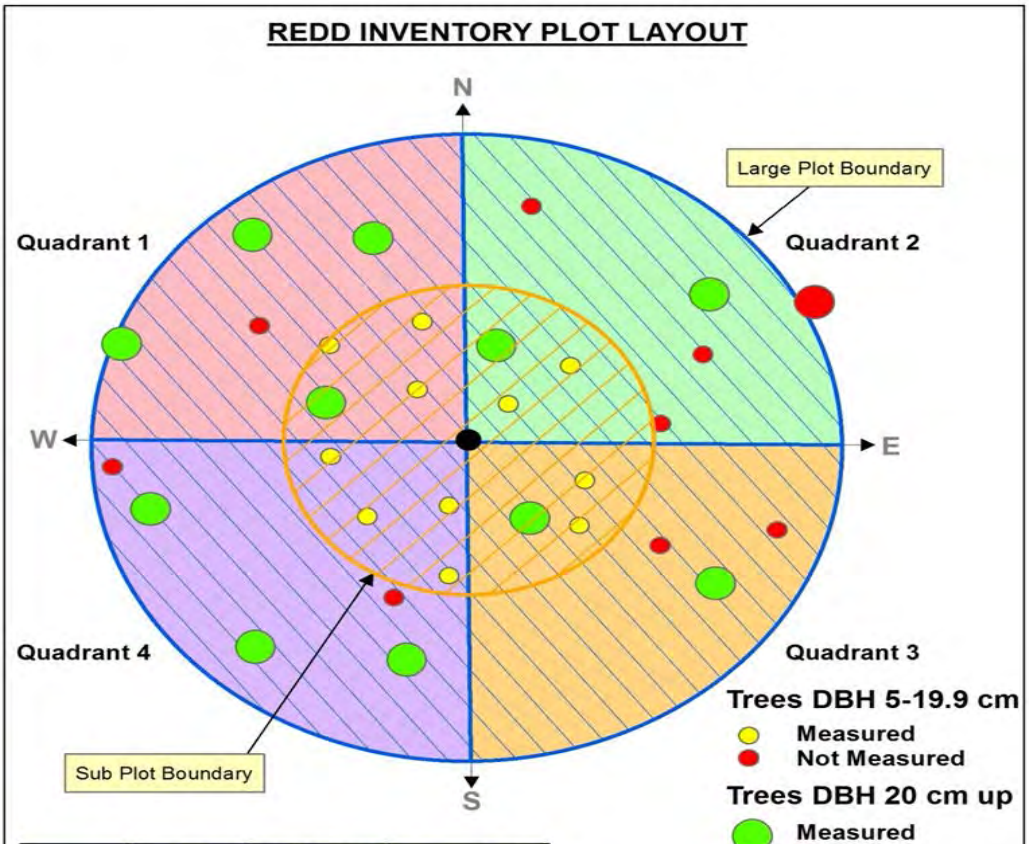
INTERNATIONAL CLIMATE INITIATIVE
Regional project
Climate Protection through Forest Conservation in Pacific Island Countries

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany



Plot	Plot Radius (m)	Plot Sample Area (m^2)	Tree DBH Measured (cm)
Sub Plot	5.61	100	5 - 19.9
Large Plot	13.82	600	20 up

Measurement, Reporting and Verification (MRV) Manual

for Improved Forest Management (Logged to Protected Forest) in Central Suau REDD+ area / Papua New Guinea

SPC Secretariat of the Pacific Community

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Measurement, Reporting and Verification (MRV) Manual

for Improved Forest Management (Logged to Protected Forest) in Central Suau REDD+ area / Papua New Guinea

February 2015

SPC
Secretariat of the Pacific Community

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On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany

Prepared by:

ÖSTERREICHISCHE BUNDESFORSTE

On behalf of:

SPC/GIZ Regional Project

'Climate Protection through Forest Conservation in Pacific Island Countries'

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Abbreviations

AGLB	Above Ground Live Biomass
AGB	Above-Ground Biomass
AGC	Above Ground Carbon
CCB	Climate, Community and Biodiversity
CCBA	The Climate, Community & Biodiversity Alliance
CCBS	Climate, Community and Biodiversity Standards
DBH	Diameter at Breast Heigth
GoPNG	Government of Papua New Guinea
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit
CVF	High Conservation Value Forest
IFM-LtPF	Improved Forest Management - Logged to Protected Forest
IPCC	Intergovernmental Panel on Climate Change
JICA	Japanese International Cooperation Agency
LCC	Land Cover Change
MRV	Monitoring Reporting Verification
PD	Project Document
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
PPA	Preliminary Project Area
PSP	Permanent Sample Plots
REDD+	Reducing Emissions from Deforestation and Degradation
SPC	Secretariat of the Pacific Community
UNFCCC	United Nations Framework Convention on Climate Change
VVB	Validation/Verification Body
VCS	Verified Carbon Standard

1. Introduction

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Secretariat of the Pacific Community (SPC) have been supporting Papua New Guinea's efforts to establish Reducing Emissions from Deforestation and forest Degradation (REDD+) demonstration activities that will reduce emissions while providing alternative revenue options for rural areas. As part of this support, GIZ has committed to supporting the development of a draft Project Document (PD) for Central Suau demonstration site in Milne Bay Province. Suau is one of five national REDD demonstration sites selected through a multi-institutional assessment. The PD has been prepared under the Verified Carbon Standard (VCS) and Climate, Community & Biodiversity Standards (CCBS) in compliance with the VCS VM0011 methodology. The specific eligible activities in the project are defined as:

"Conversion of logged forests to protected forests includes (LtPF): and specifically, protecting unlogged forests that would be logged in the absence of carbon finance."

The MRV Manual is the deliverable 4 of the project "Project Design Document Development for Forest Carbon Project (Logged – Protected Forest) in Central Suau", financed by GIZ and developed by Österreichische Bundesforste AG (ÖBf) in close cooperation with Papua New Guinea Forest Authority (PNGFA).

The purpose of this manual is to provide an overall review of the components that will be part of a Measurement, Reporting and Verification (MRV) system for REDD+.

Monitoring systems that allow for credible measurement, reporting and verification (MRV) of REDD+ activities are among the most critical elements for the successful implementation of any REDD+ mechanism. MRV systems cover, the carbon models and associated data, analysis and inputs, administrative processes, and the reporting processes.

