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# Tree growth relationships and silvicultural tools to assist stand management in private native spotted gum dominant forests in Queensland and northern New South Wales.

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www.fwpa.com.au
FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia
T +61 (0)3 9927 3200 F +61 (0)3 9927 3288
E info@fwpa.com.au W www.fwpa.com.au

# Tree growth relationships and silvicultural tools to assist stand management in private native spotted gum dominant forests in Queensland and northern New South Wales.

Prepared for

**Forest & Wood Products Australia**

by

**T. Lewis, D. Osborne, B. Hogg, S. Swift, S. Ryan, D. Taylor and J. Macgregor-Skinner**

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**Principal Researcher:**
**T. Lewis, D. Osborne, B. Hogg, S. Swift and M. Bristow**
Department of Employment, Economic Development and Innovation Qld.
LB 16, Fraser Rd, Gympie, Qld, 4570.

**D. Taylor**
Department of Environment and Resource Management
27 O'Connell St, Gympie, Qld, 4570.

**S. Ryan**
Private Forestry Southern Queensland
Mary St, Gympie, Qld, 4570

**R. Waterworth**
Department of Climate Change
GPO Box 854, Canberra, ACT, 2601.

**J. Macgregor-Skinner**
Private Forestry & Resources, Industry & Investment
135 Murwillumbah St, Murwillumbah, NSW 2484

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**Forest & Wood Products Australia Limited**
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9927 3200 F +61 3 9927 3288
E info@fwpa.com.au
W www.fwpa.com.au

# Executive Summary

Spotted gum dominant forests occur from Cooktown in northern Queensland (Qld) to Orbost in Victoria (Boland *et al*. 2006) and these forests are commercially very important with spotted gum the most commonly harvested hardwood timber in Qld and one of the most important in New South Wales (NSW). Spotted gum has a wide range of end uses from solid wood products through to power transmission poles and generally has excellent sawing and timber qualities (Hopewell 2004). The private native forest resource in southern Qld and northern NSW is a critical component of the hardwood timber industry (Anon 2005, Timber Qld 2006) and currently half or more of the native forest timber resource harvested in northern NSW and Qld is sourced from private land. However, in many cases productivity on private lands is well below what could be achieved with appropriate silvicultural management.

This project provides silvicultural management tools to assist extension staff, land owners and managers in the south east Qld and north eastern NSW regions. The intent was that this would lead to improvement of the productivity of the private estate through implementation of appropriate management. The other intention of this project was to implement a number of silvicultural experiments and demonstration sites to provide data on growth rates of managed and unmanaged forests so that landholders can make informed decisions on the future management their forests.

To assist forest managers and improve the ability to predict forest productivity in the private resource, the project has developed:

- A set of spotted gum specific silvicultural guidelines for timber production on private land that cover both silvicultural treatment and harvesting. The guidelines were developed for extension officers and property owners.
- A simple decision support tool, referred to as the spotted gum productivity assessment tool (SPAT), that allows an estimation of:
    1. Tree growth productivity on specific sites. Estimation is based on the analysis of site and growth data collected from a large number of yield and experimental plots on Crown land across a wide range of spotted gum forest types. Growth algorithms were developed using tree growth and site data and the algorithms were used to formulate basic economic predictors.
    2. Pasture development under a range of tree stockings and the expected livestock carrying capacity at nominated tree stockings for a particular area.
    3. Above-ground tree biomass and carbon stored in trees.
- A series of experiments in spotted gum forests on private lands across the study area to quantify growth and to provide measures of the effect of silvicultural thinning and different agro-forestry regimes.

The adoption and use of these tools by farm forestry extension officers and private land holders in both field operations and in training exercises will, over time, improve the commercial management of spotted gum forests for both timber and grazing. Future measurement of the experimental sites at ages five, 10 and 15 years will provide longer term data on the effects of various stocking rates and thinning regimes and facilitate modification and improvement of these silvicultural prescriptions.

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# Chapter 1. An introduction to spotted gum forests, silviculture and stand management

## Introduction

Native spotted gum dominant forests occur across a wide range of sites and contain a complex mix of tree species and age classes. They extend from near Cooktown in northern Qld to Orbost in Victoria (Boland *et al*. 2006) and occur in high rainfall areas on the coastal ranges through to relatively dry sites in western Qld. Whilst spotted gum is regarded as a commercial tree species for timber production, there are significant differences in productivity levels between spotted gum forests due to a range of edaphic and other factors including topography, climate, fire frequency and intensity, as well as management (Florence 1996). Given their extensive distribution, spotted gum dominant forests are one of the most economically important forest types for timber production (Anon 1989, Anon 2004, Anon 2005). Spotted gum is the most commonly harvested hardwood timber in Qld and one of the most important hardwood forest types for sawlog production in NSW. It generally has excellent sawing and timber qualities (Hopewell 2004) and is used in a diverse range of solid wood products, including high value feature quality uses, structural timber and power transmission poles.

The private native forest resource in southern Qld and northern NSW is a critical component of the hardwood timber industry (Anon 2005, Timber Qld 2006), particularly in light of the reduction in future availability of timber from Crown forest (i.e. under the Regional Forest Agreement in south east Qld logging of native forest on public land is due to cease by 2024). The private resource also represents an important alternative source of income for landholders to supplement traditional livestock grazing enterprises and is a desirable economic use of land, when compliant with the respective Vegetation Management legislation. Currently half or more of the native forest timber harvested in northern NSW (approximately 260 000 $m^3$) and Qld (in excess of 200 000 $m^3$) is sourced from private land and this resource will assume greater importance in the future.

Increasing the extent and improving the productivity of the private resource is a key outcome for both landholders and the timber industry. In general, productivity on private land is well below potential and a number of forestry related organisations have recognised this deficiency and are currently promoting the need for improved management. Principally this has involved education and capacity building among landholders. However, there is a clear need to provide reliable estimates of potential productivity and comparative growth rates between managed and unmanaged forests, so that landholders can make informed decisions on the cost/benefits of improved forest management in relation to other land uses and identify particular areas for investment.

## Spotted gum forests

### Land use

Forests dominated by spotted gum are one of the most commercially important forest types in Qld and NSW for timber production. These same forests also form a very important land resource to the grazing industry, as beef cattle grazing is practiced in most privately owned forests and forms the primary source of income for most landholders. In general, the more productive valleys and flats have been largely cleared for grazing, whereas in most cases the hill country which is usually less productive for livestock grazing has only been selectively cleared. Spotted gum forest has typically been retained on these ridges and slopes, where the poorer soil types made clearing uneconomical. On many of these spotted gum sites, grass production can be low and timber production or a combination of timber production and cattle grazing can provide a higher gross margin than grazing production alone (Schulke 2007). Hence, on ridges and slopes that have previously been cleared of spotted gum forest, it may be beneficial to allow the development of a regrowth forest to maximise returns through a combination of grazing and timber production.

### Distribution and ecology

There are a number of spotted gum species which are closely related. They belong to the genus *Corymbia* which was previously the name given to an informal subgenus within *Eucalyptus*. The main commercial species in southern Qld and northern NSW is *Corymbia citriodora* subsp. *variegata* which occurs along the east coast of southern Qld (to approximately Gladstone and west to Carnarvon Gorge) and northern NSW (generally north of Grafton) (Anon 1989; Brooker and Kleinig 2004).

Lemon-scented gum (*C. citriodora* subsp. *citriodora*) is very similar to *C. citriodora* subsp. *variegata* but occurs north of about Maryborough (Brooker and Kleinig 2004). Broad-leaved spotted gum (*C. henryi*) is also closely related. This species occurs naturally from Coffs Harbour in northern NSW, north to Brisbane and west to Toowoomba in south-east Qld (Brooker and Kleinig 2004). *Corymbia maculata*, the most southern spotted gum, occurs along the coast of NSW from Bega in the south to Manning Valley in the north (Brooker and Kleinig 2004). It is thought that natural hybrids within these species occur where their distributions overlap.

For the purposes of this report, 'spotted gum' refers to *C. citriodora* subsp. *variegata*, *C. citriodora* subsp. *citriodora* and *C. henryi*. *Corymbia maculata* was not included in the study area of the current project. Figures 1 and 2 show the distribution of spotted gum within Qld and northern NSW.

Spotted gum forests range from tall open forest in the coastal regions to open woodlands further inland. Considerable variation in both canopy cover and tree height is a feature of these forests, and this is thought to be influenced primarily by rainfall, soil type and soil depth. Spotted gum forests are typically dry sclerophyll forests and in general are structurally similar, with a relatively open crown cover (canopy) of dominant trees and an understorey that can be grassy or shrubby depending on the site and management history (particularly fire frequency). In the wetter parts of the coastal ranges, a shrubby understorey comprising acacias or other tree species is often present. Fire occurs relatively frequently in many spotted gum forests, mostly through prescribed burning by landholders. Where fire is less frequent the understorey may become shrubby with acacias, *Lophostemon confertus* (brush box or supple jack) and lignotuberous regeneration being common components.

In the border ranges and hinterland areas of south east Qld and northern NSW, spotted gum can occupy the drier ecological niches surrounding wetter forests. Typically they are found from mid-slope to ridge-top locations, on shallower soil types and on more westerly aspects in the higher rainfall zones. These sites can be considered in terms of a transitional zone between the wet and dry sclerophyll forest, containing some aspects of both. In wetter areas where fire is infrequent it is not uncommon for rainforest species to develop in the understorey. The dominant species associated with these transitional forests, such as ironbark, white mahogany and grey gum, extend their range into the dry sclerophyll forests. For the purposes of this report 'spotted gum forests' include the mix of different tree species (i.e. not just spotted gum) occurring within the forest.

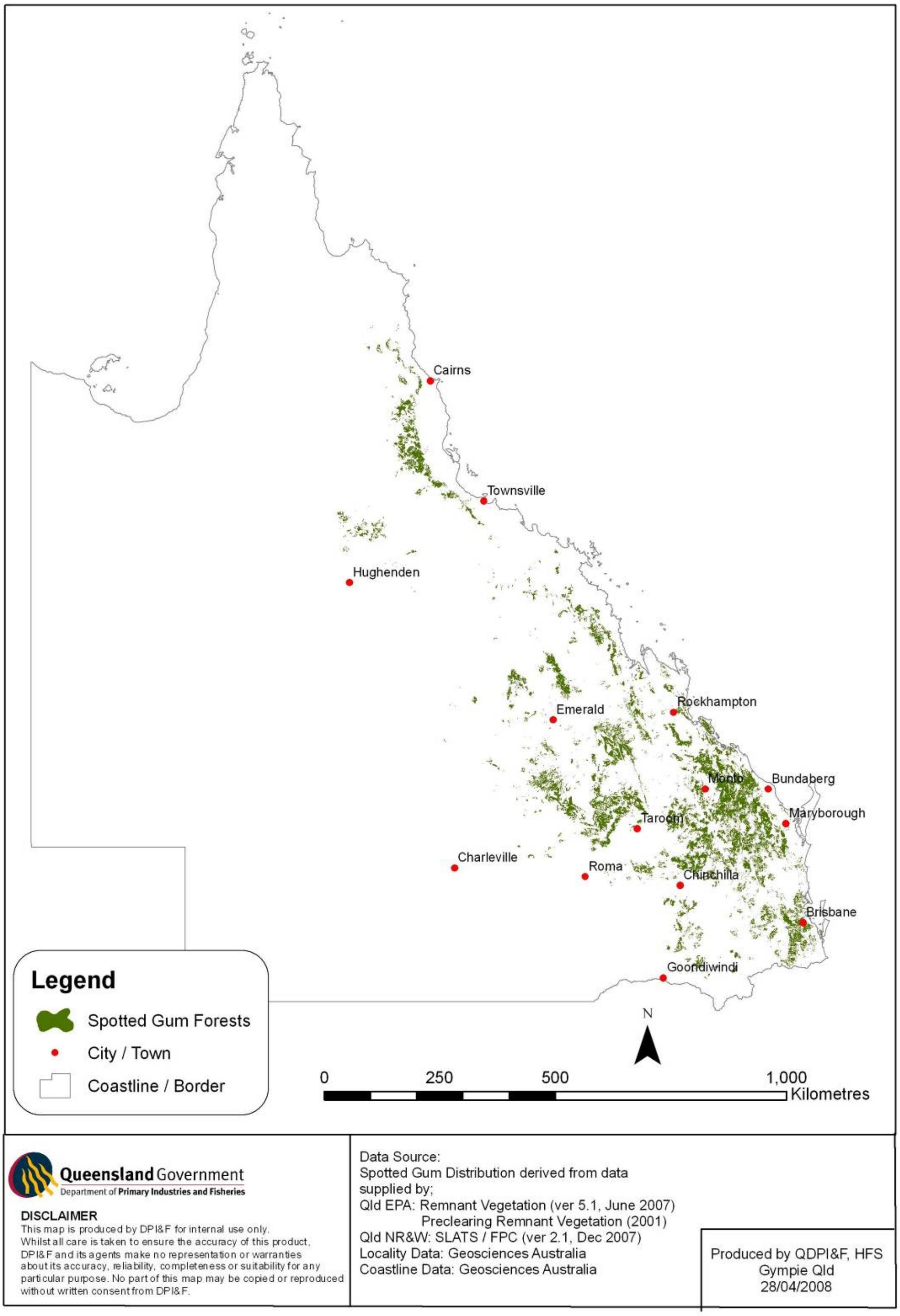


**Figure 1**. Distribution of spotted gum in Queensland.

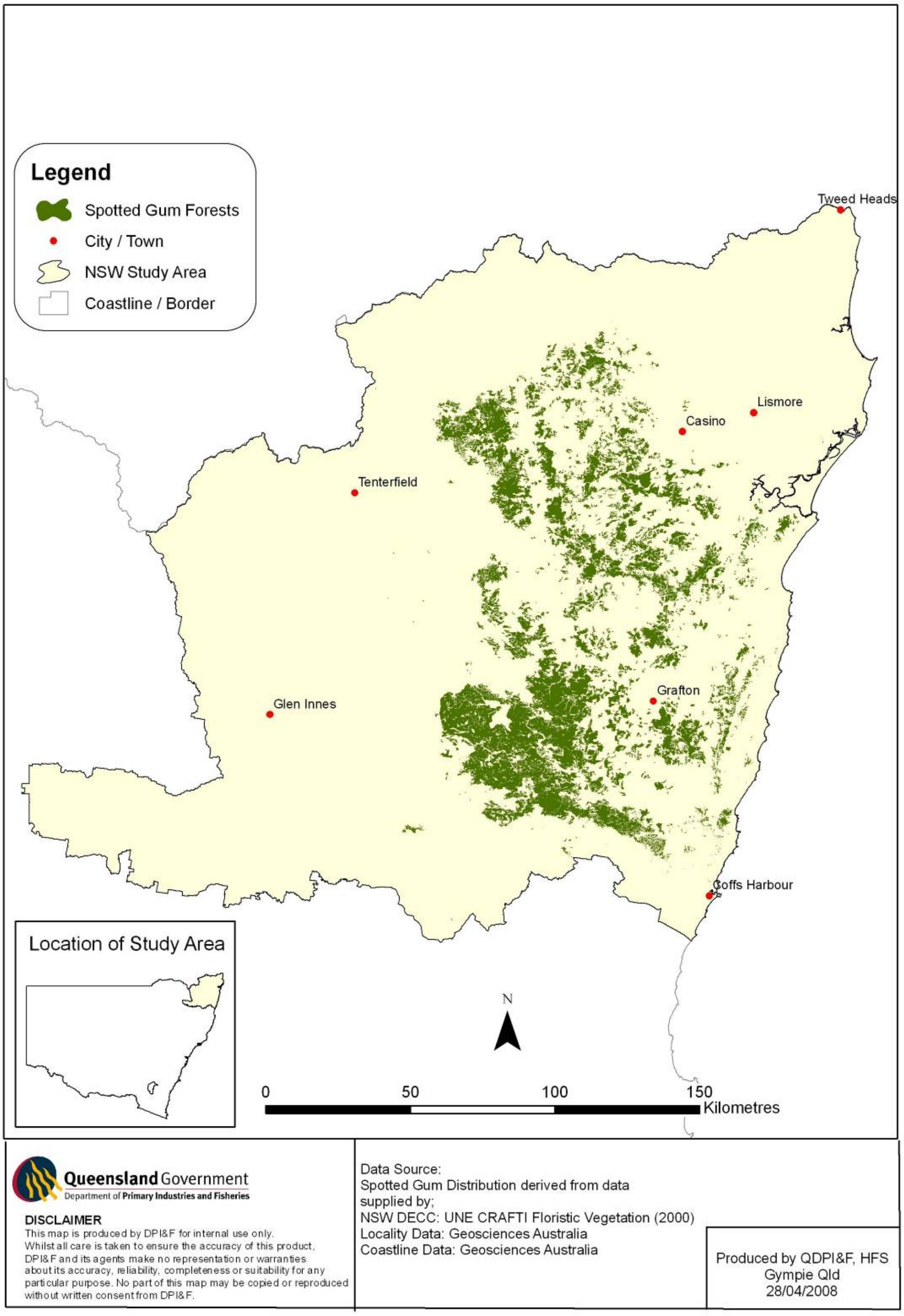


**Figure 2**. Distribution of spotted gum in northern NSW.

## Forest structure

Spotted gum forests are generally uneven-aged, with a mix of size and age classes. Most spotted gum forests have a relatively open canopy allowing light to reach the lower layers of the forest. The structure of a forest refers to:

- The density of trees across a range of sizes.
- The presence/absence of an understorey and the number of layers within the understorey.
- The growth stage (i.e. age classes) of the trees.

Forests are also often referred to as 'regrowth' or 'old growth' forests based on their structure.

On private land, significant areas of spotted gum forest are regrowth forests. These are forests which have developed through regeneration on previously cleared land. Regrowth forests can become densely stocked if left unthinned and as the trees develop, a high proportion can become suppressed under those that were able to more rapidly become dominants. These forests are readily identifiable by a lack of large old 'mature' trees. In contrast, old growth forests usually have lower stockings and tend to be dominated by large senescent trees. Regrowth forests generally have more potential for productive growth due to the age of the trees and lack of suppression from the large older trees.

From a timber production perspective, certain forest structures can be more productive than others, depending on tree spacing and the size class distribution.

## Tree growth stages

The trees in spotted gum forests go through several growth stages, and while this is not always related to size, it provides an indicator of the relative potential for growth. The following terms are used to describe the composition of a forest as a succession of growth stages with age: (i) seedling; (ii) sapling; (iii) pole or advanced growth; (iv) mature; and (v) overmature or senescent.

Seedling development in height and diameter occurs as environmental conditions permit, however mortality rates are usually high in this early stage. When conditions are favourable for growth and in the absence of fire, spotted gum can develop rapidly in height and diameter into the sapling stage at which it is usually able to withstand low intensity fire. Further growth from this point is dependent on stand density as well as the presence available gaps in the tree canopy. Henry and Florence (1966) suggested that canopy openings of 30–40 m in diameter are required to produce unimpeded development of the young stems.

From the sapling stage, trees may grow into the advanced growth stage where tree height approaches canopy or mature tree height. These trees are referred to as 'subdominant' and given sufficient space should grow into the mature stage (i.e. increase in diameter and height to reach full potential while still maintaining an actively growing healthy crown). In the event these trees grow up under an existing tree crown, they may become suppressed and often develop a malformed crown.

Severe suppression often results in the tree losing its vigour, thereby being unable to regain its potential growth rate even following release from the overtopping canopy.

Where a tree successfully becomes part of the canopy, steady growth continues and the mature stage is reached. Trees may remain in the mature stage for some time before an eventual decline to the senescent stage. At this point the crown starts to decline and the bole of the tree may exhibit defects indicating internal decay.

While the above growth stages are generalised, it is important to recognise these in terms of selection for growing stock in a managed forest.

### Regeneration

Most overstorey species in spotted gum dominated forests are lignotuberous and thus do not normally rely on growth directly from a seedling into the sapling stage for regeneration. Lignotubers form at the base of young seedlings as a woody mass, providing stored resources (starch reserves) for the tree to reshoot if the above ground foliage is removed by fire, browsing or other disturbances (Henry and Florence 1966, Walters *et al.* 2005). When established, lignotubers can persist in the forest understorey for many years (reports suggest up to 80 years), and provide an effective pool of plants (up to 2500 regenerating stems per hectare) for regeneration. In the absence of damage from fire or grazing, and overstorey suppression, this regeneration can grow rapidly and may reach high densities that can decrease the grazing value of the forest through reducing grass growth (Scanlan and Burrows 1990). Careful management with prescribed fire and selective thinning may be necessary to maintain an appropriate density of regeneration. In some wetter spotted gum forests near the coast, regeneration can be less abundant as lignotubers may be absent or in very low numbers and there is often intense competition with the understorey vegetation (Anon 1989). In such instances disturbance (e.g. fire) is thought to be important for allowing regeneration. In fact, low-intensity fire and soil disturbance can encourage seedling regeneration in most spotted gum forests.

Spotted gum does not normally flower and set seed on a regular basis and hence forest regeneration occurs episodically when seed crops coincide with good rainfall years (Dale and Hawkins 1983). However, isolated trees often flower and seed on a more regular basis because there is less competition for resources.

## Silviculture and stand management

Silviculture can be defined as the science and art of managing forests. Science in that many of the values in forests can be defined in technical terms and art in that there is a great deal of intuition in forest management. Classic silviculture (Troup 1955, Kostler 1956) refers to silviculture principally in terms of managing forests for timber production.

The goal of silviculture is to manage forests for sustainable wood production with due regard for other forest values. Optimum forest productivity can be achieved through sustainable forest management, which is essential for the maintenance of ecosystems supporting tree growth. Sustainable management involves maintaining important ecological values such as soil nutrients, soil structure for water storage and biodiversity.

## Basal area and tree stocking

Basal area is a forestry term used to compare the density of trees in a forest. It is calculated as the sum of the cross sectional area of each tree at 1.3 m (DBH) height and is usually expressed on a per hectare basis. This area can then be used to compare the density of different forest stands. Basal area incorporates all trees irrespective of size (although normally down to a specified minimum size) and is often used as a guide to determine whether the stand density is appropriate for the desired use of the forest (i.e. whether the stand requires thinning or not).

Tree stocking is another measure of stand density. This is expressed on a per hectare basis and trees are usually divided into diameter classes to provide a table of size distribution. One of the main advantages of stocking is that it is easy to measure and stands are usually thinned or harvested to provide a specified residual stocking. In a forest, trees are usually regarded as being a permanent part of the stand (i.e. not susceptible to mortality through factors like fire) when they are greater than 10 cm DBH. Below this size, trees are usually regarded as being 'regeneration' and are counted separately or ignored during inventory.

Many private spotted gum forests are in a poor growing condition as a result of past of harvesting or lack of thinning. Many are overstocked with between 200–1000 trees per hectare (>10 cm DBH). In these forests, basal area often ranges between 15–30 $m^2$/ha, and may even be higher. These forests tend to have low or no commercial productivity due to intense inter-tree competition. Further, grass production is low or absent from this type of stand, thereby providing little to no livestock grazing benefits. While overall production may be high in terms of total volume, growth is distributed across many small trees which may never reach a commercial size.

