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Final report

project

Assessment, management and marketing of goods and services from cutover native forests in Papua New Guinea

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Contents

1 Executive summary

There are 29 million hectares of closed forest in Papua New Guinea (PNG) and almost all this area is under customary community ownership. Forests are a major contributor to the PNG economy and play a vital role in sustaining the traditional subsistence livelihoods. While economic contributions of forest industries have been significant, current levels of harvesting by the log export industry are considered unsustainable and accessible primary forests are likely to be logged over in the next 15-25 years. Future timber production from native forests will be increasingly dependent on harvesting in forests that have been cutover in past operations. There are now about 4.4 million hectares cutover forests, about 40 percent of total area of accessible and merchantable forests.

With improved management, these cutover forests may provide ongoing financial benefits and services for their local owners. However, poor knowledge of the goods and benefits (such as timber, carbon, biodiversity, and community and cultural uses) that can be provided is a constraint on investment and policy development. This project aimed to assess the future capacity of cutover forests to supply timber and environmental services and to investigate different production options for community forest owners, particularly those involving small-scale or portable sawmilling operations.

Data from 120 permanent sample plots in cutover forest maintained by the PNG Forest Research Institute indicated 20% of plots had been subjected to wildfires that occurred in the 1997 El-Niño drought. Of the unburnt plots, 75% were increasing in timber volume at rates that could sustain a future harvest (about 1 m3/ha/year of merchantable volume). The remaining 20% of plots were declining in volume and basal area and will need rehabilitation to restore productive potential. Carbon in above ground woody biomass is recovering at an average sequestration of 1.12 tonne C ha/yr after logging and will therefore take about 75 years to return to the pre-harvest carbon stock. Models developed from this plot data were integrated into a forest assessment and modelling system. Remote sensing studies indicated that readily-available ASTER data combined with more efficient techniques for field assessment can provide an accurate assessment of the condition of cutover forests. Forest management plans were generated for two community forests that will facilitate sustainable management and forest certification.

A financial model was developed to analyse the viability of small-scale forest operations. This analysis indicated that with current market prices, for forests within 170 km of markets, a single small-scale mill producing operated efficiently (1000 m^3/yr of log input and 50% recovery) with export of green sawn timber of higher value species and selling other species locally was the most profitable model, earning PNGK 1.9 million for the community in net profit over a 20 year life-time, with almost 15% return on sales and a relatively short capital payback time (3 years). Selling all products locally was also moderately profitable (PNGK 0.6 million of accumulated profits over 20 years). For community forest enterprises that are a greater the distance from markets, higher volumes of material are required to be processed and sold in order to be financially viable. Leadership, business management, technical skills and access to working capital are barriers to wider successful adoption of small-scale sawmilling. Profitable value-adding (drying and planing) in PNG requires larger-scale aggregation of green sawn product from a number of operations. This adds complexity for communities and increases capital requirements.

Results from the project were transferred to researchers and forest managers in government and NGOs through workshops and targeted training. With improved management there is significant potential for cutover forests to provide ongoing supplies of timber for local use and sale and to provide other ecosystem benefits such as higher carbon storage. Wider adoption of sustainable management can provide significant financial and community benefits to community forest owners.

2 Background

Tropical forests cover 10% of global land area but remain a scientific frontier due to structural and biological complexity and high temporal variability associated with complex successional processes (Chambers et al. 2001). A constraint in further understanding is the limited number of long-term studies quantifying tropical forest dynamics and the impacts of anthropogenic and natural disturbances, such as harvesting and fire (Clark et al. 2001; Lewis et al. 2009). Long-term studies, whilst difficult to maintain, especially in developing countries, are essential to the development and testing of hypotheses regarding processes and rates of ecological recovery following disturbance, both anthropogenic and natural (Taylor et al. 2008). This project aimed to build on long-term research supported by ACIAR and other donors to improve the knowledge base for future management of native forests in Papua New Guinea (PNG).

The total land area of PNG is 46.3 million ha, with about 28 million ha covered by closed natural forest. The forests of PNG are structurally diverse and complex, and have had limited scientific investigation. With approximately 11,000 different plant species, the tropical forests and freshwater wetlands of PNG are considered to be of similar biological and conservation importance to the Amazon and Congo Basin. Almost all of the forests in PNG are under customary ownership by local communities, tribal groups or individuals. Forests play a vital role in sustaining the traditional subsistence livelihoods of most of the population. Forest resources are also a major contributor to the national economy. The sector employs about 10,000 people, log exports were valued at over US$170 million in 2006 industry and these contributed some 200 M Kina in export duties, royalties and taxes (PNGFA 2009).

However, current operations generally do not generally meet required standards or deliver long-term benefits for landowners. Financial returns to resource-owners have fallen substantially in real terms over the last decade and are often too small to impact on living standards. Employment and other ‘spin-off’ benefits are usually taken by outside workers. Local communities are receiving very little in services or other government expenditures from current operations.

Sustainable management of natural forests is considered an integral part of the strategy for future economic development of PNG. The National Forest Policy states that the forest resource will be managed for the broad range of commercial benefits and non-commercial values it can provide for present and future generations. Sustainable forest management requires a sound scientific understanding of the forest resource, enabling government policy, operational guidelines and adequate supervision of forest harvesting operations.

Aside from being a major contributor to different sectors of the PNG economy, PNG’s forests play a vital role in sustaining the traditional subsistence livelihoods of most of the population and contribute significant environmental values. The current level of harvesting by the log export industry is considered unsustainable and accessible primary forest is likely to be logged out in the next 15-25 years (Shearman et al. 2009, Filer et al. 2009). Most logging in PNG forests has been selective, with not all trees removed during the harvesting operation. Cutover forest varies in condition and production potential, depending on the nature and timing of previous harvesting and the recovery rate of the forest. Because they are generally the most accessible and some of the most productive forest in PNG they will form a major part of the future estate for timber production. Some areas have been subjected to further harvesting in larger scale or small scale operations.

There is considerable concern about the sustainability of current management practices, the recovery of forests after harvesting and the potential of forests to provide timber or other community needs (Shearman et al., 2009). Shearman et al. (2009) suggested that logging in PNG’s forests results in high levels of impact and that there is little prospect

that they will recover to original levels of timber volume or biomass in the short term. However, there is little published evidence to support these claims.

An economic challenge looms for PNG as revenues from log export based on primary forest decline. Properly managed, areas that have been previously harvested since large-scale forest operations began in the 1980s may have the capacity to continue to make a major and more sustainable contribution to the PNG economy, while maintaining many of the other values that PNG society values from their forests.

Sustainable, community-based forest management has significant potential to contribute to the economic development of local communities. Developing more sustainable management options for PNG forests would also improve the market reputation of PNG timber and open new pathways and markets for forest products. More appropriate forest management systems and forest certification, such as prescribed by the Forest Stewardship Council (FSC), need to be more widely applied.

This project aimed to provide an improved basis to analyse options for community-based management, focusing on techniques to assess resource condition and availability and processing and marketing requirements.

Research was undertaken in partnership with the PNG Forest Research Institute (FRI) and the Village Development Trust (VDT). The intention was to employ two staff at FRI but early in the project was agreed that existing staff would be assigned to the project.

VDT is an eco-forestry based local NGO, which was supported by Interchurch Organisation for Development Cooperation (ICCO) of The Netherlands. VDT's goal in small-scale forestry projects is to empower landowners to manage their own forest resource through capacity building and skills training. The project paid for the employment of a project officer at VDT (Mr Francis Inude). Unfortunately VDT encountered financial difficulties and was placed in administration in early 2010. This impacted on capacity to deliver final project results to collaborating communities.

A consultant, Mr Jim Grigoriou was commissioned to undertake the assessment of market prospects for PNG native timbers and to develop and apply the financial analysis model for small –scale timber harvesting.

A staff member of FRI, Mr Cossey Yosi was successful in obtaining a John Allwright fellowship to undertake a PhD at the University of Melbourne and has been contributing to project outputs and outcomes. Mr Yosi commenced in July 2007 and his study will be completed in June 2011.

The comprehensive permanent sample plot (PSP) database maintained by the FRI has been remeasured and maintained with previous support from ACIAR and provided an opportunity to analyse information about changes in cutover forests over a measurement period of over 15 years. The project undertook significant work to improve the database, remove persistent errors, and make it accessible for analysis. Targeted re-measurement of PSPs and the collection of ancillary information such as spatial location and soil carbon samples added valuable information. Assessment of goods (such as timber) and services (such as carbon sequestration, biodiversity, and community and cultural benefits) was identified as a priority, and can be undertaken using a combination of remote sensing, Geographic Information Systems (GIS), forest modelling, PSPs and cultural surveys.

Tools were intended to provide information on forest resources to governments and local communities and would be based on forest growth modelling, remote sensing, and GIS. Systems that facilitate improved decision making were also to be explored. Ultimately the project hoped to facilitate a move toward sustainable and certified forest utilisation.

The project engaged NGO staff directly in project activities and provided a direct linkage between PNG communities interested in economically-viable and environmentally-sustainable management of their forest resources and timber importers in Australia and elsewhere seeking products that meet certified standards. The project included training of

local communities and NGO staff and production of demonstration materials suitable for presentation to local communities. Outputs from the project have been published in refereed journals and presented at international and national conferences. Papers presented at a workshop to complete the project are being compiled for publication as an ACIAR technical publication to be finalised by June 2011.

3 Objectives

Objective 1: To classify PNG's secondary forests in terms of condition and capacity for future growth and to produce timber and other products and values

Activities:

- Workshop to prioritise attributes and values of secondary forests
- Assessment of existing sample plots (PSPs) and new temporary plots in cut-over forest
- Integration and analysis of remotely-sensed and field plot data and testing of multi-phase approaches to forest assessment

Objective 2: To assess the future market opportunities for different products and develop effective methods for linking local producers with purchasers of sustainably produced timber

Activities:

- Review of wood properties and qualities of different PNG timber species in relation to current international market requirements.
- Analysis of existing forest operations that are considered to meet appropriate legal requirements and certification standards
- Analysis of certification of forest management arrangements and test of adoption by smaller scale, local forest management.

Objective 3: In collaboration with forest owners, to analyse options for future supply of different products and services in relation to their community values or external markets, and to design appropriate management strategies

Activities:

- Modelling of alternative forest management scenarios
- Discussion and analysis with stakeholders

Objective 4: To train community based NGO staff in:

- forest assessment and analysis of different forest management options that will allow local forest owners to obtain future sources of revenue from their forests
- relevant quality control approaches
- management of marketing linkages

Activities:

- Workshops and field-based training

4 Methodology

4.1 Classification of PNG's secondary forests in terms of condition and capacity for future growth and to produce timber and other products and values (Objective 1)

4.1.1 Workshop

A project workshop was held on the 13th and 14th of March, 2008 in Lae, PNG to review the status and prioritise attributes and values of secondary forests. The 23 participants comprised stakeholders in the management of secondary forests. A full report from the workshop is provided in Appendix 1, and further details of workshop outcomes are explored elsewhere in this report. It was concluded that secondary forest is a large (3.4 million hectares; 10% of forested area), but poorly understood resource in PNG. Its neglect and ongoing degradation was attributed to poor knowledge of the goods and services that may be available. Therefore assessment of this resource was identified as a priority, and should be based on remote sensing and growth modelling to classify secondary forest according to the products it may provide now and into the future. Communication to communities of the goods and services that are available and the flow of these resources in the future is paramount to ensure they benefit from their resource and to avoid further degradation.

