Papua New Guinea's National REDD+ Forest Reference Level

Modified Submission for UNFCCC Technical Assessment in 2017

Government of Papua New Guinea

Contents

Acronyms

AGB	Above Ground Biomass
AD	Activity Data
AFOLU	Agriculture, Forestry and Other Land Use
AGP	Annual Greenest Pixel
ALOS	Advanced Land Observing Satellite-1
ALU	Agriculture Land use software
AP	Action Plan for the National Forest Monitoring System
BGB	Below Ground Biomass
BUR1	Biennial Update Report 1
CCDA	Climate Change and Development Authority
CEPA	Conservation and Environment Protection Authority
CLASLITE	The Carnegie Landsat Analysis System Lite
COP	Conference of the Parties
CSO	Civil Society Organisations
DAL	Department of Agriculture and Livestock
DFAT	Department of Foreign Affairs
DLPP	Department of Lands and Physical Planning
EF	Emission Factor
EFDB	Emission Factor Data Base
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FMA	Forest Management Areas/Agreements
FREL/FRL	Forest Reference Emission Levels/Forest Reference Levels
FRI	Forest Research Institute of the Papua New Guinea Forest Authority
FRIMS	Forest Resource Information Management System
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GIS	Geographic Information System
GoPNG	Government of Papua New Guinea
ILG	Incorporated Land Groups
IPCC	Intergovernmental Panel on Climate Change

JICA	Japan International Corporation Agency
LANDSAT	Land and Satellite Imagery
LULUCF	Land Use, Land Use Change and Forestry
MOU	Memorandum of Understanding
MRV	Measurement, Reporting and Verification
NEC	National Executive Council
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NGO	Non-Government Organisations
NMB	National Mapping Bureau
NSO	National Statistics Office
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
PNGFRI	Papua New Guinea Forest Research Institute
PSP	Permanent Sample Plots
QA/QC	Quality Assurance/Quality Control
REDD+	Reduced Emissions from Deforestation and Degradation and Conservation, Sustainable management of forests and Enhancement of Forest Carbon Stocks
R-PP	Readiness Preparedness Proposal
SABL	Special Agricultural and Business Leases
SFM	Sustainable Forest Management
SIS	Safeguards Information System
SLMS	Satellite Land Monitoring System
TWG	Technical Working Group
TWS	Technical Working Session
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNITECH	Papua New Guinea University of Technology
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in developing countries
UPNG	University of Papua New Guinea

1. Introduction

1.1 PNG and global efforts to combat climate change

The Island of New Guinea is the largest tropical island in the world and contains the third largest tropical rainforest after Amazon Basin and Congo basin. Papua New Guinea (PNG) is a well-known centre for biological endemism and diversification. Most forests in PNG are under customary ownership and play an important role in sustaining the traditional subsistence livelihoods of most of the population. Currently PNG's forests are relatively intact. PNG's forest covers 80% of the country's land area and 60% of the forest are undisturbed. Nevertheless, the forest is coming under increasing pressure from logging, agriculture (commercial and small-scale) and mining.

PNG has taken a global lead in seeking to combat climate change, particularly by proposing measures to realise the carbon abatement opportunity offered by preserving and sustainably managing tropical forests, that is, by introducing the pre-cursor to the concept of REDD+ into the international negotiations at COP11[1] in Montreal in 2005. Since then, the Government of PNG through the Climate Change and Development Authority (CCDA) and PNG Forest Authority (PNGFA) have been putting much effort into the country's REDD+ readiness, with the support of international multilateral and bilateral development partners.

1.2 Background on the MRV for REDD+ under the UNFCCC

The UNFCCC calls for developing countries aiming to access performance-based payments for the implementation of REDD+ activities to develop four REDD+ design elements:

i. A national strategy or action plan;

ii. A national forest reference emission level and/ or forest reference level (FREL/FRL);

iii. A national forest monitoring system;

iv. A system for providing information on how the REDD+ safeguards are being addressed throughout the implementation of REDD+ activities.

The national forest monitoring system provides transparent information on the status of forests and REDD+ implementation in a country. It has two core functions:

1. Monitoring national policies and measures for REDD+;

2. Measuring, Reporting and Verifying (MRV) national scale GHG emissions and removals in the forest sector.

The UNFCCC has defined FREL/FRLs as benchmarks for assessing each country's performance in implementing and reducing emissions and increasing removals associated with the implementation of REDD+ activities. The Conference of the Parties (COP16) in Cancun encouraged developing country parties to contribute to mitigation actions in the forest sector, in accordance with their respective capabilities and national circumstances, and stated that, "more broadly, FREL/FRLs are considered relevant to assess country's performance in contributing to mitigation of climate change through actions related to their forests."

[1] the eleventh session of the Conference of the Parties

According to UNFCCC COP decision 12/CP.17, developing countries aiming to implement REDD+ activities are invited to submit a national forest reference level to the secretariat, on a voluntary basis and when deemed appropriate. The information contained in the submission should be transparent, accurate, complete and consistent. It also be developed pursuant to recent IPCC guidelines as adopted or encouraged by the COP. In agreement with these decisions, PNG has held extensive consultations and technical analysis for the development of its FRL.

1.3 Objectives of developing a national FRL

PNG understands that a country may consider using variations of FRLs for different or combined reasons. Nonetheless, the FRL for PNG is prepared to achieve the following national and international objectives:

Nationally:

- To assess PNG's performance in implementing REDD+ activities; and
- To assess PNG's performance in contributing to national climate change mitigation actions related to its forests.

Internationally: In accordance with decision 12 of COP 17, there are three (3) other reasons PNG has undertaken to come up with its FRLs:

- To access results-based payments for REDD+ results-based actions;
- To assess progress on the outcomes of the policies and measures taken to mitigate climate change in the forestry sector for domestic reasons;
- To contribute to international mitigation efforts through REDD+ actions under the UNFCCC.

1.4 Background on work towards developing the FRL

PNG has taken a global lead in seeking to combat climate change by introducing the concept of REDD+ into international negotiations, part of which included the need to initiate discussions on the FREL/FRL specifically.

In 2014, as part of the ongoing collaboration between the UN-REDD, the EU and the FAO, the first consultative meeting was held to review PNG's NFMS, GHGi and FRL for REDD+. The main objective of this was to ensure effective stakeholder participation was provided for the on-going work on REDD+ especially for the FRL and GHG inventories for the agriculture and forestry sectors. This meeting aimed to inform stakeholders on the international guidance available for designing and constructing REDD+ FRLs and also to agree on a Road Map for its development.

Since this time, three (3) more consultative meetings and two working sessions were held consisting of the various technical teams from the respective government and international agencies held in both June and October 2016. The main objectives of these working sessions were to update and further track the progress of PNGs REDD+ FRL and GHGi for the AFOLU sector since 2014. Reports were drafted to capture the outcomes of PNG's progress and to propose ways forward through Work Plans/Roadmaps in preparation for the submission of FRLs by the beginning of 2017.

At each event staged, more than seventy (70) participants from various cross sectors of the community were in attendance ensuring that there was fair representation from government non-government, private and local communities in PNG.

Some of the key outcomes from these workshops and meetings were used as the basis for proceeding with the continued development of the REDD+ FRL for PNG and included:

- The need for further dialogue to continue between CCDA, PNGFA and other key stakeholders with the objective of finalising the National FRL Report before its submission to the UNFCCC.
- The creation of an online forum for discussions between stakeholders in relation to the GHGi of the AFOLU sector as well as to continually update stakeholders on its progress.

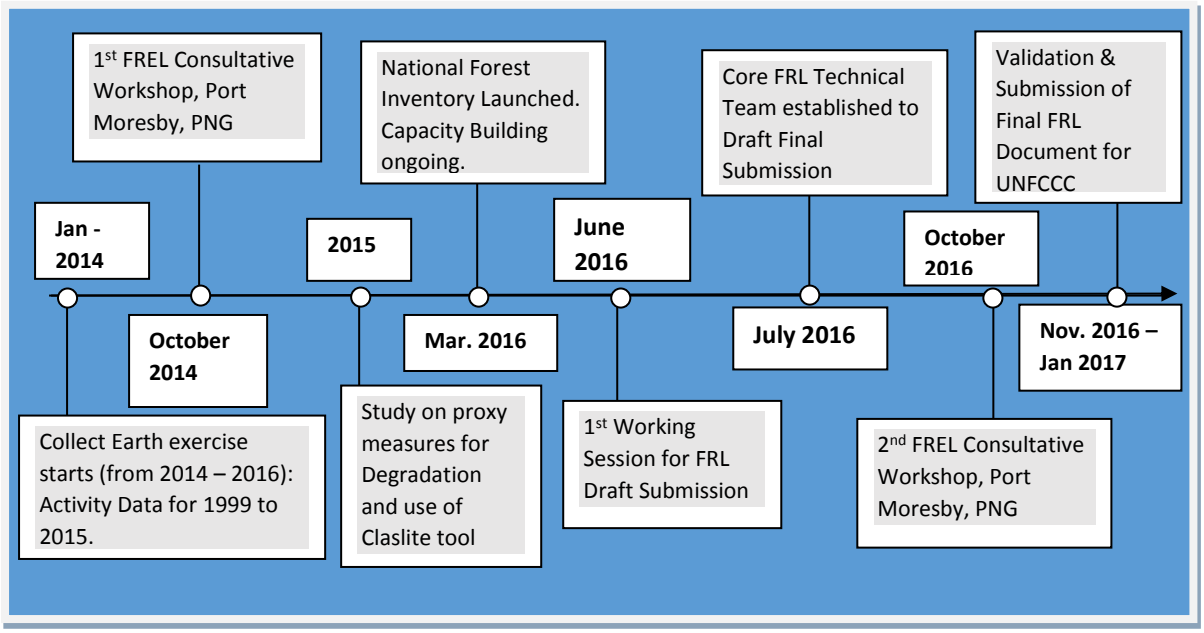

Figure 1.1: Timeline for the Development of PNG's FRL

PNGFA launched its forest base map towards the end of 2013 based on 2012 Rapid Eye data which was developed with the assistance of JICA. PNGFA also completed the assessment of all the forest types in the country using Collect Earth in 2013, a Google Earth plugin developed by FAO for forest sampling analysis in synchrony with the Google Earth Engine. The support for this was provided as part of the funding from the UN-REDD National Programme.

The Multipurpose National Forest Inventory

The capacity on forest monitoring of PNG using remote sensing technology has significantly improved in recent years. However a large information gap still remains. National scale information on carbon stock in the diverse forests subject to different disturbances is poorly known. Previous studies were too scattered and the estimation of average carbon stock in PNG forests were often contradictory.

The necessity for an NFI to better understand, plan and manage PNG's forest has been recognized for many years. Designing and planning an NFI for PNG has been attempted a number of times but was never implemented due to lack of funding and capacity. This was finally realized in 2015 when funding by the European Union (EU) and the UN-REDD became available. The official launch of the full implementation of the NFI was officiated by the Prime Minister of PNG and the international community and also included the launch of the PNG Forest Monitoring and REDD+ Web-portal. These initiatives aim to accurately estimate GHG

emissions from forest and land use change meeting the requirements of Tier 3 emission factors (as prescribed by the IPCC for REDD+ Measurement, Reporting and Verification (MRV).

PNGFA and its collaborating partners established the methodology for NFI and prepared important field manuals for the implementation process. A number of trainings, including species identification, soil survey, biodiversity assessment and data management were also conducted and significant capacities built. NFI field implementation commenced in December 2015 and continues full scale operation from 2016 with an expected end date in 2017/2018. Biodiversity information collected in the NFI will also be contributing to the requirements of Environmental Safeguards of REDD+. Beyond REDD+, PNG's first NFI will also make a significant scientific contribution to the understanding of PNG's tropical rainforest and the biodiversity within.

So far only initial data has been derived from the total area earmarked (0.5%), with about 75% completed. Information availability on land use and land use change will be a major step forward and a milestone achievement for the country. Based on this forest inventory and via input obtained from respective stakeholders, important measures such as a national land use plan for the country, will be a possible future objective and a major advantage for the country.

