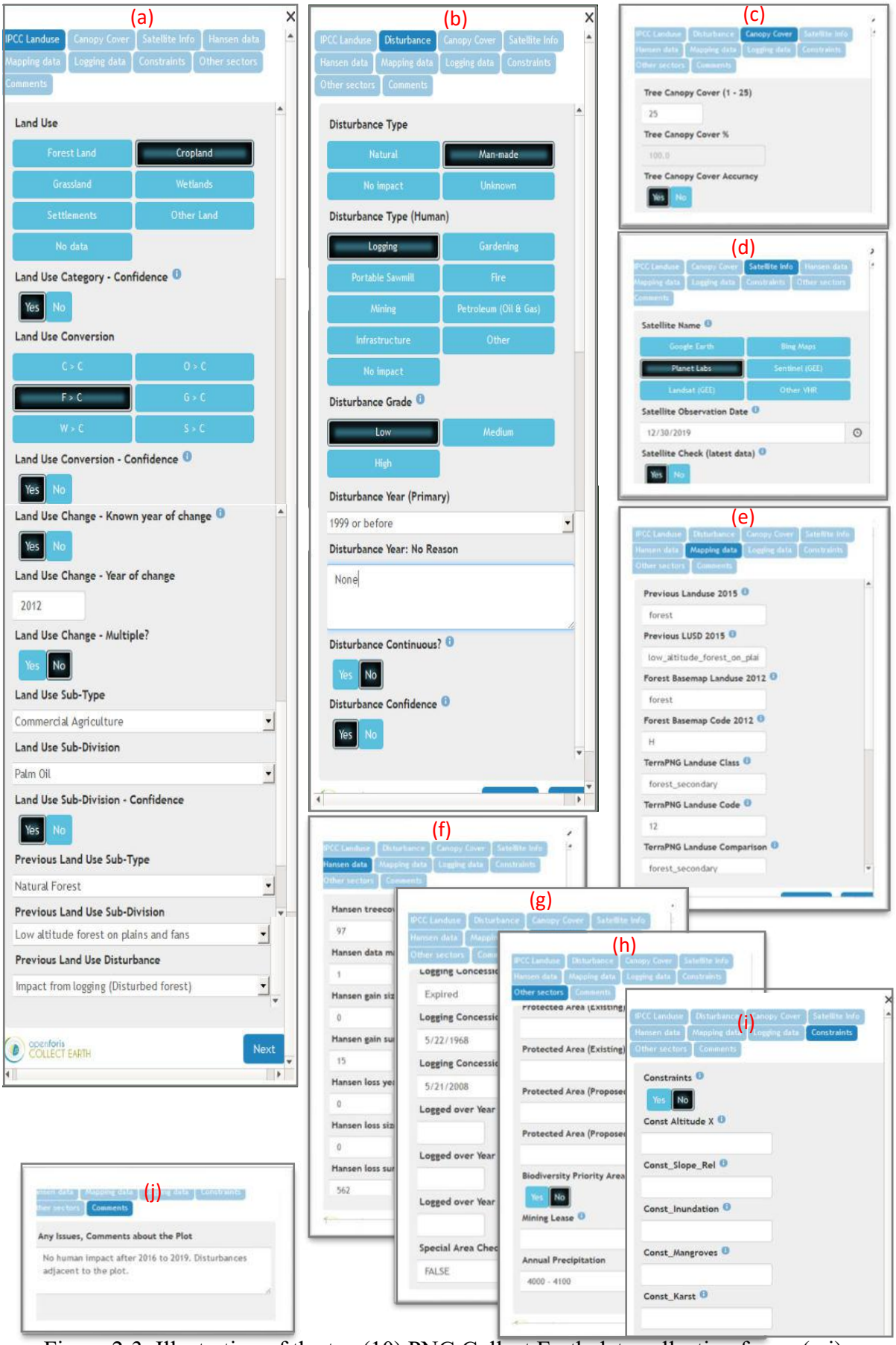

Figure 2-3. Illustration of the ten (10) PNG Collect Earth data collection forms (a-j).

2.3. Integrated services

Interpreting satellite imagery is a method of remote sensing by which information is obtained about objects on the surface of Earth and landscape. Rather than using complex computer interpretation methods, both the previous and current assessments applied simple digital image interpretation methods of visual interpretation of processed satellite imagery via web mapping platforms.

Collect Earth is synchronized to work with Google Earth and several integrated services through the Application Programming Interface or API keys provided by the web mapping developers through agreements with FAO. The key web mapping platforms that used in this assessment include Google Earth, GEE, Bing Map and the newly introduced Planet Labs. The main web mapping services used for the assessment — Google Earth, Bing Map and Norway's International Climate and Forest Initiative (NICFI) — are outlined below.

Google Earth: A widely used web mapping application that shows a 3D representation of Earth based on satellite imagery, mostly using archived imageries mostly from the National Aeronautics and Space Administration (NASA), GeoEye, Digital Globe (WorldView and QuickBird), Spot Image, Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER), BlackBridge (RapidEye), ImageSat International and Meteosat. The high-resolution imagery resolutions range from 0.5 to 2.5 metres.

This assessment used the updated version of GEE, or **Earth Engine** (Figure 2-4). Earth Engine, in conjunction with Collect Earth, presents multiple interfaces in one window, including:

- Dual prototype map frames for false color composites of Landsat 7 and 8;
- A new frame for Sentinel-2 satellite imagery for the last 12 months' snapshots; and
- Statistical charts on vegetation indices from Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat 7/8 and from Sentinel-2 are instantly shown about the plot site.

The false color Landsat 7 and 8 imageries are the key data source for land use change detection. 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 Earth Engine. Most areas in PNG are mainly covered by cloud year-round, presenting a major challenge for optical-based imagery assessment. The United States Geological Survey composites are the best Landsat images taken in each year to make cloud-free images, which are freely available through GEE.

Copernicus Sentinel-2 is a satellite managed by European Space Agency that provides medium-resolution imagery (10–15 metres) of the world. Launched in 2015, it also provides false color composites of the last 12 months of the location surrounding a plot. This offers a snapshot of the current status of the plot site, while the Landsat data are used to interpretate year of land use change.

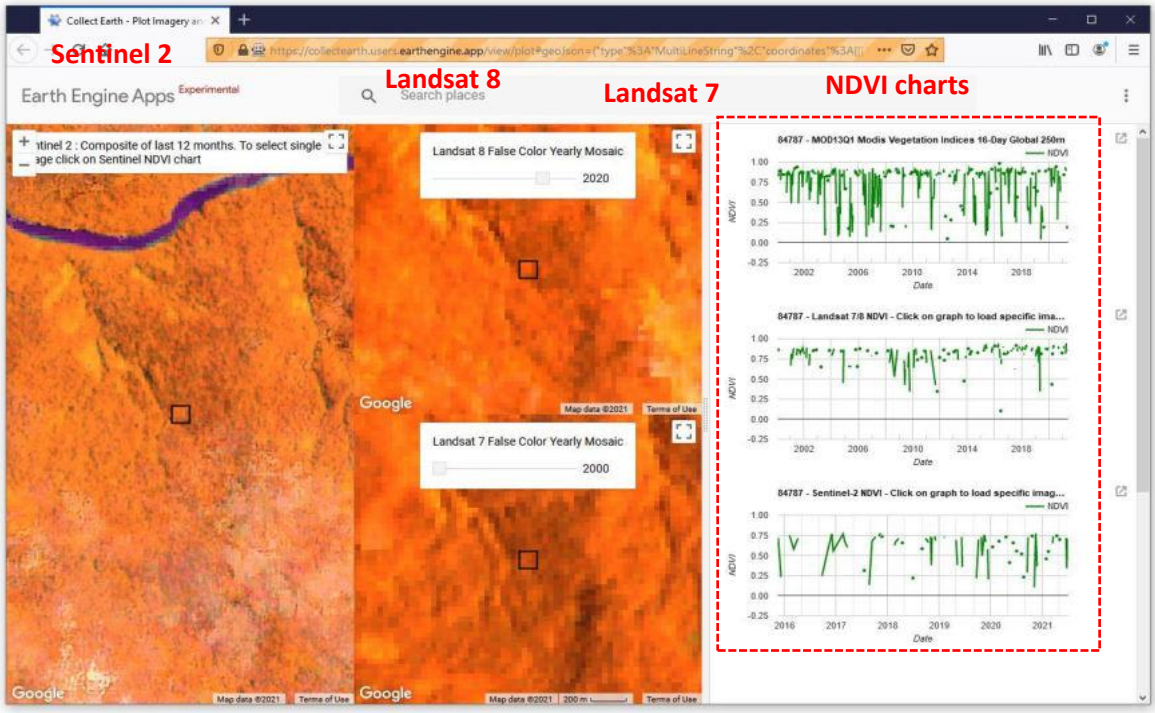

Figure 2-4. Earth Engine: plot imagery and statistical window to verify year of land use change.
Source: Collect Earth 2021.

Bing Maps: A web mapping service provided by Microsoft Bing using images from World-View, QuickBird, IKONOS, Satellite Pour l'Observation de la Terre (SPOT) and others with resolution ranging from 0.5—2.5 metres. A substantial area of PNG is not covered by high-resolution images in either Google Earth or Bing Maps, and area coverage of high-resolution imageries varies. In some cases — especially the more remote parts of PNG — Bing Map did not provide good images (Figure 2-5).

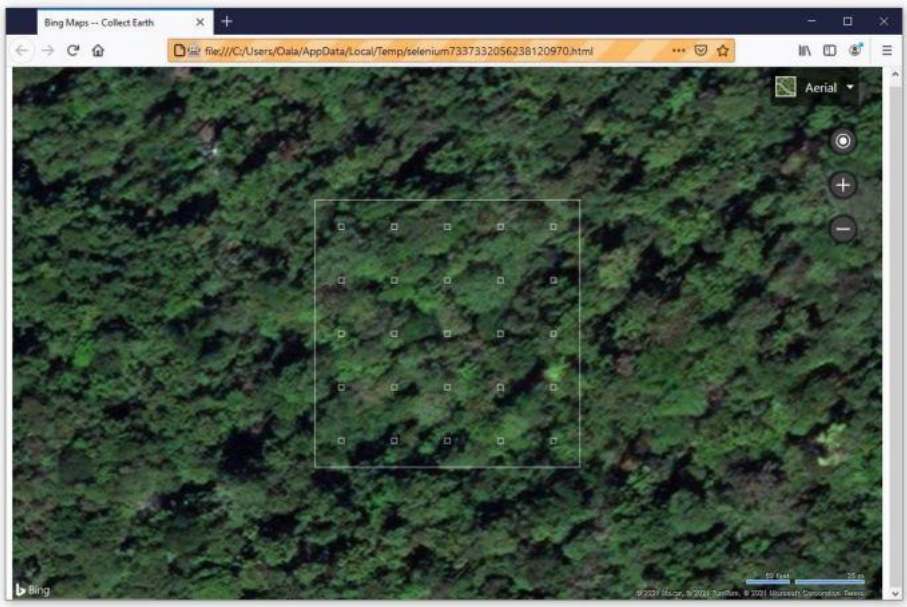

Figure 2-5. Bing Maps web mapping window showing high-resolution coverage of a plot.
Source: Bing Maps 2021.