Forests that are well managed for timber production have lower stockings (generally <200 trees per hectare) and are comprised of trees of good form and desirable species. This serves to concentrate growth onto fewer trees, giving larger individual incremental growth on selected quality trees (i.e. trees are spaced to provide an adequate growing space for each tree). In Qld, stocking ranges of between 80–150 trees/ha (>10 cm DBH) are common for well managed productive forests, with basal areas generally in the range of 6–14 $m^2$/ha. Wide spaced stands where grazing is incorporated may be lower again. Stands managed in these ranges are generally for sawlog with occasional poles or girders. Stands managed for poles or piles usually are at higher stockings, in the range of 150–200 trees per hectare. High quality sites such as those found on deep fertile soils with higher rainfalls tend to be able to support higher basal areas and tree stockings than poorer sites with lower rainfall.

## Tree stocking and grazing production

Spotted gum forests are not usually found on the more productive land types that have been cleared to encourage grazing production. However, there are some land types that are quite productive in terms of cattle production and timber production (e.g. spotted gum and ironbark and on duplexes and loams). In spotted gum forests grazing productivity varies greatly due to climatic factors (e.g. rainfall), geographic factors (e.g. soil types, position in the landscape) and tree stocking. While most of these factors cannot be controlled by landholders, it is possible to manipulate tree stocking to improve the grazing value of the land. As trees and grasses compete for resources to grow (e.g. water, sunlight and soil nutrients), a high density of trees will result in low grass production. In fact, there is a know relationship between tree basal area and grass production (e.g. Scanlan and Burrows 1990). For example, in the Burnett region of Qld, a spotted gum and ironbark forest with a stand basal area of 8 $m^2$/ha will produce approximately 2200 kg of dry matter per hectare, whilst the same forest type with a basal area of 20 $m^2$/ha, would only produce half as much herbaceous biomass (Shulke 2007).

In spotted gum forest and woodland it is possible to maintain a predominantly grassy understorey through management of tree stocking. This can involve selective thinning of the forest to a desired stocking and may also involve the use of fire and grazing to control the density of regeneration. The challenge for private landholders is to determine the stand density and the combination of tree sizes within the stand that provides the maximum return from the combination of grazing and timber over the long term. Some landholders choose to retain trees in spotted gum forests at a basal area that is sub-optimal for grazing production (e.g. 7–12 $m^2$/ha), because when the timber and grazing enterprises are combined they provide suitable long term financial returns (Shulke 2007).

## Stocking, site quality and growth

The objective of silviculture for timber production should be to achieve a stand stocking and tree size range that achieves maximum productivity, while meeting relevant legislative requirements. Ideally, retained trees should be represented across the range of diameter classes (including the commercial size cases). A well managed stand has a structure with a large number of trees in the smaller diameter range (i.e. saplings and advanced regrowth) tailing to a small number of trees in the large diameter classes (e.g. sawlogs and mature trees) (Figure 3).

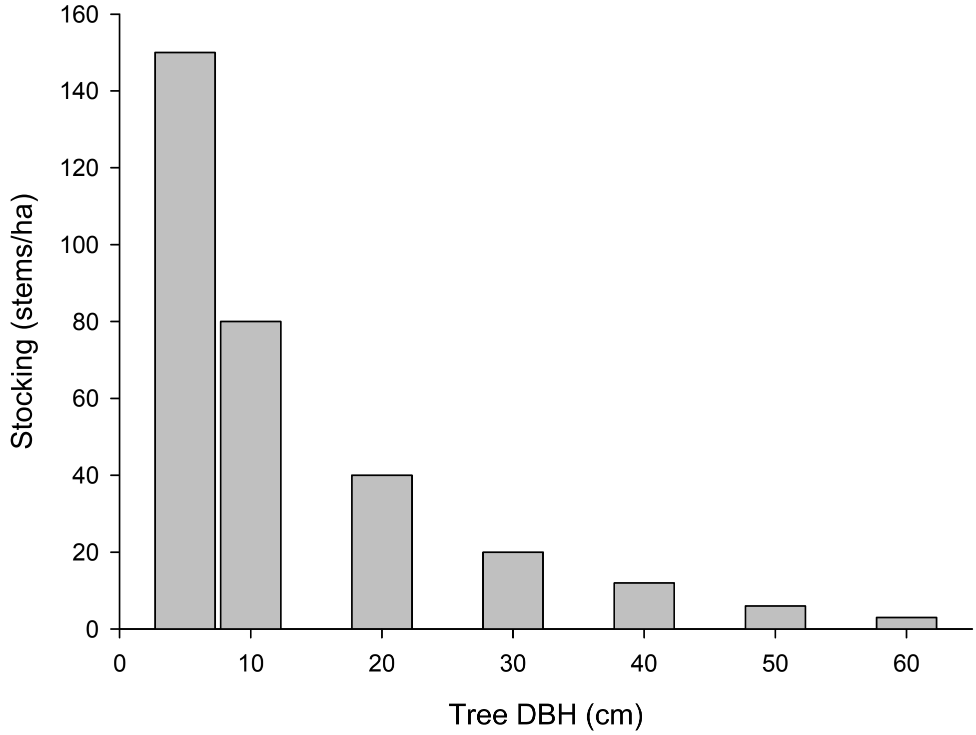


**Figure 3**. Desirable diameter (DBH) distribution in a well managed spotted gum forest.

Growth rates and stocking levels in dry sclerophyll forests vary considerably with forest condition, tenure, management history, species composition and geographic location. Tree growth rates are relatively slow and vary with the stocking and structure of the stand, and condition of the individual tree. Most species in spotted gum forest types tend to be 'shade intolerant' and consequently are susceptible to growth suppression from overtopping trees.

In terms of sawlog production, average growth rates for unmanaged dry sclerophyll, spotted gum forests are generally below 1 $m^3$/ha/yr, (i.e. 0.2–0.5 $m^3$/ha/yr) and may be negligible where the forest is in a poor growing condition. Silviculturally well managed spotted gum forests with selected growing stock have been recorded to grow at up to 1.5 $m^3$/ha/yr of log volume (Taylor 1997). In terms of diameter growth, mean annual increments (MAI) for unmanaged forest are generally in the order of 0.1–0.5 cm/yr, although spotted gum may grow as much as 2 cm/yr over a long period if managed for optimum growth. As discussed previously, site productivity potential varies considerably and strongly influences canopy height, stem length, stocking (and BA) and growth rates.

**Harvesting and products**

Like silvicultural thinning, harvesting represents an opportunity to improve the future productivity of the forest by removal of mature and senescent trees and retention of good quality growing stock. While spotted gum may be the primary species of commercial value, certain other components (e.g. ironbarks, white mahogany) may also be of commercial value at a harvest.

Spotted gum produces hard, strong and durable timber (density of 745 to 1080 kg/$m^3$) with a wide array of uses. The sapwood is susceptible to *Lyctus* and must be treated to prevent attack. It can be dried satisfactorily and machines and finishes well. During a harvest several products may be obtained from a spotted gum forest. These may include: sawlogs (which may be divided into different grades), girders, poles, piles, veneer logs, salvage logs, fencing (e.g. split posts and round posts) and landscaping products. These products may differ greatly in value. Detailed specifications of the different products and stumpage prices are outlined in Mathews and Ryan (2005). Sawlogs are the most common product from a spotted gum forest harvest. The high value products, like poles and girders, usually make up a smaller proportion of the forest.

Harvesting operations in dry sclerophyll forests are generally based on selective felling of commercial size trees with a minimum diameter at breast height over bark (DBHOB) of approximately 40 cm to produce a log with a top diameter under bark of no less than 30 cm. For poles, a straight bole length of greater than 9.5 m is required. Smaller sized trees are also harvested at times to meet particular markets. Typically, 5–10 $m^3$/ha of log timber is removed at each logging event but in some drier areas this may be as low as 1–2 $m^3$/ha. Salvage logging for fencing and landscaping timber normally occurs with or immediately following a sawlog/pole harvest. Time between harvests is usually in the order of 20–40 years, depending on harvest intensity, forest condition and retained growing stock. Harvest intervals may be as little as 10 years in a well managed forest, where selection has optimised tree spacing and quality of retained growing stock.

## Silvicultural systems

Silvicultural systems are a combination of the many facets of forest management that go together, usually in logical progression to form a cycle, to manage tree growth from a seedling to a harvested log. There are a number of variations to this however the principal components remain essential to an eventual harvest. These components include: (i) harvesting; (ii) thinning; (iii) regeneration; and (iv) forest protection.

### Harvesting

Harvesting is the major management tool used to manipulate the composition and structure of the larger commercial sized trees in spotted gum forests. Harvesting should involve a rigorous selection process prior to the felling, either selecting trees for harvest directly or selecting the retained stand. Forest harvesting can vary substantially in intensity (amount of timber removed) and interval (length of time between harvests), particularly on private land. Ideally harvesting operations should remove approximately 10–30 % of the standing basal area, thereby leaving space for the next crop to rapidly grow through. Harvesting should always be planned to comply with environmental guidelines and legislative requirements. The two most commonly used harvesting techniques adopted in spotted gum forests are single tree selection and diameter limit harvesting.

Single tree selection or selective harvesting is the practice of selecting and harvesting only a proportion of the standing trees in a forest at any one time. This system is suitable due to the mixed composition and structure of many spotted gum forests, the products removed (mostly sawlog) and the need for regular harvests to provide continuous wood supply to industry. For private forest owners, this represents the best silvicultural system for a regular return from their forest. It is usually applied to an uneven-aged stand where there are a range of tree size classes and ages and only those large enough for harvest are considered for removal. Harvesting should aim to remove the largest trees which have reached maximum value. Harvesting can be combined with thinning of the lesser sized trees to allow growing space for the retained stand. Harvest intervals vary from of 10–50 years depending on growth rates and volumes removed. This allows time for smaller trees to grow through into the commercial size classes, thus forming a continuous cycle of removal of the larger older trees and allowing younger trees to grow through for subsequent harvests. This system is relatively simple and retains a forest structure with all tree size classes represented at all times. At harvest any tree that has symptoms of declining health, has a deteriorating fault or has reached its optimum product value should be removed.

Another common method of harvesting used on private land is called 'diameter limit harvesting'. In many instances this produces what is termed 'high grading' which often results in a degraded forest with little potential for future commercial growth. Diameter limit harvesting is a simplistic harvesting method where all merchantable trees above a certain diameter are harvested. In most cases this results in harvesting of the more vigorous and better quality trees leaving defective, non-commercial trees or suppressed subdominant trees as the future growing stock. Often these retained trees are incapable of realising acceptable growth rates or yielding a commercial product. This system is principally responsible for the current poor condition of much of the private native forest resource.

Australian Group Selection (AGS) is one of several other harvesting systems used by forest managers in coastal eucalypt forests to produce timber and regenerate areas following harvesting. The technique involves harvesting a group of mature trees as opposed to single tree. Removal of a group creates gaps in the canopy to allow light onto the forest floor and encourage regeneration and development. AGS can also be a useful tool in 'locked up' spotted gum forests to stimulate dormant lingotubers in the understorey. The objective is to harvest groups of commercially mature trees for commercial products, whilst retaining other groups, usually younger trees, as growing stock for harvesting in 5–20 years time. In addition to maximising regeneration, AGS allows forest managers to disperse the impacts of harvesting and maintain a diversity of tree ages in the forest.

In some cases there may be a need to undertake a major disturbance of the forest, generally termed a 'reset' harvest. Through a lack of management stands can become moribund or stagnant and require a relatively intense logging operation which includes significant disturbance in comparison to a normal harvest or thinning operation. However, this may reduce the stand stocking in the short term to below the canopy cover and/or basal area required to be maintained under various legislation.

## Non commercial thinning/silvicultural treatment

Thinning of non-commercial trees is an integral component of commercial forest management. Along with harvesting it is another tool for manipulating the tree spacing and composition to achieve productive forest growth. Selective harvesting of commercial species in most forests can result in an increase in the proportion of the non-commercial component over time. This, combined with excessive regeneration has resulted in many forests becoming 'overstocked' with trees under intense competition for available resources. When this occurs, trees grow very slowly and are not able to produce commercial size logs in an acceptable timeframe.

To maximise commercial gain, silvicultural thinning within the unmerchantable components of the stand is undertaken around five years after harvest. This is done to thin out regeneration resulting from the harvest and to remove trees that were unmerchantable during the harvest process (e.g. due to excessive fault or non-commercial species). Killing these trees is essential to provide a large enough gap or growing space for the retained trees. Thinning involves killing by ringbarking, chemical injection or felling of trees that do not form a useful component of the stand.

When thinning spotted gum forest there are a number of issues which may arise due to legislative requirements (e.g. the Code Applying to a Native Forest Practice on Freehold Land 2005). Silvicultural thinning to waste may be necessary where a large component of the forest does not have a ready market (i.e. non-commercial species and defective and small commercial trees). Where a need exists to thin to levels where productivity is optimised, these components are normally either killed standing or felled to waste so that large numbers of dead trees are not left standing. Landholders should refer to their local legislative requirements prior to thinning operations.

## Regeneration management

Management of regeneration in an essential component of sustainable forest practice as it ensures the future growing stock. Part of a successful silvicultural system needs to ensure that regeneration requirements are catered for. Successful regeneration occurs when the trees establish and develop as part of the stand. Single tree selection management ensures that suitable forest structure is retained and this maintains the regenerative capacity of the forest.

Post harvest management often involves top disposal burning where the felled tree heads are burnt (generally in winter or spring) to reduce fire hazard and provide a seedbed for regeneration. Low stocking rates following harvest will allow regeneration to develop. Although often impractical, the co-ordination of harvesting to occur while the trees are bearing mature seed will maximise the success of regeneration.

Management of fire and grazing in dry sclerophyll forests is also essential to the successful re-establishment of a harvested stand.

**Forest protection through fire and grazing management**

Fire, or the lack of fire, has a major influence on forest vegetation in most eucalypt forests. Fire is both a forest management tool and an essential component of many forest ecosystems. Exclusion of fire from some forests can be detrimental to certain forest values. However, fire that is too frequent can also have negative impacts on the forest stand (e.g. by not allowing development of regeneration). The use of fire as a silvicultural tool can reduce the intensity of wildfires and promote regeneration through creation of a seedbed (Debuse and Lewis 2007).

Grazing by its very nature has an impact on fire intensity and regeneration. Forested areas with heavy grazing pressure effectively lower the fire risk by reducing pasture biomass (i.e. fuel loads). High grazing intensities for short periods of time can also be an effective method of reducing spotted gum regeneration where excessive regeneration is an issue. However, livestock may need to be excluded for periods of time to allow regeneration in some forests.

## Project aims and report structure

This project was designed to investigate the productivity of spotted gum forests in the subtropics within a study area extending from Rockhampton in central Qld, south to include the North East Regional Forest Agreement area in NSW (Figure 4). In order to provide silvicultural guidelines and management tools to assist property owners in managing their spotted gum stands for maximum benefit, this project aimed to:

- Develop silvicultural guidelines based on research data and expert knowledge for use by landholders and extension officers.
- Collect, collate and summarise existing growth data from yield and research plots across the study area and use soil, site and climatic data to develop growth algorithms for the study area.
- Develop a simple decision support tool for estimation of growth rates and potential economic returns from a specific site based on user input of potential forest products available from the site.
- Develop a module for the decision support tool to allow calculation of pasture development and livestock carrying capacity under a range of tree stockings for a particular site and provide predictions of financial returns from grazing.
- Develop a module for the decision support tool to allow estimation of forest carbon (trees only) for a given site in the study area, using the National Carbon Accounting Scheme and FullCAM (Richards and Evans 2000).
- Establish and measure a series of tree growth experiments in spotted gum forests on private land to determine the effects of different tree stockings and thinning regimes on growth rates across the study area (i.e. with varied climate, soil and topography).

This report has been divided into ‘self contained’ chapters prepared by different authors under the current project. The following chapter draws on the above discussion on forest management to provide silvicultural guidelines to assist landholders manage their timber resource in spotted gum forest. Chapter 3 provides the methodology for the development of the decision support tool, the pasture module and the carbon module. The decision support tool, referred to as SPAT (spotted gum productivity assessment tool) is available upon request from the authors. Chapter 4 summarises the establishment of experimental plots in private native forest to determine the effects of thinning treatments on tree growth through continued monitoring.

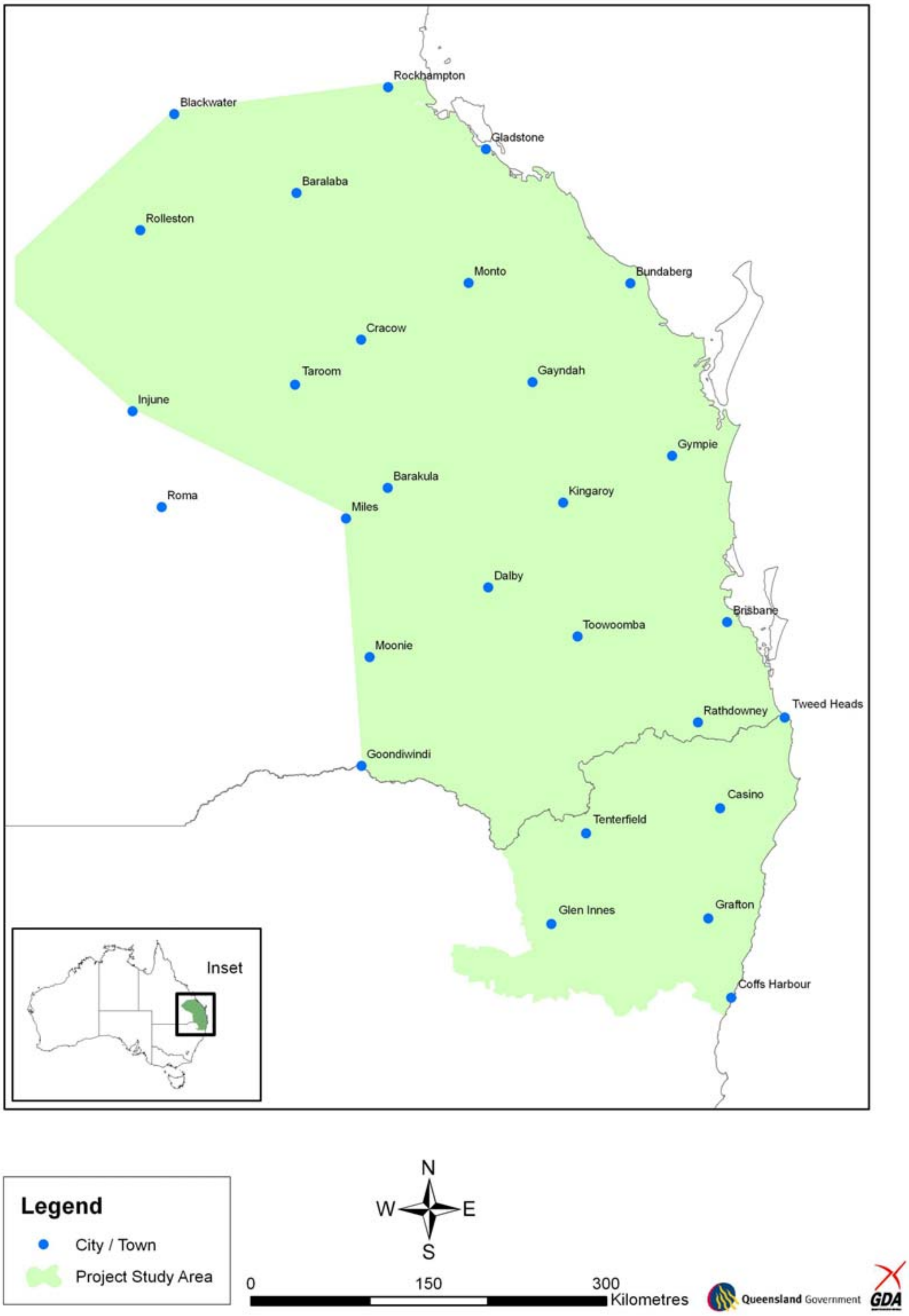


**Figure 4.** Study area for the current project.

# Chapter 2. Spotted gum forest silvicultural guidelines for landholders

## Authors: D. Taylor, S. Ryan, D. Osborne, S. Swift and J. Macgregor-Skinner

## Introduction

South eastern Qld and northern NSW have large areas of native forest and while the variation in climate, geology, geography and topography has led to the development of a wide variety of forest types, spotted gum dominant forests are some of the most extensive and important from timber, grazing and biodiversity viewpoints. Typically, many of the spotted gum forests utilised for timber production are uneven or multi-aged and generally comprise a mix of tree species of which only some species and some trees are suitable for timber production. Many previously harvested stands have become unproductive, either through overstocking (by allowing high densities of regrowth) or through removal of the quality growing stock leaving a high proportion of old and unmerchantable trees. This leads to poor recovery of saleable timber products and low financial returns. With properly applied management incorporating an understanding of tree growth habit, timber production can be a valuable enterprise on most farms, complementing other land uses such as cattle grazing. Forests that are silviculturally well managed for timber production are significantly more productive than poorly managed or unmanaged forests. To ensure forests remain healthy and productive, it is necessary for landholders and extension officers to have an understanding of the silvicultural requirements of their forest.

In most forest types managed for commercial timber production, silvicultural inputs are aimed at improving the sustainable yield and quality of saleable timber products while maintaining environmental values. The type and diversity of silvicultural activities can vary with forest type, location and expected timber products. Forest management can aim for the production of traditional products such as sawlogs, poles and fencing timber or to more niche products such as timber for wood turning and small scale forestry. In spotted gum forest, managing for timber production involves manipulation of the trees in the forest to ensure a suitable mix of species and size classes. There are four important silvicultural principles should guide forest management for timber production:

1. Tree spacing – trees need to be spaced adequately to reach their growth potential.
2. Tree form – trees which have the least defect, are straight and have the longest bole should be retained over trees that are unlikely to be merchantable.
3. Tree vigour – trees that have the greatest vigour should be retained and those that are suppressed should be thinned.
4. Tree species –tree species that have the best potential for financial returns should be retained over trees species that are unlikely to be merchantable.

With the Regional Forestry Agreement in south east Qld and the future removal of timber harvesting from state forests in the region there will be less hardwood timber available from Crown land. Given this and the rapidly growing population in the region, demand for good quality solid timber products sourced from sustainably managed private native forests is likely to increase dramatically in the future. The aim of this component of the project is to provide guidelines for forest management. Given that silvicultural requirements do vary between different forest types and the condition or stage of each forest (Florence 1996) we have focussed these guidelines specifically for harvesting and thinning spotted gum dominant forests in south east Qld and northern NSW.  These guidelines will enable private forest owners to manage their timber resources sustainably to ensure a balance between productivity (revenue from timber) and long-term forest health. Such management is all the more important as timber supplies from Crown forests in Qld are phased out and the demand for native hardwoods and price of quality timber increases.

## Guidelines for harvesting

### Principles

These guidelines for harvesting provide some direction for operational managers to apply in the field.  These guidelines must be interpreted with the understanding that across the landscape there is always great variation in forest condition, productivity and past management and the guidelines should be interpreted to suit relevant conditions, markets and any legislative requirements. Other information of relevance is described in the NSW silvicultural guidelines (Anon 2009).

### Harvesting objectives

Harvest time is the logical time to cash in your investment from the forest stand, but more importantly it is a time to invigorate the stand, removing senescent and defective trees and retaining only healthy quality trees for future growth. Generally the objectives of the harvest are to:

- Remove accumulated capital growth in a forest.
- Maintain or reinstate a productive forest structure and composition consistent with sustainable forest management (retain quality growing stock) including the retention of seed trees if necessary.
- Encourage regeneration within sizable gaps in the canopy.
- Encourage growth on specific trees by removal of poorly formed or slower growing (suppressed) trees.
- Comply with relevant legislation and environmental guidelines.

