Celebrating 20 years of Community Development Service in Papua New Guinea – 1993-2013

FPCD-IGES Community-based Forest Monitoring Project

April 2013 Report

Institute for Global Environmental Strategies (IGES)
2108-11 Kamiyamaguchi, Hayama, Kanagawa 240-0115 Japan
Phone: +81-46-855-3830 • Facsimile: +81-46-855-3809
E-mail: fc-info@iges.or.jp

Foundation for People and Community Development (FPCD)
Section 60, Lot 8, Queenscliffe St., Korobosea
Port Moresby, National Capital District
Papua New Guinea

Authors

Henry Scheyvens (IGES), Lavinia Poruschi (Consultant), Yati A. Bun (FPCD), Taiji Fujisaki (IGES), Ram Avtar (UNU-ISP).

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Acronyms and abbreviations

AGLB	above ground living biomass
C	carbon
CFMP	Community-based Forest Monitoring Project
CI	confidence interval
COP	Conference of the Parties (to the UNFCCC)
CV	coefficient of variation
DBH	diameter at breast height
DF	degrees of freedom
FPCD	Foundation for People and Community Development
FSC	Forest Stewardship Council
FY	fiscal year
GIS	geographical information systems
Ha	hectares
IGES	Institute for Global Environmental Studies
IPCC	Intergovernmental Panel on Climate Change
LLG	local level government
PNG	Papua New Guinea
PSP	permanent sample plot
REDD+	Reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
SD	standard deviation
SE	standard error
UNFCCC	United Nations Framework Convention on Climate Change
UNU-ISP	United Nations University Institute for Sustainability and Peace

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1. Introduction and backdrop

Approximately 60% of Papua New Guinea (PNG) is covered by natural forests, making it one of the most significant areas of largely intact tropical forest in the world. Almost all of the PNG's forest is owned by local clans according to their customs.

The customary land owners face a fundamental set of problems. Their cultural systems and traditional livelihoods are closely tied to forests, but they also desire the benefits that they anticipate "development" will bring. However, their knowledge, skills and institutions to develop their resources for cash income is limited.

Rather than aiming to build the capacity of the customary owners to manage their forest resources, PNG's forest policies focus on alienating timber rights from the customary owners and making these rights available to logging companies. For as long as the logging takes place, this form of forestry generates some benefits for some of the local people through royalties, employment and the construction of infrastructure. However, it mostly does not appear to generate sustainable benefits over the longer term and, due to inadequate monitoring and enforcement, can result in widespread environmental damage (ITTO, 2007; LaFranchi, 2004).

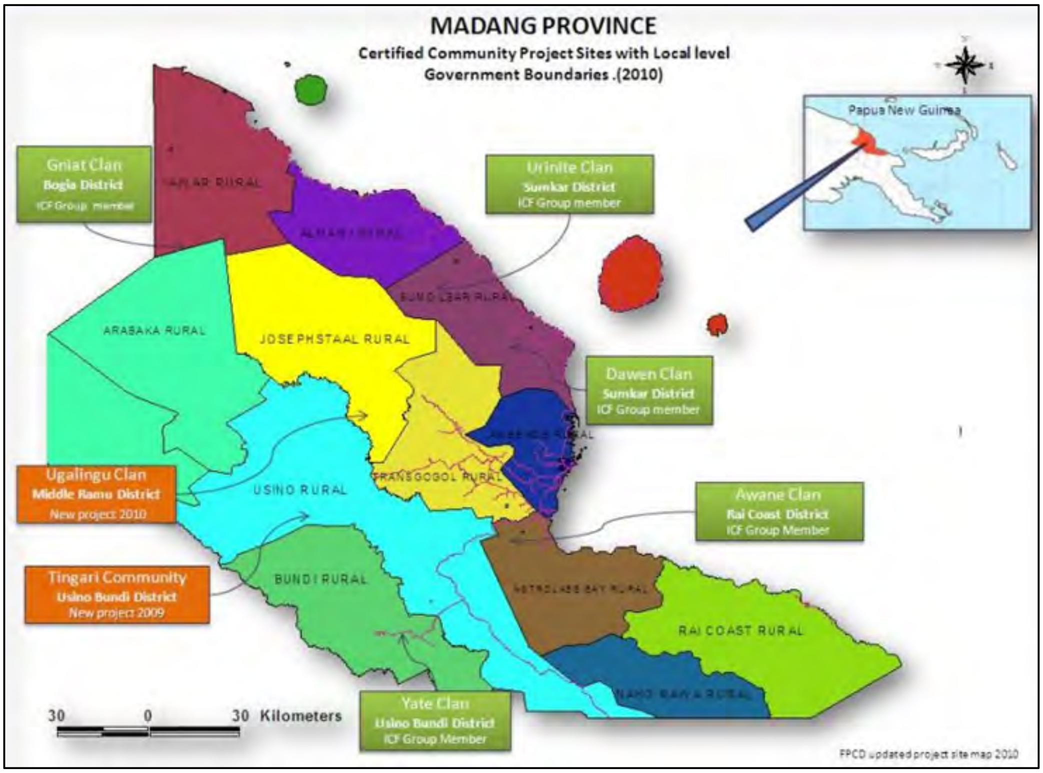
With this backdrop, the Foundation for People and Community Development (FPCD), a Papua New Guinean non-government, not-for-profit organisation, is developing an alternative, community-based forestry model. Under this model, communities who request assistance from FPCD are trained to manage their forest resources in accordance with Forest Stewardship Council (FSC) principles, and on timber milling (Image 1) and marketing, and business management.

Image 1: FSC certified community timber milling – Yate clan, Brahman

FPCD was awarded a FSC Group Certificate in June 2007. Through its Certified Community Forestry Programme, FPCD is assisting six clans in Madang Province – Gniat, Namokanam (Urinite), Dalomes (Dawen), Awane, Yate and Ugalingu – to manage their forests. Other clans, such as the Tingari near Brahman, are also being assisted through the Certified Community Forestry Programme to join the Group Certificate. The locations of the project communities are shown in Figure 1.

This report first explains the objectives of the Community-based Forest Monitoring Project (CFMP), and then sets out the generic steps for biomass assessment and how these have been approached under the CFMP. The rationale for engaging communities in forest monitoring is then explained and the activities to build the capacity of the communities on forest monitoring are outlined. The report then provides some of the results from the analysis of the sample plot measurements. Remote sensing analysis has been introduced more recently into the project for land cover mapping. Different satellite image sets were assessed in terms of their suitability to the scale of the project sites. The results of this analysis are also discussed. The report finishes with concluding observations and sets out the major project activities for FY2013.

Figure 1: Location of the project communities



2. CFMP objectives

FPCD and the Institute for Global Environmental Studies (IGES), a Japan-based independent policy research institute, launched the Community-based Forest Monitoring Project (CFMP) to complement the Certified Community Forestry Programme. The scope of the monitoring includes the response of forests to forestry operations, as required by the FSC standards, as well as assessment of forest biomass.