NICFI: Through a NICFI-funded deal, Planet entered a comprehensive partnership with Airbus and KSAT to provide users all over the world access to high-resolution base maps of 64 tropical countries, including PNG. These mosaics, produced using Planet Dove satellite, capture images to combat deforestation and forest degradation. The base maps, which cover the area between latitudes 30 degrees north and 30 degrees south, comprise countries with various rainforest habitats. Users can expect to see two mosaics a year between December 2015 and August 2020, followed by monthly mosaics from September 2020 for the next couple of years (Figure 2-6): The left side shows previous image and the right side shows the latest image and users can slide two images over the plot).

2.4. Assessment approach

The foundations of the 2015 assessment approach were maintained in the new assessment (

Figure 2-7). For this assessment, FAO and PNGFA used 10 operators based in Port Moresby who assessed sampling plots covering the land mass of PNG. The operators are made up of foresters and GIS experts from PNGFA and the FAO-PNG office, as well as local staff contracted by GGGI under the NDC Partnership.

The assessment had two phases, with 2,002 prioritized sampling plots to be assessed in Phase 1 and another 23,277 plots in Phase 2. In total, 24,851 were assessed, as the 23,277 plots in Phase 2 were reduced by eliminating other non-forest categories that were fully or purely non-forest and found to be likely the same in 2016, 2017, 2018 and 2019.

Phase 1: The main activity in Phase 1 was to determine land use change between 2016 and 2019. In total, 2,002 sampling plots were identified for verification or to be assessed for land use change or forest disturbance. The target plots were identified through a GIS analysis using previous assessment plots (2000–2015) with Global Forest Change (GFC)[17] data occurrence areas between 2016 and 2019.

The prioritized sampling plots (Table 2-2.) were those that had either direct or indirect tree cover loss in or around the plot. Direct occurrence implies that the tree cover loss area overlaps or partially overlaps the 1-hectare sampling plot. Indirect occurrence implies that the tree cover loss occurs around the plot vicinity, which is defined by the 4-kilometer grid and does not occur over or on the plot. This assessment of target plots started in 2020 but was halted due to COVID-19 restrictions. Restarting after the lockdown, it was completed by end of 2020 and reviewed in early 2021.

[17]University of Maryland. [https://storage.googleapis.com/earthenginepartners-hansen/GFC-2020-v1.8/download.html]

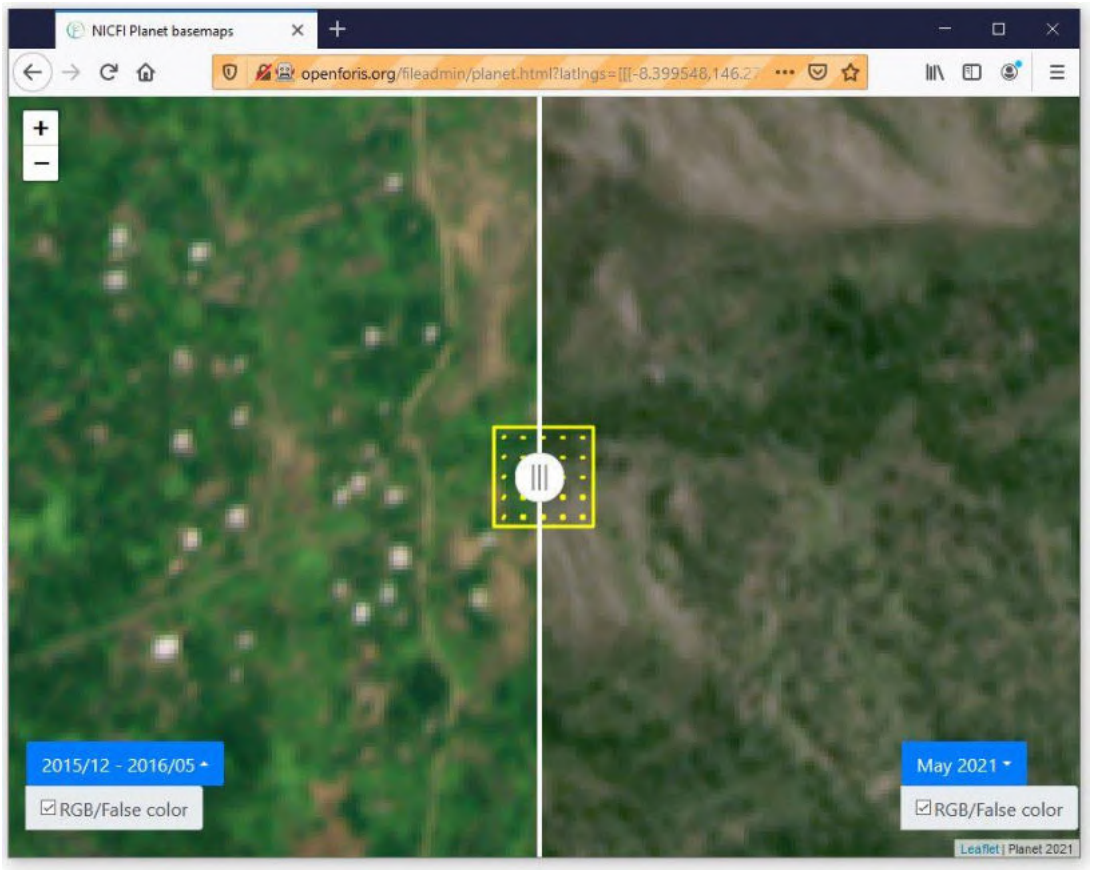

Figure 2-6. Dual map frames for swiping images of the NICFI Planet base map window showing a plot in PNG. Source: NICIFI Planet 2021.

Table 2-2. Identifying land use change using Global Forest Change (GFC) tree cover loss information for 2016–2019.

How the change was identified	**GFC tree cover loss extent**	**Number of plots**
GFC tree cover loss occurring in 2016, 2017, 2018 or 2019 is identified directly on the plot. This is suspected to be a potential land use change or forest disturbance	Minimum 1 hectare	481
GFC tree cover loss occurring either in 2016, 2017, 2018 or 2019 is identified indirectly on the plot	≥ 20 hectares occurring at the center plot	1,157
GFC tree cover loss-sum for the four-year period occurring indirectly on the plot	≥ 200 hectares occurring within the 4-kilometer grid	
GFC tree cover loss occurring in 2016 is identified directly on the plot. Verify if this is not continued from 2015. This are also suspected to be a potential land use change or a forest disturbance	Minimum 1 hectare	132
GFC tree cover loss occurring in 2015 is identified indirectly on the plot	≥ 20 hectares occurring at the center plot	202
GFC tree cover loss-sum for the four-year period occurring indirectly on the plot	≥ 200 hectares occurring within the 4-kilometer grid	
Evidence of tree cover loss in remote forest area, suspected to be infrastructure. Verify if these are mining activities	Minimum 1 hectare	30
		2,002

Phase 2: The main activity in Phase 2 was to update the data on forest disturbance and canopy cover, with a total of 23,277 sampling plots across the country needing to be reassessed (Table 2 3). Canopy cover was applied to all the samplings plots, and crop cover to the 2,479 cropland sampling plots using the updated data collection forms discussed in Section 2.1. For forest land, only 18,244 plots were rechecked and updated, using the forest disturbance data collection form.

Table 2 3. Number of target plots in each land use category required to be checked in Phase 2.

Land use	**Number of plots**
Forest land	18,244
Cropland	2,479
Grassland	1,252
Settlement	184
Wetland	1,017
Other land	34
No data	67
Total	**23,277**

