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Review of Agroforestry in Tropical Savanna Regions of Northern Australia

A report for the RIRDC/Land & Water
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Joint Venture Agroforestry Program

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Foreword

There is a need for new industries to supplement existing primary industry and natural resource based activities in the tropical savannas of northern Australia. Other regions of Australia have shown that new industries based on timber plantations, tree crops, grazing systems and sustainable management of native forest could provide ecological sustainable development, long-term employment and wider benefits to those regional economies.

This publication considers the performance of a range of tree species investigated in plantation and native forest trials across north Queensland, Northern Territory and northern Western Australia over the last 30 years. Recommendations are that there is an urgent need for a strategic approach to R & D in agroforestry in Australia's tropical savannas together with long-term monitoring, management and review of current and future trials.

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This report, a new addition to RIRDC's diverse range of over 1000 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Simon Hearn

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Rural Industries Research and Development Corporation

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
BRS	Bureau of Rural Sciences
CALM	(Western Australian) Department of Conservation and Land Management
CSIRO	Commonwealth Scientific and Industry Research Organisation
DBIRD	(Northern Territory) Department of Business, Industry & Resource Development (subsumed Northern Territory Department of Primary Industries & Fisheries)
DBH	Diameter at Breast Height (stem diameter at 1.3m from the ground)
DPI	(Queensland) Department of Primary Industries
FPC	(Western Australian) Forest Products Commission
GANT	Greening Australia Northern Territory
JVAP	Joint Venture Agroforestry Program
NHT	Natural Heritage Trust
NQAA	North Queensland Afforestation Association
ORIA	Ord River Irrigation Area
QFRI	Queensland Forestry Research Institute (part of DPI)
RIRDC	Rural Industries Research and Development Corporation
MAR	Mean Annual Rainfall
MDIA	Mareeba Dimbulah Irrigation Area
Spha	Stems per hectare
TSCRC	Tropical Savannas Cooperative Research Centre

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Executive Summary

In the tropical savannas of northern Australia there has been considerable interest from landowners, communities and local councils to establish sustainable, commercial land uses that involve trees in multi-functional systems. In these regions there is a need for new industries to supplement existing primary industry and natural resource based activities. New industries based on timber plantations, tree crops, grazing systems and sustainable management of native forest could provide ecologically sustainable development, long-term employment and wider benefits to those regional economies.

This report collates and reviews information on the tree component of past and current agroforestry, farm forestry and/or plantation forestry activities in Australia's tropical savannas. Developing from the RIRDC-JVAP report on 'Agroforestry R&D Priorities for Northern Australia' (Turvey and Larsen 2001), this study focuses on the climatically unique tropical savanna region. Poor soils, high evapotranspiration and medium to low rainfall distributed in a distinct wet season, followed by a variable but often extended dry season, characterise the region. Eco-environmentally sustainable land use options in the savanna region are limited. Despite these biophysical challenges, plantation forestry shows promising early growth rates of potentially high-value timber and non-timber species.

Results and location for a number of older (1970-1998) and more recent (1998 onwards) tree establishment projects funded by a range of agencies across northern Queensland, Northern Territory and northern Western Australia are presented. Thirteen (13) research/demonstration projects, consisting of 74 plantings were considered in all. Each of these projects was short-term (1-4 years), and focused on identifying suitable species to grow on sites in northern Australia. Locations of sites and species growth rates are presented, and recommendations from these projects discussed.

For the potential of this region to be fully evaluated, the need for long-term, strategic approaches to R&D including land suitability investigations; economic feasibility; species-site matching; targeted genetic improvement; establishment silviculture; utilisation and value-adding of forest products from both plantations and native forest resources are recommended.

1. Introduction

1.1 Agroforestry/Farm forestry in Australia's savannas

Agroforestry is the incorporation of trees for forest products into agricultural systems. The incorporation of trees into productive agricultural systems is one of the ways deep-rooted vegetation can be returned to the landscape while maintaining a level of agricultural productivity. Agroforestry has the potential to provide multiple benefits simultaneously. It can improve agricultural productivity, diversify and increase farm income, conserve land, maintain biodiversity and contribute to the national timber supply (Prinsley and Davis 2000). This report focuses on the tree component of agroforestry systems. Farm forestry, in this report, is discussed as a type of agroforestry, which combines aspects of traditional plantation forestry, with those of native forest management to meet the specified aims of the farmers involved. The choices and decisions are made at the farm or community level.

The long-term nature of traditional forestry enterprises, where financial returns are realised at the final harvest, does not necessarily fit together with farmers' or community's need to maintain their income levels in the short and medium term. To meet these requirements, farm forestry can be adapted. For example, by introducing or managing natural, fast growing, non-timber forest products (e.g. bush tucker species such as wattle seed) into farm forestry enterprises it is possible to provide cash flow in the short to medium term.

Another example is the management of natural forests by manipulating grass-tree interaction in grazing systems. In grazed savanna systems, removing the woody plant component (including woody weeds) will lead to increased pasture and hence animal production (Burrows 1993). Financial returns from the sale of forest products from this woody plant component (e.g. fence posts, bush tucker, plant extractives products, feature timber) could add to farm or community cash-flow. Maximizing the economic and environmental value derived from improved management of native vegetation on farms should be a priority research area in northern Australia (Turvey and Larsen 2001).

In addition, agroforestry and farm forestry can provide environmental benefits including: erosion control and soil stabilisation, reduced pressure on native forests, mitigation of salinity problems, protecting and enhancing biodiversity and reducing wind-speed within the landscape, which can increase cropping and stock yields.

In northern Australia, agroforestry activities have focused on the higher rainfall zones of Queensland's wet tropics and Northern Territory's Melville Island. Despite this, in their recent review of agroforestry R&D in northern Australia, Turvey and Larsen (2001) recognised that agroforestry in the whole northern Australian region is in its infancy:

"There are very large gaps in basic information required to underpin agroforestry development, and there is a lack of coordination of information which does exist."

Within northern Australia, tropical savannas have received the least attention with respect to commercial forestry. Lower rainfall regions have often been considered more marginal for traditional forestry. Previous JVAP studies in southern Australia, have demonstrated significant prospects for commercial agroforestry in the low rainfall regions of Australia and benefits should be achievable with further private and public R&D investment and encouragement of innovation and infrastructure (Prinsley and Bicknell 1992; Lowry and Seebeck 1997; Zorzetto and Chudleigh 1999; JVAP 2000a; JVAP 2000b; Reid and Stephen 2001; Turvey and Larsen 2001).

With the exclusion of vegetation dynamics in native forest agroforestry in relation to woodland management and grazing systems, there has been no long-term, strategic investigation of plantation and forest productivity or sustainability in tropical savannas of northern Australia. The scarcity of

long-term, strategic agroforestry or plantation forestry research in Australia's tropical savannas suggests that the potential for commercial agroforestry remains unidentified.

1.2 Australia's tropical savanna regions

This study adopts the coverage used by the Tropical Savannas CRC shown by the red line in the map of Figure 1. Tropical savannas of northern Australia cover around 1.9 million km² across the top of the continent (CRC Tropical Savannas website 2003). They lie in a tropical climatic zone with medium to low rainfall (400 – 1200mm MAR) characterised by two distinct seasons: the 'wet' and the 'dry', with high daytime temperatures and high evapotranspiration rates (Bureau of Meteorology 1989).

Australia's tropical savannas are also referred to as the monsoonal tropics and the wet-dry tropics. This extensive zone has variable conditions and may be subdivided further into drier or wetter regions with shorter or longer seasons (Gentilli 1972; Nix 1983). The climate of tropical savannas and their variability in latitude, solar radiation, precipitation, temperature and evaporation is discussed extensively by Nix (1983).

Rainfall distribution in these northern seasonally dry tropics is generally very different to southern Australian low rainfall areas. It can be highly irregular, however tropical savanna systems are characterised by basically all precipitation in the summer months (December – March) followed by an extended dry season (up to 8 - 9 months) with little, or no rainfall. The distinct seasonal variation in rainfall can place considerable stress on soil moisture through evaporation and transpiration in the dry season. Even though aridity is an important factor, the challenge of establishing trees in such regions is increased by the desiccating effects of low relative humidity, e.g. 10 – 20 %, and by greater extremes of heat and cold owing to little cloud cover and clear skies (Nix 1983; Turnbull 1986a; Evans 1992).

The soils of Australia's tropical savannas are generally very old, well weathered and characterised by their infertility. The Tropical Savannas CRC (website 2003) makes the following generalisations about soils across the region:

- soils are more fertile in the south-east sector of the tropical savannas while in the north-west shallow lithosols (skeletal soils in which only the 'bones' of the soil remain) and infertile deep sandy soils dominate;
- predominance of poor fertility across the tropical savannas;
- concentration of fertile cracking clay soils in the inland drier regions.

Soils and climate are major determinants of vegetation and potential land use in the region. Around 100 years ago cattle grazing was introduced to the region and pastoralism is the primary land use today. Much of the research into productivity of savannas has revolved around pastures, carrying capacity and animal productivity, not the surrounding ecosystem (Holmes and Mott 1993). Grazing systems, land degradation, vegetation dynamics and tree-grass relations have been the focus of long-term study and recent debate in Australia's tropical savannas [summarised in (Burrows 2002)]. The social, economic and environmental constraints of developing policy for this region are discussed further in Holmes and Mott (1993).

Open woodlands with grassy understorey are the major vegetation type in Australia's tropical savannas. Gillison (1983) discusses the ecology, physiognomy and adaptations of plants of this region. Woodland species are tolerant of water stress, nutrient deficiency and fire incidence. Plants cope with water stress with a range of mechanisms including sclerophylly, modified leaves (e.g. needle-like reduced leaves of *Casuarina* species, and phyllodes of *Acacia* and *Melaleuca* species), and high oil content (e.g. *Eucalyptus* species). Eucalypts of restricted height (15-25m) and open canopy dominate Australia's tropical savanna woodlands in areas receiving more than 600mm MAR, with *Acacia* or *Casuarina* species inhabiting the drier, and often less fertile areas (Gillison 1983; Turnbull 1986a; Boland *et al.* 1992).

These harsh climatic and edaphic conditions can make plant growth difficult. Consequently, Australia's tropical savannas are generally considered marginal for plantation forestry. In higher rainfall, more fertile areas of the tropics forestry is a more viable option, however is generally excluded due to high land prices and competing land uses from other industries (e.g. horticulture, sugar cane). Traditional forestry, with a long lead-time until commercial return, may be consigned to the more marginal areas. The prolonged dry period of the savannas, which is experienced every year from May through to November, is a disadvantage to selecting suitable species for plantation development. With the development of irrigation systems such as the Ord River Irrigation Area (WA), the Mareeba-Dimbulah Irrigation Area (Qld) and the Burdekin Irrigation Area (Qld), plantation forestry has become a promising prospect for some parts of tropical savannas. Locations of these research activities are shown in Figure 1.

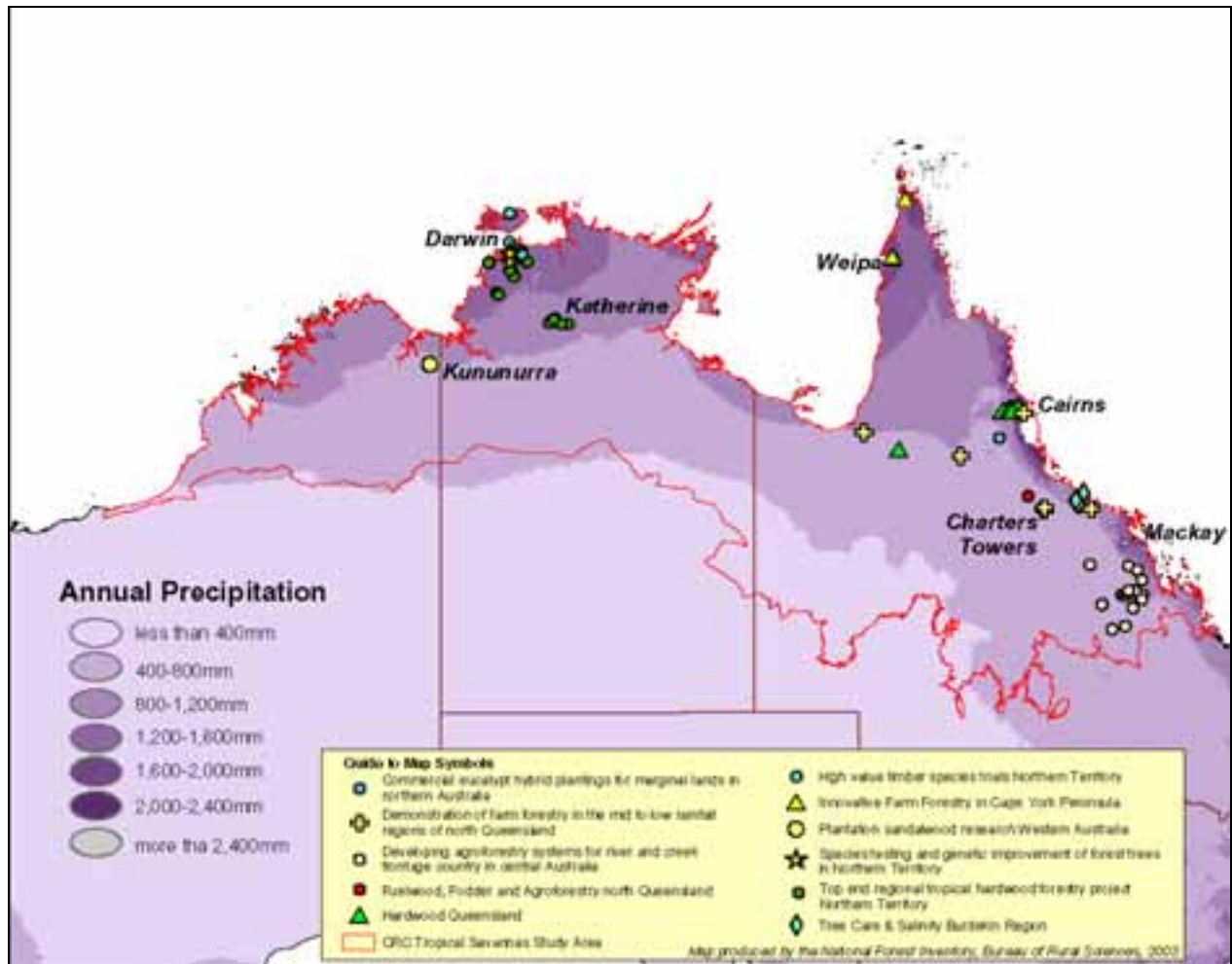


Figure 1. Map showing Australia's tropical savannas and the scarcity of research activities in the region and their location. The various symbols represent projects discussed in Chapters 2 and 3. The National Forest Inventory, Bureau of Rural Sciences 2003, provided data, analysis and map production.