In terms of terminology, we would like to recall that both VCS/CCBA use the term Monitoring Plan, instead of MRV system. In our understanding, a monitoring plan is specifically targeted to monitor project activities, while a MRV system targets national-level REDD+ systems. Considering the project's aim on designing a VCS/CCBA voluntary project, our focus shall be thus on the monitoring plan.

2. Specific MRV Requirements under VCS and CCB Standards

The specific MRV requirements as outlined by the VCS+CCB Guidance on Project Development Process cover 4 steps to be implemented:

- Preparation of a monitoring plan

Note that VCS requires that the monitoring plan be described in the project description. In contrast, the CCB Standards do not require that the monitoring plan for the community and biodiversity components of the project be described in the project description.

Where the project description does not set out the monitoring plan for the community and biodiversity components of the project, the project proponent drafts and submits to CCBA a monitoring plan for the community and biodiversity components of the project within six months of the project start date or within one year of validation. There is no specific template for monitoring plans submitted to the CCBA.

- Preparation of a monitoring & implementation report

At the end of the monitoring period the project proponent drafts a monitoring & implementation report, using the VCS+CCB Monitoring & Implementation Report Template, containing information about the carbon, community and biodiversity components of the project. The monitoring & implementation report serves as the VCS monitoring report and the CCB project implementation report when projects are following the joint VCS+CCB process.

- Public consultation

The project proponent selects a validation/verification body (VVB) that is eligible under both the VCS and the CCB Standards to undertake project verification. The project proponent submits the draft monitoring & implementation report to the VVB, who in turn submits it to CCBA. The draft monitoring & implementation report is posted on the CCBA website for a 30-day public comment period.

Where the VCS+CCB Monitoring & Implementation Report Template has not been used (i.e., separate VCS and CCB Standards reports have been issued), only the CCB Standards report needs to be submitted to CCBA. The project proponent updates the monitoring & implementation report, as necessary, taking due account of comments received as part of the public comment period.

- Verification

The VVB assesses the project and its GHG emission reductions and removals against all applicable VCS and CCB Standards rules and requirements. The VVB produces a verification report, using the VCS+CCB Verification Report Template, and issues a VCS verification representation and a CCB verification statement.

This report primarily considers the requirements for planning of monitoring activities, i.e. preparation of the **monitoring plan**. The remaining steps comprise activities that need to be completed following the implementation of the project.

3. Monitoring Plan

The monitoring plan details how the following will be monitored:

- Project implementation.
- Accounted pools and emissions
- Natural disturbance.
- Leakage.

3.1. Purpose

This section provides the methodology for monitoring the parameters employed to calculate carbon changes due to forest degradation, as well as emissions due to implementation of the project and baseline activities, plus emissions as a result of leakage.

Separate procedures for forest stratification and Permanent Sample Plot (PSP) measurement have been prepared and are shown in Annex 1.

After monitoring has been implemented, the results are consequently applied to revise the net anthropogenic GHG emission reductions for the subsequent reporting period.

3.2. Technical Description of the Monitoring Task

Forest inventory data obtained in the PSPs that are established in the Project Area is required for:

- The Measured Data pathway, ex ante estimation for the baseline degradation calculations
- Monitoring of the carbon change throughout the crediting period to obtain ex post estimations of growth foregone and emissions due to natural disturbances.

Sample plots in this project are permanent in nature. For measuring the carbon change under the IFM-LtPF project, Permanent Sample Plots (PSPs) are more suitable than Temporary Sample Plots, as they are statistically more accurate and efficient in estimating changes in forest carbon. The measurements collected within the same plots under the PSPs approach throughout the crediting period allows the monitoring of the growth of individual trees, survivors, mortality, and growth of new trees at specific time intervals. In addition, the PSPs also permit the verification body to find, measure at random, and to verify in quantitative terms, the design and implementation of the carbon monitoring plan. The following sections describe the procedures for establishing PSPs in the Project Area.

3.3. Frequency of Monitoring and Reporting

The historical reference period is a predetermined amount of time before the project start date, from which data can be taken in order to make ex ante estimation of natural disturbances and illegal harvesting and also to analyze leakage due to implementation of the project.

In principle a five-year timeframe for a historical reference period as close as possible to the project start date shall be used so as to limit uncertainty of the data collected. At a practical level:

- Land and forest cover stratification should be conducted every 5 years.
- The PSP should be measured every 3 years. The plots can be allocated to two separate groups which can be measured every alternate year.

Table 1: Frequency of monitoring and reporting

Process	**Period**
Mapping to determine the Project Boundary	10 years
Stratification of land and vegetation cover	10 years
Measurement of PSP plots	PSP should be measured every 3 years. The plots can be allocated to two separate groups which can be measured every alternate year.
Estimation of Carbon Stocks in Biomass Pools	10 years

3.4. Eligible Carbon Pools

The table below presents the justification, for inclusion or exclusion of carbon pools in the present IFM-LtPF Methodology in accordance with applicable VCS rules.

Table 2: Summary of carbon pools eligible under the Methodology

Carbon Pool	Status for IFM-LtPF Methodology	Justification
Aboveground Biomass (tree#)	Included	Anticipated to significantly increase under IFM-LtPF
Aboveground Biomass (non-tree)	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline
Belowground Biomass	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline
Deadwood	Not included	Not anticipated to significantly decrease under IFM-LtPF
Litter	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline
Soil	Not included	Unlikely to decrease as a result of the project activities, or increase due to the baseline

The above ground carbon (AGC) pool is the only carbon pool to be monitored. Monitoring of AGC is conducted through two key activities:

- Identification of the project area and stratification of forest with common vegetation and biomass attributes.
- Measurement and analysis of permanent sample plots and the estimation of above ground biomass (AGB). AGB is then conversion into AGC estimates.

3.5. Data Available at Validation

The table below shows all data and parameters that are determined or available at validation, and remain fixed throughout the project crediting period. Data and parameters monitored during the operation of the project are included in Section 4.2 (Data and Parameters Monitored) below.

<table>
<tr><td>Data / Parameter</td><td colspan="4">$A_{project, j, t=0}$</td></tr>
<tr><td>Data unit</td><td colspan="4">ha</td></tr>
<tr><td>Description</td><td colspan="4">Project Area within each stratum j, (where j=1,2,3 … J strata) where the IFMLtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence t=0 year</td></tr>
<tr><td>Source of data</td><td colspan="4">GIS maps defining the boundaries of forest vegetation types within the project area. These total areas have buffers deducted from them to derive the net project areas.</td></tr>
<tr><td rowspan="5">Value applied:</td><td>Strata Class</td><td>Gross Area</td><td>Buffer Area</td><td>Net Area</td></tr>
<tr><td>Hma</td><td>19,428</td><td>5,598</td><td>13,829</td></tr>
<tr><td>Hmb</td><td>401</td><td>8</td><td>393</td></tr>
<tr><td>P</td><td>1,340</td><td>246</td><td>1,095</td></tr>
<tr><td>Total</td><td>21,169</td><td>5,852</td><td>15,317</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td colspan="4">Project area by stratum was derived by stratification remote sensing images. The methodologies for remote sensing and forest stratification are provided in the appendices.