As a guide to best practice harvesting the primary aim is to remove trees that have either reached their optimum value, are in decline, have a deteriorating defect, are suppressed or have only a poor quality product. Trees are only retained if they are in a vigorous growing condition with the potential to produce a quality forest product. To achieve this, the landholder approaches the harvest by focusing on the trees that are to be retained rather than looking for any tree with a harvestable product to remove. This approach ensures that only vigorous quality trees are retained at the optimal stocking levels, or if it is a reset harvest, sizable gaps are opened up to encourage a significant uninhibited regeneration event.

Recognition of stand condition is an important stage in harvest planning since this will affect the type of harvest, which trees are selected, the intensity of harvest and how many trees are selected. Older mature stands, or stands in poor condition due to past management may need a more intense harvest where the larger or poor quality trees are removed to make way for more vigorous trees, while a younger regrowth forest may only need a light thinning.

### Tree selection

Only acceptable trees should be retained. Acceptable trees should:

- Be a preferred species.
- Have a straight bole and limited defect (e.g. no fire scars, defect bumps, large dead vertical branches, stem damage, fungi).
- Be a dominant or co-dominant tree.
- Have a healthy crown (e.g. a uniform even dense crown with limited occurrence of mistletoe, epicormic shoots and dead branches).

Crown assessment is a widely used tool for selection of trees for retention. Generally, trees with crowns in good condition in terms of dominance (size, shape and leaf density (optimally conical)), that have a low percentage of dead branches and have an absence of mistletoe, will grow significantly faster than those with poorer crowns. Poorly formed crowns are an indicator of the tree being under stress (often from being suppressed) and thus not capable of an acceptable growth rate.

### Harvest spacing

To maintain stand structure, spacing between trees varies with different tree sizes. Generalised spacing to retain the desired stocking of about 130–150 stems per hectare is summarised below in Table 1. Trees other than the required retained trees are removed in the harvest.

It is recommended when tree marking that a number of sample plots are completed to allow assessment of stocking and size class distribution as the work progresses. An easy method is the use of 1/20$^{th}$/ha circular plots (approximately 12.6 m radius) and measure the DBHs of the retained trees in that area. This will give a stand table showing size class retained and stocking retained.

**Table 1.** Generalised spacing of spotted gum stands to optimise growth and returns.

| Tree Size (DBH) | Spacing | Other |
|---|---|---|
| >80 cm | Remove all trees unless required as seed trees. | Excludes habitat trees. Possible product range: Girder, Veneer Billet, A class sawlog. |
| 60–80 cm | Retain acceptable trees if they are still in an actively growing condition at an average spacing of about 15 m (minimum 9 m) Remove others unless required for seed trees. | Possible product range: Girder, Veneer Billet, A class sawlog. |
| 40–60 cm | Thin to an average spacing of about 9 × 9 m with a minimum of 6 m between acceptable trees. | Possible product range: Girder, 15.5 m+pole (depending on bole length), Veneer Billet, A class sawlog. |
| <40 cm | Thin to an average spacing of about 9 × 9 m with a minimum of 6 m between acceptable trees. | Usually only removed for poles, round timber or if poor quality or in decline. Check the pole size and strength class (i.e. D line measurement to ensure that the pole has reached its maximum size before harvesting). |

## Guidelines for thinning treatments

### Principles

Most existing spotted gum forests on private land are a result of significant harvesting events in the past (often 3–4 in the past 100 years, removing the best trees and leaving useless material) or are regrowth from past clearing practices. Generally these forests have had little or no follow-up management and are in a poor productive state. An unproductive forest can be recognised by a number of simple criteria, namely:

- There are generally more unmerchantable trees than merchantable trees (often by a factor of 10:1).
- There are 2–8 times more trees per ha than is optimal (150 stems/ha).
- There is a high percentage of trees in poor health (suppressed, poor crown development and health, stem defects such as large broken branch stubs, fire scars, dry sides, sever termite infestation).

Clearly any crop where the majority of the product is defective is a failure and in need of significant intervention. However, it is a relatively simple process to improve the quality of most spotted gum stands.

## Stand assessment

Stand assessment requires a landholder to go into their forest and in a number of representative sites do a count of the number of trees per hectare and determine:

- How many actually have a quality merchantable product and are in a vigorous growing state.
- How many have a merchantable product but have a significant defect or are in decline with a poor quality crown (this sector is ready for harvest).
- How many trees have no merchantable product and are robbing valuable nutrient and available moisture from the best trees (this sector requires chemical thinning).

One way of achieving this is by marking out a 1/20 ha circle (12.6 m radius) or 1/10 ha circle (17.8 m radius) and counting and measuring the diameter and merchantable length of all the trees in the plot, then multiplying by 20 or 10 respectively to calculate the stems/ha and standing volume. The next step is to paint mark the best 6–7 stems (for a 1/20 ha plot) in the plot (or 12–13 stems for a 1/10 ha plot). Trees are retained based on a number of rules, they must:

- Be a preferred species.
- Have a straight bole and limited defect (e.g. fire scars, defect bumps, large dead vertical branches, forks, stem damage, fungi etc).
- Have a healthy crown (e.g. a uniform even (optimally conical) and dense with limited occurrence of mistletoe, epicormic shoots and dead branches).
- Be a dominant or co-dominant tree (do not leave suppressed trees).

This form of simple assessment gives an indication of the number of trees per hectare that could be harvested, the stocking and the size class of the retained trees. It also provides the number of trees that will require chemically thinning per hectare.

## Treatment

Silvicultural treatment aims to reduce the stocking of the stand to a selected, optimal level. In a managed stand this usually occurs around 5 years after a harvest when the post harvest regeneration has reached the height and form to make an informed choice on the best quality stems (greater than 6 m high).

In an unmanaged forest, where treatment may not have occurred before, this is usually done at the same time as a harvest (if there are a viable number of harvestable trees). The best trees are selected for retention whilst ensuring that the desired stocking is achieved. Any tree not marked that has a harvestable product is harvested and all other trees (i.e. those that are competing with the retained trees) are destroyed unless required as habitat trees within the relevant legislation.

## Method

- Determine a suitable stocking. Usually in spotted gum forests this is between 130–150 trees/ha in the 900 mm + rainfall zones and 100–130 trees/ha in the 600–900 mm rainfall zones.

- Select acceptable trees at suitable spacings. A rough guide is that trees in the 10–20 cm DBH class should average about 5–7 m apart, in the 20–30 cm DBH bracket they should be at about 7–8 m apart and in the >30 cm bracket they should be at >10 m spacing). This is a rough guide – you need to aim for average spacing over the stand since there will always be trees retained either closer or further apart.
- Paint mark the trees you wish to retain (this is the usual method).
- Trees to be destroyed are usually treated (poisoned) with Tordon®DSH at the rate recommended by the supplier. *Nominally this is a 4:1 water to Tordon mix with 1 ml/cut injected into trees with a base diameter <25 cm and 2 ml/cut into trees over 25 cm at the base*. This is usually injected into cuts made with a tomahawk into the stem of the tree. The cuts must penetrate into the sapwood, should be at the same height on the stem and at no more than 12 cm centres around the tree (this should leave about a finger width between each cut to allow the chemical to go back down to kill the roots). The cuts are made horizontal to the stem so that a pocket is provided for the chemical to sit in and not leak out. The chemical is taken up by the tree in seconds.

Treatment will be required after each harvest to manage the regeneration that inevitably occurs in a disturbed stand. This management system results in an improvement in the stand quality and productivity each time it occurs and is critical to achieve a productive and profitable stand.

# Chapter 3. Spotted gum growth relationships and development of a productivity assessment tool


## Authors: T. Lewis, B. Hogg, D. Osborne and S. Swift


## Introduction

Reliable estimates of forest productivity are essential for improved predictions of timber yields for the private native spotted gum resource in southern Qld and northern NSW. The aim of this component of the project was to estimate the potential productivity of native spotted gum forests on private land by making use of available inventory and experimental data collated from Qld and northern NSW for spotted gum forest on Crown land (i.e. state forests). It is well known that potential productivity varies from site to site, depending on soil type (and fertility), climatic factors (e.g. temperature and rainfall patterns) and other site factors (e.g. altitude, soil depth, aspect). We measured a range of these site factors to determine their relative importance in predicting productivity of spotted gum forest. While measures such as stand height and height-diameter relationships are known to be useful predictors of productivity (e.g. Vanclay 1992), we aimed to determine productivity for a site where this information was not available (e.g. a young regrowth forest). Measures of site index which incorporate DBH and height are available for spotted gum forest near Maryborough (Grimes and Pegg 1979), but there is little other published information to provide estimates of native spotted gum forest productivity. Only Bauhus *et al.* (2002) provide growth estimates for spotted gum forest in NSW.

Through estimation of stand productivity we developed a simple decision support tool for use by landholders and extension officers. It is hoped that the tool will allow private landholders to see the benefits of maintaining their timber resource and the comparative values of various management options. The tool has components for timber production and grazing production and allows landholders to see the relationship between tree basal area and pasture growth. The decision support tool also allows landholders to estimate the quantity of carbon that is stored in the trees in their forest. This chapter summarises the information used to develop the spotted gum productivity assessment tool (SPAT). In particular it focuses on the methodology and data used for calculation of basal area and stand volume productivity.

## Methods

### Site selection and field sampling

For the purposes of this study we defined spotted gum forest as a forest or woodland (Specht 1970) where 30% or more of the stems in the stand are spotted gum. This definition takes into account the fact that many spotted gum forests contain a mix of other tree species. Using this definition we were able to select sites for which growth data was available in the defined study area in Qld and northern NSW. Queensland data was obtained for: (i) permanent growth plots (e.g. detailed yield plots); and (ii) selected forest research experiments designed for assessing tree and forest response to applied treatments. Yield plots were established in Qld from the 1950s to assess the volume of growing trees and provide resource estimations across different forest types. A subset of these plots became 'detailed yield plots' where more detailed measurements were carried out and all individual trees were tagged. Data was retrieved from a total of 217 plots in Qld. Data for northern NSW was obtained from State Forests NSW. This included data for 15 plots located on state forests in north eastern NSW within the defined study area. The NSW data also originated from a network of permanent growth plots established for resource estimations.

Between December 2008 and June 2009 a total of 129 plots across 28 different state forests were visited in the Qld study area. At each site we recorded: soil type (Isbell 1996), depth to relevant horizons (those layers present in the soil at a given plot), soil colour (based on Munsell 1994 colour charts), soil texture (i.e. an estimate of the percentage of clay, silt and sand in the soil), field soil pH in all horizons, slope, aspect, position in landscape (lower, mid, upper, ridge), landform (level or gently undulating plains, gently undulating rises or low hills, undulating or rolling hills, steep hills), understorey structure (grassy, with shrubs <2 m, or with mid-stratum of small trees and tall shrubs 2–10 m in height), basal area (three basal area sweeps per plot) and an estimate of average merchantable height (heights measured for at least five trees per plot. At 22 plots tree diameters were also measured. This was done only where plots lacked adequate growth data through time. Photographs and other relevant notes (e.g. evidence of recent harvesting) were also recorded for each site.

While detailed yield plots have generally been maintained, there were some plots, particularly experimental plots, where pegs had been removed (e.g. during harvesting operations, or at the completion of the experiment). In most cases we were able to find some evidence of pre-existing plots (e.g. tree tags), but in 10 cases we were unable to locate evidence of the plot, in which case the plot was excluded from the data set.

### Tree growth data used

From the 232 plots for which we had data available, we focussed our analysis on 124 plots in Qld and 14 plots in NSW (Figure 5). The final selection of plots for Qld was chosen based on their locations. Where several plots were located within close proximity representative plots were selected for measurement and others were excluded. In the case of experimental data where all plots were located within a given logging compartment, we randomly chose only one plot in each experimental treatment. The majority (63%) of plots that were excluded from the data set were experimental plots. Certain yield plots were randomly selected for inclusion/exclusion if multiple yield plots were located in the same logging compartment of a state forest. Several plots were also excluded from the data set due to plot access issues or a lack of data (e.g. certain plots that only had data for stems >20 cm DBH). One NSW plot was excluded from the dataset because this plot had been affected by a severe wildfire.

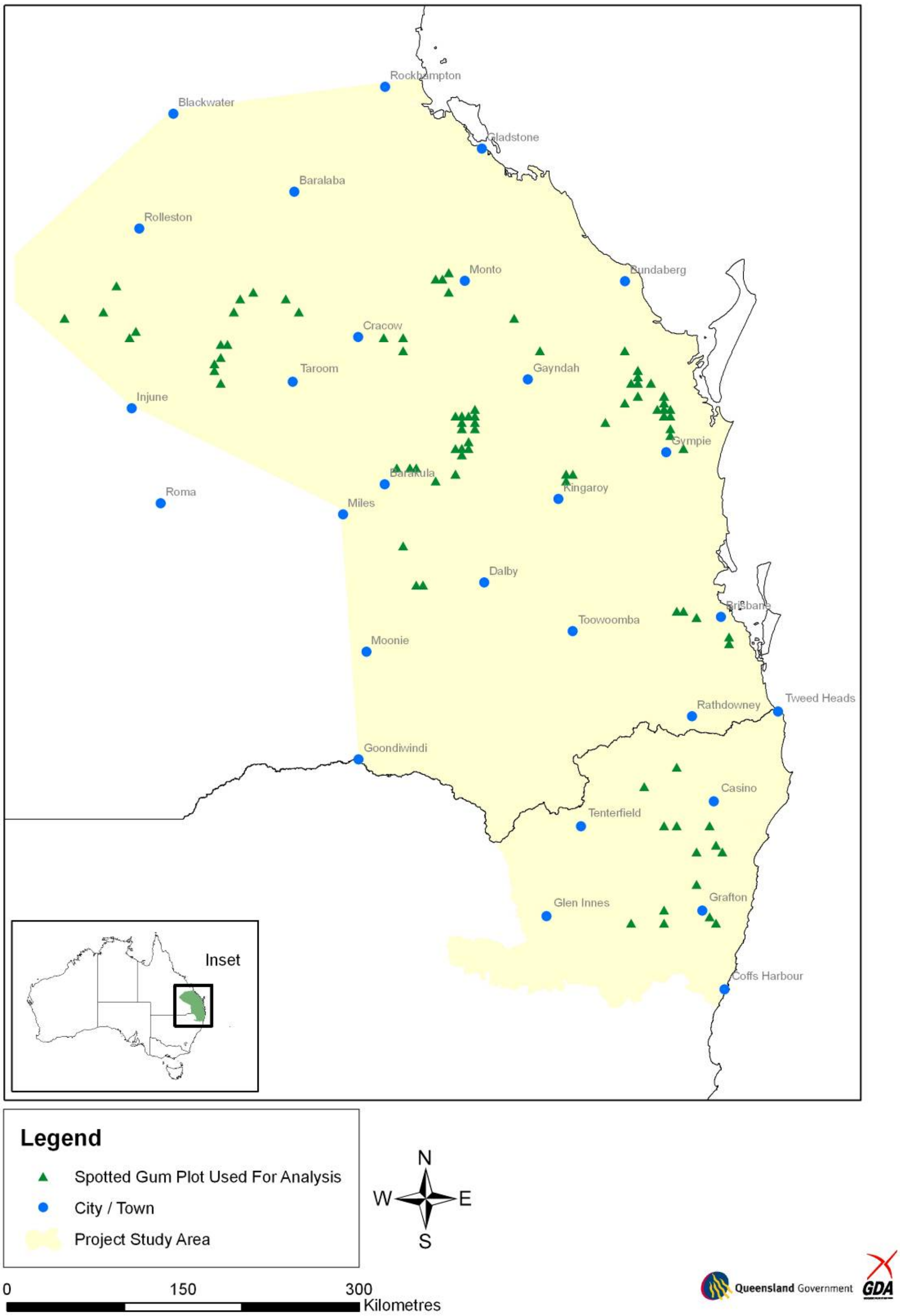


**Figure 5.** Locations of the 138 plots across the project study area. These plots were selected for analysis of stand productivity (basal area and volume periodic annual increment).

Plot sizes varied from 0.04 to 0.5 ha, with an average size of 0.33 ha. Plots were either rectangular or circular. Period of data collection varied between plots. On average (across the 138 plots) growth increment data was calculated for 10.2 years. The earliest measurements used were made in 1971 and the latest measurements were made during the current project in 2009. The longest period of data measurement was for a NSW plot (1982 to 2006). The increment data include all removals during the period of interest. Hence we report production basal area over the period as opposed to actual standing basal area, in order to minimize differences as a result of harvesting and mortality.

We analysed growth for all trees with a DBH >10 cm, as this was generally the minimum size measured. Our analysis is based on all tree species contained within the forest (as spotted gum forests contain a mix of different tree species), not just spotted gum. Stem volumes were estimated using a DBH based volume equation developed for this forest type. This equation included an easting adjustment to take into account that trees in the west of the study area on average have a lower stem volume (shorter bole for a given DBH) than those in the east.

**Site descriptions**

A sample of representative site descriptions for seven regions (Moreton, Maranoa Balonne, Mary, Coastal Burnett, Darling Downs, Inland Burnett and Fitzroy) is shown in Appendix 1.

Soil types were generally Kurosols (60% of plots; Grey, Brown, Red and Yellow), Kandosols (14% of plots; Grey, Brown, Red and Yellow), Dermosols (10% of plots; Grey, Brown, Red) and Chromosols (8% of plots; Brown, Red and Yellow). All soils had an A horizon that was acidic (pH from 4–6.5). Slopes varied from 1–53%, with an average slope of 8%.

Long-term annual average rainfall varied from 610 mm at Braemar State Forest near Dalby to 1359 mm at Goomboorian State Forest near Gympie. Long-term average annual rainfall for the 138 plots was 913 mm.

**Analysis of the spotted gum growth data**

In addition to the site variables recorded in the field we had access to a range of climatic variables. The climatic variables were extracted from the SILO Data Drill program developed by the Qld Government Department of Environment and Resource Management (http://www.longpaddock.qld.gov.au/silo/). Using this program we obtained interpolated daily climatic information for each plot. Given that there is a lag between climatic events (e.g. rainfall) and tree growth (e.g. Fensham *et al.* 2003) we used climatic data for the year prior to the year for which we had growth data. For example, if growth data was available from 1981–1994 we used the climatic data for the period 1980–1993. Climatic variables included: annual rainfall (mm), evaporation (mm), potential evapotranspiration (calculated using the FAO Penman-Monteith formula), average minimum temperature (ºC), average maximum temperature (ºC), average minimum relative humidity (%, estimated from minimum temperature), average maximum relative humidity (%, estimated from maximum temperature). From this data we also estimated length of dry periods (average number of consecutive dry months per year in the increment period, where a dry month was defined as a month with <30 mm of rain) and Prescotts soil moisture index (PSMI).

This soil moisture index provides an estimate of available soil moisture based on mean monthly rainfall (R) and monthly potential evaporation (E) such that: PSMI = 0.445 * R / $E^{0.75}$ (McKenzie and Ryan 1999). Using the soil data we also calculated our own soil moisture availability index based on Williams (1983) and Gardner (1988). This index uses soil texture and structure to allocate an amount of water that can be retained to a given depth for a given textural class. We calculated this index to a depth of 100 cm as there was available soil data to this depth for most plots. Where soil texture information was not available to this depth we assumed texture of the lowest horizon extended to100 cm.

To make use of the soil variables recorded in the field we converted the Munsell (1994) soil colour categories to a continuous variable using the Buntley and Westin (1965) index. This index attributes a numeric value to the soil hue and this value is multiplied by the chroma (the saturation of the colour). In this index higher values are attributed to brighter colours. Our soil variables were somewhat limited by the depth to which we could sample and we did not provide any quantitative measure of soil fertility (no soil chemistry analysis). However, based on horizon colours and depths, soil types and using expert knowledge, we derived a soil fertility class for each plot, with classes ranging from one (most fertile) to four (least fertile).

We analysed the effects of the above variables on periodic annual increment (PAI) for basal area and volume using GenStat (Release 11.1). We used all-possible subset regression for screening of explanatory variables to select the best explanatory variables for regression. This method was used in preference to other variable selection methods as it allows determination of the best model for each number of explanatory variables and provides output to compare competing models (to see how similar they are). In addition to multiple linear regression we also ran general linear models for screening covariates (continuous explanatory variables) and factors (e.g. soil type). We ran initial analyses with all available variables to determine which variables were relevant to spotted gum forest productivity. Correlation matrices were used to determine whether explanatory variables were highly correlated. In many cases the climatic variables were highly correlated and it was not sensible to use several climatic variables in the regression model. Where two statistically significant variables were correlated we ran models with both variables included, and then dropped the least significant variable from the model. For example, for prediction of volume PAI, the best statistical relationships included both rainfall and minimum temperature. However, because these variables were significantly correlated, and rainfall was the better of the two predictors we decided to drop minimum temperature from the model. This also made more sense for the productivity assessment tool given that this tool was developed to be easily used by landholders and it is assumed most landholders have detailed knowledge of the annual rainfall for their property but would have difficulty obtaining information on average minimum temperatures.

Through a series of analyses we determined that annual rainfall was consistently the best predictor of basal area PAI and volume PAI. Adding other non-correlated variables did not greatly improve the regression model. A number of variables had a significant influence on spotted gum volume productivity on their own (e.g. potential evapotranspiration, evaporation, maximum humidity, maximum temperature, minimum humidity, minimum temperature, soil pH at top of A horizon, longitude, slope, number of consecutive dry months per year, Prescotts soil moisture index) but when included with rainfall did not improve the statistical model. Interestingly, soil variables, such as soil fertility class, and the Buntley-Westin index had no significant influence on basal area or volume PAI.

Through polynomial regression we found that addition of a quadratic term significantly improved the accuracy of prediction of basal area and volume PAI from rainfall. Hence we used a quadratic relationship between basal area PAI and rainfall and between volume PAI and rainfall in the productivity assessment tool. Rainfall not only explained the highest proportion of the variance in the data, but was considered suitable for use by landholders in the SPAT.

### Carbon predictions for the decision support tool

The carbon component of the SPAT is based on the FullCAM carbon accounting model developed by the Australian Government, Department of Climate Change (Richards and Evans 2000). We used a growth model (tree yield formula) which assumes that undisturbed sites tend towards an equilibrium basal area (or natural basal area) which is an expression of the sites productivity. This equilibrium basal area is based on the forest productivity index (FPI) and allows an estimate of the maximum biomass production for a given site. The above-ground tree mass of a site asymptotically approaches the maximum above-ground biomass as the forest matures through time. The tree yield formula used for tree growth is:

$$T(A) = M * \exp(-k / d)$$

Where:

$T$ = Aboveground mass of the trees (tdm/ha)
$A$ = Growth stage of the forest (in years), which is based on the initial basal area.
$M$ = Maximum aboveground biomass of trees (tdm/ha)
$k$ = $2 * G$ – 1.25. Where $G$ = Tree age of maximum growth (in years) expressed as a multiplier of the maximum aboveground biomass plus a constant). This is also usually the age at which the canopy closes.
$d$ = Adjusted growth stage of forest (in years). This is calculated from an assumed basal area to biomass ratio of seven (taken from Snowden *et al.* 2007) and $M$ for the site.

