

Present Status of Reforestation in PNG —Research Needs—

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Abstract

Despite centuries of subsistence agriculture, today about 80% of 467,500km² of Papua New Guinea land is covered with forests. Commercial logging started in the early seventies and to date, according to one estimate, over 850,000ha have been logged though this figure may be grossly underestimated. While no serious attempts have so far been made to manage the logged-over forests on sustained yield principles, reforestation (and afforestation) has been going on for the past 40 years at a slow pace. To date, about 42,000 hectares of plantations have been raised, of which 37.4% consists of kamarere (*Eucalyptus deglupta*), 14.1% of *Pinus* spp., 12.4% of Klinkii pine and 12.1% of Hoop pine. Other successful species are Teak, *Eucalyptus robusta*, *E. grandis*, *Terminalia brassii*, *Octomeles sumatrana* (Erima) and *Acacia mangium*. Some enrichment trials have also been conducted in recent years. The species tried are: *Pterocarpus indicus* (PNG Rosewood), *Dracontomelon dao* (Walnut), *Pometia pin-nata* (Taun), *Anisoptera thurifera* (Mersawa), *Terminalia brassii*, Mahogany and Klinkii pine.

The paper reviews the present status of reforestation, constraints and problems leading to the priorities in research for the management of logged-over forests including the rehabilitation of degraded areas.

Introduction

Despite centuries of subsistence agriculture, today about 80% of 467,500km² of Papua New Guinea land is covered with forests of varied types ranging from mangrove forests on sheltered coasts to lowland, swamp and montane forests besides savanna forests in rain shadow areas and anthropogenic grasslands. These forests fulfilled almost all the basic needs of the people in the past and are still an integral part of their culture and provide fertile grounds for gardening. Being situated in a typical tropical climatic zone, the forests are characterized by high temperature and rainfall throughout the year except in the Highlands above 2,000m altitude resulting in a high biodiversity. Although over 200 tree species have commercial value (besides non-wood products), only about 40 have been accepted in the timber market and are being exploited since the early seventies in increasing volume. In 1991, a total of 1.5 million m³ of timber was exported out of about 3 million m³ harvest, indicating an increase of 15% in export volume and 28% in earnings (K105.89 million) over the 1990 figures (Anon., 1991d). According to Bun (1992), timber concessions have been granted on 5.7 million ha until December 1991 out of which 0.850 million ha have been logged. The figure of logged-over forests appears to be underestimated and needs verification. The logged-over forests have not been subjected to silvicultural treatment and only a few studies have been conducted on natural regeneration and timber stand improvement techniques in recent years. Although no definite figures are available on degraded forests (either due to commercial logging or other causes, such as, shifting cultivation), reforestation and afforestation have been carried out in the country for the last 40 years.

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Reforestation policy

The new National Forest Policy (and Forestry Act) promulgated in 1991 contains the following statements in relation to reforestation (Anon., 1991a ; Anon., 1991b).

- “ • Reforestation will be promoted as a means to maintain a permanent forest estate to supply existing and new forest industries. Programmes for plantation development will be guided by economic criteria and feasibility studies to assess commercial potential of processing plantation material for a variety of end uses.
- A programme of afforestation of non-forested and severely deforested land shall be pursued.
- Woodlot establishment, agroforestry and tree planting, including planting programmes contracted to youth groups in both rural areas and urban centres, will be promoted and supported by active forestry extension, with emphasis on those areas of the country where there is a shortage of wood and wood products for domestic consumption.”

The following strategies are planned to implement the policy statements :

- “ • Encourage reforestation by timber companies (as part of timber projects) or as commercial enterprises in their own right. Plantation decisions to be guided by options for profitable processing within the country.
- Promote plantation establishment by landowner groups.
- The PNG Forest Authority to take primary responsibility for supervising long-term investment in reforestation and undertake reforestation programmes where social and environmental factors are a prime consideration, engage youth groups and set up mechanisms to facilitate reforestation by timber companies.
- Initiate studies to look into the commercial feasibility of wood chipping, wood pulp, sawn timber and veneer production based on plantations.
- Give priority to managing existing plantations for sustainable output.
- The National Forest Service to set up a forestry extension capacity.”