The remote sensing analysis used Landsat satellite images captured during 2014. It is assumed that no significant land-use changes occur during the interim period between image capture and project commencement date. This assumption has been verified by on the ground inspections during the initial forest inventory.</td></tr>
<tr><td>Purpose of Data</td><td colspan="4">Determination of baseline scenario</td></tr>
</table>

<table>
<tr><td>Data / Parameter</td><td colspan="8">$A_{IFM\_LtPF\_baseline, j, t=i}$</td></tr>
<tr><td>Data unit</td><td colspan="8">ha</td></tr>
<tr><td>Description</td><td colspan="8">Net project Area within each stratum j, (where j=1,2,3 … J strata) where the IFMLtPF project baseline activity will be implemented; determined each year of the project, where t=1 to i years</td></tr>
<tr><td>Source of data</td><td colspan="8"></td></tr>
<tr><td rowspan="6">Value applied:</td><td rowspan="2">Strata</td><td colspan="7">Net project area subject to IFMLtPF by year</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>Hma</td><td>2,317</td><td>1,955</td><td>1,556</td><td>1,677</td><td>2,092</td><td>2,194</td><td>2,039</td></tr>
<tr><td>Hmb</td><td>1</td><td>14</td><td>0</td><td>0</td><td>0</td><td>353</td><td>26</td></tr>
<tr><td>P</td><td>0</td><td>342</td><td>132</td><td>0</td><td>621</td><td>0</td><td>0</td></tr>
<tr><td>Total</td><td>2,319</td><td>2,313</td><td>1,691</td><td>1,681</td><td>2,718</td><td>2,553</td><td>2,072</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td colspan="8">The areas of baseline activities by year are determined:
1. Evaulation of areas available for harvest based on accessibility and other limiting factors.
2. Evaluation of annual harvesting areas under standard concession management rules.</td></tr>
<tr><td>Purpose of Data</td><td colspan="8">Determination of baseline scenario</td></tr>
</table>

Data / Parameter	$B_{project, j, t=0}$	
Data unit	kg / ha	
Description	Total AGB of all trees >5cm DBH per hectare within each stratum j, (where j=1,2,3 ... J strata) where the IFMLtPF project activity will be implemented; determined ex ante - before the start of the IFM-LtPF project activity, hence t=0 year	
Source of data	Forestry inventory	
Value applied:	Strata	Total AGB (kg/ha)
	Hma	295,443
	Hmb	237,477
	P	328,762
Justification of choice of data or description of measurement methods and procedures applied	Biomass is calculated: 1. Measurement of individual trees within sample plots located within each stratum. 2. Estimation of individual tree biomass using the appropriate biomass allometric equation. These are described in the appendices. 3. Estimation of biomass per hectare by converting total biomass to biomass per hectare.	
Purpose of Data	Determination of baseline scenario (AFOLU projects only)	

<table>
<tr><td>Data / Parameter</td><td>$B_{IFM\_LtPF,\ j,\ t=0}$
$B_{IFM\_LtPF\_Sawlog\_Trees,\ j,\ t=0}$
$B_{IFM\_LtPF\_Damaged\_Trees,\ j,\ t=0}$
$B_{IFM\_LtPF\_Residual\_Trees,\ j,\ t=0}$</td></tr>
<tr><td>Data unit</td><td>kg / ha</td></tr>
<tr><td>Description</td><td>Total AGB of all trees >5cm DBH per hectare within each stratum j, (where j=1,2,3 … J strata) impacted on by IFMLtPF project activity; determined ex ante - before the start of the IFM-LtPF project activity, hence t=0 year.

This is the equivalent biomass of the sawlog trees that would be harvested under the baseline scenario plus the biomass of trees damaged and killed by the harvesting operations. The residual trees remaining post-harvest are calculated as the difference between preharvest biomass and the removals from harvesting and damaged trees.</td></tr>
<tr><td>Source of data</td><td>Forestry inventory</td></tr>
<tr><td>Value applied:</td><td>
<table>
<tr><td rowspan="3">Strata</td><td colspan="3">BIFMLtPF</td><td></td></tr>
<tr><td>Total</td><td>Sawlog trees</td><td>Damaged residual trees</td><td>Live residual trees</td></tr>
<tr><td colspan="4">kg/ha</td></tr>
<tr><td>Hma</td><td>TBA</td><td>78,973</td><td>TBA</td><td>TBA</td></tr>
<tr><td>Hmb</td><td>TBA</td><td>23,478</td><td>TBA</td><td>TBA</td></tr>
<tr><td>P</td><td>TBA</td><td>106,716</td><td>TBA</td><td>TBA</td></tr>
</table>
</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td>Biomass is calculated:
1. Sawlog trees are identified during the initial forest inventory.
2. Estimation of individual tree biomass for sawlog trees is estimated using the appropriate biomass allometric equation. These are described in the appendices.
3. Estimation of biomass per hectare of sawlog trees by converting total biomass to biomass per hectare.
4. Estimation of biomass as a percentage of residual biomass using RIL references for PNG.</td></tr>
<tr><td>Purpose of Data</td><td>Determination of baseline scenario (AFOLU projects only)</td></tr>
</table>

<table>
<tr><td>Data / Parameter</td><td>$B_{IFM\_LtPF\_Sawlog\_Tree\_Sawlog\_Gross, j, t=0}$
$B_{IFM\_LtPF\_Sawlog\_Tree\_Sawlog\_Net, j, t=0}$
$B_{IFM\_LtPF\_Sawlog\_Tree\_Logging\ Waste, j, t=0}$</td></tr>
<tr><td>Data unit</td><td>kg / ha</td></tr>
<tr><td>Description</td><td>Total AGB of all sawlogs harvested in the baseline activity; determined ex ante - before the start of the IFM-LtPF project activity, hence t=0 year.</td></tr>
<tr><td>Source of data</td><td>Forestry inventory</td></tr>
<tr><td>Value applied:</td><td>
<table>
<tr><td rowspan="3">Strata</td><td colspan="3">BIFMLtPF_Sawlog_Tree_Sawlog</td></tr>
<tr><td>Gross</td><td>Net</td><td>Logging waste</td></tr>
<tr><td colspan="3">kg/ha</td></tr>
<tr><td>Hma</td><td>45,497</td><td>31,848</td><td>13,649</td></tr>
<tr><td>Hmb</td><td>14,524</td><td>10,167</td><td>4,357</td></tr>
<tr><td>P</td><td>54,672</td><td>38,270</td><td>16,402</td></tr>
</table>
</td></tr>
<tr><td>Justification of choice of data or description of measurement methods and procedures applied</td><td>This information is estimated directly from forest inventory measurements.