The relationship between $M$ and the average annual FPI is taken to be (from observations in experiments):

$$M = [\ 6.0109 * \text{sqrt(FPI)} - 5.2912\ ]\ \hat{}\ 2.$$

The FPI is a measure of site productivity due to soil, sunlight, rainfall, evaporation, and frost. The FPI varies during the year, where higher values of FPI result in more biomass production by the trees. The FPI is described by Richards (2002), Technical Report 27 of the National Carbon Accounting Reports series. In the SPAT FPI is obtained by entering a latitude and longitude. FPI was averaged over a 1 $km^2$ grid for use in the tool and was only calculated within the defined study area.

The SPAT also provides an estimate of tree carbon. This assumes that approximately 50% of biomass is carbon (Gifford 2000), and adds an additional 25% for carbon stored in the tree roots (Snowdon *et al.* 2000, Mokany *et al.* 2006).

**Grass growth predictions for the decision support tool**

Pasture production was estimated using tree basal area and pasture production relationships derived from the GRASP pasture growth model (Littleboy and McKeon 1997) and data were extracted from the StockTake database (Department of Primary Industries and Fisheries 2004). This model uses historic rainfall data to predict pasture growth for a given tree basal area (for a given basal area it assumes that trees make a proportion of the water and nitrogen resources unavailable for pasture growth). Polynomial regressions between pasture growth and tree basal area were run for the range of different land types and regions included in the SPAT (Appendix 2). Appropriate land types (i.e. those containing spotted gum) were selected from the large number of grazing land types in the StockTake database that are used in the grazing land management (GLM) workshops.

## Results and discussion

Outputs from this component of the study are in the form of a spotted gum productivity assessment tool in a Microsoft Excel spreadsheet. The required inputs and outputs available from the tool are described in Appendix 2. The SPAT incorporates the data described above to allow an estimation of:

1. Tree growth rates (basal area and volume PAI) on specific sites and financial returns based on user inputs (i.e. prices of products obtained from the forest and the proportion of the forest that is unmerchantable).
2. Pasture production (annual grass production, utilisable grass production and carrying capacity) and expected financial return from livestock grazing at a given site. This is dependent on providing the correct region, land type, land condition, tree basal area and livestock price.
3. Above-ground tree biomass and carbon stored in trees for a specific site. This is dependent on providing a latitude and longitude for the site of interest and the basal area of the forest.

A summary of the spotted gum growth relationships used in the SPAT to predict tree growth is included below.

For the selected 138 plots standing basal area varied from 2.7 to 29.1 $m^2$/ha. Basal area increments ranged from 0.014 to 0.857 $m^2$/ha/year with an average of 0.21 $m^2$/ha/year. Similar basal area increments were reported for a study in NSW spotted gum forest (Bauhus *et al.* 2002). Standing stem volumes varied from 5.0 to 105.9 $m^3$/ha. Volume increments ranged from 0.08 to 4.6 $m^3$/ha/year with an average of 0.86 $m^3$/ha/year.

There was a significant quadratic relationship between basal area PAI and rainfall ($F_{2,135} = 80.1$, $P < 0.001$) which explained 54% of the variance in the data (Figure 6).There was also a significant quadratic relationship between volume PAI and rainfall ($F_{2,135} = 73.3$, $P < 0.001$) which explained 51% of the variance in the data

(Figure 7). Despite the large number of variables investigated, a large amount of variation remained unexplained. It is likely that there are complex interactions between a range of variables that influence productivity in these forests. It is also likely that there are variables that we did not measure (e.g. quantitative measures of soil fertility) that could help reduce the unexplained variation.

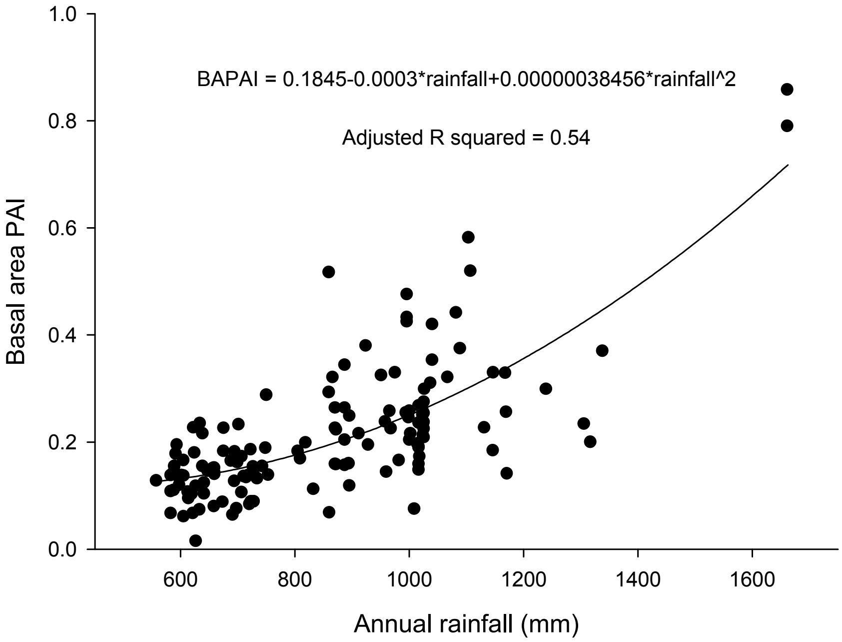


**Figure 6.** The quadratic relationship between basal area PAI ($m^2$/ha/year) and annual rainfall over the relevant period of growth for each plot.

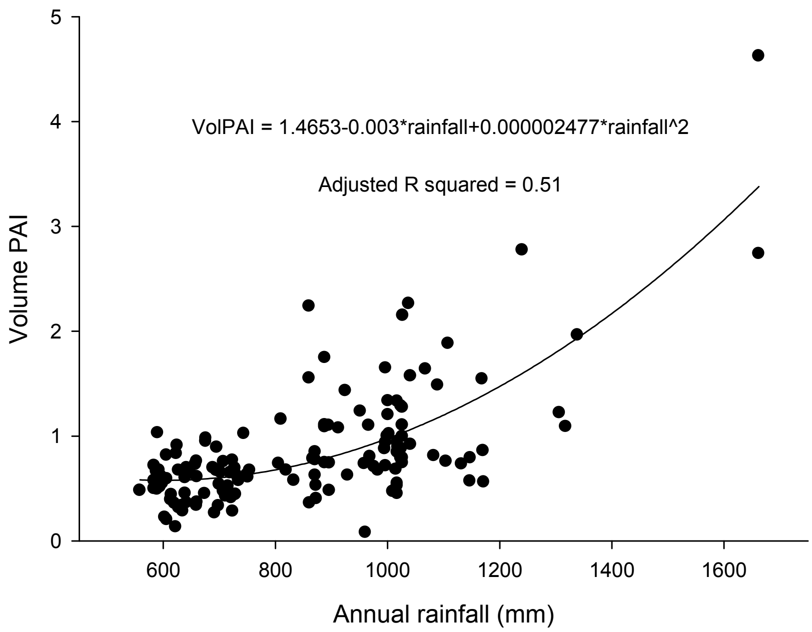


**Figure 7.** The quadratic relationship between volume PAI ($m^3$/ha/year) and annual rainfall over the relevant period of growth for each plot.

The above relationships between rainfall and basal area and volume PAI were incorporated into the SPAT to allow estimation of basal area and volume production for a spotted gum forest at a particular site (with a known rainfall). This estimate of stand productivity does not take into account the effects of forest management, which can significantly improve commercial productivity by concentrating growth on merchantable stems rather than unmerchantable stems. Users of the SPAT need to provide an estimate of the proportion of the forest that is unmerchantable, as this will have a large bearing on the financial returns gained from the forest. The proportion of the stand that is unmerchantable will be heavily influenced by past management. That is, a stand that has been well managed will have a higher proportion of merchantable trees than a stand that has not been well managed.

The SPAT assumes that stand productivity does not vary across a range of standing basal areas (5–15 $m^2$/ha). This is because there was no significant relationship between volume PAI and standing basal area where tree basal area was less than 15 $m^2$/ha ($P$ >0.05, Figure 8). This suggests that for a given site where an equilibrium basal area has not been reached, a forest with lower basal area will put the same volume of wood into fewer trees than in a forest with higher basal area. Results from historic native forest thinning experiments in spotted gum forest support this assertion (see Appendix 3). That is, in comparing thinned (various densities) and unthinned stands, stand volume ($m^3$/ha) increased at similar rates through time. However, when forest management is used to lower the basal area of non-merchantable trees and maintain productive growing conditions, growth rates will be greater on merchantable trees (Appendix 3).

It is important to realise that the lack of relationship between volume PAI and standing basal area (Figure 8) will not hold at very low basal areas (e.g. <5 $m^2$/ha) because at very low basal areas tree growth increments can decline. This is because a minimum density of trees is required to create an environment that improves conditions for growth (e.g. soil building processes that maintain the organic content of the soil and improve infiltration) and at very low basal areas trees are more susceptible to attack by insects, frost, and wind and storm damage. Further, at low basal areas (where canopy closure has not been reached) it is likely that the trees are not fully utilising the resources of a given site.

When plots with higher basal area (i.e. >15 $m^2$/ha) where included in this analysis, there was a tendency for volume increment to increase at higher basal areas ($F$ = 11.1, $P$ = 0.001; Figure 9). However, there was a large degree of variation in volume increments particularly at higher basal areas. The plots with high basal areas (>20 $m^2$/ha) were generally in locations where site productivity (particularly rainfall) was higher.

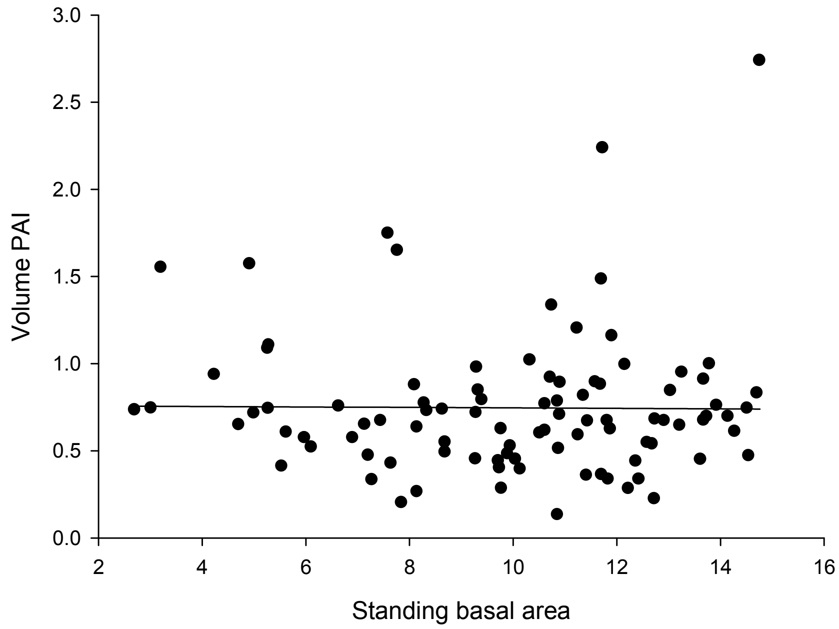


**Figure 8.** The lack of relationship between volume PAI (m³/ha/year) and standing basal area ($m^2$/ha) for plots with a basal area <15 m²/ha.

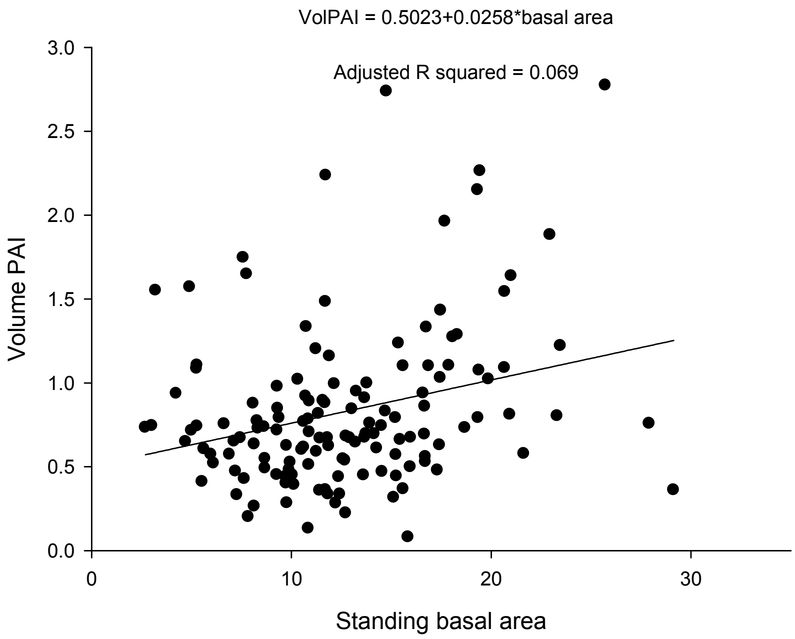


**Figure 9.** Relationship between volume PAI (m³/ha/year) and standing basal area ($m^2$/ha) for all plots.

It is assumed that the results reported here from Crown forests can be applied to private native forest. While this is a reasonable assumption with regard to stand productivity (e.g. Brack 2004), there may be some differences in tree growth rates and the proportions of merchantable and unmerchantable trees between Crown and private forest due to management history (e.g. differences in forest harvest history, fire management and grazing management). Long term monitoring of plots established on private lands (Chapter 4) is required to allow a future comparison of growth rates between private and Crown lands.

# Chapter 4. Establishment of experimental monitoring plots in private native forest.

**Authors: S. Swift, D. Osborne and B. Hogg**

## Introduction

An important initiative of this project was to establish a number of tree growth monitoring plots and experimental sites across the study area in private native forests. Most of the previous work on spotted gum forests has been based on Crown forests (e.g. Chapter 3, Grimes and Pegg 1979, Bauhus *et al.* 2002) and while the work completed on Crown lands is invaluable, there are differences in forest structure and species composition between these lands and private native forests. These differences arise from differences in management history. Management regimes in the Crown sector are aimed at timber production with other benefits (e.g. grazing and apiary) seen as of secondary importance, while in many cases on private land, management is aimed at grazing production with timber production seen as a secondary land use.

The information on the effects of thinning treatments on tree growth in spotted gum forests on Crown land (e.g. Appendix 3) needs to be complimented by accurate scientific information on spotted gum growth on private lands across a range of climatic regions and aiming to capture some of the differences in stand structures brought about by grazing land management. The aim of this component of the project was to establish research and demonstration sites for monitoring over time, to capture variation in site and climate across the region. Specifically, we aimed to establish monitoring sites to determine the effects of thinning treatments (various tree densities) on tree growth. The establishment of these sites was necessary due to the lack of native forest silvicultural data on private lands. These sites will form a basis that will allow future data collection to provide information on a range of different silvicultural treatments in private native forest. Collaboration with private landholder forestry interest groups (e.g. the private forestry development committees, PFDCs) and industry interest groups (e.g. AgForests and AgForce) should assist with long-term maintenance of the monitoring plots and extension of monitoring results to private landholders.

## Methods

Under the auspices of this project 13 sites have been established and/or measured in spotted gum dominant forest types with assistance from the PFDCs, AgForests and AgForce. Eight sites were specifically established for this project and at a further five sites plots were remeasured at existing trials that had been established previously and measured by PFDCs. Remeasuring these previously established plots was considered important to provide longer-term data that will be useful for future analyses. However, some of these plots were initiated as demonstration sites and were not designed to be analysed as stand alone experiments. These sites (and the individual plots within sites) will be valuable as part of a larger data set across the geographic and climatic range of the project. Previous data are the intellectual property of the initiating organisation and hence have not been provided as part of this report.

All newly established sites (apart from experiment 13) have been designed with at least two replications of three thinning treatments. These treatments depended upon site and stand quality, the amount of area available and local landholder input about acceptable treatment stocking minima and maxima. These experiments have an unthinned control and at least two thinning treatments with tree stocking reduced to 50–200 stems/ha.

The study area and site location details are shown in Figure 10. All sites (including the newly established sites) were re-measured in 2010 and tree identification tags were checked at this time. Plot measure data are stored on the Department of Employment, Economic Development and Innovation (DEEDI) database. An example of plot records and details of codes used (e.g. species codes, measure variables) are shown in Appendix 4. Sites have been allocated a Native Forest Queensland (NFQ) experiment number for ease of record and data management. Detailed commencement reports for each of the experiments established and used in this project were reported in Milestone Report 4 of this project (Swift and Osborne 2008).

A summary of each of the experimental sites (e.g. current and past management) and details of experimental designs are provided in Appendix 5. It is considered far too soon to draw any conclusions from the data at this time and therefore, while the results are presented, no interpretation is attempted.

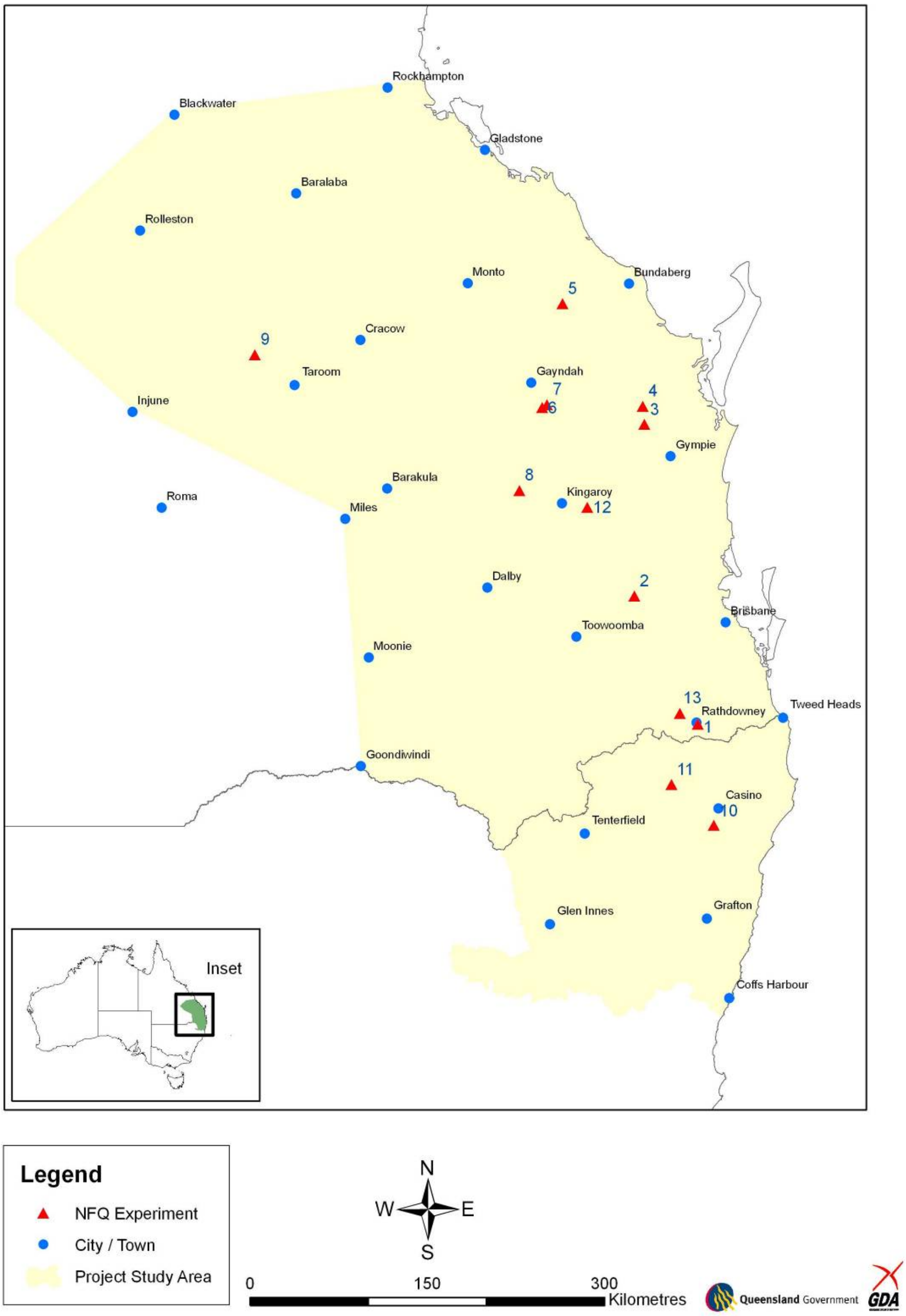


**Figure 10.** The project study area and experimental locations on private land.

## Results and discussion

Across all plots, stocking varied from 13 to 1975 stems per hectare. Average stocking, DBH and basal area for the different treatments in the established experiments are provided in Table 2. Average DBH for trees present at the initial measure (i.e. ignoring recruits) increased in all treatments (Table 2). Stocking, average DBH and basal area for all plots across a range of stockings at the demonstration monitoring plots are provided in Table 3. The increases in stocking between the initial and 2010 measures (Tables 2 and 3) were due to recruitment of new trees into the plots.

Across all plots there was a trend of higher DBH increments at lower tree stockings for trees present at the initial measure (i.e. ignoring recruits) (Figure 11). Across all trees measured the average increment (± standard error) was 0.54 ± 0.01 cm/year and the maximum increment was 6.2 cm/year. At stockings of <150 stems per hectare average DBH growth increment was 0.81 ± 0.02 cm/year; at stockings of 150–600 stems per hectare average increment was 0.41 ± 0.02 cm/year; and at stockings of >600 stems per hectare average increment was 0.44 ± 0.02 cm/year. At stockings above 250 stems per hectare DBH increment was relatively constant (Figure 11), although still variable. There was considerable variation in diameter growth increment across all trees measured (Figure 11) which was not surprising given the short time frame between measures, the variation between plots (i.e. site related variation) and variation in forest health and vigour. These growth increments are similar, or slightly higher than those reported from thinning experiments on Crown land (Appendix 3). Further growth data needs to be collected from the private native forest monitoring sites to allow a more detailed comparison to the thinning experiments on Crown land.

Preliminary results for each plot in each experiment are reported in Appendix 5. Due to slow and variable growth rates between years, native forest growth data needs to be collected over a long period of time to ensure reliable recommendations can be made from the results. Hence the data presented should not be used to formulate management plans or guidelines and future measurements at the 13 monitoring sites is needed to provide long term growth data on private native forests to aid private native forest management.