Complementarity with the NDCs

The submission of PNG's FRL is also in line with PNG's Nationally Determined Contribution (NDC). The intended Nationally Determined Contribution (INDC) was previously submitted to the UNFCCC on September 2015 before the Paris Agreement in December, and was formally registered on the 21st of March 2016 as its Nationally Determined Contribution (NDC) under the Paris Agreement, referring to the National Climate Action Plan. PNG's National Climate Action Plan has no set targets for emission reductions in the land use and forest sector. Rather, it sets out mitigation actions derived from its National Policies: The Vision 2050 and the Medium Term Development Strategy 2030.

In 2016, the GoPNG created a working group of technical experts to develop the country's FRL. This team consists primarily of technical experts from the CCDA and PNGFA and has taken the leading role in steering this initiative with active participation from other key line agencies as well. The substantive technical and financial support for this has been provided through respective international development partners including FAO, JICA and the EU and with vital stakeholder feedback from the other relevant GoPNG agencies, private sector stakeholders and civil society organisations in PNG as well.

2. Definitions

2.1 PNG's National Forest Definition

Prior to determining whether deforestation, afforestation or reforestation is occurring, and to define the areas within which degradation and the other REDD+ activities may occur, it is paramount that the forest has to be defined first. As part of the guidelines for submission of information on forest reference levels, country Parties should provide the definition of forest used.

Under the IPCC 2003 GPG the forest includes "*all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, subdivided into managed and unmanaged, and also by ecosystem type as specified in the IPCC Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest*

land category." The 2006 Guidelines make reference to *threshold values* for the forestland definition. This indicates that the IPCC anticipates countries to define their forest with quantitative thresholds.

PNG's national forest definition is "*land spanning more than 1 hectare, with trees higher than 3 meters 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 in Decision #256 of Meeting #07/2014.

This national definition is defined slightly differently from the definition which was reported to FAO's FRA 2015, which defined forests as "*Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use*". Such slight differences do not affect actual the data obtained through the assessment using remote sensing technologies currently used for national scale assessment in PNG.

There was no national forest definition used in PNG prior to 2014, therefore, all default definitions under the IPCC 2006 were observed as reflected in all past GHG inventories carried out by the respective government authorities.

Forestland in PNG is classified into Natural and Plantation forest and subdivided based on the vegetation and plantations types. Vegetation type is classified based on the structural formation and described in PNG Resource Information System (PNGRIS) Publication No.4 (Hammermaster & Saunders, 1995). There are 12 natural vegetation/forest types in PNG forest. Montane coniferous forest is included due to the high conservation value of this specific forest type.

Table 2.1: Forest vegetation classification in PNG and their short description. Full description is available in Hammermaster & Saunders (1995).

Forest types	Short description
(a) Natural Forest	
Low Altitude Forest on Plains and Fans	below 1000 m
Low Altitude Forest on Uplands	below 1000 m
Lower Montane Forest	above 1000 m
Montane Forest	above 3000 m
Dry Seasonal Forest	restricted to southwest PNG in a low-rainfall area (1800-2500 mm)
Littoral Forest	dry or inundated beach
Seral Forest	river line, upper stream, river plains and volcano blast area
Swamp Forest	swamp area
Woodland	low and open tree layer
Savanna	low (< 6m) and open tree layer in low rainfall area with a marked dry season
Scrub	community of dense shrubs up to 6 m
Mangrove	along coastline and in the deltas of large rivers

Montane coniferous forest	high altitude forests dominated by coniferous species (Podocarpaceae)
(b) Plantation Forest	
Forest Plantations	Includes all species of Eucalyptus Plantation, Araucaria Plantation (*Araucaria cumminghamii* (Hoop Pine) and *Araucaria hunstanii* (Klinkii Pine)), Pinus Plantation, Acacia Plantation, Terminalia Plantation, Rubber Plantation and others not included above.

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

- Primary forests – Naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed.
- Disturbed forests – Naturally regenerated forest where there are clearly visible indications of human activities. (FRA, 2015).

In addition to the above, the definition for Deforestation and Forest Degradation are included as part of the REDD+ activities and is defined according to conversions between land-use types, as follows:

- Deforestation is the conversion from forest land to any non-forest land. Primary deforestation is the conversion of primary forest. Secondary deforestation is the conversion of degraded forest.
- Forest degradation is the conversion from primary forest to disturbed forest.
- Carbon stock enhancement is the conversion of any non-forest land to forest land.
- The sustainable management of forests and forest conservation concern the accumulation of carbon in forest land remaining forest land. These are not currently included in the scope.

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

Table 2.2 : IPCC Land Use Categories.

IPCC Land use Category	**Sub-type Category**	**Sub-division category**
Forestland	Natural Forest	Low altitude forest on plains and fans, Low altitude forest on uplands, Lower montane forest, Montane forest, Montane coniferous forest, Dry seasonal forest, Littoral forest,

		Seral forest, Swamp forest, Savanna, Woodland, Scrub, Mangrove
	Plantation Forest	Eucalyptus, Araucaria, Pinus, Acacia, Terminalia, Teak, Rubber, Other Forest Plantation
Cropland	Subsistence Agriculture	Shifting, Permanent
	Commercial Agriculture	rice, spices, tea, sugar, coffee, palm oil, cocoa, coconut, cocoa/coconut, other
Grassland		herbland, rangeland, other
Wetland		river, lake, dam, nipa swamp[2], other swamp
Settlement		village, hamlet, large settlement, infrastructure
Otherland		bare, sand, rock
*No data		cloud, sea, other reasons

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

3. Scope

The FRL's scope is set in terms of the REDD+ activities, the carbon pools and the greenhouse gases included in the FRL.

3.1 REDD+ activities

The REDD+ activities covered are:

- Deforestation
- Forest degradation
- Carbon stock enhancement

The REDD+ activities not currently covered are:

- Sustainable management of forest
- Conservation of carbon stocks

No activities on carbon stock enhancement was detected during the historical reference period (2000-2013) by the forest and land use assessment using Collect Earth. However the government has recently set the policy for targeting of 800,000 ha tree planting. It is anticipated that tree planting would become one of the major REDD+ activities in the near future. Thus carbon stock enhancement is included in REDD+ activities although it has been negligible amount of carbon removed by increase of forest area.

The sustainable management of forest and the conservation of carbon stocks both concern the accumulation of carbon in existing forests, especially forests managed through sustainable harvesting practices. There is no data currently available that would allow for including estimates, but PNG plans to include them in future improvements to the FRL.

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

3.2 Carbon pools

The carbon pools covered are:

- Above-ground biomass
- Below-ground biomass

The carbon pools not currently covered are:

- Litter
- Deadwood
- Soil-organic carbon

3.2.1 Deadwood

According to the 2006 IPCC Guidelines, dead wood should be estimated at a tier 1 level for deforestation and carbon stock enhancement (land that is converted from forest land to any other land use and vice versa). For forest degradation (forestland remaining forestland), deadwood carbon stocks are assumed to be in equilibrium under tier 1 subsequently emissions are zero. However 2006 IPCC Guidelines do not provide default values of deadwood carbon stock in forest because of the paucity of published data. PNG has no country specific carbon stock value for dead wood to allow for reliable estimation. Since no reasonably reliable data is available to use in PNG, carbon pools in Deadwood is not covered in the FRL.

Dead wood is potentially a large carbon pool, particularly in disturbed forest, and may constitute 10-40% of aboveground biomass (Uhl & Kauffman 1990). Fox et al. (2010) estimated biomass of dead wood in PNG forests as 25% of aboveground living biomass at logged over forest and 10% of aboveground living biomass at primary forest from their observation.

National Forest Inventory currently under implementation in PNG includes the data collection of deadwood. Within a couple of years, PNG will be able to accurately estimate the carbon stock of deadwood in Forest.

3.2.2 Litter

According to the IPCC 2006 Guidelines, litter is treated identical as dead wood (see previous paragraph). However IPCC 2006 Guidelines provides default values of carbon stock in Litter only for broadleaf deciduous and needleleaf evergreen forest for tropical region, while most of PNG forests are in different group (broadleaf evergreen). PNG has no country specific carbon stock value for litter to allow for reliable estimation.

The IPCC 2006 Guidelines default value of litter of broadleaf deciduous forest in tropical region is 2.1 tC/ha. This is 1.5% of average carbon stock in total living biomass of primary forests in PNG (144 tC/ha, Table 6.2) and not significant carbon pool. Since no reasonably reliable data for estimating carbon stock in litter is available in PNG and litter is insignificant carbon pool, it is not covered in the FRL. Country specific data will be available within 1-2 years as the national Forest Inventory progresses. Litter will be included in national emission calculations then.

3.2.3 Soil organic carbon

McIntosh et al. (2016)[3] reported that up to 50–75% of PNG forest carbon could be held in the soil. Land use can have a large effect on the size of this pool through activities such as conversion of Forest Land to Cropland, where 20-40% of the original soil C stocks can be lost (IPCC 2006). Emissions from this carbon pool as the results of deforestation could be significant. According to the 2006 IPCC guidelines soil organic carbon should be estimated at a tier 1 level for all considered REDD+ activities. However PNG forest soil have not been classified into the soil types provide in 2006 IPCC Guidelines for their default values. It is currently not possible to estimate the emissions from soil organic carbon pool. On the other hand, it is possible to identify the soil type and climate of all the point where forest conversion occurred using Collect Earth tool. PNG has been rapidly accumulating the data set of soils under National forest Inventory and other studies. PNG does not cover soil organic carbon pool in FRL, however PNG will be able to include it within a few years.

3.2.4 Non-CO2 emissions

The emissions from non-CO_2 GHG are not included in the FRL because the reliable data is lacking and also they are likely insignificant. In principle, these would occur due to burning during the forest degradation, drainage of organic soils upon deforestation and mineralization of carbon after deforestation. About 3% of forest is affected by fire in PNG but year of when fire occurred and frequency are not known in most cases. There is no reliable data of distribution of organic soil and their drainage, which could cause CH_4 and N_2O emissions.

4. Reference period

As a result of broader stakeholder consultations held recently it was agreed that the preferred reference period to use for PNG would be the period from 2001-2013. The most reliable national land use data in PNG is available during the selected period. PNG uses Landsat 7 & 8 imageries as the primary information sources for the assessment. Reliable land use change data is available starting from 2001 after launching of Landsat 7 in 1999.

There might be some intervention of REDD+ activities to the GHG emission in LULUCF sector in very recent years. It is necessary to fully investigate the influence of REDD+ related policy and measures in recent years but this will take some time. However it is very unlikely that there was REDD+ intervention to the data up to 2013. PNG considers the period from 2001-2013 is the most appropriate for the historical reference period for predicting future emissions under business as usual scenario.

5. Scale

The dangers posed from climate change and the importance of forests in tackling this issue is a key concern for the Government of PNG. PNG has succeeded with other parties in having REDD+ embedded into Article 5 of the *Paris Agreement* as a positive measure for reducing GHG emissions within developing countries. In line with this objective, PNG's political leadership called for tangible actions to be taken to reduce GHG emissions through REDD+ and put in place long term political visions, plans and strategies, most notably; the Vision 2050, Medium Term

[3] McIntosh, P.D.; Doyle, R.; Nimiago, P. 2016. *Field guide for sampling and describing soils in the Papua New Guinea National Forest Inventory, 3rd edition.*

Development Plan (MTDP) 2015-2018, the National Strategy for Responsible Sustainable Development (StaRS) and recently enacted *Climate Change (Management) Act*, 2015 to ensure this was achieved.

PNG aims to address REDD+ at the national level where reducing emissions from the forest sector becomes an important policy priority. As such, PNG has decided to develop its forest reference levels at this scale, where all REDD+ efforts are also better monitored and measured, as a result of the latest GIS and Satellite Land Monitoring Systems, equipment and tools which have been introduced and built into the country's existing national agencies. This will effectively contribute towards the country's policy directions and act as a guide for its forest policy.