4.1.2 Permanent sample plot assessment and analysis

Between 2008 and 2010 Project Scientist Dr. Fox spent extended periods at FRI collating and cleaning permanent sample plot (PSP) data collected between 1992 and 2008. Plot data collected between 1992 and 2008 was collated, cleaned, and transferred into a Microsoft Access database including all PSP measurements derived from the International Tropical Timber Organisation (ITTO) PSPs, the Sustainable Forest Management (SFM) PSPs, and PSPs established under ACIAR funding. Cleaning the PSP database was undertaken with local staff (Joe Pokana, Kunsey Lavong and Forova Oavika) to locate original measurement sheets and correct database errors. Significant errors were corrected and several entire measurements were corrupted which needed to be manually corrected. These corrupted measurements and persistent errors had limited previous analysis of the database. Consistency checks conducted toward the end of 2008 confirmed that the database was clean and accessible, and that analysis of the condition, stocking and growth rates of PNG's forest could commence.

To strengthen the PSP dataset, FRI implemented a re-measurement program using project funding. During the period 2007-2010 32 PSPs were remeasured in Western, New Ireland, Manus and West New Britain, Milne Bay, Central, Chimbu, Morobe, and East New Britain Provinces. This was 25% of the total plots. Spatial information for remeasured plots was collected using GPS units purchased under the project. Additional information was collected on soil carbon stock by Patrick Nimiago also under project funding. All remeasured data has been entered in the improved PSP access database.

The database includes ancillary information collected during this project, such as GPS locations for all plots. A new data structure was established for the database to ensure consistency. The new database includes a data entry system with error checking, a reporting system for summarising across PSPs, a data export system for extracting data to excel, and system for printing data sheets for new field measurements. It is intended that the new system improve accessibility within PNGFRI and PNGFA to the PSP data facilitating opportunities for PSP data interrogation and analysis. This database is the

most extensive database of field measurements in PNG and will also have an important role as for Monitoring, Reporting and Verification (MRV) for national REDD+ reporting.

Analysis of the condition, stocking and growth of PNG's forest based on these PSPs involved has been published in 3 papers (Fox et al. 2010 and 2011a and Yosi et al. 2011). Refer to Appendices 2-4 for detailed description of methods.

The PSP database provided the basis for development of growth models for secondary forest in PNG. Individual-tree growth models were developed that matched the scale of community forest utilisation in PNG. These formed the basis of sustainability and scenario analysis for small-scale utilisation at the community level. The tropical forests of PNG are structurally complex and highly diverse both in structure and the species they contain. Because individual trees in PSPs are spatially mapped, the project examined spatial competitive processes governing tree growth and fitted hierarchical Bayesian models to the PSP data (Fox et al 2011c). Refer to Appendix 5 for a full methodological description of the approach.

4.1.3 Integration and analysis of remotely-sensed and field plot data and testing of multi-phase approaches to forest assessment

To facilitate forest classification in community areas, a suite of remotely sensed optical (LANDSAT 5, LANDSAT 7 ETM, and ASTER) and radar (JERS-1) data was acquired for the study areas during 2008. In subsequent work, ASTER (Advanced Spaceborne Thermal Emission Radiometer) remotely sensed data was been found to be most useful for forest classification and modelling for the study areas. During 2009, ASTER data was processed to create a digital elevation models (DEM) that described the hilly topography of project areas. DEMs were very useful for informing the best route for road construction, particularly for the Sogi and Kgwan project areas.

To complement optical ASTER data, geo-corrected radar data from the JERS-1 platform was acquired for the entire land area of PNG in 2008. This has been processed to provide forest canopy backscatter information for the forest. To compliment optical and radar data, bioclimatic data has also been acquired for PNG from the WorldClim database (Hijmans et al. 2005); this data has been found to compliment remotely sensed data for the modelling of forest biomass. Unfortunately, forest classification using JERS-1 and LANDSAT had limited success and these approaches were discontinued in favour of ASTER. A publication describing application of ASTER remote sensing in community forest areas will be published in an ACIAR technical publication early in 2011.

In a collaboration with Dr. Mark Williams, a remote sensing scientist originally from Fugro EarthData Inc and now a remote sensing consultant working in Melbourne, the project generated high resolution forest resource information (merchantable timber volume and carbon) for the Sogi project area based on state of the art GeoSar remote sensing. The collaboration initially focused on the Sogi project area, but has potential for application to the whole of PNG, providing important outputs for REDD mechanisms and the analysis of trade-offs between timber and carbon.

The project developed a stratified random sampling technique that built on, but differed from, a random cluster sampling design developed in an earlier ACIAR project (FST/1998/201). After stratification based on ASTER remote sensing, a pilot survey of each stratum was recommended with 20 samples in each stratum. Field sampling involved random variable radius plots using a factor 2 prism wedge to select measurement trees. A field collection proforma for variable radius plots has been created as part of the assessment and modelling tool in excel. On each measurement tree the diameter at breast height was measured. If buttressing was present at breast height then a new point of measurement was created above the buttress, and a new point of measurement was established. Species was also recorded. For common forest types, look up tables were used to estimate total height and merchantable height. However, for less common forest types, it was recommended that height and merchantable height be

measured in the field. At each field sample an accurate GPS location was captured; it is recommended that a GPS is placed in the plot centre and left to average while the plot is being measured. This results in the best spatial accuracy and facilitates integration with ASTER data.

The modern inventory technique described above can be used to estimate forest stocking, composition, merchantable timber volume and forest carbon. This modern forest inventory approach also facilitates calibration of remotely sensed estimates of merchantable volume and biomass for wall to wall mapping. The technique can also be used more generally to improve the efficiency and accuracy of forest assessment in PNG, and was the subject of much discussion at the workshop 'Improving inventory for timber and carbon in Papua New Guinea ' help during March 2009. A report from the workshop is included in Appendix 6. During the workshop the technique was communicated to the PNG Forest Authority, the Office of Climate Change and Development and to organisations involved in forest certification in PNG (FORCERT, VDT, and FPCD). Current inventory methods prescribed in the Forestry Act require a strip-line sampling approach covering 1% of the forest area, and this approach is used by both PNGFA and forest certification bodies. The approach is inefficient and may be biased; the forest sampled on strip-lines may not be representative of other areas of the resource. There is considerable scope to improve the accuracy and efficiency of the strip-line approach using a random variable-radius sampling strategy.

During September 2008 and March 2009, Dr. Fox and Francis Inude implemented the random variable-radius plot survey method for primary forest in the Sogi project area. This required a two week jungle trek through the remote Transgogol and Usino-Bundi Local Level Government (LLG) areas of the Sogi project during September 2008. During March 2009, the project team revisited the Sogi project area and implemented a further week of field work to supplement information in the lowland forest around Yagi. The approach worked well for the Sogi project area, and yielded a forest classification and estimates of the timber and carbon resource. ACIAR project staff at VDT, Mr. Inude was trained in the design, implementation, and analysis of random variable-radius plots, and subsequently implemented an inventory of community forests in Yalu and Gabensis in Morobe Province during July 2009. Dr. Fox and Mr. Inude completed an inventory of the Kgwan community forest area in September 2009.

The integration of remotely sensed (ASTER) data and random variable-radius plot survey has been completed for each ACIAR project area during 2010 and is detailed in the publication to be published in the ACIAR technical publication early in 2011.

4.2 Assessment of future market opportunities for different products and develop effective methods for linking local producers with purchasers of sustainably produced timber (Objective 2)

4.2.1 Timber marketing and review of international market requirements

In collaboration with the project partner, Peter Mussett of the Woodage (http://www.thewoodage.com.au/), an initial review of PNG wood properties (specifically those available in secondary forest) and their suitability for international markets was completed in 2008.

During 2009, Mr Jim Grigoriou, an economist and commercialisation manager, was contracted by the project to conduct a review of the production, consumption and pricing of native tropical hardwoods for international markets. Some important conclusions emerged from the review as described in the results and discussion section.

4.2.2 Forest certification in PNG

An initial analysis indicated that there was little need to add to the current information provided by NGOs supporting forest certification bodies in PNG, Village Development Trust (VDT), Forest Certification Services (FORCERT), Foundation for People and Community Development (FPCD). Project staff and collaborating scientists participated in a 2 day workshop on "the future of Forest Certification in PNG" held in Port Moresby on 11th and 12th March 2008. During the workshop the requirements, challenges, and benefits of forest certification were discussed. Requirements for forest certification are determined by the FSC (Forest Stewardship Council) that addresses the social, environmental and economic requirements for certification. Requirements for certification are rigorous, and to date only 15,000 ha in PNG has been officially certified. Certification empowers landowners, improves livelihoods, preserves the natural environment, and can facilitate sustainable development. For these reasons it was a priority that the forest assessment activities underway in this project inform and improve forest certification efforts in PNG.

Formal requirements for certification have already been documented in FORCERT guidelines. The challenges facing communities in meeting these requirements, and the success of certification generally have been reviewed for PNG by Bun and Scheyvens (2007). Therefore, it was decided that Activity 2.2 "Analysis of existing operations that are considered to meet legal requirements and certification methods" was not needed.

4.3 Analysis of options for future supply of different products and services in relation to their community values or external markets, and to design appropriate management strategies in collaboration with forest owners (Objective 3)

4.3.1 Production and supply models for community forest management

During 2010, a consultant, Mr Jim Grigoriou, was contracted by the project to assess the financial viability of community forestry in PNG. He developed an economic analysis tool to assess different production models for community based forest management in PNG. This can be used to assess the financial viability of alternative timber production and supply models that can be adopted by community forest enterprises. Models that are currently being used by communities (i.e. working towards certification and processing green boards for local sale), as well as alternative models involving value adding by drying and ‘dressing’ of the timber for sale to local and overseas markets were evaluated for their economic sustainability.

4.3.2 Community forest management

In consultation with project partner Village Development Trust (VDT) areas for assessment work were identified in 2008; the medium scale community operations of Sogi (20,000ha) in Madang Province, and Kgwan in Chimbu and the small scale operations at Yalu (5,000ha) and Gabensis (2,000ha) in the Morobe province. Sogi and Kgwan community operations are based in primary forest, while Yalu and Gabensis are based in secondary forest. Dr Fox and Francis Inude (VDT/ACIAR project officer) conducted community awareness on the ACIAR project during 2008, spending extensive time in each community to understand local conditions and expectations from community forest management.

Primary forest pilots – Sogi and Kgwan

In consultation with VDT and other project partners it was decided to expand the original focus of the project from secondary forest to community management of both primary and secondary forest. This decision was made on the basis that there are areas of primary forest in PNG that are under community management, and that analysis of the scientific basis for this was worthy of examination.

The Sogi Medium Scale Eco-forestry Project was selected as a case study because it was a priority project area for VDT. The Sogi project was so named because it incorporates two language groups; the Sob language and the Girawa language. It is located close to Madang, PNG, and extends over a large area of primary rainforest with a population of 2,600 living in eight distinct villages. ACIAR project work is concentrated at Yagi village where landowners are milling timbers, predominantly Kwila (*Intsia bijuga*) for export as community based fair trade (CBFT) product. CBFT and Pre-Certified producer status are the first two steps toward full FSC (Forest Stewardship Council) certified status. The first shipment has been exported to an Australian timber merchant specialising in certified tropical timbers.

The Yagi community is also engaged in road construction and maintenance, which will provide access to markets to sell produce, and assist in transporting timber to Madang. Community work is also underway completing a community resource centre from locally milled timbers. This was made available to project staff (Prof. Rod Keenan, Dr. Julian Fox, and Francis Inude).