The volumes of sawlogs are estimated using a volume equation provided by the PNGFA - 0.189523+0.0000547982*([DBH]-2.4)^2-0.00892138*[SL Log Length]+0.0000528219*([DBH]-2.4)^2*[SL Log Length]. These volumes are converted to biomass using species specific basic densities.

A 35% logging waste reduction factor is applied to estimate net sawlog biomass.

The net biomass of sawlogs is assumed to be harvested wood product and a different emissions rate may be applied to this biomass.</td></tr>
<tr><td>Purpose of Data</td><td>Determination of baseline scenario (AFOLU projects only)</td></tr>
</table>

Data / Parameter	$C_{project, j, t=0}$ $C_{IFM\_LtPF, j, t=0}$ $C_{IFM\_LtPF\_Sawlog\_Trees, j, t=0}$ $C_{IFM\_LtPF\_Damaged\_Trees, j, t=0}$ $C_{IFM\_LtPF\_Residual\_Trees, j, t=0}$ $C_{IFM\_LtPF\_Sawlog\_Tree\_Sawlog\_Gross, j, t=0}$ $C_{IFM\_LtPF\_Sawlog\_Tree\_Sawlog\_Net, j, t=0}$ $C_{IFM\_LtPF\_Sawlog\_Tree\_Logging Waste, j, t=0}$
Data unit	tonnes / ha
Description	Molecular carbon content of biomass estimates.
Source of data	Forestry inventory
Value applied:	C = 0.5 * B / 1000
Justification of choice of data or description of measurement methods and procedures applied	The molecular carbon estimates is estimated by multiplying the various biomass estimates by the nominated carbon 0.5 and converting the estimates from kg to tonnes by dividing by 1000.
Purpose of Data	Calculation of baseline emissions

3.6. Data to be Monitored

Complete the table below for all data and parameters that will be monitored during the project crediting period (copy the table as necessary for each data/parameter). Data and parameters determined or available at validation are included in Section 3.5 (Data and Parameters Available at Validation) above.

Data / Parameter	$A_{project,\ j,\ t=i}$
Data unit	hectares
Description	Project Area within each stratum j, (where j=1,2,3 … J strata) where the IFMLtPF project activity will be implemented; determined ex post – during the IFM-LtPF project activity, hence t=i year
Source of data	Analysis of remote sensing data.
Description of measurement methods and procedures to be applied	Project area by stratum will be checked by stratification remote sensing images. The methodologies for remote sensing and forest stratification are provided in the appendices. The remote sensing analysis shall use satellite images captured near to the specified remeasurement dates. Land use mapping shall be verified by on the ground inspections during the forest inventory.
Frequency of monitoring/recording	Every 5 years
Value applied:	NA
Monitoring equipment	NA
QA/QC procedures to be applied	NA
Purpose of data	Calculation of project emissions
Calculation method	
Comments	

Data / Parameter	$B_{project, j, t=i}$
Data unit	kg / ha
Description	Total AGB of all trees >5cm DBH per hectare within each stratum j, (where j=1,2,3 … J strata) where the IFMLtPF project activity will be implemented; determined ex post – during the IFM-LtPF project activity, at t=i year
Source of data	Forest inventory
Description of measurement methods and procedures to be applied	Biomass is calculated: 1. Measurement of individual trees within sample plots located within each strata. 2. Estimation of individual tree biomass using the appropriate biomass allometric equation. These are described in the appendices. 3. Estimation of biomass per hectare by converting total biomass to biomass per hectare. Note: It is assumed that undisturbed natural forest, as envisioned under the the IFMLtPF project activity, will on average have net biomass increment of zero. This assumes that total biomass from tree mortality equals total biomass from tree growth.
Frequency of monitoring/recording	2 years. This period is required to provide adequate maintenance of permanent sample plots while minimizing the frequency of measurements. In practice, clusters will be scheduled for on a 2 year basis. All plots within a cluster shall be measured in the same measurement period.
Value applied:	
Monitoring equipment	
QA/QC procedures to be applied	
Purpose of data	Calculation of project emissions
Calculation method	Biomass is calculated: 1. Measurement of individual trees within sample plots located within each stratum. 2. Estimation of individual tree biomass using the appropriate biomass allometric equation. These are described in the appendices. 3. Estimation of biomass per hectare by converting total biomass to biomass per hectare.
Comments	

3.7. Parameters Obtained from the Literature/Reports to be Reviewed/Verified (not Monitored)

3.7.1. Allometrics for calculation of above ground live tree biomass

The carbon stock was estimated for the living trees with DBH larger or equal to 5 cm using the Allometric Equations method. In the absence of species specific or national specific allometric equations in Papua New Guinea, the Chave, et. al. (2005) equation for wet tropical forests was applied. This widely used equation relates DBH and species specific wood density (ϱ) to estimate Above Ground Live Biomass (AGLB) per tree measured in the forest plots.

$$AGLB_i = 0.0776\left[\rho_i D_i^2 H_i\right]^{0.940}$$

AGLB = Above ground live biomass in kilograms

D = Diameter at breast height (1.3m above ground) in centimeters

H = Tree height in meters

ϱ = Specific gravity in grams per cubic centimeter

The resulting AGLB is the total biomass of the stem, crown, and leaves for trees in kilograms. Chave et al. (2005) found that locally, the error on the estimation of a tree's biomass was in the order of ± 5 percent.

In order to validate the applicability of the Chave equations used to estimate AGB, the source data used to develop the equation was reviewed. The Chave equation collates destructive sampling data from 27 different tropical forest sites, and it was confirmed that one of these sites was a wet, old growth forest type measured at Marafunga in Papua New Guinea. The latitude and longitude of these measurements was entered into Google Earth, and the site was found to be located 313 km north-west of the PPA. It can be concluded that the Chave equation is representative of the forest type/species and conditions in the Project Area, and that it covers the range of potential independent variable values. Furthermore, the Chave equation is listed as one of the preferred equation in the parameters section of the CP-AB module.