With the information on forest biomass, the feasibility of REDD+ can be explored. REDD+ is a concept that Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are currently designing to provide forest managers in developing countries payments for protecting and enhancing the carbon stocks in their forests. The sample plots established and measured by local communities under the CFMP will generate some of the data necessary for REDD+ feasibility assessment at the project sites.

Reflecting FPCD's approach to community forestry, the monitoring is not conducted by outside professionals. Rather, FPCD foresters build the capacity of the participating clans to do the monitoring of their forests themselves.

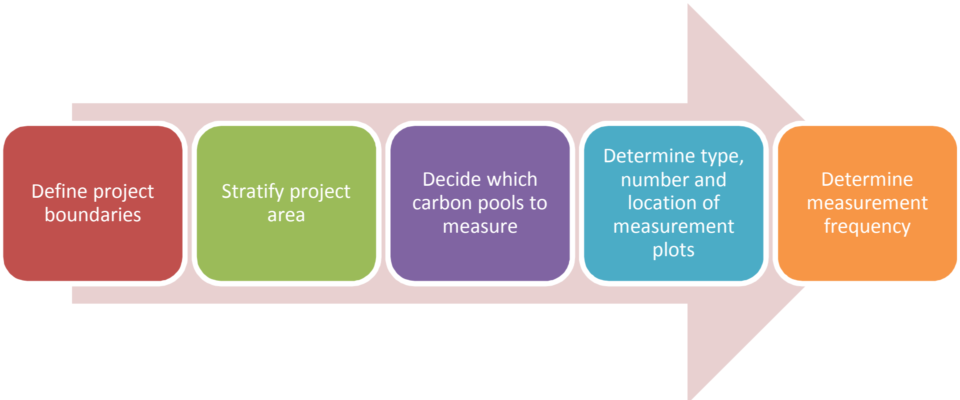
The objectives of the CFMP are to:

- Develop and implement an approach to community-based forest monitoring;
- Analyse the data generated by the communities and assist the communities in interpreting the results;
- Assess the feasibility of REDD+ to provide an additional incentive for community-based forest management at the project sites.

3. Biomass monitoring steps

There are a basic set of steps for developing a robust biomass assessment and monitoring plan that have been incorporated into the CFMP. These are listed in Figure 2.

Figure 2: Basic steps for assessing and monitoring forest carbon stocks



3.1.Defining project boundaries

The boundaries of the project area in which the biomass assessment takes place need to be clearly defined and properly documented to aid accurate measuring, accounting and verification. The boundaries of all the sites under the CFMP have been surveyed by the FPCD foresters working together with the communities. The FPCD foresters facilitated a process in which the participating clans agreed with neighbouring clans on the land boundaries. There are no major outstanding land disputes affecting the boundaries of the project sites. The CFMP built on the previous boundary survey work conducted by FPCD by ensuring all boundaries were demarcated using handheld global positioning system (GPS) devices.

Table 1 provides some basic information about the participating clans, including their forest areas. The communities that are involved in the forest monitoring hold between 270 and 6,300 hectares (ha) of land, most of which is forested. Most of the forest has previously been mapped as low altitude natural tropical rainforest, though some has been disturbed by human activities, e.g. shifting cultivation and, to a lesser extent, commercial logging, and by natural events such as storms. The forests have high species diversity, with over 60 species identified in the sampling.

Table 1: Profiles of participating clans

Clan	Clan Leader	Location	Population	Forest size
Urinite	Tobias Kaim	Malas village, Sumgilbar LLG, Sumkar District	- Malas village: 600 - Namokanam clan: 14 (8 adults, 6 children).	375 ha
Awane	Gamaura Sagigi	Erima village, Rai Coast District	- Erima village population: 300	1,293 ha
Dawen	Jonah Barumtai	Aronis village, Sumkar District	- Aronis village population: >1,000 - Dalomes Clan: 400	624 ha
Yate	Lucas Yarope	Brahman village, Usino-Bundi District	- Clan population: 26 (11 adults, 15 children)	520 ha
Gniat	Job Silas	Bangapala Bogia District	-Village population: 1,200 -Clan population: 113	6,365 ha
Ugalingu clan - Sogeram	Umari Bagusa	Korom village, Usino Rural LLG, Usino Bundi District		1,632 Ha
Tingari	Phillip Angiya Gendo Mavi Clan	Tingari village, Usino Rural LLG, Usino Bundi District		13,000 ha

Note: The first 5 clans are currently participating in the CFMP. It is expected that Tinagari and/or Sogeram clans will be brought under the CFMP in FY2013.

3.2.Stratifying the project area

When forest areas within the forest boundaries clearly have different biomass densities, then stratifying the forest can increase the efficiency of sampling, i.e. the same accuracy and precision of the biomass estimate can be achieved for less cost. By dividing the forest into relatively homogenous areas, the number of sample plots required for a given level of confidence can be reduced. This is possible when there is smaller variation in carbon stocks in identifiable stratum than there is in the whole area.

Stratification was considered for the project area. While large variation in forest biomass has been observed across the project area, due in part to high relief and disturbance, stratification prior to sampling was found to be difficult because there are no obvious differences in biomass density due to variations in vegetation types or environmental factors (e.g. soils, drainage, altitude, etc.). Post-sampling stratification using the sample plot data was attempted by was found not to increase sampling efficiency. However, recent remote sensing analysis suggests that it may be possible to map three forest types – dense, sparse, and secondary – and if these forest classes and their mapping are validated by ground surveys, then stratification will be introduced into the sampling design (see Section 6 for further discussion).

Mapping of forest biomass densities alone is not sufficient for REDD+ feasibility assessment. Existing land uses and drivers of land use change also have to be assessed and mapped. FPCD has conducted participatory land use mapping with all communities under its Certified Community Forestry Programme for them to plan and place controls on their land use. This mapping is highly relevant to projecting likely future emissions scenarios. The CFMP has supported the participatory land use mapping by building the capacity of FPCD foresters on geographical information systems (GIS). Figures 3-6 provide examples of the land use maps they have produced with the communities.