A baseline survey of demographic information for the Sogi project area was conducted by Mr. Francis Inude during April 2008. It involved visiting the 8 villages of the Sogi project and conducting community surveys. The baseline survey indicated that government services such as schools and health facilities are limited or non-existent in the remote mountainous villages of the Sogi project area. A major challenge is access to the villages, with several days of hard walking on bush tracks required to reach remote villages. This presents a major problem when urgent medical assistance is required. Malaria, diarrhoea, pneumonia, TB, and venereal diseases are prevalent. Educational services are limited with elementary level (Prep, Grade 1 and 2) schooling only available in Kikirai, Igoi and Kasuwal. These limited services have resulted in a majority of the population being semi or completely illiterate. The main income source for villagers is subsistence farming, but this is limited by difficulties in transporting goods to local markets. These constraints have resulted in average annual income from farming being less than 50 kina.

The Kgwan Eco- Habitat Project was also selected as a case study area by VDT. The Kgwan project was so named because it incorporates three clan groups where K represents Kunaiku clan, G for Gereglkane clan and Wan is for the Wandike clan. It is located in the Gembogl district of Mitnande LLG in Chimbu Province, PNG and is about four hours drive northeast of Kundiawa, the provincial capital. The project area covers a large tract of primary montane (2750 - 3500m a.s.l) forest extending to Asaro (famous for the Asaro mud men) in Eastern Highland Province. Kgwan consists of 599 people living in three distinct villages.

A baseline survey of demographic information for the Kgwan area was conducted by Francis Inude during January 2009, and involved visiting the 3 villages of the Kgwan project and conducting community surveys. The baseline survey indicated that limited government services (schools and health facilities) are available, but are located some distance from the remote mountainous villages of the Kgwan project area. The Gembogl district hospital is 3 km from Danbagle village in the Kgwan Project. Education services can also be reached, however, a daily commute of 20km to the nearest provincial high school results in most school aged children not attending school.

The main income source for villagers is subsistence farming, but this is limited by difficulties in transporting goods to local markets. These constraints have resulted in average annual income from farming being less than 150 kina.

Secondary forest pilots – Yalu and Gabensis

Secondary forest pilot project areas were located in the community forests of Yalu and Gabensis. Detailed descriptions of these project areas are being compiled by Cossey Yosi as part of his PhD studies.

Assessing and integrating community values

Mr Cossey Yosi as a part of his PhD studies undertook a program of community interviews in project areas with a view to assessing and integrating community values in management planning. The methodology and outcomes of this work are being written up as part of his PhD to be completed in July 2011.

4.4 Training community based NGO staff and PNG forest service staff

4.4.1 Training of community based NGO staff

Community based NGO staff involved in community forest management and forest certification (Peter Damm and Cosmas Makamet from FORCERT, Yati Bun from FPCD, and Francis Inude, Steven Yandima and Kentas Igai from VDT) participated in project workshops during 2008 and 2009.

VDT ACIAR project officer Francis Inude has received extensive training in forest assessment. He has been engaged in all project activities in PNG. He has been trained in PSP establishment and analysis; He accompanied Dr. Fox and Joe Pokana on Danaru PSP (Madang Province) remeasurement during July 2008. Accompanied Joe Pokana, Kunsey Lavong on PSP remeasurement trips to Manus (May 2008), and lead a PSP remeasurement team to East Sepik (December 2008). He has also been trained by Joe Pokana in PSP data entry.

Following this training, he led the establishment of the first PSPs in high elevation *Nothofagus* forest in the Kgwan community forest during September 2008. The two PSPs are among the first to be established in high altitude montane forest in PNG, and will provide valuable information on forest growth, carbon storage and carbon sequestration.

From the 2nd to the 4th of July 2008, Mr. Inude received GIS and GPS training (along with Joe Pokana) at Jais Aben resort in Madang. Arc GIS (Geographic Information System software) along with PNG spatial data and GPS software was installed on his computer. Training focused on the analysis of spatial data in VDT project areas, the transferring of GPS information and map creation.

From 20th of September 2008 to the 2nd of October 2008, Mr. Inude accompanied Dr. Fox on the implementation of a random variable radius plot inventory of the Sogi project area. During this period he was trained in the implementation of this new inventory strategy. Mr. Inude used these learned skills to implement a similar inventory in Gabensis and Yalu community forests during May 2009.

Mr. Inude visited Australia for intensive training with Dr. Fox from the 2nd of February to the 13th of February 2009. During this period he received refresher training in GIS, and new training in the analysis of remotely sensed data. He also received training on analysis of random variable radius plot inventory data.

A number of other staff from project partner VDT have been engaged in project activities. Kentis Igai (Forest certification officer), Thomas Warr (Coordinator - community participation), and Steven Yandima (Executive Director) attended project workshops on the 13th and 14th of March, 2008, and the 1st to the 3rd of April 2009. Kentis Igai accompanied Dr. Fox on the visit to Sogi (23rd March - 28th March, 2009) and received training in the application of a random variable radius inventory.

Staff from other community based NGOs operating in PNG have also been actively engaged in project activities.

The final day of the workshop 'Improving inventory for timber and carbon in Papua New Guinea' (3rd of April, 2009) was set aside to assist community based NGOs with the estimation of forest carbon and the application of new inventory techniques. CCFP foresters Pamela and Ruben in particular benefited from the application of new techniques to the data they had collected on forest carbon.

4.4.2 Training of PNG government forest service staff

A significant program of training and capacity building of PNG government forest service staff has been undertaken;

- During 2008, Dr. Fox spent extended periods at FRI in Lae working with ACIAR project scientists Joe Pokana and Kunsey Lavong. During this time extended training in GPS use improvement of PSP measurement protocols and PSP database creation and error correction occurred.

- PNGFRI project staff Kunsey Lavong and Joe Pokana were involved in intensive training in Australia with Dr. Fox between 3rd November and 16th November 2008 on GIS, GPS (Global positioning system), and carbon estimation.
- Many other PNGFRI staff (Patrick Nimiago, Martin Golman, Frank Asok, and Bruno Kuroh and others) have attended project workshops during 2008, 2009, and 2010.
- PNGFA staff (Goodwill Amos, Ripa Karo, Rabbie Lalo and several other staff) have also participated in project workshops in 2008 to 2010.
- Staff from the newly created PNG Office of Climate Change and Development (Lois Nakmai, Raymond Yauieb, and Frank Asok) attended the workshop in 2009, and have been receiving ongoing technical advice from Dr. Fox on estimating forest carbon.
- Former project staff Joe Pokana has moved to the PNG Office of Climate Change and Development to take up the position of Director of REDD and climate change. He has indicated that the training and collaboration as an ACIAR scientist, particularly on estimating forest carbon, has been important in his new role.
- PNG project staff (Mr. Pokana, Mr. Lavong, Mr. Inude) have been equipped with GPS units, new measurement apparatus, and prism wedges (for implementing variable radius plots).

During March 2010, Dr. Fox facilitated participation in the two-week intensive course "Forest Resource Assessment" undertaken by Master of Forest Ecosystem Science students at the University of Melbourne for forest scientists from a range of institutions in PNG. Unfortunately logistical problems prevented scientists from PNGFA, PNGFRI and VDT attending. However, Mr Ben Konsolo and Mr Frank Alkam from the Office of Climate Change and Development attended and benefitted greatly.

5 Achievements against activities and outputs/milestones

Objective 1: To classify PNG's secondary forests in terms of condition and capacity for future growth and to produce timber and other products and values

no.	activity	outputs/ milestones	completion date	comments
1.1	Workshop to prioritise attributes and values of secondary forests	Workshop report	Yr 1: Jan - Mar	Activity complete.
1.2	Assessment of existing sample plots (PSPs), data entry and checking	Report on PSP database and Journal publication	Yr 1 and 2	Activity complete.
1.3	Collate and analyse remote sensing data for study area	Report	Yr 1: Jan – July	Activity complete.
1.4	Design sampling strategy	Report	Yr 1: Jan – July	Activity complete.
1.5	Assess temporary plots in cut-over forest	Report on data collection	Yr 2: Mar - Sep	Activity complete.
1.6	Integration and analysis of remotely-sensed and field plot data	Report and Journal publication	Yr 2: Sep - Mar	Activity complete.

PC = Partner Country, A = Australia

Activity 1.1

A key achievement from the workshop was agreement that secondary forest is a large but poorly understood resource. Its neglect and ongoing degradation was attributed to poor knowledge of the goods and services that may be available. Participants agreed that assessment of this resource is a priority, and could be based on remote sensing and growth modelling to classify secondary forest according to the products it may provide now and into the future.

Another outcome of the workshop was the importance of PNG's forest for subsistence livelihoods. To explore this further, Ms. Dalia Bastyte, a Masters student from Lithuania visited Australia and accompanied Dr. Fox to the Sogi project area in March 2009. Her travel was fully funded by the European Union and is the basis of her Masters Thesis. Dalia has assisted the ACIAR project by evaluating the importance of local biodiversity to communities in Madang Province and the Sogi project, i.e., its importance to local people for construction, food, household needs, medicinal, religious, spiritual and recreational values. She did this by talking to community members in focus groups. It was also valuable for female community members to spend time with Dalia and develop cross-cultural friendships. The collaboration has resulted in the article; 'The value of local biodiversity to communities in Madang Province, Papua New Guinea' to be published in the upcoming ACIAR proceedings in 2011.

Activity 1.2

The improved PSP database was completed and analysis of the database has resulted in three journal publications (simply cite and ;

- "Assessment of aboveground carbon in primary and selectively-harvested tropical forest in Papua New Guinea" was a collaborative effort between project scientists at Melbourne University (Prof. Rod Keenan, Dr. Fox, Mr. Cossey Yosi), PNGFRI (Mr. Patrick Nimiago, Mr. Forova Oavika, Mr. Kunsey Lavong), and the newly created Office of Climate Change and Development (Mr. Joe Pokana). The article was published in the tropical forests journal Biotropica and is included in Appendix 2. Based on the PSP data the first defensible estimates of forest carbon were generated for PNH.
- "Forest carbon dynamics in Papua New Guinea; isolating the influence of selective-logging and El Niño" was a collaborative effort between project scientists at Melbourne University (Prof. Rod Keenan, Dr. Fox, Mr. Cossey Yosi), The French tropical forest research institute CIRAD (Ghislain Vieilledent), and the Office of Climate Change and Development (Mr. Joe Pokana). The article is in review in the high impact journal Ecosystems and is included in Appendix 4. In this manuscript the PSP data is modelled to estimate carbon sequestration rates in different forests.
- "Dynamics of natural tropical forest after selective timber harvesting in Papua New Guinea" is a result of research undertaken by ACIAR John Alright Fellow Cossey Yosi. The article is in review in the journal Forest Ecology and Management and is included in Appendix 3. This manuscript examines the recovery of forest after harvesting using the PSP data.

Activity 1.3

A publication describing application of ASTER remote sensing in community forest areas has been written by Dr. Fox that is to be published in an ACIAR proceedings early in 2011; "Assessing timber and carbon stocks for community forest management". The paper describes methodology and results of forest assessment for project areas. A publication has also been written by Dr. Williams that is to be published in an ACIAR proceedings early in 2011; "Remote sensing techniques for tropical forest assessment".

Activity 1.4

A random variable-radius plot sampling strategy has been developed that can be used to efficiently calibrate and validate remotely sensed estimates of merchantable volume and biomass.

A publication has been written by Prof. Cris Brack that is to be published in an ACIAR proceedings early in 2011; "Improving forest inventory in tropical forest management; moving away from the 1% stripline method in Papua New Guinea". Application of the modern inventory technique is also described in "Assessing timber and carbon stocks for community forest management" to be published in the same proceedings.

Activity 1.5

Forest assessment for all ACIAR project areas was completed in 2008 and 2009 and is detailed in "Assessing timber and carbon stocks for community forest management" to be published early in 2011.

Activity 1.6

The integration of remotely sensed (ASTER) data and random variable-radius plot survey has been completed for all project areas and is detailed in "Assessing timber and carbon stocks for community forest management" to be published early in 2011.