3.7.2. Wood density

A total of 200 Genera were identified in the inventory. A complete list of species identified in the inventory and their respective densities can be found in Annex 6. Genus and/or species specific wood density values were determined for the species observed in the inventory from the following sources in order of priority:

- Eddowes (1977) - The utilization of Papua New Guinea timbers. This was used as the leading source of timber density estimates for PNG.
- Global Wood Density Database. Chave J, Coomes DA, Jansen S, Lewis SL, Swenson NG, Zanne AE (2009) Towards a worldwide wood economics spectrum. Ecology Letters 12(4): 351-366. Preference is given wood density estimates from PNG/Australia and South East Asia, in order of priority.
- IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4. Table 4.13 – Basic Wood Density of Tropical Tree Species.
- Where no wood density was available for the species, there were assigned a wood density value of 0.585 g/cm3. This figure was derived from the weighted average wood density of tree species in the forest inventory with identified wood density estimates.

3.7.3. Carbon fraction

The C fraction of biomass are reported in tonnes of C/ha (Mg C/ha) assuming that dry biomass is 50 percent C (Clark et al. 2001, Houghton et al. 2001, Malhi et al. 2004). This is an acceptable approximation; however, the wood C fraction does exhibit some small variation across species and tree ages (Elias & Potvin 2003).

The 90% confidence intervals (CI) were calculated from the calculated carbon per ha in each plot using the following standard formula:

$CI = t\alpha/2 \cdot s/\sqrt{n}$

Where

t is the Student's t value,

α determines the level of confidence

s is the standard deviation of the sample and n is the sample size.

The average carbon stock densities and their variability (in units of tonnes C per hectare) in the aboveground live biomass (AGLB) were calculated for the three forest strata present in the Project Area.

3.7.4. Estimation of harvestable sawlog volume

The equation used for estimation of commercial sawlog volume calculation is as follows:

$V = 0.189523 + 0.0000547982 \times (D - 2.4)^2 - 0.00892138 \times L + 0.0000528219 \times (D - 2.4)^2 \times L$

Where: D is diameter in cm

L is log length in meters

V is log volume in cubic meters under bark

This equation was developed by the PNG Forestry Department as part of the Inventory program which has been used in PNG for calculating standing log volumes for a long period of time.

The equation generates a gross estimate of yield per log. Net volume on a per hectare basis is calculated by applying a 35% reduction to account for merchantability, log defect and breakage.

All species have been treated as commercial. A maximum sawlog diameter limit of 65cm was used on Eucalyptopsis spp logs as this species is known for high frequency of defect (hollow logs) in large diameter logs.

3.7.5. Estimation of biomass of sawlog trees biomass, damaged trees and residual trees

Biomass of sawlog trees are calculated according to the biomass equations described in 5.1.1. The biomass of the non-sawlog trees is calculated as the difference between the total biomass less the biomass of sawlog trees.

The biomass of trees that are heavily damaged are estimated as a percentage of the non-sawlog trees. It is assumed that 24.7% of original tree population is destroyed by logging. The residual standing biomass after extraction is estimated as the original biomass less the sawlog tree biomass and heavily damaged tree biomass. (See : Plinio Sista, Douglas Sheilb, Kuswata Kartawinatab, Hari Priyadib (2003) Reduced-impact logging in Indonesian Borneo: some results confirming the need for new silvicultural prescriptions. Forest Ecology and Management 179 (2003) 415–427)

3.8. Natural Disturbance

Natural disturbances caused by fire (including human induced), windstorms, landslides or volcanoes can have impacts on both the extent of the forest area and the carbon. As a consequence, emissions from such disturbance must be measured and factored out of the estimation of the ex post net anthropogenic GHG emission reductions. Events due to natural disturbances will be identified using the following procedures:

- Regular familiarization with meteorological reports of the Project Area - the frequency of monitoring is dependent on the susceptibility of the region to natural disturbances
- Analysis of best available satellite imagery to monitor the Project Area, specifically to identify and estimate the areas that have been disturbed within the Project Area
- Aerial surveillance and/or ground patrolling followed by field checking to verify the extent (area) of the damage and quantification of the GHG emissions.

For the baseline, it is assumed that natural disturbance is minimal and will be compensated through small amounts of natural reforestation of currently bare land. Therefore the net natural area disturbance in the baseline is assumed to approximate to zero hectares.

Natural disturbance will be assessed once every 5 years as part of the project area review. Should significant levels of natural disturbance occur, then this will result in a reduction in net project area and an increase in carbon emissions.

3.9. Leakage

3.9.1. Identifying leakage

The objective of leakage assessment and management is to provide an ex post estimate of the actual decrease in carbon and increase in GHG emissions (other than carbon changes) that arise as a result of the implementation of the project activity. Where an increase in GHG emissions occurs outside a project's boundary but is measurable and attributable to the project activity, this is known as project leakage.

For an IFM-LtPF project activity, there are two sources of leakage that need to be considered and addressed in this Methodology:

- Carbon from degradation due to shifting of the baseline activity, i.e. removal of harvested wood products including sawlog, pulp log and commercially harvested fuel wood and emissions from the associated activities outside the Project Area,
- Carbon from market leakage , due to shifts in supply and demand of the products and services affected by the project activity, which in this case is the supply and demand of timber.

3.9.2. Leakage due to activity shifting

Any activity shifting due to selective logging which includes removal of harvested wood projects comprising sawlog, pulp log and commercially harvested fuel wood by the Project Proponent must be assessed as a component of leakage. Activity shifting leakage situations become evident where the Project Proponent has:

- Intensified operations for selective logging, i.e. has legal authorization for selective logging and increase logging operations in other owned and/or operated lands to recover the harvesting loss due to the IFM-LtPF project; or
- Shifted operations for selective logging from the Project Area to another forest area within the host country.

The Project Proponent must provide documentation for the potential leakage areas due to activity shifting i.e. other lands owned and/or operated by the Project Proponent, including geo-referenced or digital maps illustrating the physical location(s) and their boundaries, existing land uses and management plans at each verification period.

Leakage due to activity shifting will be assessed once every 3 years as part of the project area review. Should significant levels of activity shifting occur, then this will result in an increase in carbon emissions.