Present Status

According to a recent report (Anon., 1991c), a total of about 42,000ha is under plantations. This figure may be, however, slightly over-estimated because it has not taken into consideration the reduction of planted area due to failures, fire and harvest. Most of these plantations are on state land except in one case (JANT) where leasing of customary land for reforestation was practiced. Most reforestation projects were initiated as experimental projects without clear criteria for commercial viability and end use. As a result, there are currently a number of plantations which have reached or are reaching maturity without any plans for their proper utilization. Furthermore, in the majority of the plantation projects, due to various reasons (lack of infrastructure etc.) post-planting management practices (pruning, thinning) were not followed.

Tables 1 and 2 and Figures 1 and 2 extracted from the Report (Anon., 1991c) provide the latest statistics on the established plantations in the country in terms of area, localities, landownership, problems, species and age classes.

The following broad conclusions can be drawn from these tables and figures.

- 1) Most of the plantations to-date are on state lands. Serious problems and delays have been encountered to get the land for reforestation from customary landowners.
- 2) The most common species so far is kamarere (*E. deglupta*), although other species, such as teak, *T. brassii*, *O. Sumatrana*, *Araucaria* spp., *Acacia* spp. and *Pinus patula* have proved successful.
- 3) The end use has not been defined for most of the species except for kamarere and *A. mangium* by JANT for chipping, *Araucaria* for plywood and of course teak for export as sawn timber.
- 4) Post-planting management practices have not been followed except in *Araucaria* spp.

- 5) The most common age class is 0-5 year indicating on increase in planting in recent years followed by 6-25 years.

The same workshop identified the following constraints on the development of large, economically viable plantation projects :

- 1) Non-availability and security over land.
- 2) High cost of production (infrastructure, transport and labour).
- 3) Lack of technical and management expertise.
- 4) Lack of end use and market.
- 5) Insufficient research on plantation forestry.

However the positive factors include, good sites and excellent growth potential, and relative proximity to major markets.

Current establishment program

The three largest companies (JANT, SBLC and OBT) have a combined annual target of 2,500ha (3,000 ha if land availability problems for JANT are solved) of reforestation in logged-over lowland forests. The proportion of the main species consisting of *Eucalyptus deglupta*, but other species, such as, *Acacia mangium*, *Terminalia brassii*, *Octomeles sumaturana*, *Tectona grandis* is being increased. *A. mangium* is likely to replace *E. deglupta* in JANT plantations because of its faster growth and greater volume, as shown below.

Table 1 Major Reforestation Projects
(Projects with planted area > 1000ha)

| Project | Planted area (ha) | Land title | Managed by | Main issues/Problems |
|------------------------------------|-------------------|------------------------------|-------------------|-------------------------------------------------------------------------------|
| Gogol (Madang) | 4,640 | Leased customary | Jant/Province | Land leases |
| Open Bay (ENB) | 4,310 | State | Open Bay | |
| SBLC (WNB) | 5,280 | State | SBLC | Funding |
| Bulolo/Wau (Morobe) | 11,466 | State | DOF | Shortage of skilled staff, 2nd rotation establishment, protection |
| Brown River (Central) | 1,800 | Customary (previously State) | not managed | Insufficient control by DOF over harvesting operations, land disputes |
| Keravat (ENB) | 1,849 | State | Province | LTC to rule on validity of State's land title, management/funding/utilization |
| Lapegu (ENP) incl. Nompia/Norikori | 4,320 | State | Province | Management/funds, utilization |
| Waghi (WHP) | 1,940 | State | Province | Land pressures, utilization management/funding |
| Ulabo (Milne Bay) | 1,010 | Customary (partly leased) | Ulabo T. C. / DOF | Land leases |

Source: Workshop on Reforestation Strategies and Programmes, Loloata Island Resort (PNG), 21 to 23 October 1991.