Objective 2: To assess the future market opportunities for different products and develop effective methods for linking local producers with purchasers of sustainably produced timber

no.	activity	outputs/ milestones	completion date	comments
2.1	Review current international market requirements wood properties and compare with qualities of PNG timber species	Report	Yr 1: Mar – Dec	Activity complete.
2.2	Analyse forest management certification requirements and adoption in smaller scale, local forest management.	Report	Yr 1: Mar – Dec	Not completed. Partners considered sufficient information already available.
2.3	Analyse existing forest operations that are considered to meet legal requirements and potentially international certification standards	Report	Yr 1: Oct – Dec	Not completed. Partners considered sufficient information was already available.
2.4	Establishment of marketing linkage, for community produced timber, with the Australian timber marketing partner	Report	Yr 2	Activity complete.

PC = Partner Country, A = Australia

Activity 2.1

In collaboration with the project partner, Peter Mussett of the Woodage, an initial review of PNG wood properties (specifically those available in secondary forest) and their suitability for international markets has been compiled. To develop this further, Mr. Jim Grigoriou was engaged to review international market possibilities for PNG timbers. A copy of his report is included at Appendix 7. A brief summary was prepared and has been distributed to participating NGOs (Appendix 8).

Activity 2.2 and 2.3

An initial analysis found there was little need for additional information to that provided by NGOs implementing forest certification in PNG (VDT, FORCERT, FPCD) were actively engaged in project activities. Formal requirements for certification are documented in FORCERT guidelines, and the requirements for certification generally have been reviewed for PNG by Bun and Scheyvens (2007). This engagement helped project scientists understand the formal requirements for certification and the many challenges facing communities in satisfying these requirements. The consultant Jim Grigoriou examined some of the challenges facing small scale producers in his report (Appendix 7).

Activity 2.4

Linkages with Australian timber marketing partners at the Woodage were established in 2008. The project facilitated the involvement of Woodage staff in project workshops in 2008. This linkage has been strengthened by Jim Grigoriou who had extensive liaison with Peter Mussett during 2009 and 2010. This linkage with the Woodage is described in reports in Appendix 7 and 8.

Objective 3: In collaboration with forest owners, to analyse options for future supply of different products and services in relation to their community values or external markets, and to design appropriate management strategies

no.	Activity	outputs/ milestones	completion date	Comments
3.1	Analysis of alternative forest management scenarios and wood supply options	Report	Yr 3: Jan – Mar	Completed for the two larger community forests, Sogi and Kgwan. This component will be completed in the PhD study of Mr Cossey Yosi. Due for submission in June 2011.
3.2	Discussion and analysis with stakeholders	Report	Yr 3: Apr – Jun	Activity complete.
3.3	Prepare management plan	Report	Yr 3: Apr – Sep	Activity complete.

Activity 3.1

With the creation of resource information for ACIAR project areas this information can be used to explicitly compare options for forest utilisation and monetary returns. For example, an evaluation for the Sogi project area revealed that a large-scale log export operation that returns 30 Kina/m^3 to communities for commercial tree species would yield a total return of approximately 9 M Kina. However, if the community entered into community forestry with sawn or semi-processed wood products certified as Community Based Fair Trade product returns can be much higher, with Kwila returning 900 Kina/m^3 and Mixed hardwoods returning 600 Kina/m^3. Therefore assuming 40% recovery a return of approximately 13.5 M Kina for Kwila and 63.4 M Kina for Mixed Hardwoods could be possible. Clearly, the scale and timing of these two utilisation approaches are vastly different with returns from community forestry spread over a long time horizon; annual production is limited. However, informing the community of the value of their resource under different production models can help them make decisions.

Community forest assessment undertaken as part of the project also allowed an estimate of alternative revenue from voluntary forest carbon agreements. Applying the accounting structure of the Voluntary Carbon Standard (VCS 2008a, 2008b, 2008c) reduction in carbon stock in above-ground vegetation due to harvesting was estimated to be 165,000 tC or 600,000 tCO_2 across the study area. Assuming a conservative carbon price of 20K/tCO_2 this would equate to an income of 12 M Kina. Therefore, returns to the community from a voluntary carbon agreement could exceed returns they receive from a commercial log export operation (9 M Kina) if all revenue went to the community. This does not factor in the return to government from export taxes or other payments to the community. A combination of community based timber production and voluntary carbon agreements may provide the optimal return, and preserve many other values of the forest due to their lower impact. This information was presented to the Sogi community during April 2009.

During 2010, Jim Grigoriou visited many NGOs and communities participating in community forest management and developed an economic analysis tool to assess different production models for community based forest management in PNG. This tool

can be used to assess the financial viability of alternative timber production and supply models that can be adopted by community forest enterprises. Models that are currently being used by communities (i.e. working towards certification and processing green boards for local sale), as well as alternative models involving value adding by drying and 'dressing' of the timber for sale to local and overseas markets were evaluated for their economic sustainability.

Activity 3.2

Community consultation and discussion has been ongoing through project activities. Results from assessment and modelling have been communicated to communities. Discussions have been conducted with the Sogi community in April 2009, and Kgwan community in September 2009. Cossey Yosi has established a dialogue with Yalu and Gabensis communities, and outcomes from his work will be communicated to these communities early in 2011.

On 25th and 26th October 2010 a final workshop was run at PNGFRI which included discussion and analysis with PNG government stakeholders.

Activity 3.3

Certification and Sustainable Forest Management (SFM) are gaining international prominence, although appear to be at the early stages in most tropical countries, where its technical and financial viability at a commercial scale is being assessed. The intention of the project was to help communities formulate forest management plans that facilitate SFM and certification. Consistent with this, forest management plans have been completed for the two primary community forest project areas, Sogi and Kgwan.

Forest management plans for project areas have been completed collaboratively by Mr. Inude and Dr. Fox, with participation from local communities.

Objective 4: To train community based NGO staff in forest assessment and analysis of different forest management options that will allow local forest owners to obtain future sources of revenue from their forests.

no.	activity	outputs/ milestones	completion date	comments
4.1	Workshops and field-based training	Report	Yr 2-3	Activity complete.

Activity 4.1

Community based NGO staff involved in community forest management and forest certification (Peter Damm and Cosmas Makamet from FORCERT, Yati Bun from FPCD, and Francis Inude, Steven Yandima and Kentas Igai from VDT) participated in project workshops during 2008 and 2009.

VDT ACIAR project officer Francis Inude has received extensive training in forest assessment. He has been engaged in all project activities in PNG as described in the methodology section. Francis visited Australia for intensive training with Dr. Fox from the 2nd of February to the 13th of February 2009. During this period he received refresher training in GIS, and new training in the analysis of remotely sensed data. He also received training on analysis of random variable radius plot inventory data.

A number of other staff from project partner VDT have been engaged in project activities. Kentis Igai (Forest certification officer), Thomas Warr (Coordinator - community participation), and Steven Yandima (Executive Director) attended project workshops on the 13th and 14th of March, 2008, and the 1st to the 3rd of April 2009.

Staff from other community based NGOs operating in PNG have also been actively engaged in project activities.

- Peter Dam (FORCERT; Forest management and certification) has attended both workshops, and has received technical advice from Dr. Fox and Dr. Cris Brack on methods for calculating forest carbon, and inventory techniques.
- Yati Bun (FPCD; Foundation for People and Community Development) has attended both workshops. Dr. Fox visited FPCD head office in Madang on the 4th of July to meet with staff and discussed project activities.
- Francis Hura Hura (TNC; The Nature Conservancy) attended a workshop following a meeting with Dr. Fox at TNC head office in Madang.
- Pamela Avusi and Ruben Taminza (CCFP; Community Carbon Forestry Project) attended the workshop held on the 1st to the 3rd of April 2009.

The final day of the workshop 'Improving inventory for timber and carbon in Papua New Guinea' (3rd of April, 2009) was set aside to assist community based NGOs with the estimation of forest carbon and the application of new inventory techniques. CCFP foresters Pamela and Ruben in particular benefited from the application of new techniques to the data they had collected on forest carbon.

6 Key results and discussion

6.1 Prioritising attributes and values of secondary forest

A key outcome from the workshop was that secondary forest is a large but poorly understood resource. Its neglect and ongoing degradation was attributed to poor knowledge of the goods and services that may be available. Participants agreed that assessment of this resource is a priority, and could be based on remote sensing and growth modelling to classify secondary forest according to the products it may provide now and into the future.

Participants also agreed that the PSP sampling program maintained by PNGFRI provides a sound basis for assessment activities; it provides excellent geographic coverage, and includes up to 15 years of continuous measurement.

From discussions on marketable products in secondary forest it was agreed that there will be a predominance of minor timber species, and that there are definite market prospects for these timbers, particularly when sold as certified or community based fair trade product. Group exercises demonstrated the array of goods and services that communities draw from secondary forest. Goods and services included timber for local construction and for selling, fuel wood, medicinal plants, wildlife conservation, carbon sequestration, fruits and nuts, and fresh water. This utilisation is influenced by accessibility to towns which determines if the community has ready access to markets. Accessible secondary forest is likely to be used for forestry or agriculture with products flowing to nearby towns, while remote communities will use secondary forest for subsistence purposes. A second group exercise examined community level decision making, the sorts of information required to make decisions, and how project outputs can effectively inform this process.

6.2 Improving and reporting from the Permanent Sample Plot database

An improved PSP database resulted in the following collaborative analysis and key results;

- Yosi et al. (2011) examined condition and dynamics of natural tropical forest after selective timber harvesting in PNG. BA increment over time since harvesting was positive on 68 (76%) of the 89 plots that had not been subject to fire and that the average BA increment on these plots was 0.42 m^2/ha /yr. Average BA increment across all plots over up to 25 years after harvesting was 0.18 m^2/ha/yr. These results provide an improved basis for determining timber yield and setting annual allowable cuts in larger and smaller-scale forest operations in PNG.
- Plot data provided a basis for assessment of aboveground carbon in primary and selectively-harvested tropical forest in PNG (Fox et al. 2010) This provided statistically robust estimates of provincial averages for carbon in aboveground biomass (AGB) that will assist the PNG government move toward a Tier 3 compliant Green House Gas (GHG) inventory of forested land. Methods and results described in Fox et al. (2010) were also of interest to communities in PNG that are seeking to participate in voluntary carbon markets.
- Analysis of the impact of selective-harvesting and the El Niño-Southern Oscillation (ENSO) induced fires on forest carbon (C) and C sequestration (Fox et al. (2011). This was done using a hierarchical Bayesian model (HBM) with derived parameters that can be used to estimate the C and CO_2 balance of selective-harvesting, forest regeneration and degradation after fire, all of which are important inputs for timber volume estimation and climate change mitigation initiatives.

6.3 Analysis of condition of cutover forests in PNG

As described above, Yosi et al. (2011) examined the recovery of selectively-harvested forest in PNG from PSP database and found there was a consistent increase in stand BA and residual timber volume over the plot measurement period. In PNG's natural forests, earlier research studies indicated that BA in undisturbed forests was about 30-32m^2/ha. Yosi et al (2011) found that average BA in plots on forests disturbed from logging is about 18m^2/ha; a reduction of about 40% from the original unlogged forest. Yosi et al. (2011) also found that BA increment after harvesting was positive on 68 (76%) of 89 plots and the average BA increment on these plots was 0.42 m^2/ha/yr. Average BA increment across all plots over up to 25 years after harvesting was 0.18 m^2/ha/yr. Recovering plots are therefore likely to reach the BA of undisturbed stands within 70 to 100 years.

