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THE POTENTIAL OF INCORPORATING HIGH-VALUE TREE SPECIES IN PAPUA NEW GUINEA AGROFORESTRY SYSTEMS TO ENHANCE LANDOWNER LIVELIHOODS

Peter Kanowski & Hartmut Holzknecht
The Fenner School of Environment & Society
The Australian National University
Canberra

and

Andrew McGregor
Koko Pacific Ltd
Suva, Fiji

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FOREWORD

The Australian Centre for International Agricultural Research (ACIAR) seeks to promote poverty alleviation and livelihood enhancement through more productive and sustainable agriculture emerging from international research partnerships. Papua New Guinea (PNG) is one of our most important partner countries. Some 85% of PNG's population continues to live in rural areas, depending in large part on production from their customary land for both food and cash crops.

Papua New Guinea is one of the cradles of agriculture globally, and trees grown or managed for particular purposes are an integral part of traditional PNG farming and land use systems. The diversity and dynamism of these systems reflect Papua New Guinean's high levels of innovation and adaptation in agriculture.

While traditional agricultural systems in PNG have adapted to incorporate new crops and opportunities arising from access to the market economy, these innovations have not generally extended to trees grown for wood production. Instead, PNG's rich natural forests have been exploited for their commercial timbers, but at rates that cannot be sustained. There are successful plantation forests managed by the state, and major industries are based on estate crops such as cocoa and coffee grown largely by landowners, but the balsa industry of East New Britain is the only commercial forestry enterprise based largely on smallholder growers.

This report explores how the capacity of PNG landowners for tree growing, and their interests in accessing the cash economy, might be informed by the experience of commercially-oriented agroforestry elsewhere, and fostered to enhance the livelihoods of PNG landowners. It reviews the policy context for landowner tree growing in PNG, the nature of traditional agroforestry systems, and what can be learnt from experiences in other places and from other crops in PNG. The report concludes that, subject to enabling conditions, there are good prospects for the incorporation of high-value tree growing into PNG agroforestry systems, and suggests a research agenda for exploring how those prospects might be realized.

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Notes on the authors

Professor Peter Kanowski
Peter Kanowski is Professor of Forestry in the Fenner School of Environment & Society at the Australian National University. His roles comprise academic and professional leadership; research and teaching focused on forest and environmental policy, and on sustainability; and policy learning and development, and community engagement, associated with forest-related issues. Peter works extensively in each of these arenas with partners, representing a diversity of forest-sector interests, internationally, nationally, and locally.

Dr Hartmut Holzknecht
Hartmut Holzknecht is a social anthropologist with major interests in natural (including forestry and agriculture) and human (institutions, tenure systems) resource management issues, in socio-cultural, socio-economic and socio-political persistence and change, and in applied anthropology. Dr. Holzknecht is a Papua New Guinea citizen with secondary and tertiary education in Australia. His PhD in Social Anthropology is from The Australian National University. As both an academic and an applied anthropologist for over 30 years, Dr. Holzknecht has been involved in a wide range of activities - mostly focused in Papua New Guinea - in research, teaching, training, publications and writings, administration, private enterprise, consulting and project work. He has been an active consultant in Papua New Guinea to individuals, village and community groups, local firms, provincial governments, government departments, non-governmental organizations (at local, regional, national and international levels), aid organizations, and multilateral institutions.

Dr Andrew McGregor
Andrew McGregor has a B.Ag.Econ. (University of New England) and a MS and PhD from Cornell University. Dr. McGregor has consulted widely around the Pacific on economic aspects of a broad range of economic, agricultural, micro- and macro-enterprises, marketing, farming organizations, trade issues, feasibility and evaluation studies, and worked with most of the major bilateral and multilateral organizations active in the Pacific region (including USAID, AusAID, FAO, World Bank, NZAID, ADB, Secretariat of the Pacific Community, UNDP, EU, Development Bank of the Federated States of Micronesia, ESCAP, various ministries and government departments in Fiji and other Pacific states, University of the South Pacific, South Pacific Project Facility, East-West Center, JICA, and others).

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ACIAR Project FST/2005/050

Summary

The depletion of Papua New Guinea's natural forests, the skills and innovativeness of many PNG landowners in adaptive farming systems, and the good market prospects for tree species that can be grown in PNG, create new opportunities for PNG customary landowners to benefit from deliberately planting and managing commercially valuable trees. These have been recognised in the development of a PNG National Ecoforestry Policy and in ACIAR's 2004 PNG consultation, which identified the "improvement of traditional agroforestry systems" as a priority.

Research and experience in PNG farming systems and in forestry suggest that there are both land use systems and regions in which various forms of high-value tree growing could be developed on a commercial scale. Production systems and tree species are likely to vary between regions: for example, polycultural systems will be appropriate in some contexts, and small-scale monocultural systems in others. In some cases, farmers or their customary land groups may primarily finance tree planting themselves, whereas business partners may be required to co-invest in other cases. There is already good knowledge of PNG land use systems, candidate species, and institutional and structural constraints to adoption, and some knowledge of landowner decision-making processes relevant to tree-growing. There is also substantial experience internationally in the development of strategies for fostering greater adoption of high-value tree growing by farmers.

PNG landowners have a demonstrated enthusiasm for adopting new crops which generate cash returns and for which risks are low; experience in other tree crop industries in which landowners participate - notably coffee, cocoa and oil palm – are instructive for the development of high-value tree growing strategies. This study has identified key factors influencing, and constraints to, adoption of tree growing by PNG landowners. Although public policy is supportive of tree growing by landowners, constraints to governments' capacity means that incentives and support mechanisms will need to be developed by other parties, principally business and CBOs/NGOs. Development and implementation of a strategy for facilitating commercial tree growing by PNG landowners needs to take account of the current knowledge base, of factors which determine adoption by landowners, and recognize the respective roles and capacities of the interested parties - governments, prospective investment partners, CBOs and NGOs, research providers, and landowners – in fostering high-value tree-growing on a commercial scale.

Work conducted for this study suggests that an effective strategy for facilitating commercial-scale high-value tree growing by PNG landowners could best be developed by focusing initial efforts on a small number of pilot regions, in which prospects are promising because of the presence and interest of potential co-investment partners. The proposed strategy would identify specific production systems and constraints to their adoption for each region, and systematically address those opportunities and constraints in conjunction with co-investment and adoption partners.

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Scoping Study for ACIAR Project FST/2004/050

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1. BACKGROUND and CONTEXTS

1.1 Papua New Guinea, its forests, and forest-based development

Papua New Guinea (PNG) is a global centre of biological and cultural diversity. PNG ecosystems are characterised by high levels of diversity and endemism (ITTO 2005; Sekhran and Miller 1994). PNG's population of about 6.5 million people is linguistically and culturally diverse, comprising some 900 different language groups (Wurm *et al.* 1981). Customary land and natural resource rights are enshrined in PNG's 1975 Constitution, reflecting the fundamental importance of these assets to PNG's people, and remain in force over some 98% of the country's area.

Around 85% of PNG's population continues to live in rural areas, depending in large part on production from their customary land for both food and cash crops, and functioning in both subsistence and cash economies. In addition to meeting their subsistence needs from farming, landowners seek to generate income to allow the purchase of store goods and to meet family educational and medical expenses (Hunt 2000).

PNG is believed to be one of the cradles of agriculture globally (Groube 1982, 1989; Groube *et al*. 1986), with evidence of systematic forest clearing and associated agriculture for at least 40,000 years. Trees grown or managed for particular purposes are an integral part of traditional PNG farming and land use systems, and the diversity and dynamism of these systems reflect Papua New Guinean's high levels of innovation and adaptation in agriculture. These systems vary with geographic region, and within regions, involving what Filer and Sekhran (1998: 38) describe as "a bewildering variety of garden and tree crops".

Some 60%, or c. 26 million ha, of PNG's total land area of 46 million ha is still forested (Filer & Sekhran 1998). PNG's forests are globally significant, both because of their biodiversity values and because they represent the third largest remaining area of primary rainforest globally after the Amazon and the Congo. As for these other regions, PNG's forests are under strong pressure from large-scale commercial logging. The income from the forestry sector, almost completely from round log exports, has been nationally significant since the 1980s (Filer & Sekhran 1998). However, unsustainable forest harvesting levels and practices over more than 30 years, extensively documented elsewhere (e.g., Filer and Sekhran 1998; Hunt 2000; ODI 2006) mean that commercially-accessible natural forests will largely be depleted by 2015 (Shearman and Cannon 2002). Further, the history of unsustainable forest harvesting practices means that the secondary forests resulting from harvesting since 1970 are unable to support the levels of yield envisaged in forest management planning. Some 4 million ha of PNG's forests have been intensively harvested for log export; perhaps 0.5 million ha of these have been converted to agriculture, around 1 million ha may be regenerating, but around 1.5 million ha remains as degraded secondary forest (Filer and Sekhran 1998).

Small-scale 'eco-forestry' projects, based principally around the use of portable sawmills, were initiated largely by non-government organizations in the 1980s as an alternative to the large-scale industrial exploitation model of native forests (see Holzknecht et al, in prep.). Although there are an estimated 1,000 working portable sawmills in PNG, most are not being used efficiently (Groves 2001); as Hunt (2000: Ch. 4) discusses, eco-forestry enterprises have not proved profitable without external subsidization.

While the exploitation of natural forests has dominated the PNG forestry sector, there has been limited plantation forestry development. The first of these was the establishment of *Araucaria* plantations in the Bulolo/Wau district in the 1950s, adjacent to extensive native *Araucaria* stands. The c. 8,000 ha of these plantations have subsequently supported PNG's principal plantation forest-based industry. Smaller areas of plantation forest, of eucalypts and acacias grown for woodchips near Madang, and of balsa for speciality uses in East New Britain Province, have also been established and sustained (Midgley et al 2010, ODI 2006). Nucleus estate agriculture with other tree crops, initially with coffee in the Highlands and more recently with oil palm in East and West New Britain, Oro and other provinces, has also been particularly successful - although it should be noted that the central role of plantation estates in coffee production has now diminished, and smallholder coffee production on customary-owned land now provides up to 80% of PNG's coffee exports.