Table 2 Major Reforestation Projects
(Projects with planted area > 1000ha)

| Project | Planted area (ha) | Planting commenced | Planting ceased | Main Species | End-use | Commercial harvesting |
|------------------------------------|-------------------|--------------------|-----------------|-----------------------------------------------------|-----------------------------|------------------------------------------------------|
| Gogol (Madang) | 4,640 | 1975 | Continuing | Kamarere | Wood chips | Commenced |
| Open Bay (ENB) | 4,310 | 1985 | Continuing | Kamarere | Wood chips | Nil |
| SBLC (WNB) | 5,280 | 1976 | Continuing | Kamarere, Erima | Sawn timber, wood chips (?) | Some thinnings only |
| Bulolo/Wau (Morobe) | 11,466 | 1951 | Continuing | Hoop pine Klinkii pine | Plywood, sawn timber | Thinnings from early 1970s, clear-felling since 1986 |
| Brown River (Central) | 1,800 | 1954 | 1975 | Teak | Sawn timber | Thinnings and some clear-felling |
| Keravat (ENB) | 1,849 | 1951 | 1973 | Teak, Kamarere | | Balsa harvesting only |
| Lapegu (EHP) incl. Nompia/Norokori | 4,320 | 1964 | 1984 | <i>Pinus patula</i> | Sawn timber | Thinnings only |
| Waghi (WHP) | 1,940 | 1968 | 1983 | <i>Eucalyptus robusta</i> <i>E. grandis</i> | Firewood | Harvesting commenced in early 1980s. |
| Ulabo (Milne Bay) | 1,010 | 1985 leased | Continuing | Kamarere, <i>T. brassii</i> , <i>Acacia mangium</i> | | Nil |

Source: Workshop on Reforestation Strategies and Programmes, Loloata Island Resort (PNG), 21 to 23 October 1991.

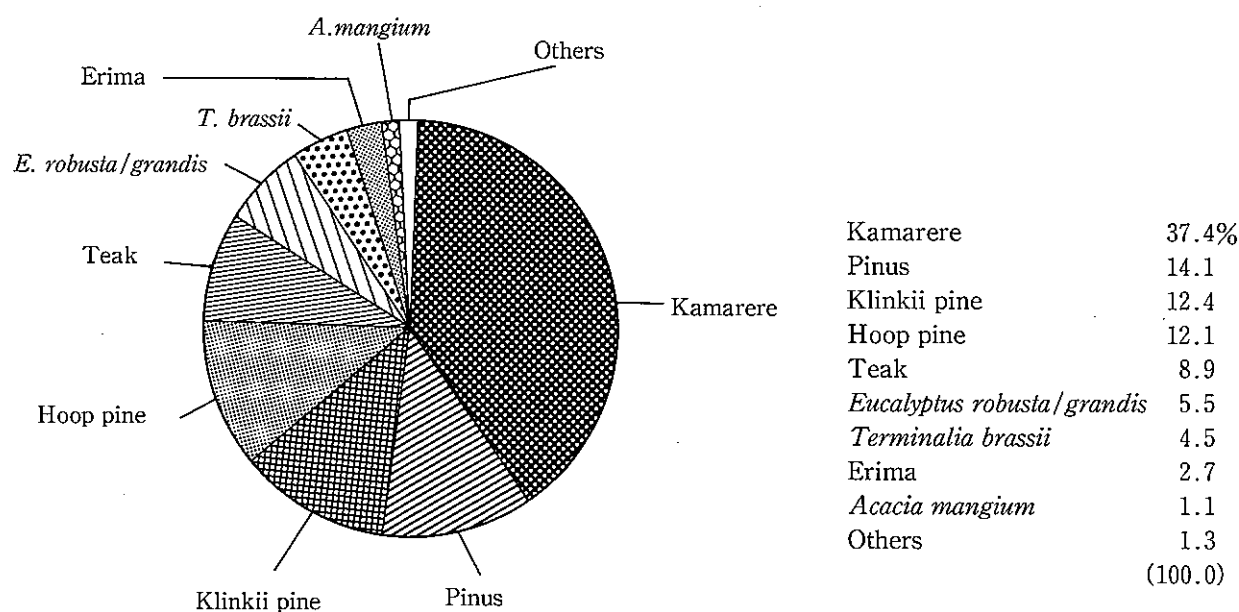


Fig. 1 PNG forest plantations and species distribution

From database as of 1, 1, 1991-36,930ha.