6. Emission Factor Estimates

An emission factor (EF) is a coefficient that qualifies emissions per unit 'activity'. To estimate emissions and removals from forest land, the EF should be multiplied by information on the extent of human activities (called 'activity data' – AD).

The IPCC (2006) provides three tiers for the development of GHG emissions and removals. Tiers represent an increasing level of expected accuracy of emission factors. The choice of which tier to use will depend on a country's data availability and capacity. With regards to the choice of EF, the tier levels can be distinguished as follows:

- Tier 1: Use of default EF provided through the Emission Factor Database, or alternatively in the IPCC Guidelines; the IPCC suggest this method "should be feasible for all countries".
- Tier 2: Use of country specific EF or non-default more specific factors. This may include EF from the Emission Factor Database if they are specific for the country.
- Tier 3: Higher order methods are used including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national to fine-grid scales.

Properly implemented, tier 2 and 3 methods are expected to provide estimates of greater certainty than Tier 1.

For estimating the EF for PNG, the following steps were taken;

1) Stratify the forest in PNG.
2) Review existing PNG data and determine if appropriate country specific carbon stock for each forest strata and other land use is available.
3) Refer IPCC Guideline (2006) for identifying the most appropriate default values of carbon stock for those forest strata and other land use, which PNG data is not available or insufficient to set country specific values.

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

6.1 Forest stratification

There are 12 vegetation types in PNG's natural forest, which is described in PNGRIS Publication No.4 (Hammermaster & Saunders 1995). For the Collect Earth assessment, "mountain coniferous forest" was added because of the high conservation value of the specific forest type. 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 4).

6.2 Above ground biomass in unit area of each forest strata in PNG

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 is one of the major objectives of PNG's first National Forest Inventory, which is currently under implementation. However, it will take another 2-3 years before the full information derived from the National Forest Inventory become available. 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 forest are preferred and selected for ecological studies, and consequently, aboveground biomass of study plots may 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.

6.3 IPCC Guidelines

Other than five forests type discussed in the above section, no sufficient information on above ground biomass is available. IPCC Guideline (2006: Table 4.12) provides above ground biomass per unit forest area of each Global Ecological Zone described by FAO (2001). Global Ecological Zone and the PNG forest classification provided in PNGRIS (1995) are correlated well. Figure 6.1 shows similar distribution of montane vegetation and dry vegetation between the PNG Forest Base Map (PNGFA 2014) and Global Ecological zone (FAO 2001). The description of Ecological Zone in tropical climate is summarised in Table 6.1.

Table 6.1: Summary of Climate Domains and Ecological Zone (FAO 2001) relevant to PNG environment.

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

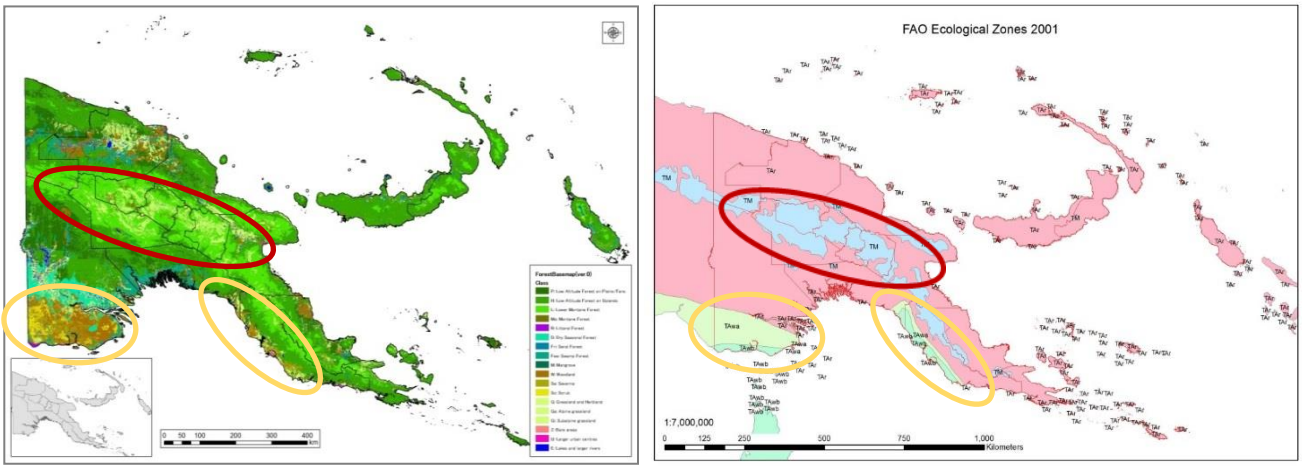

Figure 6.1. Correlation between PNG forest classification in Base Map (Left: PNGFA/JICA 2014) and Global Ecological Zone (Right: FAO 2001). The red ellipse show the distribution of montane vegetation and the yellow ellipse shows the distribution of dry vegetation.

The default values of IPCC Guidelines for above ground biomass for associated Ecological Zone were applied to each of all other forest type as shown in Table 6.2. 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 FRL submission and appropriate values will become available as the National Forest Inventory progresses. In the future, all the Emission Factors used in this FRL submission should be replaced with the country specific values obtained through the National Forest Inventory, which is currently being implemented. After National Forest Inventory is completed then PNG will be able to report near Tier 2-3 level of GHG emission of LULUCF sector.

Table 6.2: Above and belowground biomass 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

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.

6.4 Carbon stock in non-forest land in PNG

In line with the IPCC guidelines, the calculations of emissions from deforestation deduct the removals from post-deforestation regrowth in cropland and grasslands with trees. To approximate such removals in croplands and grasslands, IPCC default values are used since no country specific data on the biomass and the increment in biomass of land use other than forest is available in PNG.

The relative areas of different land-use types after deforestation are the starting point for calculating post-deforestation biomass and its growth. The IPCC guidelines include default values for biomass and the growth duration, which allows to recover mean annual increments for these.

Table 6.3: Aboveground biomass and mean annual increment of Cropland used for post deforestation GHG removal.

		coconut	oil palm	shifting cultivation	permanent subsistence	other
Relative area	%	1%	31%	63%	3%	2%
AGB	t d.m. /ha	196	136	45	45	45
Source		Table 5.3, IPCC 2006	Table 5.3, IPCC 2006	Table 5.1, IPCC 2006	Table 5.1, IPCC 2006	same as subsistence
Growth duration	Years	20	20	8	8	8
Mean annual increment in AGB	t d.m. /ha /yr	9.80	6.80	5.59	5.59	5.59

The average mean annual increment in living biomass 8.11 t d.m. /year /ha, based on a weighted mean of the mean of the annual increments in AGB and a root-shoot ratio of 0.37.

The approach taken to determining removal factors for post-deforestation land use represents an approximation. In reality, the land uses have different growth rates for different time frames. The summary removal factor is applied regardless of the age of post-deforestation regrowth. In theory, applying this increment factors across a very long time span (>50 years) could result in considerable carbon removals, potentially excluding biomass in some kinds of natural forests. In practice this will not occur because of the limited duration of the reference period and future accounting periods.

The expected duration of growth for shifting cultivation is given in the IPCC guidelines. The expected duration of growth for the other land uses was taken to correspond to 20 years in accordance with the default IPCC time horizon for conversion between land use types.

6.5 Calculation of emission factors

The Emission Factors for emissions in primary deforestation, secondary deforestation and forest degradation 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)

Table 6.4: Emission Factor of deforestation of primary forest, deforestation of degraded forest and forest degradation.

(tCO2e /ha /yr)

	EF deforestation (primary forest)	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

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 relate 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-FA.

6.6 Calculation of emissions and removals

The emissions and removals are calculated as follows:

Emissions and Removals = Emission and Removal Factor x Activity Data

The emissions and removals to consider depend on the REDD+ activities.

For deforestation, the emissions from primary deforestation and from secondary deforestation, as well as the removals from post-deforestation regrowth need to be considered.
For forest degradation, the emissions from forest degradation are calculated using the equation above. The results represent the net of emissions from the logging event (or other degrading event) and removals from subsequent regrowth because the emission factors reflect average conditions of logged forests.

For carbon stock enhancement, only the removals from increment in plantations are considered. The emissions from clearing of vegetation present on lands before conversion to plantations are not covered. The error introduced by this simplification is expected to be small since plantations are established on grasslands that have largely herbaceous vegetation.

7. Historical land use

7.1 Step by step description of data processing

7.1.1 Collect Earth

Collect Earth (CE) is one of the tools that was developed by FAO under the Open Foris Initiative where software tools are open source and freely available online[4]. Open source software allows any party to verify the assessment conducted therefore improves the transparency of REDD+ process. One of the advantages of using CE software is that it can be customized according to the country's specific requirements or circumstances and when the software is modified there are regular updates of this online. The tool is linked to various application programs to enable the CE tool to operate functionally, i.e., Google Earth, Google Earth Engine and Bing Maps. The approach used for the CE is based on point sampling and the assessment used is detailed to capture the data for the six IPCC land use categories (Bey *et al*. 2016) .

The CE assessment for PNG was basically mapped out in grids of 0.04 degree (4.44 km x 4.44 km) and 0.02 degree (2.22 km x 2.22 km) for the smallest four provinces with a total of 25,279 points, the size of one point is one hectare and with twenty-five points in a square (100m x 100m). These points have been assigned unique ID numbers but are not in a sequential manner. There are twenty-two (22) provinces with individual collect project files created and the total number of points varies depending on the size of the province.

Two CE assessments have been carried out for PNG so far; one in 2013 and the other in 2016. The most recent assessment was to determine the historical changes in forest and land use from 1999-2015; basically to identify the main drivers and rate of deforestation and forest degradation.

With the customized CE of PNG, six IPCC land use categories are further classified according to the vegetation type and land use in the country. For the specific land use category it would have a broad category (sub-type) which would then be further classified under the general categories (sub-division category) shown below.

When operating the CE tool the assessors visually interpret the points on Google Earth with the aid of Bing maps and the available high resolution imagery. However, when there is no high resolution imagery much of the assessment is dependent on Google Earth Engine to assess the six land use categories most essential for the change detection (land use change) with Landsat 7 and 8. This is based on time series and different band combinations use of 'false colours' to enhance the vegetation cover, land use, natural phenomena and different landscape. There are different time series for Landsat 7; from years 1999 to 2016, and Landsat 8; from years 2013 to 2016. The operator can use Landsat 7 to detect any changes prior to 2013 when there is a significant land use change and Landsat 8 is used to determine the current land use. It is therefore, essential for the operator to always verify the changes with Landsat 8.

Additional tools were also used for the assessment of existing data such as the PNG Forest Basemap, 2012 (ver.1.1), logging concession maps and the forest inventory mapping system (FIMS) boundaries. A set of hierarchical rules were established and used to determine the land use based on a certain percentage and taking into account the forest definition as well.

[4] http://www.openforis.org/tools/collect-earth.html

7.1.2 The application of land use hierarchical rules.

A single land use class is easier to classify however, it becomes challenging when there is a combination of two or more land use classes within the area of interest. Thus, this is where the hierarchical rules are important to determine the land use.

The rules or assigned percentages are based on the land use definition which refers to the "description of the socio-economic function of the land", where the 'land use' is given preference when determining the 'land use' or 'land cover'[1] type. This means that a plot with ≥10% coverage by 'settlement' is considered 'settlement' because the rule says that settlement takes precedence even though the plot has >10% forest cover and so forth. The hierarchical rule table is shown below.

Table 7.1: Land use Hierarchical Rules.

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

[1] *Land cover is considered to be the observed physical cover of the Earth's surface.*

For the historical assessment, the level of disturbance is associated with the different land use categories as a result of human impact, i.e., logging, fire, gardening, grazing, 'wokabaut' sawmill (portable sawmill) and others. The degree of human impact is determined by the operator's own interpretation and local knowledge (field experience) of the area. As for the land use change, the operator has to use Google Earth Engine with the different time series on Landsat 7 and Landsat 8 to determine the actual year of change from one land use conversion to another.