Notwithstanding PNG's rich natural resource endowment, and the substantial contributions of the mining and forest industries to national income, PNG ranks very poorly on the UN's Human Development Index - at 145 of 177 countries in 2007 (UNDP 2007). The reasons for this situation have been discussed extensively (e.g., AusAID 2006; Filer & Sekhran 1998: Ch. 3); while analyses and proposed policy responses vary, there is broad agreement on the need for PNG landowners to generate income from land uses that are more sustainable and enduring than industrial scale logging has been (e.g., AusAID 2006, Chapter 9).

The income-generation options for many PNG landowners are very constrained. The area that can be developed under intensive agriculture is limited by inherent environmental constraints, particularly soils (Blaikie and Brookfield 1987), and by lack of infrastructure. Consequently, incorporation of other commercially valuable crops, such as trees, into land use systems is a good option for landowners in many parts of PNG. Growing commercial trees can build on PNG landowners' tradition of innovation in farming systems, and capitalize on the improving terms of trade for high-value tropical timber. As AusAID (2006: 120) comments:

> "While there is obvious potential in the land-abundant Pacific countries for large plantations, land tenure constraints mean that the greatest potential for plantations may be at the community or household level… New plantations would need to focus on a few species in which the Pacific has some comparative advantage in meeting the demands of specialty markets unlikely to be supplied by other countries producing plantation woods. Likely candidates are teak and mahogany because the supply of high-quality furniture timbers from natural forests is in decline,

and export markets are increasingly prepared to pay a premium for quality timber from sustainably-managed sources."

1.2 This report

This report is the outcome of a Scoping Study commissioned by ACIAR in 2005, and undertaken by a team based at the Australian National University. The terms of reference for the study are presented as Annex 1; the project team comprised the authors of this report. The study involved extensive dialogue with representatives of PNG institutions and PNG experts, and was informed by advice from a reference group; members of this group are listed in Annex 2.

1.3 PNG's forest policy

The development and evolution of forest policy in PNG and associated forest policy and management issues, have been reviewed extensively by – amongst others – Filer and Sekhran (1998: Ch. 6), Forest Trends (2006), ITTO (2005), Hammond (1997), Holzknecht and Golman (2009) and ODI (2006). In essence, forest policy has – as in other forest-rich but capital-poor nations - focused on facilitating and attempting to regulate access to PNG's natural forest resources.

In principle, PNG forest policy and management should be consistent with the fourth goal of the Constitution of PNG (Papua New Guinea 1975):

> "… for Papua New Guinea's natural resources and environment to be conserved and used for the collective benefit of us all, and be replenished for the benefit of future generations".

Regrettably, this constitutional goal has seldom been realized in the exploitation of PNG's natural forests. The decade after independence was characterized by increasing public and political concerns about the conduct and impacts of forestry activities, prompting the establishment of the Barnett Royal Commission in 1987. His report described "a forestry industry out of control", and initiated a series of reforms, articulated in a new *Forestry Act* and *National Forest Policy* (Filer and Sekhran 1998, Ch. 6).

1.3.1 The 1991 National Forest Policy

The 1991 *National Forest Policy* remains the formal articulation of PNG's forest policy; its principal features are:

1. Management and protection of the nation's forest resources as a renewable natural asset;
2. Utilization of the nation's forest resources to achieve economic growth, employment creation, greater Papua New Guinea participation in industry and increased viable onshore processing.

However, in practice, many of the aspirations of the policy have not been realized, reflecting capacity, political and resource constraints. The public and private economic benefits of large-scale natural forest exploitation, its environmental and social impacts, and possible alternative forest-based development strategies continue to be widely discussed in PNG and internationally (e.g., Bond 2006; Filer and Sekhran 1998; Hunt 2000).

1.3.2 The draft National Eco-Forestry and Reforestation Policies

Recognition of the limitations of the 1991 *National Forest Policy* led to the formulation by the PNG Forest Authority of draft *National Eco-Forestry* and *Reforestation* Policies (PNGFA 2004a; PNGFA 2004b).

The draft *National Eco-Forestry Policy* defines 'eco-forestry' principally in terms of diverse forms of 'ecologically and economically sustainable' management of forest ecosystems, including planted and agroforestry systems. It commits the PNGFA to work with other agencies and interests to 'encourage and contribute to the replication of improved agroforestry systems & practices' (¶4b), and suggests a range of extension and technical support activities to foster adoption. These include training and awareness programs (¶6), and a marketing information system and agency (¶7.2).

In the light of the National Executive Council not having endorsed the draft *National Eco-Forestry Policy*, in late 2010 the PNG Forest Authority withdrew the draft policy for substantial review and redrafting.

The draft *National Reforestation Policy* promotes reforestation and the establishment of 'woodlots, agroforestry and tree planting' (¶III: 5), encourages the use of high-value local species (¶IV: 9), timber production within agroforestry systems (¶IV: 13), and discusses the respective responsibilities of landowners and other parties (¶V: 1.5).

1.3.3 Regulatory treatment of planted trees

Under the current *National Forest Policy* and associated regulations, planted tree crops are subject to the same regulatory requirements as timber harvested from natural forests (Anon 2000). This means, for example, that they are subject to high levels of oversight and control, such as export approvals. Depending on implementation, this may prove a disincentive to tree growing by landowners (Byron 2001).

1.3.4 Summary – policy context

The development of the draft *National Eco-Forestry* and *Reforestation* Policies is indicative of an emerging focus on forms of forestry activity other than industrial-scale logging. As a consequence, the PNG policy framework for commercial tree growing by landowners is favourable. In practice, however, as many analysts have noted (e.g., Bond 2006; Hunt 2000), policy implementation is severely constrained by capacity and resource limitations, and little of the good intent of policies is able to be realized by government agencies. For these reasons, as Filer and Sekhran (1998) have noted, community-based and non-governmental organizations have played and continue to play, fundamentally important roles in policy implementation. The situation also favours project interventions, such as that to which this report is directed, to facilitate policy implementation.

2. KNOWLEDGE REVIEW: COMMERCIAL TREE GROWING IN AGRO-FORESTRY SYSTEMS

The growing, manipulation and multiple uses of trees is ubiquitous in traditional land use systems across the Pacific, and has been reviewed by – amongst others - Clarke and Thaman (1993, 2005), Kanowski *et al.* (2005), Kennedy and Clarke (2004), Thaman (2002), and Vergara and Nair (1985). This is the case in PNG as in other Pacific nations, and these practices are amongst those now generally described as 'agroforestry'. The managed landscapes across much of PNG include these dynamic agroforestry systems (Kennedy and Clarke 2004).

2.1 Agroforestry

There are numerous definitions of agroforestry, dating from Lundgren's (1987: 48) characterization of it as:

> .. a collective name for all land-use systems and practices in which wood perennials are deliberately grown on the same land management unit as crops and/or animals … either in some form of spatial arrangements or in a time sequence.

More recent definitions have emphasized both the dynamic nature of agroforestry systems and their role in delivering socio-economic as well as environmental benefits:

> .. a dynamic, ecologically based natural resource management practice that, through the integration of trees and other tall woody plants on farms and in the agricultural landscape, diversifies production for increased social, economic, and environmental benefits. (Schroth *et al.* 2004a: 2)
>
> Agroforestry is increasingly recognized as a useful and promising approach to natural resource management that combines goals of sustainable agricultural development for resource-poor tropical farmers with greater environmental benefits than less diversified agricultural systems, pastures, or monoculture plantations. Among these expected benefits is the conservation of a greater part of the native biodiversity in human-dominated landscapes that retain substantial and diversified tree cover. (Schroth *et al.* 2004b: xi)

In some countries, such as Australia, the term 'farm forestry' is also used to describe various forms of tree growing by farmers (e.g., Reid and Stephen 2001). Although there have sometimes been differences in emphasis between the two terms - with 'agroforestry' focusing more on the land use systems, and 'farm forestry' more on the role of farmers or landowners in resource use choices - both terms are now generally interpreted in the broad sense represented above, incorporating both human and environmental dimensions.

2.2 PNG agroforestry systems

Customary agroforestry systems operating in PNG may be classified into four broad categories, defined principally by geographic region, although each has many variants within the region. These are:

1. *Highlands systems, characterized by sweet potato and casuarina* (Bourke 1989)
   In the Highlands region of PNG, the predominant agroforestry complex is a combination of sweet potato and casuarina (mainly *Casuarina oligodon*) in a number of complex agronomic and cultural associations across that region (Bourke 1989; Bourke 1997; Bino and Kanua 1996; Clarke, 1971).

   Major components of this system are numerous species of annual and perennial food crops (especially sweet potato and banana), Arabica coffee (*Coffea arabica*) and casuarina. Other food crops include taro, sugarcane, maize, various kinds of 'pitpit', cassava, amaranths and others. Other tree components are nut and oil pandanus. Pigs commonly graze under established coffee/casuarina/banana stands.

   Coffee was promoted as a village cash crop in the highlands from the mid-1940s, initially using short-term or permanent shade tree species. From the 1960s, coffee became progressively incorporated into the existing agroforestry systems, so that today it is an accepted component of these systems.

   These agricultural systems have intensified in recent decades, driven largely by significant increases in population (e.g., Brookfield and Hart 1974).

Photo 1: Sweet potato gardens amongst casuarina trees (Chimbu Province).