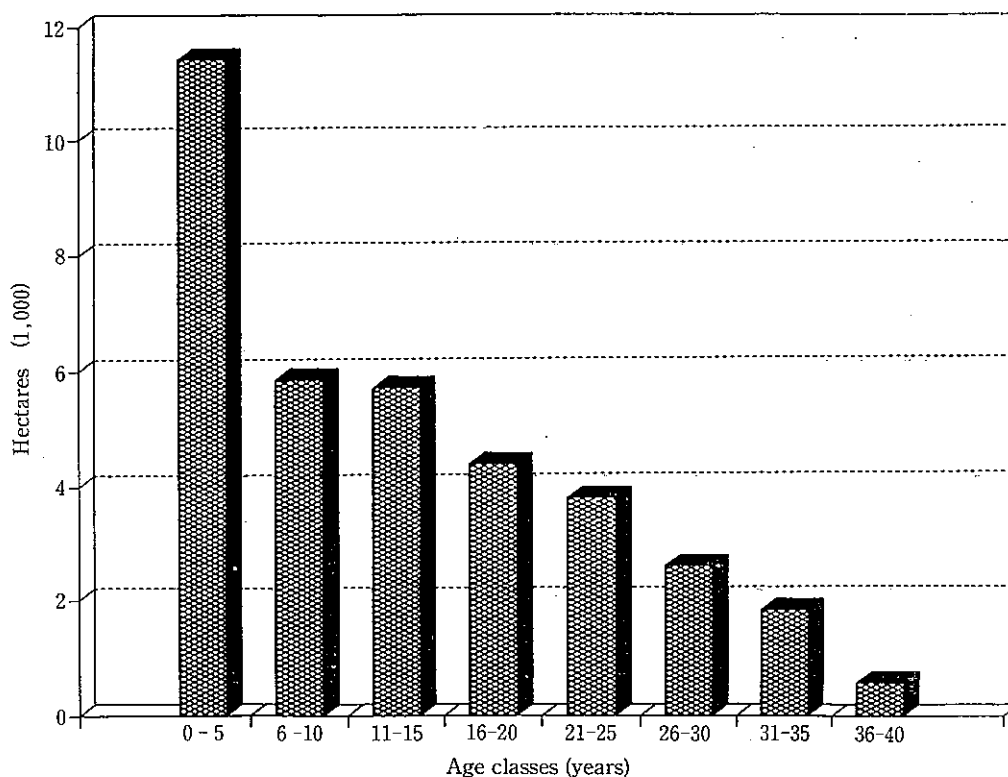


Fig. 2 PNG forest plantations, age class distribution

| Species | Spacing (m) | Age (years) | Ht (m) | DBH (cm) | Yield (m ³ /ha) | survival (%) |
|--------------------|-------------|-------------|--------|----------|----------------------------|--------------|
| <i>E. deglupta</i> | 4 × 4 | 10 | 29.7 | 25.6 | 168.9 | 57 |
| <i>A. manqium</i> | | | | | | |
| Plot 1 | 4 × 4 | 6 | 22.6 | 15.2 | 156.6 | 80 |
| Plot 2 | 4 × 4 | 6 | 21.7 | 19.6 | 164.1 | N/A |

Source: Personal communication, JANT.

They will follow a 7 or 8 year rotation for *A. manqium* compared to 10 or 11 years in the case of Kamarere.

Similarly, the SBLC are also planting about 500ha with *A. manqium* out of 750 ha annual target.

Bulolo-Wau plantation project tries to keep up with the replanting areas clear-felled by PNG Forest Products for their plymill, at the rate of up to 300ha/yr, mainly hoop pine.

The NZ/PNG reforestation project has an annual target of 500ha on four lowland sites in four provinces-mainly with kamarere (*E. deglupta*) and few other species, such as, teak, *A. manqium*, *Gmelina arborea*.