1.3 The role and opportunities for agroforestry and plantation forestry in northern Australia

In the late 1960's and early 1970's CSIRO established a number of exotic timber species on higher rainfall sites in Northern Territory's savannas. Species included the well-known and valuable teak and mahogany timbers that had well-established international markets. Management of these stands was variable as was survival and early growth rates. For a number of reasons, they were not reviewed for their importance until relatively recently (Robertson 2003).

In the early 1980's ACIAR began research on climatic matching, fuelwood, leaf oil and fodder studies for trees in the tropics (Boland 1989). Tree planting to meet fuelwood needs emerged as a major task in developing countries and the benefits of trees to farmers and community groups were promoted as a solution (Turnbull 1986b; Boland 1989). The idea of multipurpose trees providing fodder, building materials, foods, extractives and medical plants, along with services such as shade, shelter and soil and water protection was investigated. Australian tree species were selected for community forestry, or multipurpose, values rather than for cultivation in large-scale, or industrial, timber plantations. Seed collections were made and trials were established using genera including *Acacia* sp., *Eucalyptus* sp., *Casuarina* sp., *Grevillea* sp., *Melaleuca* sp. and others. The result of this international work highlighted the range of valuable tropical savanna tree species, and was complemented by the Landcare program, which focused on the services trees can provide in the landscape.

The National Forest Policy statement agreed to by State and Federal governments in 1992, recommended a ban on further clearing of native forest for plantations on publicly-owned land, with the intention to encourage plantation expansion on previously cleared grazing or farming land. In Queensland, this coincided with a private forestry initiative called the TreeCare program (Queensland Forest Service, followed by the Department of Natural Resources – commenced 1990), which was an integrated catchment management program focused on extension with farmers about trees on farm. It had many similarities with the national Landcare program. About the same time the Joint Venture Agroforestry Program was established (1993) with joint funding from the Rural Industries, Land and Water Resources and Forest and Wood Products Research and Development Corporations. In 1997 the Federal government's Natural Heritage Trust (NHT) program reinvigorated community and grower interest in farm forestry, and a number of projects have established demonstration plantings across northern Australia. In addition, the coordination of agroforestry R&D through JVAP has led to a more coordinated national approach to research into trees for low rainfall areas (JVAP 2000a).

However, research efforts to date in savanna regions have been small, unconnected and characterised by short term funding. There has been growing interest in the potential for commercial outcomes from high-value timber and non-timber species in regional areas of northern Australia. Farmers, communities and local government in these regions recognise the need for new industries to supplement existing primary industry and natural resource based activities. As reported for other parts of Australia, there is a belief that sustainable agroforestry industries in Australia's tropical savannas could help to alleviate dryland salinity (Sun *et al.* 1994; Sun and Dickinson 1995; Lowry and Seebeck 1997; Zorzetto and Chudleigh 1999; JVAP 2000b; Snell and Brooks 2001), reduce wind and water erosion, provide shade and shelter for animals (Lowry and Seebeck 1997; JVAP 2000b; Burrows 2002) and contribute to biodiversity preservation, all through planting or managing native forests.

Multi-purpose trees research highlighted the potential of some native forest species from the region, and led the way for more targeted research. Early plantation trial results, both non-irrigated and irrigated, suggest that with appropriate taxa-site matching, improved genetic material and targeted establishment silviculture (including nursery techniques), plantation timber and non-timber industries are possible. Species investigated in both farm forestry projects and broad-scale or industrial plantation forestry projects include many exotic timber species. High value timber species from the Meliaceae family, e.g. *Khaya* spp. (African mahogany), *Swietenia* spp. (American/Honduras mahogany), *Cedrela odorata* (West Indian cedar), and the fragrant sandalwoods (*Santalum* spp.) are increasingly selected.

Other studies have highlighted the commercial production potential of non-timber forest products. The emerging bush food industry, which utilises a variety of native species, is ideally suited to dryland agriculture. Australian native produce industries currently have an annual retail turnover of \$14M, with strong demand for products such as *Acacia* seed, native figs, quandongs, and others (Phelps 1997). For example, *A. victoriae* and *A. colei* are ideal for dryland cultivation as they are rapidly growing small shrubs or trees, naturally occurring in low rainfall areas on a broad range of soils (Thomson 1992). Such species are known to yield commercial returns of high protein, edible wattle seed in less than 5 years (Thomson 1992; Phelps 1997; Simpson and Chudleigh 2001). For

future development opportunities, the bush food industry has acknowledged that plantation based production systems are essential. As demand increases the volumes of wild harvested produce will not meet demands in terms of quantity, continuity of supply and quality of the product (Phelps 1997).

A number of agroforestry reviews in Australia have suggested that new products (e.g. bioenergy, extractives, specialty timber products, etc.) and more traditional products (e.g. fodder, fence posts, sawn timber, commercial firewood) from agroforestry systems are desirable. These studies highlight further research into market research and economic assessment of such systems as high priorities (Evans 1992; Lefroy and Oldham 1992; Prinsley and Bicknell 1992; Lowry and Seebeck 1997; Baruah 1999; Zorzetto and Chudleigh 1999; Jones 2001; Reid and Stephen 2001; Simpson and Chudleigh 2001).

1.4 Objectives and Methodology

This project aims to complete a desktop study reviewing the tree component of agroforestry systems in tropical savanna regions of northern Australia incorporating a review of research results and other activities. The specific objectives are:

1. To review suitable, sustainable and commercial agroforestry for the tropical savanna regions of northern Australia.
2. To identify a list of high priority alternative sustainable land use options based on regional soils, climate and industries that can be integrated into existing agricultural enterprises.
3. To recommend areas of further research in tropical savanna regions of northern Australia.

2. Early dryland plantation agroforestry (1970's – 1998)

Early dryland plantation agroforestry research in Australia's tropical savannas reflected international themes concerning the performance of high-value exotic timber species in plantations, and selection and domestication of Australian trees, for other than timber purposes, for experimentation in other countries.

2.1 CSIRO species trials in the Northern Territory from 1969 to 1979

Early CSIRO research in the Northern Territory focused on high-value exotic timber species trials to identify viable, commercial species suitable for plantation forestry. The program started in 1969 with over 190 species tested over the following decade. Test sites were located at Humpty Doo, Howard Springs, Gunn Point and Melville Island, all receiving greater than 1600 MAR (locations shown in Figure 1: *High value timber species trials NT*). Trees were established at a high stocking (>1000 spha), with erratic management conducted thereafter.

In 1982 and 2002 these plantings were assessed. Species, sources details and stand health comments at 2002 assessment are shown in Appendix 7.1. Results for surviving species highlight a number of promising species. Exotic species with good growth rates include rosewood, *Pterocarpus* spp., African mahogany, *Khaya* spp., and the Indian medicinal plant belerica, *Terminalia belerica*. Good growth was also achieved from the native eucalypts red mahogany, *E. pellita* (Cardwell prov.), and Cape York red gum, *E. brassiana*, and the valuable Cajuput oil producing *Melaleuca cajuputi* (Table 1).

Table 1. Average predominant height (m) and DBH over bark (cms) for surviving species at 2002 assessment. Species planted across three sites in “CSIRO species trials in the Northern Territory from 1969 to 1979” project [common names shown in Appendix 7.1].

Location	Species	Ht (m)	DBH (cm)	Age at last measure (yrs)
Howard Springs (approx 1900 MAR)	<i>Adina cordifolia</i>	18.6	25.6	32
	<i>Pterocarpus indicus</i>	20.2	22.4	35
	<i>Eucalyptus nesophila</i>	21.6	21.7	32
	<i>Pterocarpus santalinus</i>	21	19.2	32
	<i>Terminalia belerica</i>	21.5	19.1	32
Gunn Point (approx 1530 MAR)	<i>Eucalyptus nesophila</i>	20.1	23.8	31
	<i>Pterocarpus santalinus</i>	19.5	28.7	31
	<i>Khaya senegalensis</i>	21.9	23.4	29
Humpty Doo (approx 1390 MAR)	<i>Tectona grandis</i>	20	17.1	17
	<i>Eucalyptus pellita</i>	30.9	35.8	30
	<i>Khaya grandifolia</i>	33.5	27.5	30
	<i>Melaleuca cajuputi</i>	31.7	45.6	30
	<i>Eucalyptus brassiana</i>	23.1	26.3	24

Data provided by DBIRD, (Robertson 2003).

Propagation material has been collected from selected, vigorous trees of *Khaya* spp. in these plantings, for inclusion in more recent taxa trials in Northern Territory and north Queensland (see sections 3.1 & 3.7). From these early CSIRO plantings, and subsequent street trees planted in Darwin and Weipa following Tropical Cyclone Tracey (1974), *Khaya senegalensis* has been identified as a farm forestry

plantation species with potential for northern Australia. Performance (growth rate, stand condition and form) of this species is highly dependent on level of silvicultural input. In open conditions, *K.senegalensis* has heavy branching and reduced bole length (Figure 2). With the addition of irrigation, and early form pruning, good growth rates and form can be achieved (Bristow *et al.* 2001).



Figure 2. Typical *Khaya senegalensis*, African mahogany, paddock tree Northern Territory.

2.2 ACIAR Dryland Agroforestry Species trials north Queensland

Following ACIAR trials in the early 1980's, QFRI's predecessor (Queensland Forest Service) established a series of species trials in the tropical dryland regions of Queensland in 1989 and 1990, described fully in Bell *et al.* (1991), and Ryan and Bell (1991). Two of these trials were located in north Queensland at Mareeba and Charters Towers (660 mm MAR), shown in Figure 1 (*Fuelwood, Fodder and Agroforestry north Queensland*). Species and provenances investigated were a subset of the multipurpose trees described in Turnbull (1986) and Boland (1989), and are displayed in Appendix 7.1.

The *Acacia* spp., *Eucalyptus* spp. and *Casuarina cunninghamiana* tested were considered to be suited to tropical savanna climates and soils, and capable of producing fuelwood and other timber products. Australia's ubiquitously occurring river red gum, *Eucalyptus camaldulensis* (Petford provenance), western white gum, *E. argophloia*, the edible wattle-seed producing *Acacia salicina* and *A. holosericea* (Coopers Ck NT provenance) had good early survival and growth (Bell *et al.* 1991; Ryan and Bell 1991). Condition of nursery stock and incidence of follow-up rain after planting were discussed as reasons for mortality in this project.

2.3 Lower Burdekin TreeCare and salinity trials in north Queensland

Primary producers in the Burdekin catchment and surrounding regions are enduring a slump in sugar prices. This, coupled with increasing salinity problems from a well-documented rising water table,

has triggered substantial regional interest in using deep-rooted perennial vegetation to generate commercial solutions to various environmental problems.

High temperatures and relatively low and unreliable rainfall coupled with land clearing for agriculture such as flood irrigated sugar cane has lead to increasing amount of salinity affected sites in the Lower Burdekin catchment (Sun and Dickinson 1995). Between 1991 and 1995 QFRI established a number of taxa trials at three non-saline sites and two saline sites in the lower Burdekin region (Sun *et al.* 1994; Sun and Dickinson 1995; Snell and Brooks 2001) (see Figure 1: *Tree Care and Salinity Burdekin region*). Species investigated are shown in Appendix 7.3.

Results for non-saline sites:

On reviewing the plantings, Snell and Brooks (2001) found a small subset of the 40 taxa tested on non-saline sites proved to have good growth and survival, these included northern provenances of:

- River red gum, *Eucalyptus camaldulensis*;
- Lemon-scented gum, *Corymbia citriodora*;
- Black she-oak, *Casuarina cristata*;
- African mahogany, *Khaya senegalensis*.

Other species such as spotted gum, *Corymbia variegata*, black ironbox, *E. raveretiana*, ironbark, *E. drepanophylla*, and neem, *Azadirachta indica*, also showed adequate survival and growth on non-saline solodic soils in the Burdekin region.

Results for saline sites:

Maintaining consistent growth and survival rates across increasing levels of salinity is a characteristic of salt tolerant species (Sun *et al.* 1994; Sun and Dickinson 1995). Species that have shown good growth and survival characteristics on saline soils included:

- Swamp she-oak, *Casuarina glauca*;
- River she-oak, *Casuarina cunninghamiana*;
- Black she-oak, *Casuarina cristata*;
- River red gum, *Eucalyptus camaldulensis*;
- Grey box, *Eucalyptus moluccana*;
- Paperbark, *Melaleuca leucadendron*;
- Ironbark, *Eucalyptus drepanophylla*;
- African mahogany, *Khaya senegalensis*;
- Northern black wattle, *Acacia auriculiformis*;
- Grey ironbark, *Eucalyptus paniculata*;
- Black ironbox, *Eucalyptus raveretiana*;
- Red mahogany, *Eucalyptus pellita*;
- Lemon-scented gum, *Corymbia citriodora*;
- Forest red gum, *Eucalyptus tereticornis*.