Figure 3: Awane land use map

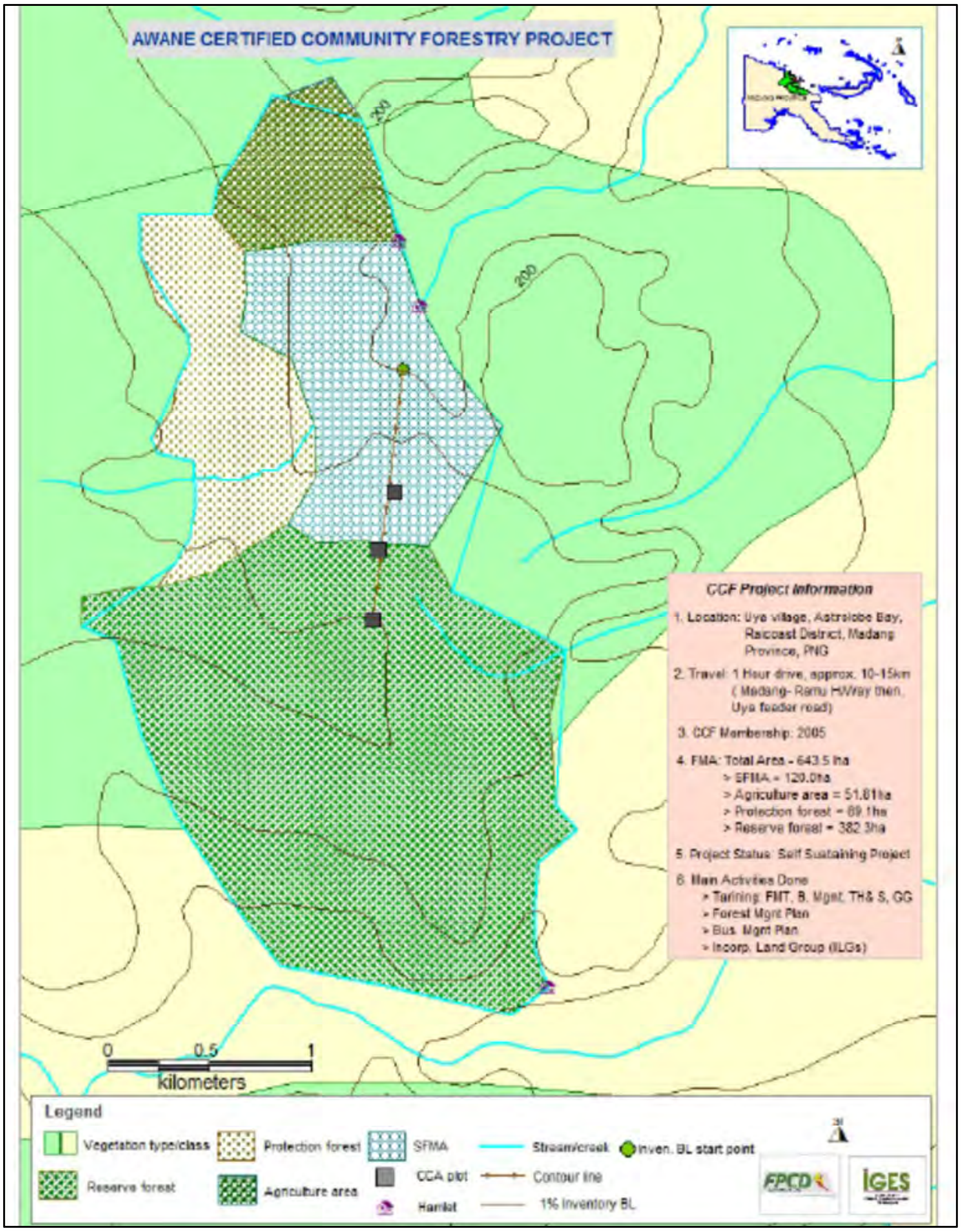


Figure 4: Yate land use map

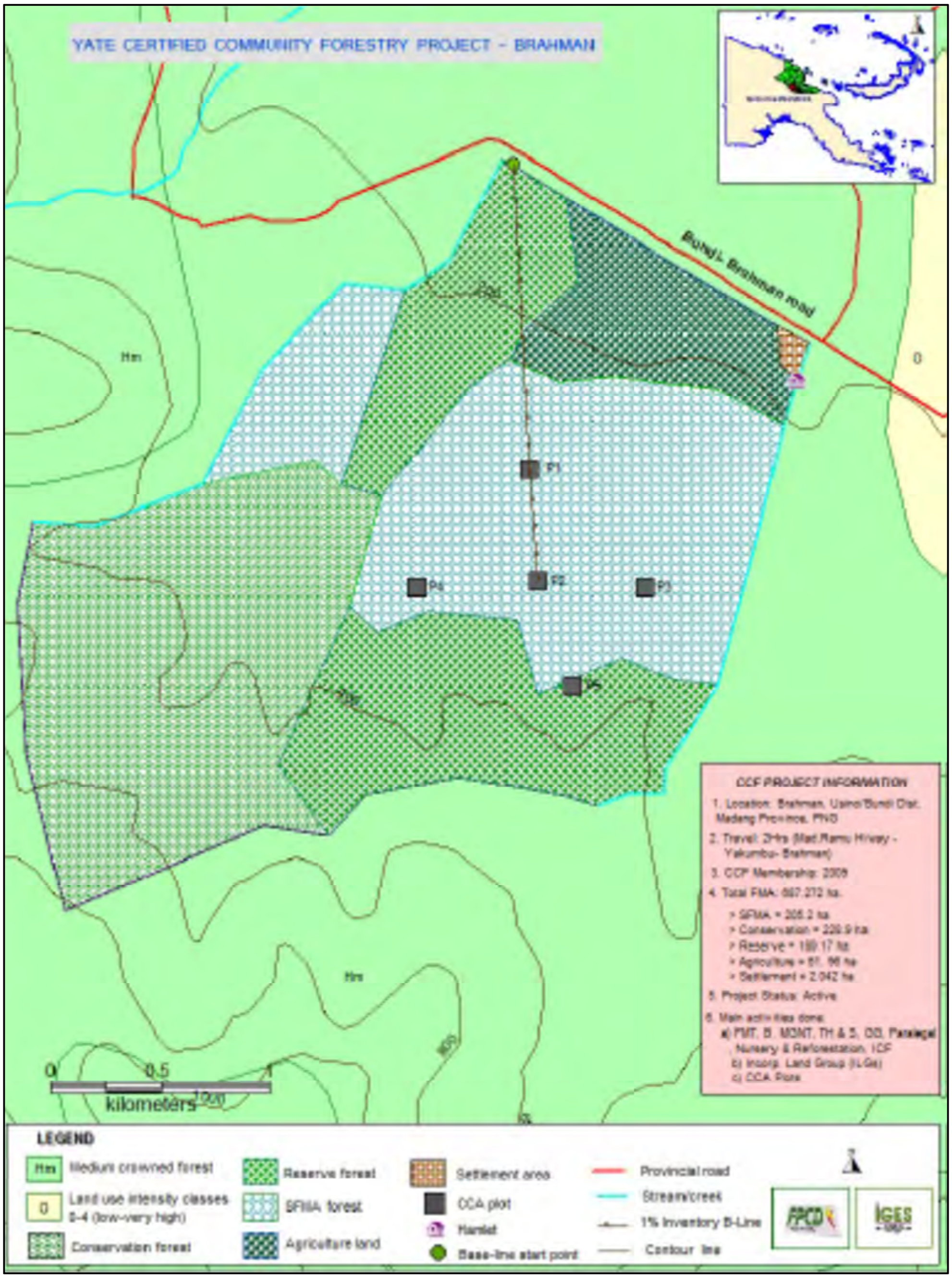


Figure 5: Urinite land use map

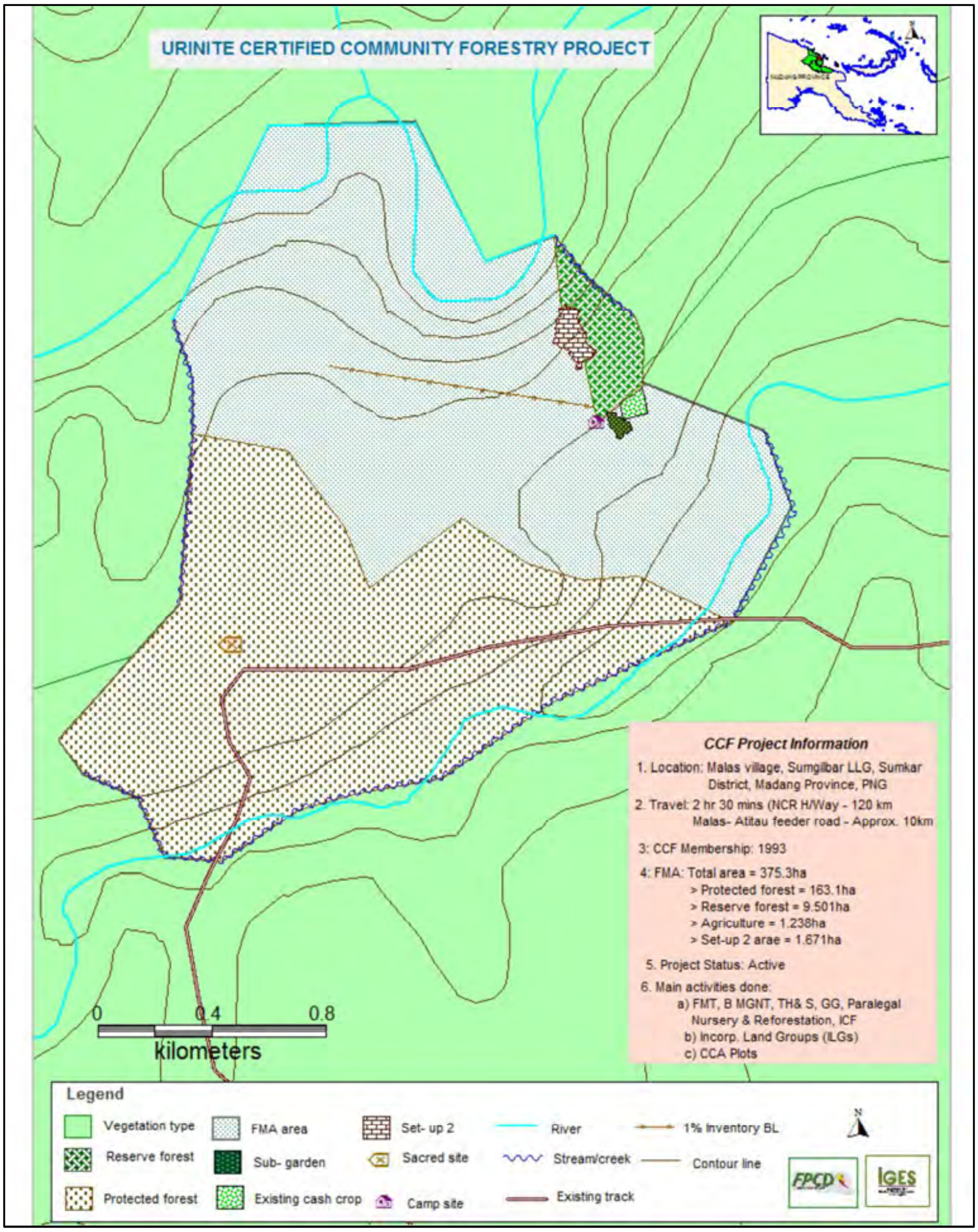
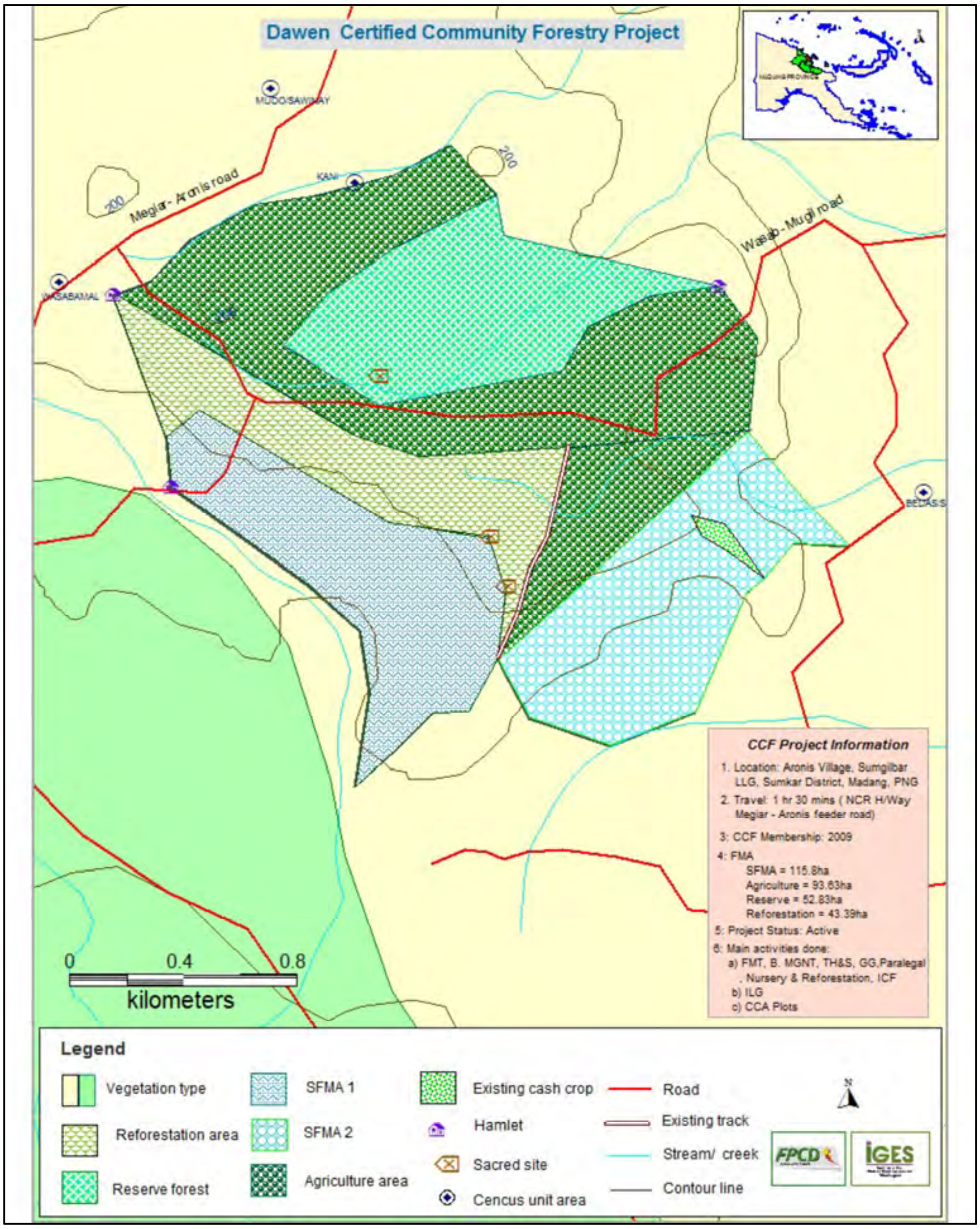


Figure 6: Dawen land use map



3.3.Deciding which carbon pools to measure

The Intergovernmental Panel on Climate Change (IPCC) identifies the following forest carbon pools: living biomass (above ground, below ground), dead organic matter (litter, deadwood) and soils (IPCC, 2006, 3.15). In tropical rainforest, most carbon is stored in above ground biomass; hence, our measurements focus on this pool. Initially, trees with a diameter at breast height (DBH) ≥ 10 cm were measured, but in the initial sample plots it was observed that significant biomass also likely exists in the 5-10 cm DBH class. Therefore, the measurements of above ground living biomass (AGLB) are for all trees ≥ 5 cm DBH ($AGLB_{\geq 5cm}$).