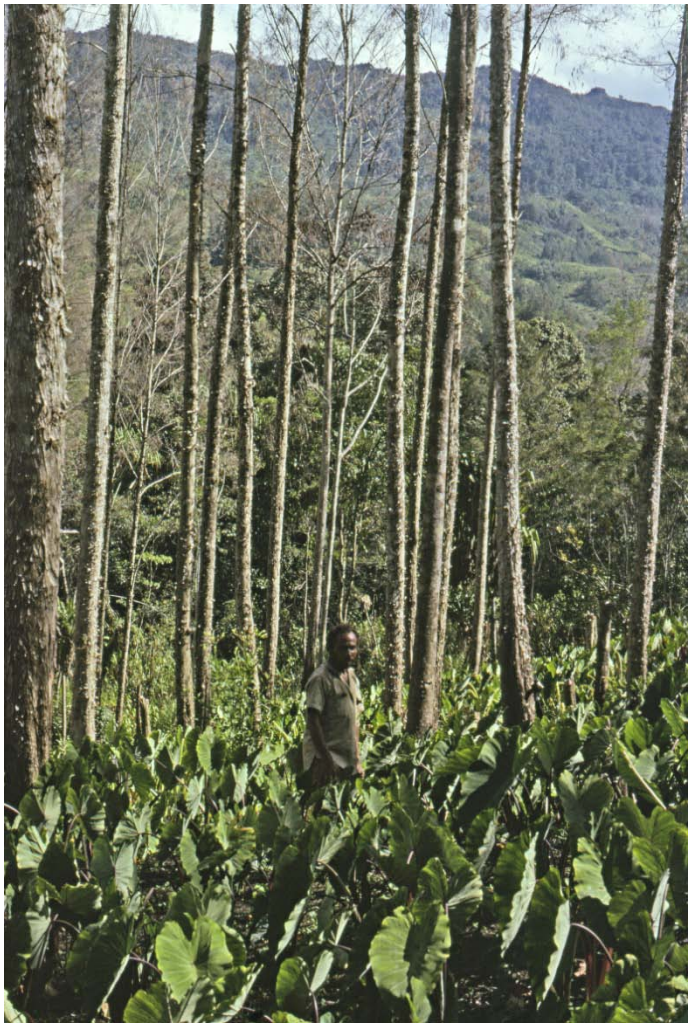

Photo 2: Taro gardens under casuarina trees (Oksapmin area, Western Province).

2. *Lowland to mid-montane systems* (Allen 1989; Clarke 1971)
   These agroforestry systems are dominated by assemblages of annual and perennial food plants and trees in different combinations. Arboriculture niches usually contain groups of species with similar ecological requirements - e.g., in the upper Leron Valley of Morobe Province, breadfruit, pandanus and betelnut palm are planted together (Holzknecht 1999). In the Sepik, two species of fruit tree, *Pometia pinnata* and *Artocarpus altilis* (breadfruit), are planted into the shifting cultivation cycle and the leaves of the former are used as mulch and green manure for yam cultivation. Stands of wild and cultivated sago are important parts of this system in some areas; in others, bananas are the major food crop in association with yams and sweet potato. As noted in 2.5.2, cocoa is now grown with galip (*Canarium* sp.) as well as *Gliricidia sepium* and coconut in East New Britain Province.

Photo 3: Landscape showing banana gardens, breadfruit trees, okari nut trees and black palm (Western Province).

Photo 4: Breadfruit trees in banana garden (Markham Valley, Morobe Province).

3. *Coastal systems* (Clarke & Thaman eds. 1993; Bourke & Betitis 2003)
   Coastal agroforestry systems are the most diffuse of the four described, largely because coastal populations have historically been relatively small and coastal environments are varied. In these systems, as for others, fruit and nut tree species such as *Artocarpus* and *Canarium* are key elements, in combination with other annual and perennial food plants such as sweet potato, cassava and bananas.

Photo 5: Papaya, breadfruit, banana, betelnut, coconut, pine tree, Barringtonia (East New Britain Province). (photo: H. Holzknecht)

Photo 6: Banana gardens under coconuts.

4. *Islands systems* (Bourke & Betitis 2003)
   Other than very small islands, where diversity is limited, island ecosystems and agroforestry systems within them are dominated by a range of fruit and nut tree species - including *Canarium*, *Barringtonia*, breadfruit and coconut, in association with numerous species of annual and perennial food crops, especially bananas and cassava.

Photo 7: Cocoa, galip nut trees and coconuts (East New Britain Province).

Photo 8: Barringtonia nut trees under coconuts (Buin area, North Solomons Province).

These systems are flexible, and their management is very adaptive. PNG landowners have proven very adept at incorporating new elements or components (e.g., cocoa, coffee) that are well-suited ecologically, that provide products which contribute either to the subsistence or cash economies, and that can be maintained through intermittent rather than intensive management.

2.3 High-value tree growing in agroforestry systems

Much of the initial focus of agroforestry research globally was on the on-farm benefits of trees (see, for example, Steppler and Nair 1987). Subsequently, the focus of agroforestry research and development, such as that facilitated by the World Agroforestry Centre[1] and national programs (such as the Australian Joint Venture Agroforestry Program[2]), has broadened to emphasize the income-generation and livelihood-enhancing potential of trees grown as part of farming systems.

Many such systems exist globally, mirroring the diversity of farming and agroforestry systems. An emerging feature of tree growing by farmers in many countries is the establishment of business partnerships between forestry companies and farmers for commercial tree growing (e.g., Desmond and Race 2000; Mayers and Vermeulen 2002; Vermeulen *et al.* 2008). While the majority of these partnerships favour farm-scale plantation forests, or their equivalent, many other forms of tree growing on farms are also amenable to the production of high-value commercial trees (e.g., Herbohn *et al*. 2001; Reid and Stephen 2001). A number of recent examples from Asia and the Pacific, e.g., the case of teak in Laos (Midgley *et al.* 2007) or the Solomon Islands (ACIAR Project FST/2007/020; ACIAR 2008) illustrate this for the

[1] (formerly International Centre for Research in Agroforestry, ICRAF) www.worldagroforestry.org
[2] now concluded; www.rirdc.gov.au/programs/aft.html

case of resource-poor farmers in circumstances with various similarities to PNG. In principle, at least, there seems a strong conjunction between these farm-based forms of high-value tree growing and the ubiquity of tree growing and management in traditional land use systems in Melanesia, as noted above. The following sections explore the extent to which this conjunction might be realized in PNG.

2.4 Factors influencing landowners' decisions to adopt tree growing

There has been considerable research in many countries into the constraints limiting adoption of commercial tree growing by landowners, much of which has been set in the broader context of farmer adoption of innovation (e.g., Ison and Russell 2000; Pattanayak *et al*. 2002). For example, Pattanayak *et al*. (2002: 4-5) report five general categories of determinants of farmer behaviour: (1) farmer preferences, (2) resource endowments, (3) market incentives, (4) biophysical factors, and (5) risk and uncertainty. Fulton and Race (2000), also drawing from the farmer adoption literature, focused on socio-economic factors relevant to landowner decision-making about the adoption of new farming practices, including commercial tree growing. They identified four categories of factors, which overlap with those nominated by Pattanayak *et al*. (2002):

- the social units of resource management - the nature of farming enterprises, and relevant socio-economic characteristics;
- internal social dynamics of these management units - including family and other organizational structures and roles;
- decision processes - these tend to be complex, and incorporate assessments of risk and expression of individual and family preference, as well as assessments of financial costs and returns;
- the nature and extent of external links, such as partnerships with industry or government.

Whatever the classification, these categories may be aggregated into "process" and "infrastructure" categories (Schirmer[3], pers. comm.), where the former refers to farmer decision-making about adoption and innovation, and the latter to factors that support a particular innovation and adoption - such as extension services, market development, nurseries, or transport infrastructure. The elements of both categories are important in determining the extent and success of adoption.

We integrate the classifications suggested by Pattanayak *et al*. (2002) and Fulton and Race (2000) to structure the discussion below, for the specific case of commercial tree growing by PNG landowners. There are also important lessons for commercial tree growing from the established PNG primary production sectors of coffee, cocoa, oil palm and vanilla; these are reviewed in 2.5.

2.4.1 Landowner preferences and decision processes

There is little knowledge specific to commercial tree growing for wood production by PNG landowners, but there is a considerable body of knowledge derived from both agricultural crops and woody estate crops such as coffee, cocoa and oil palm (Bourke and Harwood 2009). These suggest that PNG landowners view choices

[3] J Schirmer, Research Fellow, Fenner School of Environment and Society, ANU

about the planting of trees for commercial purposes (compared with, as an example, cultural reasons) as they would for any other commodity crop, and thus that their decision to plant will be determined principally by the expected returns compared to those from alternative uses for their resources, taking into account their assessment of the attendant risks. These findings are consistent with those reported for farmers elsewhere. In the case of PNG landowners, for whom labour may be the only resource they have to invest, returns to labour are likely to be one of the most compelling decision factors.

While the threshold value of return on labour relevant to decisions varies between locations (depending on alternative income generation opportunities) as well as between individuals, the minimum rural wage - of Kina 20 per week - is one common benchmark used by many PNG landowners. However, the low inputs usually required for tree planting, and the flexibility of timing in planting and management compared to other crops, are advantageous, and help mediate the disincentive of the long delay until a return on investment.

There are two broad patterns of behaviour that PNG landowners display in production decisions in response to returns on labour. The first is where cash returns to labour are low, whether in the short-term or long term; here, landowners typically aim for a 'target income'. For example, they might produce enough copra to generate a certain amount of cash, typically to pay school fees. Once they have generated this amount of income, they do not continue production, as they judge that further production is not worth their while. In contrast, when returns to labour are high – such as for oil palm, cocoa, coffee or vanilla - landowners are very responsive to price; they produce more when prices are higher, and less when prices fall. In this case, they are seeking to generate cash surpluses, not simply to achieve a target amount of money before ceasing production. These behavior patterns can also be expected to apply to tree growing.