The change in BA over time observed in Yosi et al. (2011) suggests that a significant proportion of native forests in PNG are recovering after disturbance from conventional harvesting. This is in contrast to the suggestion of (Shearman et al., 2009) that harvested forests in PNG are permanently degraded.

6.4 Growth and yield modelling

The intent of growth and yield modelling as part of ACIAR FST/2004/061 was twofold; to develop a suite of models that could be used by both PNG forest management agencies for wide area application, and also could be used by communities and NGOs to improve community forest management. To satisfy these objectives an integrated forest assessment and forest growth modelling system was created in Microsoft excel.

Quantitative study of the permanent sample plot (PSP) databases provided insights into growth, mortality and recruitment processes driving forest dynamics in PNG. Initially, the competitive influences affecting individual tree growth and mortality were quantified, and predictive models for growth and mortality were constructed based on a hierarchical Bayesian modelling (HBM) methodology. The HBM method allows the parameterisation of a global model with species-specific parameters; therefore species level growth and mortality traits are preserved in model predictions, even for rare species. A range of spatial and non-spatial competition indices were compared for the PSP data and it was found that a simple non-spatial competition index (Basal area of competing trees within 20 metres of the subject) adequately characterised competitive influence on growth and mortality (See Fox et al. 2011c for further details).

The forest assessment tool is based on a stratified random variable radius plot inventory. The assessment tool incorporates lookup tables that facilitate the calculation of plot- and estate-level above ground live biomass (AGLB; Mg /ha) and merchantable volume (MV; m^3/ha). This forest assessment is then used as a basis for the individual-tree growth and yield module using HBM models described above which can be used to simulate forest development into the future. The growth and yield module consists of lookup tables for species-specific parameters for a growth, mortality and recruitment model. Each tree measured in the assessment therefore becomes a tree in the simulation that is subject to perturbations from growth and possible mortality into the future. New trees eventuate in the simulation from the recruitment model that uses tree density and species present on each plot to create a probability of recruitment.

A simple tree level simulator housed in accessible software can assist community-level decision making with regards to the design and intensity of selective harvesting regimes. For example, after the forest assessment is complete, a simulation of a harvesting event can be implemented with different size limits, cutting intensities, and different species. For community forest management, this with will allow communities to maximise returns from harvesting while preserving other forest values. Small-scale, high-value utilisation

scenarios can be effectively explored using such models. Utilisation below unsustainable levels, which has been set in the simulator according to species specific growth rates, will ensure that high-end products can be harvested in community areas in perpetuity.

There have been communications from PNG Forest Authority that they are considering a new pre-harvest inventory method based on a stratified random variable radius plot inventory. If this is the case, PNGFA can populate the assessment and modelling tool with inventory information and run scenarios for large scale logging. The scenarios can help identify mode appropriate and sustainable harvesting in terms of size limits, species mixes and cutting cycles. Currently, a default size limit of 50cm is used on a 35 year cutting cycle. It is intended that the assessment and modelling tools developed as part of ACIAR project FST/2004/061 can help refine this approach for more sustainable forest harvesting.

6.5 Analysis of forest carbon stock and dynamics

Analysing the potential of cutover forests to supply different types of services was an objective of the project. PNG along with other rainforest nations became the focus of the climate change mitigation initiative Reducing Emissions from Deforestation and forest Degradation (REDD) in developing countries. This has the potential to supply an alternative source of revenue to community forest owners. Hence, there has been intense interest both from within PNG and among the international scientific community to develop methodology to support the REDD mechanism. This methodology requires estimates of forest C, and changes in C due to selective logging and other disturbances. The forest assessment work undertaken as part of this project provided an opportunity for ground based estimation of forest C from PSPs and the estimation of C flux due to selective logging. Although not explicitly stated as a project objective, this work was undertaken following requests for assistance from PNG partner organisations. The estimation of forest C was also included as a theme in our workshops due to requests for technical assistance from within PNG. Feedback from NGOs and government representatives has been very positive.

The project provided the first comprehensive assessment of aboveground C stocks for tropical native forests in PNG along with methods that can be used for estimating forest C from other forest inventory data (Fox et al. 2010). Average aboveground carbon in stems great than 10cm diameter for 115 one hectare plots in secondary lowland tropical forest was 66.3 ± 3.5 MgC/ha (95% confidence interval) while for 10 primary forest plots the average was 106.3 ± 16.2 MgC/ha. We applied ratios based on field observation, in-country studies, and the literature to estimate unmeasured pools of aboveground carbon (stems less than 10cm diameter, fine litter and coarse woody debris). Total aboveground carbon was estimated; 90.2 and 120.8 MgC/ha in secondary and primary lowland forest respectively. Our estimate for primary tropical forest is lower than biome averages for tropical equatorial forest and we hypothesise that frequent disturbance from fire, frost, landslides and agriculture are limiting carbon stock development (see Fox et al. 2010). These results are an important contribution to policy discussions on the future management of PNG forests and the development of REDD mechanisms. Outputs from the project have encouraged transparency and consistency in the estimation of forest C within PNG (Fox et al. 2010).

The project also examined the impact of selective-harvesting and the El Niño-Southern Oscillation (ENSO) induced fires on forest carbon (C) and C sequestration using the PSPs (Fox et al. 2011a). To achieve this, a hierarchical Bayesian model (HBM) was developed and parameters derived that can be used to estimate the C and CO_2 balance of selective-harvesting, forest regeneration and degradation after fire, all of which are important inputs for climate change mitigation initiatives. HBM parameters indicated; C stock in aboveground live biomass (AGLB) of 137 ± 9 (95% CI) MgC/ha in primary forest, compared with 62 ± 18 MgC/ha for secondary (approximately 55% difference); Note that

C stock reported in Fox et al. (2011a) includes all stems where as stock reported in Fox et al. (2010) included only stems greater than 10cm. C sequestration in primary forest of 0.23 ± 1.70 MgC/ha/yr which was lower than in secondary forest, 1.12 ± 3.41 MgC/ha/yr; ENSO induced fire resulted in significant C emissions (-6.87 ± 3.94 MgC/ha/yr). Emissions from ENSO fires results from ongoing tree mortality up to 10 years after the fire event of 1997. High variability between PSPs in C stock and C sequestration rates, and autocorrelation among remeasurements of individual PSPs, necessitated random plot effects for both stock and sequestration (See Fox et al. 2011a for more explanation). The HBM approach allowed inclusion of hierarchical autocorrelation, providing valid confidence intervals on model parameters and efficient estimation. Model parameters have revealed the C balance of PNG's forests, following different interventions and these models can be used as quantitative inputs for climate change mitigation initiatives.

C sequestration in regrowth was estimated to be 1.12 ± 3.41 MgC/ha/yr (Fox et al. 2011). The PSPs represent a valuable sample of selectively-harvested forest in the Oceania region with good spatial and temporal representation (Fox et al. 2010) and the average sequestration estimate (1.12 Mg C/ha/yr), despite high uncertainty (± 3.41), is a sound estimate for C recovery rates after selective-harvesting. If we assume that the 3.4 M ha harvested between 1961 and 2002 is harvested at the average annual rate of 0.083 M ha, then the net C sequestered since harvesting began can be calculated as 80 MtC or 294 $MtCO_2$ over this period. If we include parameter uncertainty in this estimate the 95% CI for sequestered C is 80 ± 244 Mt C. Despite this high uncertainty, if the average sequestration occurred across selectively-harvested forest it would offset approximately one third of the emissions from decomposition of collateral damage and sawmilling residue (917 $MtCO_2$).

There has been speculation (Shearman et al. 2009) that harvested forest in PNG are degraded to the extent that they are incapable of recovery. The present study suggests otherwise, indicating that selectively-harvested forests are reasonably stocked after harvesting (62 ± 18 MgC/ha), and are recovering C at the rate of 1.12 ± 3.41 MgC/ha/yr. The high variability indicates that some plots are degrading but the bulk of plots are either maintaining or increasing biomass and carbon stock. If the average sequestration rate is maintained at a linear rate, it would take approximately 65 years for harvested forest to recover the 75 MgC/ha that was displaced during selective-harvesting.

6.6 Remote sensing for forest assessment in PNG

The objective of the remote sensing component of project FST/2004/061 was to develop a cost effective system that could be applied for forest assessment in PNG to support community forest management. Many remote sensing data sources are prohibitively expensive either in image acquisition or processing. The application of optical remote sensing in the tropics is restricted by the prevalence of clouds, which preclude ground reflection. Optical sensors with low temporal resolution (infrequent acquisition over the area of interest) will be restricted due to difficulties in acquiring cloud free images. Other remote sensing data sources such as Synthetic Aperture Radar (SAR) are unaffected by cloud cover, but require complicated processing which is computationally intensive.

After reviewing cost effective methods that could be replicated in PNG, it was decided to use the Advanced Spacebourne Thermal Emisson Reflection Radiometer (ASTER) platform. ASTER has been successfully used for forest assessment and has also been used to derive Digital Elevation Models (DEMs). ASTER spectral bands include a stereo pair (bands 3N and 3B) for generating DEMs which are very useful for estimating hydrology and topography in study areas. Most importantly, it has successfully been used to differentiate primary and selectively-harvested forest in the tropics (Broadbent et al. 2006) which is a requirement for assessment of forests in Papua New Guinea due to the extensive and expanding areas that have been selectively-harvested (Shearman et al. 2009; Filer et al. 2009). ASTER data has also shown potential for forest change detection.

An additional benefit of using ASTER data is that it is comparatively cheap ($150 per scene) and easy to source and download. Image acquisition for ASTER is facilitated by an image search facility through the Japanese Space Agency website (http://imsweb.aster.ersdac.or.jp/ims/html/DPR/DPR_Menu.html). The area of interest can be defined, and thresholds for cloud cover can be set. Using this facility ACIAR project FST/2004/061 acquired Level 2B cloud free images over the four project areas. Level 2B images have been subject to radiometric and geometric correction, and can therefore be projected with other data layers and GPS locations for field data in a GIS system.

Remote sensing analysis for ACIAR project areas demonstrated that ASTER could be used for mapping forest condition (primary and secondary forest) and spectral information could be integrated with field sampling for forest assessment.

6.7 Modern forest inventory in PNG

The PNG Forestry Act (1991) sets out a standard of a 1% (by area) systematic strip-line sample measurement to support national, provincial and forest-level planning. These striplines are comprised of a continuous strip of rectangular "plots" and were expected to be parallel to each other to aid in the construction of maps. However, a strip-line approach for forest inventory has several shortcomings;

1. it is expensive and inefficient compared to more targeted and more efficient sampling designs;
2. it is often biased in that it creates quite accurate information in one area of the forest, and no information elsewhere; and
3. sampling statistics cannot be used for field data collected in strip-lines.

Modern multi-phase forest inventory techniques such as stratified random sampling overcome these shortcomings, and can be combined with remote sensing information for wall to wall forest assessment. ACIAR project FST/2004/061 used a stratified random sampling technique that built on, but differed from, a random cluster sampling design developed in an earlier ACIAR project (FST/1998/201). After stratification based on ASTER remote sensing, a pilot survey of each stratum is recommended with 20 samples in each stratum. Field sampling will be random variable radius plots using a factor 2 prism wedge to select measurement trees. A field collection proforma for variable radius plots has been created as part of the assessment and modelling tool in excel. On each measurement tree the diameter at breast height is measured. If buttressing is present at breast height then a new point of measurement is created above the buttress, and a new point of measurement is established. Species is also recorded. For common forest types, look up tables can be used to estimate total height and merchantable height. However, for less common forest types, it is recommended that height and merchantable height be measured in the field. At each field sample an accurate GPS location must be captured; it is recommended that a GPS is placed in the plot centre and left to average while the plot is being measured. This will result in the best spatial accuracy and will facilitate integration with ASTER data.