PNG's National GHG inventory will be the updated version from previous GHG inventories due to the uses of different data and its sources. PNG's reports will be consistence because of the currently improvement of its activity data with the use of Collect Earth together with the use 2006 IPCC Guidelines for National GHG Inventory, thus the methodologies used will be consistence to improve PNG's GHG emission and removal estimation reported in FRL, Third National Communication (TNC) report and first Biannual Update Report (BUR1).

Furthermore, there were not enough data used in the previous GHG inventory reporting's, such as PNG's Second National Communication (SNC), the data used was in the absence of collect earth activity data and relevant sources therefore the figures presented in this report were inadequate and doesn't give the an accurate representation of PNG's GHG emissions. Hence, the current data used in PNG's FRL and upcoming reports will supersede any previous data reported for PNG.

7.1.3 Quality Assurance and Quality Control

The data goes through the quality assurance and quality control which is carried out by the officers at the PNGFA Headquarters. The data is checked by Saiku Analysis which is another tool that is operated by Java script to identify error plots but most importantly for the data analysis. In the Saiku analysis the data is sorted into different folders which can be filtered according to the operator's preference on the sort of information that can be displayed in excel, graphs or saved as pdf documents, etc. There are other additional information included as well such as, soil, climate and population.

The error plots are re-assessed with guidance from the excel spreadsheet to check if the information or data provided is correct for these plots. The data goes through the cleaning process then a quality check is carried out on a certain percentage before the final analysis is conducted.

Another major quality check was conducted by comparing Collect Earth data against Global Forest Watch data (Hansen data) managed by University of Maryland (Hansen *et al.* 2013). All the plots where Hansen data showing a total of 200 ha and above tree cover loss within 1600 ha (4x4 km) around the plot in 2000-2015 but neither deforestation nor forest degradation was recorded by Collect Earth assessment, were re-assessed. Most cases the difference between Collect Earth data and Hansen data were due to the lack of details of land cover interpretation of Hansen data. For instance harvesting of old oil palm trees and replanting in oil palm plantation is reported as tree cover loss and gain in Hansen data but it is Cropland remaining Cropland in Collect Earth assessment (therefore neither deforestation nor forest degradation). However, some of the missed deforestation and forest degradation were identified and corrected through the practice. Also, all the plots where Hansen data showing 20ha or less tree cover loss within 1600 ha around the plot but deforestation or forest degradation was recorded in Collect Earth assessment, were re-assessed and some errors were corrected. These quality check process ensure the reliability of the Collect Earth Assessment data.

7.2 Summary of Activity Data

i. Land use of PNG in 2013

PNG has a total of about 46.1 million hectare of which 78.1% is forested with 13 natural forest types and one forest plantations with various species planted (Figure 7.1). The second major land use in PNG is cropland, which covers 11% of the total land area. Grassland covers 5.3% and wetland comprised 4.6% of the total land mass. Other Land including bare soil and rock covers 0.1% of the total land area. Settlements including villages and cities cover 0.8% of the land area.

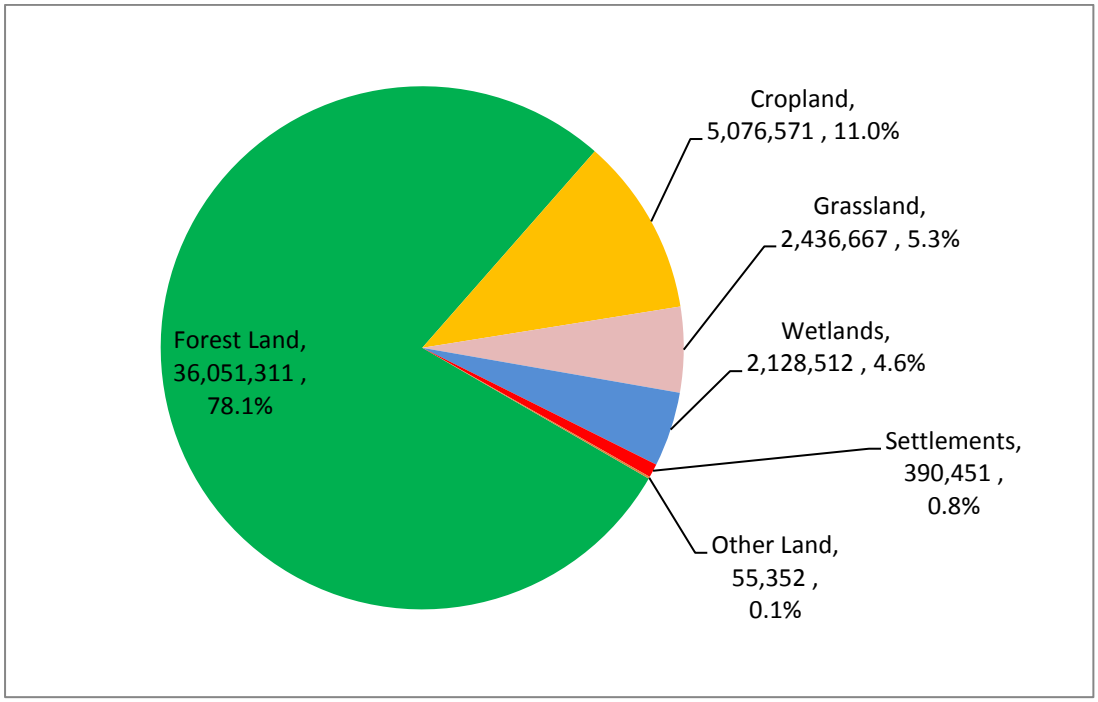

Figure 7.1: Land use in Papua New Guinea in 2013 (PNGFA Collect Earth Assessment).

ii. Status of Forest Land in 2013

Forest Composition and distribution

There are 14 forest types (13 natural vegetation type and one forest plantation) in PNG as described in Chapter 2. Among those, three forest types (low altitude forest on plain and fans, low altitude forest on uplands, lower montane forest) account for more than ¾ of forest in PNG (Figure 7.2). Plantation forest (various plantations species; mono-type or mixed) account for only 0.1% of PNG forest.

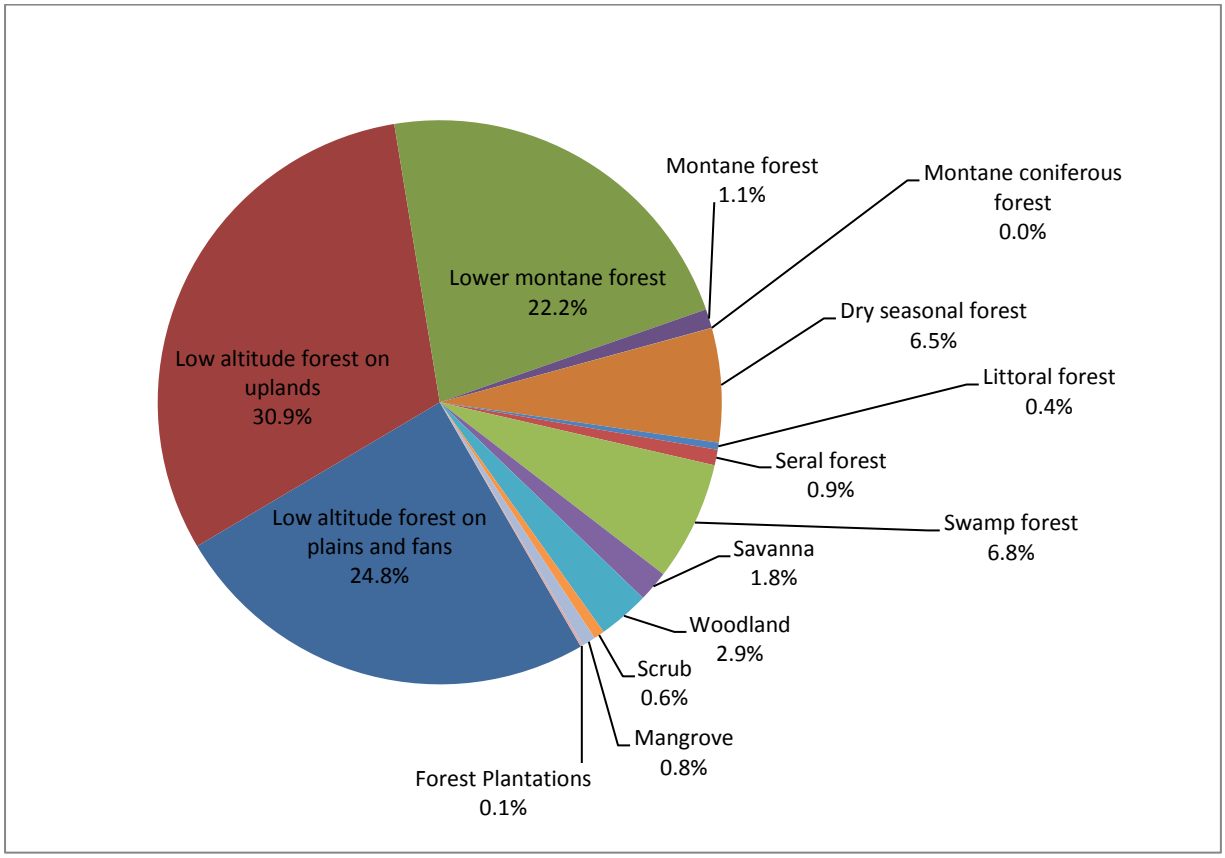

Figure 7.2: The composition of forest types in PNG (PNGFA Collect Earth Assessment)

Forest Disturbance

The recent Collect Earth assessments results shows that 9.9% of PNG's forest is disturbed by large scale logging and 0.2% is disturbed by small scale logging using portable sawmill. Small scale temporary gardening cause 8.2% of forest disturbance (Figure 7.3).

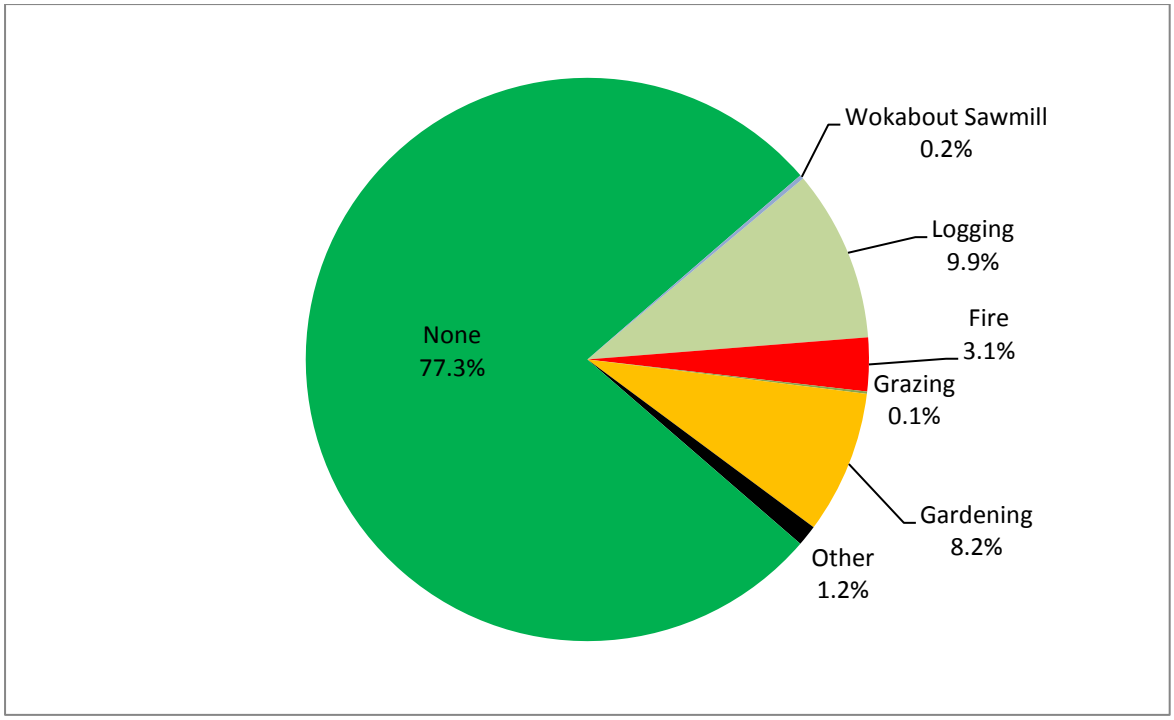

Figure 7.3: Composition of un-disturbed and disturbed forest by various causes in PNG (PNGFA Collect Earth Assessment)

iii. Forest change 2000 - 2013

Deforestation 2000-2013

In the last 13 years, about 194,026 ha of forest has been cleared and converted to other land use. This is 0.5% forest loss in 13 years. The highest annual deforested are is 39,677 ha in 2013