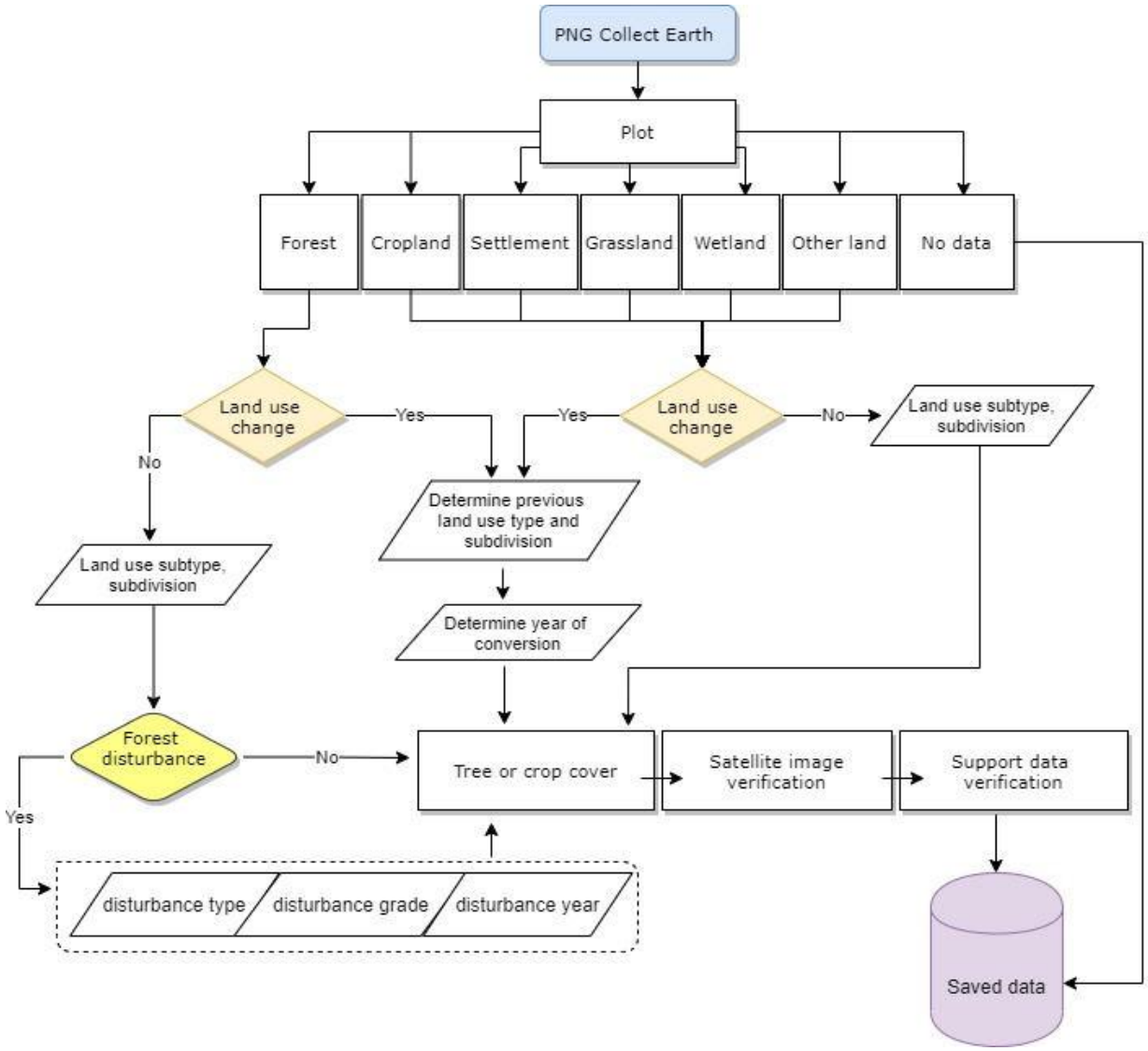

Figure 2-7. Overall steps of the PNG land use and land use change assessment

3. Data checking

This is the third time PNG has used Collect Earth for the national-level forest and land use change assessment, and the tool had been developed and improved through its use in PNG. In the initial assessment, several data errors caused by customizing the tool had to be corrected. Collect Earth is a user-friendly tool that requires minimal GIS and remote sensing skills, but a good understanding of the land. As such, the assessments were conducted by multiple local area officers, mainly from the PNGFA. It is therefore important to have quality assurance and control processes and systems in place, to ensure results are standardized and consistent. These processes were applied to all data during the assessment period during two data checking and cleansing sessions between November 2020 to March 2021. Figure 3-1 shows the general process applied to conduct the general quality assurance and control process.

Figure 3-1. Data checking and cleansing: general workflow

There were two main sources of error:

- Systematic or human integrity errors
- Operator errors from assessment

The first data checking session included resolving data integrity errors in sampling plots, such as missing or blank records, odd values, typing errors or incorrect input values. After cleansing these errors, two casual operators were hired to perform the second data cleansing session. After a brief training in November 2020, they worked on cleansing errors in the assessment from December 2020 to February 2021. These errors were detected after the Phase 1 assessment was completed, when the data were compared with GFC tree cover loss directly and indirectly occurring on the plot. The aim of the re-check analysis was to identify:

- GFC tree cover loss is directly or indirectly on the plot, but the operator says no land use change or forest disturbance, or potential GFC tree cover loss year is determined but the operator does not specify any year
- The operator says yes to land use change and there is GFC tree cover loss indirectly on the plot.
- GFC tree cover loss was occurring directly or indirectly on the plot in 2015, but the operator says land use change or forest disturbance occurs in 2016 or the other way around.

Once identified, the plots with errors were reassessed and modified to contain a land use conversion or allocated a human impact (Figure 3-2). Sampling plots were unchanged if tree cover was incorrect due to some image processing and analysis error. The data were tested again after the quality checks, which identified a few additional errors, leading to a second data cleansing session.

During the second session, it was found that forest disturbed by gardening was overestimated and was almost on a similar level to logging. Forest disturbed by others was also high and needed rechecking. To overcome this, sampling plots categorized as forest disturbed by gardening that were within logging concession and near outside the concession were reassessed. These improved the distribution of forest disturbance between 2016 to 2019.

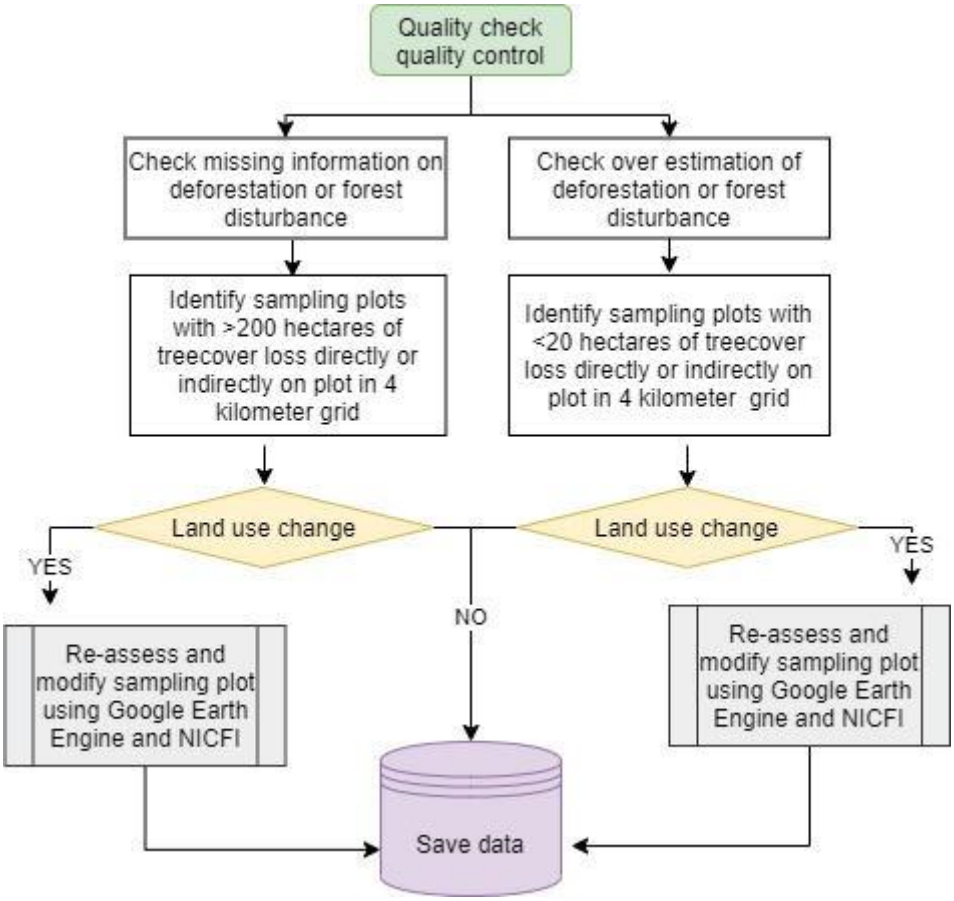

Figure 3-2. Flow chart showing reassessment of sampling plots with missing information and overestimation of deforestation or forest disturbance.

4. Data analysis

The data collected through this assessment were analyzed using Saiku, a software linked to Collect Earth that offers a user-friendly, web browser-based analytics solution to quickly and easily analyze data and create and share reports (Barber 2017, updated in 2018[18]). The solution connects to a range of Online Analytical Processing servers — including Mondrian; Microsoft Analysis Services; Systems, Applications and Products; Business Warehouse; and Oracle Hyperion — and can be deployed rapidly and cost effectively to allow users to explore data in real time (Barber 2017, updated in 2018).

Saiku has facilitated the analysis through simple drag-and-drop function. For example, to determine areas in hectares of only forest land subdivisions for 2019, a simple query (Figure 4-1) is developed by dragging and dropping the 'Area (Ha)' measure to COLUMNS and 'Land use subdivision' dimension to ROWS. Applying the filter function allows the user to focus the forest land subdivision, by dragging and dropping 'Land use category' dimension to FILTER. Once done the 'land use category' is double-clicked, the filter dialogue appears to choose the forest land category.

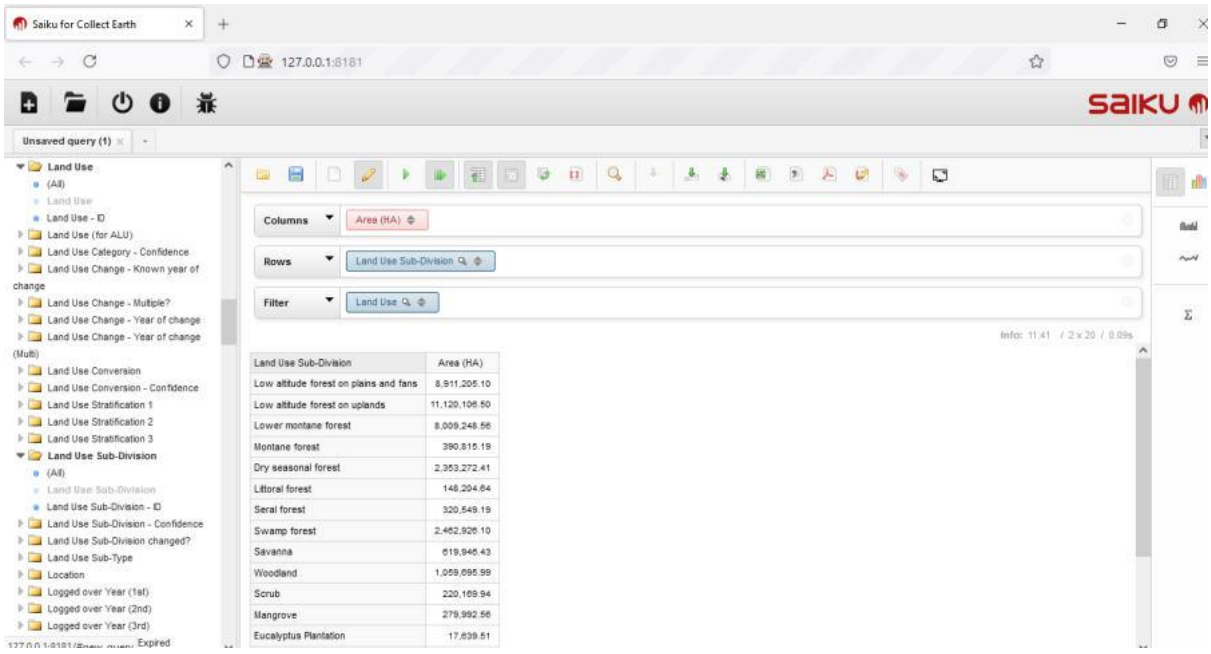

Figure 4-1. Analysis of data collected by Collect Earth using Saiku

A key function of Saiku is exporting the results in tables in graphics to other file formats such as PDF, JPEG and CSV. The commonly used Saiku export function in this assessment is exporting to MS Excel, allowing analysis to be performed using analysis functions that are unavailable in Saiku. In MS Excel, the data were reanalyzed to develop charts and graphs to present information that was relevant to the objective of the assessment. All derived

[18] https://buildmedia.readthedocs.org/media/pdf/saiku-documentation/latest/saiku-documentation.pdf

information is presented in the results sections of this report (Chapter 2 Forest and Land Use in 2019 and Chapter 3 Forest and Land Use Change During 2000-2019).

5. 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 underlies it, the analysis of uncertainties makes it possible to identify opportunities for improvement.

5.1. Qualitative analysis

In terms of forest and land use area and area change in, several major sources of error in estimating past land use trends from the Collect Earth exercise are expected, including random and systematic classification errors and random sampling errors.