The litter and soil layer observed at the project sites is thin, so these pools were ignored. Below ground living biomass in roots was ignored in the sampling because of the difficulty of measurement, but could be incorporated into the total biomass estimate by using a suitable root-to-shoot default ratio.

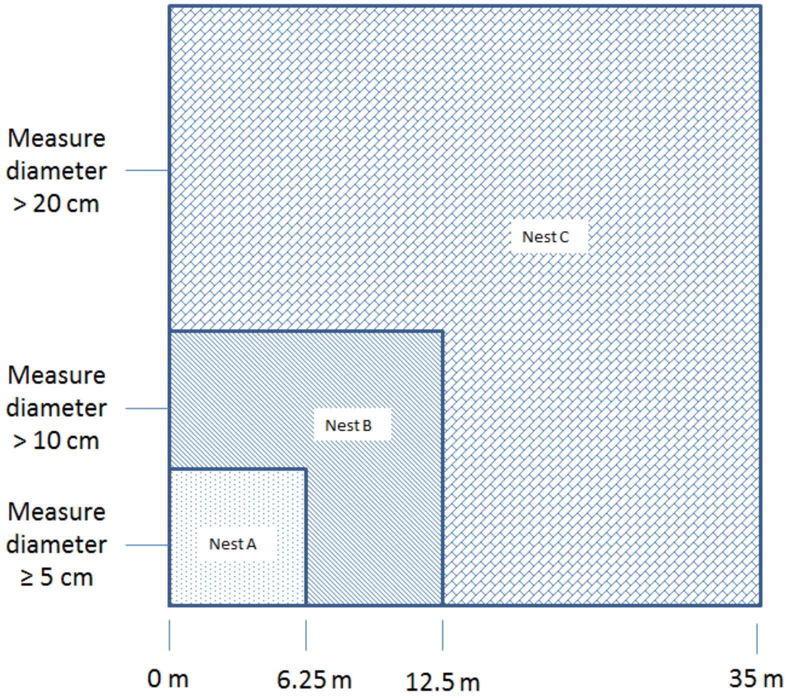
Initially, both standing and lying deadwood were measured. Standing deadwood was later found to be insignificant so was dropped from the monitoring, whereas lying deadwood was found to comprise about 6% of the aboveground biomass and was retained in the monitoring.

The soils are general thin, so soil organic matter was excluded from the monitoring.

3.4.Determining type, number and location of measurement plots

Sixteen nested 35 X 35 m permanent sample plots (PSP) have been located systematically in forest across the project sites. As the natural diameter class distribution in a natural forest has an inverse J shaped curve, and as most of the stand basal area are contained in the few large trees, the nested sample design has a wider sampling area to cover the few large trees with decreasing sample areas for the lower diameter classes ranges (Figure 7).

Figure 7: Sample plot shape and dimensions



One purpose of the 16 PSPs is to estimate the variation in carbon stocks across the forests and then to use this to determine the total number of sample plots required for an acceptable precision and accuracy. The results of the analysis are discussed in Section 5.

Section 6 discusses an attempt that has been made to differentiate between sparse and dense forest using remote sensing. To validate the mapping of these land cover classes, further ground-based measurement has been conducted. The measurement involves a rapid assessment of biomass using point sampling, and this is discussed further in Section 6.

3.5. Determining measurement frequency

Re-measurement of the plots will initially be conducted at least once every two years. While changes in carbon stocks in the forests are expected to be slow, the initial high frequency of measurement will contribute to validating the early measurements and will contribute to building community capacity for forest monitoring.

4. Building community capacity for forest monitoring

4.1. Rationale for community-based forest biomass monitoring

The CFMP aims to generate information on biomass to assist communities in making informed decisions about their forest use and management options. In Decision 4/CP.15, the UNFCCC Conference of the Parties (COP) encourages the development of guidance for "full and effective engagement of indigenous peoples and local communities in, and the potential contribution of their knowledge to, monitoring and reporting of [REDD+] activities." The CFMP clearly responds to this call be engaging local communities in forest mapping and measurement. The call from the COP for community participation in REDD+ is particularly important for Papua New Guinea, as communities own almost all of the country's forests.

Through the CFMP, communities generate new knowledge that places them in a more informed position to consider different forest management options. The monitoring could of course be conducted by professionals, but when conducted by communities and matched with awareness activities, the communities are likely to be in a better position to consider how REDD+ activities could be designed to best reflect their interests. They are also in a better position to understand complex concepts associated with climate change, such as carbon, and less vulnerable to manipulation by outsiders (e.g. the so-called "carbon cowboys"). Their future depends upon wise decisions about their resources, and through assessing and monitoring their forests, local communities are more able to make these decisions.

4.2. Capacity building activities

The approach of the CFMP has been to engage fully with the participating communities in all aspects of forest monitoring, with the aim of building largely self-reliant community-based forest monitoring teams. We use the term "monitoring" very broadly to include (i) mapping, (ii) measurement (forest assessment), and (iii) continuous observation and periodic re-measurement of the forest.

The key capacity building activity under the CFMP is the implementation of a training programme on forest monitoring in each community. The clan leaders are first consulted and the communities select about 8-10 of their members for the forest monitoring training. The participation of women is encouraged.

The training programme runs over three days. Day 1 is spent in and around the villages and involves training on (i) the purpose and principles of forest monitoring, (ii) the monitoring variables, methods and equipment, (iii) data recording, and (iv) team management. Days 2 and 3 are spent in the forest, where the trainers guide the teams in locating, setting up, measuring and recording data from PSPs (Images 2-7). A community-friendly field manual has been drafted as a resource for the training and to guide the monitoring (Image 8).

The community forest monitoring teams are trained on how to locate and set out nested rectangular plots; tree marking and tagging; and on the use of GPS, survey tapes, DBH tapes, and clinometers. In addition to tree measurement, the community teams take measurements for estimating biomass in lying deadwood and they record site conditions, such as altitude, slope, aspect, and disturbance (natural and human causes). The teams also record tree species in their local languages.