**Table 2.** Summary of plot data from measures made at private native forest experiments during this project. Mean DBH was calculated for stems measured on both occasions (i.e. recruits were ignored). In experiment 11, measures took place before and after logging, but in all other cases treatments were applied prior to or immediately after the first measure.

| Experiment | Plot numbers | Treatment | Year of initial measure | Mean stocking (stems/ha) | | Mean DBH (cm) | | Mean BA (m²/ha) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Initial measure | 2010 measure | Initial measure | 2010 measure | Initial measure | 2010 measure |
| 1 | 1, 4 | 50–99 | 2008 | 66 | 80 | 16.2 | 19.7 | 2.0 | 6.2 |
| 1 | 2, 5 | 100–150 | 2008 | 136 | 136 | 16.3 | 19.4 | 4.8 | 5.2 |
| 1 | 3, 6 | Control | 2008 | 824 | 960 | 10.4 | 11.5 | 9.9 | 11.9 |
| 2 | 1, 6, 11 | 75 | 2009 | 75 | 75 | 11.9 | 13.9 | 1.0 | 1.3 |
| 2 | 3, 5, 12 | 100 | 2009 | 129 | 129 | 11.2 | 13.4 | 1.4 | 1.9 |
| 2 | 2, 8, 9 | 200 | 2009 | 202 | 202 | 11.3 | 13.2 | 2.3 | 3.0 |
| 2 | 4, 7, 10 | Control | 2009 | 1283 | 1283 | 6.9 | 7.7 | 6.8 | 8.1 |
| 3 | 10, 14 | 70 | 2006 | 103 | 106 | 28.8 | 30.8 | 7.1 | 9.2 |
| 3 | 9, 12 | 100 | 2006 | 106 | 106 | 24.9 | 26.8 | 5.8 | 6.7 |
| 3 | 7, 13 | 200 | 2006 | 128 | 128 | 28.0 | 29.5 | 8.8 | 9.5 |
| 3 | 8, 11 | Control | 2006 | 247 | 247 | 24.3 | 25.5 | 13.0 | 14.2 |
| 6 | 7, 8, 10, 11 | 50 | 2008 | 50 | 50 | 20.5 | 22.9 | 1.8 | 2.2 |
| 6 | 1, 2, 4, 6 | 100 | 2008 | 100 | 101 | 17.2 | 18.3 | 3.1 | 3.3 |
| 6 | 3, 5, 9, 12 | Control | 2008 | 248 | 249 | 15.3 | 16.0 | 5.1 | 5.6 |
| 7 | 14, 18 | 50 | 2008 | 50 | 50 | 22.4 | 24.0 | 2.0 | 2.3 |
| 7 | 13, 17 | 100 | 2008 | 100 | 101 | 23.4 | 24.4 | 4.5 | 4.9 |
| 7 | 15, 16 | Control | 2008 | 500 | 501 | 17.0 | 17.5 | 12.4 | 13.0 |
| 8 | 1, 6, 9 | 100 | 2008 | 100 | 100 | 29.5 | 30.4 | 7.2 | 7.6 |
| 8 | 2, 5, 7 | 200 | 2008 | 200 | 200 | 26.6 | 27.0 | 12.4 | 12.8 |
| 8 | 3, 4, 8 | Control | 2008 | 348 | 341 | 21.9 | 22.3 | 15.5 | 16.1 |

**Table 2.** *cont.*

| Experiment | Plot numbers | Treatment | Year of initial measure | Mean stocking (stems/ha) | | Mean DBH (cm) | | Mean BA (m²/ha) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Initial measure | 2010 measure | Initial measure | 2010 measure | Initial measure | 2010 measure |
| 9 | 1, 5 | 50 | 2008 | 50 | 50 | 19.1 | 19.9 | 1.6 | 1.7 |
| 9 | 3, 6 | 100 | 2008 | 100 | 101 | 20.1 | 20.5 | 3.4 | 3.5 |
| 9 | 7, 8 | 127 | 2008 | 127 | 127 | 24.7 | 25.2 | 6.2 | 6.8 |
| 9 | 2, 4 | Control | 2008 | 421 | 421 | 18.9 | 19.2 | 13.6 | 13.8 |
| 11 | 2, 4 | <500 | 2008 | 480 | 385 | 25.2 | 25.6 | 31.2 | 25.6 |
| 11 | 1, 3, 5, 6 | >500 | 2008 | 575 | 463 | 24.1 | 24.2 | 31.4 | 25.2 |

**Table 3.** Summary of plot data from measures made at private native forest demonstration sites during this project. These sites had a range of stockings but did not have set stocking treatments. Mean DBH was calculated for trees measured on both occasions (ignoring recruits and trees that died or were removed).

| Experiment | Plot | Stocking (stems/ha) | | Mean DBH (cm) | | BA (m²/ha) | |
|---|---|---|---|---|---|---|---|
| | | 2008 | 2010 | 2008 | 2010 | 2008 | 2010 |
| 4 | 1 | 144 | 144 | 18.3 | 19.5 | 4.1 | 4.6 |
| 4 | 2 | 206 | 206 | 23.4 | 23.9 | 11.5 | 11.8 |
| 4 | 3 | 175 | 175 | 19.2 | 19.6 | 7.0 | 7.2 |
| 4 | 4 | 425 | 413 | 15.5 | 15.7 | 11.8 | 12.0 |
| 4 | 5 | 31 | 63 | 20.7 | 22.3 | 1.3 | 1.6 |
| 4 | 6 | 206 | 188 | 20.7 | 20.6 | 11.8 | 9.5 |
| 4 | 7 | 13 | 13 | 34.6 | 35.9 | 1.5 | 1.5 |
| 4 | 8 | 88 | 88 | 41.6 | 42.0 | 12.7 | 13.0 |
| 5 | 1 | 120 | 120 | 16.5 | 17.7 | 2.6 | 3.0 |
| 5 | 2 | 180 | 180 | 17.2 | 18.4 | 4.8 | 5.4 |
| 5 | 3 | 120 | 120 | 11.2 | 11.8 | 1.2 | 1.4 |
| 5 | 4 | 80 | 80 | 15.7 | 16.4 | 1.8 | 2.0 |
| 5 | 5 | 160 | 140 | 22.7 | 23.2 | 9.5 | 5.1 |
| 5 | 6 | 902 | 882 | 9.0 | 9.3 | 6.8 | 7.0 |
| 5 | 7 | 120 | 1163 | 9.6 | 9.8 | 9.8 | 10.1 |
| 5 | 8 | 1243 | 1243 | 10.0 | 10.3 | 12.5 | 13.1 |
| 5 | 9 | 120 | 120 | 18.9 | 19.9 | 3.4 | 3.8 |
| 5 | 10 | 200 | 201 | 13.0 | 13.9 | 2.9 | 2.0 |
| 5 | 11 | 1403 | 1404 | 9.1 | 9.5 | 5.8 | 5.2 |
| 5 | 12 | 192 | 192 | 12.4 | 13.1 | 3.7 | 3.9 |
| 5 | 13 | 252 | 252 | 13.7 | 14.6 | 5.1 | 5.5 |
| 10 | 1 | 250 | 250 | 29.4 | 29.5 | 19.2 | 19.4 |
| 10 | 2 | 420 | 420 | 24.7 | 25.5 | 24.8 | 26.3 |
| 10 | 3 | 180 | 180 | 32.3 | 32.9 | 17.1 | 17.7 |
| 10 | 4 | 260 | 260 | 23.7 | 24.3 | 14.1 | 14.8 |
| 10 | 5 | 100 | 100 | 36.8 | 37.9 | 11.8 | 12.4 |
| 10 | 6 | 420 | 420 | 18.6 | 19.2 | 14.1 | 15.0 |
| 10 | 7 | 150 | 150 | 25.9 | 26.0 | 10.4 | 10.7 |
| 10 | 8 | 100 | 100 | 20.9 | 21.6 | 4.0 | 4.2 |
| 10 | 9 | 210 | 200 | 30.8 | 31.2 | 18.5 | 18.6 |
| 10 | 10 | 160 | 160 | 23.0 | 23.8 | 8.9 | 9.3 |
| 12 | 1 | 108 | 152 | 26.8 | 27.3 | 6.4 | 6.8 |
| 12 | 2 | 120 | 156 | 22.3 | 22.8 | 6.0 | 6.3 |
| 12 | 3 | 212 | 244 | 15.8 | 16.3 | 6.6 | 6.9 |
| 12 | 4 | 140 | 220 | 14.3 | 14.7 | 3.1 | 3.5 |
| 12 | 5 | 76 | 172 | 23.0 | 23.5 | 3.4 | 3.8 |
| 12 | 6 | 100 | 192 | 24.6 | 25.0 | 5.1 | 5.5 |
| 13 | 1 | 160 | 160 | 23.9 | 26.3 | 7.6 | 9.2 |
| 13 | 2 | 120 | 120 | 18.1 | 21.3 | 3.1 | 4.3 |
| 13 | 3 | 80 | 80 | 23.0 | 25.9 | 3.4 | 4.3 |

**Table 3.** *cont.*

| Experiment | Plot | Stocking (stems/ha) | | Mean DBH (cm) | | BA (m²/ha) | |
|---|---|---|---|---|---|---|---|
| | | 2008 | 2010 | 2008 | 2010 | 2008 | 2010 |
| 13 | 4 | 100 | 100 | 19.0 | 21.3 | 2.9 | 3.7 |
| 13 | 5 | 180 | 180 | 22.3 | 23.8 | 7.3 | 8.3 |
| 13 | 6 | 140 | 140 | 20.8 | 22.8 | 5.4 | 6.3 |
| 13 | 7 | 120 | 120 | 23.5 | 25.6 | 5.3 | 6.3 |
| 13 | 8 | 120 | 100 | 19.5 | 21.7 | 4.2 | 3.9 |
| 13 | 9 | 1142 | 1123 | 10.8 | 11.6 | 11.7 | 13.2 |

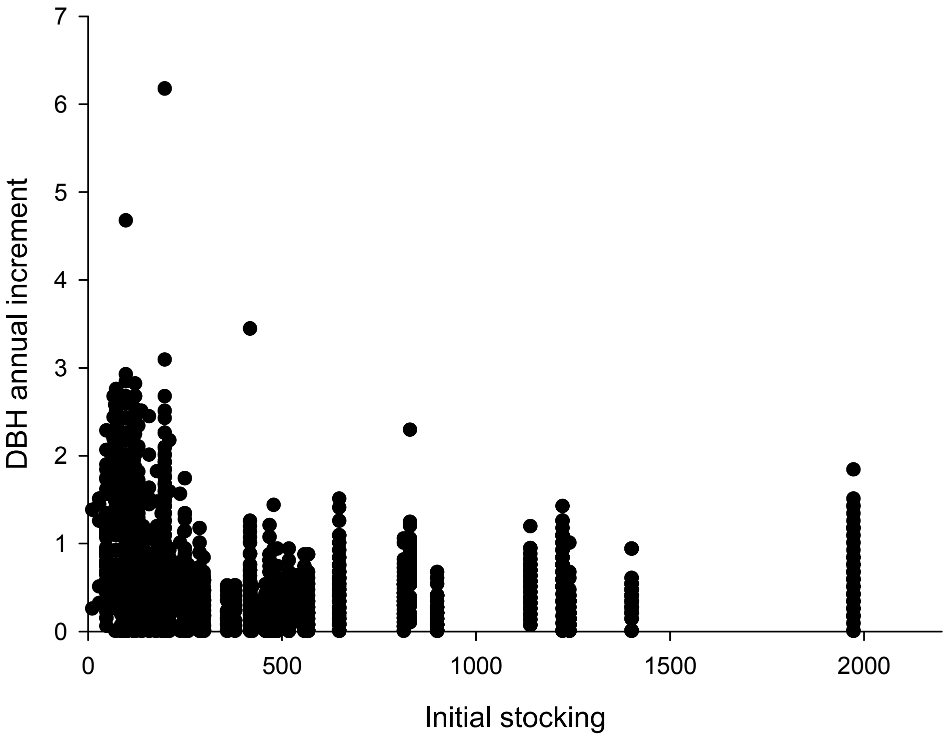


**Figure 11.** Plot showing the relationship between DBH annual increment for trees measured on both occasions (no recruits) and initial stocking for all plots established in private native forest. Diameter increment was calculated for the period between the initial measure (see Tables 2 and 3) and the 2010 measure. Negative increments were not included as these are likely to be the result of measuring error associated with the small time frame between measures. This is a very short period of growth and caution is needed in interpreting this data.

## Recommendations

This suite of monitoring sites is a good starting point to allow the collection of robust data on the growth of private native forest. With management, measurement and analysis these experiments and monitoring sites will go some way towards allowing future silvicultural management of private native spotted gum forests to be based on reliable experimental data. To realise this aim there does need to be an effort made by the parties that have been involved in this project (both private and government forestry organisations, forestry companies and landholders) to ensure that this work continues beyond the completion of the current project.

Management of these sites will need to be undertaken on a regular basis to ensure that plot identity is maintained and that there are no compromising external effects that could bias future results. It is likely that these monitoring plots will be affected by fire, weed invasion and drought into the future. Recording these events is important because this will allow any effects to be taken into account when interpreting future data.

Measurement and maintenance of these monitoring plots should be carried out on a five yearly cycle. If measures extend beyond the 5 year time frame, plot identity and plot tags could be difficult to locate, and this could decrease the value of these plots through limiting data continuity through time.

The number of experiments established under the current project is considered a bare minimum to investigate the effects of thinning across the range of spotted gum forests in south east Qld and northern NSW. Ideally other sites should be established to provide representative experiments on a range of private native forest site types across the climatic range.

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## Glossary

**Acceptable tree:** An acceptable tree must not be in a declining state, and is a well formed tree with a good crown, at least a merchantable log length, no bad fire scar, free from disease/pathogens/damage and with less than 50% of the crown infested with mistletoe.

**Advanced growth:** Well developed young trees (saplings).

**Abiotic:** Non biological factors (e.g. climate, topography or soil).

**Basal Area:** The cross sectional area of a tree expressed in $m^2$ used as a measure of forest density. The forestry standard is that basal area (BA) uses the DBH measurement for calculation.

**Biodiversity / species diversity:** The range of different living species (e.g. plant and animal species) in an area.

**Biomass**: The total weight of living material (organic matter) within a given unit or area (e.g. above ground tree biomass).

**Biotic:** Factors associated with living organisms.

**Bole:** The stem of a tree that is suitable for harvesting, usually taken as the section from stump height to crown break.

**Canopy:** The continuous layer of a forest made up of the tree crowns.

**Carbon Sequestration:** the process where trees and other plants take up carbon dioxide from the atmosphere and store it in their leaves, branches, stems and roots.

**Codes of Practice:** Guidelines to indicate best practice and to maintain integrity, sustainability and compatibility with environmental values.

**Co-dominant trees:** Trees that extend their crown into the canopy and receive direct sunlight from above but limited sunlight from the sides (i.e. one or more sides of a co-dominant tree are crowded by the crowns of dominant trees).

**Coppice:** Regrowth on a stump after a tree has been felled. Coppicing is used as a commercial method of regeneration in some areas.

**Crown class:** The position of a tree crown in relation to the crowns of adjacent trees. The classes commonly used are: dominant, co-dominant, sub-dominant or intermediate and suppressed.

**DBH:** Diameter at breast height. The diameter (in cm) of the tree trunk, measured at 1.3 m from the ground.  This is measured standing on the top side of the tree. Unless otherwise specified DBH is usually measured over the bark of a tree.

**Defect:** Damage to the tree that make that section of the tree useless for milling or structural timber.

**Directional felling:** Felling a tree in a desired direction to minimise damage to other trees or to minimise environmental impact.

**Ecology**: Refers to the distribution and abundance of plants and animals and the interaction between plants and animals in relation to their environment.

**Ecosystem:** A community of interacting, living organisms and the environment in which they live.

**Edaphic:** Environmental conditions associated with the soil.

**Epicormic growth:** Shoots growing from dormant buds beneath the bark. This often occurs after fire, drought, stress or when branches are heavily pruned and can reduce timber quality.

**Even-aged forest:** A forest composed of trees of the same age class. This is usually the result of one regeneration event.

**Forest structure:** Refers to the spatial distribution, density, age or size class distribution and understorey within a forest.

**Forest type:** Relates to the unique species association and age class of a forest. Forest types may vary due to environmental factors and management history.

**Forest composition:** Relates to the species diversity and frequency of species found in a forest.

**Forest management:** The intentional intervention by humans to influence forest composition or structure.

**Forest Productivity Index (FPI):** "The FPI is a dimensionless measure of site productivity due to soil, sunlight, rainfall, evaporation, and frost. The FPI varies during the year. Higher values of FPI result in more NPP produced by the trees" (Richards and Evans 2000)

**Form:** The shape and/or straightness of the stem and/or the nature of the branching.

**Girder:** High quality and high value logs which are used typically as structural bridge timbers. These products have a long length, large diameter and very little defect.

**Harvest:** The planned felling of merchantable trees and the removal of logs for utilisation as timber products.

**Harvesting plan:** A management plan for an area to be harvested.

**High grade harvesting:** Harvesting of all or most trees in a stand which are either of good form, vigour or have a commercial product in the bole. Generally, trees remaining in a high graded stand are small, defective or non-commercial. Many of these remaining trees can be suppressed with little to no growth potential.

**Harvest residue:** The debris and waste products remaining on the ground after a logging operation.

**Inventory:** a list of tree species, numbers in each diameter class or log volume in a forest.

**Lignotuber:** The lignotuber is a root swelling at or just below ground level, acting as a store of starch reserves. Lignotuberous plants can survive in the forest understorey for many years and have the capacity to produce shoots after the destruction of the above ground foliage through disturbance like fire, drought or grazing.

**M.A.I:** Mean annual increment – annual incremental growth of a measured parameter from tree/stand establishment (tree or stand parameter over tree or stand age). In native forest M.A.I. and P.A.I. are used interchangeably.

**Merchantable height:** The distance from the ground to the highest point of the tree bole from which a commercially viable sawn product is estimated to exist.

**Merchantable volume:** The available volume of timber is of a standard acceptable to industry.

**NPP:** Net primary productivity - is the rate at which all the plants in an ecosystem produce net useful chemical energy; it is equal to the difference between the rate at which the plants in an ecosystem produce useful chemical energy and the rate at which they use some of that energy during respiration.

**Old growth:** Large old senescent trees.

**Overstocked:** Refers to a forest where the number of trees in a given area is too high for the most efficient production of desired forest products.

**P.A.I:** Periodic annual increment – annual incremental growth of a measured parameter over the measure period.

**Pole:** High quality and high value logs. These products have a long length and can have very little defect.

**Prescribed burning:** The practice of deliberately burning an area for a desired outcome. In most cases prescribed burning in forests is done to reduce fuel loads and may be referred to as fuel reduction burning.

**Log ramp or dump:** Log storage area or location where harvested logs will be stored prior to loading for transport to the mill or processing plant.

**Regrowth forest:** Forests which have naturally regrown after a major event has cleared patches of forest. This clearing can be caused by natural or human activities.

**Residual stocking:** The fraction of the forest that remains intact following a stocking reduction event (e.g. silvicultural thinning or harvesting).

**Roundwood:** Timber products that utilise the log in an unsawn form (in the round form). Generally refers to lower grade products such as fence posts and piles, although may also refer to high value poles and girders.

**Sawlog:** Logs of a suitable length and diameter that have an allowable amount of defect for processing into sawn timber.

**Shade intolerant:** Refers to plant species that do not grow or that grow slowly in a shaded environment. Shade intolerant trees having become suppressed often fail to regain acceptable growth rates even if the overhead canopy is removed.

**Silviculture:** the science and practice of the management of forests for timber production.

**Silvicultural thinning:** see Treatment

**SPAT:** Spotted gum Productivity Assessment Tool developed under the current project. Decision support tool used to assist in management of spotted gum native forests.

**Stand density:** see Stocking.

**Stand potential:** The maximum expected production of timber derived from a given forest area under optimum growing conditions.

**Stand structure:** The compositional range of sizes, shapes, species and characteristics of trees and the understorey in a forest.

**Stocking:** The density or number of trees within a defined area.

**Treatment:** Killing the unwanted or non-productive component of a timber stand. This is generally done to improve growth on the merchantable component of the stand.

**Total height:** The distance from the ground to the highest point of the tree.

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## Researcher's disclaimer

End users need to be aware that while the guidelines and the SPAT are derived from the best data currently available, this is an incomplete data set and there are substantial gaps in the data and our knowledge.

End users need to be aware of the limitations of the material provided, such as:

- The silvicultural guidelines are current recommended practice however, it is recommended that professional advice be sought to plan and carry out any harvesting or treatment operations.
- The user must comply with the appropriate legislative requirements.
- The data from which the SPAT tree growth algorithms were derived is from spotted gum sites within the project study area and the SPAT should only be used for spotted gum forests within that area.
- The grass and pasture module in the SPAT is from Qld regions within the project study area.
- The SPAT carbon module is static.

# Appendix 1. Representative spotted gum site descriptions

## Authors: D. Osborne and S. Swift

## Region – Moreton

### Land type – Mixed open forests on duplex's and loams

**Location** – Enoggera S.F. (Brisbane) – Site 0697
**Rainfall** – 1170 mm **Elevation** – 190 m **Aspect** – East **Slope** – 49%

### Vegetation

**Understory Structure** – Open with some eucalypt regeneration.
**Major Species Composition** – Spotted gum, white mahogany, narrow-leaved red ironbark.

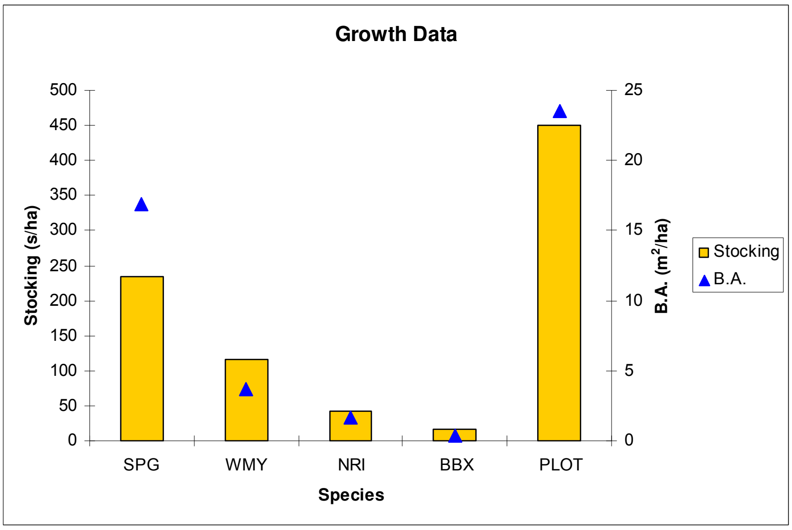
### Soils

**Soil Type** – Brown Kurosol.

| Depth (cm) | Description |
|---|---|
| 10 | Dark brown, weakly structured sandy loam with 20–50% rock, pH of 5.5, clear change to |
| 50 | Bright brown weakly structured sandy clay loam with 20–50% rocks, pH of 5.5, gradual change to |
| 65 | Bright brown weakly structured light clay with 10–20% rocks, pH of 5.0, gradual change to |
| 250 | Dull yellow orange strongly structured light clay with >90% rocks, pH of 5.0. |

### Stand Growth

Average merchantable height is 9.5 m.



**Land type – Tall open forests on steep hills and mountains**

**Location** – Daisy Hill S.F. (Brisbane) - Site 0380
**Rainfall** – 1339 mm **Elevation** – 116 m **Aspect** – North West **Slope** – 18%

## Vegetation

**Understory Structure** – Open with wattle and eucalypt regeneration.
**Major Species Composition** – Spotted gum, broad-leaved red ironbark and grey gum.