To reduce the uncertainty of classification error, PNG defines the land use subdivision based on the existing classification system described Section 1.1.3 based on the carbon stock amount will be considered in future, based on the progress and results of the country's ongoing National Forest Inventory (NFI).

Potential sources of error contributing to uncertainty of the sampling assessment include sampling and human errors. Sampling error arises from unrepresentative samples and variability resulting from the use of samples, while human error arises from misinterpreting historical LULUCF (Potapov et al. 2008).

Several important error sources must also be considered when estimating carbon stocks for PNG's land-use types. The set of forest carbon stock values used in this assessment is taken from literature and little direct information is available on the error. Nonetheless, PNG expects the following typical errors to occur for carbon stock value:

- Random and systematic measurement errors, since the literature values were all derived from primary (usually plot-based) measurements where measurements can have error;
- Random sampling errors, since the plot-based measurements that underlie estimates reported in literature and in the 2006 IPCC guidelines only sample the forests.
- Systematic representation errors from using IPCC default values that might be imperfectly suitable for PNG's forests (systematic error).
- Systematic representation errors from approximating forest carbon stocks in all of PNG's forest types from literature values that were developed for the most abundant types of forests; and
- Systematic model errors from inferring forest degradation carbon stocks from measurements in a single type of forest.

5.2. Quantitative analysis

Implementing a statistically valid ground truth survey is not practical, considering that most of PNG is not accessible. As such, estimating the uncertainties of forest and land use change area is purely statistical, with no ground truth. The team used the 2006 IPCC guidelines,

complemented by Global Forest Observations Initiative (GFOI)'s 'Methods and Guidance Documentation (MGD)[19]on Estimating Uncertainties of Land Areas'[20], to estimate the uncertainty analysis by proportion without verification (it is always good practice to verify land classifications).

The team estimated the area of each land use category by multiplying the total area (A) by the proportion of sample plots in the specific land category. The percentage uncertainty associated with the area estimate was calculated as ±1.96 multiplied the standard error of A*i* divided by A*i*.

The standard error[21] of an area estimate was 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 is the total number of sample points

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

[19] https://www.fao.org/gfoi/components/methods-and-guidance-documentation/en/
[20] https://www.reddcompass.org/uncertainty
[21] Standard error is the standard deviation of the sampling distribution.

6. Estimating Forest Carbon Stock in PNG

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.

6.1. 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 6-2)

6.2. Above Ground Biomass

Above ground biomass of a unit forest area of each forest type and different type of disturbances needs to be estimated to calculate emissions from deforestation and forest degradation. Collecting such information was one of the major objectives of PNG's first National Forest Inventory. However, it needs a few years before the full information derived from the National Forest Inventory become available to utilize. Therefore, the review of existing information was conducted to identify the most appropriate aboveground biomass per unit area of each forest strata. The forest biomass information derived from small plot (e.g. 1 ha) in a specific forest was excluded from consideration because of the 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 lower than averages for tropical equatorial forest (Gibbs & Brown 2007: 328 t/ha; IPCC 2006: 350 t/ha; Lewis et al. 2009: 404 t/ha). Often well-developed large forests are preferred and selected for ecological studies, and consequently, aboveground biomass of study plots may be biased toward more productive forest. On the other hand, PSP plots are often located in proximity to roads or villages due to management reasons. They may have been subject to some degree of previous disturbance and it might cause lower carbon stock.

However 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), generate estimates in agreement with Fox et al. (2010). Consequently, it is considered most appropriate to apply the average above ground biomass provided by Fox et al. (2010) to estimate carbon stock of the primary forest of five lowland tropical rainforest type (low altitude forest on plains and fans, low altitude forest on uplands, littoral forest, seral forest and swamp forest) in PNG.

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. It is considered most appropriate to apply the above ground biomass for logged over lowland tropical rainforest reported in Fox et al. (2010) to logged forests of the five-forest type (low altitude forest on plains and fans, low altitude forest on uplands, littoral forest, seral forest and swamp forest) in PNG.

There is no information on aboveground biomass of the forests disturbed by anthropogenic activities other than commercial logging. This information will be available as National Forest Inventory proceeds. In this FRL submission, the same aboveground biomass used for estimating carbon stock of logged over forest is also used for the forest disturbed by anthropogenic activities other than commercial logging for the five forest types of lowland tropical rainforest discussed above. These five forest types consist of 64% of PNG's forest.

These data represent an average condition of degraded forests in PNG. Such an average condition results from an initial loss of carbon during a logging event and the regrowth of carbon during subsequent forest recovery. Using these data to build emission factors for forest degradation, as is undertaken below, results in estimating a net of losses from disturbance and gains from subsequent recovery.

The data represent logging in concessions primarily, and for small-scale logging activities may not be fully adequate. No high-quality information is currently available to estimate the degrading effects of small-scale activities, which is the data from large-scale logging activities were used in lieu. The impact of this simplification is deemed to be small, since small-scale logging accounts for only <1% of all logging by area.

6.2.1. IPCC Guideline (2006)

Other than five forests type discussed in the above section, no sufficient information on above ground biomass is available. IPCC Guideline (2006: Table 6-2) 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) are correlated well. Figure 6-1 shows similar distribution of montane vegetation and dry vegetation between the PNG Forest Basemap (PNGFA 2014) and Global Ecological zone (FAO 2001). The description of Ecological Zone in tropical climate is summarised in Table 6-1.

Table 6-1: Summary of Climate Domains and Ecological Zone (FAO 2001) relevant to PNG

Climate domain		Ecological zone	
Domain	Domain criteria	Zone	Zone criteria
Tropical	all months without frost; in marine areas, temperature >18°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

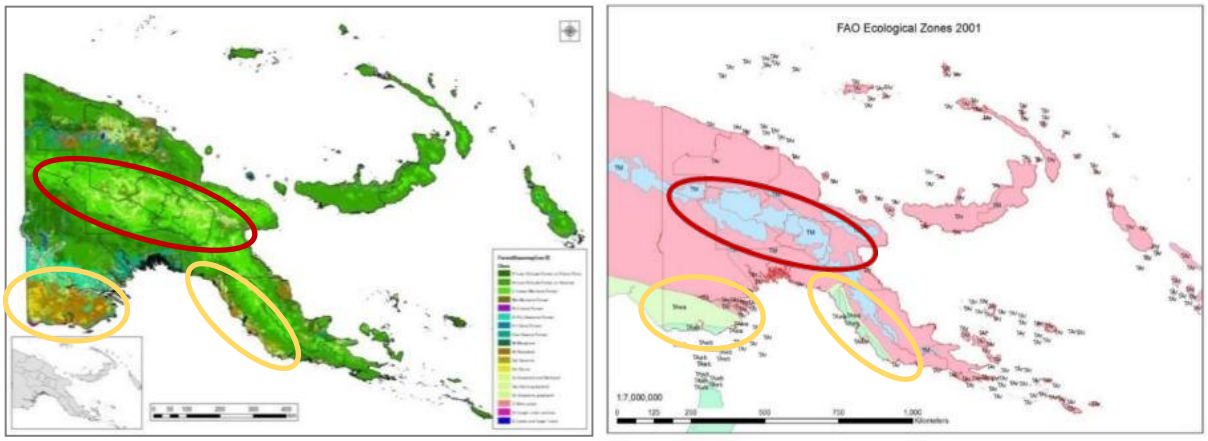

Figure 6-1: Correlation between PNG forest classification in Basemap (Left: PNGFA/JICA 2014) and Global Ecological Zone (Right: FAO 2001). The red ellipse shows the distribution of montane vegetation and the yellow ellipse shows the distribution of dry vegetation.

The default values of IPCC Guidelines for above ground biomass for associated Ecological Zone were applied to each of all other forest type excluding the five-forest type, which country specific value was available as shown in Table 6-2. 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 value. 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 6-2). Several carbon pools are not included in the scope of this assessment and appropriate values will become available after the National Forest Inventory is completed. All the Emission Factors used will be replaced with the country specific values obtained through the National Forest Inventory. After National Forest Inventory is completed then PNG will report near Tier 2-3 level of GHG emission of LULUCF sector.

For some of the forest types, the carbon stock in degraded forests had to be estimated as a percentage reduction from the primary forest carbon stock. The percentage reduction was estimated at 65.47% based on the measurements for low altitude forest on plains and fans.

Table 6-2: Above and below ground biomass in a unit area of PNG forests

Forest type	Human impact	Aboveground biomass			Belowground biomass	
		Source	Ecological zone as per IPCC guidelines	Dry matter (tonnes/ha)	Dry matter (tonnes/ha)	Root to shoot ratio
Low altitude forest on plains and fans	Primary	Fox *et al.* (2010)	Tropical rainforest	223	83	0.37
	Logged			146	54	0.37
	Other disturbance			146	54	0.37
Low altitude forest on uplands	Primary			223	83	0.37
	Logged			146	54	0.37
	Other disturbance			146	54	0.37
Littoral forest	Primary			223	83	0.37
	Logged			146	54	0.37
	Other disturbance			146	54	0.37
Seral forest	Primary			223	83	0.37
	Logged			146	54	0.37
	Other disturbance			146	54	0.37
Swamp forest	Primary			223	83	0.37
	Logged			146	54	0.37
	Other disturbance			146	54	0.37
Lower montane forest	Primary	IPCC Guideline (2006)	Tropical mountain system	140	38	0.27
	Logged			92	25	0.27
	Other disturbance			92	25	0.27
Montane forest	Primary			140	38	0.27
	Logged			92	25	0.27
	Other disturbance			92	25	0.27
Mountain coniferous forest	Primary			140	38	0.27
	Logged			92	25	0.27
	Other disturbance			92	25	0.27
Dry seasonal forest	Primary		Tropical dry forest	130	36	0.28
	Logged			85	24	0.28
	Other disturbance			85	24	0.28
Woodland	Primary			130	36	0.28
	Other disturbance			85	24	0.28
Savanna	Primary			130	36	0.28
	Other disturbance			85	24	0.28
Scrub	Primary		Tropical shrubland	70	28	0.4
	Other disturbance			46	18	0.4
Mangrove	Primary		Tropical wet Mangrove	192	94	0.49
	Other disturbance			126	62	0.49
Forest plantation	Primary		Tropical rainforest (plantation)	150	56	0.37
	Other disturbance			98	36	0.37

6.3. Forest Carbon Stock and Emission Factors

6.3.1. Carbon Stock in Forest Land

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

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

Where:

A is the forest strata area in hectares
B is the unit total living biomass in tons per hectare
C is the carbon stock in tons per hectare
R is the Root-to-shoot ratio
CF is the Carbon fraction i.e. 0.47 from IPCC 2006
Note: to calculate carbon stock as tCO2, C*44/12

The forest carbon stock in PNG was estimated as 3,982 million ton (Mt) (Annex 2.10). This is lower than the estimate by Bryan et al. (4770 Mt, 2010a) and lower middle of the 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 low estimate of this assessment is largely due to the lower above ground biomass per unit area applied. If the default value for Tropical rain forest (300 t/ha) in IPCC Guidelines (2006) was applied 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 5814 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 will provide more reliable country specific information within a couple of years. It will enable PNG to estimate forest carbon stock in PNG significantly more accurate.