3.9.3. Market leakage

Market effects due to the presence of an IFM-LtPF project could occur in two main ways:

- Intensification of existing harvest practices
- Formation of new enterprises and hence new (or modified existing) FIRs for sanctioned selective logging.

The Project Proponent must demonstrate how market leakage has been accounted for in accordance with the most recent version of applicable VCS rules.

Market leakage will be assessed once every 3 years as part of the project area review. Should significant levels of market leakage be demonstrated, then this will result in a decrease of net emission reductions and consequently in less carbon credits for trade.

Annex 1 – Field Measurement Procedures

1 Stratification of the Project Area

1.1 Overview

To facilitate the field work and increase the accuracy and precision of the parameters that are to be measured, the Project Area is to be divided into sub-populations or "strata" that form relatively homogeneous units. This makes monitoring more cost effective because it decreases the sampling and monitoring efforts, whilst maintaining the same level of confidence.

Land cover stratification is the process of dividing the land cover of a target area (the overall population) into relatively homogenous land cover strata (subpopulations). The process primarily consists of analysis of satellite imagery using Remote Sensing and Geographic Information Systems (GIS) tools for interpretation of vegetation cover. Forest condition characteristics that can be readily captured in imagery analysis include color, canopy closure and roughness of the canopy layer.

Recent satellite imagery available over the PPA suffered from various quality issues:

- Landsat 7 images from 2011 - 2014 period all suffer from cloud cover over parts of the PPA as well as heavy striping. Multiple images were used to increase cloud free coverage.
- A Landsat 8 image from 2014 provides useful data over coastal areas but is cloud covered in the hilly interior of the PPA.
- The steep topography over much of the PPA means there is a lot of shadow effect in the images.

The PPA is mostly forested. Non forest areas consist mostly of shifting cultivation areas along the coastal belt and close to villages. As such land cover patterns are relatively predictable.

The PPA is relatively small and as field teams spent 6 weeks in the field there is a high degree of familiarity with the area.

Mature coconut plantation areas were digitized off a high resolution image on Google earth. However differences are minor.

1.2 Definition of Forest

PNG has not submitted an official forest definition (minimum indicator values for forest) to the UNFCCC. In the absence of this definition, we used the national definition (GoPNG 2014):

The official definition of forests indicates the minimum area to distinct forest from non-forest, among other indicators, and is used to adjust the minimum mapping unit in historical land cover classification. As a consequence, the area of each polygon of forest mapped is at least as large as defined hereafter.

The Government of PNG defines forest as follows:

"Land spanning more than one (1) hectare with trees higher than three (3) meters and a canopy cover of more than ten (10) percent (%)" (GoPNG 2014).

Note that the GoPNG definition of forest is not clear on restrictions to the definition of natural forest areas. In the Milne Bay Forest Base Map 2012 the following are classified as non-forest strata, although in theory they also fit the above criteria for forest:

- Mature coconut plantation, which is classified as agriculture plantation;
- Shifting agriculture areas, which include patches of regenerating forest. These are classified under Agriculture land use.

1.3 Definition of Land Cover Strata

The Table below shows land cover strata identified in the stratification process:

Table 3: Land Cover Strata Used in the LCC Analysis

Land Cover Strata	Code	Description
Low Altitude Forest on Plains and Fans	P	Crown diameter >8m. Canopy is generally 30–35m high and irregular in both height and closure. Stem diameters generally range from large (70-89 cm) to small (30-49 cm) but very large stems (90+ cm) are not uncommon. The floristic composition is very mixed with no single-species dominance (definition for Pl).
Low Altitude Forest on Uplands < 550m altitude	Hma	Low altitude forest on uplands. The canopy of this forest type is 25-30m in height, is generally only slightly uneven and has a 60-80% crown closure. Except for Araucaria, emergent species rarely exceed 40m in height. Very large stem diameters (90cm+) are rare except for Araucaria. Floristically the forest is very mixed (definition for Hm).
Low Altitude Forest on Uplands 550-1000m altitude	Hmb	
Lower Montane Forest	L	Lower montane forest (above 1000m). This forest has an even to slightly undulating canopy 20-30m in height. Canopy closure varies from dense to slightly open. The canopy height decreases with increasing altitude. Stem diameters are generally medium (50-69cm) to small (30-49cm).
Mangrove and Nipah	M	Dominated by mangrove with small areas of associated nipah.
Secondary Forest	Se	Consists of old shifting cultivation areas where a tree canopy has regenerated and is dominant. Vegetation consists of a mix of pioneer species, fruit trees, and scattered small residual pockets of forest. May also include scattered small pockets of recent clearance, and also small pockets of degraded primary forest.
Agriculture	O	Consists of areas dominated by recent clearance for shifting agriculture. Land cover has no or a low canopy. May also include scattered small pockets of secondary forest.
Agriculture Plantation	Qa	Agriculture plantation. In the project area this is limited to coconut plantations generally located around the villages.
Grassland and Herbland	G	
Lakes and Large Rivers	E	
Coastal Open Land	Col	

The strata and descriptions are based on those found in the Milne Bay Forest Base Map 2012[1] except for the Hmb, Se, and Col strata. Boundaries between strata have been updated using 2014 imagery and some adjustments to strata have been made.

[1] The JICA - PNGFA Milne Bay Forest Base Map 2012. One of the key outcomes of the recently completed JICA-PNGFA Project is a national level forest base map known as the National Forest Base Map 2012.

The Low Altitude Forest on Uplands (H) strata as described in Milne Bay Forest Base Map 2012 has an altitude limit of 1000m. In the field a change in species composition was noticed at an altitude of around 550m. From this altitude up *Castanopsis* spp began to dominate. It has therefore been decided to break the "Low Altitude Forest on Uplands" strata into the following two sub strata:

Hma	Medium Crowned Low Altitude Forest on Uplands up to 550m altitude.
Hmb	Low Altitude Forest on Uplands 550 - 1000m altitude. .

The Hmb strata could potentially be reclassified as HsCa (Small crowned forest with *Castanopsis*) as described in the PNG HCVF toolkit Appendix 8. However this will need further checking on the ground due to the limited amount of inventory and reconnaissance done in these areas.

Two forest classes identified in the Milne Bay Forest Base Map, namely Littoral Forests (coastal zone forests) and Seral Forest (regenerating disturbed forests) which covered a very small proportion of the PPA area have been merged into the other strata, primarily secondary forest.

In the Central Suau area there are two main agricultural systems:

- Coconut plantations for copra production
- Shifting cultivation for food crops.