Snell and Brooks (2001) reviewed these plantings at age 5 years (Sun and Dickinson (1995) assessed at age two) finding that the three *Casuarina* spp., *E. camaldulensis* and *M. leucadendron* exhibited a higher survival than other species with increasing salinity (Figure 3). It is recommended that site preparation techniques could maximise growth and survival on saline sites. Mounding, growtubes and organic mulch have improved growth and survival of trees planted on these and other saline sites in Queensland (House *et al.* 1998).

2.4 Ord River early sandalwood plantation projects

The Ord River Irrigation Area (ORIA) at Kununurra in the East Kimberley area of northern Western Australia contains around 14 000 hectares of developed land that has access to irrigation from Lake Argyle on the Ord River (see Figure 1: *Plantation sandalwood research WA*). In the early 1980's CALM began testing Indian sandalwood, *Santalum album*, in this region (Figure 4). From 1993 until

2002 a research scientist and a number of student projects were based in Kununurra investigating the silvicultural requirements of *S. album* in a flood irrigated system (Vernes and Robson 2002).

Experiments in this region have included irrigated plantations of sandalwood in association with other high-value timber species. Sandalwood, *Santalum* spp., are all obligate semi-parasitic trees, which can only survive by parasitising the roots of other living grasses, shrubs, and trees. India and Australia are currently the world's two largest producers of sandalwood and Australia therefore has a strong economic interest in the maintenance of this industry (Statham 1990; Radomiljac *et al.* 1999; Vernes and Robson 2002).

The development of plantations is not straightforward, as sandalwood is parasitic, requiring the establishment of a series of host plants of appropriate type and size. In the early 1990's Western Australian researchers addressed these issues in an attempt to define appropriate silvicultural techniques to enable both the host species and parasite to be managed for high value forest products (Applegate *et al.* 1990; Loneragan 1990; Fox *et al.* 1994; Radomiljac 1998; Radomiljac *et al.* 1998a; Radomiljac *et al.* 1998b; Brand 1999; Radomiljac *et al.* 1999). This early research identified suitable hosts, establishment techniques, spacing and irrigation rates for *S. album* in plantations in the ORIA.



Figure 3. Species trial on a saline site in the Burdekin region. Tree species in the foreground failed, however several *Casuarina* species (in background) showed high survival and maintained relative canopy size with increasing salinity classes.



Figure 4. One of the early sandalwood, *S. album*, planted at CALM-FPC research station, Kununurra, northern Western Australia (age 12 years).

3. Recent dryland plantation agroforestry (post- 1998)

In 1997, RIRDC funded a review of tropical agroforestry that identified a range of multipurpose species that could produce timber products, while promoting grass production and quality below the canopy, and supplying fodder as dry-season feed for grazing animals (from leaf matter) (Lowry and Seebeck 1997). The four most attractive tree species discussed were; *Albizia lebbeck* (siris), *Albizia procera* (forest siris), *Gmelina arborea* (yemane) and *Tipuana tipu* (tipuna). Expected suitability for these species across different zones was presented, however, growth rates were not discussed, and these species have not been tested extensively in more recent trials.

Recent plantation agroforestry in Australia's tropical savannas, since the start of the Federal Government's NHT program, has had a farmer or community focus. Questions addressed in the last five years are about low volume, high value products from smaller, more intensively managed areas of land. Research projects directed at improving timber species performance through tree improvement and breeding and further species-site matching; developing silvicultural regimes through addition of irrigation to lower rainfall site; and investigating the performance of bush tucker species that are known to provide early returns make up the bulk of recent agroforestry activities.

3.1 Top End Regional Tropical Hardwood Forestry Project

Commencing in 1998, this project was a collaborative project involving GANT, DBIRD, NTDPF (now part of DBIRD), the Northern Territory Forestry and Timber Products Network, and NHT (Clark 2003). The project established 24 farm forestry species trial and demonstration plantings approximately 1 ha each across four target regions (see Figure 1: *Top end regional tropical hardwood forestry project NT*):

- Darwin Rural Area
- Lower Mary River Catchment
- Douglas\Daly
- Katherine

Species and provenances investigated in the trials are shown in Appendix 7.4 (NB. demonstration species not listed). Clarke (2003) reports that early growth results have highlighted four preferred species; African mahogany, *Khaya senegalensis*, teak, *Tectona grandis*, river red gum, *Eucalyptus camaldulensis* and red mahogany, *Eucalyptus pellita*. Growth across sites was highly variable. In general, sites without irrigation had much lower survival, and poorer height and diameter growth than sites with irrigation and good management (Clark 2003).

In the first year of planting several sources of *T. grandis* were planted. Early results suggest that the El Salvador provenance performed better than those from Honduras (Figure 5). Belerica, *Terminalia belerica*, survived the natural ravages; cyclones, fires and termite attack in the older CSIRO trials, and on that basis alone was included in these trials as a survivor in the Northern Territory environment. The timber of this species is of little/no value although the tree is grown for medicinal purposes in India where it is a native (Reilly 2003). Figure 5 shows the average height and diameter growth at age 3.5 years of a range of the species planted in year one of this project. The variations denoted by the error bars are attributed to the differences between good sites (with maintenance and irrigation), and poor sites (little/no maintenance and no irrigation).

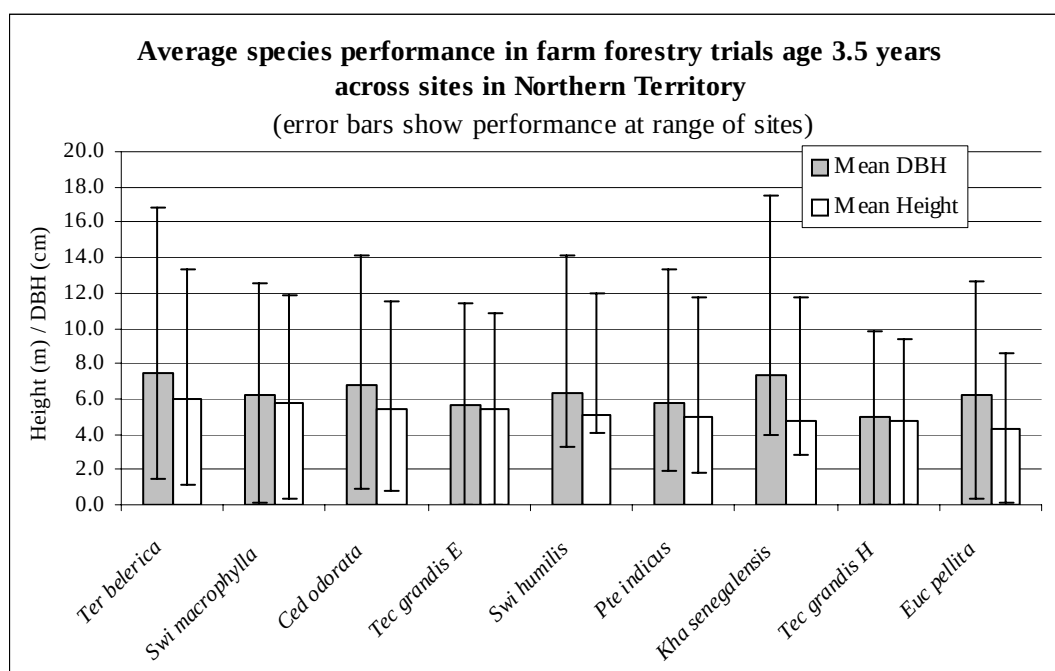


Figure 5. Height (m) and DBH (cm) of a range of species at age 3.5 years, averaged over various irrigated and non-irrigated sites in Northern Territory, error bars indicate the range of good (upper bar) and poor sites (lower bar). NB. *Tec grandis E* = *T. grandis* sourced from El Salvador, *Tec grandis H* = *T. grandis* sourced from Honduras.

Plantings in the second year of the project also produced variable performance across species and sites (Figure 6). For example, after 2.5 years *K. senegalensis* averaged more than 10m in height and 14 cm DBH on good sites, but less than 2m in height on poor sites. Similar variation across sites is reflected in other species.

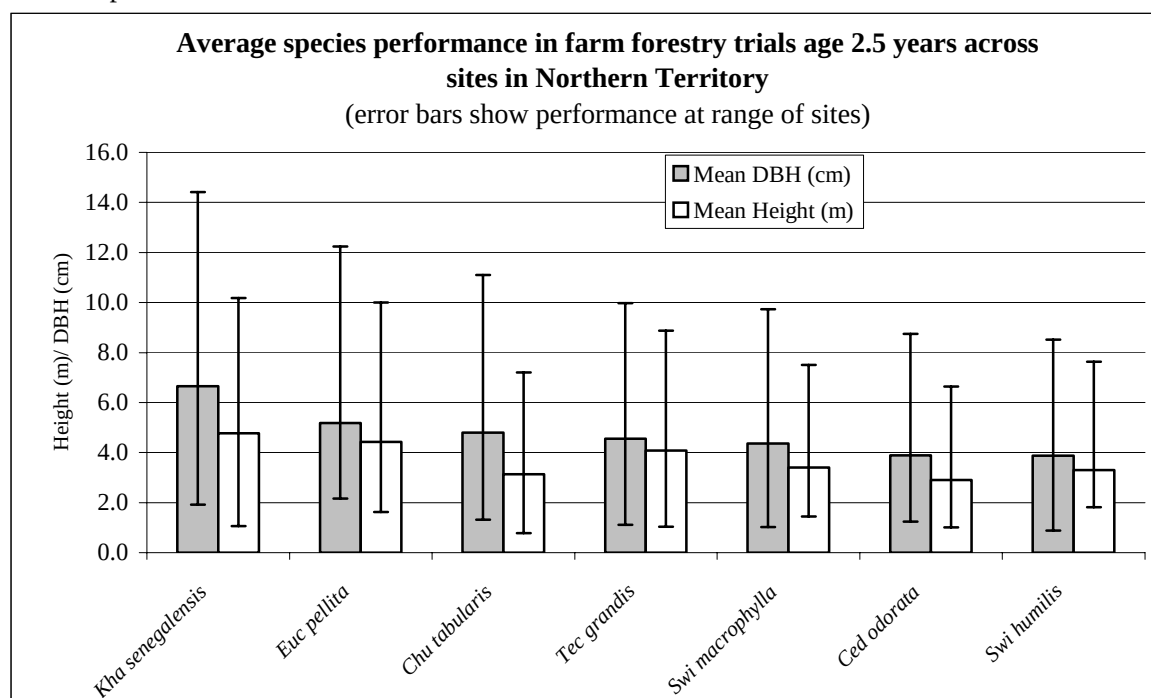


Figure 6. Height (m) and DBH (cm) of a range of species at age 2.5 years, averaged over various irrigated and non-irrigated sites in Northern Territory, error indicate the range of good (upper bar) and poor sites (lower bar).

3.2 Plantation sandalwood expansion in the Ord River Irrigation Area and other regions

Plantation grown sandalwood products have the potential to supplement the Australian sandalwood industry and maintain the global resource currently in decline (Applegate *et al.* 1990; Baruah 1999; Vernes and Robson 2002). The sustainable harvest from Indian native forests is estimated to only yield 1000 tonnes annually (Vernes and Robson 2002), while the world market demand is suggested to be between 5000 and 6000 tonnes (Radomiljac *et al.* 1998c).

Since about 1999, there has been a rapid expansion of *S. album* plantation development in the ORIA. In a recent state-of-the-resource report, Vernes and Robson (2002) suggest that there are approximately 830 ha of sandalwood plantations in the ORIA, with an expected increase of 120-150 ha per annum over the next ten years. This is principally through private companies. In Western Australia, private companies have factored an age of 15 years for the main harvest (Vernes and Robson 2002). One of the private companies in the ORIA, Integrated Tree Cropping (ITC), has refined the CALM-FPC developed system, with attention focusing on establishment silviculture, and management of light and water regimes (Figure 7). In the future, Western Australia's FPC will be focussing on tree breeding and silvicultural treatments to improve growth rates and heartwood formation in *S. album* (Jones 2003). Timber species studied in the Kununurra area by FPC since 1981 are shown in Appendix 7.5.

There are no commercial sandalwood plantations in Queensland. QFRI has a number of small silvicultural trials with various *Santalum* spp. investigating nursery techniques and host specificity (Figure 8). Additionally, QFRI has developed protocols for the clonal propagation of selected materials for several of sandalwood species (Vernes and Robson 2002), and judging from interest, expansion of commercial plantations into north Queensland is expected in future years.



Figure 7. ITC *S. album* plantation, age 12 months with hosts *Sesbania formosa* and teak (*Tectona grandis*), Kununurra, Western Australia.



Figure 8. *S. album*, height 1.8m, age 15 months with hosts *Sesbania sesbans*, and wattle seed host (*Acacia colei*) in QFRI experiment, north Queensland.

3.3 Commercial eucalypt hybrid plantings for marginal lands in northern Australia

This 3-year project (2000-2003) was developed and managed by QFRI in association with the State-wide *Hardwoods Queensland* project, and with funding support from JVAP (see Figure 1: *Commercial eucalypt hybrid plantings for marginal lands in northern Australia*). It aims to select and improve taxa for the 650-900 mm MAR zone of northern Australia that are suitable for commercial hardwood plantations (JVAP 2000a). The project has initiated improvement of the genetic resources of potentially valuable parents of *Eucalyptus* hybrids (river red gum, *E. camaldulensis*) and commenced the testing of a selection of eucalypt hybrids on marginal areas in northern Australia.

In particular the project has established:

- A genetic base (seed orchard) of *E. camaldulensis* that will provide improved seed and be a source of pollen for the production of eucalypt hybrids;
- Five taxa (species – provenance – hybrids) trials across three key zones in Queensland;
- A vegetative propagation study of *Eucalyptus* and *Corymbia* species and hybrids.