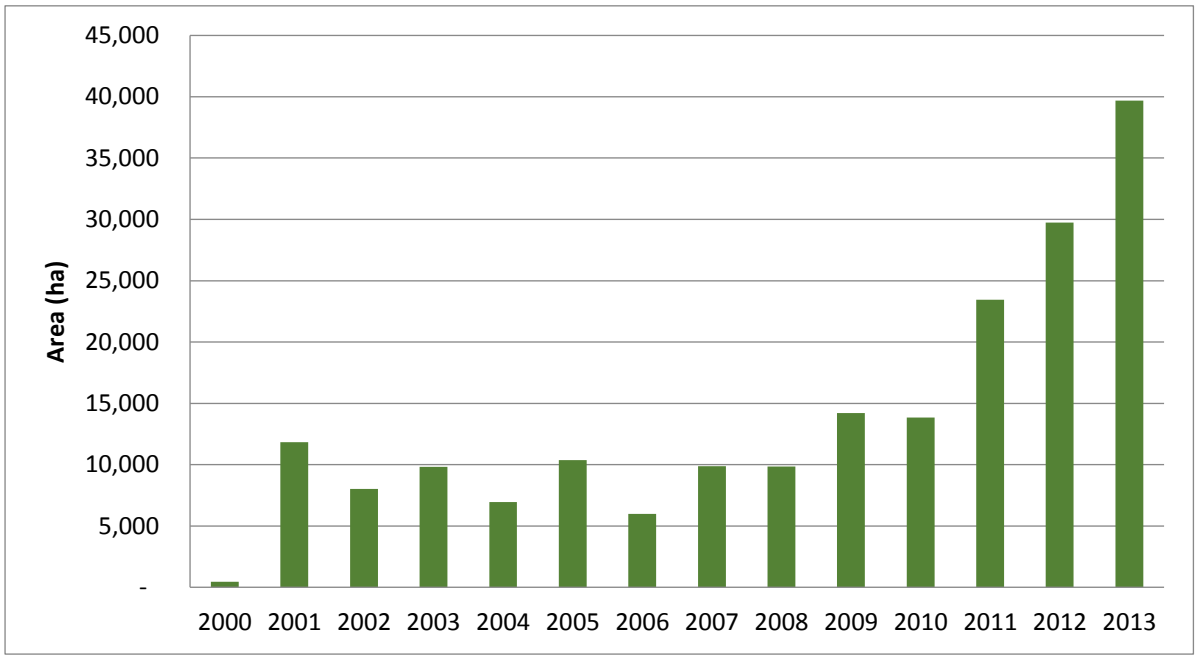

Figure 7.4: Deforestation occurred in PNG 2000 – 2013 (PNGFA Collect Earth Assessment)

The majority (99.3%) of deforestation was Forest converted to Cropland (Figure 7.5).

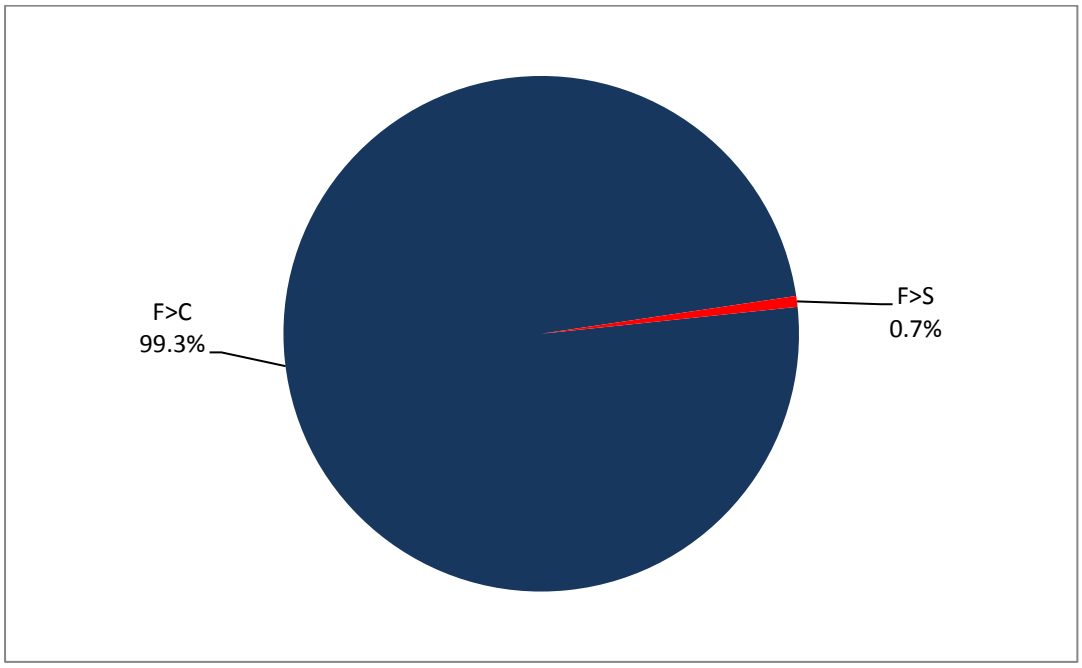

Figure 7.5: Proportion of Forest converted to various land use from 2000 to 2013 in PNG (PNGFA Collect Earth Assessment)

Among the Forest converted to Cropland, the main driver of deforestation are shifting cultivation (66.3%) and Oil Palm plantation (24.4%) as shown in Figure 7.6. While Oil Palm plantation are mostly operated by private companies in commercial scale, shifting cultivation is the subsistence farming operated by families. Majority population of PNG rely on this type of farming for their living.

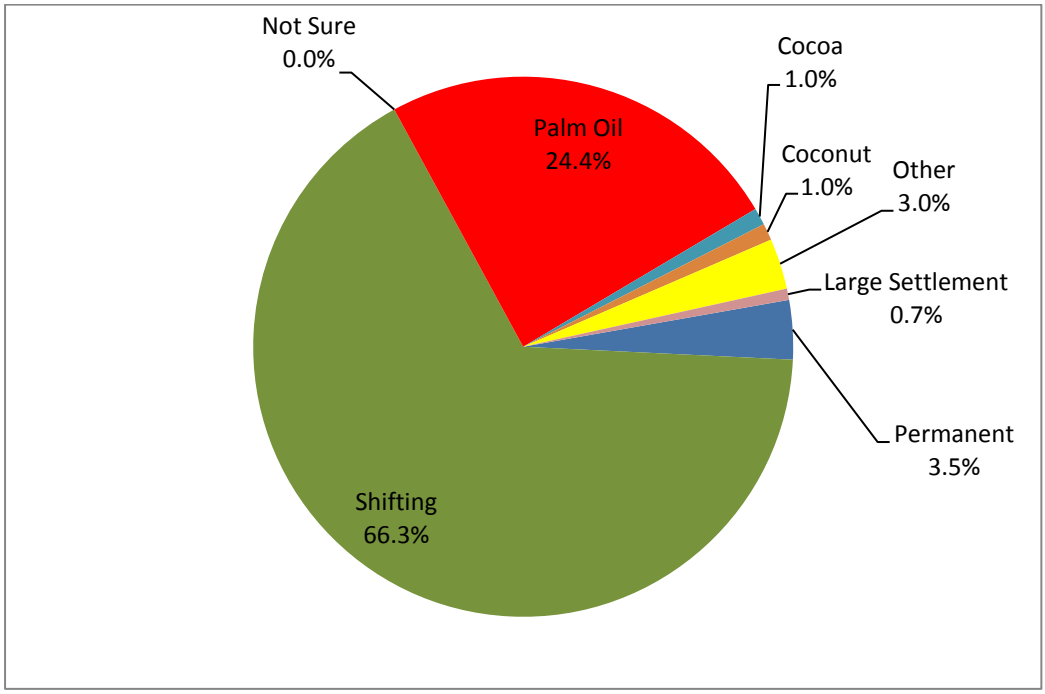

Figure 7.6: Drivers of conversion from forest land to cropland in 2000-2013(PNGFA Collect Earth Assessment)

Forest degradation 2000-2013

A total of 2,091,710 ha of Forest was disturbed (degraded) between 2000 and 2013. Forest area degraded during the period is nearly 10 times higher than the area deforested in the same period. Annual area of forest degradation is shown in Figure 7.7. The largest forest degradation was recorded in 2010 with 185,075 ha disturbed by commercial logging.

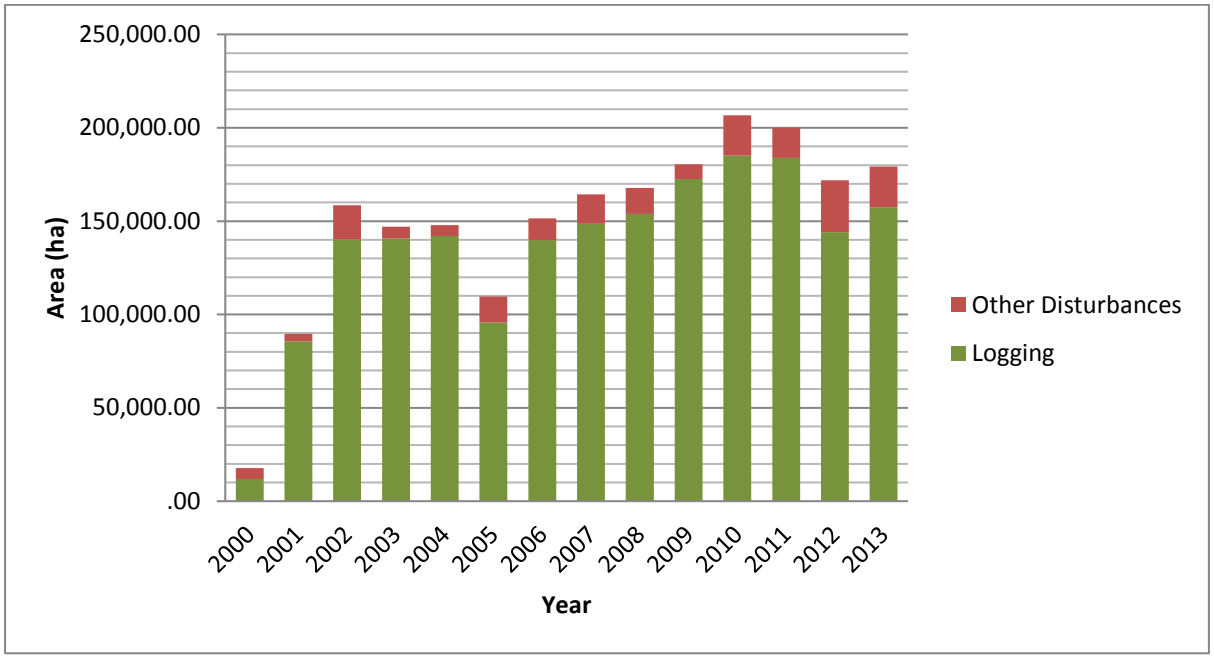

Figure 7.7: Annual forest degradation in PNG from 2000 to 2013 (PNGFA Collect Earth Assessment)

Almost all the disturbance (90.1%) recorded from 2000 to 2013 were due to commercial logging and other impacts caused by small scale logging using portable sawmill, gardening and fire are not significant. In 2013, 22.7% of PNG forest was disturbed. The most significant cause of disturbance was commercial logging (9.9%) but gardening (8.2%) and fire (3.1%) were also significant (Figure 7.3). Forest affected by fire would have been affected repeatedly since long time ago and they were not assessed as the new disturbance during the studied period from 2000 to 2013. There might be some similar cases for the disturbance by gardening but some of the unknown or natural disturbance might have been identified as gardening. This needs further investigation.