Issues related to risk are discussed subsequently. Other factors, discussed in subsequent sections, relevant to landowner preferences and decision processes are:

- the period until income generation. PNG landowners generally have low cash incomes and short life expectancies, and thus a high time preference for income;
- lack of information on the income generation opportunities from tree growing, and the management skills and market infrastructure necessary to secure this income;
- lack of suitable planting material;
- social organisation and resource endowments.

In summary, PNG landowners behave largely as do those in other countries in relation to decisions about tree growing; in typical PNG circumstances, return on labour is a central consideration to the allocation of a landowner's resources. Given the relatively low and flexible inputs typically required for commercial tree establishment and management within farming systems, these present little disincentive; however, the delay in income generation from tree planting, landowners' assessment of risk factors, the lack of market and management

information, and the lack of planting material are all constraints to adoption of commercial tree planting.

2.4.2 Social organisation and resource endowments

The social organisation of landowners in relation to resource management in PNG varies considerably depending on the particular resource management activity, with the different sexes, individuals, families and groups all playing particular roles, depending on the nature of the activity. For example, preparing a new yam garden requires a pool of labour for the hard task of turning the soil, so the garden owner calls in relatives and friends to assist and, in return, gives his labour for similar activities when asked by others. In other cases, such as for banana garden establishment, the nuclear family unit may provide an adequate labour resource. Typically, the harder physical work, such as clearing a new area of forest or building a fence around a new garden, is carried out by men while the ongoing planting and maintenance is usually carried out by women and children. Particular crops are seen as 'male' crops, and others as 'female' crops, with associated gender constraints; others (for example, yams) are traditionally prestige crops associated with men and male status, and so only men plant and later harvest these crops.

Land and land-based resources available to PNG landowners are typically determined by the nature of customary groups, and by customary tenure and land management systems. Landowners are members of kin-based customary social groups, each of which generally has specific and clearly demarcated resource endowments. Resource rights are inherited, and in-marrying partners can acquire usage but not permanent rights. Only group members with permanent land and resource rights can establish long-term economic crops on their own land. Use of particular parts of the group's resource endowment may circulate amongst group members over subsequent cropping cycles. Traditionally, clan elders have mediated decisions about allocation and use of land, and have struck a balance between individual and group interests. For example, an individual seeking to use a particular area of land for a specific use (for example, to extend an existing garden, or prepare a new one in a different area) must undertaken discussions with and seek approval from his clan elders, who generally also manage land use. The elders will assess other competing requests prior to making a decision; this is not necessarily a short or quick process, and may or may not be resolved amicably.

Societal changes over the past few decades have tended to favour the individual rather than the group (e.g., as Alhamid 2005 found for West Papua), and the extent to which customary consensual group decision processes now prevail varies greatly between communities. However, customary processes remain strong in most communities, particularly those less impacted by development. Overall, these social processes are not expected to constrain commercial tree planting to any significant extent, although they may shape particular outcomes.

Most PNG landowners in traditional settings have little if any uncommitted capital. Most now have some cash crops, as well as crops to meet their subsistence needs, because of the need to pay for services such as education. Given these needs, and

the attractions of access to services and consumer goods, most landowners would like to increase their cash flow and reserves.

In summary, these factors favour commercial tree growing by landowners, so long as land use rights are uncontested and suitable planting stock can either be grown by the landowner or obtained from local nurseries. The tenure of planted trees is clearly held by those who planted them, and tree growing offers a low-input means of enhancing capital assets.

2.4.3 Market incentives and external links

Market demand and prices

Demand and prices for tropical forest products are strong, and expected to remain so. Both current prices and trends, and medium-term price expectations, for tropical timber are favourable, with a projected increase in the World Bank real timber price index[4] from 129 in 2006 to 151 in 2015 (World Bank 2007a). These projections are consistent with FAO expectations (e.g., Morrell 2001), and with recent price trends for tropical timbers. ITTO (2005) reports that prices for premium tropical hardwoods have increased significantly since 2000; for example, the price of teak in the USA market has nearly tripled, and those of South American mahogany and virola have doubled. While there is no comparable assessment of the market for other categories of wood products from PNG, such as eaglewood and sandalwood, both current levels of demand and underlying demand factors – such as the growth of Asian populations and economies – suggests that demand and prices for quality products will continue to be strong.

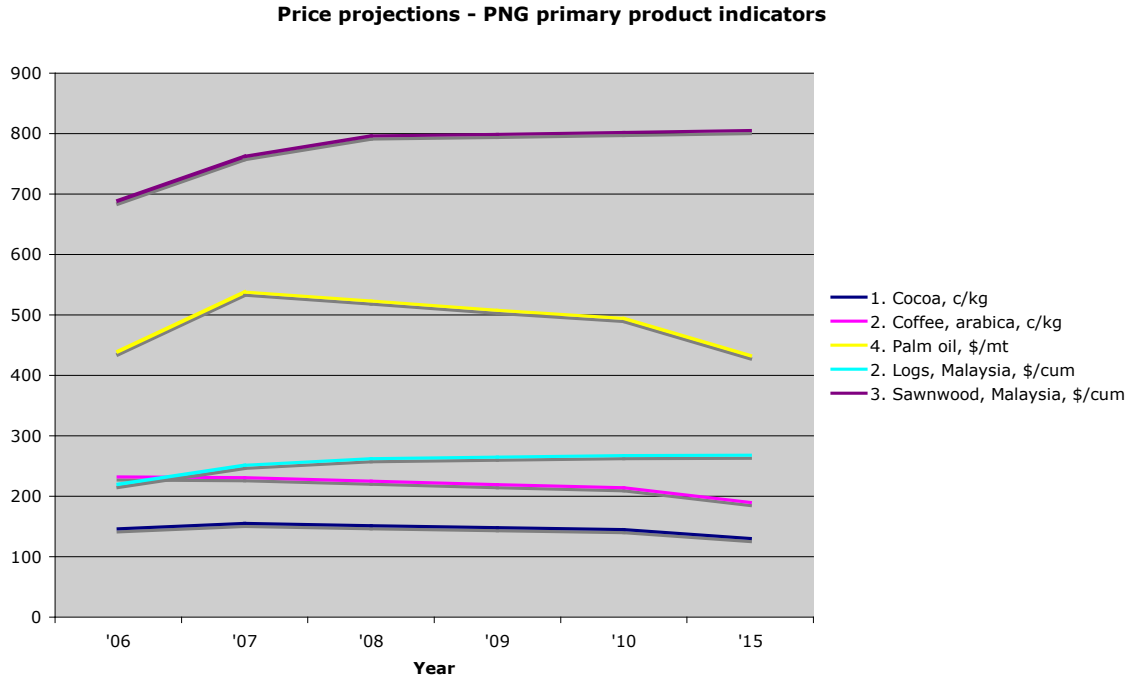

Figure 1. Actual (2006) and forecast (2007-2015) prices for tropical timber and principal PNG agricultural commodities (Source: World Bank 2007b).

[4] Index values are in constant 1990 dollar terms, i.e., inflation is factored out

This projected real timber price increase contrasts with declining or static real prices projected for PNG's other principal primary product exports – cocoa, coffee, coconut and palm oil (World Bank 2007b) – although the potential growth of biofuels may alter the projections for palm oil and perhaps coconut. World Bank forecasts for tropical timber and the principal PNG agricultural products are shown in Figure 1.

Market infrastructure

Market infrastructure comprises a functional marketing chain linking producers with markets, necessarily involving intermediaries; information flows to producers about demand and price trends and market access; technical extension services; and the physical infrastructure necessary for products to reach markets.

In PNG, there are few effective government extension services, or other market infrastructure systems, at either national or provincial levels. Market infrastructure is best-developed for the established smallholder crops of coffee, cocoa and oil palm, and also in some other industries such as chicken meat production. In these cases, the industry has developed the relevant infrastructure; relevant experience is reviewed in 2.5. In some other cases, particularly for forest-based enterprises, NGOs have sought to provide some market infrastructure services.

As discussed further in 2.5, physical infrastructure - particularly road access to markets - is similarly problematic for many PNG landowners.

In summary, projected market demand and price trends for tropical timber are strong, and counter to those for PNG's other principal primary product exports. However, the market infrastructure necessary for tree growers to access and benefit from this market outlook is absent or weak, and represents one of the greatest constraints to the adoption of commercial tree growing by PNG landowners.

2.4.4 Biophysical factors

PNG's highly diverse range of natural environments provide both opportunities and constraints to tree growing. Of the total "gross [commercial] forest area" of c. 29 million ha (1995 data), c. 16 million ha has been excluded from commercial logging on the basis of altitude, slope, terrain or seasonal inundation (McAlpine and Quigley 1998). The remaining 13 million ha could be taken as a conservative estimate of the area potentially available for commercial tree growing; it does not include extensive areas of grassland, many of them formerly forested, which are also suitable for tree growing. The 1.5 million ha of degraded secondary forest identified by Filer and Sekhran (1998) is also an obvious target for reforestation.[5]

In those areas that are suitable for commercial tree growing, the range of potential species is strongly determined by environmental and site conditions. There are many species of commercial value, both native and exotic, well adapted to these environments; these are discussed further in 2.6.

[5] There has been recent debate about the extent of deforestation and degradation in PNG (Filer et al 2009, Shearman et al 2009). While important, this debate is not material to the case made here.

In summary, biophysical factors in PNG provide constraints to, but also many suitable environments for, commercial tree growing. Whilst they may be limiting at particular sites, they are not limiting at geographic region or national scales.