Image 2: Classroom training - Awane

Image 3: Classroom training - Dawen

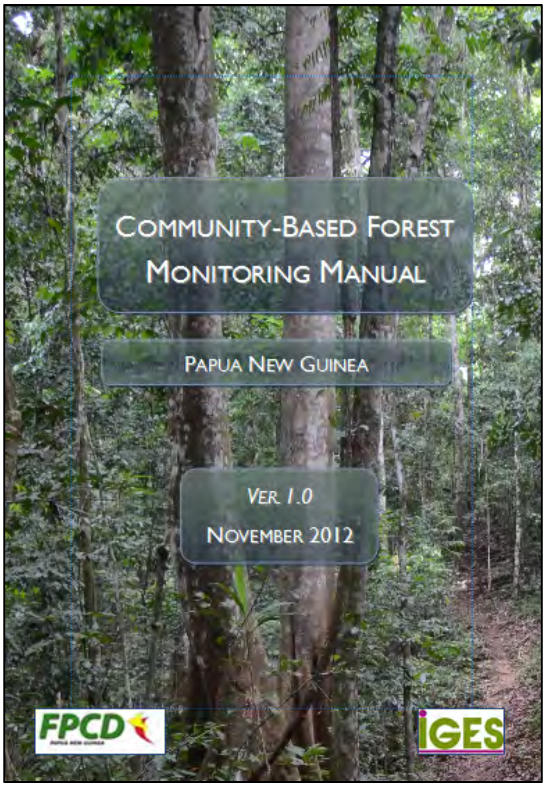
Image 4: Classroom training - Bangapala

Image 5: Clinometer training - Dawen

Image 6: DBH training - Bangapala

Image 7: GPS training – Awane

Image 8: Field manual



5. Results of forest biomass monitoring

Table 2 presents the results of the analysis of carbon stock estimates from the 16 35 m^2 permanent sample plots (PSPs). The average carbon stock across the 16 Project PSPs in aboveground living biomass$_{\geq 5cm}$ (ABLB$_{\geq 5cm}$) and lying deadwood is 127.7 ± 46 tC/ha. Trees$_{\geq 5cm}$ DBH account for 94% of the measured biomass and lying deadwood accounts for 6%. Belowground living biomass (BGLB) is estimated in Table 3 using *BBD = exp(-1.0587 + 0.8836 x ln ABD)* (from Cairns, Brown, Helmer, & Baumgardner, 1997). Carbon is converted to CO_2e by the factor 44/12 to give an average of 555.3 (±198) tCO_2e/ha.

Table 3 compares these results with those of other studies. The most relevant of these is the estimate provided by Fox et al. (2010) from 1 ha sample plots in Madang province, PNG. There is no significant difference between the estimates from the community measurements under the CFMP and the estimate in Fox et al. (2010). We can thus say that the measurements provided by the CFMP are reasonable.

Table 2: Summary of carbon stock estimates

Carbon Pool Totals	Mean	SD	SE	Approx CI	CI%	% of overall mean
Trees ≥5 cm (tC/ha)	120.1	47.1	14.9	29.8	25%	94%
Lying Dead Wood (tC/ha)	7.6	7.2	2.3	4.6	60%	6%
Total above ground (tC/ha)	127.7	46.0	14.5	29.1	23%	100%
Below ground trees (tC/ha) [calculated]	23.7	8.1	2.6	5.1	22%	
Grand total above and below ground (tC/ha)	151.4	54.0	17.1	34.2	23%	
Total carbon stock (tCO_2e/ha)	**555.3**					

Table 3: Comparison of carbon stock estimates for tropical forest

Source	Unit of measurement	Estimate
CFMP	$Trees_{\geq 5cm}$ + lying deadwood	127.7 ± 40 tC/ha
	AGLB + BGLB	151.4 ± 54.0 tC/ha
Intergovernmental Panel on Climate Change default (IPCC 2006)	Lowland tropical forest	180 tC/ha
Gibbs and Brown (2007)	Tropical forest	164 tC/ha
Lewis et al. (2009)	Tropical forest	202 tC/ha.
Fox et al. (2010)	$Trees_{\geq 10cm}$	106.3 ± 22.7 tC/ha
Abe (2007)	litter + understory + $lianas_{\geq 5cm}$ + standing deadwood + $trees_{\geq 5cm}$	251.8 ± 62.6 tC/ha

One purpose of the 16 PSPs is to estimate the variation in carbon stocks across the forests and then to use this to determine the total number of sample plots required for an acceptable precision and accuracy. We specified the estimate of mean carbon stock per hectare with (2-tailed) 90% confidence and 10% error, as required by the Chicago Climate Exchange. The formula used to calculate the total number of sample plots required is:

$$n = \frac{CV^2 t^2}{E^2}$$

Where: *n* = number of samples, *CV* = coefficient of variation, *t* = student's *t* value for a 90% confidence interval at a specified degree of freedom, *E* = acceptable level of error (10%) of the true mean

The initial plot size was set to 25 m^2. From the 16 25 m^2 PSPs the total number of sample plots required was estimated at 105. This number reflects large variation in biomass across the forests.

To increase the efficiency of the sampling, the plot size was extended from 25 m^2 (area = 625 m^2) to 35 m^2 (area = 1,225 m^2). Table 4 presents the results of the processed data. For 35 m^2 plots, for the same precision and accuracy of the average per hectare carbon stock estimate, the total number of plots required drops to 40, which is less than half the number of 25 m^2 plots required. As increasing the plot size adds no travel time to and from the plots, and as the 35 m^2 plots require less than double the time of the 25 m^2 plots to measure, using 35 m^2 plots clearly increases the sampling efficiency.

Table 4: Estimated of no. of plots required

Plot size	**35 m^2**	**25 m^2**
No. of plots	16	16
Mean	127.7	129.5
SD	46.0	75.8
CV	0.4	0.6
DF	15	15
t-value (90% CI)	1.753	1.8
Total no. of sample plots needed (90% CI)	**40**	**105**

6. Land cover mapping

Remote sensing has been introduced into the CFMP to provide more accurate mapping of land cover, and later to contribute to the projection of emissions scenarios. Comparing several potential sources for satellite data based on spatial and spectral resolution, period of image capture, availability of satellite images for the project areas, spectral resolution, and price, indicates that only a few options are suitable. For the purposes of testing different remotely sensed data options for land cover mapping at the project sites, one RapidEye image and one image from the ALOS PALSAR sensor, for which maximum resolution was sought, were purchased.

The selection of land cover classes for the CFMP sites was based on extensive knowledge of the local people and FPCD foresters, and with a view to the monitoring of forest carbon stock changes. Land cover classification in other studies in PNG was also considered. Table 5 lists the land cover classes selected and provides a brief description based on local knowledge.