Forest increase (carbon stock enhancement) 2000-2013

There was no forest increase (converted to Forest from other land use type) was recorded by Collect Earth assessment during 2000-2013.

8. National Circumstances

Decision 12/CP.17 invites Parties to provide details on how national circumstances have been taken into account in the construction of the FRL. The below section reviews the historic trends in drivers of forest cover change and likely future trends based on available evidence.

8.1 National Economic and Policy Context

Policy Environment

PNG's policy environment is centred around the long term development strategy laid out in 2010 by the PNG Vision 2050. This is the blueprint document for all government policies/strategies and all sectors are required to align themselves with this framework. This policy is founded upon the country's National Constitution[5] and further incorporates its objectives within its 'Seven Pillars.'[6] Pillar five (5) deals with the need for a Sustainable Development approach to all natural resources in PNG and specifies the need for measures to be adopted to increase both domestic and international/global resilience to the impacts of climate change and environmental destruction.

Box 1: Goals of the MDTP2

- Increasing the countries Human Development Index (HDI) rating in 2016-2017 towards PNG becoming one of the top 50 countries on the HDI by 2050; and
- Achieving this by and through becoming a world leader in responsible, sustainable development.

Vision 2050 also forms the basis for central national planning and for Medium Term Development Plans to be produced on a three yearly basis (to be extended to five years to fit with government terms). The most recent of these is the MDTP 2 (2015-18)[7], which sets out an ambitious target for development (see Box 1) and is linked closely to the National Strategy for Responsible Sustainable Development (StaRS) that was launched by the Prime Minister in 2014.

These most recent national development policies identify a shift in national planning away from strategies focused on economic growth through natural resource extraction to one that is based around a more sustainable development pathway. E.g., the StaRS establishes the development paradigm for the implementation of the Vision 2050 and its core pillars. It is a holistic approach to responsible sustainable development and is a national government consolidated approach in addressing significant sectors towards socio-economic development which are also financially supported through the national budget. The key Guiding Principles within this policy document relating to Climate Change are incorporated into the concept of 'sustainable development' mentioned in MTDP II and include principles such as biodiversity retention and ecosystem services (potential mechanism to support REDD+), resource and energy efficiency, low carbon and low emission, and precautionary approaches.

Sector-specific policies such as those within Climate Change, also address these broad objectives, e.g., the first *National Climate Compatible Development Management Policy*

[5] Specifically, the 5 National Goals and Directive Principles - Integral Human Development, Equality and Participation, National Sovereignty and Self-Reliance, Natural Resources, Resource Creation and Environment; and Papua New Guinean Ways.

[6] Human Capital Development, Gender, Youth and People Empowerment; Wealth Creation; Institutional Development and Service Delivery; Security and International Relations; Environment Sustainability and Climate Change; Spiritual, Cultural and Community Development; and Strategic Planning, Integration and Control.

[7] This second phase of the National level planning policy was recently passed by Parliament in 2016 and replaces the previous interim planning document of 2016-17.

(NCCDMP) endorsed in 2013, includes a national-level Carbon Neutrality goal of 50% by 2030 and 100% by 2050. PNG's first ever Climate Change law, the *Climate Change (Management) Act, 2015,* gave prominence to the implementation of the NCCDMP entrenching these objectives within national legislation. Furthermore, it recently enacted the *Paris Agreement (Implementation) Act 2016*, which aims to 'domesticize' Article 5 of the Paris Agreement within the country's legal framework, ensuring REDD+ (and related activities) are enforceable within the country.

These changes in strategic direction are however operating in a challenging economic environment. The high reliance on extractive industry revenue has made the country vulnerable to changes in global commodity markets and with declining prices for oil and minerals the country has seen a rapid slow down in growth and a significant drop in government revenue (of -20% in 2015). This latter element has led to significant efforts to reduce spending with major sector budgets being cut significantly in 2015 (37% cut in health, 36% cut in infrastructure, 30% cut in education[8]). Within this economic context significant shifts in economic policy appear unlikely, particularly those that would reduce the country's aim to access foreign investment and export revenue – a factor particularly relevant to log exports and large scale agricultural investments. Thus, while PNG's log exports contribute under 10% of PNG's exports and large scale commodity exports could provide the economic 'space' to reduce reliance on this revenue, the current global economic climate has made this situation unlikely.

8.2 The drivers of forest cover change in PNG

As reported in Chapter 7, the results of Collect Earth assessment show that 0.5% (194,025 ha) of forest was lost in 13 years (2000 -2013) and 6% (2,097,710 ha) forest was degraded in the same period. About 99% (192,711 ha) of deforestation was due to conversion to Cropland and among that, 66% (124,664 ha) was shifting cultivation and 24% (47,351 ha) was Oil Palm plantation. Almost all forest degradation was caused by commercial logging.

Drivers of Deforestation and Forest Degradation

Commercial Logging:

This driver has had a significant impact on forest cover in PNG. Over 3.8m ha of forest has been identified as being degraded through logging and 8.4m ha of forest land are under current timber concessions. The sector has been a mainstay of the rural and national economy since the 1970's and the country has consistently been one of the most significant global exporters (see Figure 8.1).

[8] Paul Flanagan, (2015) *PNG's frightening Final Budget Outcome*, Australian National University.

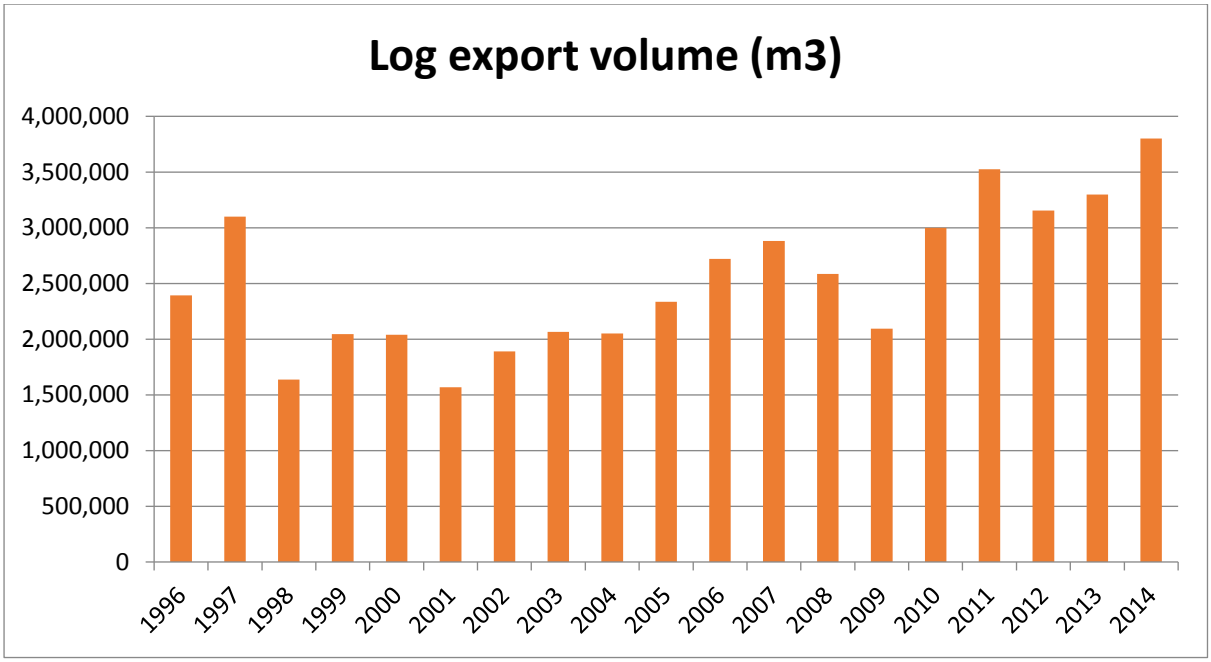

Figure 8.1: PNG annual log export volume 1996-2014 (Yosi 2015).

PNG timber industry is driven by a complex mix of international demand and domestic political and economic factors that have evolved over the past forty years. A number of efforts have been made to strengthen and reform the sector and while progress has been made, the line agencies responsible remain unable to deliver significant or rapid improvements. This is due to a lack of resources, technical capacity and the generally low levels of competency across logging companies, communities and provincial, district and local governments, as well as the challenging position that the regulator faces when being perceived as needing to deliver whilst not restricting economic opportunities.

The current Forestry Act was passed in 1991, which, accompanied with subsequent regulations, was intended to improve logging standards and mechanisms for acquiring and managing concessions. Following a pause in concession allocation the opening up of the new Forest Management Areas (FMA) through the 1991 Act led to a significant increase in the allocation of concession areas and production levels . This trend continued until the financial crash of 1998 which limited both demand and available finance for logging operations.

A steady recovery occurred over subsequent years linked also to a shift in destination markets from a predominantly Japanese market to a Chinese market. This shift was driven partially by higher import standards in Japan and rapidly increasing demand from a growing Chinese market . Production and exports were once again hit by the global financial crisis in 2009, although exports rebounded quickly to exceed previous levels. This increase has been driven by extraction from land areas under Special Agricultural Business Leases (SABLs) which, following amendments to the Forestry Act in 2003 and 2007, allow timber harvested and exported under Forest Clearance Authorities (FCA), free from the majority of safeguards put in place by the regulations of the Forestry Act. It is estimated that there are currently 4m ha of closed canopy forest in SABLs that would currently be available for harvesting.

Forestry legislation is also pivotal to the implementation of REDD+ by virtue of its nature and its mandate by law. All policy and programs developed within this sector have a direct implication

on the various aspects of REDD+ and MRV. In this context, the legal framework sets out clear objectives for its forest programmes under the National Forest Policy, the National Forestry Development Guidelines (NFDG) and the Forestry and Climate Change Framework for Action (FCCFA). These policies attempt to recognize and place emphasis on the need for forest inventories, forest plans to be drafted and monitoring of forest resources. Recently, certain forestry initiatives took a shift from the traditional view to a more sustainable approach that sought to meet certain international climate change benchmarks. In anticipation of the need to re-align its programs and activities with these benchmarks, they have sought to amend their existing Forestry Laws and Policies as well, with expected revisions to be completed in 2017.

Future Trends:

It is difficult to provide accurate predictions of the future direction of the PNG timber industry based solely on domestic policy. A log export ban set to come into force in 2020 combined with proposals to cancel 'undeveloped' SABLs, restrictions on foreign firms leading plantation development activities and the high operating costs and operational risks of working in PNG, have led some industry participants to expect a future decline in activity and revenues from the logging industry.

Such predictions are hard to fully justify particularly given the role that commercial forestry has played in delivering 'immediate development' and investment in rural PNG and its importance in local political processes. Indeed proposals to cancel SABLs have been put on hold until the 2017 election and the proposals for a log export ban have been in place 2010 with its implementation date continually rolled back. International demand is similarly difficult to predict but with China's growth continuing – if decreasing in speed – and certification systems remaining in their infancy, a rapid drop in demand appears unlikely. Domestic supply, while increasingly limited within existing concession areas, also remains substantial with PNGFA having identified a further 8.4m ha of viable concession areas.

Based on these factors it is anticipated that without interventions to address the current situation and provide viable alternatives to either continuation of a business as usual scenario and the implementation of REDD+ activities current situation will continue. Indeed there also remains the potential for a rapid increase in clearing as an unintended consequence of threats to cancel 'undeveloped' SABLs.