2.4.5 Risk and uncertainty

The risks associated with tree growing in PNG can be classified as those associated with catastrophic loss, that is, complete or substantial loss of planted tree assets, and those associated with markets. In PNG, catastrophic loss might happen through the loss of the trees to other parties, to pests, or to fire.

The risks of loss of planted trees to other parties are low; land and natural resource rights are secure with customary owners, although boundary disputes continue to occur. Individual planted trees are unambiguously the property of the individual(s) who planted and managed the tree, subject to the caveats outlined in 2.4.1. Customary sanctions against theft are strong.

There is no history of catastrophic loss of commercial trees to pests in PNG. Ensuring that species are well adapted to the environment in which they are planted is likely to be the best strategy for minimizing such risks. The catastrophic loss risk most relevant to commercial tree growing in PNG is that of fire; although use of fire is traditionally regulated by custom, changes in attitudes to and practices with fire mean that fires in grassland areas have become problematic for tree growing. It will be necessary to change people's behaviour in relation to grassland burning to reduce fire risks in these environments to acceptable levels. One of the starting points in this process of attitudinal change is that landowners have an asset worth protecting from fire.

The other principal risks to commercial tree growing are those associated with marketing infrastructure – for example, that extension advice is not available when needed, that demand and prices do not meet minimum expectations, that the marketing chain and physical infrastructure are inadequate to enable small-scale growers to access markets. Many of these are also significant issues for small-scale forest growers globally (e.g., Herbohn *et al.* 2001; Mayers and Vermeulen 2002; Reid and Stephen 2001), as they are for prospective tree growers in PNG. The ways in which forest industries elsewhere, and how other industries in PNG, have sought to address them, are instructive, as discussed in 2.5 below. The development and maintenance of this marketing infrastructure is the principal means of addressing the uncertainties inherent in primary production systems, especially those for a long-term crop such as trees.

Typical PNG landowners, with few - if any – asset reserves, cannot afford to not be risk-averse, and so manage their production systems to minimize risks, especially those of catastrophic loss. In these terms, they behave more generally like poor small-scale farmers (e.g., Mayers 2006). However, in very interesting ways PNG farmers combine this conservative approach with great interest in new food crops, new cash crops and new ideas and are keen to try these out as well. In summary, while there are significant risk issues for commercial tree growing in PNG, these differ little from those faced, and addressed, by small-scale tree growers elsewhere,

or by other primary industries in PNG. Fire is the most significant non-market risk, although it is essentially limited to trees growing in or adjacent to grasslands. Market risks and uncertainties are more pervasive, but can also be addressed more systemically. Assuming that these constraints can be addressed, commercial tree crops also offer advantage to landowners in terms of their risk management strategies, as they do to farmers elsewhere; these include capital accumulation "on the stump", flexibility in terms of harvest timing, and market trends and cycles that run counter to those of other commodity crops.

2.5 Lessons from other PNG primary production sectors

PNG's long-established coffee and cocoa sectors, and the more recent oil palm and vanilla sectors, are the country's dominant non-forestry primary industries, and each is based on small-scale growing by landowners. Despite important differences from timber production, their experiences are instructive for commercial tree growing; relevant background is detailed in McGregor (2006) as well as Bourke and Harwood (2009), and principal lessons from that study relevant to commercial tree growing are summarized below[6].

2.5.1 Coffee

Coffee was first planted in PNG in the 1880s, but remained insignificant as a cash crop until the early 1950s, when commercial production of Arabica coffee commenced on small expatriate-owned plantations and in villages in the central highlands. Smallholder coffee production expanded rapidly in the central highland regions in the 1960s, as a result of extension activities, the absence of alternative cash-earning opportunities, high export prices for coffee, the construction of the Highlands Highway. Coffee now comprises 40% PNG's agricultural exports, worth 5% of GDP. Some 250,000 smallholders account for 85% of production, and 43% of PNG rural households derive livelihoods from coffee. Around 6000 traders buy cherry or beans from "roadside" and these are processed by 45 wet bean and 57 dry bean factories, and there are 18 exporters. All segments in the marketing chain are competitive to some degree. The Coffee Marketing Board was established in 1962 (subsequently becoming the Coffee Industry Corporation), and has focused on improving quality standards, price stabilization, and funding and directing research and development; it has not assumed direct marketing roles.

Reasonable levels of coffee production can be achieved by 6 years of age, and reasonable yields continue through about age 25 with adequate management. Given the nature of the product and processing, coffee is more amenable to decentralized processing and marketing, involving many actors, than is timber. Notwithstanding these differences from commercial tree growing, the PNG coffee industry offers a number of lessons for smallholder tree growing:

- a large tree crop industry can be based on semi-subsistence farmers operating on customary land;
- farmers will produce if they are confident that somebody will buy their product, even if the price is relatively low;

[6] This section is based on work by McGregor (2006), which draws substantially on ADB (2005).

- the presence of local entrepreneurs, who buy the crop from landowners and process it to market standards, is essential; and
- transportation infrastructure is critical, both to adoption and continuing participation in the market. Serious marketing problems continue for growers in more remote locations without adequate road links.

2.5.2 Cocoa

Cocoa is the third most important agricultural industry in PNG in terms of exports, and the second most important industry in terms of providing livelihoods. The industry is now dominated by smallholder growers – in 2001/2002, smallholders accounted for about 85% of national cocoa production, with the plantation sector contributing the remainder. Over 90,000 households in lowland coastal provinces depend on growing cocoa for their livelihoods; just over half of these are in East New Britain Province, although the recent arrival the cocoa pod borer (*Conopomorpha cramerella*) is now having a very significant impact on production there (Bourke and Harwood 2009; this impact now being countered by much better cocoa block management). Hybrid cocoa begins providing income from year 3, and has an economic life of c. 20 years.

Despite relatively low yields, the PNG cocoa industry has remained internationally competitive due to a low level of purchased inputs and a competitive marketing system. There are currently nearly 2,500 wet bean dealers, 5,500 licensed fermentaries, and 16 cocoa exporters. There is active price competition at each stage in the marketing chain. The Cocoa Board plays a regulatory but not a direct marketing function; it requires fermentaries and exporters to display wet and dry bean prices, respectively. The competitive marketing system has resulted in low marketing margins and relatively high grower prices. This contrasts with the situation in other Pacific Island countries, where parastatal monopolies have dominated cocoa marketing, and the sector has faltered or stagnated.

These features of the cocoa market chain are analogous to those of coffee, and equally relevant to commercial tree growing. Other relevant features of the PNG cocoa industry to commercial tree growing are:

- the potential for commercial tree growing to be integrated with cocoa production, echoing the original introduction of cocoa as an intercrop in coconut plantations. Cocoa is grown in PNG at altitudes less than 800 m and where annual rainfall is greater than 1800 mm. Commercially valuable tree species adapted to these environments and to the cocoa production system might include kwila, teak and galip; some East New Britain cocoa plantations have already started intercropping cocoa with galip as well as with other trees;
- the hitherto good prospects for the further expansion of cocoa production, including to Bougainville and the East Sepik (Asian Development Bank 2004), may be tempered by the impact of the cocoa pod borer. The incorporation of commercial tree growing into cocoa production systems, as either integrated or complementary plantings, may offer the best means of maximizing returns on labour and resources (as, for example, in East New Britain; Midgley *et al.* 2010); and

- processing requirements for cocoa are minimal because it is exported as dried beans; more concentrated processing facilities, with higher levels of investment, are likely to be necessary for value-adding to timber.

2.5.3 Oil palm

Oil palm, dating from the mid-1960s, represents PNG's newest tree crop industry and has become the second most important agricultural export earner after coffee. It is arguably PNG's most efficient agricultural industry, with yields amongst the highest in the world. In contrast to coffee and cocoa, oil palm growing and processing are highly concentrated around a few large nucleus plantation enterprises, with processing facilities and surrounding smallholder blocks. The large palm oil enterprises have found it necessary to invest in physical infrastructure such as roads and ports. Lack of access to debt and/or equity capital is also a significant constraint to some PNG oil palm enterprises.

The Oil Palm Industry Corporation (OPIC), organized, funded, and administered by the industry, is responsible for the conduct of technical extension and social benefit programs for the smallholder oil palm producers. The companies carry out all marketing functions themselves. The nucleus estate companies pay for smallholder fruit based on a formula administered by OPIC. The nucleus enterprise structure of the oil palm industry brings considerable benefits to smallholder growers in the form of extension services and input supply.

The total area planted to oil palm currently exceeds 81,000 ha, much of it in West New Britain Province. About 10,000 smallholders grow oil palm. Smallholder production almost doubled during the 1990s, and now account for about 30 percent of total palm fruit production. Some 70 percent of smallholder production originates in West New Britain, and an additional 25 percent from Oro Province; there are two smaller projects involving smallholders in Milne Bay and New Ireland, and Ramu Sugar (now Ramu Agri Industries Ltd.) is developing a nucleus scheme in the Markham Valley. Given the constraints of access to land on a large scale, future growth in PNG palm oil production will be dependent almost entirely on smallholders. Although oil palm begins yielding 3-5 years after planting, economic yields are not produced until c. 8 years.

As a consequence, the PNG oil palm industry is pioneering the development of innovative leasing arrangements for oil palm cultivation on customary land. For example, NBPOL's Kulu-Dagi Oil Palm Project leases the land from a company established and owned by local customary landowners. It pays an annual rental when the oil palm comes into production, and a royalty on the marketed crop to the smallholder-owned company.

Of the three existing PNG tree crop industries, oil palm may be the most analogous to larger scale commercial tree growing, because the latter may also:

- require substantial investment in supporting infrastructure such as roads, and in processing and marketing infrastructure;

- benefit from economies of scale, which are likely to be more similar between wood products and palm oil than with coffee and cocoa, where it is possible for exporters to ship just one or two containers in a year;
- require technical support, such as in the provision and distribution of high quality planting material;
- require a high level of extension advice, at least in the start-up phase;
- benefit from a substantial nucleus, or nucleus-like, enterprise, as the basis for raising capital for infrastructure and other investments, and for undertaking marketing; and
- require the establishment of financial and institutional arrangements through which participating landowners receive some regular income stream, for example an annual land rental, in advance of the income generated by timber harvesting.