About 200ha of *Pinus* (mainly *P. patula*) and *Eucalyptus* (*E. robusta/grandis*) are planted in the Eastern Highland. Province by the Provincial Forestry Division with financial assistance from the Department of Forests.

Woodlot plantings are carried out by landowners for commercial purposes; balsa (*Ochroma lagopus*) in New Britain and kamarere in Gogol (Madang), *Casuarina oligodon*, *Pinus patula*; *Eucalyptus grandis* and *E. robusta* in the Highlands, *Tectona grandis* in the Central Province. The actual annual target is uncertain and not known.

In a workshop on reforestation strategies and programs in 1991 organized by the Department of Forests and PNG/NZ reforestation project, the following three principal objectives were identified to justify reforestation :

- (1) Land rehabilitation—reforestation to rehabilitate degraded sites.
- (2) Land protection—reforestation to protect land against soil and wind erosion and to protect water supplies.
- (3) Economic objectives—reforestation as a viable commercial enterprise as a form of land use.

Research in plantation forestry

1 Reforestation/afforestation

In PNG, research in production forestry started on a small scale in the early 1950s in order to replace Araucarias which were harvested from natural forests for manufacture of plywood in Bulolo-Wau area and species trials of exotic pines in the Eastern Highland Province. Subsequently a research station was established in Bulolo with facilities for silvicultural, pathological and entomological research. Thereafter, a Forest Product Research Branch was established at the Headquarters (Port Moresby) to study the wood properties of commercial species in close cooperation with CSIRO, Australia. During the same period a number of Japanese scientists were studying the wood properties of PNG commercial species which were being imported in increased volume in that country. With further expansion of the research activities in the 1970s, a Research and Training Division was created in the Department of Forests (earlier Office of Forests) with main research centers in Port Moresby (Forest Products), Bulolo (Silviculture, Tree Improvement and Protection) and Lae (Botany) and a field research station in Madang. Finally in 1989, FRI was established in Lae with a grant aid from the Government of Japan, with facilities for major research in all the fields while field stations were maintained in Bulolo and Madang.

Table 3 summarizes research achievements so far in terms of species and aspects for reforestation and afforestation. It is evident that information on seed collection, storage and germination is available for all the proven reforestation species except for newly introduced species, such as, *Cordia alliodora* or indigenous multipurpose tree species (MPTS). Similarly nursery practices for a number of important reforestation species including exotics have been standardized. In the case of establishment and post-planting management practices, (tending and pruning), reliable information is available on a number of species such as, *Eucalyptus* spp., hoop and Klinkii pine, other exotic *Pinus* spp., *A. mangium* and *A. auriculiformis*, *T. brassii* and *O. sumatrana*. Regarding growth and yield, the only species with reliable information are *E. deglupta*, hoop and klinkii pines, *O. sumatrana* and *Leucaena* spp. In the area of tree improvement research, the most appreciable achievement is the establishment of seed orchards (both seedlings and clones) and seed production stands (including *Acacia* spp. from different provenances) of a number of important species. Species trials of exotic tropical pines and provenance trials of a few species (such as, *E. deglupta*, hoop pine, *A. mangium* and *A. auriculiformis* have been successfully completed.

2 Enrichment planting

In the management of logged-over degraded forests in future in PNG the technique of enrichment planting will play a more important role for the following reasons :

- 1) Highly selective nature of logging which may leave behind an inadequate number of residuals of commercial and lesser known timber species.
- 2) Problem of availability of land for reforestation.
- 3) Problem of plantation ownership.
- 4) Sensitiveness to drastic adverse environmental impacts associated with clear-felling (after selective logging) followed by the establishment of monoculture, especially changes in soil properties, biodiversity and in some cases even in permanent water table.
- 5) Low cost of establishment and maintenance.