6.3.2. Calculation of Emission Factors

The Emission Factors for emissions in primary deforestation, secondary deforestation and forest degradation (Table 6-3) are calculated as follows:

Carbon stock = (Aboveground biomass + belowground biomass) x 0.47 (IPCC Guidelines 2006)

Emission factor = (Carbon stock before land use conversion – Carbon stock after land use conversion) x 44/12 (IPCC Guidelines 2006)

The Removal Factors for removals in carbon stock enhancement and for post-deforestation regrowth are established as follows;

Removal factor = (Increment in above-ground biomass + increment in below-ground biomass) x 0.47 (IPCC Guidelines 2006) x 44/12 (IPCC Guidelines 2006)

For carbon stock enhancement, this calculation is carried out for plantations since only there the conversion from non-forests to forests was observed. The removal factor amounts to 24.7 tCO2e /ha /yr, based on a default increment of 9.5 m3 merchantable volume /ha /yr, an average biomass

conversion and expansion factor of 1.1 and a root-to-shoot ratio of 0.37 as per the 2006 IPCC guidelines.

For post-deforestation regrowth, the calculation is carried out drawing on the mean annual increment calculated above. Applying a mean annual increment is a simplification because of two reasons. First, for some of the vegetation types considered growth levels off after relatively short periods of eight years. Second, once that happens, the related areas of individual vegetation types should give greater weight for vegetation types with longer growth periods for establishing a weighted mean. Calculations of post-deforestation regrowth may be refined in future iterations.

Values for post-deforestation land use types were derived from IPCC default values. The values of "cropping systems containing perennial species" were applied to PNG's land use categories "shifting cultivation" and "subsistent agriculture, permanent". This match of categories was undertaken in a group discussion among sector experts from the CCDA and the PNG.

Table 6-3: Emission Factor of deforestation of primary forest, deforestation of degraded forest and forest degradation

Land Use Subdivision	EF deforestation (primary forest)	(tCO2e /ha /yr)	
		EF deforestation (degraded forest)	EF forest degradation
Low altitude forest on plains and fans	526.50	344.70	181.79
Low altitude forest on uplands	526.50	344.70	181.79
Low Montane Forest	306.41	200.61	105.80
Montane forest	306.41	200.61	105.80
Montane Coniferous forest	306.41	200.61	105.80
Dry Seasonal forest	286.76	187.75	99.02
Littoral Forest	526.50	344.70	181.79
Seral forest	526.50	344.70	181.79
Swamp Forest	526.50	344.70	181.79
Savannah	286.76	187.75	99.02
Woodland	286.76	187.75	99.02
Shrub	168.89	110.57	58.32
Mangrove	493.01	322.78	170.23
Plantation Forest	354.15	231.86	122.28

Annex 2: Supplementary Materials

Annex 2.1: Descriptions of Land use Subtypes and Subdivisions

Annex 2.1-A: Forest land subdivisions and the descriptions

Land use subtype and subdivision		Description
Natural forest (Hammermaster and Saunders 1995)		
1	**Low-altitude forest on plains and fans (P)**	Distinguished by crown size, canopy height, and canopy closure, elevation below 1,000 metres and species composition. The key factor that differentiates plains and fans forests is the gentle slope and flat landform characteristics. The three main low latitude forest types on plains and fans are large to medium crowned forest (Pl), open forest (Ps) and small-crowned forest (Ps).
	Large-to-medium-crowned forest (Pl)	A tall forest with average canopy height of 30–35 metres. Emergent trees often attain and sometimes exceed 50 metres. The canopy is irregularly open and irregularly uneven in profile. The forest occurs on well to imperfectly drained alluvial plains and on gently sloping undissected fans.
	Open forest (Po)	Canopy height can reach 30 metres, often with large crowned emergents to 40 metres. 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 includes strangling figs, and Octomeles sumatrana in frequently flooded areas.
	Small-crowned forest (Ps)	Dense, even canopy of small crowns, 25–30 metres in height, with no emergents. This subtype occurs on flat to gently undulating plains and fans where soils are often gravelly and/or poorly drained. It may contain mixed species similar to those of the open forest, but a single species (for example, Intsia, dipterocarps such as Hopea and Vatica) often dominates the canopy.
2	**Low-altitude forest on uplands (H)**	Distinguished by crown size, canopy height, and canopy closure, elevation below 1,000 metres and species composition. The key factor that differentiates upland forests is the slope. The three main low latitude forest types on uplands are large-crowned forest (Hl), medium-crowned forest (Hm) and small-crowned forest (Hm).
	Large-crowned low-altitude forest on uplands (Hl)	Uneven canopy, 30–35 metres in height with a 60–80% closure. Emergents can reach 40 metres. Large (70–89cm) stem diametres predominate. Very similar to the large- to medium-crowned forest on plains and fans in both structure and floristic content.
	Medium-crowned low-altitude forest on uplands (Hm)	Canopy height of 25–30 metres, generally only slightly uneven, with a 60–80% crown closure. Except for Araucaria, emergents rarely exceed 40 metres. Very large (90cm+) stem diametres are rare, except for Araucaria. Floristically, the forest is very mixed.
	Small-crowned low-altitude forest on uplands (Hs)	Relatively even canopy, 20–30 metres in height, with a 60–80% closure and no emergents. Large (90cm+) stem diametres are rare; most trees fall into the medium (50–69 centimeter) to small (30–49centimeter) classes. May be a mixed forest which is poorly developed due to adverse site or climatic conditions or a forest in which small-crowned (<8-meter) trees predominate the canopy.
3	**Lower montane forest (L)**	A small crowned forest between 1000 - 3000m elevation ranges. The two main lower montane forest type are small-crowned (Ls) and small-crowned forest with conifers (Lc).
	Small-crowned lower-montane forest (Ls)	Even to slightly undulating canopy, 20–30 metres in height. Canopy closure varies from dense to slightly open, and canopy height decreases with increasing altitude. Stem diametres are generally medium (50–69 centimetres) to small (30–49 centimetres). The forest occurs throughout the mountain ranges in the 1,400-3,400-meter altitude range.

	Small-crowned forest with conifers (Lc)	Canopy height of 15–25 metres with emergent conifers. Crowns are small (<8 metres) to very small. Although stem diametres of associated broadleaf species are generally small (30–49 centimetres), coniferous stem diametres often exceed 50 centimetres. The forest occurs in many places in the mountain ranges above 2,400 metres altitude.
4	**Montane forest (Mo)**	A "mossy forest" with a dense, even, dark toned, almost velvety textured canopy, 5–15 metres in height, usually without emergent. Stems are very thin and crooked. The forest occurs throughout the higher mountain ranges above 3,000 metres.
5	**Dry seasonal forest (D)**	Fairly open canopy, 20–25 metres in height with emergents to 30, and occasionally 40, metres. Stems are often low-branched and crooked.
7	**Littoral forest (B)**	A mixed crown forest with irregularly open, uneven canopy of medium (8–15 meter) crowns, 20–30 metres in height. Other littoral forest types inlcude: forest with casuarina equisetifolia (BCe) and forest with melaeuca leucandendron (BMl).
6	**Seral forest (Fri)**	Irregularly open to open, uneven, medium (8–15-meter) to small (<8-meter) crowned canopy up to 30 metres in height. Large-crowned (>15-meter) emergents, 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. Other seral forest types include; riverine successions with Casuarina grandis (FriCg), riverine successions with Eucalyptus deglupta, commonly known as Kamarere (FriK), riverine successions with Terminalia brassii (FriTb), and volcanic successions (Fv)
7	**Swamp forest (Fsw)**	Irregularly open, almost even canopy of medium (8–15-meter) to very small (<8-meter) crowns, 20–30 metres in height. A dense understory of sago palms is often visible. In some intermontane basins, the forest is extremely low in height, up to 5 metres and can be a pure stand of Nothofagus or Poducarpus. Swamp forest with Campnosperma (FswC) is a dense, even canopy of small crowns, 20–30 metres in height. Although rarely seen under the dense canopy, there is a lower layer of sago palms. Other swamp forest types include: swamp forest with melaleuca leucadendron (FswML) and swamp forest with terminalia brassii (FswTb).
8	**Savanna (Sa)**	Low tree layer, generally less than 6 metres tall, and open. The ground layer is clearly visible and is dominated by grasses with some shrubs and herbs. Savanna is further subdivided into Savanna with gallery forest (Saf) and Savanna with Melaleuca leucadendron (SaMl).
9	**Woodland**	Low and open tree layer but the ground layer is usually dense and may include shrubs, herbs or grasses, or any combination of these three. Sub-classes include riverine successions dominated by woodland (Wri), riverine successions with *Casuarinas grandis* woodland (WriCg), volcanic successions dominated by woodland (Wv), swamp woodland (Wsw) and swamp woodland with *Melaleuca leucandendron* (WswMl).
10	**Scrub**	A community of dense shrubs up to 6 metres in height, with or without low, scattered trees. Occasional low trees may be present but mainly for the most part the scrub comprises of the tree - fern *Cyathea* with a tangled mass of scrambling *Bambusa*.
12	**Mangrove**	A wide range of communities from almost bare tidal flats with scattered halophytic herbs, to mangrove forest over 30 metres in height.
13.Plantation forest		
13.01	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 commercial or ecological forestry management.
13.02	Eucalyptus	Planted forest predominantly composed of exotic eucalyptus tree species established through planting and/or deliberate seeding. Mostly Australian evergreen trees or occasionally shrubs of the myrtle family that have rigid entire leaves and umbellate flowers and are widely cultivated for their gums, resins, oils, and woods.
13.03	Balsa	Planted forest predominantly composed of exotic balsa tree species established through planting and/or deliberate seeding.
13.04	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 grows to a height of 90 metres. The bole is straight, cylindrical and self-pruning up to 35 metres or more and up to 300 centimetres in diameter.
13.05	Pinus	Planted forest predominantly composed of exotic Pinus tree species established through planting and/or deliberate seeding.
13.06	Acacia	Planted forest predominantly composed of exotic Acacia tree species established through planting and/or deliberate seeding.
13.07	Terminalia	Planted forest predominantly composed of exotic Terminalia tree species established through planting and/or deliberate seeding.
13.08	Other	Any other forest plantation composed of trees established through planting and/or deliberate seeding (other species not captured are covered under this class – an example is rain tree)

Annex 2.1-B: Forest disturbance types and descriptions.