2.5.4 Vanilla

Vanilla production is a recent industry in PNG, which expanded rapidly from only a few hundred households in 1998 to 50,000 on 2003. Such meteoric growth, which saw PNG become the third-ranked world producer, is unprecedented in PNG agriculture.

A number of factors favoured the rapid expansion of vanilla production in PNG:

- the foundations of the industry had already been laid by one company's (Bangui Bio Products Ltd) investment in the East Sepik, which acted as nucleus, and by their encouragement of surrounding small holders to plant vanilla. This provided the critical mass upon which a substantial small-holder based industry could quickly develop once the right price incentives existed;
- agro-ecological conditions in parts of the East Sepik Province proved ideal for vanilla production;
- PNG vanilla farmers had not experienced the previous periods of low vanilla prices, and they expected the initial high prices to continue into the future;
- the declining value of the kina compared with US dollar significantly increased the kina price received by PNG growers; and
- the high value of vanilla means that small-scale production was attractive to small-scale semi-subsistence farmers, who could access sufficient land to plant within traditional land tenure arrangements.

Vanilla production thus expanded from the East Sepik, which nevertheless remains the dominant area (70% of production), to all the lowland and island provinces. However, this rapid expansion of a largely unregulated industry, largely unsupported by market infrastructure, has created a number of serious problems. One is that many of the areas into which vanilla has expanded are too humid for high-quality vanilla production; a second is the general absence of extension services and market infrastructure outside the East Sepik; a third is that, as a consequence of the second, PNG producers undertake their own curing, in contrast to other major vanilla producing countries, where curing is undertaken by specialist businesses. This has led to poor and inconsistent product quality. At the end of 2004, there were 70 licensed vanilla exporters; in the short term, growers have benefited from the competition created by the large number of exporters, which has raised buying prices. However, many of these traders have inadequate understanding of the

product and were willing to purchase inferior quality vanilla at inflated prices. The overall consequences have been a negative impact on the quality of PNG vanilla, on its overall reputation on the market, and thus on price and market access.

Vanilla's high unit value, and its non-perishability when cured, makes it particularly attractive to remote locations with poor or non-existent road access. Vanilla also fits well into integrated cropping systems, and is particularly compatible with cocoa in the East Sepik Province; as noted above, cocoa production systems may also be particularly amenable to the incorporation of commercial tree crops. In comparison to alternative crops, vanilla is an exceptionally high unit value niche product that requires only a small area of land for a farmer to obtain an acceptable level of income. It therefore shares some attributes with commercially valuable trees such as sandalwood and eaglewood.

Whilst there are important difference between vanilla growing and marketing and that of trees for wood production, there are some important general lessons that can be drawn from the PNG vanilla industry experience to guide the development of smallholder-based commercial tree growing:

- the responsiveness of semi-subsistence PNG farmers to market opportunities, if they perceive they will earn a high cash return from their effort;
- the critical importance of ensuring the crop is adapted to the site;
- the importance of market infrastructure adequate to ensure farmers receive appropriate, accurate and timely information and advice, and to ensure that quality control systems are in place; and
- the particular benefits of high unit value niche products to landowners in remote locations.

2.6 Common challenges which approaches to commercial tree growing in PNG will need to address

It is evident from the review of the four sectors above that there is a suite of common challenges to any primary production sector in PNG. The most critical of these are:

- the lack of market and physical infrastructure, including access to finance, to planting material, and to transport infrastructure;
- lack of technical advice, extension services, extension information for growers;
- the need for external investors to address these constraints, act as a catalyst for smallholder production, and generate a critical mass of resource;
- the important facilitating roles of industry development institutions in establishing and sustaining industries;
- the high rate of time preference of landowners for income, and the need for production systems to deliver some level of income from an early stage; and
- the need to work with customary land and tree tenure arrangements, both in established and innovative ways.

2.7 Lessons from elsewhere – facilitating smallholder-based agricultural development and tree growing

In addition to the experiences of other primary production sectors in PNG, there is a wealth of information and experience relevant to both smallholder-based agricultural

development in general (e.g., FAO 2001) and tree growing in particular (e.g., Byron 2001; Mayers and Vermeulen 2002). Amongst the former, the nucleus enterprise model (NEM) – defined as a commercial agro-industry entity that has access to markets, technology, and production inputs as well as possessing the management skills and the financial resources required to extend this access to associated smallholders – has become one of the most successful forms of smallholder agricultural development. The nucleus enterprise is often a commercial agro-processing entity, but can be some other type of agro-industry entity that incorporates the above features.

Although traditional nucleus estates can qualify as nucleus enterprises, the nucleus enterprise concept is much broader than the former. While the NEM is likely to utilize contract growing schemes as a mechanism to link the nucleus enterprise with smallholder suppliers, the NEM treats outgrowers as partners in the enterprise rather than as mere contract suppliers. The nucleus enterprise provides a guaranteed market outlet for associated smallholders, as well as technical extension services and credit in the form of production inputs. In order for the NEM program to be successful, the nucleus enterprise must also exercise some degree of management control over the smallholders' production and post-harvest practices.

Such NEMs have been applied to high value vegetables, fruit and other food crop production, as well as to livestock and industrial crops. Various forms of NEM have already been applied to tree growing – for example, in Brazil, Thailand and South Africa – and show considerable promise (Mayers 2006). Their potential has also been recognized by potential investors in PNG tree growing, such as the PNG Sustainable Development Program (PNGSDP 2004).

A second general lesson that emerges from experience with smallholder commercial tree growing elsewhere is that some form of pre-harvest payment is necessary to facilitate adoption where the period to harvest cycles is more than c. 3-5 years. For crops with these short harvest cycles, arrangements such as provision of credit on favourable terms may be adequate to facilitate adoption. However, for tree crops with longer production cycles, arrangements which deliver a regular income stream to the landowner are demonstrably necessary for, and successful in, facilitating adoption. These arrangements are typically part of formal joint venture or leasing agreements, and deliver landowners a regular (usually annual) income as a pre-payment of a proportion of the anticipated harvesting income, and/or as a land lease fee. In Australia, for example, adoption of commercial tree growing by farmers was very low until joint venture and leasing schemes introduced annuity payments (Schirmer and Kanowski 2005).

2.8 Candidate commercial tree species for incorporation into PNG agroforestry systems

The final section of this Knowledge Review considers tree species that might be good candidates for incorporation into PNG agroforestry systems[7]. It does so by identifying and reviewing candidate species in four categories:

1. Indigenous species grown on long rotations for solid wood production;

[7] The synopsis presented here is drawn largely from McGregor (2006).

2. Exotic species grown on medium to long rotations for solid wood production;
3. Species for which wood is a complementary, rather than primary, product; and
4. Species for essential oil production.

2.8.1 Longer rotation indigenous species for solid wood production

Kwila (*Instia bijuga*) and hoop and klinkii pines (*Araucaria cunninghamia & A. hunstenii*) are good examples of species in this category; the former is a high-value lowland hardwood, and the latter are high-value softwood with wide altitudinal adaptation. Both are commercially important, with kwila sourced from native forests and hoop and klinkii pine from plantations.

Kwila, which is often marketed under its Indonesian name of *merbau*, is a pioneer species, adapted to a wide range of site conditions in PNG at altitudes below 450 m. It has a range of traditional values and uses throughout the Pacific (Thaman *et al.* 2005), as well as its more recent importance in the tropical timber trade; its hard, durable wood is suitable for uses ranging from exterior and structural uses through to interior joinery, furniture and handicrafts. Commercial overexploitation throughout its natural range has led to its nomination for inclusion in Appendix 2 of CITES (Chen 2006). Kwila has the highest unit value of species exported from PNG as sawnwood or veneer exports, at around (2005 prices) US$110/ m^3. Many natural populations in PNG have been severely depleted.

Kwila is easily propagated, and appears to grow well in a variety of environments ranging from the semi-natural to the highly modified, but relatively little is known about appropriate management regimes under cultivation. Rotations of 50-80 years are likely to be necessary to produce the solid wood sizes necessary for some of its principal uses.

Hoop and klinkii pines are PNG's most important forest plantation species, with c. 8,000 ha established on the sites of former natural stands around Bulolo. Hoop pine is a major plantation species in Queensland, with some 44,000 ha established (Forestry Plantations Queensland 2006), and is also planted by farmers as a high-value farm forestry species. The wood of hoop and klinkii pines is fine grained, and used for a range of speciality products – joinery, children's furniture, and food packaging – as well as for commodity softwood solid wood and veneer uses. Although the *Araucaria* species have lost some of their comparative advantage as plantation *Pinus* species have occupied commodity markets in Australasia, they retain advantages in niche markets and as the only softwood well adapted to PNG conditions.

Plantation establishment and management regimes for *Araucaria* species are well known, in both PNG and Australia, with typical rotation lengths of 35-45 years. The most likely areas for the expansion of hoop and klinkii pine in PNG are those around existing plantations at Bulolo and Wau, and in the Eastern Highlands. Ramu Agri Industries has recently begun establishing hoop pine on an experimental scale in the Markham Valley, and results will be instructive in terms of its adaptation to those fertile and well-drained lowland environments to which it is potentially suited.

2.8.2 Medium-longer rotation exotic species for solid wood production

Teak (*Tectona grandis*), mahogany (*Swietenia macrophylla*) and rosewood (*Pterocarpus indicus*) are examples of species in this category. Teak is widely cultivated in Asia, where it is the resource for many value-adding industries on both large and small scales, and sufficient areas have been established in PNG to indicate its excellent adaptation and potential in the seasonally dry parts of the country. For these reasons, teak is used to represent this category of species.