Enrichment planting can be defined as artificial regeneration to supplement the poor stocking of desir-

Table 3 Summary of research achievements/trials

| Species | Aspects | | | | | | | | | | | | | | | | |
|----------------------------------|---------------------------------------|-------------------|----------------|----------------|---|----------------|----------------|----------------|------------------|------------------|----------------|----------------|---|----------------|----------------|----------------|----------------|
| | Seed collection, storage, germination | Nursery practices | Establishment | | | | | | Growth and yield | Tree improvement | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| <i>Eucalyptus deglupta</i> | x | x | x | x | x | — | — | x ^o | x | — | x | x | — | x | x | x | x |
| <i>E. robusta</i> | x | x | x | x | x | — | — | x ^o | x ^o | — | — | — | — | — | — | — | x |
| <i>E. grandis</i> | x | x | x ^o | — | x | — | — | x ^o | x ^o | — | — | — | — | — | — | — | — |
| Hoop pine | x | x | x | x | x | x | — | x | x | — | x | x | x | — | x | x | x |
| Klinkii pine | x | x | x | x | x | x | — | x | x | — | x* | — | — | — | x | x | x |
| <i>Pinus patula</i> | x | x | x | x | x | x ^o | x ^o | x ^o | x ^o | x | x | — | — | x | x | — | x |
| <i>P. strobus</i> | x | x | x | x ^o | x | x | x ^o | — | — | x | — | — | — | — | — | x | x |
| <i>P. kesiya</i> | x | x | x | x ^o | x | x | x ^o | — | — | x | x | — | x | — | x | — | — |
| <i>P. merkusii</i> | x | x | — | — | — | — | — | — | x ^o | x ^o | x | x | x | x | x | — | x ^o |
| <i>P. tecunumanni</i> | x | x | — | — | — | — | — | — | x ^o | — | x | x ^o | — | — | x | x | x ^o |
| <i>P. caribaea</i> | x | x | x | — | x | — | — | x | x ^o | x | — | x | — | — | x | x | x ^o |
| <i>Tectona grandis</i> | x | x ^o | x | x | x | — | — | — | x | — | x | — | — | — | x | — | x |
| <i>Acacia mangium</i> | x | x | x | x ^o | x | — | — | — | x | x ^o | x ^o | — | — | — | — | x ^o | x ^o |
| <i>A. auriculiformis</i> | x | x | x | — | x | — | — | — | — | x ^o | x ^o | — | — | — | — | x ^o | x ^o |
| <i>A. crassicarpa</i> | x | x | x | — | — | — | — | — | — | x ^o | — | — | — | — | — | x | — |
| <i>A. aulococarpa</i> | x | x | x | — | — | — | — | — | — | x ^o | — | — | — | — | — | x ^o | — |
| <i>Ochroma lagopus</i> | x | x | x | — | — | — | — | — | — | — | — | — | — | — | — | — | x |
| <i>Gmelina arborea</i> | x | x ^o | x | — | — | — | — | — | — | — | x | — | — | — | — | x | — |
| <i>Cordia alliodora</i> | — | x ^o | x | — | — | — | — | — | — | — | — | — | — | x | — | — | — |
| <i>Terminalia brassii</i> | x | x | x | x | x | — | — | — | — | — | — | — | — | x ^o | — | — | — |
| <i>Octomeles sumatrana</i> | x | x | x | x | x | — | — | — | x ^o | — | — | — | — | — | x | — | — |
| <i>Leucaena</i> spp./varieties | x | x | x | x | x | x | — | — | x ^o | x | x | — | x | — | — | x | x ^o |
| <i>Paraserianthes falcataria</i> | x ^o | x ^o | x | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| <i>Anthocephalus chinensis</i> | x ^o | x ^o | x | — | — | — | — | — | x ^o | x ^o | — | — | — | — | — | — | — |
| <i>Terminalia impediens</i> | — | x ^o | x | x ^o | — | — | — | — | x ^o | — | — | — | — | — | x ^o | — | — |

Sources: Davidson and Fairlamb, 1973; Lamb and Bruce, 1974; Howcroft and Davidson, 1974 a, b, c; Lamb, 1976; Smith, 1978; Skelton, 1981 a, b; Skelton, 1982; Doran and Skelton, 1982; Skelton, 1983; Skelton and Howcroft, 1986; Srivastava, 1992; White and Cameron, 1972.