Under the shifting cultivation system secondary forests regenerate in ex-cultivation areas and are commonly associated with new clearance and residual pockets of degraded primary forest in a heterogeneous mix. In the Milne Bay Forest Base Map these areas are predominantly found in the "Agriculture Land Use" strata. However significant portions of this class also qualify as forest following the above definition.

In the absence of clear guidance, areas dominated by secondary forests have been separated from areas dominated by agriculture. The decision on whether to categorize these areas as forest or non-forest can be made at a later time. It should be noted that defining the cut-off between agriculture (non-forest) and secondary forest in shifting cultivation areas is somewhat subjective – in the long term guidance is required to address this issue.

2 Measurement of PSPs

2.1 Inventory Planning

Procedures for terrestrial field measurements have been designed according to requirements set out in the document "Approved Verified Carbon Standard VM0011 – Methodology for Improved Forest Management – Logged to Protected Forest: Calculation GHG Benefits from Preventing Planned Degradation" (Carbon Planet Ltd 2011).

The inventory required establishment of Permanent Sample Plots (PSP) that can be relocated and re-measured as required in the future. Given the steep topography of the PPA and difficult access, it was decided to locate the PSPs in clusters. The basic cluster design decided upon was a group of 24 circular plots in a 3 x 8 or 6 x 4 grid, with a distance of 200m between plots in both directions.

Prior to mobilization, nine cluster locations were identified using GIS software covering the following three land cover strata considered to contain commercial log stocks.

- Low Altitude Forest on Plains and Fans
- Low Altitude Forest on Uplands < 550m altitude
- Low Altitude Forest on Uplands 550-1000m altitude

The survey was designed with the aim of attaining carbon stock estimates with 90% confidence intervals to within 10% of the total carbon stocks for the designated above ground carbon pools.

- Plot Design and Field Measurement Procedures

A nested circular plot design was used

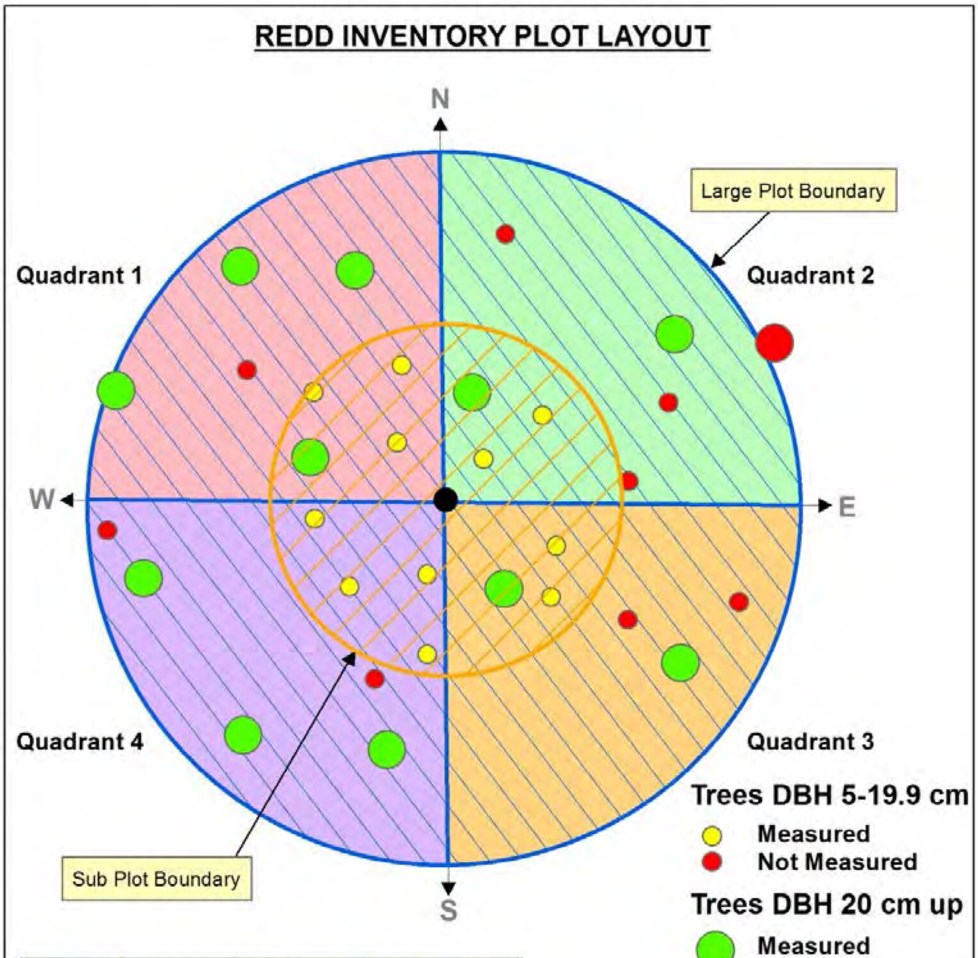
Permanent plot center poles (1.3m long, 40mm diameter plastic pipes) were planted at each plot center point and the location captured by GPS. An aluminum plate with the plot number imprinted was screwed on each pole.

A Land Use and Biomass Field Evaluation Form was filled out for each plot describing the forest and plot site.

All trees greater or equal to 20cm DBH were measured in the large plot. All trees greater than or equal to 5cm and less than 20cm DBH were measured in the small plot. Plastic labels were nailed onto all trees. Tree numbers were written on the label using permanent markers (see photo on cover).

For all trees the measured, the following was recorded in tally sheets:

- Genus and where known species
- Diameter at breast height were measured using diameter tapes
- Total tree heights were measured using laser rangefinders.
- Commercial sawlog lengths and log grades were recorded for trees with diameter 50cm up that met the minimum log grade specifications.
- Tree location in the plot (drawn on a tree map)



Plot	Plot Radius (m)	Plot Sample Area (m^2)	Tree DBH Measured (cm)
Sub Plot	5.61	100	5 - 19.9
Large Plot	13.82	600	20 up

Figure 1: Inventory Plot Design

- Tree Height Estimation

Total tree heights were directly measured for most trees. Unfortunately total tree heights in Cluster 13 were not measured due to failure of the laser height measuring devices due to moisture damage. The tree heights for these species were estimated using DBH height diameter regression equation derived from the direct tree diameter and height measurements.

The derived equation was as follows:

Tree height = $\alpha_1 + \alpha_2$*DBH- α_3*DBH^2+ α_4*DBH^3

Table 4 shows the results of the selected tree height regression equation.