A field collection proforma for variable radius plots has been created as part of the assessment and modelling tool in excel. The assessment modelling tool can be used to summarise information from the pilot sample. Sampling statistics can then be used to determine if accuracy requirements are satisfied or if further sampling is required.

6.8 Community forest assessment

The basic methodology for community forest assessment is to;

1) stratify the forest resource using ASTER remote sensing
2) conduct a pilot sample of the stratified resource by placing 20 random variable radius plots in each stratum

3) use sampling statistics to determine the number of further plots to satisfy accuracy limits; finalise field sampling
4) use spatial modelling of AGLB and Merchantable Volume from field samples against spectral information from ASTER data
5) predict wall to wall GIS layers
6) create maps and summary information for communities.

This methodology could be implemented by NGOs with technically proficient and trained staff. Communities would be involved in field data collection.

Maps and summary information can inform community management and improve decision making. The information can be used to explicitly compare options for forest utilisation and monetary returns. In the Sogi project area, which contains a large resource of high value timber species such as *Intsia Bijuga* (Kwila), this comparison of different utilisation approaches and their monetary returns was very useful in helping the community understand the value of their resource.

Based on forest assessment in the Sogi project area there was 1.4 million m^3 of merchantable timber in the 20,000 ha of community forests. Using the DEM to generate hydrology and topography we could exclude areas from harvesting based on the PNG Logging Code; 50m stream buffers and the exclusion of slopes more than 30%. Accessible merchantable timber was reduced to 943,960 m^3 comprising a Kwila volume of 37,760 m^3 and a mixed hardwood volume: 264,300 m^3. Assuming the Kwila and mixed hardwoods are the main commercial timber species we can estimate returns from different utilisation approaches; Large-scale log export operations return 30 Kina/m^3 to communities for commercial species, therefore a return of approximately 9 M Kina could be expected. However, if the community entered into community forestry with wood products certified as Community Based Fair Trade product returns can be much higher, with Kwila returning 900 Kina/m3 and Mixed hardwoods returning 600 Kina/m3. Therefore assuming 40% recovery a return of approximately 13.5 M Kina for Kwila and 63.4 M Kina for Mixed Hardwoods. Clearly, the scale and timing of these two utilisation approaches are vastly different with returns from community forestry spread over a long time horizon; annual production is limited. However, informing the community of the value of their resource under different production models can help them make decisions.

6.9 Review of international market requirements

A review of the production, consumption and pricing of native tropical hardwoods for international markets identified that there were definite prospects for small scale timber producers and community managed forests in PNG. The best markets for green sawn timber from community managed forests based in PNG were identified as those that offer the highest price and are sympathetic to small volumes and variable quality. It was concluded that traders, be they local timber merchants or overseas importers need to aggressively market and educate customers about lesser known species from PNG and the utility of non select grade timbers. High prices are critical to the success of community managed forest enterprises as significant resources are needed to manage, process and transport timber products. High profit margins can be achieved by making a product unique and convincing buyers that the value they receive extends beyond its functional utility. This review is included in Appendix 7 and a brief summary for communicating to NGOs in Appendix 8.

Important conclusions were;

- tropical logs that have been easy to access have long since been sourced and commercial harvesting from primary forests is moving to more remote and difficult areas where the marginal cost of log extraction will continue to rise and be passed on to users in the form of higher prices.

- Scarcity is also being driven by bans on tropical log exports by some large producers (e.g. Indonesia) and export quotas by select countries (e.g. Peru's mahogany export quota).
- On the demand side, the interest in 'select grade' tropical hardwoods by architects and builders in industrial economies such as the United States and Australia, sees this product class increasingly earmarked for high priced niches such as boat building, mouldings and furniture. In Europe, species such as mahogany and walnut can be viewed as being 'noble', thereby commanding a higher price.
- Government policies in many tropical countries are supporting the value added production of tropical logs into higher priced processed wood products. Many countries are focusing on the harvesting and processing of lesser known species.
- It is only a few select African states, Papua New Guinea and Myanmar that continue to export a significant volume of their tropical logs that are not processed into higher priced wood products.

6.10 Analysis of alternative forest management scenarios and wood supply models

Four production and supply models were considered for community forest areas in this project. All models included costs associated with achieving and maintaining full forest certification over the twenty year analysis period as well as the implementation of reduced impact logging practices for tropical forests. The most viable production and supply models that communities can adopt to harvest their forest resource are considered to be as follows.

A. Communities working to achieve environmental certification are processing 'green' timber boards which are sold in the nearest commercial centre. The community is certified as Fair Trade, which is the first of three stages towards achieving full certification. No timber value adding is undertaken.
B. Communities process 'green' timber boards where Category 1, A grade material is sold to a central marketing unit, an organisation specifically established to export sawn timber material. All other timber is sold to local buyers. No value adding occurs. The community is certified as Fair Trade.
C. Communities value add to their Category 1, A and B Grade sawn timber via kiln drying and 'dressing'. The timber is then exported. All other timber (mixed hardwoods) is sold locally as 'green' material. The community is certified as Fair Trade.
D. Communities value add to their Category 1, A and B Grade sawn timber via kiln drying and 'dressing'. This and all other material (mixed hardwoods, green) is sold locally - no exporting takes place. The community is certified as Fair Trade.

A financial model was developed to evaluate the performance of these different production models over a twenty year time period. Analysis of the different production models found the most profitable model was the export of higher value species as 'green' sawn timber via a central marketing unit, and all other timber is sold locally (Production Model B). This production model earned accumulated profits of PNGK 1.9 million over the twenty year life of the study, achieved an average return on sales of 15% and had the shortest capital payback time (three years). The next most profitable model was the processing and sale of 'green' sawn timber for local buyers only (Production Model A). This achieved low profitability and return on sales (accumulated profits of PNGK 0.6 million over the twenty year life of the study and average return on sales of 4.84%). Start up capital costs were the same as the model involving the export of green timber (Model B) but it took a year longer to pay back this capital.

Forest certification is a significant cost that is currently not expected in the local market. If communities choose not to pay for certification, the profitability of Model A and B increase by 10% and 6% respectively. Investing in value adding for the output from a single

portable sawmill was not justified on current timber prices. To make value adding profitable, a significantly higher scale of production is required to cover the high fixed and variable costs associated with operating a timber yard (4,000 – 5,000 m3 log intake per annum).

In summary, this study has found that community based small scale portable sawmill operations can become economically viable. Profitability is driven by the following factors.

1) The entrepreneur and the team. The importance of leaders with good business development skills and willing workers cannot be underestimated. Successful operations need leadership that can manage the operation's affairs and effectively negotiate with buyers. Operations also require committed workers to work the mill at a high level of productivity. This will require attractive salaries and equitable distributions of surpluses to the community to provide incentives for personal efforts and to encourage those with the physical capacity, interest and willing to learn through training to work on behalf of the community
2) Market prices and operating costs. Timber prices fluctuate with general economic activity. In Papua New Guinea this is substantially influenced by international mineral and agricultural commodity prices.
3) Mill productivity. The rate limiting factor for a community forest enterprise is mill productivity. Maintaining maximum productivity from the capital investment is a critical determinant of profitability. Having a tractor to move the mill intact, push small logs, clear undergrowth and transport boards to a roadside can greatly increase production and profitability. A four wheel drive truck that can operate during the wet season can be used to transport timber to buyers. Operators have indicated that with dedicated staff and mechanisation (tractor and skidder) production can reach 3m³ per sawmill per day.
4) Recovery. Profitability improves markedly the greater the recovery of merchant grade boards from logs. Careful selection and proper felling of logs can maximise the proportion of merchantable timber that can be extracted during the milling process.
5) Distance to market. Increased volume can offset distance. Producers located more than four hundred kilometres from a commercial centre can be marginally profitable if they produce at least 1000 m³ of boards per annum. Private operators have indicated that to remain viable, they need to operate within one hundred kilometres of their buyers.
6) Capital. The way communities access capital to commence a portable sawmill operation is critical to its success. Taking on debt at high interest rates to purchase equipment has made it difficult for communities to operate and earn surpluses. In some cases, disillusioned communities stop production.

6.11 Discussion and analysis with stakeholders

Community consultation and discussion has been ongoing through project activities. Project FST/2004/061 used four community project areas (Sogi, Kgwan, Yalu and Gabensis) with a long history of stakeholder discussion and analysis undertaken by VDT. At the commencement of the project all participating communities had agreed to undertake community forest management with support from VDT. Despite this, project staff visited all communities and conducted awareness of Project FST/2004/061's activities. Throughout the project, VDT had continuous communication with communities, principally through VDT project staff Francis Inude. This communication facilitated the iterative development of forest management plans. Results from technical assessment and modelling undertaken by project staff have been communicated to communities. Community forest management plans have been compiled as a result of this formulation. They are described in more detail below.

Mr Cossey Yosi as a part of his PhD studies undertook a program of community interviews in project areas with a view to assessing and integrating community values in management planning. The exact methodology and outcomes of this work are being written up as part of Cossey's PhD to be completed in July 2011.

On 25th and 26th October 2010 a final workshop was run at PNGFRI which included discussion and analysis with government stakeholders. Unfortunately our NGO partner, Village Development Trust, went into administration at the end of 2009. This limited stakeholder (NGO and community) discussion and analysis in the final year of the project.

6.12 Community forest management plans

Certification and Sustainable Forest Management (SFM) are gaining international prominence, although appear to be at the early stages in most tropical countries, where its technical and financial viability at a commercial scale is being assessed. The intention of ACIAR project FST/2004/061 was to help communities formulate forest management plans that facilitate SFM and certification. Francis Inude and Dr. Fox in collaboration with communities prepared forest management plans for the Sogi and Kgwan project areas. This work was predominantly undertaken by VDT with continuous communication with participating communities. These management plans were intended to facilitate CBFT (Community Base Fair Trade) certification. Francis delivered plans to Sogi and Kgwan communities in May 2010. Unfortunately, Francis left VDT in June 2010, and there has been no follow up on implementation since. The project has therefore not be able to test the response of the communities to the management plans.

As mentioned above, in November 2009, The Director of VDT (Steven Yandima) and many staff were terminated. The organisation survived through 2010 under administration with a new Director Robert Songan. Francis Inude voluntarily left the organisation in November, but returned as ACIAR project staff from March to July 2010. Unfortunately VDT has had no capacity to continue with implementation of the project community assessments, management plans, and wood supply options during 2010. Through this interruption the contribution of VDT to project outcomes has been compromised. Despite this Francis worked with Dr. Fox during 2010 to finalise forest management plans for project areas.

6.13 ACIAR technical report

During October 2010, project FST/2004/061 held its final workshop at FRI in Lae where project outcomes were presented to stakeholders. Proceedings from the workshop will be published as an ACIAR technical report early in 2011 "Native Forest Management in Papua New Guinea; Advances in assessment, modelling, and decision making".

This publication will document "state of the art" and recent advances in the fields of assessment, modelling and decision making with respect to native forest management in PNG. Examples of advances are the application of new remote sensing technologies, new methods for field assessment with examples of local, provincial and national level applications. Improved forest timber and carbon assessments can ensure sustainability indicators for tree crop industries, improved economic returns to participating communities through certification, and sustainable management. Improved methods for forest carbon assessment can foster landowner involvement in carbon trading.

The intended audience includes Policy Makers, Scientists, Non Government Organisation (NGO) extension officers working with communities, and University educators in Papua New Guinea, and across Melanesia and the Asia-Pacific Region. This publication will yield significant scientific impacts.