Early results of the taxa trials suggest that eucalypt hybrids have good early potential in the region. Selections of these *E.camaldulensis* hybrids have subsequently been planted in other areas of Queensland's tropical savannas (see sections 3.5 and 3.6). The vegetative propagation study has clearly shown that no single treatment is optimal for the rooting of *Eucalyptus* and *Corymbia* species and hybrids and each new taxon will require development of unique protocols to ensure rooting success.

3.4 Hardwoods Queensland

Following on from Queensland's *Private Plantation Initiative* (1997-1999) and continuing the State's push to expand its hardwood plantation resource, a second program was developed to meet the challenges arising from growing hardwood plantations; namely Hardwoods Queensland (1999-2002). Hardwoods Queensland is developing high-value, short-rotation plantation hardwoods using genetic material of suitable native tree species to make rotation lengths for high-value timbers economically viable by reducing them to 25 years or less. It is predicted that wood products from these sustainably produced plantation hardwoods will be sought after for their appearance, hardness, durability and strength. Hardwoods Queensland's approach to plantation hardwoods research is addressing the whole research and development continuum, including genotype selection and mass planting stock production, establishment and management prescriptions, pest and disease protection, processing and marketing (Hardwood Queensland website 2003). Its involvement in agroforestry in tropical savannas was small, but allowed extension of research techniques and resources for a number of associated research projects (see 3.1, 3.3, 3.5, 3.6, and 3.8).

3.5 Developing agroforestry systems for River Frontage Country in Central Queensland

This 3-year project (1999-2002) was developed by DPI in association with the Nebo-Broadsound Landcare Group, and with funding support from NHT. The objective of this project was to demonstrate and evaluate the potential economic and ecological benefits from both managed native forests on frontage country and mixed species plantations on frontage country already cleared. The project established 20 ha of forestry plantations trials and demonstration plantings, and four native forest trial sites managed through thinning and selective harvesting, destocking and burning to improve timber-grass productivity relationships.

Four properties established paired thinned and un-thinned sites in regenerating native forest red gum, *Eucalyptus tereticornis*, on flood prone frontage country. Tree diameter response to thinning has been recorded. In two years post-thinning there was an average increase in diameter per stem of 3.5% in

thinned treatments, compared with 2.5% in un-thinned treatments at the Cardowan site (Figure 9) (Queensland Department of Primary Industries and Central Queensland Forest Association 2002).

A large range of native and some exotic timber species were investigated in demonstration plantations across five sites and three planting seasons. Species, taxa and source information is shown in Appendix 7.6. Trials were established as demonstrations, using property owners/workers and local Landcare volunteers to assist (Figure 10).

Early growth results for all species at all sites are summarised by planting year in Figures 11 and 12. Figure 11 shows highly variable survival between taxa; more than half the taxa have poor early survival (< 75% survival at year 2). Height growth after 2 years highlighted a number of *E. grandis* x *E. camaldulensis* hybrid clones and *E. camaldulensis* provenances as the fastest early performers. Figure 10 also shows the variation in height growth between years 1 and 2 is dissimilar across species highlighting the problems of basing success, or selection, on early performance.

The one-year height data from the plantings established in the second year of the project is shown in Figure 12. Survival was still variable, however only a quarter of species investigated had poor establishment rates (< 75% survival) at year 1. As with the older plantings, a number of *E. grandis* x *E. camaldulensis* hybrid clones, and *E. camaldulensis* provenances were among the best performers.



Figure 9. Native forest management is explained at this forest red gum, *E. tereticornis*) thinning demonstration site at Cardowan, Connors River, in Central Queensland.



Figure 10. Planting a farm forestry demonstration site at Weita, near Nebo, Central Queensland.

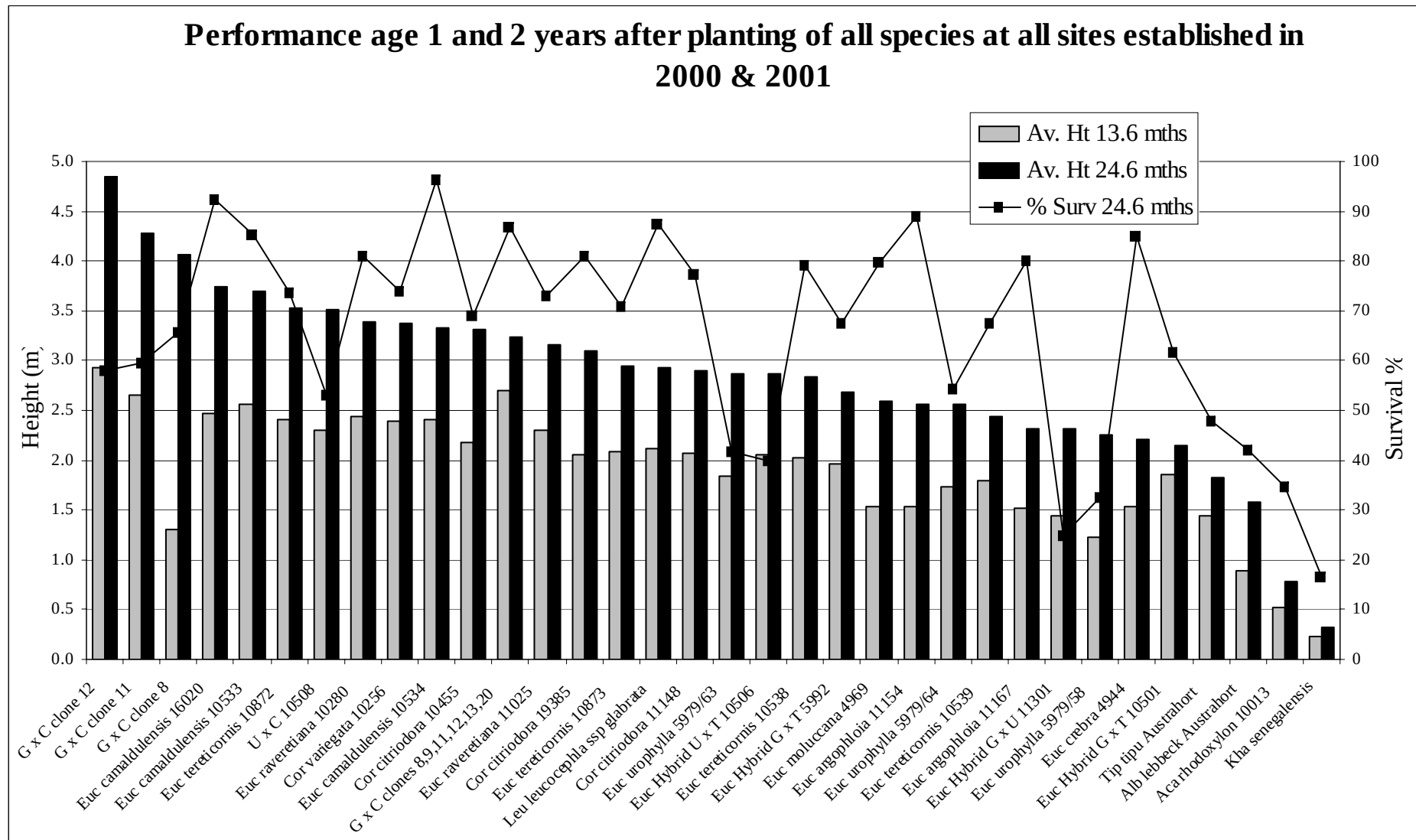


Figure 11. Average height (m) and percent survival at age 13.6 and 24.6 months after planting of all species planted at all sites in year 2000 and 2001 trials.

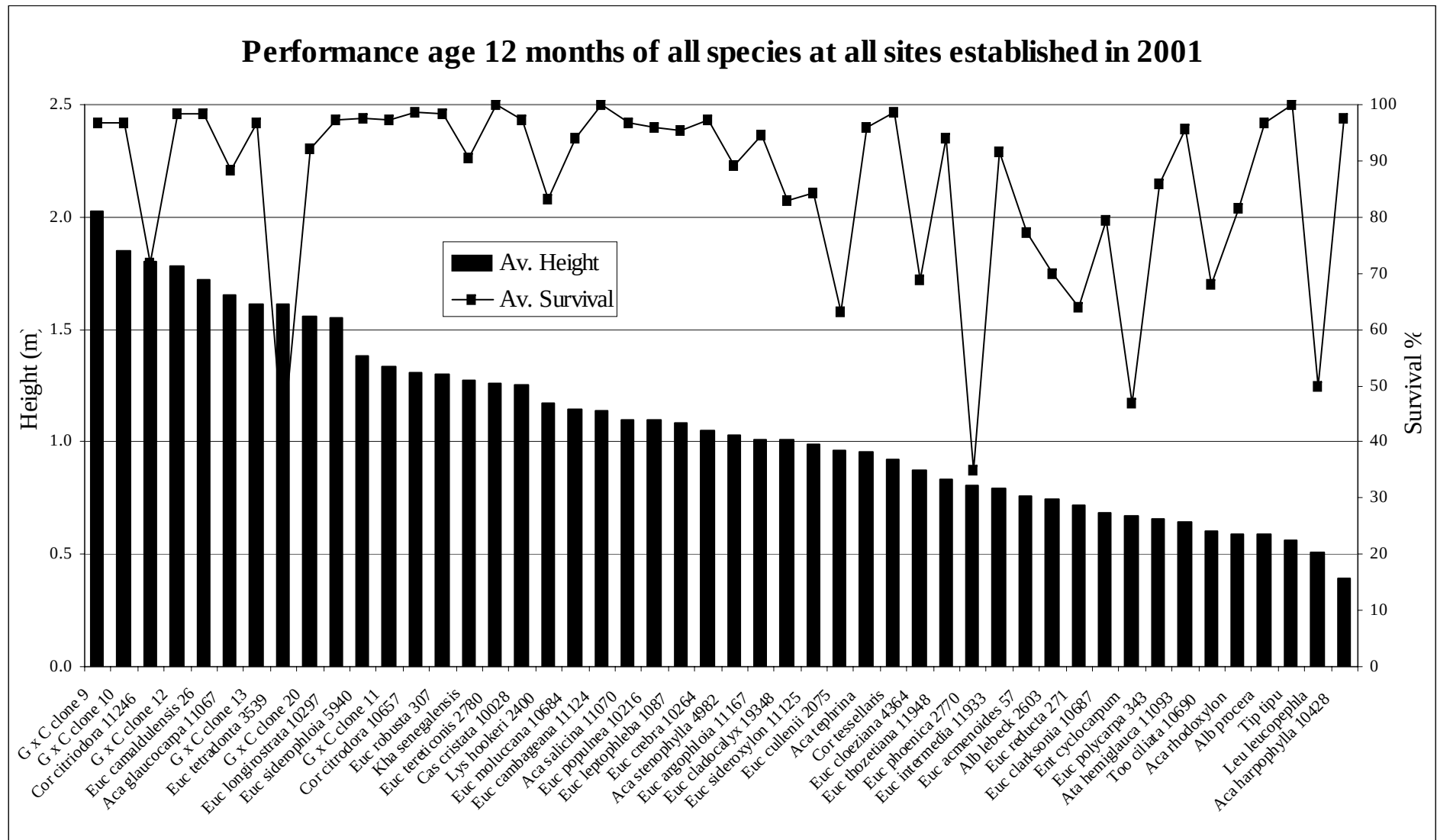


Figure 12. Average height (m) and percent survival at age 12 months after planting of all species planted at all sites in year 2001 trials.

3.6 Demonstration of Farm Forestry for the mid to low rainfall regions of north Queensland

This one-year project (2001 – 2002) was lead by QFRI, with extension support from NQAA and funding from NHT. The project established a range of demonstration taxa trials across sites in medium-low rainfall areas, in the tropical savanna region of north Queensland. Target areas were the Gulf savanna shires, the Upper Burdekin and the Lower Burdekin regions (around the towns of Charters Towers and Ayr respectively) (see Figure 1: *Demonstration of farm forestry in mid to low rainfall regions of north Queensland*).

Seven taxa trials were established with local government and private growers contributing on-ground works (site preparation, irrigation, fencing); five trials were irrigated and two were not. Of the irrigated trials, two of these were irrigated with excess treated-effluent water from town council managed facilities (Normanton and Charters Towers). Native timber species were principally used, with two locally popular exotic timber species, African mahogany, *K. senegalensis*, and West Indian cedar, *Cedrela odorata*, planted on some sites. Species and taxa investigated are shown in Appendix 7.7; not all species were planted on all sites.

At the conclusion of the project, trials were between 5 and 6 months old. Each trial had been assessed for survival and early growth, shown in Figures 13 and 14. Survival and growth was better with irrigation than without. These very early results suggest that on both irrigated and non-irrigated sites river red gum, *Eucalyptus camaldulensis*, and three of the cloned hybrids of *E. grandis* x *E. camaldulensis* showed the best height growth (Figure 15). The high-value cabinet timber species, *K. senegalensis* and *C. odorata* had good early survival, but slow growth; growth rates of these species are expected to improve over time (Figure 16).