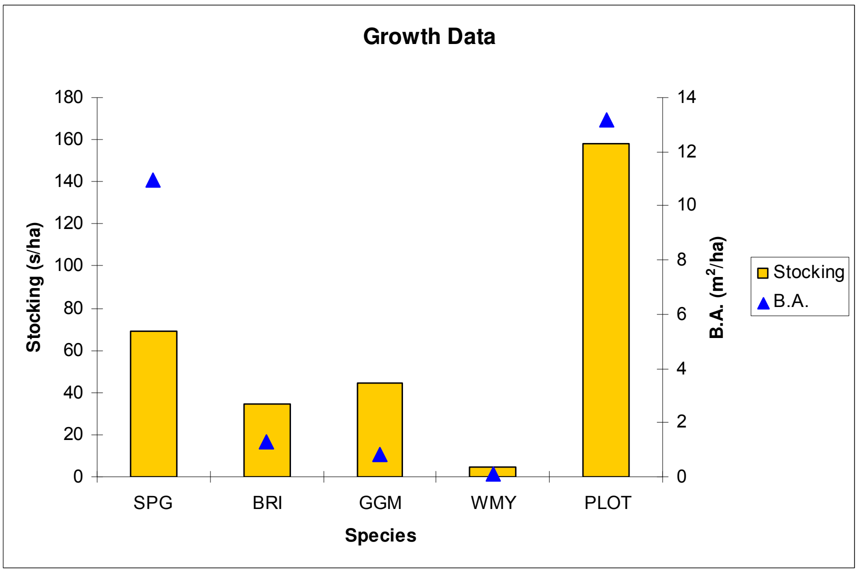
## Soils

**Soil Type** – Grey Dermosol.

| Depth (cm) | Description |
|---|---|
| 5 | Brownish black, moderately structured clay loam, pH of 5.0, gradual change to |
| 18 | Greyish yellow brown moderately structured light clay with <2% rocks, pH of 5.0, clear change to |
| 50 | Light grey strongly structured heavy clay with <2% rocks, pH of 4.5, gradual change to |
| 90 | Dull yellow orange moderately structured medium heavy clay with <2% rocks, pH of 4.5, diffuse change to |
| 100+ | Light grey strongly structured heavy clay with 2-10% rocks, pH of 4.5. |

## Stand Growth

Average merchantable height is 14 m.



**Land type – Tall open forests on steep hills and mountains**

**Location** – Mt Glorious S.F. (Brisbane) – Site 1346
**Rainfall** – 1306 mm **Elevation** – 473 m **Aspect** – North West **Slope** – 47%

## Vegetation

**Understory Structure** – moderately dense shrubby understory with areas of advanced regeneration and tall shrubs.
**Major Species Composition** – Spotted gum, white mahogany, grey gum.

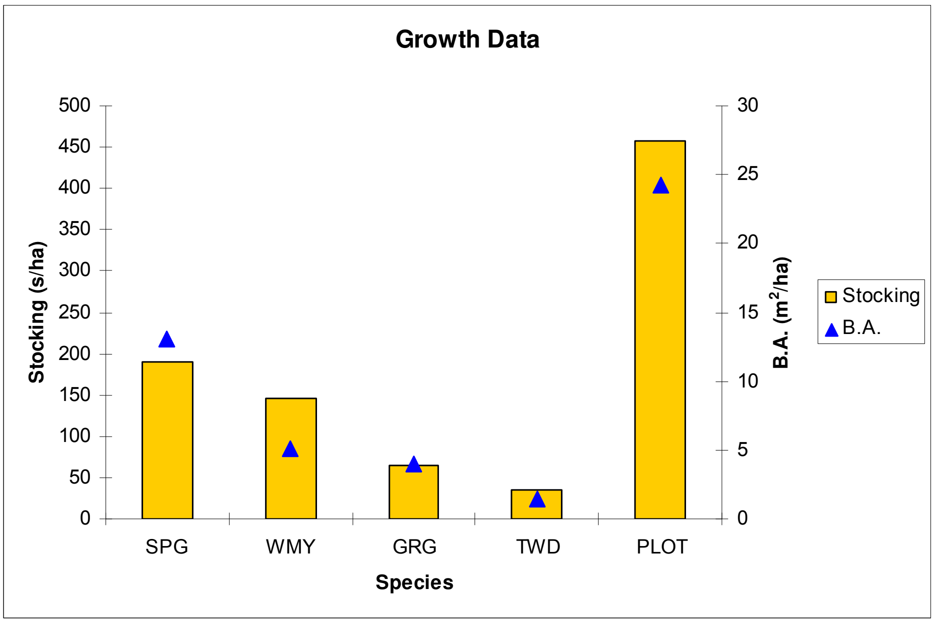
## Soils

**Soil Type** – Brown Kandosol.

| Depth (cm) | Description |
|---|---|
| 15 | Brownish black, weakly structured sandy loam (organic) with 2–10% rock, pH of 6.0, clear change to |
| 30 | Dull brown weakly structured sandy clay loam with 10–20% rocks, pH of 5.0, gradual change to |
| 75 | Dull orange unstructured loam coarse sandy with 20–50% rocks, pH of 5.0. |

## Stand Growth

Average merchantable height is 8 m



## Region – Maranoa Balonne

### Land type – Narrow-leaved ironbark

**Location** – Barakula S.F. (Chinchilla) – Site 0448
**Rainfall** – 622 mm **Elevation** – 402 m **Aspect** – North East **Slope** – 3%

### Vegetation

**Understory Structure** – Open understory with wattle and cypress regeneration.
**Major Species Composition** – Narrow-leaved red ironbark, spotted gum, cypress.

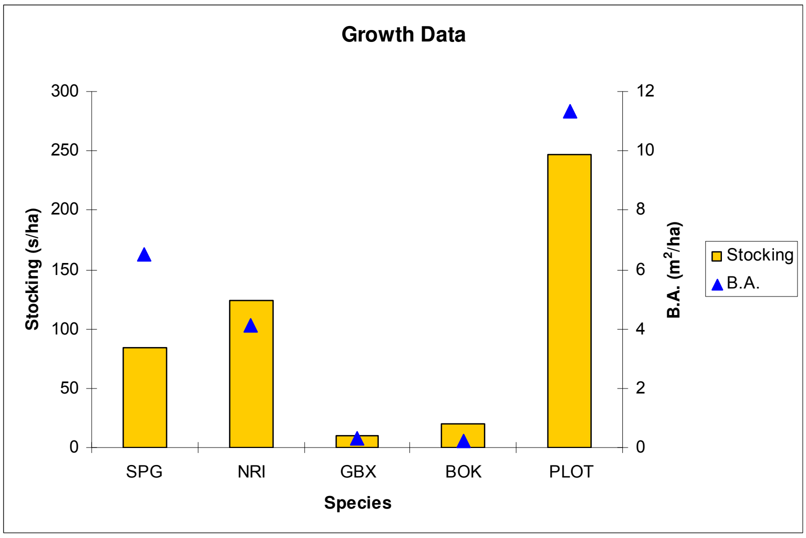
### Soils

**Soil Type** – Brown Sodosol.

| Depth (cm) | Description |
|---|---|
| 10 | Brown unstructured fine sandy loam with <2% rock, pH of 6.0, clear change to |
| 21 | Dull yellowish brown unstructured fine sandy loam with <2% rocks, pH of 5.5, abrupt change to |
| 28 | Greyish yellow brown strongly structured medium heavy clay, pH of 6.0, gradual change to |
| 48 | Dull yellowish brown moderately structured light medium clay, pH of 7.5, gradual change to |
| 88 | Dull yellowish brown strongly structured clay with 20–50% rocks, pH of 8.0, gradual change to |
| 95 | Decomposed sandstone, 50–90% rock, pH 8.0. |

### Stand Growth

Average merchantable height is 8 m.



**Land type – Cypress pine on duplex soils**

**Location** – Braemar S.F. (Kogan) – Site 0078
**Rainfall** – 639 mm **Elevation** – 392 m **Aspect** – North **Slope** – 2%

## Vegetation

**Understory Structure** – Open with some eucalypt regeneration.
**Major Species Composition** – Spotted gum, cypress, narrow-leaved red ironbark.

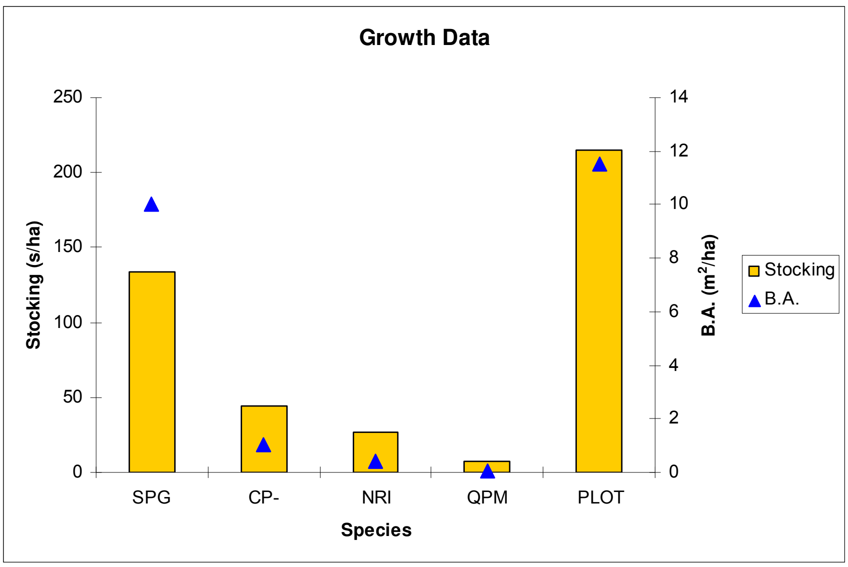
## Soils

**Soil Type** – Grey Kurosol.

| Depth (cm) | Description |
|---|---|
| 10 | Brownish black, unstructured sandy clay loam fine sandy, pH of 5.5, clear change to |
| 18 | Greyish yellow brown, unstructured sandy clay loam fine sandy, pH of 4.5, clear change to |
| 32 | Dull yellowish brown unstructured fine sandy loam+, pH of 5.0, abrupt change to |
| 45 | Brownish grey, strongly structured light medium clay with <2% rocks, pH of 5.0. |

## Stand Growth

Average merchantable height is 9 m.



# Region – Mary

### Land type – Mixed eucalypts on uplifted coastal plains

**Location** – Veteran S.F. (Gympie) – Site 0875
**Rainfall** – 925 mm **Elevation** – 190 m **Aspect** – North West **Slope** – 5%

## Vegetation

**Understory Structure** – Open and grassy.
**Major Species Composition** – Spotted gum, white mahogany, grey gum and grey ironbark.

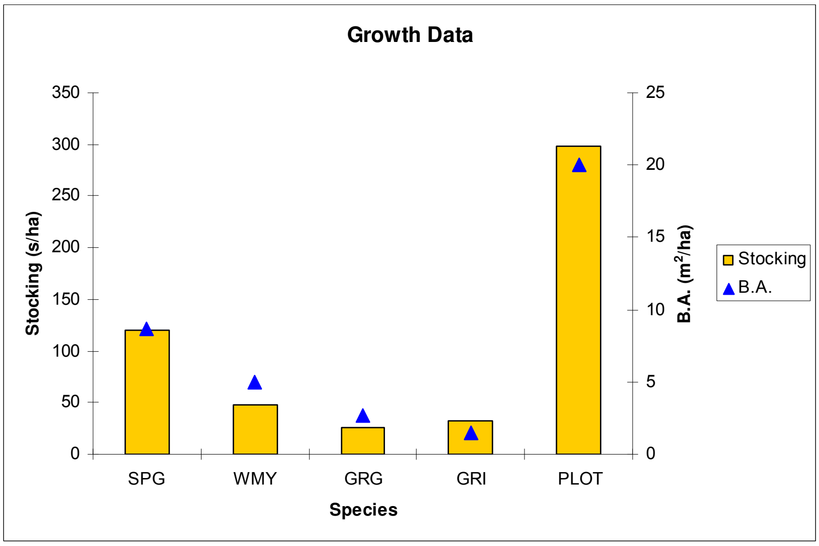
## Soils

**Soil Type** – Brown Dermosol.

| Depth (cm) | Description |
|---|---|
| 5 | Brownish black, weakly structured clay loam with <2% rock, pH of 6.0, gradual change to |
| 15 | Greyish yellow brown, weakly structured light clay with 2–10% rocks, pH of 5.5, clear change to |
| 35 | Bright brown moderately structured medium heavy clay with <2% rocks, pH of 5.5, gradual change to |
| 60 | Yellow orange, moderately structured heavy clay with 2–10% rocks, pH of 5.5, diffuse change to |
| 85 | Decomposed siltstone/mudstone, pH of 4.0. |

## Stand Growth

Average merchantable height is 11 m.



**Land type – Ironbark and spotted gum ridges**

**Location** – Neerdie S.F. (Gympie) – Site 1047
**Rainfall** – 959 mm **Elevation** – 161 m **Aspect** – South West **Slope** – 35%

## Vegetation

**Understory Structure** – Open and grassy.
**Major Species Composition** – Spotted gum, white mahogany, grey ironbark.

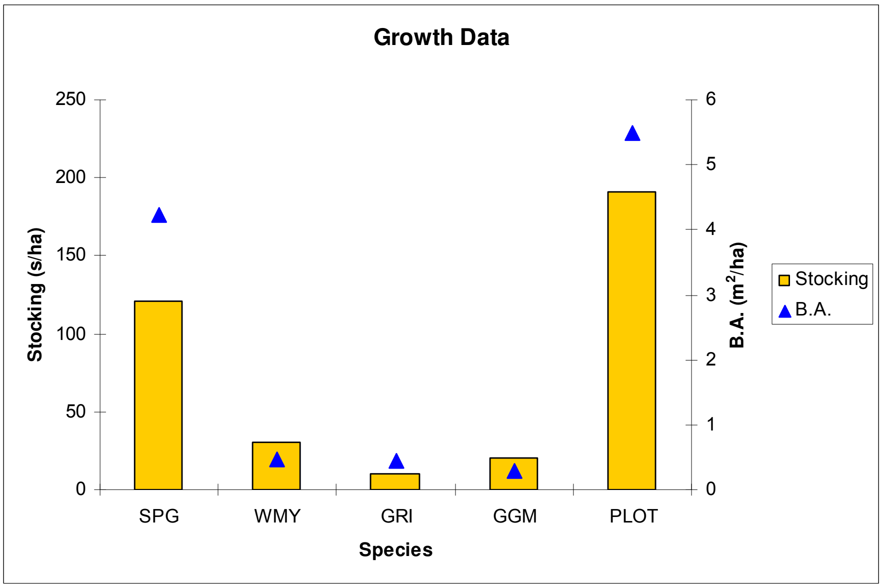
## Soils

**Soil Type** – Brown Chromosol.

| Depth (cm) | Description |
|---|---|
| 18 | Brownish black, unstructured sandy clay loam with 2–10% rock, pH of 6.0, gradual change to |
| 30 | Dull brown, unstructured light clay with 2–10% rocks, pH of 6.0, gradual change to |
| 50 | Dull orange, moderately structured light clay with 20–50% rocks, pH of 6.0, diffuse change to |
| 120 | Light grey, moderately structured medium heavy clay with 20–50% rocks, pH of 6.5. |

## Stand Growth

Average merchantable height is 10 m.



## Region – Coastal Burnett

### Land type – Ironbark and spotted gum on duplexes and loams

**Location** – Tiaro S.F. (Tiaro) - Site 1150
**Rainfall** – 1001 mm **Elevation** –61 m **Aspect** – North **Slope** – 2%

### Vegetation

**Understory Structure** – Open understory with minimal regeneration, dense wattle developing in adjacent, recently logged area.
**Major Species Composition** – Spotted gum, broad-leaved red ironbark.

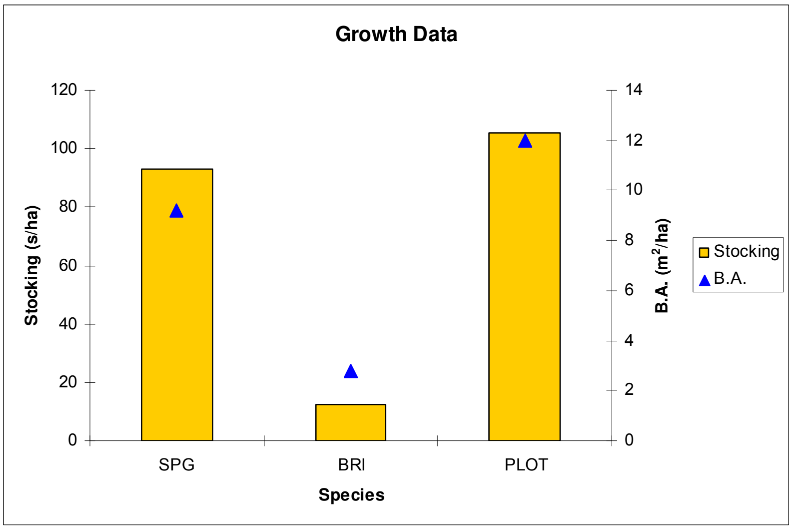
### Soils

**Soil Type** – Grey Kurosol.

| Depth (cm) | Description |
|---|---|
| 7 | Greyish yellow brown, unstructured sandy clay loam fine sandy -, pH of 5.5, clear change to |
| 22 | Greyish yellow brown, unstructured sandy clay loam fine sandy, pH of 4.5, clear change to |
| 40 | Brownish grey, strongly structured silty light medium clay, pH of 4.5, gradual change to |
| 68 | Greyish yellow, strongly structured heavy clay, pH of 4.5, clear change to |
| 75 | Brownish grey, unstructured decomposing siltstone/mudstone, pH of 4.5. |

### Stand Growth

Average merchantable height is 10 m.



# Region – Darling Downs

## Land type – Ironbarks and spotted gum ridges

**Location** – Durikai S.F. – (Warwick) – Site 0862
**Rainfall** – 590 mm **Elevation** – 745 m **Aspect** – North East **Slope** – 3%

## Vegetation

**Understory Structure** – Open with some understorey shrubs and eucalypt regeneration.
**Major Species Composition** – Spotted gum, broad-leaved red ironbark, grey box.

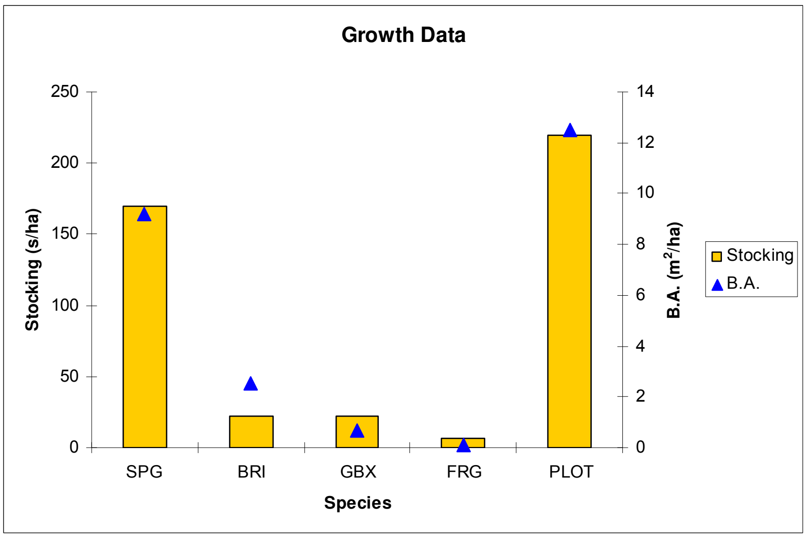
## Soils

**Soil Type** – Yellow Chromosol.

| Depth (cm) | Description |
|---|---|
| 5 | Brownish black, unstructured sandy loam with 2-10% rocks, pH of 5.0, clear change to |
| 30 | Greyish yellow brown, unstructured sandy clay loam with 10–20% rocks, pH of 5.0, clear change to |
| 40 | Bright yellowish brown, weakly structured light medium clay with 2–10% rocks, pH of 7.5, gradual change to |
| 70 | Bright yellowish brown, unstructured medium clay with 10–20% rocks, pH of 7.0. |

## Stand Growth

Average merchantable height is 7.5m.



**Land type – Spotted gum and narrow-leaved ironbark on hills and ridges**

**Location** – S.F. 132 Allies Creek (via Mundubbera) – Site 0242
**Rainfall** – 689 mm **Elevation** –384 m **Aspect** – North **Slope** – 6%

## Vegetation

**Understory Structure** – Generally open with some wattle, red ash and eucalypt regeneration.
**Major Species Composition** – Spotted gum, narrow-leaved red ironbark, Queensland peppermint and red ash.

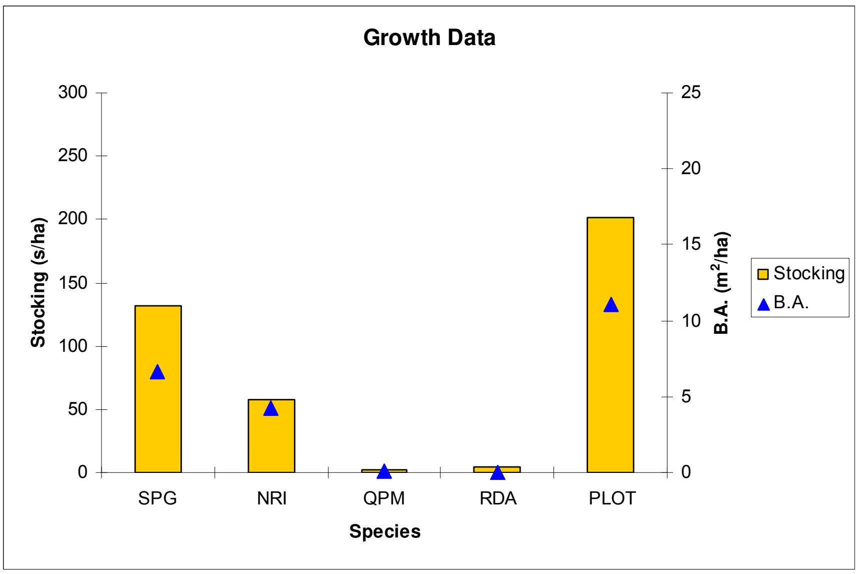
## Soils

**Soil Type** – Grey Kurosol.

| Depth (cm) | Description |
|---|---|
| 15 | Greyish yellow brown, unstructured sandy loam with <2% rocks, pH of 6.0, gradual change to |
| 25 | Greyish yellow brown, unstructured sandy clay loam with10–20% rocks, pH of 6.0, clear change to |
| 35 | Greyish yellow brown, unstructured sandy clay loam with 20–50% rocks, pH of 5.5, abrupt change to |
| 40 | Dull yellow orange, moderately structured sandy clay, pH of 5.5, gradual change to |
| 65 | Dull yellow orange, moderately structured light medium clay, pH of 5.5. |

## Stand Growth

Average merchantable height is 6 m.



**Land type – Spotted gum ridges**

**Location** – S.F. 15 Morella (via Injune) – Site 0135
**Rainfall** –794 mm **Elevation** –396 m **Aspect** – North East **Slope** – 8%

## Vegetation

**Understory Structure** – Open with wattle, cycads, red ash and eucalypt regeneration.
**Major Species Composition** – Spotted gum and narrow-leaved red ironbark.

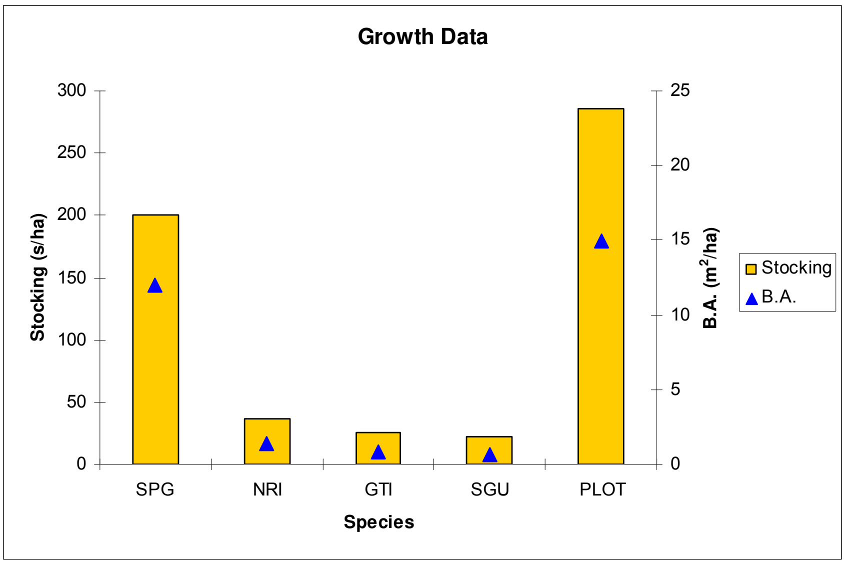
## Soils

**Soil Type** – Red Kandosol.

| Depth (cm) | Description |
|---|---|
| 20 | Greyish brown, unstructured sandy loam, pH of 6.0, gradual change to |
| 55 | Dull brown, unstructured sandy clay loam, pH of 5.5, gradual change to |
| 70 | Bright reddish brown, unstructured sandy clay, pH of 5.5, gradual change to |
| 80 | Reddich brown, unstructured sandy light medium clay, pH of 5.0. |

## Stand Growth

Average merchantable height is 8 m.