Table 5: Land cover classes for mapping of the CFMP project sites

Land cover class	Details	Sites where present
Dense forest	This is the dominant land cover. It consists mostly of lowland tropical rainforest; forest at Bangapala may be classified as swamp forest.	All
Sparse forest	Selectively logged forest or other natural forest with low biomass.	Maybe all
Secondary forest	Found in former garden areas or other previously cleared areas.	All
Swamp	Possibly only found at Bangapala.	Bangapala
Grasslands	Grasslands (mostly *Imperata cylindrica*) can populate an area after land degradation. Grasses, including pit-pit (*Miscanthus floridulus*), grow along river banks.	Bangapala
Gardens	Forest is cleared in small patches to grow subsistence crops. The gardens are abandoned after a couple of years when the soil nutrients are depleted.	All
Settlements and surrounds	Settlements and surrounds consist of huts, grassed areas, planted vegetation such as betel nut, coconut and cocoa, and some gardens. There are no extensive road networks, and the access roads are mostly narrow, one-lane, unpaved bush tracks.	All
Water	There are creeks at all sites. Bangapala has some oxbow lakes.	Present at all, but may only be a significant land cover class to be mapped at some sites

Classification can occur through an “unsupervised” process which is based purely on a mathematical algorithm, or a “supervised” process, where training areas for each of the classes are selected in the scene to “educate” the software on the types of classes and how to recognize them. A supervised process was used, taking advantage of the extensive knowledge on land cover at the project sites.

The method of classification can be performed as a pixel-based process, relying on the spectral resolution/radiometric resolution of the image, or an object-based process, dividing an image into objects types of different shapes and colours. Due to time and software limitations, only pixel-based classification was applied.

6.1.Classification results: Landsat

Land cover mapping was attempted using freely available Landsat data for both Bangapala and Awane. Landsat data could be appropriate for tracking large land cover changes in larger community forests of about 5,000 ha or more, such as in Bangapala (Figure 8), but less useful for smaller community forests of less than 1,000 ha, such as Awane (Figure 9). Regardless of forest size, Landsat images cannot be used to map all significant land cover change drivers in PNG, e.g. subsistence gardens, because of its medium resolution.

Figure 8: Bangapala land cover map generated using Landsat image

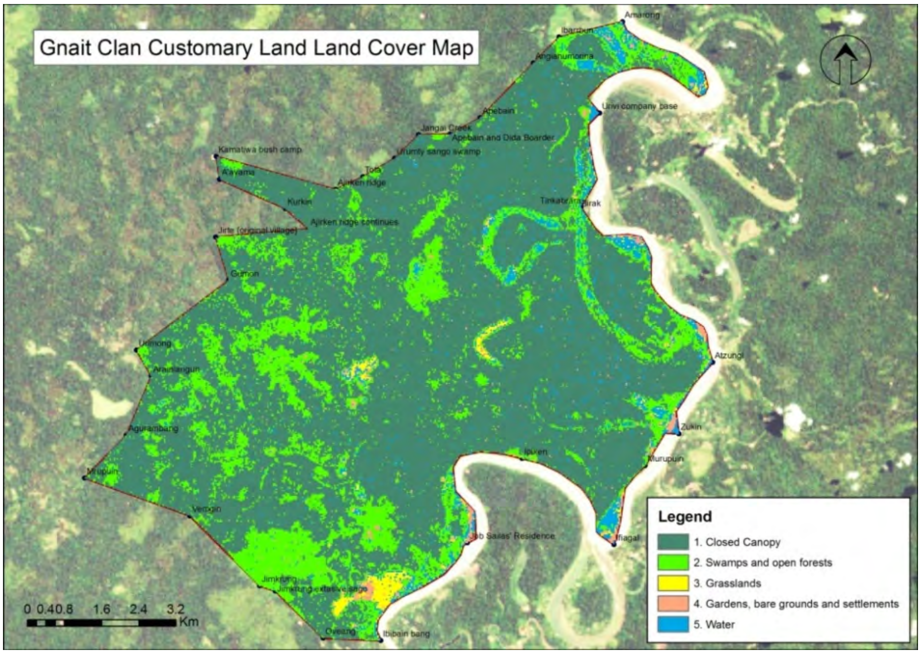
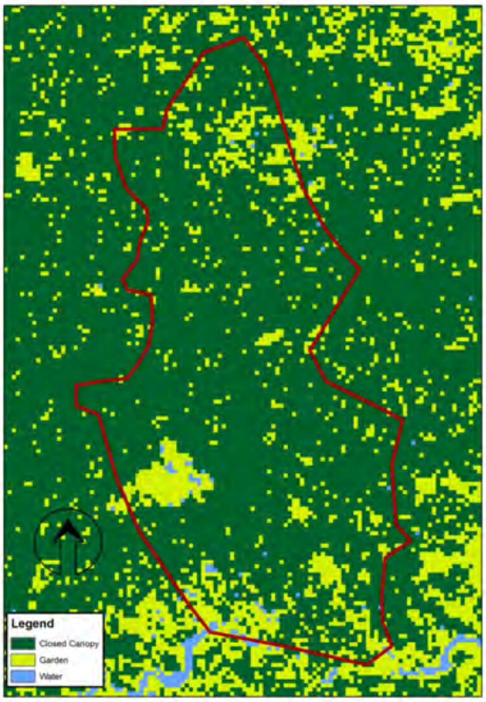


Figure 9: Awane land cover map generated using Landsat image

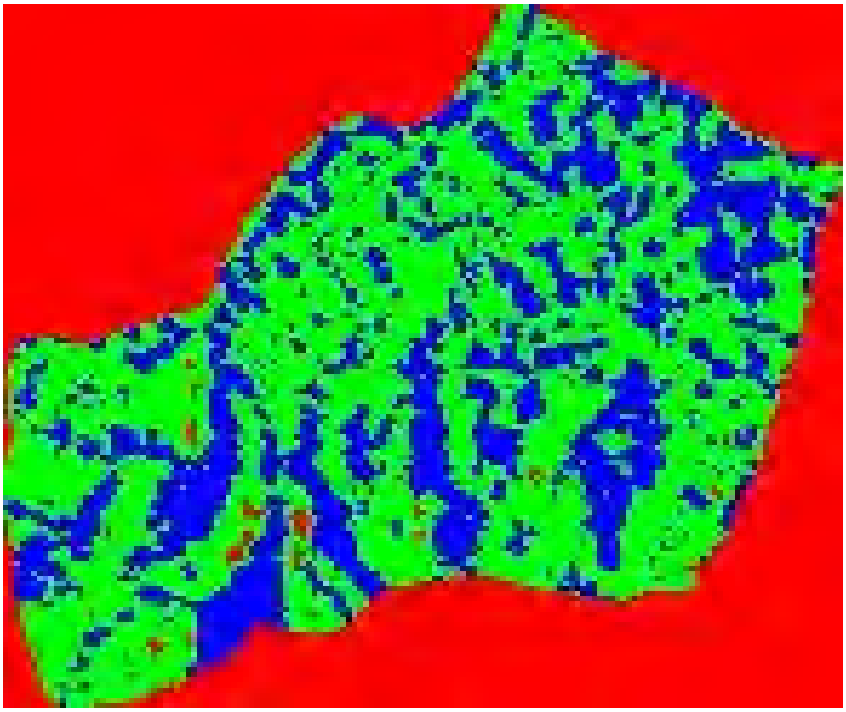


6.2.Classification results: PALSAR

The potential of PALSAR application was tested for the Brahman site. The Brahman forest starts on alluvial river flats then climbs very steeply. High relief proved to be an obstacle to the use of PALSAR data for land cover mapping. Also, even at the best resolution, full polarimetric, (22 m after processing), at 520 ha the area of the forest was found to be too small for accurate mapping using PALSAR.