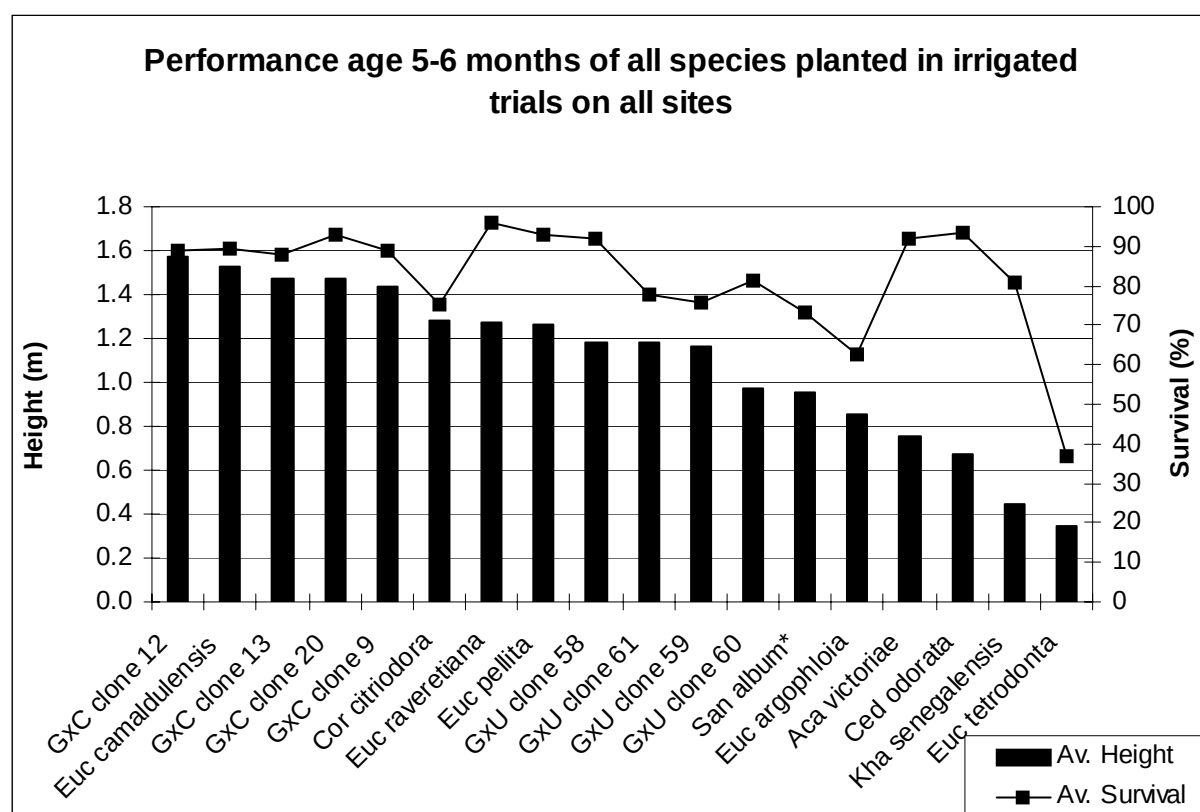


Figure 13. Average height (m) and percent survival at age 5-6 months of all species planted in irrigated demonstration trials. (* = *S. album* at this site was measured at age 10 mths).

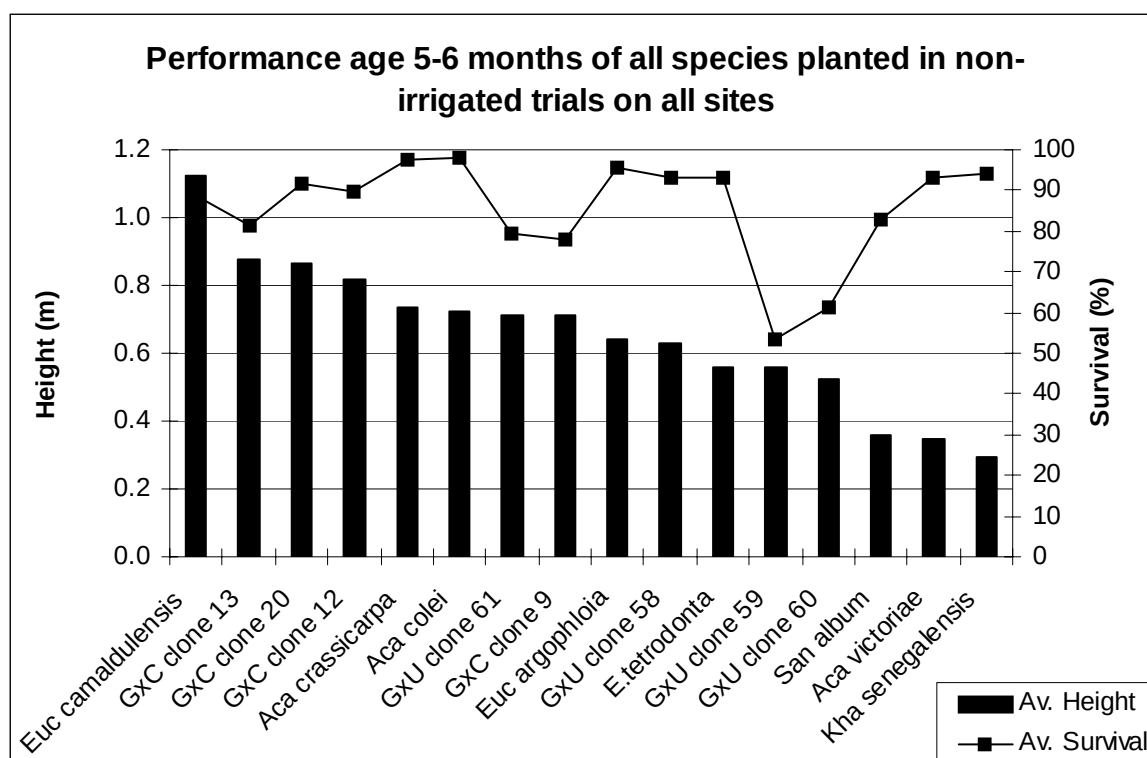


Figure 14. Average height (m) and percent survival at age 5-6 months of all species planted in unirrigated demonstration trials.



Figure 15. Irrigated demonstration farm forestry planting at Charters Towers showing the fast establishment of river red gum, *Eucalyptus camaldulensis*, age 3 months.



Figure 16. African mahogany, *Khaya senegalensis*, 1.6m in height, age 15 months in an unirrigated trial, Walkamin, north Queensland.

3.7 Innovative Farm Forestry Production Systems for Cape York Peninsula

QFRI coordinated this 2-year farm forestry project (2001-2003) in partnership with Comalco, Napranum aboriginal community (Weipa) and Injinoo aboriginal community (near Bamaga), and support from NHT and the Queensland government's Cape York Partnerships program. The project is aimed at selecting suitable previously mined land for forestry plantations and/or enrichment plantings. A range of species demonstration and training trials was established, investigating selection of appropriate commercial species to create multiple use plantation, native forests and regeneration areas.

Indigenous communities were trained in plantation planning and establishment, and in seed collection from other plantation and native forest activities, including mine rehabilitation resources. The project looked at providing Cape York Peninsula communities with an alternative sustainable land use able to be integrated into existing agricultural enterprises and rehabilitated landscapes. The project was used as a starting point for the development of enterprises, including plantations and commercial nurseries and associated value adding options for indigenous communities.

Fieldwork is due to be completed during June 2003, with several plantings established at Injinoo and Weipa (Figure 1: *Innovative farm forestry in Cape York Peninsula*). Plantings are essentially taxa trials used as demonstration and training tools. In addition, endemic species were included in mixed species designs to enhance biodiversity and provide long-term protection of native flora.

3.8 Species testing and genetic improvement of forest trees for Northern Territory

This RIRDC 2-year project is a collaboration between researchers in Queensland and the Northern Territory (QFRI and DBIRD 2001-2003). Following on from earlier species-site trials, this project aims to increase knowledge of suitable fast growing, marketable dryland species. The project tests growth and survival of pure species against hybrid taxa.

Taxa included in this project are: *Corymbia citriodora*, *C. nesophila*, *Eucalyptus camaldulensis*, *E. cloeziana*, *E. pellita*, *E. tetradonta*, *E. grandis* x *E. camaldulensis* hybrids, *E. grandis* x *E. pellita* hybrids, *E. grandis* x *E. urophylla* hybrids, *Khaya senegalensis*, *K. anthotheca*, *Pterocarpus dalbergioides*, *P. macrocarpus*, *Swietenia humilis*, *Chukrasia tabularis*, *Acacia crassicarpa*, and *A. mangium*; source material is shown in Appendix 7.8.

This project established three genetic resource trials:

- Species and taxa trial at Berry Springs, Northern Territory;
- *Eucalyptus pellita* provenance seedling seed orchard at Howard Springs, Northern Territory;
- *Khaya senegalensis* clonal seed orchard in Northern Territory and north Queensland.

Each of these will be valuable for future species and provenance selection and as a resource for improved genetic material. Reporting on this project is being finalised by Northern Territory DBIRD researchers by the end of June 2003.

Early performance of a range of species in the species/taxa trial is shown in Figure 17. At this early stage, *Acacia mangium* is growing very well with an average height of more than 4 m, closely followed by *Pterocarpus macrocarpus*. Gympie messmate, *Eucalyptus cloeziana*, is a desirable hardwood species investigated extensively in QFRI's Hardwoods Queensland project. Low rainfall provenances of this species were selected for this trial, yet their early growth rates still poor in comparison to other, perhaps less tested taxa.

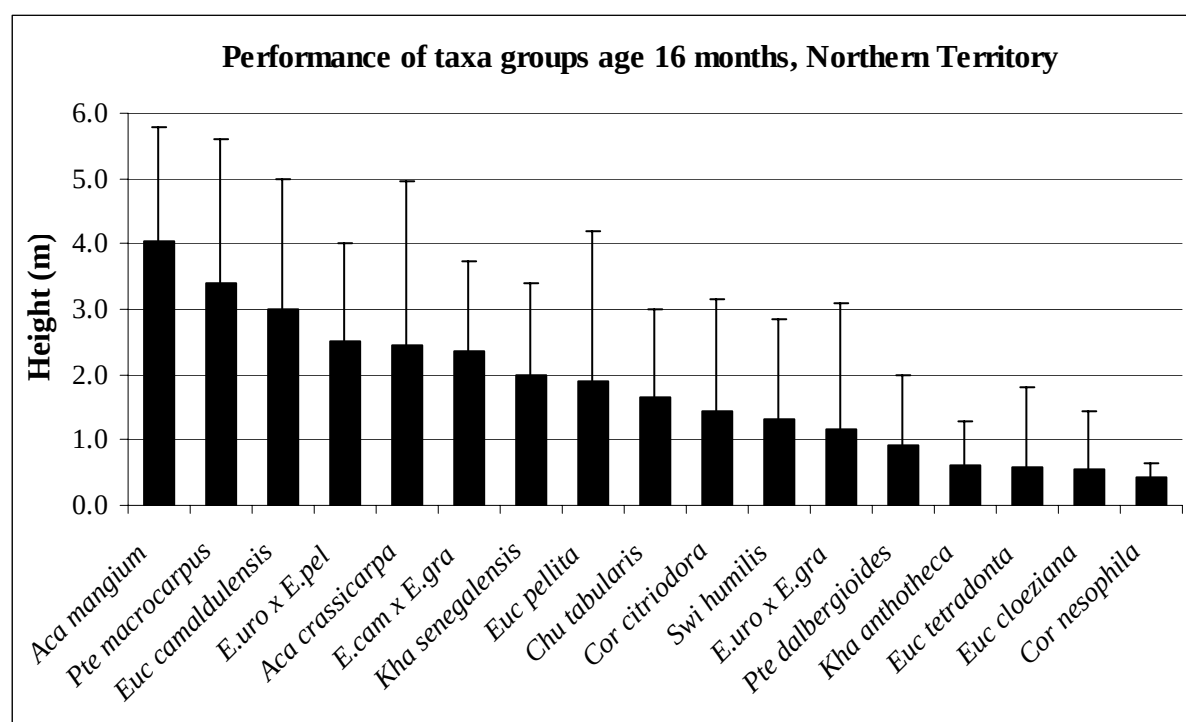


Figure 17. Average height (and maximum height shown by upper bar) of species age 16 months, at Berry Springs site Northern Territory. Provenances/taxa are averaged by 'taxa groups', i.e. all data for *Eucalyptus camaldulensis* provenances were averaged, and are represented in *Euc camaldulensis*.

3.9 Native forest agroforestry and grazing management

The beef cattle grazing industry is the major user and manager of land in the tropical savannas. It contributes hundreds of millions of dollars to regional economies across northern Australia and provides employment for thousands, both directly and indirectly via service industries. Cattle grazing properties have existed in the tropical savannas for more than a century and as such played a significant part in the region's history and development (Burrows 1993; Holmes and Mott 1993; Burrows 2002; CRC Tropical Savannas website 2003).

The pastoral industry of northern Australia differs greatly from that in the south. Broadly speaking the poor soils result in pastures of low nutrient value. To sustain an economically worthwhile herd, properties must therefore be very large. In fact, some of the largest grazing properties in the world are to be found in this region of Australia (Holmes and Mott 1993; CRC Tropical Savannas website 2003).

Climatic and edaphic factors partly determine carrying capacities of land in Australia's tropical savannas, although the relationship between the two is not entirely straightforward. The case where "more rain equals higher carrying capacity" is not always true. To begin with, very high rainfall tends to leach away nutrients from the soil, so that while there may be plenty of lush plant growth during the wet season, its nutritive value is very low. Areas further inland tend to have better soils, more nutritious native pasture species and generally higher carrying capacities (Holmes and Mott 1993; CRC Tropical Savannas website 2003). Then again, these are also the areas that are more susceptible to drought (CRC Tropical Savannas website 2003).

Burrows (2002) reported that there is a vast resource of information on the management of Queensland's 60 million ha of grazed native woodlands, which are assigned for agricultural (grazing) purposes. These woodlands carry around three million cattle and contribute around \$600M to Queensland's economy. They are also a source of timber and non-timber products (e.g. fencing materials, firewood, honey, etc). About 60% of the State's hardwood production is sourced from private forests (Queensland Department of Primary Industries 1998), although not all of this is from grazed woodlands.