Teak's natural range extends from India to Vietnam; it has also been widely planted in other parts of SE Asia since the 14th Century (WCMC 2006). Its wood is strong and durable, and used for a wide variety of applications, from boat building to fine furniture. World demand outstrips supply, and is expected to continue to do so for the next 30 years (Midgley 2006); prices for higher grades have increased significantly as a result. Two shipments from PNG in 2004 attracted prices between US$390-520 m^3, which are consistent with those reported by Midgley *et al.* (2006) for a wider range of age and size classes.

In addition to being harvested from native forests, teak has been grown for c. 150 years in longer-rotation plantations and is increasingly grown on short rotations in a variety of systems by small-scale farmers (Midgley *et al.* 2006). Teak grows best in the seasonally dry tropics, with annual rainfall of 1200-2500 mm, on freely drained soils. Around 1,500 ha of teak plantations have been established at three locations in PNG, and have demonstrated the species' commercial potential there.

The high level of market demand for a range of size classes, high prices, the high level of knowledge about its cultivation in a diversity of systems, and the wide adaptation of the species, make teak an attractive species for incorporation into PNG agroforestry systems in environments to which it is adapted. However, a number of constraints need to be addressed to realize this potential, notably the time to first harvest and the currently limited access to good-quality germplasm.

2.8.3 Species for which wood is a complementary, rather than primary, product

This category of species includes indigenous or naturalised nut and fruit trees, such as galip (*Canarium indicum*, *C. salomonese* and *C. harveyi*), okari (*Terminalia kaernbachii*), or breadfruit (Artocarpus altilis); estate species such as coconut (*Cocos nucifera*) and rubber (*Havea brasilensis*); and domesticated exotics, such as neem (*Azadirachta indica*). For these species, grown primarily for their non-wood products, wood production can offer a very attractive supplementary income, as the case of rubber wood demonstrates (Kanowski 2005). Of these, galip and coconut are indicative of those with most potential for wood or wood fibre production, and are discussed below as representatives of this group.

Galip

Indigenous nuts play an important role in subsistence and food security in the Pacific, where they remain "a seasonally important part of rural people's diets" (Evans 1996). They also have unrealized potential as export products, though realizing this would require substantial market development.

Galip is one of the principal indigenous and domesticated nuts in lowland and island PNG, where – like okari - is it widely cultivated. Its wood, trading as red canarium,

features prominently in PNG timber exports; it is usually harvested as a byproduct of operations seeking higher value species. There has been some recent investment in galip growing in East New Britain, where it has been intercropped with cocoa, planted as hedgerows, and – occasionally – as stand-alone orchards; the East New Britain Provincial Government has also developed a proposal for a nucleus estate/ smallholder project for galip. The NEM model is both appropriate and necessary for the development of an indigenous nut industry, and the apparent compatibility of galip with cocoa production is advantageous. The development of an indigenous nut industry would be a prerequisite to the larger-scale planting of galip and its subsequent availability for wood production.

Coconut

Coconuts are a traditional component of island, coastal and lowland agroforestry systems in PNG. Some 200,000 households grow coconuts, and it is estimated that copra production provides an (admittedly meagre) income for 40% of those living in coastal mainland or island areas, many of these households having few alternative income sources.

Coconut plantations were established from the turn of the 20th Century, and now occupy c. 260,000 ha. Around half of these have now reached an age at which they are senile and unproductive, and the coconut industry more generally is struggling, as a consequence of poor markets for coconut oil and comparatively low yields of copra, exacerbated by a deterioration in transport infrastructure. These plantations represent a significant wood and fibre resource, which have begun to be exploited for "palmwood" products (e.g. ACIAR 2010, Arancon 1997, Pacific Green 2007). As a result, a significant market as emerged for coconut stems in Fiji and the Philippines. The increasing demand for coconut wood may represent a market opportunity for PNG coconut growers, but – given its ubiquity across coastal and island Asia and the Pacific – the longer term prospects for coconut as an agroforestry species in PNG will also depend markedly on the competitiveness of other coconut products.

2.8.4 Species for fragrant wood and oil production

Sandalwood (*Santalum austrocaledonicum*, *S. yani* and *S. macgregorii*) and eaglewood (principally *Aquilaria* spp.) have a high commercial value for the production of sandalwood and sandalwood oil, and of gaharu, respectively. These species occur naturally in PNG, and have been heavily exploited to the point of economic or actual extinction in many locations (Gunn *et al.* 2004; Thomson and Bosimbi 2004). Given the nature of their products, both sandalwood and eaglewood have high value to weight ratios, and are thus more similar in market terms to a spice such as vanilla than to other wood products.

Sandalwood is a parasite, and amenable to cultivation as an intercrop in a variety of situations – including alleys, home gardens, fallows, windbreaks and woodlots (Thomson 2006). There are examples of successful production systems in other Pacific Island countries (e.g., Vanuatu; Naupa *et al.* 1999; Thomson 2006) and in Australia (Montreal Process Implementation Group 2008). Demand exceeds supply, and real prices have increased and may be expected to continue to do so. However,

the extended period, of at least 15 years, until sufficient oil-bearing heartwood is produced is a major disincentive to smallholder planting of sandalwood; the nature and high unit value of the product also means that there may also be greater risks for joint venture investors in retaining their assets once they reach marketability, compared to the risks associated with investment in more conventional wood products. Nevertheless, the silvicultural and production characteristics of sandalwood mean it is well suited to smallholder production, particularly where its production can be integrated with that of other crops which generate income more quickly.

Much less is known about eaglewood cultivation, but it largely shares the production and market characteristics of sandalwood. It appears amenable to plantation cultivation, and perhaps to artificial inoculation for resin production (Gunn *et al.* 2004); the high prices for gaharu are prompting considerable research investment, as well as overexploitation of natural populations. In the short term, at least, sandalwood is likely to represent the better prospect for incorporation into PNG agroforestry systems, if constraints associated with the delayed income stream can be addressed.

3. DEVELOPING A STRATEGY FOR FACILITATING ADOPTION OF HIGH-VALUE TREE GROWING BY LANDOWNERS IN PNG

3.1 The basis for a strategy for facilitating high-value tree growing by PNG landowners

The depletion of PNG's natural forests, the skills and innovativeness of many PNG landowners in adaptive farming systems, and the good market prospects for species that can be grown in PNG, create new opportunities for customary landowners to benefit from deliberately planting and managing commercially valuable trees. This has been recognised in the development of a draft PNG National Ecoforestry Policy in 2004 and in ACIAR's (2004) PNG consultation, which identified the "improvement of traditional agroforestry systems" as a priority.

A similar transition, from a forest sector based on native forest exploitation to one based on planted forests of various forms, is occurring in Australia and elsewhere (Kanowski 2005). In the Australian case, research and development to facilitate adoption of high-value commercial tree growing has been a national priority for nearly 20 years, and continues to be a high priority on both national and regional development agenda (e.g., Williams *et al.* 2001; DAFF 2006). Australian strategies to promote commercial tree growing by farmers have focused, similarly, on the identification of factors influencing farmer decisions, the associated constraints to adoption, and addressing those constraints.

Research conducted as part of this study, and other research and experience in PNG farming systems and forestry (e.g., Kennedy and Clarke 2004), suggest that there are both land use systems and regions in which various forms of high-value tree growing could develop on a commercial scale in PNG. Production systems and tree species are likely to vary between regions: for example, polycultural systems will be appropriate in some contexts, and small-scale monocultural systems in others; in

some, tree planting may be financed primarily by farmers themselves or their customary land groups, whereas business partners may be required to co-invest in other, larger-scale, proposals. There is already good knowledge of PNG land use systems, candidate species, and institutional and structural constraints to adoption, and some knowledge – from anthropological and agricultural research - of landowner decision-making processes (see Mulung 2011). There is also substantial relevant experience in Australia and elsewhere of the development of strategies that have been successful in fostering greater adoption of commercial tree growing by farmers (e.g., Byron 2001; Herbohn *et al.* 2001; Mayers and Vermeulen 2002; Reid and Stephen 2001).

Development and implementation of a strategy for facilitating commercial tree growing by PNG landowners needs to take account of the current knowledge base, of factors which determine adoption by landowners, as reviewed in Section 2, and recognize the respective roles and capacities of the interested parties - governments, prospective investment partners, CBOs and NGOs, research providers, and landowners – in fostering commercial tree growing. The principal considerations in developing such a strategy are summarized below.

3.2 Factors to consider in a developing a strategy to facilitate adoption of agroforestry systems incorporating high-value trees in PNG

The preceding analysis of policy and economic, and social and cultural, factors suggests the following considerations are relevant to the development of a strategy for facilitating commercial tree growing by PNG landowners:

Policy, institutional and market environment

- Formal forest-related policies in PNG are supportive of commercial tree growing by landowners, but do not provide any incentive or support mechanisms to encourage adoption;
- The regulatory treatment of all forest products as equivalent, regardless of whether they originate from natural or planted forests, may act as a disincentive to commercial tree growing by landowners;
- Relevant PNG institutions support development of commercial tree growing by landowners, but relevant extension services are essentially absent; and
- Real prices for high-value tropical timber are predicted to rise, in contrast to those for other PNG primary commodity products;

Landowner attitudes, behaviour and adoption

- Landowners are eager to adopt and sustain production of crops that will generate cash returns in the short term, for which markets are assured, and for which risks are comparatively low;
- Smallholders are already important growers for a number of tree crops - principally coffee, cocoa, and oil palm and - on a smaller scale, commodity production of acacia and eucalypts. Experience in each of these sectors is highly relevant to strategies seeking to facilitate the adoption of commercial tree crops; and
- Traditional PNG agroforestry systems, and other PNG agricultural production systems, offer good platforms for adoption of commercial tree growing.