Most of the area was correctly mapped as forest (Figure 10). The green colour was expected to indicate dense forest, the blue colour sparse forest, and the red colour, garden and other areas with low biomass. However, due to topographic effects, the steeply sloping areas appear as blue, masking the density of the biomass. This suggests that it is not appropriate to use radar sensed images for mapping of most of the project sites.

Figure 10: Brahman land cover map based on ALOS PALSAR radar data



6.3.Classification results: RapidEye

The best results were achieved using RapidEye data. Supervised classification using two classification algorithms – maximum likelihood classifier (MLC) and support vector machine (SVM) – was applied. The results for the SVM classification for Awane are presented in Figure 11.

The target for map accuracy was set at 85%, which is commonly accepted as appropriate for land cover mapping (Foody, 2009; Wulder, Franklin, White, Linke, & Andmagnussen, 2006). Ground validation surveys have been conducted to assess map accuracy, but the results are still to be analysed. The sample plots for ground validation were set at 25 m x 25 m, reflecting pixel size and the positional error of the GPS device and the satellite data. The sample points were distributed as follows: 16 each in sparse forests, dense forests and secondary forests, and eight in gardens.

For the dense and spare forests classes, samples were located at 100 m intervals along a 500 m by 500 m grid. For gardens and secondary forest, due the small size of the areas concerned the practical solution was to identify the centroid of polygons that marked the gardens or secondary forest areas and randomly select a sufficient number of these locations for sampling.

At each verification sample plot, information was collected on the land cover class and GPS reading of location, and digital images were captured. An angle gauge with a Basal Area Factor of 5 was used to conduct a quick inventory to allow estimation of basal area for the sparse and dense forests. Ten – 15 trees were counted at each point. Figure 12 shows the lay out of the validation sample plots.

Figure 11: Awane SVM-based land cover map

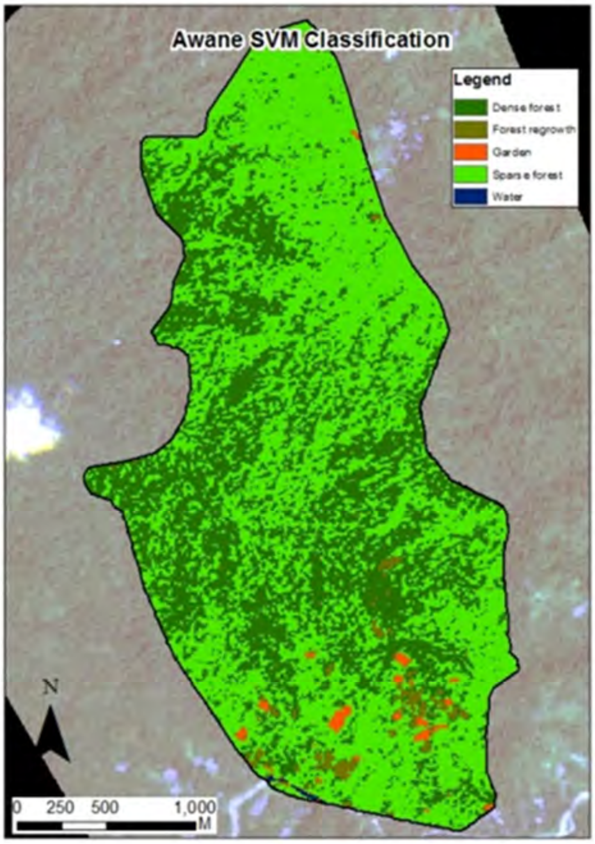
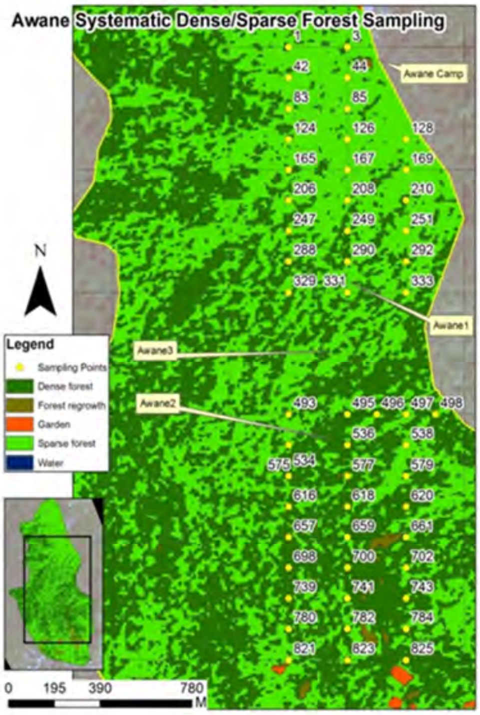
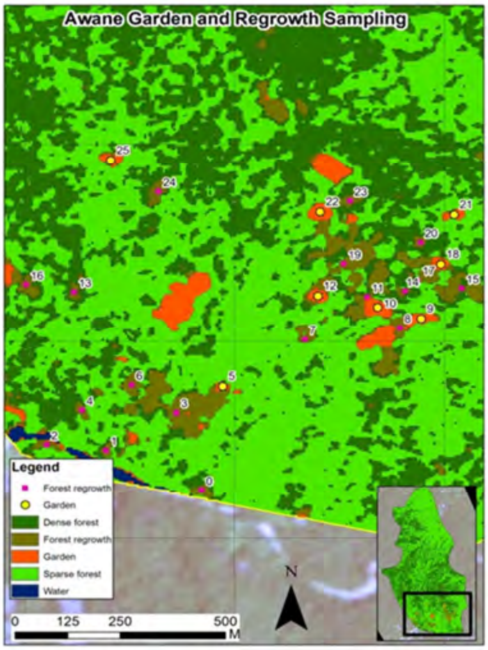


Figure 12: Map verification sampling plots for Awane





7. Conclusions and next steps for the CFMP

The CFMP has progressed steadily and provided an opportunity for learning for both the implementing partners and the participating communities. The results of the analysis of the sample plot data support the contention that with appropriate training and on-going support, local communities can take accurate forest measurements for credible assessment of forest biomass.

Remote sensing analysis was introduced into the project in 2012. The suitability of different image data for remote sensing analysis at the scale of the project communities was tested, and RapidEye was found to be a good option. A method for ground validation of the land cover maps was developed and was implemented in Awane. The remote sensing analysis may be able to distinguish between sparse and dense forests, which will mean an adjustment of the ground-based measurement sampling design.

The following activities are proposed for FY2013:

- Training to be conducted with new clans brought under the project and plots established in their forests;
- Development of community-friendly database for processing field data using MS Access;
- Land cover mapping of all project sites using RapidEye images;
- Further ground-based measurement, if sparse and dense forests can be accurately mapped;
- Projection of baselines and modelling of REDD+ scenarios.

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