Tree-grass dynamics have been the focus of long-term studies in Queensland (Burrows 2002). There is a gradual increase in stand basal area and understorey shrub/tree populations within Queensland's grazed woodlands. This process, known as woodland thickening, is most likely caused by changed fire regimes since livestock grazing became the major land use in these woodlands. The motivation for clearing woody vegetation in the grazed savannas is to improve herbage and animal production, so woodland thickening and its management is a contentious issue with graziers. In a cost-benefit analysis of vegetation clearing, Rolfe (2002), highlights the difficulty in balancing the private benefits gained by landholders with the potential public losses resulting from land clearing. That the most productive land types have already been extensively cleared and that some of the less productive land types (such as eucalypt woodlands) will offer only marginal (production) benefits to landholders, and perhaps increased public losses (as in increased salinity and erosion), is the other side to the argument (Holmes and Mott 1993; Rolfe 2002).

In a recent summary of the debate, Burrows (2002) reiterates that the major objective of woodland forest management practice is to maintain tree grass relationships to maintain grazing value of this land, while still preserving ecological processes provided by deep rooted tree vegetation (Skarpe 1991; Burrows 2002; Scanlan 2002).

4. Discussion

Lack of knowledge about forestry has been identified as a substantial impediment for farm forestry and agroforestry development and expansion (Zorzetto and Chudleigh 1999; JVAP 2000a; Buffier and The Allen Consulting Group 2002). The northern Australia agroforestry sector is small and fragmented across a vast area including three States/Territories each having different resource-based legislation, together with differences in growing conditions. The challenges facing forest growers, at any scale, in this region are large.

Studies on irrigation and water balance, nutrition, espacement and stand management, pests and disease monitoring, and sawing/processing studies to ascertain the characteristics of the timber and identify utilisation potential which are critical to provide growers with the necessary information to evaluate the economic potential of forest activities. Thus far, research into these topics is either patchy or absent.

4.1 High priority species for plantation agroforestry

This report has presented growth data, much of it very young, for high priority species suitable for timber products grown in plantation forestry in Australia's tropical savannas. These include *Eucalyptus camaldulensis* on drier sites and *E. pellita* on wetter sites, and also their hybrids. A number of new, readily available eucalypt hybrids, e.g. *E. grandis* x *E. camaldulensis* clones, or *Corymbia* complex, are showing good survival and early growth rates over a broad range of soils and rainfall zones. *Acacia mangium*, internationally recognised as a pulp and sawn timber species, and *A. crassiparva* have also shown good performance in the savannas higher rainfall areas.

High-value speciality timbers from exotic species have been popular with private growers in the "low volume-high value" style agroforestry system. Growth data discussed in this report suggest that, although early growth rates in young trees are poor compared with eucalypt and *Acacia* species, the older material of species such as African mahogany (*Khaya* spp.) is promising. High-value non-timber products from a plantation resource, such as sandalwood (*S. album*), are attracting a lot of interest. Western Australian studies have shown that early silvicultural testing can lead to substantial improvement in survival and early growth with this high value species. With irrigation, a large area of the tropical savannas could be suitable for integrated plantations of this parasitic species.

Previous reviews have identified that other commercial products from agroforestry systems can help redress the current reliance on imports, and could potentially provide export opportunities (Lefroy and Oldham 1992; Prinsley and Bicknell 1992; Lowry and Seebeck 1997; Zorzetto and Chudleigh 1999; JVAP 2000a; Simpson and Chudleigh 2001; Turvey and Larsen 2001; Buffier and The Allen Consulting Group 2002). Potential products from tropical savanna systems could include biomass, fodder for animals, firewood, fence posts, bush tucker, and environmental services including erosion and salinity control, shade and shelter of wildlife, and biodiversity control. A number of these products are already extracted from native forests, or are suitable to grow in plantations, in Australia's tropical savannas.

The development of native forest agroforestry systems in grazing land management systems could be integrated for multiple benefits (Burrows 1993; Turvey and Larsen 2001; Burrows 2002). Therefore the implementation of agroforestry systems within current grazing land management systems, which maintain vegetation cover in a better-balanced tree-grass relationship, could produce public benefits.

4.2 Suitable locations for plantation agroforestry

From projects conducted thus far, target areas for further agroforestry and plantation research include the irrigated agricultural areas of the ORIA (WA), MDIA (Qld), and BIA (Qld) where seasonally flood irrigated species trials have generated good survival and growth rates, and trees have

applications in reducing water table depth and mitigating effects of salinity. Areas where establishment and dry season irrigation water is available should also be examined for plantation development if suitable soils can be identified. For example, in areas where irrigation from bores, rivers or dams are possible and/or adjacent to rural towns where treated-effluent water is available agroforestry systems should be explored.

Higher rainfall areas of the tropical savannas with appropriate soils on cleared, ex-agricultural or ex-mining land, including those nearby to the towns of Darwin, Katherine, and Weipa will also be suitable for plantation investigations.

5. Recommendations

Agroforestry in northern Australia is in its infancy. Those wishing to invest in farm forestry are faced with shortages of information on all aspects of such new enterprises. The projects reviewed in this study were all short term (1-4 years) and are now completed (to the author's knowledge, there are no existing research projects continuing past June 2003). All of the trials were essentially matching species, or taxa, to site with more recent establishment of genetic improvement studies, provenance seedling seed orchards with key eucalypts (*Eucalyptus camaldulensis* and *Eucalyptus pellita*) and a clonal seedling seed orchard with the promising African mahogany (*Khaya* spp). Now that funding has ceased for the projects reviewed in this study, the R&D investment to date needs being built upon to be of long-term value to growers, communities and industry. Early growth data may not be indicative of long-term growth performance. There is an urgent need for a long-term, strategic approach monitoring and review these and future trials.

Genetic improvement of identified high priority species via appropriate tree breeding will enhance their profitability in agroforestry systems, just as it has done in more conventional plantation forestry. The existing plantings of suitable species and provenances in northern Australia will be the immediate starting point for genetic improvement. For example, selections can be made in appropriate plantings and clonal seed orchards established. Alternatively, local material may be supplemented by appropriate introductions to broaden and enrich local germplasm. Other strategies are also available. Good examples of the implementation of two of these strategies are to be seen in aspects "Species testing and genetic improvement of forest trees in Northern Territory" (see section 3.8). In addition, it is important to enlarge the suite of species/hybrids investigated. For example, Darwin stringybark (*E. tetradonta*), a valuable species occurring naturally throughout far northern Australia, is lacking or represented by only a few provenances, in very few, recent trials. Furthermore, new hybrid combinations (e.g. *Corymbia* complex) are continually emerging and need to be assessed on a range of sites.

It is vital to create an integrated approach to research into exotic species including species-site matching, silviculture, pest and diseases and wood properties across the region. Work of this nature should be confined initially to high priority species already emerging as promising for certain parts of the region eg. *Khaya senegalensis*, *Swietenia* spp., *Pterocarpus* spp. and *Tectona grandis*. Turvey and Larsen (2001) have drawn attention rightly to the need for research to determine optimal silvicultural regimes for agroforestry plantings in northern Australia, including:

- responses to ripping, mounding on various soils;
- irrigation (amount, timing type, water balance, economics, environmental impacts);
- weed control;
- nutrition (fertiliser rates, timing, response);
- espacement and design (mixtures vs. monocultures);
- stand management (pruning and thinning: age, timing and products from these activities);
- monitoring of, and protection from pests & diseases.

Sawing studies and wood quality testing should be undertaken on samples from trees of adequate age or size and number grown in appropriate stand conditions. Most of the exotic species are already known for the excellence of their wood qualities from native forests elsewhere, but their potential under plantation conditions is not well known. This information is essential to evaluating the economics of a plantation resource. Improved market information should be collected for non-timber agroforestry products and services, both those that are unique to tropical savannas, and those that are common to other areas of Australia.

Stakeholders in northern Australia should be invited to collaborate in integrated and focussed research and development projects designed to underpin the development of a sustainable

agroforestry industry in the region. This could be facilitated through the revised 2020 vision, perhaps in a Regional Plantation Committee, or similar structure. A result should be that agroforestry research and development in Australia's tropical savannas be integrated as in models like the "Hardwoods Queensland" project. The CRC Tropical Savannas could coordinate such a group.

More than 30 years of research on woodland management in grazing lands in Queensland can benefit the implementation, success and integration of native forest agroforestry systems across Australia's tropical savannas. Research, development and extension of information could address:

- vegetation thickening/thinning processes and management;
- tree-Grass relationships as affected by rainfall, soils, tree basal area, ground cover/pasture condition and quality;
- tree growth rates at varying density/thinning regimes and other silvicultural practices;
- ecosystem services (carbon, salinity, biodiversity, hydrology) as influenced by woodland structure;
- tree cover seed yield/timing/and litter fall;
- factors affecting tree seedling regeneration and tree coppicing and management of this;
- timber and non-timber products from native forests, as sustainable products from vegetation management;
- definition of mechanisms by which trees in the landscape can be recognised and valued.

It is important to address policy solutions to attract investment and participation in all systems of agroforestry. For example, most of the cleared, potentially available land for plantation expansion is on leasehold land. There is a need therefore to resolve forest property rights on leasehold land, to remove any impediment to further development.

5.1 Specific recommendations for further research and development

1. Maintain genetic improvement of identified high priority species via appropriate tree breeding and expand the representation of new species/hybrids in future trials.
2. Develop integrated research into exotic species including species-site matching, silviculture, pest and diseases and wood properties.
3. Determine optimal silvicultural regimes for agroforestry plantings.
4. Undertake sawing studies, wood qualities testing on samples from tree grown in stand conditions.
5. Collect market information for timber and non-timber agroforestry products and services.
6. Utilise research on woodland management in grazing lands in Queensland to implement integrated native forest management across all Australia's tropical savannas.
7. Address policy solutions to attract investment and participation in all systems of agroforestry.
8. Form a Regional Plantation/Forest Committee for the tropical savannas region, that would invite collaboration for integrated and focussed R, D & E projects.

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7. Appendices

7.1 CSIRO Forestry Trials Northern Territory 1969-1979

Table shows species/taxa used and source information where available, plus health comments on two assessments (data provided by DBIRD 2003).

Species	Seedlot no. and source details	Comments on assessment in 1982 and 2002
<i>Adina cordifolia</i>	S8275 Sudan	Health satisfactory, thinned in 1999 to 848 spha
<i>Alstonia scholaris</i>	S8476 India	Health poor 1982, in 2002 no survivors
<i>Pterocarpus indicus</i>	D82 Darwin Bot Gardens	Health satisfactory. Alternate rows planted with <i>Callitris intratropica</i> , all <i>C.intratropica</i> thinned at age 5 yrs
<i>Eucalyptus nesophila</i>	D175 Melville Is	Health satisfactory
<i>Eucalyptus nesophila</i>	D175 Melville Is	Health satisfactory
<i>Pterocarpus santalinus</i>	D317 Radio Block	Health mediocre-good across sites in 1982, only assessed Gunn Point planting in 2002; satisfactory
<i>Terminalia belerica</i>	S9432 India	Health good
<i>Tectona grandis</i>	Unknown	Health poor in 1982, not assessed in 2002
<i>Tectona grandis</i>	Provenance trial	Health good in 1982, but poor in 2002.
Seedlots investigated:		Danida Seed lot S10361/3008 Mysore (India)
		3016 Mysore (India)
		3021 Kerala (India)
		3034 Orissa (India)
		3040 (Thailand)
		3042 (Thailand)
		3049 (Java)
		S9615 Taungoo (Burma)
		D459 Melville Island (NT)
<i>Anthocephalus cadamba</i>	Various provenances including: S8365 India	Health of remaining trees good in 1982, in 2002 no survivors
<i>Eucalyptus pellita</i>	Cardwell	Health good in 1982, but survival poor in 2002
<i>Khaya grandifolia</i>	D488 Ivory Coast	Health good
<i>Melaleuca cajuputi</i>	Local D413	Health good in 1982, but survival poor in 2002
<i>Eucalyptus brassiana</i>	10970 Ex CSIRO	Health good, trees all have a lean
<i>Acacia mangium</i>	S12251 Nth Qld	Health good in 1982, in 2002 no survivors
<i>Xylia dolabriformis</i>	S9243 Burma	Health satisfactory in 1982, in 2002 no survivors
<i>Khaya senegalensis</i>	Provenance trial	Health satisfactory in 2002, not assessed 1982.
Seedlots investigated:		Seed lot D500 Ghana
		Seed lot D522 Noumea
		Seed lot S10066 Senegal
		Seed lot S10053 Uganda

7.2 ACIAR Fuelwood, Fodder and Agroforestry north Queensland

Table shows species/taxa used and source information where available.