# Region – Inland Burnett

## Land type – Narrow-leaved ironbark and wattles

**Location** – S.F. 227 Cloncose (via Cracow) – Site 0389
**Rainfall** – 653 mm **Elevation** – 419 m **Aspect** – South **Slope** – 2%

### Vegetation

**Understory Structure** – Open with wattle and eucalypt regeneration.
**Major Species Composition** – Narrow-leaved red ironbark, spotted gum, Queensland peppermint and swamp box.

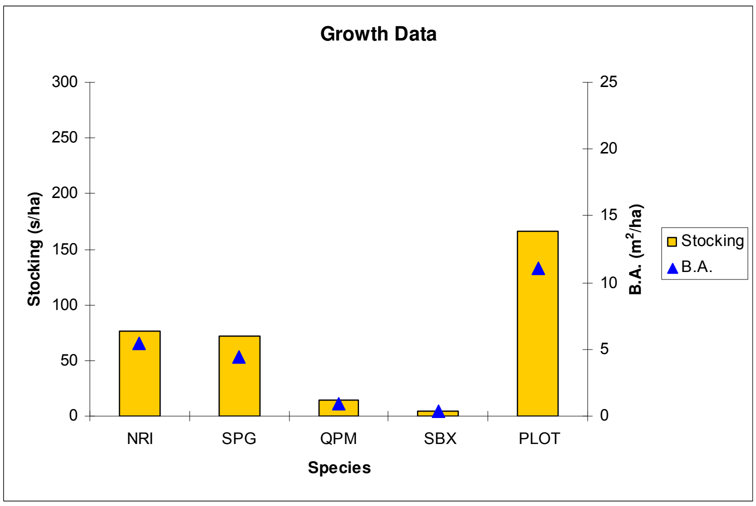
### Soils

**Soil Type** – Yellow Dermosol.

| Depth (cm) | Description |
|---|---|
| 5 | Brownish black, weakly structured sandy clay loam with <2% rocks, pH of 6.0, clear change to |
| 30 | Brown, unstructured clay loam sandy with 10-20% rocks, pH of 5.5, gradual change to |
| 52 | Bright brown, strongly structured medium clay with <2% rocks, pH of 5.5, clear change to |
| 80 | Bright yellowish brown, strongly structured medium clay with <2% rocks, pH of 5.5, gradual change to |
| 110 | Dull yellow orange, strongly structured medium clay with <2% rocks, pH of 5.5. |

### Stand Growth

Average merchantable height is 8 m.



**Land type – Spotted gum ridges**

**Location** – S.F. 28 Coominglah (via Monto) – Site 0139
**Rainfall** – 810 mm **Elevation** – 523 m **Aspect** – East **Slope** – 8%

## Vegetation

**Understory Structure** – Moderately dense with wattle, eucalypt regeneration and *Allocasuarina*.
**Major Species Composition** – Spotted gum, grey gum and narrow-leaved red ironbark.

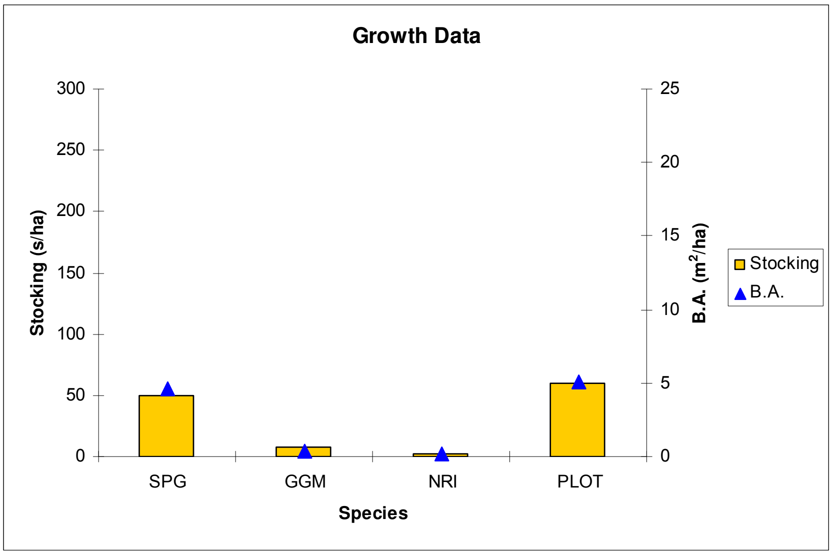
## Soils

**Soil Type** – Grey Kandosol.

| Depth (cm) | Description |
|---|---|
| 12 | Brownish black, unstructured sandy loam, pH of 6.5, clear change to |
| 40 | Dull yellowish brown, unstructured sandy clay loam with 2–10% rocks, pH of 5.5, gradual change to |
| 52 | Dull yellow orange, unstructured sandy clay with 2–10% rocks, pH of 5.5. |

## Stand Growth

Average merchantable height is 9 m.



**Land type – Tall woodland on snuffy red soils**

**Location** – S.F. 28 Coominglah (via Monto) – Site 0141
**Rainfall** – 702 mm **Elevation** – 479 m **Aspect** – West **Slope** – 6%

## Vegetation

**Understory Structure** – Moderately dense with wattle and eucalypt regeneration.
**Major Species Composition** – Spotted gum, narrow-leaved red ironbark and forest red gum.

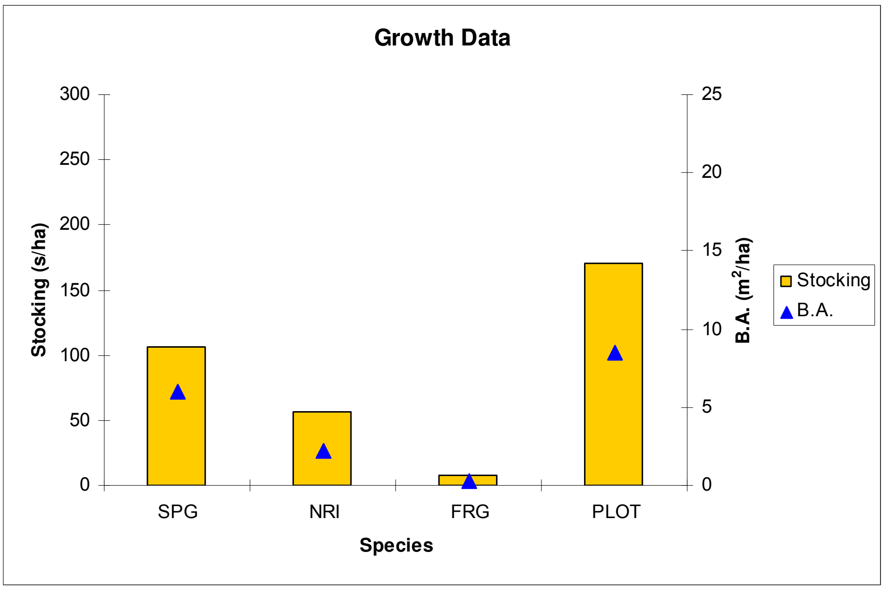
## Soils

**Soil Type** – Red Kandosol.

| Depth (cm) | Description |
|---|---|
| 15 | Dark reddish brown, unstructured loam, pH of 6.0, gradual change to |
| 40 | Dull reddish brown, unstructured clay loam, pH of 5.5, gradual change to |
| 100 | Reddish brown, weakly structured clay loam with 2–10% rocks, pH of 6.5. |

## Stand Growth

Average merchantable height is 10 m.



## Region – Fitzroy

### Land type – Eucalypts and bloodwood on sandy tableland

**Location** – S.F. 46 Glenhaughton (via Taroom) – Site 0168
**Rainfall** – 597 mm **Elevation** – 422 m **Aspect** – South East **Slope** – 4%

### Vegetation

**Understory Structure** – Open with some eucalypt and wattle regeneration.
**Major Species Composition** – Spotted gum, narrow-leaved red ironbark, and silver-leaved ironbark.

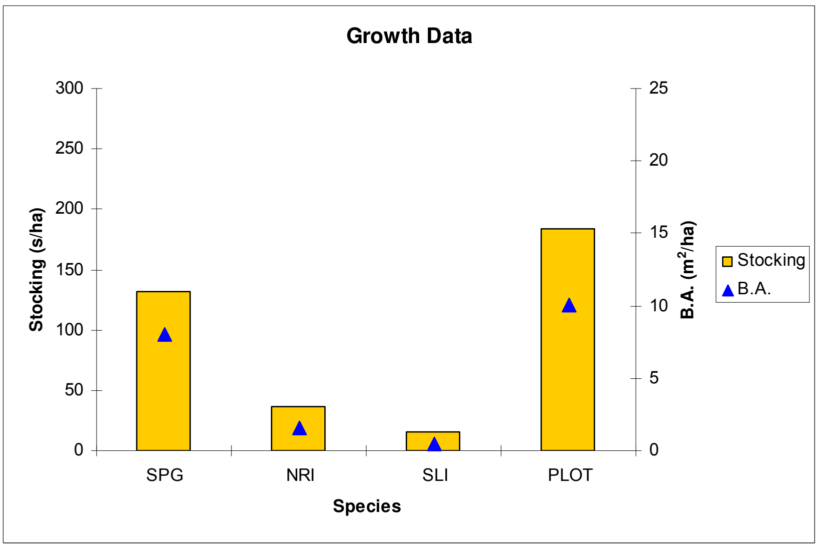
### Soils

**Soil Type** – Red Dermosol.

| Depth (cm) | Description |
|---|---|
| 4 | Dark reddish brown, unstructured clay loam fine sandy, pH of 6.0, clear change to |
| 16 | Dark reddish brown, weakly structured light clay with 2–10% rocks, pH of 5.5, clear change to |
| 48 | Dull reddish brown, strongly structured medium clay with 2–10% rocks, pH of 5.0, clear change to |
| 100 | Dull reddish brown, moderately structured heavy clay with 2–10% rocks, pH of 4.5, clear change to |
| 150 | Dull yellow orange, moderately structured light medium clay with 20–50% rocks, pH of 4.5. |

### Stand Growth

Average merchantable height is 9 m.



# Appendix 2. Spotted gum productivity assessment tool (SPAT) - Operation manual

**Authors: S. Swift, B. Hogg, D. Osborne and T. Lewis**

## Introduction

The spotted gum productivity assessment tool (SPAT) is a decision support tool written to assist landholders considering management alternatives for spotted gum forests. The SPAT provides an estimation of the productivity and financial returns from both spotted gum forest and livestock production. The tool also allows estimation of the amount of carbon (C) that is stored in trees within a given spotted gum forest.  It must be noted that this SPAT only allows estimations on land where spotted gum is, or was (prior to clearing) a common component of the forest. This manual provides a guide on how to use the SPAT.

To use the tool you will need a copy of Microsoft Excel® and the file spat.xls (which contains the SPAT).

When you open the **spat.xls** file, a **Security Warning** box (Figure 2A) will appear (because macros are used in the background to run the various components of the tool).

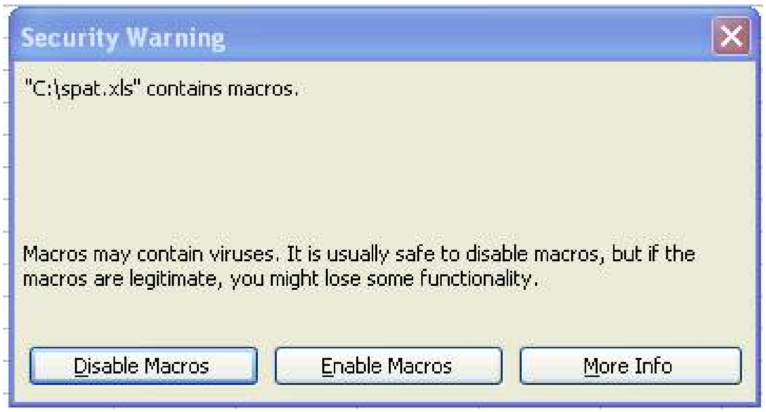



**Figure 2A**. Security warning box.

If you wish to run the SPAT you will have to click the '**Enable Macros**' button and the Program will open.

If the SPAT does not run you will need to change the macro security settings in Microsoft Excel® because, if the security settings are set above Medium, the SPAT will not open. To change the macro security settings in Microsoft Excel® you will need to open Microsoft Excel® and then:

- From the '**Tools**' drop down menu, select '**Macro**' then '**Security**' this will open the **Security** box.
- From the **Security** box, select the '**Medium**' Security Level.
- Click **OK.** The window will disappear.

## Running SPAT

On the opening page of the SPAT (Figure 2B) click the '**Start**' button to run the tool or the '**Exit**' button to cancel and return to Microsoft Excel®.

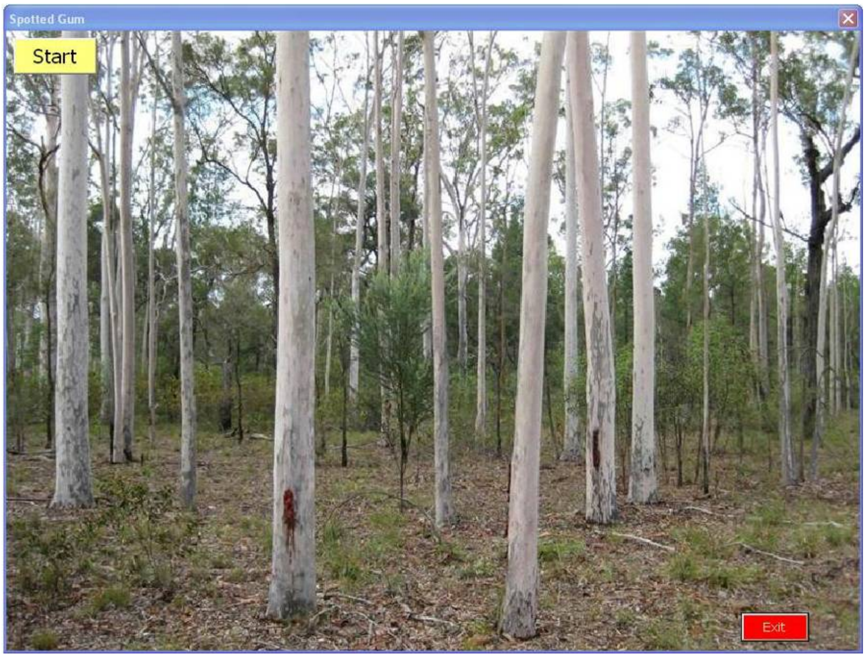



**Figure 2B.** The opening page of the decision support tool.

After pressing the **Start** button, a '**Conditions of Use**' window (Figure 2C) will appear. Read the conditions to ensure that you have a full understanding of the limitations and restrictions of the Tool. If you agree to the conditions of use, then click the '**I Accept the Conditions of Use**' button. If you don't agree to the conditions of use, then click the '**I Decline**' button to return to Microsoft Excel®.

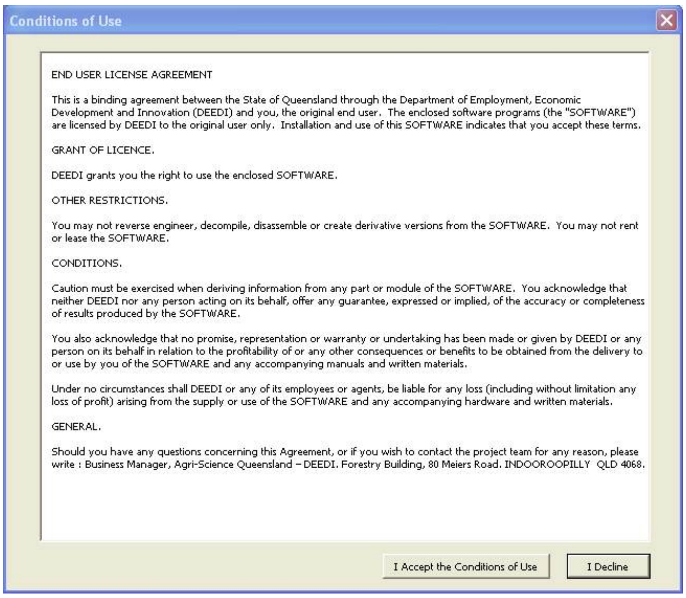



**Figure 2C.** Conditions of use window.

Once opened, the SPAT will display four tabs or pages (**Wood**, **Pasture, Carbon** and **About**). The **Wood** tab (Figure 2D) will display first.

## Wood

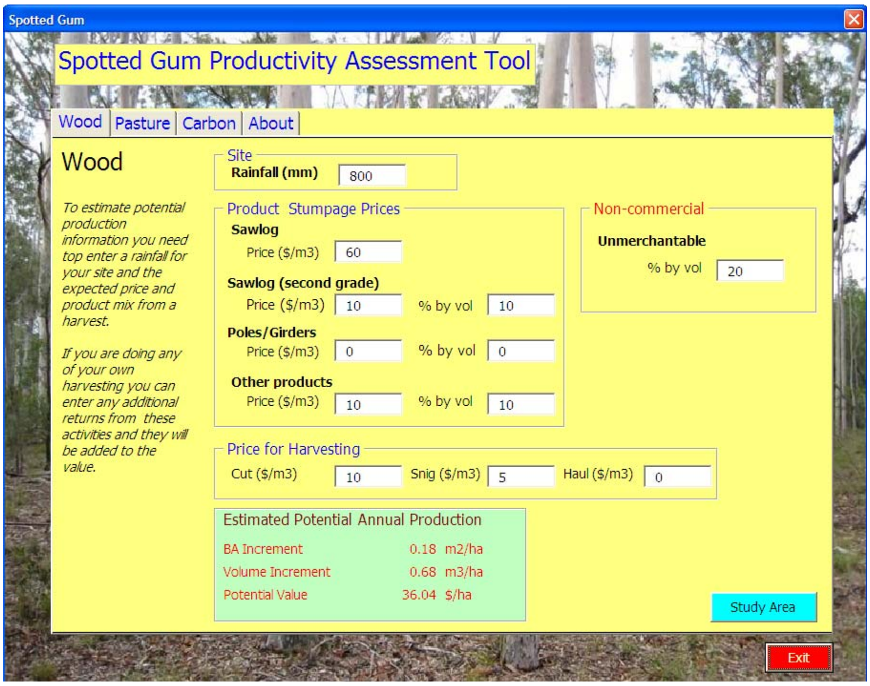



**Figure 2D.** The Wood tab.

This page is used to estimate the potential productivity and value of timber in your spotted gum forest. You need to enter values for your specific location. These values may vary depending on site quality, past stand management, stand quality and price offered by the purchaser.

The accuracy of the 'potential value' figure calculated for your forest is increased if you have some knowledge of the potential products available from your forest and the values of those products. If you require assistance on the value of different products you can contact your local forestry extension officer or timber industry representative.

### Timber Inputs

The variables which you need to enter are:

**Site**
*Rainfall* – This is the annual rainfall (in mm) for your site, which has a strong influence on the growth of your forest. It may be an average of the property rainfall records or district averages from the Bureau of Meteorology. If you know the latitude and longitude of your spotted gum forest you can obtain an average rainfall value under the '**Carbon**' tab (see later section).

**Product Stumpage Price**
*Sawlog Price ($/m$^3$)* – Sawlogs are logs which can be processed into sawn timber. These are of a suitable length, diameter and have an allowable amount of defect.

This section requires you to enter the stumpage price (in $\$/m^3$) which is the price for sawlogs that has been negotiated with the purchaser (i.e. the value of the timber to the landholder, exclusive of harvesting costs).

*Sawlog (second grade) Price ($\$/m^3$)* – Sawlogs that have some defect that may still be able to be processed into sawn timber. Enter the second grade sawlog stumpage price (in $\$/m^3$) that has been negotiated with the purchaser.

*Poles/Girders Price ($\$/m^3$)* – Poles and girders are high quality and high value products/logs which are used typically for power poles and structural bridge timbers. These products have a long length, large diameter and very little defect.

This section requires you to enter:

1. The stumpage price which is the pole or girder price ($\$/m^3$) that has been negotiated with the purchaser.
2. An estimate of the percentage of the harvestable volume which is pole or girder quality.

If your forest contains both poles and girders you can enter an average price, or enter one of these products into the 'Other products' input section (see below).

*Other Products Price ($\$/m^3$)* – Other products include low grade timbers which can be utilised for fencing material (posts/rails), piles and firewood etc.

This section requires you to enter:

1. The stumpage price which is the price ($\$/m^3$) of other products that the purchaser has offered you for your standing trees.
2. An estimate of the percentage of the harvestable volume which can be used for other products.

**Non-commercial**

*Unmerchantable* – This includes trees that have poor form or excessive defect and can't be economically or safely sawn. Trees that are too small to be sawn, or of a species that doesn't produce sawn timber are also considered unmerchantable. It is generally the unmerchantable fraction of a forest which is targeted in treatment thinning operations to maximise the economic productivity of the retained stand.

This section requires you to enter an estimate of the percentage of the stand that is unmerchantable.

**Price for Harvesting**

This section should be completed only if you plan to undertake part or all of the harvesting operation yourself and it requires you to enter the following information:

*Cut ($\$/m^3$)* – This is the amount of extra stumpage the purchaser will pay you per cubic metre because they do not need to employ a cutter. This operation requires trees to be felled and presented at stump as logs that meet the specifications set by the purchaser.

*Snig ($\$/m^3$)* – This is the amount of extra stumpage the purchaser will pay you per cubic metre because they do not need to employ a snigger. The operation requires logs to be presented at a roadside log dump which is accessible to the haulage trucks.

*Haul ($/m³)* – This is the amount of extra stumpage the purchaser will pay you per cubic metre because they do not need to employ haulage contractors. The operation requires logs to be transported to the purchasing sawmill.

**Estimated Annual Production**

This section provides the outputs for the potential economic productivity of your spotted gum forest. It is important to note that economic productivity can be altered by varying your forest management (e.g. changes in treatment operations or changes in commercial harvest intensities) and by obtaining the best price for your timber.

*Basal Area Increment ($m^2$/ha)* – This is the estimated amount of increase in basal area per hectare in one year.

*Volume Increment ($m^3$/ha)* – This is the estimated amount of increase in volume per hectare in one year.

*Value ($/ha)* – This is an estimate of the potential economic return from timber products for each hectare of spotted gum forest in one year.

## Pasture

The second tab is the pasture tab (Figure 2E).