Notes on Table 3

1 Abbreviations

- x Almost completed or practice standardized.
- No or very little research
- o More research is needed
- * Failed or terminated or destroyed

2 Establishment

- (1) Planting
- (2) Spacing
- (3) Tending
- (4) Pruning
- (5) Thinning
- (6) Fertilizer application

3 Tree improvement

- (1) Species trials
- (2) Provenance trials
- (3) Progeny trials
- (4) Hybrids
- (5) Seedling seed orchard
- (6) Clonal seed orchard and clone banks
- (7) Seed production stands
- (8) Candidate seed tree selection

able timber species especially with species of high commercial value, indigenous or exotic. The ideal conditions for enrichment planting would be ; (1) low density of residuals or potential crop trees (PCT) in the logged-over forest which can not sustain the level of output required in the next cut ; (2) insufficient natural regeneration due to a number of causes, such as, absence of mother trees, unpredictable flowering and fruiting of desirable species, poor dispersal of seeds, insufficient light, drought, landslides, fire, heavy compaction of soil by machines during logging operations or biotic factors (e.g., grazing) ; and (3) management decision which will depend on diagnostic sampling to determine whether the logged-over forest is to be converted into a monoculture or regenerated through enrichment planting. A few trials so far conducted during the last 2-5 years are very encouraging. The species tried under PNG/NZ Reforestation project are (M. Yagro-Reforestation Branch-Personal of Communication) :

- | | |
|------------------------------------|----------|
| (1) <i>Swietenia macrophylla</i> | : 7.7ha |
| (2) <i>Tectona grandis</i> | : 5.0ha |
| (3) <i>Pometia pinnata</i> | : 5.0ha |
| (4) <i>Calophyllum</i> spp. | : 23.0ha |
| (5) <i>Castanospermum australe</i> | : 0.5ha |

Besides, a trial was conducted under FAO project using the following species :

- (1) *Dracontomelon dao* (PNG Walnut)
- (2) *P. pinnata* (Taun)
- (3) *Anisoptera thurifera* (Mersawa)
- (4) *Terminalia brassii*

Another trial has just been completed on enrichment planting of hoop and klinkii pine seedlings in the logged-over forests. The results are being analysed and written up.

PNG/NZ project adopted a spacing of 8m × 4m and 10m × 4m. Planting lines run in east to west direction for maximum light availability. The undesirable big trees are poison-girdled. Normally the tending schedule is 4-3-2 in the first three years.

There is thus a large scope for such trials under different logging regimes, degree of degradation of logged-over forests, soil and climatic conditions and inclusion of more species, such as *O. sumatrana*, *Acacia* spp., *Hopea*, etc.

3 Extension of planting

This could also play an important role especially in maintaining a permanent estate of natural forests. The advantages of such plantings are as follows :

- (1) Direct involvement of the landowners.
- (2) Fulfill basic needs of the people for fuelwood and timber.
- (3) Reduction of pressure on natural forests both for timber needs as well as gardening.

Woodlots have already been placed by the people in certain provinces, such as, *C. obigodon* and *P. patula* in the Highlands, *Tectona grandis* in Central Province, *E. deglupta* in Madang, *Ochroma lagopus* in New Britain and New Ireland. This practice could be further encouraged and expanded both in terms of increased number and more species. However, the success depends on dedicated extension services provided by the Department of Forests.

Research needs : program

When one studies Table 3, research gaps in plantation silviculture including tree improvement can be identified which are briefly discussed below :

1 Choice of species

Though, a number of species, especially *E. deglupta*, hoop and klinkii pines, *P. patula*, *T. grandis*, *A. mangium*, *T. brassii*, *O. sumatrana*, have proved successful, the full potential of other species, such as, *P. strobilus*, *P. merkusii*, *E. robusta* and *E. grandis* (in the swamps of the Highlands), *Acacia* spp., *G. arborea*, *P. falcataria* and *A. chinensis* has not been realized. This is partly due to insufficient research on the species/site requirements and lack of market for end use. Besides, a number of other potential, high value indigenous species have not been tried in large plantation projects or for enrichment planting. Only during the last few years, a few trials have been conducted.