Table 4: Regression Results

Coefficient Estimates					
	Estimate	Std. Error	Wald test	p-value	
α_1	3.27846	0.197330	16.614	0.0000	
α_2	0.776157	0.0144124	53.853	0.0000	
α_3	-0.00633336	0.000241003	-26.279	0.0000	
α_4	0.0000162342	8.509073E-7	19.079	0.0000	
Summary Analysis of Variance Table					
Source	df	SS	MS	F	p-value
Regression	4	1114410.	278603.	12810.58	0.0000
Residual	3264	70985.	21.7478		
Lack of fit	630	20507.2	32.5511	1.70	0.0000
Pure Error	2634	50477.8	19.1639		
Reason for termination: Converged normally.					

In future PSP measurements, all trees shall be measured for tree height.

2.2 Determining the number of PSPs

The number of PSPs in each stratum is determined by taking measurements in preliminary sample plots randomly laid in each stratum to achieve the desired level of precision using the following procedure:

Step 1: Select the number of preliminary sample plots (sp) to be established (between 6 and 10 for each stratum).

Step 2: Set the geographic location of the preliminary sample plots in each stratum by employing, for example, a random function available in the Geographic Information System (GIS) platform (e.g. ArcGIS).

Step 3: Locate the preliminary sample plot on the ground using GPS and maps.

Step 4: Establish the sample plot of specific size and shape

Step 5: Measure the DBH and tree height of all trees as defined by the relevant authority of the host country. Use the standard forestry techniques and equipment such as DBH tape and clinometer for measuring DBH and tree height, respectively.

Step 6: Use field data to calculate the carbon in the AGB in each preliminary sample plot and stratum as per the calculation in Section 3.2.1.2, and employ the following equation to estimate the standard deviation for each stratum:

Equation 7-1

$$sd_j = \sqrt{\frac{\sum_{sp=1}^{SP} (\overline{C}_{AGB\_gstock,sp,j} - \overline{C}_{AGB\_gstock,j})}{N_j - 1}}$$

Parameter	**Description**	**Unit**
sd_j	Standard deviation for carbon in the aboveground biomass in the stratum *j*, (where *j*=1,2,3, ... *J* strata)	tC ha^{-1}
$\overline{C}_{AGB\_gstock,sp,j}$	Average carbon per hectare in the aboveground biomass of the growing stock in the preliminary sample plot *sp (where sp*=1,2,3 ... *SP* preliminary sample plots), of the stratum *j*, (where *j*=1,2,3, ... *J* strata)	tC ha^{-1}
$\overline{C}_{AGB\_gstock,j}$	Average carbon per hectare in the aboveground biomass of the growing stock in the stratum *j*, (where *j*=1,2,3, ... *J* strata)	tC ha^{-1}
N_j	Total number of sampling units in the stratum *j*, (where *j*=1,2,3, ... *J* strata)	dimensionless

Step 7: Apply the precision level of 10% of the true value of the mean at the 95% confidence interval for accurate estimation of net change in the carbon stock in the project area.

Step 8: Apply the equation below to estimate the total number of PSPs, N, in all strata for the entire Project Area:

Equation 7-2

$$N = \frac{\left(\sum_{j=1}^{J} N_j \times sd_j\right)^2}{\left(\frac{N_j^2 \times err^2}{t_{stat}^2}\right) + \left(\sum_{j=1}^{J} N_j \times sd_j^2\right)}$$

Parameter	**Description**	**Unit**
N	Total number of Permanent Sample Plots in the Project Area	Number
N_j	Number of sampling units in stratum *j* (where *j* = 1,2,3 ... *J* strata)	Number
sd_j	Standard deviation of carbon density for the stratum *j*, (where *j*=1,2,3, ... *J* strata)	tC ha^{-1}
t_{stat}	Sample statistic from the t-distribution for the 95% confidence level	dimensionless
err	Allowable error (calculated by mean carbon density by desired precision)	dimensionless

Step 9: The following equation is then used to calculate the number of PSPs in each individual stratum:

Equation 7-3

$$n_j = N \times \frac{N_j \times sd_j}{\sum_{j=1}^{J} N_j \times sd_j}$$

Parameter	Description	Unit
n_j	Number of Permanent Sample Plots in stratum *j*, (where *j*=1,2,3, … *J* strata)	Number
N	Total number of Permanent Sample Plots in the Project Area	Number
N_j	Total number of sampling units in the stratum *j*, (where *j*=1,2,3, … *J* strata)	Number
sd_j	Standard deviation of carbon density for the stratum *j*, (where *j*=1,2,3, … *J* strata)	$tC\ ha^{-1}$

Equation 7-3 determines the number of PSPs for each stratum based on the variability in the stratum. A stratum with higher variability will require a higher number of sample plots than a stratum with less variability.

In the project area, PSP have already been established as part of the PD preparation activities. These data shall be analyzed to determine whether further PSP plots are required to be established to attain the required precision of estimates.

Cluster sampling has been used for laying out the ground location of the PSPs in each stratum. Care has been taken to randomize the location of the clusters to avoid bias, such as locating PSPs along a road for example, in order to maintain the statistical rigor and validity of the calculations.

- Parameter measurement in the PSPs

After determining the number of PSPs in each stratum, and the sampling design for on the ground location of the PSPs, field measurements will be conducted. A forest inventory manual has been prepared for the project that includes:

- A plan of the data collection procedures including the specification of merchantable tree in terms of species, minimum DBH and tree form, rules for borderline trees, locating trees during the following monitoring period, and measurement techniques for the DBH and tree height.
- A plan of the data recording procedures and resources, such as paper forms or handheld PDAs.

Prior to deployment to the field, the field team are trained to ensure a thorough knowledge of the forest inventory methods described in the manual. After establishing a PSP on the ground, all trees as defined by the relevant authority in the host country will be measured for their DBH and tree height (H) using appropriate equipment.

The equipment employed in the forest inventory, principally diameter tapes / height clinometers / GPS, are checked to verify they are in good condition and fit for purpose.

A sample, with target being 10%, of plots shall be independently checked by the forest inventory project leader to ensure the forest inventory manual is being correctly implemented and the data is being recorded to the required standards.

Plot data is archived as follows:

- Plot data is recorded on plot sheets in the field.
- The plot sheets are collated and bound into a single document.
- Two photocopies of the plot sheets are prepared.
- Following capture of the plot data into a database, the data is manually checked and verified. Three copies of the database plot records are also prepared.