Species	Common Name	CSIRO Seedlot No.
<i>Acacia ampeliceps</i>	salt wattle	15734
<i>Acacia aneua</i> (Noonbah)	mulga	NIL
<i>Acacia bancroftii</i>	Bancroft's wattle	15589
<i>Acacia burrowii</i>	Burrow's wattle	15556
<i>Acacia crassicarpa</i>	brown salwood	15128
<i>Acacia cretata</i>		14588
<i>Acacia deanei</i>	Dean's wattle	15470
<i>Acacia difficilis</i>		16173
<i>Acacia eriopoda</i>	pindan	17164
<i>Acacia fasciculifera</i>	rose wattle	15469
<i>Acacia harpophylla</i>	brigalow	16577
<i>Acacia holosericea</i>	silver leafed wattle	16143
<i>Acacia murrayana</i>	colony wattle	14119
<i>Acacia neriifolia</i>	oleander wattle	14735
<i>Acacia tumida</i>		17046
<i>Acacia ramulosa</i>	black gidgee	13795
<i>Acacia salicina</i>	cooba	16648
<i>Acacia saligna</i>	golden wreath wattle	15791
<i>Acacia stenophylla</i>	river cooba	14670
<i>Acacia torulosa</i>	deep gold wattle	14183
<i>Acacia torulosa</i>	deep gold wattle	17490
<i>Alphitonia petrei</i>	pink ash	15506
<i>Casuarina cristata</i>	belah	15216
<i>Eucalyptus argillacea</i>	northern grey box	13942
<i>Eucalyptus argophloia</i>	western white gum	15504
<i>Eucalyptus camaldulensis</i>	river red gum	14338
<i>Eucalyptus camageana</i>	Coowarra box	12937
<i>Eucalyptus cloeziana</i>	Gympie messmate	13543
<i>Eucalyptus intertexta</i>	western red box	17244
<i>Eucalyptus leptophleba</i>	molloy red box	15248
<i>Eucalyptus melanophloia</i>	silver-leafed ironbark	15220
<i>Eucalyptus microtheca</i>	coolibah	15944
<i>Eucalyptus punctata</i> var long	grey gum	16008
<i>Eucalyptus raveretiana</i>	black ironbox	17272
<i>Eucalyptus staigerana</i>	lemon-scented ironbox	13631
<i>Eucalyptus tereticornis</i>	forest red gum	12965
<i>Eucalyptus thozetiana</i>	yapunyah	17087
<i>Grevillea pteridifolia</i>	fern-leafed silky oak	16575
<i>Melaleuca bracteata</i>	river tea-tree	14903
<i>Sesbania formosa</i>	corkwood	17363

7.3 Lower Burdekin TreeCare & salinity trials in north Queensland

Table shows species/taxa used and source information where available from (Snell and Brooks 2001)

Species	Common name	Seedlot No.	Source details
<i>Acacia auriculiformis</i>	black wattle	16145	Wenlock River
<i>Acacia auriculiformis</i>	black wattle	16484	Morehead River
<i>Acacia crassicarpa</i>	brown salwood	212	Kuranda
<i>Agathis robusta</i>	kauri pine	2629	Rock gardens
<i>Araucaria cunninghamii</i>	hoop pine	1364	Taromeo
<i>Azaderachta indica</i>	Neem		India
<i>Callitris collumellaris</i> var <i>campestris</i>	northern cypress pine		Chinchilla
<i>Casuarina cristata</i>	belah	1089	Bringalily
<i>Cedrela odorata</i>	West Indian cedar	25013	BQ
<i>Eucalyptus alba</i>	poplar gum		Ingham
<i>Eucalyptus argophloia</i>	western white gum	480	Nudley
<i>Eucalyptus brockwayi</i>		2156	Nindethana Seed
<i>Eucalyptus camaldulensis</i>	river red gum	15049	Bullock Ck
<i>Eucalyptus camaldulensis</i>	river red gum	16230	Emu Ck
<i>Eucalyptus camaldulensis</i>	river red gum	12968	Burdekin River
<i>Eucalyptus camaldulensis</i>	river red gum	13264	Quilpie
<i>Eucalyptus camaldulensis</i>	river red gum	12499	Charleville
<i>Eucalyptus camaldulensis</i>	river red gum	12498	Goondiwindi
<i>Eucalyptus camaldulensis</i>	river red gum	B34	Petford - Irvinebank
<i>Eucalyptus citriodora</i>	lemon-scented gum	52	Davies Ck
<i>Eucalyptus citriodora</i>	lemon-scented gum	2104	Irvinebank
<i>Eucalyptus citriodora</i>	lemon-scented gum		Gibbs Ck
<i>Eucalyptus cloeziana</i>	Gympie messmate	121	Cardwell
<i>Eucalyptus cloeziana</i>	Gympie messmate	122	Toolara
<i>Eucalyptus cloeziana</i>	Gympie messmate	124	Emerald
<i>Eucalyptus cloeziana</i>	Gympie messmate	125	Clemant
<i>Eucalyptus cloeziana</i>	Gympie messmate	130	Eungella holding
<i>Eucalyptus cloeziana</i>	Gympie messmate		Ravenshoe
<i>Eucalyptus cloeziana</i>	Gympie messmate	128	Watsonville
<i>Eucalyptus cloeziana</i>	Gympie messmate	7	Coominglah
<i>Eucalyptus crebra</i>	ironbark	110	Maryborough
<i>Eucalyptus drepanophylla</i>	ironbark	87	Barron River
<i>Eucalyptus grandis</i>	rose gum		Ravenshoe
<i>Eucalyptus intermedia</i>	red bloodwood	196	Mt Garnet
<i>Eucalyptus intermedia</i>	red bloodwood	198	Danbulla
<i>Eucalyptus leptophleba</i>	molloy red box	1087	Windsor
<i>Eucalyptus maculata</i>		181	Dunmora
<i>Eucalyptus microcorys</i>	tallowwood	2596	Amamoor
<i>Eucalyptus molucana</i>	grey box	2015	Herberton
<i>Eucalyptus paniculata</i>	grey ironbark	301	Seed Service WA
<i>Eucalyptus pellita</i>	red mahogany	291	Kuranda
<i>Eucalyptus pellita</i>	red mahogany	289	Kuranda
<i>Eucalyptus raveretiona</i>	black ironbox	15943	Rockhampton
<i>Eucalyptus robusta</i>	swamp mahogany	306	Cowra

Species	Common name	Seedlot No.	Source details
<i>Eucalyptus robusta</i>	swamp mahogany	15945	Byfield
<i>Eucalyptus tereticornis</i>	forest red gum	14846	Cardwell
<i>Eucalyptus tereticornis</i>	forest red gum	13	Imbil
<i>Eucalyptus tereticornis</i>	forest red gum	379	Ravenshoe
<i>Eucalyptus tessellaris</i>	carbeen	365	Tolga
<i>Eucalyptus urophylla</i>	Timor gum	14532	Flores Island
<i>Flindersia brayleyana</i>	Queensland maple		Lake Eacham
<i>Grevillea robusta</i>	southern silky oak	2345	Jimna
<i>Khaya senegalensis</i>	African mahogany		Africa via Darwin St Trees
<i>Paulownia fortunei</i>	paulownia	Powton	China
<i>Paulownia tormentosa</i>	paulownia		China
<i>Pinus caribaea (hond.)</i>	Caribaeian pine	2199	Glenbora Best
Pinus hybrid	Caribaeian pine		QFS - Toolara

7.4 Top End Regional Tropical Hardwood Forestry

Table shows species/taxa used and source information where available.

Species	Common Name
<i>Cedrela odorata</i>	West Indian cedar
<i>Chukrasia tabularis</i>	East Indian mahogany
<i>Chukrasia velutina</i>	Indian mahogany
<i>Dalbergia sp.</i>	Borneo teak
<i>Enterolobium cyclocarpum</i>	Guanacaste
<i>Khaya senegalensis</i>	African mahogany
<i>Pterocarpus indicus</i>	Padauk/ PNG rosewood
<i>Pterocarpus macrocarpus</i>	rosewood
<i>Swietenia humilis</i>	Central American mahogany
<i>Swietenia macrophylla</i>	American mahogany
<i>Tectona grandis</i>	teak
<i>Terminalia belerica</i>	belerica
<i>Adenanthera pavonina</i>	red bead tree
<i>Callitris intratropica</i>	cypress pine
<i>Canarium australium</i>	canarium
<i>Castanospermum australe</i>	blackbean
<i>Elaeocarpus grandis</i>	blue quandong
<i>Erythrophleum chlorostachys</i>	Cooktown ironwood
<i>Eucalyptus camaldulensis</i>	river red gum
<i>Eucalyptus pellita</i>	red mahogany
<i>Melaleuca cajuputi</i>	Paperbark/ cajuput
<i>Melaleuca leucadendra</i>	paperbark
<i>Nauclea orientalis</i>	Leichardt
<i>Syzigium armstrongii</i>	bush apple
<i>Terminalia microcarpa</i>	damson
<i>Toona ciliata</i>	red cedar

7.5 CALM-FPC species tested in Kununurra plantations from 1981

Table shows species/taxa used, no seedlot details provided (data from Jones, 2003).

Species	Common Name
<i>Acacia aulococarpa</i>	brown salwood
<i>Acacia auriculiformis</i>	black wattle
<i>Acacia crassicaarpa</i>	brown salwood
<i>Acacia mangium</i>	brown salwood
<i>Acacia trachycarpa</i>	sweet scented mini-ritchi
<i>Adenanthera parvonina</i>	false sandalwood
<i>Albizzia lebeck</i>	siris
<i>Anacardium occidentale</i>	cashew nut
<i>Anthocephalus chinensis</i>	Cape York leichhardt
<i>Azadirachta indica</i>	neem
<i>Bauhinia cunninghamii</i>	bauhinia
<i>Cassia siamea</i>	senna
<i>Castanospermum australe</i>	black bean
<i>Casuarina equisetifolia</i>	beach she-oak
<i>Cathormium umbellatum</i>	Cathormium/rosewood
<i>Cedrela odorata</i>	West Indian cedar
<i>Cordia sebestina</i>	Cordia/etou
<i>Dalbergia cochinchinensis</i>	
<i>Dalbergia latifolia</i>	East Indian rosewood
<i>Dalbergia melanoxylon</i>	African blackwood
<i>Dalbergia retusa</i>	rosewood
<i>Dalbergia sissoo</i>	Indian rosewood
<i>Enterolobium cyclocarpum</i>	Guanacaste
<i>Eucalyptus camaldulensis</i>	River red gum
<i>Eucalyptus jensenii</i>	wandi ironbark
<i>Eucalyptus papuana</i>	ghost gum
<i>Gmelina arborea</i>	yemane
<i>Instia bijuga</i>	kwila
<i>Khaya anthotheca</i>	African mahogany
<i>Khaya senegalensis</i>	African mahogany
<i>Melaleuca leucodendron</i>	paperbark
<i>Pongamia pinnata</i>	Indian beech
<i>Pterocarpus angolensis</i>	muninga
<i>Pterocarpus indicus</i>	amboyna
<i>Pterocarpus macrocarpus</i>	Burma paduak
<i>Pterocarpus marsupium</i>	
<i>Santalum album</i>	Indian sandalwood
<i>Santalum austrocaledonicum</i>	sandalwood
<i>Santalum macgregorii</i>	sandalwood
<i>Sesbania formosa</i>	corkwood
<i>Swietenia humilis</i>	Central American mahogany
<i>Swietenia macrophylla</i>	American mahogany
<i>Swietenia mahogani</i>	Spanish mahogany
<i>Tectona grandis</i>	teak
<i>Terminalia pilulonis</i>	
<i>Terminalia platyphylla</i>	chestnut tree
<i>Toona ciliata</i>	red cedar

7.6 Developing agroforestry systems for river frontage central in Central Queensland

Table shows species/taxa used and source information where available.

Species	Common Name	Seed Batch No./supplier	Source details
<i>Acacia aulacocarpa</i>	brown salwood	11099	n/a
<i>Acacia auriculiformis</i>	northern black wattle	CSIRO	Roberts Creek QLD
<i>Acacia cambagei</i>	gidgee	n/a	Cape River QLD
<i>Acacia crassicarpa</i>	brown salwood	16128	n/a
<i>Acacia glaucocarpa</i>	glory wattle	11067	SF 865 Byfield
<i>Acacia harpophylla</i>	brigalow	10428	Bioela
<i>Acacia harpophylla</i>	brigalow	16577	Chinchilla QLD
<i>Acacia pendula</i>	myall	n/a	n/a
<i>Acacia rhodoxylon</i>	spear wattle/rosewood	10013	Clermont
<i>Acacia rhodoxylon</i>	spear wattle/rosewood	n/a	unknown
<i>Acacia salicina</i>	cooba sally wattle	11070	Bioela
<i>Acacia salicina</i>	cooba sally wattle	18543	Lake Buchanan QLD
<i>Acacia stenophylla</i>	river cooba	4982	Theodore
<i>Acacia stenophylla</i>	river cooba	19029	Stuart Ck WA
<i>Acacia tephрина</i>	boree	n/a	n/a
<i>Albizia canesiens</i>	belmont siris	n/a	Belmont (Rocky)
<i>Albizia lebbbeck</i>	siris	Austrahort	India/Burma via Qld trees
<i>Albizia lebbbeck</i>	siris	2603	Rockhampton
<i>Albizia lebbbeck</i>	siris	2603	n/a
<i>Albizia procera</i>	forest siris	n/a	Mackay
<i>Albizia procera</i>	forest siris	n/a	Eton Range QLD
<i>Atalaya hemiglauca</i>	whitewood	11093	Cunnamulla
<i>Casuarina cristata</i>	belah	10028	Yaamba
<i>Casuarina cristata</i>	belah	Austrahort	Yaamba QLD
<i>Casuarina cunninghamiana</i>	river she-oak	13517	Annan River QLD
<i>Casuarina glauca</i>	swamp she-oak	17200	Aberdare Colliery WA
<i>Casuarina obesa</i>	swamp she-oak	15396	Dumbleyoung Lake WA
<i>Chuckrasia tabularis</i>	East Indian rosewood	20124	n/a
<i>Chuckrasia tabularis</i>	East Indian rosewood	28006	n/a
<i>Corymbia citriodora</i>	lemon-scented gum	10455	Biloela
<i>Corymbia citriodora</i>	lemon-scented gum	11148	Hughenden
<i>Corymbia citriodora</i>	lemon-scented gum	19385	Cheviot Hills
<i>Corymbia citriodora</i>	lemon-scented gum	10657	SF 754 Herberton
<i>Corymbia citriodora</i>	lemon-scented gum	11246	Yeppoon
<i>Corymbia citriodora</i>	lemon-scented gum	12274	Biloela
<i>Corymbia tessellaris</i>	carbeen	n/a	Mackay
<i>Corymbia tessellaris</i>	carbeen	18166	Moura QLD
<i>Corymbia variegata</i>	spotted gum	19666	Richmond Range SF NSW
<i>Corymbia variegata (maculata)</i>	spotted gum	10256	SF70 Kragra
<i>Dalbergia latifolia</i>	Indian rosewood	Austrahort	Dry Savanna – Nat. Academy Sc
<i>Delbergia melanoxylon</i>	East African blackwood	AFF	Dry and rocky hills - Nat. Acad. Sc
<i>Delbergia sissoo</i>	Indian rosewood	n/a	(salt tolerant) - Nat Acad Sc
<i>E.grandis</i> x <i>E.camaldulensis</i>	eucalypt hybrid	clone 9	Yuruga Nursery
<i>E.grandis</i> x <i>E.camaldulensis</i>	eucalypt hybrid	clone 10	Yuruga Nursery
<i>E.grandis</i> x <i>E.camaldulensis</i>	eucalypt hybrid	clone 13	Yuruga Nursery
<i>E.grandis</i> x <i>E.camaldulensis</i>	eucalypt hybrid	clone 20	Yuruga Nursery
<i>E.grandis</i> x <i>E.camaldulensis</i>	eucalypt hybrid	clone 8	Yuruga Nursery