Disturbance type	Description
Manmade	
Commercial logging	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. Only selective logging is practiced in PNG, for harvesting timber at a certain diameter. For commercial logging, a permit or license must be obtained for an acquired boundary of a forest area for a longer-term contract. Clear felling as a commercial logging activity can be practiced with a Forest Clearance Authority to harvest timber in areas that are approved for agricultural plantation activities. These areas are clearly distinguished by straight road lines and recognizable geometric patterns.
Gardening	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 as result of shifting cultivation.
Portable sawmill	Small-scale activity of harvesting timber for domestic use within a forest area using a sawmill and chainsaw.
Fire	The action of setting alight (human impact), which results in burning within a forest area. Includes slash and burn for gardening or hunting.
Other	Any disturbance to the forest caused by humans not listed here.
Mining	Any temporary/permanent roads and built-up areas linked to mining and petroleum activities.
Infrastructure	Permanent or temporary construction features for public utilities, including communication, transportation, power transmission and urbanization.
Natural	
Erosion	Wearing away or loss of vegetation due to natural agents, such as wind and water.
Flooding	Excessive waterlogging over a forest area.
Landslide	Piece of land with vegetation swept away due to unstable conditions caused by rain or by other natural phenomena.
Other	Any disturbance to the forest that is caused naturally not listed here.
No impact	
No Impact	No disturbance within or surrounding the plot.
Unknown	A disturbance that is neither manmade nor natural.

Annex 2.1-C: Cropland, Grassland, Wetland, Settlement and Other land Subtype and Subdivision descriptions

Land use	Land use subtype and subdivision		Descriptions
Cropland	***Subsistence (family) agriculture***		
	1	Permanent	Long-term gardening without moving to a new piece of land. The activity differs in PNG lowlands and highlands, dominating in the latter due to land sensitivity and close proximity to individual household or family unit/clan areas.
	2	Shifting	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	Difficult to class as permanent or shifting but the area is near or in close proximity to populated areas understood to be subsistence agriculture.
	Commercial agriculture		
	4	Tea	Large-scale estate meant for farming that specializes in tea planting.
	5	Sugar	Large-scale estate meant for farming that specializes in sugarcane planting.
	6	Coffee	Large-scale estate meant for farming that specializes in coffee planting.

	7	Oil palm	Large-scale estate meant for farming that specializes in oil palm planting.
	8	Cocoa	Large-scale estate meant for farming that specializes in cocoa planting.
	9	Coconut	Large-scale estate meant for farming that specializes in coconut planting. This includes abandoned coconut areas.
	10	Cocoa/coconut	Large-scale estate for farming that specializes in cocoa/coconut intercropping.
	11	Rubber	Large-scale estate meant for farming that specializes in rubber tree planting. This includes abandoned rubber areas.
	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. This also includes any other cropland types not listed.
Grassland	1	Herb land	Unmanaged grassland areas below 1,000 metres above sea level. Also includes trees that are sparsely distributed and fall below the forest threshold.
	2	Rangeland	Fenced grassland area that is managed for grazing in a confined area.
	3	Other	Neither rangeland nor herb land; mainly used for alpine grassland areas (>1,000 metres above sea level).
Wetland	1	River	A natural flowing watercourse, usually freshwater, that flows towards an ocean, sea, or lake.
	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. Inland water body.
	3	Dam	A manmade barrier that stops or restricts the flow of surface water or underground streams.
	5	Nipa swamp	Swamp dominated by Nipa palms, often associated with mangroves in estuarine transition zones.
	6	Other swamp	Neither river, lake, dam, nor nipa swamp. Other wetland areas not described in this document or difficult to classify.
Settlement	1	Village	Permanent human settlement of more than 10 houses comprising a community with more than one clan or tribe in a rural area. Houses are more densely distributed than in the hamlets. Scattered subsistence agriculture is usually evident in the surroundings.
	2	Hamlet	Cluster of (usually three to nine) permanent or semi-permanent houses scattered broadly over the landscape or area of interest. Hamlet inhabitants (usually one family or clan) belong to a nearby larger community or village.
	3	Large settlement	Cities, towns and district centers. Includes mining townships that are located away/far from the mining sites.
	4	Infrastructure	Permanent structures such as roads (paved or unpaved), bridges, airstrips/airports, clinics, schools and playing fields located outside of a village or large settlement or in remote areas.
Other land	1	Bare land	Non-vegetated land that is either barren for long periods of time, caused by natural or human-induced activities.
	2	Sand	Non-vegetated land such as sandy beaches, sand banks.
	3	Rock	Non-vegetated surface, mainly composed of rock. Highly likely to be found near volcanoes or on very high-altitude mountain tops.

Annex 2.2: Cropland types and the areas in each province

Province	Area in hectares												*Total*
	Permanent	**Shifting**	**Not Sure**	**Tea**	**Coffee**	**Oil palm**	**Cocoa**	**Coconut**	**Other**	**Cocoa/ Coconut**	**Sugar**	**Rubber**	
Western	9,813.48	60,843.57	1,962.70	-	-	-	-	-	5,888.09	-	-	3,925.39	**82,433.23**
Gulf	-	31,670.33	1,979.40	-	-	-	-	-	-	-	-	-	**33,649.73**
Central	38,840.78	207,798.15	1,942.04	-	-	-	-	-	5,826.12	-	-	5,826.12	**260,233.20**
Oro	15,515.83	246,313.72	--	-	-	54,305.39	-	-	-	-	-	-	**316,134.94**
Milne Bay	17,610.49	260,243.89	3,913.44	-	-	19,567.21	-	15,653.77	-	-	-	-	**316,988.79**
Hela	77,529.43	123,251.91	-	-	-	-	-	-	-	-	-	-	**200,781.34**
Southern Highlands	81,129.07	185,437.86	1,931.64	-	-	-	-	-	-	-	-	-	**268,498.57**
Enga	71,882.79	203,991.71	-	-	-	-	-	-	-	-	-	-	**275,874.50**
Western Highlands	77,919.91	103,564.44	493.16	1,479.49	5,917.97	-	-	-	-	-	-	-	**189,374.98**
Jiwaka	47,707.92	89,021.99	3,442.84	1,475.50	5,902.01	-	-	-	-	-	-	-	**147,550.26**
Chimbu	33,419.22	115,984.36	-	-	5,897.51	-	-	-	-	-	-	-	**155,301.09**
Eastern Highlands	115,581.52	190,023.85	1,959.01	-	11,754.05	-	-	-	-	-	-	-	**319,318.43**
Morobe	29,292.36	431,574.04	-	-	-	9,764.12	-	3,905.65	1,952.82	-	3,905.65	-	**480,394.64**
Madang	133,185.54	282,273.83	1,987.84	-	-	9,939.22	-	11,927.06	-	9,939.22	3,975.69	-	**453,228.40**
East Sepik	147,057.86	254,900.29	5,882.31	-	-	-	5,882.31	-	-	-	-	-	**413,722.78**
West Sepik	34,121.24	82,292.41	2,007.13	-	-	38,135.50	-	-	2,007.13	-	-	-	**158,563.42**
West New Britain	21,596.52	70,679.54	-	-	-	174,735.52	-	1,963.32	-	1,963.32	-	-	**270,938.22**
East New Britain	39,216.03	123,530.48	-	-	-	29,412.02	-	39,216.03	1,960.80	17,647.21	-	-	**250,982.56**
Manus	5,582.95	19,540.32	-	-	-	-	-	4,187.21	-	-	-	-	**29,310.48**
New Ireland	23,346.48	118,677.96	1,945.54	-	-	7,782.16	-	11,673.24	-	7,782.16	-	1,945.54	**173,153.10**
AROB	91,006.24	225,537.21	-	-	-	-	7,913.59	49,459.92	1,978.40	5,935.19	-	-	**381,830.55**
Total:	**1,111,355.65**	**3,427,151.88**	**29,447.06**	**2,954.99**	**29,471.54**	**343,641.14**	**13,795.90**	**137,986.19**	**19,613.36**	**43,267.10**	**7,881.34**	**11,697.05**	**5,172,870.88**

Annex 2.3: PNG's Annual deforestation from 2000 to 2019

Year of change	Total forest area (ha)	Total deforestation (ha)	Forest types with deforestation (2001-2019)							Annual rate of deforestation
			Low altitude forest (below 1000m)		Lower montane forest	Dry seasonal forest	Swamp forest	Savanna	Woodland	
			On plains and fans	On uplands						
2000	**36,303,784**	-	-	-	-	-	-	-	-	-
2001	**36,291,969**	**11,815**	11,821	-	-	-	-	-	-	**0.03%**
2002	**36,283,940**	**8,029**	-	2,007	4,014	-	2,007	-	-	**0.02%**
2003	**36,274,135**	**9,805**	7,851	-	1,963	-	-	-	-	**0.03%**
2004	**36,267,195**	**6,940**	3,995	-	2,952	-	-	-	-	**0.02%**
2005	**36,256,832**	**10,363**	6,346	4,014	-	-	-	-	-	**0.03%**
2006	**36,250,855**	**5,977**	4,014	-	-	-	-	-	-	**0.01%**
2007	**36,240,998**	**9,857**	5,910	1,942	2,007	-	-	-	-	**0.03%**
2008	**36,231,163**	**9,835**	3,970	3,924	1,943	-	-	-	-	**0.03%**
2009	**36,216,963**	**14,200**	6,337	5,909	1,963	-	-	-	-	**0.04%**
2010	**36,203,121**	**13,842**	11,887	-	1,966	-	-	-	-	**0.04%**
2011	**36,179,675**	**23,446**	10,262	3,902	7,964	-	-	1,315	-	**0.06%**
2012	**36,149,944**	**29,731**	15,804	9,989	1,988	1,963	-	-	-	**0.08%**
2013	**36,110,311**	**39,633**	15,868	7,891	13,955	-	-	-	1,963	**0.11%**
2014	**36,084,136**	**26,176**	19,841	7,884	493	-	-	-	-	**0.08%**
2015	**36,050,759**	**33,376**	15,807	9,893	1,959	-	3,951	-	1,957	**0.09%**
2016	**36,018,798**	**31,961**	20,176	3,965	7,838	-	-	-	-	**0.09%**
2017	**35,994,107**	**24,691**	9,902	63,986	4,433	1,963	2,007	-	-	**0.07%**
2018	**35,970,071**	**24,036**	10,262	11,767	2,007	-	-	-	-	**0.07%**
2019	**35,950,979**	**19,092**	3,906	8,344	6,841	-	-	-	-	**0.05%**

Annex 2.4: Area of forest type in each province in Papua New Guinea.