7 Impacts

7.1 Scientific impacts – now and in 5 years

7.1.1 Modern forest inventory in PNG

The PNG Forestry Act (1991) s47(1,2) sets out a standard of a 1% (by area) systematic strip-line sample measurement to support national, provincial and forest-level planning. Through workshops conducted as part of ACIAR project FST/2004/061 the replacement of the 1% strip-line approach with modern, efficient and unbiased forest inventory has been advocated. One of these modern inventory techniques is the stratified random variable radius plot inventory as successfully applied to ACIAR project areas. This approach is the basis of the forest assessment modelling tool developed in excel. There is evidence that PNGFA is starting to use the approach advocated in this project and the assessment tool with the recent completion of a trail inventory using the technique in the Kamula Dosa Forest Management Area (FMA). The assessment and modelling tool is being used by PNGFA to create project level merchantable volume and forest carbon estimates (Rabbie Lalo *pers. comm*. - Planning Analyst, PNGFA) This is completely independent of the project and can be considered a very positive scientific impact. If the trial inventory using modern inventory techniques provides satisfactory outcomes for PNGFA, there are moves to expand the technique to all future FMA assessments. However, the PNG Forestry Act needs to be updated with the requirement of 1% (by area) systematic strip-line sample measurement removed. There has been communications that this may be possible if the trial is successful.

7.1.2 Improved PSP database

The new Access database developed as part of this project provides improved accessibility to the data from within PNGFRI and PNGFA, and greatly expands opportunities for PSP data interrogation and analysis. This database will have a very important role as the most extensive database of field measurements in PNG for Monitoring, Reporting and Verification (MRV) for national REDD+ reporting.

7.1.3 Growth and yield modelling

With indications that PNG Forest Authority are moving to a new pre-harvest inventory method based on a stratified random variable radius plot inventory the assessment and modelling tool can be used to run scenarios for large-scale logging. The scenarios can help identify mode appropriate and sustainable harvesting in terms of size limits, species mixes and cutting cycles. Currently, a default size limit of 50cm is used on a 35 year cutting cycle. It is intended that the assessment and modelling tools developed as part of ACIAR project FST/2004/061 can help refine this approach for more sustainable forest harvesting.

7.1.4 Remote sensing

The project tested a range of low cost and readily available remote sensing technologies for assessing the condition of natural tropical forest. This will inform development of systems for forest monitoring in PNG.

The project has also been able to undertake further analysis in collaboration with Dr. Mark Williams, a remote sensing scientist originally from Fugro EarthData Inc and now a remote sensing consultant working in Melbourne. He generated high resolution forest resource information (merchantable timber volume and carbon) for the Sogi project area based on state of the art GeoSar remote sensing. The collaboration initially focused on the Sogi

project area, but was identified as having potential for application to the whole of PNG, providing important outputs for REDD mechanisms.

A publication has been written by Dr. Williams that is to be published in an ACIAR proceedings early in 2011; "Remote sensing techniques for tropical forest assessment".

The GeoSAR data and the remote sensing analysis that commenced as part of ACIAR project FST/2004/061 is now an important national level baseline for Monitoring, Reporting and Verification for the REDD mechanism. Dr Williams has now been employed full time by the Department of Environment and Conservation (DEC) to create this baseline information for the Kokoda area, with a view to expanding to national level analysis. This is an important scientific impact from project FST/2004/061.

7.1.5 Forest carbon stock assessment

An article on PNG forest carbon stock was published in the international journal Biotropica. This publication is the first statistically robust field based assessment of carbon stocks and dynamics in PNG forests. Methodological advances for quantifying forest carbon in PNG are being actively applied by NGOs and government bodies. The methods and results described in the manuscript have assisted with the PNG governments preparedness for REDD. Methods and results have also been of interest to the many communities within PNG that are seeking to participate in voluntary carbon markets. The methodology is the basis of a simple spreadsheet that has been disseminated in PNG (among government agencies, and NGOs). The dissemination resulting from publication in Biotropica has encouraged further implementation both within government, NGO sectors, and communities, and has encouraged transparency and consistency in the estimation of forest C. These results were also used as part of analysis to inform the PNG Government's negotiating position for the UNFCCC negotiations in Copenhagen. Results from forest C stock assessment undertaken in this project have enhanced PNG's ability to report land use change emissions; specifically, these in-country estimates can be used in place of IPCC defaults as previously applied. The project has also facilitated the measurement of soil carbon on PSPs, and results are described in a chapter by collaborating scientist Patrick Nimiago in the final workshop proceedings.

7.1.6 Assessment of CO_2 emissions from selective logging in PNG

Results from the project provided the basis for estimation of CO_2 emissions from selective-harvesting in PNG. Additional work undertake for PNG DEC was used to inform PNG's position at the Copenhagen Climate Conference in December 2009. Since completing the work, there has been considerable interest in this work from within PNGFA and PNGFRI, and a spreadsheet tool was created that is now actively being used by PNGFA to estimate concession level CO_2 emissions from selective logging. Estimation of CO_2 emissions at the concession level is supporting PNGFA identify concessions where high CO_2 emissions will occur if harvesting goes ahead. These concessions can then become candidates for voluntary carbon agreements or can be included in national REDD arrangements.

7.2 Capacity impacts – now and in 5 years

Capacity impacts in the PNG government from the project have been significant. Many PNGFRI staff were included in collaborative work and training exercises. Staff from the PNG Office of Climate Change and Development (OCCD) attended workshops and received ongoing technical advice from Dr. Fox on estimating forest carbon. Impacts of training and support are being realised more widely through government. Former project staff Joe Pokana has moved to a senior role Office of Climate Change and Development as Director of REDD Monitoring, Reporting and Verification. His training and collaboration, particularly on estimating forest timber and carbon stocks, has been important in his new role.

VDT ACIAR project officer Mr. Inude received extensive training in forest assessment and was engaged in all project activities in PNG. A number of other staff from project partner VDT were engaged in project activities. Kentis Igai (Forest certification officer), Thomas Warr (Coordinator - community participation), and Steven Yandima (Executive Director) attended project workshops on the 13th and 14th of March, 2008, and the 1st to the 3rd of April 2009. Kentis Igai accompanied Dr. Fox on the recent visit to Sogi (23rd March - 28th March 2009) and received training in the application of a random variable radius inventory. Unfortunately, VDT went into administration during November 2009. VDT has been under an administrator Robert Songan – and the last remaining staff member Mr Francis Inude, who was being employed with project funds, resigned during 2010. Problems at VDT have limited the ability to build community capacity.

Staff from other community based NGOs operating in PNG have also been actively engaged in project activities with very positive feedback. Many of these NGOs are implementing methods for forest inventory and management developed and transferred during project training activities. The community forest assessment tools developed by the project are being actively used by several NGOs, in particular FORCERT and FPCD. The project supported Peter Dam of FORCERT to customise the forest assessment tools for application to their project areas. The project also assisted Henry Scheyvens and Yati Bun customise tools for application to FPCD project areas..

During March 2010, Dr. Fox facilitated participation in the intensive course "Forest Resource Assessment" for forest scientists from a range of institutions in PNG. Unfortunately logistical problems prevented scientists from PNGFA, PNGFRI and VDT attending. However, Mr Ben Konsolo and Mr Frank Alkam from the OCCD attended and benefitted greatly.

During June 2010, Dr. Fox and Prof. Keenan conducted a special capacity building workshop for PNGFA and PNGFRI. The workshop was run due to requests for capacity building in forest inventory, remote sensing, forest carbon assessment, forest CO_2 assessment.

7.3 Community impacts – now and in 5 years

Community impacts have been more limited than expected due to the wind up of VDT in November 2009. This is unfortunate, as the final year of the project was envisaged as key time to transfer project outputs to the communities involved. Community benefits that are likely to result from the project as results of research, technical assistance and support from project staff include:

- Development of a Community Based Fair Trade, medium scale eco-forestry project in the Sogi area based on improved inventory and planning. More details of project activities can be found at: (http://www.forestscience.unimelb.edu.au/research_projects/ACIAR%20Projects/PNG%20Project/Sogi_Project.html).
- Development of more sustainable community forestry for local construction, sale to local timber merchants in Kundiawa and export of a sample of milled *Nothofagus* to the Australian timber importer, the Woodage. This community is extremely isolated and they are using milled timbers to build permanent community homes. The project assisted Kgwan with resource information, visits to the community and the recognition from being part of the project have helped maintain momentum for community forestry.

In the longer term, the extent to which the communities involved will be able realise financial benefits from the project activities will depend on the development of viable business models. This will require training in business management and access to capital to purchase equipment. Support from NGOs will also be required, and hopefully VDT can once again become a viable entity, and provide this much needed support. Project outputs

put the communities in a much better position to prepare a business case for commercial finance or development assistance but further training in business development and management is required before these communities, and others in similar situations are able to develop sustainable business enterprises based on the models developed in the project.

Potential for communities to receive financial benefit from the provision of the forest environmental service of carbon storage will depend on the establishment of a sound national policy framework, a national Monitoring, Reporting and Verification system and international funding arrangements. The tools and information developed in the project on carbon stocks and dynamics after harvesting have had a significant impact at a national level and will provide an important basis for future development of this potential at community and regional scales.

7.3.1 Economic impacts

Francis Inude, the VDT/ACIAR project officer has collected baseline information in the Sogi (Madang Province) and Kgwan study areas. It was envisaged that a data collection on the economic impacts of community forestry be collected in 2010, but due to capacity problems with VDT this never occurred.

Tangible economic impacts can be expected as community forestry enterprises develop resulting in sustainable livelihoods and development outcomes. The communities involved in project activities now have information from forest resource assessments that provide estimates of potential returns from community sawmilling or environmental service payments for carbon sequestered in their forests, both of which could provide ongoing annual incomes for these communities.

7.4 Communication and dissemination activities

The most important communication and dissemination activities were annual workshops held at PNGFRI from 2008 to 2010. Outcomes from the workshops are detailed elsewhere in this report. Project staff also provided regular briefings to senior managers in the PNG Forest Authority. VDT/ACIAR officer Francis Inude had a continuous communication with communities in project areas from January 2008 to June 2010. Dr. Fox also visited and disseminated outcomes to communities on several occasions during 2008 and 2009.

The project has maintained a set of websites since August 2008 as detailed in previous reports.

- Overall project; (http://www.forestscience.unimelb.edu.au/research_projects/ACIAR%20Projects/PNG%20Project/Index.html)
- Sogi project; (http://www.forestscience.unimelb.edu.au/research_projects/ACIAR%20Projects/PNG%20Project/Sogi_Project.html)
- Kgwan project; (http://www.forestscience.unimelb.edu.au/research_projects/ACIAR%20Projects/PNG%20Project/Kgwan_Project.html)
- PSP database; (http://www.forestscience.unimelb.edu.au/research_projects/ACIAR%20Projects/PNG%20Project/PNG_PSP.html)

These are regularly updated to reflect ongoing project activities and developments. The websites have proven an excellent communication and dissemination tool. Several international collaborations have emerged as a direct result of the websites as detailed in previous reports. They include several videos in both English and Tok Pisin that explain

project activities. Favourable feedback has been received both from within Australia and PNG; in particular people have commented that the websites have changed their view of forestry in PNG, which is generally perceived negatively.

An article on the project *Managed forests offer PNG communities new market opportunities*. In ACIAR's Partners in Research and Development, March to June 2009. p. 24-25.