Species	Common Name	Seed Batch No./supplier	Source details
<i>E.grandis</i> x <i>E.camaldulensis</i>	eucalypt hybrid	clone 11	Yuruga Nursery
<i>E.grandis</i> x <i>E.camaldulensis</i>	eucalypt hybrid	clone 12	Yuruga Nursery
<i>E.grandis</i> x <i>E.tereticornis</i>	eucalypt hybrid	5992	n/a
<i>E.grandis</i> x <i>E.tereticornis</i>	eucalypt hybrid	10501	n/a
<i>E.grandis</i> x <i>E.urophylla</i>	eucalypt hybrid	11301	n/a
<i>E.urophylla</i> x <i>E.camaldulensis</i>	eucalypt hybrid	10508	n/a
<i>E.urophylla</i> x <i>E.tereticornis</i>	eucalypt hybrid	10506	n/a
<i>Enterolobium cyclocarpum</i>	earpod tree	n/a	Houndurus
<i>Enterolobium cyclocarpum</i>	earpod tree	n/a	Dry sites survival - Nat. Adac. Sc.
<i>Eucalyptus acmenoides</i>	white mahogany	57	Cardwell
<i>Eucalyptus argophloia</i>	western white gum	11154	Chinchilla
<i>Eucalyptus argophloia</i>	western white gum	11167	Chinchilla
<i>Eucalyptus argophloia</i>	western white gum	11246	Dalby
<i>Eucalyptus camaldulensis</i>	river red gum	10533	Petford
<i>Eucalyptus camaldulensis</i>	river red gum	10534	Kennedy River
<i>Eucalyptus camaldulensis</i>	river red gum	16020	Petford (via Zimbabwe)
<i>Eucalyptus camaldulensis</i>	river red gum	26	Ward R, Charleville
<i>Eucalyptus camaldulensis</i>	river red gum	10630	Petford
<i>Eucalyptus cabbageana</i>	Dawson river gum	11124	Charters Towers
<i>Eucalyptus cabbageana</i>	Dawson river gum	12503	Charleville QLD
<i>Eucalyptus cladocalyx</i>	southern sugar gum	19348	Wilmington, SA
<i>Eucalyptus clarksonia</i>	Clarkson's bloodwood	10687	Walkamin
<i>Eucalyptus cloeziana</i>	Gympie messmate	4364	Woondum
<i>Eucalyptus coolibah</i>	coolabah	12494	Moura
<i>Eucalyptus crebra</i>	narrow-leaved red ironbark	4944	The Caves
<i>Eucalyptus crebra</i>	narrow-leaved red ironbark	10264	Clermont
<i>Eucalyptus crebra</i>	narrow-leaved red ironbark	16006	Chinchilla
<i>Eucalyptus cullenii</i>	Cullen's ironbark	2075	Mount Molloy
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#2	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#4	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#13	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#22	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#24	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#27	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#28	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#29	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#30	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#33	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#34	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#35	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#36	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#37	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#38	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#40	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#43	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#44	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#48	n/a
<i>Eucalyptus hybrid</i>	Saltgrow hyb eucs	#49	n/a
<i>Eucalyptus longirostrata</i>	grey gum	19702	aff (var Mt Moffat) QLD
<i>Eucalyptus moluccana</i>	grey box	4969	The Caves

Species	Common Name	Seed Batch No./supplier	Source details
<i>Eucalyptus longirostrata</i>	grey gum	10297	SF 302 Ballon
<i>Eucalyptus intermedia</i>	red bloodwood	11933	Wondecla
<i>Eucalyptus leptophleba</i>	molloy red box	1087	SF 144 Windsor
<i>Eucalyptus moluccana</i>	grey box	10684	Gunnawarra Stat.
<i>Eucalyptus orgadophila</i>	mountain coolibah	CSIRO	N Clermont QLD
<i>Eucalyptus phoenica</i>	scarlet gum	2770	Cooktown
<i>Eucalyptus polycarpa</i>	long fruited bloodwood	343	SF 1229 Kuranda
<i>Eucalyptus populnea</i>	poplar box	10216	Clermont
<i>Eucalyptus populnea</i>	poplar box	CSIRO	Menindee NSW
<i>Eucalyptus raveretiana</i>	black ironbox	10280	Rockhampton
<i>Eucalyptus raveretiana</i>	black ironbox	11025	Yeppoon
<i>Eucalyptus raveretiana</i>	black ironbox	11025	Rockhampton QLD
<i>Eucalyptus reducta</i>	stringybark	271	SF 144 Windsor
<i>Eucalyptus robusta</i>	swamp mahogany	307	Frazer Island
<i>Eucalyptus robusta</i>	swamp mahogany	14945	Byfield QLD
<i>Eucalyptus siderophloia</i>	grey ironbark	5940	SF 283 Benarkin
<i>Eucalyptus sideroxylon</i>	red ironbark	11125	unknown
<i>Eucalyptus sideroxylon</i>	red ironbark	19557	Gilgandra NSW
<i>Eucalyptus tereticornis</i>	forest red gum	10539	Helenvale
<i>Eucalyptus tereticornis</i>	forest red gum	10872	Laura (via a Z SO)
<i>Eucalyptus tereticornis</i>	forest red gum	10873	Mt. Garnet (via a Z SO)
<i>Eucalyptus tereticornis</i>	forest red gum	10538	Mt. Molloy
<i>Eucalyptus tereticornis</i>	forest red gum	2780	Burdekin R
<i>Eucalyptus tereticornis</i>	forest red gum	n/a	Laura
<i>Eucalyptus tetradonta</i>	Darwin stringybark	3539	Mutchilba
<i>Eucalyptus thozetiana</i>	yapunyah	11948	unknown
<i>Eucalyptus thozetiana</i>	yapunyah	20480	Clermont QLD
<i>Eucalyptus urophylla</i>	Timor gum	5979/58	Dongmen (China)
<i>Eucalyptus urophylla</i>	Timor gum	5979/63	Dongmen (China)
<i>Eucalyptus urophylla</i>	Timor gum	5979/64	Dongmen (China)
<i>Grevillea robusta</i>	southern silky oak	20463	Boyd River NSW
<i>Grevillea striata</i>	beefwood	17254	Alice Springs NT
<i>Khaya senegalensis</i>	African mahogany	Major Ck Nursery	near Townsville
<i>Khaya senegalensis</i>	African mahogany	11922	Weipa
<i>Khaya senegalensis</i>	African mahogany	n/a	Tanzania
<i>Khaya senegalensis</i>	African mahogany	20418	Darwin NT
<i>L.leucocephlia x L.pallita</i>		n/a	U of Q (sterile)
<i>Leucaena leucocephla ssp. glabrata</i>	leucaena	Commercial seed	Peru
<i>Leucaena leucocephla ssp. glabrata</i>	leucaena	K8	Peru
<i>Lysiphyllum hookeri</i>	bauhinia	2400	Duaringa
<i>Melaleuca leucadendra</i>	long leafed paperbark	Austrahort	Buffalo Ck NT
<i>Melia azedarach</i>	white cedar	n/a	n/a
<i>Samanea saman</i>	rain tree	n/a	African
<i>Tipuana tipu</i>	tipuana	Austrahort	Street trees, Brisbane
<i>Tipuana tipu</i>	tipuana	n/a	Brisbane
<i>Toona ciliata</i>	red cedar	10690	Atherton

7.7 Demonstration of Farm Forestry for the mid to low rainfall regions of north Queensland

Table shows species/taxa used and source information where available.

Native Species Planted	Common names	Seedlot No.	Source details
<i>Acacia colei</i>	Cole's wattle	11907	Mt Isa
<i>Acacia victoriae</i>	Prickly wattle	11089	Cunnamulla
<i>Cedrella olerata</i>	West Indian Cedar	unknown	unknown
<i>Corymbia citriodora</i>	Lemon-scented gum	10697	Cheviot Hills
<i>Eucalyptus argophloia</i>	Western white gum	PW-1	Burncleuth
<i>Eucalyptus camaldulensis</i>	River red gum	10626	Palmer River
<i>E.grandis</i> x <i>E.camaldulensis</i>	Eucalypt hybrid	Yuruga hybrids	Clone 9
<i>E.grandis</i> x <i>E.camaldulensis</i>	Eucalypt hybrid	Yuruga hybrids	Clone 12
<i>E.grandis</i> x <i>E.camaldulensis</i>	Eucalypt hybrid	Yuruga hybrids	Clone 13
<i>E.grandis</i> x <i>E.camaldulensis</i>	Eucalypt hybrid	Yuruga hybrids	Clone 20
<i>E.grandis</i> x <i>E.urophylla</i>	Eucalypt hybrid	Yuruga hybrids	Clone 58
<i>E.grandis</i> x <i>E.urophylla</i>	Eucalypt hybrid	Yuruga hybrids	Clone 59
<i>E.grandis</i> x <i>E.urophylla</i>	Eucalypt hybrid	Yuruga hybrids	Clone 60
<i>E.grandis</i> x <i>E.urophylla</i>	Eucalypt hybrid	Yuruga hybrids	Clone 61
<i>Eucalyptus pellita</i>	Red mahogany	Bulk seedlots from	PNG & NQ seedlots
<i>Eucalyptus raveretiana</i>	Black iron box	11025	Yeppoon
<i>Eucalyptus tetradonta</i>	Darwin stringy bark	3539	Mutchilba
<i>Khaya senegalensis</i>	African Mahogany	11895	Darwin St trees
<i>Santalum album</i>	Sandalwood	12240	Davies Cr SF SO

7.8 Species testing and genetic improvement of forest trees in Northern Territory

Table shows species/taxa used and source information where available.

Species	Common name	Seedlot No.	Source details
<i>Eucalyptus pellita</i>	red mahogany	19718	Melville Is
<i>Eucalyptus pellita</i>	red mahogany	18199/18955	Serisa
<i>Eucalyptus pellita</i>	red mahogany	5203	Qld SSO
<i>Eucalyptus pellita</i>	red mahogany	19206	Kiriwo
<i>Eucalyptus pellita</i>	red mahogany	19207	Goe
<i>Acacia crassicaarpa</i>	brown salwood	19731	Oriomo PNG
<i>Acacia crassicaarpa</i>	brown salwood	20003	Figi SO
<i>Acacia mangium</i>	brown salwood	5910	Qld SSO
<i>Eucalyptus camaldulensis</i>	river red gum	10537	Katherine
<i>Eucalyptus camaldulensis</i>	river red gum	20383	Thailand SO
<i>Eucalyptus cloeziana</i>	Gympie messmate	137	Herberton
<i>Eucalyptus cloeziana</i>	Gympie messmate	10682	Koorboora
<i>Corymbia citriodora</i>	Lemon-scented gum	11148	Hughenden
<i>Corymbia citriodora</i>	Lemon-scented gum	10895	Glenden
<i>Eucalyptus tetradonta</i>	Darwin stringy bark	n/a	Darwin region
<i>Corymbia nesophila</i>		n/a	Darwin region
<i>E.camaldulensis</i> x <i>E.grandis</i>	eucalypt hybrid	Hybrid clone 4	Kleinig
<i>E.camaldulensis</i> x <i>E.grandis</i>	eucalypt hybrid	Hybrid clone 10	Kleinig
<i>E.camaldulensis</i> x <i>E.grandis</i>	eucalypt hybrid	Hybrid clone 11	Kleinig
<i>E.camaldulensis</i> x <i>E.grandis</i>	eucalypt hybrid	Hybrid clone 12	Kleinig
<i>E.camaldulensis</i> x <i>E.grandis</i>	eucalypt hybrid	Hybrid clone 13	Kleinig
<i>E.camaldulensis</i> x <i>E.grandis</i>	eucalypt hybrid	Hybrid clone 20	Kleinig
<i>E.urophylla</i> x <i>E.pellita</i>	eucalypt hybrid	M1677 x 1EP6-034	n/a
<i>E.urophylla</i> x <i>E.pellita</i>	eucalypt hybrid	M1677 x 1EP7-015	n/a
<i>E.urophylla</i> x <i>E.pellita</i>	eucalypt hybrid	M1684 x 1EP7-002	n/a
<i>E.urophylla</i> x <i>E.pellita</i>	eucalypt hybrid	M1684 x 1EP7-015	n/a
<i>E.urophylla</i> x <i>E.grandis</i>	eucalypt hybrid	5993	n/a
<i>E.urophylla</i> x <i>E.grandis</i>	eucalypt hybrid	10509	n/a
<i>Khaya senegalensis</i>	African mahogany	n/a	n/a
<i>Khaya anthotheca</i>	African mahogany	n/a	n/a
<i>Swietenia humilis</i>	Central American mahogany	n/a	n/a
<i>Pterocarpus indicus</i>	paduak	n/a	n/a
<i>Pterocarpus macrocarpus</i>	paduak	n/a	n/a
<i>Chuckrasia tabularis</i>	East Indian mahogany	n/a	n/a