No.	Province	Natural Forest												Planted Forest	Total
		Low altitude forest below 1000m		Montane forest		Dry seasonal forest	Littoral forest	Seral forest	Swamp forest	Savanna	Woodland	Scrub	Mangrove		
		On plains and fans	On uplands	Lower (1000-2000m)	Upper (>2000m)										
1	Western	2,796,842	771,339	274,777	7,851	2,353,272	90,284	113,836	598,622	427,868	684,981	98,135	51,030	0	**8,268,838**
2	Gulf	1,248,999	1,041,162	172,207	0	0	11,876	35,629	564,128	19,794	21,773	5,938	53,444	0	**3,174,951**
3	Central	337,915	967,135	683,598	34,957	0	3,884	23,304	54,377	135,943	139,827	7,768	44,667	0	**2,433,375**
4	NCD	0	0	0	0	0	0	0	0	5,259	0	0	0	0	**5,259**
5	Oro	327,772	688,515	494,567	32,971	0		34,911	77,579	25,213	71,761	15,516	7,758	0	**1,776,562**
6	Milne Bay	259,170	389,729	138,354	0	0	15,589	1,949	5,846	5,846	40,922	1,949	40,922	3,897	**904,172**
7	Hela	3,976	103,373	659,994	17,891	0	0	0	0	0	0	0	0	0	**785,234**
8	Southern Highlands	48,291	527,339	538,929	13,522	0	0	3,863	11,590	0	0	0	0	1,932	**1,145,465**
9	Enga	3,886	52,455	613,918	130,166	0	0	0	0	0	0	0	0	0	**800,425**
10	Western Highlands	4,438	21,699	141,045	11,343	0	0	0	0	0	0	0	0	0	**178,525**
11	Jiwaka	5,902	74,759	210,505	22,133	0	0	0	0	0	0	0	0	0	**313,298**
12	Chimbu	0	127,779	269,320	7,863	0	0	0	0	0	0	0	0	0	**404,962**
13	Eastern Highlands	1,949	58,462	520,312	15,590	0	0	0	0	0	0	0	0	5,846	**602,159**
14	Morobe	121,075	796,752	1,380,646	54,679	0	0	1,953	3,906	0	3,906	27,340	0	11,717	**2,401,973**
15	Madang	657,702	810,242	495,258	29,715	0	0	37,640	103,014	0	5,943	7,924	0	5,943	**2,153,381**
16	East Sepik	911,759	982,347	233,332	3,922	0	0	27,451	698,035	0	74,509	37,255	21,568	0	**2,990,177**
17	West Sepik	722,567	1,589,648	630,239	8,029	0	0	26,093	256,913	0	4,014	4,014	2,007	0	**3,243,525**
18	West New Britain	882,642	708,075	64,727	0	0	11,769	1,961	39,229	0	0	0	15,691	5,884	**1,729,979**
19	East New Britain	182,121	753,942	278,077	0	0	5,875	1,958	0	0	0	1,958	3,917	15,666	**1,243,515**
20	Manus	91,897	46,413	0	0	0	928	0	9,747	0	0	464	6,034	0	**155,483**
21	New Ireland	182,127	408,816	106,563	0	0	0	1,938	3,875	0	0	0	29,063	1,938	**734,319**
22	AROB	116,480	201,372	102,660	0	0	7,897	7,897	35,536	0	11,845	11,845	9,871	0	**505,403**
	Total:	**8,907,509**	**11,121,353**	**8,009,029**	**390,631**	**2,353,272**	**148,102**	**320,383**	**2,462,395**	**619,922**	**1,059,481**	**220,106**	**285,971**	**52,823**	**35,950,979**

Annex 2.5: 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	0	**269,987**
2501-2600	0	0	293,919	0	0	0	0	0	0	0	1,953	0	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	0	**250,766**
2701-2800	0	0	212,073	0	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	0	**212,751**
2901-3000	0	0	180,262	0	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	0	**158,213**
3101-3200	0	0	0	99,086	0	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	0	**58,219**
3301-3400	0	0	0	38,658	0	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	0	**18,114**
3501-3600	0	0	0	12,681	0	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	0	**5,865**
3701-3800	0	0	0	1,988	0	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**

Annex 2.6: Area of forest types affected by anthropogenic activities

Forest type	Commercial Logging	Fire	Gardening	Other	Portable Sawmill	Mining	Infrastructure	No impact	*Total (ha)*
Low altitude forest on plains and fans	2,461,367.74	165,416.02	681,296.00	81,366.06	30,193.16	-	4,014.26	5,481,260.50	**8,904,913.74**
Low altitude forest on uplands	1,373,957.32	86,303.49	1,041,396.88	54,477.47	29,772.76	3,933.38	1,960.77	8,500,910.85	**11,092,712.94**
Lower montane forest	33,239.92	122,021.95	1,160,485.80	39,591.30	5,844.85	-	-	6,640,222.42	**8,001,406.23**
Montane forest	-	19,476.67	10,207.05	-	-	-	-	361,131.46	**390,815.19**
Dry seasonal forest	109,910.97	100,097.49	33,365.83	80,470.53	-	-	-	2,029,427.58	**2,353,272.41**
Littoral forest	5,887.44	1,956.72	9,809.77	-	-	-	-	130,550.70	**148,204.64**
Seral forest	7,813.60	5,888.09	15,680.02	5,831.78	3,921.43	-	-	281,414.27	**320,549.19**
Swamp forest	77,373.57	39,235.85	113,011.50	43,329.95	7,882.26	-	-	2,182,092.97	**2,462,926.10**
Savanna	-	280,768.03	3,904.73	9,790.26	-	-	-	323,541.37	**618,004.39**
Woodland	17,643.61	244,404.63	46,914.69	64,722.53	1,942.04	-	-	684,068.49	**1,059,695.99**
Scrub	4,432.49	31,346.20	3,917.87	3,925.39	-	-	1,960.77	174,587.22	**220,169.94**
Mangrove	5,889.96	1,942.04	15,627.68	31,366.64	1,979.40	-	-	223,186.85	**279,992.56**
Eucalyptus Plantation	9,809.04	-	-	1,945.54	-	-	-	5,884.92	**17,639.51**
Balsa Plantation	1,960.80	-	-	3,921.60	-	-	-	-	**5,882.40**
Araucaria Plantation	3,905.65	5,858.47	-	-	-	-	-	-	**9,764.12**
Pinus Plantation	-	5,849.66	-	-	-	-	-	1,959.01	**7,808.67**
Acacia Plantation	3,975.69	-	-	1,987.84	-	-	-	-	**5,963.53**
Terminalia Plantation	-	-	-	-	-	-	-	3,913.44	**3,913.44**
Rain Tree	-	-	-	1,952.82	-	-	-	-	**1,952.82**
Total (ha):	**4,117,167.80**	**1,110,565.32**	**3,135,617.83**	**424,679.72**	**81,535.89**	**3,933.38**	**7,935.81**	**27,024,152.06**	**35,905,587.81**
% disturbed	**11.47**	**3.09**	**8.73**	**1.18**	**0.23**	**0.01**	**0.02**	**75.26**	**100.00**

Annex 2.7: Forest converted to other land use in Provinces between 2000 and 2019

Province	Area-of-forest-converted-to-cropland-(ha)						Area-of-forest-converted-to-settlement			*Total*	*%*
	Permanent	Shifting	Oil-palm	Cocoa	Coconut	Other	Village	hamlet	Large-Settlement		
Western	1,963	25,515	-	-	-	5,888	-	-	-	**33,366**	9.4%
Gulf	-	3,959	-	-	-	-	-	-	-	**3,959**	1.1%
Central	-	7,768	-	-	-	-	-	-	-	**7,768**	2.2%
NCD	-	-	-	-	-	-	-	-	1,315	**1,315**	0.4%
Oro	-	11,637	-	-	-	-	-	-	-	**11,637**	3.3%
Milne-Bay	-	27,281	-	-	1,949	-	-	-	-	**29,230**	8.3%
Hela	-	3,976	-	-	-	-	-	-	-	**3,976**	1.1%
SHP	-	1,932	-	-	-	-	-	-	-	**1,932**	0.6%
Enga	-	5,828	-	-	-	-	-	-	-	**5,828**	1.7%
WHP	1,479	1,479	-	-	-	-	-	-	-	**2,959**	0.8%
Jiwaka	-	984	-	-	-	-	-	-	-	**984**	0.3%
Chimbu	-	3,932	-	-	-	-	-	-	-	**3,932**	1.1%
EHP	-	3,897	-	-	-	-	-	-	-	**3,897**	1.1%
Morobe	-	9,764	-	-	-	-	-	1,953	-	**11,717**	3.3%
Madang	-	15,848	1,981	-	-	-	1,981	-	-	**19,810**	5.6%
East-Sepik	1,961	13,725	-	-	-	-	-	-	-	**15,686**	4.4%
West-Sepik	2,007	60,214	36,128	-	-	2,007	-	-	-	**100,357**	28.4%
WNB	1,961	13,730	35,306	-	-	-	-	-	-	**50,997**	14.4%
ENB	-	7,833	27,416	-	-	-	-	-	-	**35,249**	10.0%
Manus	-	2,321	-	-	-	-	-	-	-	**2,321**	0.8%
New-Ireland	-	1,938	-	-	-	-	-	-	-	**1,938**	0.6%
AROB	-	-	-	1,974	-	-	1,974	-	-	**3,948**	1.1%
Total:	**9,372**	**223,561**	**100,831**	**1,974**	**1,949**	**7,895**	**3,955**	**1,953**	**1,315**	**352,805**	100.0%

Annex 2.8: Annual forest degradation by human impact type between 2000 and 2019

Year of forest degradation/ disturbance	Commercial Logging	Gardening	Mining	Portable Sawmill	Infrastructure	Other	Fire	Total (ha)
2000	9,870	2,429	-	-	-	-	1,938	14,237
2001	85,667	-	-	-	-	-	1,953	87,620
2002	140,132	1,953	-	-	-	-	-	142,085
2003	140,585	4,387	-	-	-	-	-	144,972
2004	139,942	5,838	-	-	2,007	-	-	147,787
2005	95,798	3,914	-	-	-	5,977	1,953	107,642
2006	137,796	9,782	-	-	-	1,963	-	149,540
2007	148,464	10,415	1,938	-	-	3,925	1,939	166,682
2008	153,819	5,893	-	-	-	3,947	-	163,658
2009	172,519	5,816	-	-	-	-	-	178,335
2010	182,992	19,546	-	-	-	-	-	202,538
2011	183,768	9,754	-	-	-	2,471	3,922	199,915
2012	142,127	17,846	-	-	-	1,963	3,941	165,876
2013	157,352	13,891	-	-	-	5,859	-	177,102
2014	151,342	12,260	-	-	2,007	1,938	1,981	169,528
2015	143,314	21,559	-	1,938	-	5,288	3,922	176,020
2016	102,430	19,654	-	1,961	1,961	3,959	17,664	147,629
2017	72,674	24,157	-	-	-	5,880	3,903	106,614
2018	86,728	17,680	1,981	-	1,961	1,961	1,953	112,263
2019	67,301	20,152	-	-	-	5,869	5,874	99,197
Total (ha):	**2,514,620**	**226,928**	**3,919**	**3,898**	**7,936**	**50,999**	**50,942**	**2,859,241**