The promising species are *Pterocarpus indicus*, *Calophyllum* spp., *P. pinnata*, *Intsia* spp., *Toona sureni*, *Planchonella papuana*, *C. australe*, *Anisoptera* and *Hopea*. Other reasons are also the lack of information on seed and seedling characteristics, site suitability and growth behaviour. In future, even some lesser known species may be selected for more research and trials.

2 Nursery practices

Although nursery practices have been standardized for most of the proven species for reforestation (and afforestation) including enrichment planting, there are two important aspects which have not been investigated: (1) Raising of planting stock by vegetative propagation either by rooting of cuttings or tissue culture. A number of species, such as, *T. grandis*, *Acacia mangium* (Darus 1989; 1990; Darus *et al.*, 1989), *G. arborea* (Hamsawi and Srivastava, 1985, Tang and Srivastava, 1985), *Pterocarpus indicus* are amenable to rooting of cuttings and tissue culture techniques. (2) Information on a number of high value, commercial indigenous species, such as, Taun, *Calophyllum*, *Intsia* spp., is lacking or insufficient.

3 Planting establishment

This includes planting and post-planting management practices. The most serious research gaps in this area are the lack of information on optimum spacing for most of the species both for monoculture and enrichment planting. While tending schedules for the majority of the species have been worked out on a 4-3-2-1 basis in the first four years after planting which may apply to other species also, trials are needed in order to reduce the cost of this operation without adversely affecting the growth rate and survival.

There is very little research on thinning schedules except for Araucarias. In all the species which are to be grown for saw logs, thinning schedules have to be worked out through systematic trials. Similarly very little research in PNG has been carried out on nutritional requirements of different species which should involve inoculation with mycorrhiza, rhizobium and frankia in certain species including *Anisoptera* and *Hopea*. Except for boron requirements of *Pinus* spp., very few systematic trials have been conducted on any species in this aspect. This should also include studies on the relationship between other soil characters and growth of different species.

4 Growth and yield

As shown in Table 3, in almost all the proven reforestation (and afforestation) species except for Araucarias and kamarere, reliable information on growth and yield is lacking. Some timber companies have collected the data but the results are not readily available. There is some information in the files on a few species but the data have not been analyzed. There is therefore an urgent need for the establishment of growth plots for different species under various climatic and edaphic conditions and spacing regimes in all the major plantation projects in the country.

5 Tree improvement

In this area, the most important aspects which require strengthening of research efforts are the study of natural as well as artificial hybrids of proven species for reforestation and afforestation. Successful hybrids of eucalypts and *acacias* have been produced with improved growth potential and disease resistance (Darus, 1992). Further research on second generation seed orchards of hoop and klinkii pines and

kamarere, progeny testing of *E. deglupta* and hoop pine is in progress but more work is needed on these as well as other species.

6 On-going program

Within the available resources (financial and personnel), the main current research projects are as follows:

- 1) Study of seed and seedlings of *P. indicus*, *Intsia bijuga*, *P. pinnata*, *Celtis luzonica*, *Toona sureni*.
- 2) Growth and yield studies of *Acacia* spp., *E. deglupta*.
- 3) Fertilizer trials on *A. mangium*.
- 4) Seed collection, storage and germination of timber tree species.
- 5) Provenance trials of *P. patula* and *Acacia* spp.
- 6) Establishment of seedling seed orchards of *O. lagopus*.
- 7) Rehabilitation trials of mine sites.
- 8) Establishment and management of seedling seeds and clonal seed orchards and seed production stands of a number of species (Table 3).
- 9) Selection of candidate trees.
- 10) Development of appropriate nursery techniques for high value indigenous species.
- 11) Provenance trial of *Casuarina equisetifolia*.
- 12) Progeny testing of *E. deglupta*, *A. cunnighamii* and *A. mangium*.
- 13) Special project on the study of seed and seedlings of indigenous species (JICA-FRI project).
- 14) Enrichment trials with indigenous species.

Inadequate number of trained personnel and support staff and financial constraints have not allowed to expand research in plantation silviculture including trials in degraded areas. There is a need to further prioritize research projects in this area unless financial assistance is provided to remove these constraints.

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