Land tenure, gender and resource management

- Customary land tenure does not preclude growing of tree crops on a commercial scale;
- Gender differences in terms of inheritance and use rights have some implications for investment and production strategies, but are not generally a constraint to commercial tree growing.

Principal constraints to adoption of commercial tree growing

- Poor physical and market infrastructure are significant constraints to PNG primary production industries in general, and to commercial tree growing in particular;
- Similarly, the lack of extension programs and materials, including for tree growing, represents a significant constraint to adoption and innovation;
- The lead time to income generation, the lack of financial information about tree growing options, the lack of access to investment finance, and the lack of market infrastructure, are the principal constraints to landowner adoption of many candidate tree species;
- The availability of suitable planting material of candidate species, and of relevant technical knowledge, are lesser but real constraints to adoption; and
- Fire is a significant non-market related risk factor in grassland or adjacent environments.

On this basis, it is apparent that identifying investment partners able and willing to commit resources to addressing the market and physical infrastructure constraints, by functioning as some form of nucleus enterprise, is the fundamental prerequisite to addressing these constraints in the PNG context. A number of candidate partners are apparent – these might include, but not be limited to, foundations or trusts such as the PNG Sustainable Development Program or the Ok Tedi Development Foundation[8] (PNGSDP 2004; OTDF 2001), companies such as Ramu Agri Industries Ltd. (Port Moresby Stock Exchange 2007) or those engaged in cocoa or oil palm production, and provincial government agencies with the capacity to provide investment funds.

3.3 A research strategy for facilitating high-value tree growing by PNG landowners

The results of the research described in this report suggest that a strategy for facilitating commercial tree growing by PNG landowners merits further investigation, as a means of realising the interdependent objectives of improving rural Papua New Guineans' livelihoods and developing a resource for sustainable forest-based industries. Such a strategy could be implemented on a trial basis by focusing initial efforts on a small number of pilot regions, in which prospects are promising primarily because of the presence and interest of potential investment partners. Development and implementation of the strategy in these pilot regions would provide the basis for refinement and more widespread implementation.

[8] now the Ok Tedi and Fly River Development Program

The key elements of such an initial strategy to facilitate adoption of commercial tree growing by PNG landowners would be to:

1. Identify pilot regions based on the presence and commitment of potential investment partners.
   Given the severe constraints on both national and provincial governments in PNG, involvement by private sector enterprises and relevant CBOs/NGOs will be essential to implementation of the strategy. Governments' role will be principally one of establishing and maintaining a supportive policy framework.

2. Characterize commercial tree production options for agreed priority species in each region, and assess landowner decision-making in relation to potential production systems and business models.
   These separable but interdependent steps will require:
   - identifying candidate species and preferred tree growing systems, and estimating of associated financial costs and returns over growing cycle;
   - surveying landowners to understand factors central to decision-making about production and investment choices;
   - identifying potential institutional and business models, including investment and marketing mechanisms and strategies, to facilitate landowner adoption;
   - assessing the feasibility and desirability of candidate models for each case.

3. Develop a specific strategy for each proposed species in each pilot region; the strategy would identify the roles, responsibilities and investments required of each party, including the leadership role, and address the constraints identified in Section 2.4;

4. Implement the strategies in each pilot region.
   This would require:
   - implementing preferred models in partnership with willing landowners, investment and adoption partners, and government;
   - monitoring and reviewing adoption;
   - adapting the strategies as necessary as implementation proceeds.

5. After an initial period (e.g., 3 years), review progress and experience from the suite of pilot projects, and develop and implement a national strategy on the basis of those outcomes.

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Annex 1: ACIAR FST/2005/050 Objectives, Activities & Outputs

1. Objectives:

OBJECTIVE 1: To understand both biophysical and farmer decision elements of PNG agroforestry systems relevant to incorporation of high value tree species.

OBJECTIVE 2: To understand key issues and possible options for development of a viable industry based on high value tree species grown in agroforestry systems.

OBJECTIVE 3: To understand relevant policy contexts and issues.

OBJECTIVE 4: To identify barriers to adoption that can be addressed by research or other approaches.

2. Activities:

ACTIVITY 1: Detailed review of relevant PNG farming systems, policy and industry development literature; collate and synthesize knowledge gained through a detailed desk review of agroforestry systems that incorporate new crops and new species. This work will focus principally on the Melanesia/Pacific region, but will also draw from experience elsewhere, as appropriate.

ACTIVITY 2: Consultation with relevant experts, officials and stakeholders.

ACTIVITY 3: Synthesis of current knowledge and expert and stakeholder judgment.

3. Outputs:

OUTPUT 1:

- A general review of existing customary and developing agroforestry systems, building upon previous extensive knowledge, research and documentation and in-country consultations (including at rural community level where possible).

OUTPUT 2:

- A detailed analysis of the human and organizational/institutional aspects of agroforestry systems in terms of incorporation of new species, and how/when outputs/products are harvested from these systems for domestic use, trade or sale.

OUTPUT 3:

- A review of past documented work on and existing knowledge of incorporating high-value species into PNG agriculture and forestry systems.

OUTPUT 4:

- Identification of appropriate supply chain and marketing strategies relevant to high-value timber species and likely to be successful in the Melanesian context.

OUTPUT 5:

- Identification of candidate regions/areas/agroforestry systems that might be appropriate focal points for promotion of a smallholder-based plantation industry (e.g. in terms of access, land suitability, landowner interest, existing markets).

OUTPUT 6:

- A review of the current policy environment in relation to forest plantations, agroforestry systems and ecoforestry, to help define the policy contexts necessary to support a future industry.

OUTPUT 7:

- Recommendations on a strategy to further the implementation of a smallholder-based timber plantation industry, including, for example:
    - Pilot-scale implementation of activity in case study areas identified
    - Development of partnerships with stakeholders, including relevant government agencies, universities, private sector businesses, non-governmental organizations (NGOs) and community-based organizations (CBOs), to foster development of small-scale commercial tree growing in these case study areas
    - Communication with and support for rural extension agents, such as agency staff and NGOs and CBOs, to understand the potential of and constraints to further adoption of high-value tree species in agroforestry systems
    - Development and implementation of measures to inform landowners and rural communities about the options for enhanced agroforestry systems
    - Identification of further domestication priorities for tree species, including species of high priority to local communities (e.g., locally preferred fruit and nut tree species which might also have high-value wood), and of research and implementation priorities

OUTPUT 8:

From these initial inputs, a draft industry strategy paper will be developed for circulation and feedback while further work is undertaken at provincial and local levels, addressing relevant structures and processes, training and research inputs, and cooperative marketing possibilities.

Annex 2. PNG institutional representatives and experts consulted during the Scoping Study

Ambia, Mr. V. Head, Forest Planning Division, PNGFA
Amos, Mr. G. Manager, Planning, Division of Forest Planning, PNGFA
Antonio, Mr. W. Acting Head, Melanesian Land Studies Centre, PNG University of Technology
Avei, the Hon. Sir M. Deputy Prime Minister and Minister for Petroleum
Avosa, Mr. M. Country Director, WWF/PNG, former staff member, PNGFA
Bakat, Mr. D. Head, Division of Forest Management, PNGFA
Baloiloi, Mr. M. Vice-Chancellor, PNG University of Technology
Crocombe, Prof. R. Emeritus Professor, USP, Fiji
Fairweather, Mr. K. Manager, Kutubu Transport
Freyne, Dr. D. Rural Development Advisor, Office of the Delegate of the European Union
Gowae, Mr. G. Lecturer, Dept. of Forestry, PNG University of Technology
Isan, Pastor T. Balob Teachers College
Joli, Mr. D. Leron Forestry Station
Kaip, Mr. D. Policy Analyst, Policy Secretariat, PNGFA
Kalinoe, Prof. L. Professor of Law, University of Papua New Guinea
Kambori, Mr. V. Secretary, Dept. of National Planning
Kare, Mr. D. Director, Policy Secretariat, PNGFA
Kiki, Mr. B. General Manager, PNGFA
Kimas, Mr. P. Secretary, Dept, of Lands and Physical Planning
Kimpton, Mr. R. Acting head, EU-PNG Ecoforestry Project
Kosi, Mr. T. Forester, Village Development Trust
Kumal, Mr. A. Director, Village Development Trust
Maihua, Ms. M. Head, Projects, Resource Development Division, PNGFA
Matrus, Mr. K. Special Project officer, ELCPNG
Mondiai, Mr. K. Chairman, The Ecoforestry Forum
Mulung, Mr. K. Acting HOD, Dept., of Forestry, PNG University of Technology
National Land Summit participants, Lae.
Nicholas, Mr. J. Deputy Administrator, Morobe Provincial Administration
Philemon, the Hon. B. Minister for Finance, GoPNG
Poesi, Mr. M. Forest Research Institute
Poya, Mr. N. Former, community development projects manager
Romaso, Mr. L. Director, Kum-Gie Consult Ltd.
Temu, the Hon. Dr. K. Minister for Lands & Physical Planning, GoPNG
Turia, Ms. R. Former staff member, PNGFA
Warra, Mr. T. Acting Managing Director, PNGFA
Watoka, Mr. K. Former head, Environment Division, Dept. of Environment and Conservation
Webster, Dr. T. Director, National Research Institute
Winnie, Mr. M. Special Projects, Village Development Trust
Yala, Mr. C. National Research Institute
Yandima, Mr. S. Forester, Village Development Trust
Yosi, Mr. C. Forest Research Institute
Zibe Kokino, the Hon. S. MP, former Minister for Environment and Conservation (and founder of the NGO 'Village Development Trust')