Annex 2.9: Human impact in provinces between 2000 and 2019

Province	Commercial Logging	Gardening	Mining	Portable Sawmill	Infrastructure	Other	Fire	Total
Western	598,622	19,627	-	-	-	9,813	21,590	649,652
Gulf	374,106	19,794	-	-	-	3,959	-	397,859
Central	100,986	13,594	-	-	-	1,942	1,942	118,464
Oro	25,213	11,637	-	-	-	1,939	1,939	40,729
Milne Bay	15,589	13,641	-	-	-	-	-	29,230
Hela	-	5,964	-	-	-	-	1,988	7,952
SHP	-	1,932	-	-	-	-	-	1,932
Enga	-	3,886	-	-	-	-	-	3,886
WHP	-	986	-	-	-	-	-	986
Jiwaka	-	984	-	-	-	-	-	984
Chimbu	-	1,966	-	-	-	-	-	1,966
EHP	-	3,897	-	-	-	-	1,949	5,846
Morobe	46,868	15,623	-	-	-	1,953	7,811	72,254
Madang	112,919	17,829	1,981	-	-	-	1,981	134,710
East Sepik	103,921	13,725	-	1,961	3,922	3,922	9,804	137,254
West Sepik	411,462	34,121	-	-	4,014	8,029	-	457,626
WNB	298,137	17,653	-	-	-	1,961	-	317,751
ENB	285,910	3,917	-	-	-	11,750	-	301,577
Manus	24,599	928	-	-	-	1,857	-	27,384
New Ireland	114,314	23,250	1,938	1,938	-	3,875	1,938	147,251
AROB	1,974	1,974	-	-	-	-	-	3,948
Total:	**2,514,620**	**226,928**	**3,919**	**3,898**	**7,936**	**50,999**	**50,942**	**2,859,241**

Annex 2.10: Carbon stock for each forest type in PNG based on forest extent at 2019.

Forest type	Forest status	Area (ha) (A)	Above Ground Biomass (t/ha) (B)	IPCC GL 2006		Above & Below Ground Biomass (t.d.m)	Carbon in above & below ground biomass (t)	Carbon in above & below ground biomass (tCO2e)
				Root-to-Shoot Ratio (R)	Carbon Fraction (CF)			
Low altitude forest on plains and fans	Primary	5,482,352	223	0.37	0.47	1,674,913,436	787,209,315	2,462,122,750
	Degraded	3,425,157	146	0.37	0.47	685,099,892	321,996,949	1,007,096,841
Low altitude forest on uplands	Primary	8,524,631	223	0.37	0.47	2,604,360,094	1,224,049,244	3,828,409,339
	Degraded	2,596,722	146	0.37	0.47	519,396,382	244,116,300	763,512,682
Low Montane Forest	Primary	6,642,757	140	0.27	0.47	1,181,082,216	555,108,641	1,736,190,857
	Degraded	1,366,272	92	0.27	0.47	159,635,216	75,028,552	234,663,768
Montane forest	Primary	360,947	140	0.27	0.47	64,176,391	30,162,904	94,339,294
	Degraded	29,684	92	0.27	0.47	3,468,247	1,630,076	5,098,323
Dry Seasonal forest	Primary	2,029,428	130	0.28	0.47	337,696,750	158,717,473	496,414,223
	Degraded	323,845	85	0.28	0.47	35,234,317	16,560,129	51,794,446
Littoral Forest	Primary	130,471	223	0.37	0.47	39,860,085	18,734,240	58,594,325
	Degraded	17,632	146	0.37	0.47	3,526,675	1,657,537	5,184,212
Seral forest	Primary	281,266	223	0.37	0.47	85,929,553	40,386,890	126,316,442
	Degraded	39,117	146	0.37	0.47	7,824,116	3,677,334	11,501,450
Swamp Forest	Primary	2,181,730	223	0.37	0.47	666,540,260	313,273,922	979,814,182
	Degraded	280,665	146	0.37	0.47	56,138,713	26,385,195	82,523,908
Savannah	Primary	325,483	130	0.28	0.47	54,160,439	25,455,406	79,615,845
	Degraded	294,439	85	0.28	0.47	32,034,942	15,056,423	47,091,364
Woodland	Primary	683,973	130	0.28	0.47	113,813,167	53,492,188	167,305,355
	Degraded	373,566	85	0.28	0.47	40,643,938	19,102,651	59,746,589
Shrub	Primary	174,549	70	0.4	0.47	17,105,802	8,039,727	25,145,529
	Degraded	45,557	46	0.4	0.47	2,933,871	1,378,919	4,312,790
Mangrove	Primary	229,219	192	0.49	0.47	65,575,096	30,820,295	96,395,391
	Degraded	56,752	126	0.49	0.47	10,654,605	5,007,664	15,662,270
Plantation Forest	n.a	54,765	150	0.37	0.47	11,254,277	5,289,510	16,543,788
	Total:	**35,950,979**				**8,473,058,479**	**3,982,337,485**	**12,455,395,964**

Annex 2.11: Provinces carbon stock by forest status in 2019.

Province	Forest status	Plot Count	Forest area (ha)	Above & Below Ground Biomass (t.d.m)	Carbon in above & below ground biomass (t)	Carbon in above & below ground biomass
Western	Primary	3,432.00	6,735,972.41	1,618,428,812.71	760,661,541.97	2,379,090,354.68
	Degraded	781.00	1,532,865.52	240,942,945.98	113,243,184.61	354,186,130.59
Gulf	Primary	1,181.00	2,337,666.24	690,533,998.22	324,550,979.16	1,015,084,977.38
	Degraded	423.00	837,284.35	163,301,406.28	76,751,660.95	240,053,067.23
Central	Primary	878.00	1,705,110.08	430,874,384.77	202,510,960.84	633,385,345.62
	Plantation	1.00	1,942.04	399,088.98	187,571.82	586,660.80
	Degraded	374.00	726,322.52	117,612,745.06	55,277,990.18	172,890,735.23
NCD	Degraded	4.00	5,258.67	572,142.92	268,907.17	841,050.09
Oro	Primary	800.00	1,551,582.52	394,707,833.54	185,512,681.76	580,220,515.30
	Degraded	116.00	224,979.47	41,783,884.51	19,638,425.72	61,422,310.23
Milne Bay	Primary	346.00	674,231.68	187,744,820.32	88,240,065.55	275,984,885.87
	Plantation	2.00	3,897.29	800,893.71	376,420.04	1,177,313.75
	Degraded	116.00	226,042.99	40,546,461.72	19,056,837.01	59,603,298.73
Hela	Primary	280.00	556,621.54	109,884,109.99	51,645,531.69	161,529,641.68
	Degraded	115.00	228,612.42	28,529,995.01	13,409,097.66	41,939,092.67
Southern Highlands	Primary	457.00	882,761.49	224,054,757.45	105,305,736.00	329,360,493.45
	Plantation	1.00	1,931.64	396,952.93	186,567.88	583,520.80
	Degraded	135.00	260,772.00	35,931,522.11	16,887,815.39	52,819,337.50
Enga	Primary	294.00	571,176.79	106,021,252.98	49,829,988.90	155,851,241.88
	Degraded	118.00	229,247.83	28,562,919.35	13,424,572.09	41,987,491.44
Western Highlands	Primary	246.00	121,318.34	23,711,788.76	11,144,540.72	34,856,329.48
	Degraded	116.00	57,207.02	7,463,474.96	3,507,833.23	10,971,308.18
Jiwaka	Primary	488.00	240,015.09	49,646,830.90	23,334,010.52	72,980,841.42
	Degraded	149.00	73,283.30	10,730,690.98	5,043,424.76	15,774,115.74
Chimbu	Primary	143.00	281,114.63	61,781,858.88	29,037,473.68	90,819,332.56
	Degraded	63.00	123,847.70	17,413,694.67	8,184,436.50	25,598,131.17
Eastern Highlands	Primary	266.00	518,363.31	98,635,690.88	46,358,774.71	144,994,465.60
	Plantation	3.00	5,846.20	1,201,394.67	564,655.49	1,766,050.16
	Degraded	40.00	77,949.37	9,918,082.98	4,661,499.00	14,579,581.98
Morobe	Primary	965.00	1,884,474.90	416,527,596.18	195,767,970.20	612,295,566.38
	Plantation	6.00	11,716.94	2,407,831.66	1,131,680.88	3,539,512.54
	Degraded	259.00	505,781.35	81,411,190.39	38,263,259.48	119,674,449.87
Madang	Primary	768.00	1,521,432.19	405,155,073.72	190,422,884.65	595,577,958.37
	Plantation	3.00	5,943.09	1,221,305.92	574,013.78	1,795,319.70
	Degraded	316.00	626,005.95	118,789,185.79	55,830,917.32	174,620,103.12
East Sepik	Primary	1,278.00	2,505,865.96	720,314,443.84	338,547,788.60	1,058,862,232.44
	Degraded	247.00	484,310.56	94,546,910.79	44,437,048.07	138,983,958.86
West Sepik	Primary	1,328.00	2,665,471.08	733,691,427.14	344,834,970.76	1,078,526,397.90
	Degraded	288.00	578,053.97	114,119,775.79	53,636,294.62	167,756,070.42
West New Britain	Primary	423.00	829,683.73	245,096,045.43	115,195,141.35	360,291,186.78
	Plantation	3.00	5,884.28	1,209,219.90	568,333.35	1,777,553.25
	Degraded	456.00	894,410.82	178,779,621.43	84,026,422.07	262,806,043.50
East New Britain	Primary	324.00	634,486.17	163,098,116.70	76,656,114.85	239,754,231.54
	Plantation	8.00	15,666.33	3,219,429.83	1,513,132.02	4,732,561.85
	Degraded	303.00	593,362.07	115,263,577.66	54,173,881.50	169,437,459.15
Manus	Primary	162.00	75,188.64	22,853,647.64	10,741,214.39	33,594,862.02
	Degraded	173.00	80,294.04	15,997,469.34	7,518,810.59	23,516,279.93
New Ireland	Primary	212.00	410,753.73	112,950,687.24	53,086,823.01	166,037,510.25
	Plantation	1.00	1,937.52	398,159.86	187,135.14	585,295.00
	Degraded	166.00	321,627.92	63,269,869.02	29,736,838.44	93,006,707.45
AROB	Primary	174.00	343,516.29	89,500,110.01	42,065,051.70	131,565,161.72
	Degraded	82.00	161,886.99	31,103,347.11	14,618,573.14	45,721,920.24
	Total:	**19,313.00**	**35,950,978.96**	**8,473,058,478.58**	**3,982,337,484.93**	**12,455,395,963.51**


Papua New Guinea Forest Authority
National Forest Service