8 Conclusions and recommendations

8.1 Conclusions

Objective 1: To classify PNG's secondary forests in terms of condition and capacity for future growth and to produce timber and other products and values

The project identified that cutover forests of PNG are in varying condition following different types of disturbances such as fire and harvesting. Data from 120 permanent sample plots in cutover forest maintained by the PNG Forest Research Institute indicated 20% of plots had been subjected to wildfires that occurred in the 1997 El-Niño drought. Of the unburnt plots, 75% were increasing in timber volume at rates that could sustain a future harvest (about 1 m^3/ha/year of merchantable volume). The remaining 20% of plots were declining in volume and basal area and will need rehabilitation to restore productive potential. Carbon in above ground woody biomass is recovering at an average sequestration of 1.12 tonne C/ha/yr after logging and will therefore take about 75 years to return to the pre-harvest carbon stock. With improved management, these forests can provide continuing economic and environmental benefits for their local owners if they have improved knowledge of the goods and benefits (such as timber, carbon, biodiversity, and community and cultural uses) that may be available and if this is used by the communities to manage their forests sustainably. The project developed methodologies for forest classification and assessment in terms of current condition and stocking and capacity for future growth and carbon sequestration.

Forest assessment tools created during the project can be used provide information on forest resources to governments and local communities to help inform government and village level decision making about sustainable forest management. These tools are based on modern forest inventory to determine current stock, growth and sequestration modelling to predict future stock, and remote sensing and GIS for forest classification. Ultimately these assessment tools can facilitate a move toward sustainable and certified forest utilisation.

Objective 2: To assess the future market opportunities for different products and develop effective methods for linking local producers with purchasers of sustainably produced timber

The project assessed market opportunities for forest goods and services, explored sustainable forest management options, including the possible benefits of forest certification. A financial model was used to evaluate different production models.

This analysis indicated that with current market prices, for forests within 170 km of markets, a single small-scale mill producing operated efficiently (1000 m^3/yr of log input and 50% recovery) with export of green sawn timber of higher value species and selling other species locally was the most profitable model, earning PNGK 1.9 million for the community in net profit over a 20 year life-time, with almost 15% return on sales and a relatively short capital payback time (3 years). Selling all products locally was also moderately profitable (PNGK 0.6 million of accumulated profits over 20 years). For community forest enterprises that are a greater the distance from buyers, higher volumes of material are required to be processed and sold in order to be financially viable. Leadership, business management, technical skills and access to working capital are barriers to wider successful adoption of small-scale sawmilling. Profitable value-adding (drying and planing) in PNG requires larger-scale aggregation of green sawn product from a number of operations. This adds complexity for communities and increases capital requirements.

Forest certification is a significant cost that is currently not expected in the local market. If communities choose not to pay for certification, the profitability of production models increased by 10%. Investing in value adding for the output from a single portable sawmill was not justified on current timber prices. To make value adding profitable, a significantly higher scale of production is required to cover the high fixed and variable costs associated with operating a timber yard. The project also identified factors that determine the profitability of community based small scale portable sawmill operations that can guide future efforts.

Objective 3: In collaboration with forest owners, to analyse options for future supply of different products and services in relation to their community values or external markets, and to design appropriate management strategies

With the creation of resource information for ACIAR project areas the information was used to explicitly compare options for forest utilisation and monetary returns. This was competed for Sogi and Kgwan project areas, and incorporated in Forest Management Plans. Cossey Yosi is finalising analysis of supply options for Yalu and Gabensis.

Objective 4: To train community based NGO staff in forest assessment and analysis of different forest management options that will allow local forest owners to obtain future sources of revenue from their forests, in relevant quality control approaches and management and marketing linkages.

Building community capacity in PNG is a long-term process. Few communities have the necessary language, literacy, business management or understanding of timber market supply chains to effectively develop community based enterprises. The project was successful in implementing training for community based NGO and government staff in forest assessment and management methods. NGOs are an important conduit to community participation in PNG. Generally they have an ongoing presence in communities, and best equipped to help communities implement technical activities such as forest assessments. However, NGOs can be insecure institutions, and are vulnerable to changes in funding and poor management. This project had a very good working relationship with Village Development Trust during 2008 and 2009 that provided an important conduit to communities. However, this ceased when VDT went into administration at the end of 2009. This led to difficulties for further community participation and transfer of results to communities during 2010.

8.2 Recommendations

This project has been primarily concerned with assessment of the condition of secondary and primary forests and their potential to provide future revenue to forest owners from the sale of timber or environmental services. Through the term of the project, global forest policy has increasingly focused on climate change and the fate of tropical forests. There is increased awareness about emissions associated with tropical deforestation and the need for improved forest management to maintain and enhance carbon stocks. The challenge is to develop programs that address these concerns and provide benefits to forest dependent people and local people living in and near forests. Papua New Guinea (PNG) has been active in these global policy discussions.

There are also increasing concerns about the potential impacts of climate change on PNG forests and the PNG people and the need for communities to adapt to a changing climate. PNG is developing national policies and programs for REDD+ implementation and for climate change adaptation. Further research can assist with the development of community-based enterprises that are able to take advantage of developing markets for goods and services and assist in adaptation.

Based on the experience from this project the following recommendations are made:

1. The Permanent Sample Plot system developed by the PNG FRI is an increasingly valuable resource providing long-term measurements of forest growth for forest management, ecology, biodiversity and carbon studies. It is the only source of field-based information on cut over forest in PNG (and one of the few such long-term datasets in a tropical developing country). Results from the database will be important in facilitating informed policy on cutover forest and developing effective management approaches by local communities.

   It is recommended that ACIAR continues to support FRI to maintain and remeasure these plots in a cost-effective way, to maintain the database and make the data widely available. PNG-FRI should support other research partners to undertake complementary research at these sites including on biodiversity, soil carbon and forest dynamics.

2. Development of community-based timber production models. The project demonstrated the market and economic potential for community based timber production. The wider adoption of outputs from these models is limited by the availability of capital and business management and technical skills within the community.

   It is recommended that development assistance through AusAID, PNG SDP Ltd or other donors for community-based business management and project financing to support development of community-based forest enterprises.

3. The PNG Forest Authority is developing a series of pilot projects for different types of REDD+ related activities: avoided deforestation, forest landscape restoration, secondary forest management and plantation development.

   It is recommended that ACIAR, AusAID or other donors invest in research to support properly verified forest carbon accounting and to realise wider community and environmental benefits from these projects.

4. Climate change impacts and adaptation. There is considerable concern in PNG about the increased intensity and frequency of El Nino- Southern Oscillation climate events, and related drought and fire, on people and forests in PNG. The project identified the nature and extent of some of these impacts.

   It is recommended that research is initiated to investigate the historical impacts of these events, using tree ring analysis, forest structure and anthropological investigation to investigate potential future impacts under a changing climate and to investigate ecosystem-based adaptation options for communities and for forest management in PNG.

5. Shifting agriculture is an important economic activity that meets the subsistence needs of over 80% of the PNG population. The impact of population growth and changing land use patterns on the forest fallow cycle and on related forest carbon stocks is very poorly understood.

   It is recommended that research is undertaken into the dynamics of the shifting cultivation in areas subject to high population growth and how this interacts with food supply and forest carbon balance.

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Keenan, R.J. 2009. Disturbance, degradation, and recovery: forest dynamics and climate change mitigation. Paper presented to the XIII World Forestry Congress, Buenos Aires, Argentina, October 2009.

Keenan, R.J. 2009. Native forest management options for climate mitigation in Australia and PNG. Haines R, Thistlethwaite R & Lamb D (eds.) Proceedings of the Biennial Conference of the Institute of Foresters of Australia, Caloundra, 2009.

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9.3 Conference and other presentations by project staff

Dr. Fox presented project outputs in the following Australian and international forums;

- Fox, J.C, Yosi, C.K., Keenan, R.J. 2008. Modelling the forests of Papua New Guinea. 23rd April 2008; Burnley Campus Seminar Series.
- Fox, J.C, Yosi, C.K., Keenan, R.J. 2008. Growth models for small-scale forest utilization in Papua New Guinea. FORTROP II International Conference Tropical Forestry Change in a Changing World. 18th November 2008
- Fox, J.C, Yosi, C.K., Pokana, J.N. Keenan, R.J. 2008. Estimating standing forest carbon in Papua New Guinea from permanent sample plots. FORTROP II International Conference Tropical Forestry Change in a Changing World. 19th November 2008
- Fox, J.C, Yosi, C.K., Keenan, R.J. 2009. Improving forest management practices in Papua New Guinea. Department of Forest and Ecosystem Science Seminar Series. 20th March 2009.
- Fox, J.C, Yosi, C.K., Keenan, R.J. 2009. Forest Carbon Dynamics in Papua New Guinea; Selective-logging, El Nino and REDD. P 454, Proceedings of the International Conference: Impacts of Global Change on Tropical Ecosystems; Cross-cutting the Abiotic, Biotic and Human Spheres. 27-30 July, 2009. Marburg, Germany.
- Fox, J.C., Yosi, C.K., Keenan, R.J. 2009. Forest carbon assessment in Papua New Guinea. P1, Proceedings of the IUFRO 4.01 Conference; Meeting multiple demands for forest information: New technologies in forest data gathering. City Hall, Mount Gambier, South Australia 17-20 August 2009.
- Fox, J.C, Vieilledent, G., Keenan, R.J. 2009. Modelling aboveground forest carbon dynamics in Papua New Guinea; isolating the influence of selective-logging and El Nino. P.27, Proceedings of the 23rd New Phytologist Symposium; Carbon Cycling in the Tropics. 17-20 November, 2009. Guangzhou, China.
- Bastyte, D. and Fox, J.C. 2009. The value of local biodiversity to communities in Madang Province, Papua New Guinea. P272, Proceedings of the International Conference: Impacts of Global Change on Tropical Ecosystems; Cross-cutting the Abiotic, Biotic and Human Spheres. 27-30 July, 2009. Marburg, Germany.
- Fox, J.C. 2009. Improving forest management practices in Papua New Guinea. CIRAD, Campus international de Baillarguet, Montpellier, France. 16th July
- Fox, J.C. 2009. ACIAR project activities in PNG; Forest carbon assessment in Papua New Guinea. Norway Room, Food and Agriculture Organisation, Rome, Italy. 5th August
- Fox, J.C. 2009. CO_2 emissions from selective-logging and oil palm conversion in PNG. PNG Copenhagen Preparations Meeting. University House Drawing Room, Australian National University, Canberra. . 5th November 2009
- Fox, J.C, Vieilledent, G., Keenan, R.J. 2010. Modelling forest carbon dynamics in Papua New Guinea; a hierarchical Bayesian approach. Department of Forest and Ecosystem Science Seminar Series 7th May 2010.
- Fox, J.C. 2010. Individual tree growth modelling in Papua New Guinea. CIRAD, Campus international de Baillarguet, Montpellier, France. 17th May
- Fox, J.C. 2010. Measuring forest carbon in PNG. PNG Department of Environment and Conservation Kokoda meeting. Cairns, 8th June.

- Fox, J.C, Vieilledent, G., Yosi, C.K., Pokana, J.N., Lavong, K., Keenan, R.J. 2010. Modelling forest carbon dynamics in Papua New Guinea; a hierarchical Bayesian approach. P234. Association for Tropical Biology and Conservation Annual Conference, Bali, 20th July.
- Fox, J.C, Vieilledent, G., Yosi, C.K., Pokana, J.N., Lavong, K., Keenan, R.J. 2010. Modelling forest carbon dynamics in Papua New Guinea; a hierarchical Bayesian approach. Burnley Seminar Series, 11th August.

Prof. Keenan has presented project results at the following conferences;

- Keenan, R.J. 2009. Disturbance, degradation, and recovery: forest dynamics and climate change mitigation. Paper presented to the XIII World Forestry Congress, Buenos Aires, Argentina, October 2009.
- Keenan, R.J. 2009. Native forest management options for climate mitigation in Australia and PNG. Haines R, Thistlethwaite R & Lamb D (eds.) Proceedings of the Biennial Conference of the Institute of Foresters of Australia, Caloundra, 2009.

10 Appendixes

Appendices 1 – 10 are attached.