Family Agriculture:

This term has been used to capture both gardening and shifting cultivation activities in PNG and is also the preferred term used by the Department of Agriculture and Livestock (DAL). This driver has had a significant impact on forest cover in PNG, causing widespread deforestation with the active area estimated to cover over 3.2m ha. Shifting cultivation is crucial to the economy and food security of the country. Over 80% of food energy consumed is produced domestically, overwhelmingly from small scale shifting cultivation, with the value of imports needed to replace domestic production being estimated at over $900m. Similarly while local trade is minimal, it is growing, with market value estimated at $30m per annum in 1990.

The agricultural systems used are extremely diverse and any transition to larger, more permanent and efficient forms of production have been severely limited by:

- *High levels of diversity across regions* – there are over 350 different agricultural systems practiced in PNG making development of coherent agricultural strategies difficult to achieve.
- *High transport costs* – Transport systems are very limited in PNG and the costs of transporting goods from one area to another can be in excess of international transport

values. This has reduced the impact of the broader economic developments that have occurred in PNG driving a broader spread of agricultural development.

- *Very limited extension services* – Agricultural extension services were decentralised to the provincial and district level under the 1995 Organic Law, however there has been no structured system to build capacity of service provision at these levels, making extension services for shifting / family agriculture almost non-existent except in areas directly serviced by the National Agricultural Research Institute (NARI).

Future Trends

The most significant indirect driver of expansions in shifting agriculture relate to PNG's rapidly increasing population. While the national level impacts of this have been limited due to the predominantly low population densities prevalent across PNG, as the population increases so too does the rate of increase in terms of total population numbers with current annual population increases in the region of 0.2% per annum. These increases will result in higher demand for food, a factor that is exacerbated by a trend towards increased per capita calorie? consumption linked to economic development. It is thus anticipated that there will be an increase in land areas used for family agriculture unless significant changes are made in the way that local land use planning occurs and agricultural extension services are provided.

The need for additional food production has also been recognised by the government with the PNG Development Strategic Plan 2010-2030 targeting an increase in both agricultural productivity and a 180% increase in cultivated land by 2030. While this does not differentiate between commercial and family agriculture it can be anticipated that significant increases in the cultivated area will be supported by the government in the current development context.

Commercial Agriculture:

This driver covers just 0.65m ha but has a significant impact on the local and national economy, and has significant potential for rapid future expansion. The agriculture sector exported over $1billion in 2014[9] and one of the two largest palm oil producers employs over 10,000 people as well as 8,000 small holders; while coffee and cocoa production is estimated to support the livelihoods of over 60,000 families.

Expansion of commercial agriculture plantations has been limited over the past 20 years, with coffee and cocoa production focused on the renewing of stock and improvement of growing techniques[10], while oil palm has been dominated by two firms committed to international sustainability certification that limits conversion of primary forest areas.

The expansion of SABLs underlies a potential rapid change in the nature of commercial agriculture in PNG, with over 5m ha of land leased between 2003 and 2011. Within this area over 200,000ha of new oil palm developments are underway, promoted by new operators in the sector in PNG.

Future Trends

[9] Observatory of Economic Complexity – Papua New Guinea country page available at http://atlas.media.mit.edu/en/profile/country/png/

[10] The situation for cocoa and coffee presents one of the many discrepancies between public policy and implementation. The government has issued directives that no coffee of or cocoa traders will have their licenses renewed unless they agree to invest in plantations covering 10,000 something that would require a significant expansion in area under cultivation if the policy was to be enforced. However there is limited interest in such controlled up-scaling of investment from the private sector and indeed the Productive Partnerships in Agriculture Project (PPAP) (a $100m project to support coffee and cocoa growers) is not focused on such expansion but rather strengthening of existing stock, and improved methods.

The future trajectory of expansion of commercial agriculture in PNG remains challenging to predict. Increasing regulation of the palm oil industry in Malaysia and Indonesia combined with ongoing international demand has the potential to drive expansion within PNG, where bio-physical growing conditions are good and there is currently limited regulations. Such expansion would have a significant impact on forest cover in PNG, especially if the 1m ha of forest land currently assigned to oil palm under SABLs were to be converted.

Analysis of current SABL proposals and the broader oil palm market however have noted that a very rapid increase in genuine oil palm investments may be less likely given the limited infrastructure and high costs of doing business in PNG[11]. Such caution can also be noted for many of the other proposed SABL investments. However the potential to claim access to land areas through initiating agricultural development may provide incentives for rapid deforestation of areas.

Fire:

Its prevalence is closely linked to population with fire used to control vegetation and to clear land for family agriculture. Of the 81,819 fire hotspots detected between 2002-14, over 75% occurred within 6km of a village.[12]

The extent of burning is also significantly impacted by seasonal and climatic variations, with El Nino years seeing large spikes in levels of burning and more incursions into forest areas (only 6.7% of fires on average between 2002-14 were in closed canopy forest areas, in 2015 an El Nino year, this percentage rose to 15%)[13].

Future Trends:

Future trends in fires impacting forest land are anticipated to be linked to trends in increasing population and demand for land through shifting agriculture, with spikes of higher impacts on forest areas occurring in El Nino years. Climate change, leading to more pronounced dry spells, could also play a role in increasing the incidence and prevalence of fire.

Small Scale Logging:

Broader data on the operation of small scale loggers, however, remains limited as production under 500m^3 per annum can be done by landowners without any permit. Harvesting between 500-5,000m^3 should operate under Timber Authorities (TA) issued at the provincial level but this is not identified by timber tracking systems related to the export market. Estimates from 2001 indicated that as many as 1,000 portable saw mills may be in operation, with other estimates indicating production levels at approximately 50,000m^3 per annum across the country.

Small scale logging operations are also very diverse in nature, ranging from well-supported operations focused on sustainable production to international standards and broad community development to small groups of producers operating outside of regulations, and at times infringing across customary land barriers. At the national level interest in small scale logging at the beginning of the century led to the development of the Eco-Forestry Policy (PNG Forest

[11] Nelson and the Harris paper XXX

[12] Bryan, J.E., Shearman, P.L. (Eds). 2015. The State of the Forests of Papua New Guinea 2014: Measuring change over the period 2002-2014. University of Papua New Guinea, Port Moresby.

[13] Bryan, J.E., Shearman, P.L. (Eds). 2015. The State of the Forests of Papua New Guinea 2014: Measuring change over the period 2002-2014. University of Papua New Guinea, Port Moresby.

Authority, 2004) for the sub-sector. This however was never passed and has been removed from the approval process.[14]

Future Trends

It is anticipated that small scale logging operations will remain at similar levels of production, without significant shifts in government, NGO or donor actions. Assessments of potential market development have highlighted the logistical challenges of bringing timber to either a local or international market as well as the challenges of maintaining a regular supply that is sufficient to support investments in processing facilities and markets linkages.

Fuel wood:

It is estimated that 85% of the population of PNG utilise fuel wood with consumption levels at 1.8m^3 per person per annum, some six times that of other Asia-Pacific countries.[15] This level of use equates to over 10m m^3 per annum, a significant level of resource harvesting. The vast majority of this collection is for personal use with only a small proportion engaged in the sale of fuel wood (mostly based around a rural to urban trade).

Future Trends

With no clear rural energy policy in place trends in fuel wood consumption are anticipated to increase in line with PNG's population. As population increases this process could have an increasingly significant impact on forest cover, particularly along transport routes close to emerging urban areas.

Mining:

The development of both mining, oil and gas have had a high profile in terms of land use change within PNG due to their high economic value. The actual scale of impacts on forest cover are however relatively minimal in terms of total forest area with the broader impacts of displacement of people (both towards and away from mine areas) and the development of infrastructure opening up new forest areas causing the majority of the forest cover change through drivers such as family agriculture, fuel wood collection and small scale logging.

Enhancement and Conservation Actions

Reforestation

The GoPNG have sought to reforest or restore areas that have been heavily degraded or deforested and to develop plantations on degraded land. Reforestation and plantation development has been a key policy with the highly ambitious target of reforesting 800,000ha of land between 2007 and 2050 linked to Vision 2050 with each province being set a target of 1,100ha per year. PNGFA have set a target of 80,000ha to be reforested by 2030 that is linked to the MDTPII, of which 60,000ha has already been planted.

[14] ACIAR (2012) *A review of the use of portable sawmills in Papua New Guinea and the Solomon Isles*. ACIAR project report
[15] Numbers for per person use and comparison with other countries from Nuberg (2014) Developing the fuelwood economy of Papua New Guinea *Energy for Sustainable Development 24*

Despite ambitious policy targets focused on reforestation and plantation development since the turn of the century, plantation development has struggled to achieve its targeted rates of increase. Challenges in linkages between government, landowners and investors in developing projects with long term returns has limited development, and government investment has been identified as significantly below that needed to stimulate the sector.

Future trends

Without significant transition in the way that plantation development is promoted it is not anticipated that the rate of plantation development will move beyond its current levels, with the most likely target being an additional 20,000ha of small scale plantations developed by 2030.

Conservation

PNG has an exceptional level of biodiversity for its land area and efforts have been made to ensure that high value biodiversity is protected and conserved. The protected areas network, however, is not extensive, covering just 4% of the country (across 53 protected areas – the majority of which are wildlife management areas), and can be seen as limited in terms of effectiveness with very low levels of active management[16] and significant evidence of infringement.[17]

Expansion and management of the protected area network is faced with significant challenges with conservation work drastically under resourced and with no direct land ownership, proponents of protected areas need to engage in the same land negotiations with landowners as economic activities but with no promise of future revenue. The Conservation and Environmental Protection Authority (CEPA) has a mandate to lead and manage conservation activities and have recently adopted a new Protected Areas policy (2015) and are currently also drafting a Protected Areas Bill which will aim to implement the ambitious goals of the policy by 2017. Within this Policy and Bill it proposes the establishment of a conservation trust fund to increase finance availability.

Future Trends

Areas under national and provincial protection are anticipated to increase but protected forest land is also liable to be characterised by areas that are under minimal threats from other drivers of forest cover change due to their remote locations or geographical characteristics e.g. steep slopes.

[16] GoPNG (2010) Fourth National Report to the CBD – it shows that close to 85% of protected areas are wildlife management areas and also notes a number of reviews that indicate that all most all protected areas have 'limited or no' management structure in place.

[17] Greenpeace (2012) Up for Grabs – the report notes that twelve protected areas have overlaying logging concessions and that 130,000 ha of protected areas (of just under 2m) now have overlaying SABL designations.

9. The Forest Reference Level

Approach towards establishing the forest reference level

PNG proposes a FRL that exceeds historical average emissions for expected future growth of BAU emissions in the land-use sector.

PNG is aware that most countries have projected historical emissions through using simple averages to represent their forest reference level. Only few countries have found it necessary to project an increasing trend, no country has yet projected a decreasing trend.

Using a historical average to represent future trends implies a strong assumption about the drivers of deforestation and forest degradation, namely that these remain approximately at the same level. In countries with falling emissions, using a historical average might overestimate the business-as-usual emissions during the reference period. In countries with increasing emissions, such as PNG, using a historical average would underestimate the business-as-usual emissions during the reference period.

As highlighted in the previous section on national circumstances, this future growth is anticipated as a result of the specific range of factors and supporting evidence presented concerning PNG's drivers and projected future trends.

Quantifying expected future growth of BAU emissions in the land-use sector relies on extrapolating the trends observed during the reference period. A linearly increasing trend of historical emissions growth is observed over the historical reference period. It is extrapolated for the results-reporting period.

Regressing historical emissions on the years during the reference period delivers good statistics. Both coefficients are statistically highly significant, the determination coefficient indicates a good fit and the residuals show no remaining trends. Full regression statistics are included in the annex to this report.

Expected emissions for the results-reporting period

CO2 emission and removal of the three REDD+ activities Deforestation, Forest Degradation and Carbon Enhancement during the historical reference period from 2001 to 2013 is provided in Table 10.1. During the reference period, CO2 emissions of the three REDD+ activities show rapid and steady increase (Figure 10.1). The linear model is remarkably strong with very high coefficient of determination (R2=0.84). Such trend of increasing emission is considered reflecting the national circumstance described in Chapter 8 well. It is considered that linear model is the most appropriate to be used for PNG Forest Reference Level.

PNG Forest Reference Level is;

Annual emission (tCO2e) = 1,679,607 x Year -3,339,358,085

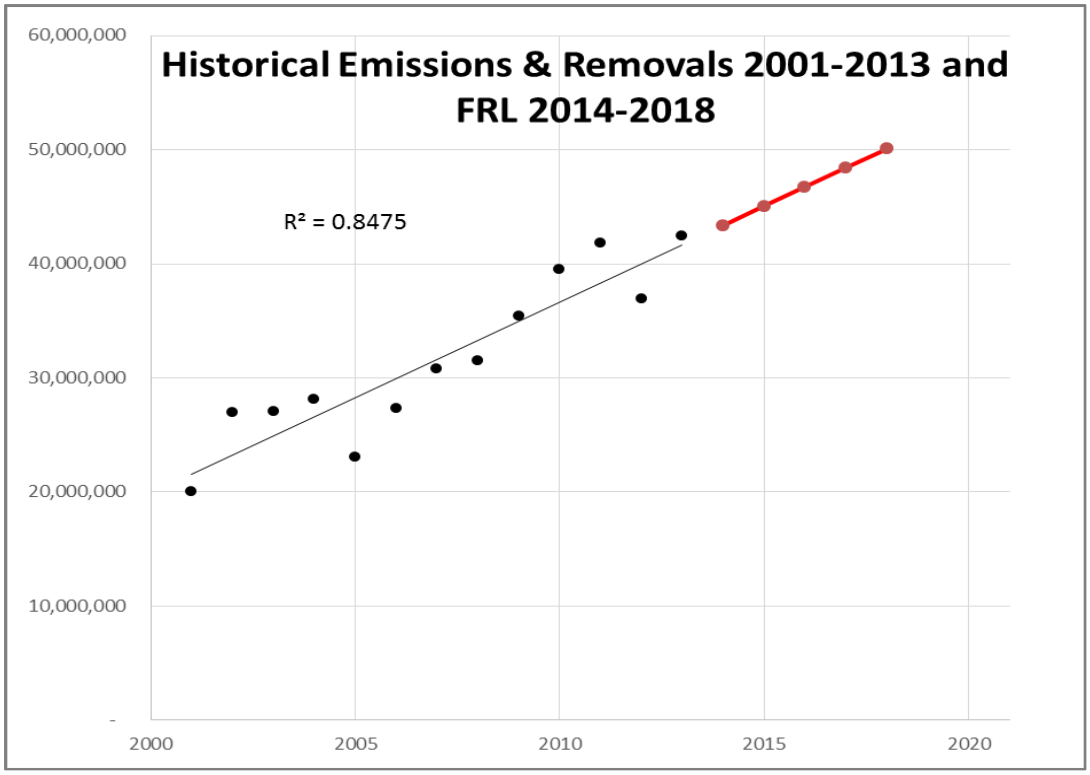

Figure 10.1: Historical Emissions & Removals 2001-2013 and FRL 2014-2018

Table 10.1: Annual CO2 emission of three REDD+ activities (Deforestation, Forest Degradation and Carbon Enhancement) during the historical reference period 2001-2013

Year	Deforestation	Forest degradation	Carbon stock enhancement	Total emissions and removals 2001-2013	FRL 2014-2018
	Emissions	*Emissions*	*Removals*	*Emissions & Removals*	*Emissions & Removals*
	tCO2e /year	*tCO2e /year*	*tCO2e /year*	*tCO2e /year*	*tCO2e /year*
2001	4,623,017	15,441,146	-	20,064,162	21,534,851
2002	1,911,491	25,101,056	-	27,012,547	23,214,457
2003	3,249,282	23,834,478	-	27,083,761	24,894,064
2004	2,131,153	25,977,828	-	28,108,981	26,573,671
2005	3,636,414	19,424,818	-	23,061,232	28,253,277
2006	1,338,504	25,969,659	-	27,308,164	29,932,884
2007	2,936,725	27,823,956	-	30,760,681	31,612,491
2008	3,014,378	28,459,714	-	31,474,091	33,292,097
2009	4,047,172	31,373,792	-	35,420,964	34,971,704
2010	4,021,547	35,461,013	-	39,482,561	36,651,311
2011	6,618,171	35,244,691	-	41,862,863	38,330,917
2012	8,798,126	28,122,531	-	36,920,657	40,010,524
2013	11,006,534	31,395,182	-	42,401,717	41,690,131
2014					43,369,737
2015					45,049,344

2016					46,728,951
2017					48,408,557
2018					50,088,164

10. Uncertainty analysis

A quantitative and qualitative uncertainty analysis is undertaken. In elaborating the FRL and the activity data and emission factors that underlie it, the analysis of uncertainties makes it possible to identify opportunities for improvement.

Qualitative uncertainty analysis

In terms of activity data, several major sources of error in estimating past land-use trends from the Collect Earth exercise are expected.

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

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

The major potential sources contributing to uncertainty of the sampling assessment such as Collect Earth are the sampling error such as unrepresentative samples and variability resulting from the use of samples and the human error such as misinterpretation of historical land use and land use change and forest.

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

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

Quantitative uncertainty analysis

In terms of activity data, the sampling error was estimated by using the spreadsheet developed by FAO for the Landuse Category and Conversion during 2000-2015 assessed by Collect Earth.

The standard error of an area estimate is obtained as A*pi (1-pi)n-1 (equation 1; taken from Chapter 3, volume 4 (AFOLU), of 2006 IPCC Guidelines, pp 3.33-3.34). The uncertainty of Forest land remaining Forest land, Forest land converted to non-Forest land, and non-Forest land remaining non-Forest land was respectively 0.67%, 16.27% and 2.43%.

PNG also has been implementing landuse assessment by the wall-to-wall mapping method using TerraAmazon software adjusted to PNG situation (called TerraPNG). Although the assessment has been completed only for the base year of 2015, the relative comparison between the results of sampling based method (CollectEarth 2016) and wall-to-wall mapping method (TerraPNG 2015) has been conducted as the accuracy assessment of TerraPNG. The overall accuracy (agreement rate) of Forest/non-Forest was 89% and IPCC landuse category was 83%. It should be noted that CollectEarth sampling based assessment is not always interpreting the landuse over the exact point location, instead using the hierarchy rule for the plot.

There is incomplete quantitative information available on error in estimating forest carbon stocks and emission factors. Those estimates of forest carbon stocks taken from Fox et al. (2010) are used for a bit more than half of PNG's forests and come with a quantification of sampling error. These sampling errors amount to around 20-30% depending on the forest types (28.4%, 16.7%, 32.0%, 21.4%, and 18.1%). There is no information on other error sources available there. Those estimates taken from the IPCC guidelines do not come with quantitative information on errors.

Approach towards reducing error

The current estimation of the uncertainties of activity data is purely statistical with no ground truth. PNG is one of the difficult countries to implement statistically valid ground truth survey since the large part of area in the country is inaccessible for the ground truth survey. But the national forest inventory currently has being implemented therefore the estimation of the uncertainties using ground-truth data will be considered in future.

Although it is difficult to collect ground truth data in PNG, it has been experimenting in assessment using Collect Earth to have multiple sets of plots for re-evaluation by multiple operators. One possibility to estimate the human error is to choose within the collection persons who have good experiences at ground survey and remote sensing to be the QC operators, who will be evaluating plots that have been evaluated by other operators. It is currently under implementation to use the data collected from this QC controllers as ground-truth and compared to the data collected by "normal operators".

Although the current approach to establishing emission factors may be affected by several error sources, in the medium term better data may become available from the results of the currently ongoing national forest inventory.

11. Proposed improvements

According to the stepwise approach to setting out the FREL, PNG proceeds to submit the current report with the anticipation that several aspects of the FREL will require further improvement in the near future once.

In the future it is anticipated that PNG's FREL report will include some of the following key improvements as indicated below:

- Once more accurate data become available, emission factors will be derived primarily from the outcomes of the NFI. Data from the NFI are currently being collected with a scheduled conclusion of this exercise in 2018. Presently this FREL report derives much of its data, e.g., emission factors, from published literature sources.
- The inclusion of other GHGs besides CO2 such as CH4 and N2O.
- Systematically tracking managed and unmanaged lands over time. Currently, anthropogenic and non-anthropogenic emission are separated through interpreters' knowledge, going forward a more systematic way to separating managed and unmanaged lands may be introduced.
- The inclusion of other carbon pools apart from living biomass such as, litter, deadwood and soil organic carbon. The current FREL only includes above-ground biomass and below-ground biomass.
- A more detailed account for post-deforestation regrowth. After deforestation some of the land is covered by perennial crops. The FRL deducts removals from post-deforestation regrowth in such perennial but there is currently no high-quality information available on the rates of increment in those crops, nor are these being tracked over time, which made it necessary to resort to the use of default increment factors and averaging techniques. As better data become available, this approach may be improved.
- A distinction between degradation drivers. There is currently no information available for emission factors which would allow for a distinction between forest degradation due to logging and other kinds of forest degradation. It is anticipated this data will become available as part of the ongoing NFI.
- The generation of emission estimates for local governments. The estimates presented in this FREL are not disaggregated for use of local governments. In the future, more detail may become available on activity data or emission factors that might make it possible to generate estimates at the level of provinces or districts.
- Broadening the scope of the FREL to include further REDD+ activities such as sustainable management of forests or conservation of forest carbon stocks. In regards to the sustainable management of forests, there is no current data available that would allow for quantifying emissions from conventional forest management as opposed to sustainable forest management. Such data would typically be collected at the level of forest concessions, however, stakeholders recognize the high importance of this improvement because of ongoing efforts to improve forest management practices in PNG. There is also some potential improvements regarding some aspects of carbon stock enhancement. Notably tree planting, is still limited. It is hoped that in the near future

better data will become available which will generate better information on the results of tree planting campaigns throughout the country.

References

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

Bey, A., Diaz, A.S., Maniatis, D., Marchi, G., Mollicone, D., Ricci, S., Bastin, J., Moore, R., Federici, S., Rezende, M., Patricia, C., Turia, R., Gamoga, G., Abe, H., Kaidong, E. & Miceli, G. (2016) Collect Earth: Land use and land cover assessment through augmented visual interpretation. Remote Sensing, 8, 807-830.

Bryan, J. Sherman, P, Ash, J. & Kirkpatrick, J.B. (2010) Impact of logging on aboveground biomass stocks in lowland rain forest, Papua New Guinea. *Environmental Applications*, 20, 2096-2103.

Bryan, J.E. & Sherman, P.L. (2008) *Papua New Guinea Resource Information System Handbook 3rd ed*. University of Papua New Guinea.

FAO (2010) *Global Forest Resources Assessment 2010 Country Report, Papua New Guinea*. Food and Agriculture Organization.

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

Guide Lund, H. (2012) *National definitions of forest/forestland listed by country*.

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

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O. & Townshend, J.R.G. (2013) *High-resolution global maps of 21st-century forest cover change*. Science, 342, 850-853.

IPCC (2006) 2006 *IPCC guidelines for national greenhouse gas inventories*. Vol. 4. IGES.

McAlpine, J. & Quigley, J. (1998) *Summary statistics from the Forest Inventory Mapping (FIM) System*. AusAID.

McIntosh, P.D., Doyle, R., & Nimiago, P. (2016) *Field guide for sampling and describing soils in the Papua New Guinea National Forest Inventory, 3rd edition*. PNG Forest Authority/FAO

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

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

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

Uhl, C. & Kauffman, J. B. (1990) Deforestation, fire susceptibility, and potential tree response to fire in Eastern Amazon. Ecology, 71, 437-449.

UN-REDD (2013) National Forest Monitoring Systems: Monitoring and Measurement, Reporting and Verification (M & MRV) in the context of REDD+ Activities.

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

Yosi, C.K. (2015) Progress of work on estimatingdegradation from selective timber harvesting in PNG using historical data on log extraction: proxy approach. PNG UN-REDD National Programme.