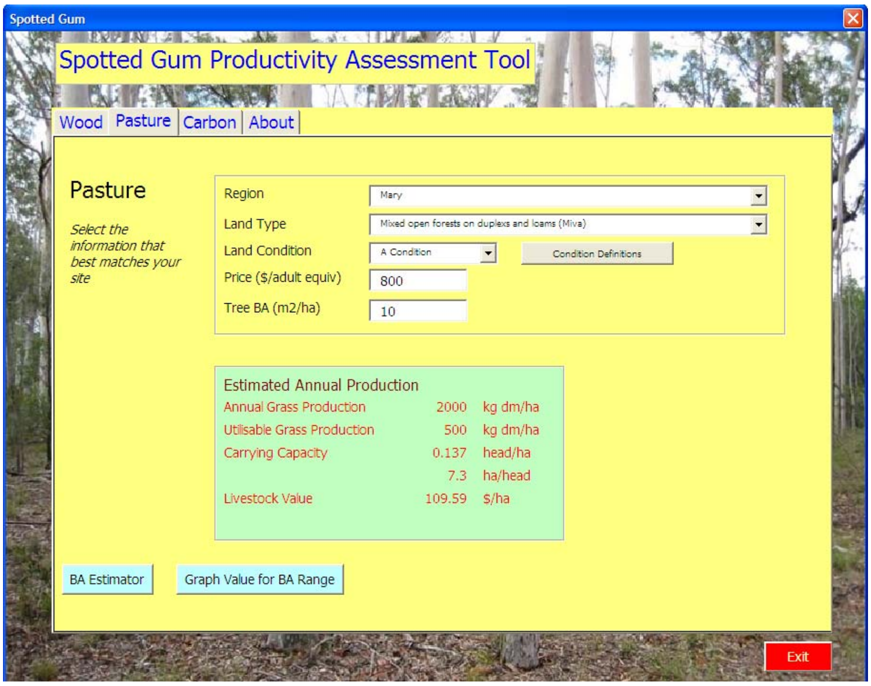



**Figure 2E.** The Pasture tab.

This tab is used to estimate the potential productivity and value of the pasture in your spotted gum forest. The estimates are dependent on the input of values for your site. These values may vary depending on location, past grazing intensities, forest management and the value of your livestock.

The accuracy of the Program is greatly increased when more detailed information is known, obtained and entered. The pasture assessment is based on the grazing land management (GLM) workshop series conducted by the former Queensland Department of Primary

Industries and Fisheries (DPI&F) which is now the Department of Education Economic Development and Innovation (DEEDI).

**Pasture Inputs**

This section requires you to enter the following information based on the GLM categories:

*Region* – Select the region which best describes the location of your spotted gum forest. The regions are limited to those in the study area.

*Land Type* – Select the option which best describes the forest association and location of your spotted gum forest. The land types are limited to those in the Queensland study area that contain spotted gum as a component of the forest.

*Land Condition* – Select the option which best describes the condition of the pasture in your spotted gum forest. These rankings are based on the GLM assessment. For a description of the different pasture conditions (Figure 2F), click on the '**Condition Definitions**' button.

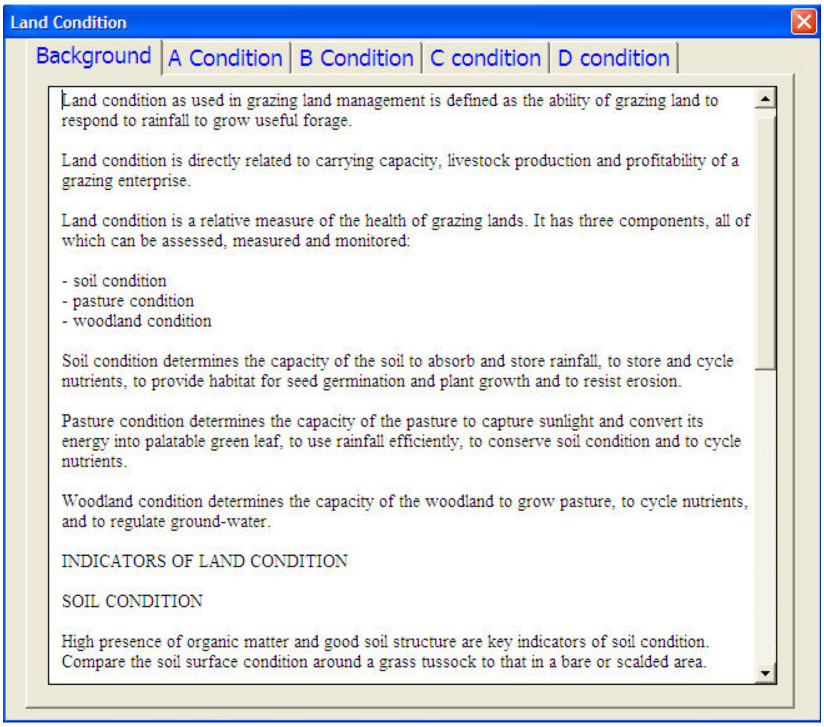



**Figure 2F.** Land Condition menu and definitions box.

*Price ($/adult equivalent)* – Enter the market value of livestock grazing in the spotted gum forest.

*Tree BA ($m^2$/ha)* – This provides a measure of the competition between trees and pasture. The greater the basal area, the greater the space that is occupied by wood, which results in less growth of pasture. This mean diameter and stocking can be used to estimate BA. To estimate BA, click the '**BA Estimator**' button.

This will open another window to assist you in calculating the basal area or stocking of all trees in the forest (Figure 2G). This is done by using a plot mean tree diameter from the stand and either a stocking or BA figure for the stand.

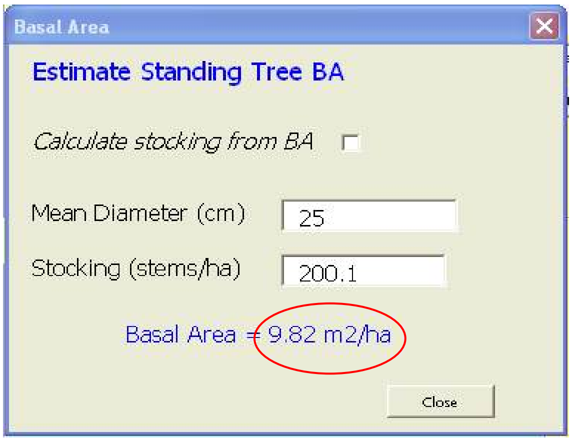



**Figure 2G.** Basal Area calculation box.

*Mean Diameter (cm)* – This is the average diameter of trees in the forest (usually only trees with a diameter greater than 10 cm are considered).

*Stocking (stems/ha)* – this is the number of trees (usually only trees with a diameter greater than 10 cm are considered) per hectare occurring in the forest.

Enter the estimated BA into the appropriate section.

If you tick the '**Calculate stocking from BA**' box, another window will appear. This window allows you to estimate the average stocking from BA calculations (Figure 2H). This application would generally be used by people who have assessed the BA of their spotted gum forest using a BA wedge or a series of monitoring plots. This is also useful for landholders who wish to thin their spotted gum forest to a desired basal area and know mean stem diameter. This calculation estimates the required stocking to be retained to achieve the desired basal area.

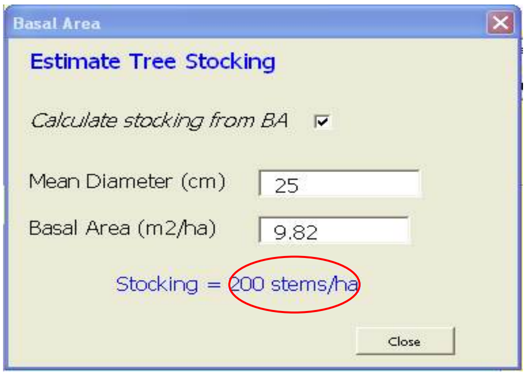



**Figure 2H.** Stocking calculation box.

To view a visual representation of the relationship between tree basal area and livestock value, click the '**Graph Value for BA Range**' button.

The displayed graph (Figure 2I) plots the details you entered on the pasture tab of the Program. The graph typically displays how an increasing BA will have a negative impact on pasture production.

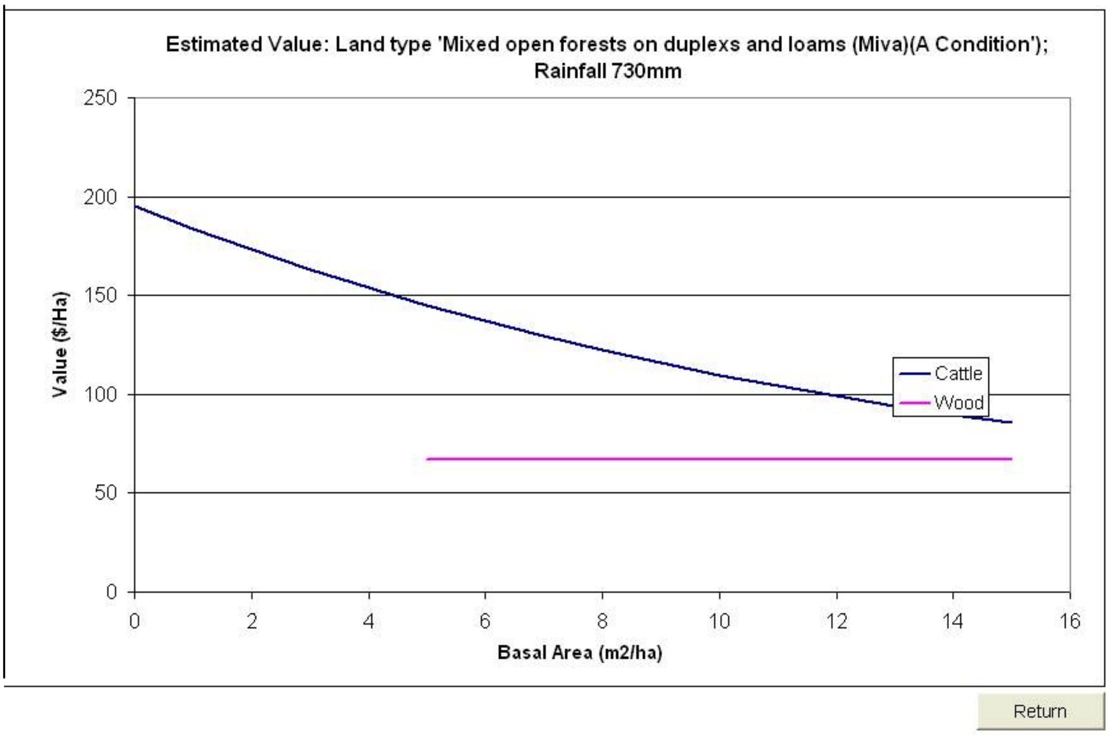



**Figure 2I.** Graphical representation of the BA and pasture interaction.

Click the '**Return**' button to return to the Program.

### Estimated Annual Production

This section estimates the potential economic productivity for livestock grazing in a spotted gum forest. Economic productivity can be altered by changes in stocking rates, seasonal variations in pasture production, forest density and the market value of the livestock.

*Annual Grass Production (kg dm/ha)* – This is the amount of pasture the forest can potentially produce per hectare over one year.

*Utilisable Grass Production (kg dm/ha)* – This is the amount of pasture available for livestock that the forest can potentially produce per hectare over one year.

*Carrying Capacity (head/ha or ha/head)* – This is the potential number of livestock that you can sustainably graze in a given hectare.

*Livestock Value ($/ha)* – This is an estimate of the yearly economic return for each hectare of spotted gum forest through grazing.

## Carbon

To estimate carbon for the forest at a given location click on the third tab (Figure 2J).


**Figure 2J.** The Carbon tab.

This tab uses the FullCAM carbon accounting model developed by the Australian Government Department of Climate Change (Richards and Evans 2000), to estimate the above ground (AG) tree biomass in a spotted gum forest and the proportion of that biomass that is comprised of tree carbon (C). The estimate of tree carbon includes both above ground (stems, branches etc) and below-ground (root) carbon. The carbon estimates are provided to give landholders some idea of the potential of their forest to store carbon.

The carbon calculator is based on a model which uses data averaged over a one km$^2$ grid in areas where spotted gum is likely to occur. The results reflect the potential carbon sequestration for the entered co-ordinate (these were correct at the time the values in used in the model were calculated). The model does not recognise management events (e.g. fire or thinning) but is initiated at a starting BA which should reflect forest condition. Understandably, the carbon capture of a site is dynamic and based on site management, but the model assumes no management during the modelled period. Those seeking further information on the effects of management on carbon sequestration or on sequestration of carbon in other components of their forest (e.g. soil carbon) are encouraged to use the FullCAM National Carbon Accounting Toolbox.

## Carbon Inputs

### Co-ordinates in Decimal Degrees

*Latitude* – This is the global north – south position of the forest. Sites are situated in the southern hemisphere and should therefore have a minus (-) sign in front of the value.

*Longitude* – This is the global east - west position of the spotted gum forest.

The location of the forest should be entered using a latitude and longitude based on the decimal degrees co-ordinate system. The decimal degrees co-ordinate system converts the traditional minutes and seconds reference of a co-ordinate into a percentage of a degree. For example, 120 degrees, 30 minutes and 00 seconds is converted into 120.500 decimal degrees.

A latitude and longitude can be obtained using a Global Positioning System (GPS) or the program Google Maps®.

*To use Google Maps®:*

- Locate and zoom into your spotted gum forest on Google Maps® using the satellite image.
- Place the cursor over the spotted gum forest.
- Right mouse click on the required position. This will open a menu box.
- Left mouse click the '**What's Here?**' option. After a few seconds a marker will appear where the cursor was located.
- Reposition the cursor over the newly created marker and the required co-ordinates for the marker will appear on the screen. The number of decimal places on each value may be reduced to three places.

Carbon production estimates are only available for private and lease hold land within the study area for sites that support spotted gum forest types. If the co-ordinates entered are for a site where spotted gum forest is unlikely to occur, for State owned land or outside the study area, then one of the following error messages shown in Figure 2K will occur.

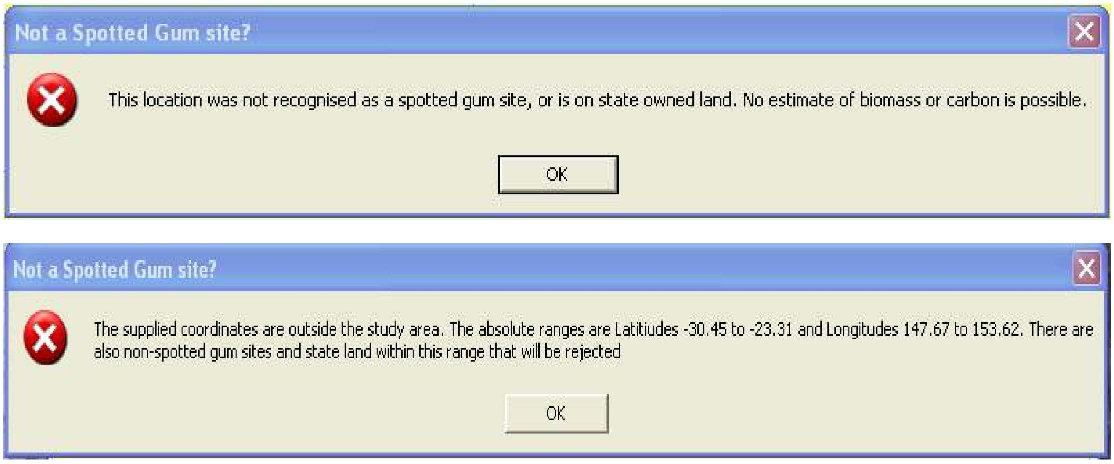



**Figure 2K.** Error messages shown when co-ordinates are not suitable.

If either of these messages appear, click the 'OK' button to return to SPAT and check the entered co-ordinates or select a nearby location.

*Initial BA ($m^2$/ha)* – This is the BA per hectare of trees in the forest. Under the '**Pasture**' tab you can use the '**BA Estimator**' to assist in estimating the BA of your forest.

Click the '**Calculate**' button to display estimates of forest biomass and tree carbon for the co-ordinate that you entered. These estimates appear in the green box on the right hand side of the display.

**Above Ground Biomass and Carbon**

The table on the right hand side of the window is the default format which displays the estimated annual above ground tree biomass (tonnes/ha) and the estimated carbon contained in trees (above and below ground carbon) on a per hectare basis for the entered co-ordinate. Tree biomass and carbon increases annually based on the FPI of the entered co-ordinate. The output simulates biomass and carbon accumulation over a 30 year period and assumes that there are no management actions which may alter the above ground biomass (i.e. harvesting, thinning, clearing, fire etc.) in that period.

The same information can also be displayed graphically by clicking the '**Graph**' button. This will open a new window and display a graph (Figure 2L) of the results for the 30 year period.

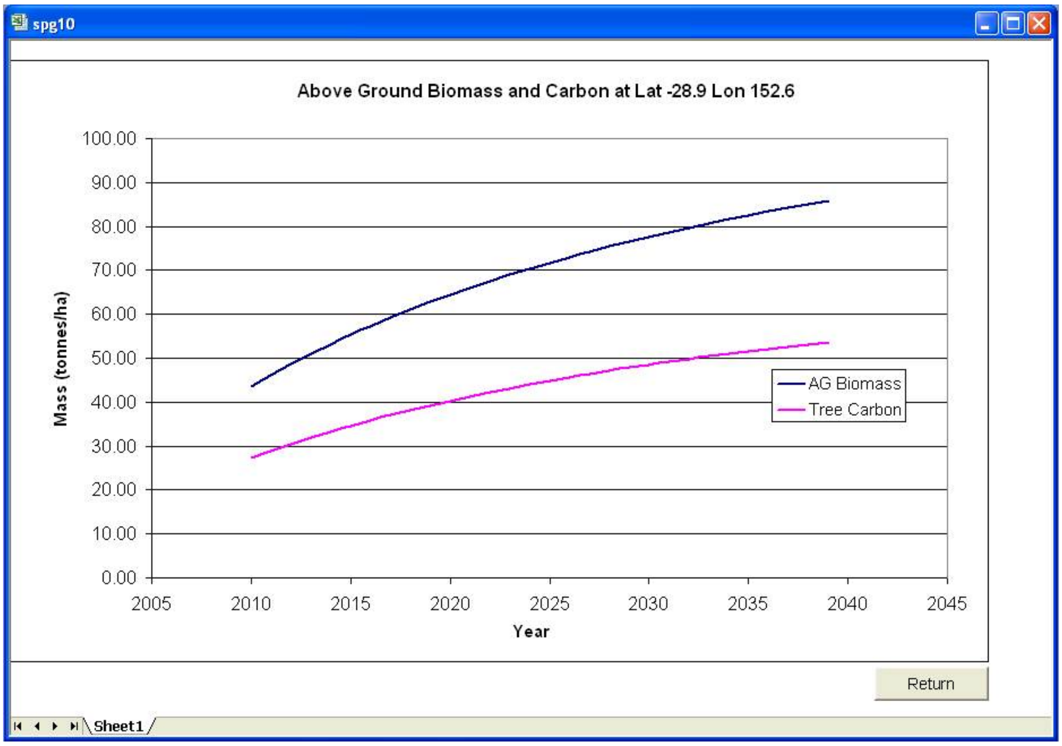



**Figure 2L.** Graph showing AG biomass and tree carbon.

Information about the area where SPAT is expected to provide reasonable estimations can be displayed graphically by clicking the '**Valid Regions**' button.

**Estimated Rainfall**
This is an estimated annual rainfall (mm) for the entered co-ordinate based on interpolated data.

**Forest Productivity Index (FPI)**
This is an estimate of the productivity of the forest based on calculations from the FullCAM model. In a spotted gum forest FPI is likely to vary between 2 and 15, depending on the site productivity (e.g. soil, sunlight, rainfall, evaporation and frost). Forest growth rates will be greater at higher FPI values.

To return to the SPAT, click the '**Return**' button.

## About

The About tab provides information about the source of the data and contact details if assistance is required.

To exit the SPAT and return to Microsoft Excel®, click the ‘**Exit**’ button.

# Appendix 3. A summary of growth from long-term thinning experiments in spotted gum forest on Crown land.

## Authors: T. Lewis, B. Hogg and D. Osborne

## Summary

This report summarises historic silvicultural thinning experiments and some relevant findings from these experiments established in spotted gum forests in Qld. While information from such experiments was used to improve the management of Qld state forests (for the former Department of Forestry), much of the information from these experiments remains unpublished and is only available in internal reports. We summarise findings from five experiments that were considered to have reasonable scientific rigour. These experiments were established in the 1960s and 1970s and measured until the mid to late 1990s.

In each experiment stand growth (volume and basal area) increased at similar rates between the various treatments (i.e. various tree densities). Where thinning treatments have been applied this growth rate is concentrated on the more commercially productive stems. After 21–27 years of growth, stand volumes were generally higher in areas that had not been thinned or were lightly thinned (130–150trees /ha) than in areas that were more heavily thinned to densities of 50–100 trees per hectare. However, merchantable product available at the next harvest is likely to be lower in the unthinned stands than in the thinned stands, as unthinned stands contained higher densities of smaller diameter trees. For trees present at the start of each experiment (those retained after thinning) diameter growth rates were improved significantly by the thinning treatments. Thinning to lower tree densities (stocking) resulted in greater diameter growth improvements. Across all experiments average diameter growth increments of trees present at the start of each experiment varied from 0.20 ± 0.03 cm per year in an unthinned treatment of an experiment in a low rainfall zone (near Dalby) to 0.78 ± 0.05 cm per year in a thinned treatment (stocking of approximately 60 stems /ha) of an experiment in a higher rainfall zone (near Maryborough). Across all experiments there was considerable variation in diameter growth, even for stands with densities ranging from 50 to 150 trees per hectare. Using data from one experiment where similar stockings were retained through time, a linear relationship was determined between stand stocking (log stocking) and diameter growth increment, which explained approximately 79% of the variance in the data.

These findings demonstrate the importance of management (e.g. thinning) for improving the growth rate of merchantable trees. Given the good regenerative capacity of spotted gum forests in Qld it is unlikely that thinning treatments will negatively impact on long-term sustainability. However, as outlined in Chapter 1 it is important for forest managers to maintain variation in the diameter class distribution of the stand (e.g. including small stems) to ensure future regeneration and sustainability following a harvest.

## Introduction

This document was written to supplement the FWPA project (PN 07.4033) final report on productivity of spotted gum forests on private land in northern NSW and southern Qld.

Potential productivity of spotted gum forests is thought to be greater than that observed from actual production of useable wood, in part due to a lack of, or poor forest management (Jay *et al.* 2007). In private forest thinning and stand improvement (i.e. removal of unmerchantable trees) are not commonly practiced and this can lead to a dense areas (overstocking) of suppressed and non-commercial trees in the stand that effectively decrease the growth of better trees through competition (Florence 1996, Bauhus *et al.* 2002, Jay *et al.* 2007). Further, harvest operations in private forest often involve 'high grading' (diameter limit harvesting) which essentially involves extraction of larger commercial trees resulting in a degraded forest stand with little potential for future commercial forest growth (as defective, unmerchantable trees or suppressed sub-dominant trees provide the future growing stock). Hence, the problems associated with lack of, or poor management have resulted in some stands with low and uneconomic growth rates. The productive potential of these stands can be difficult to restore. However, studies have shown that active management of spotted gum forest can improve the growth of trees and revenue available to the landholder (Bauhus *et al*. 2002, Ryan and Taylor 2006, Jay *et al*. 2007). Such forest management is often referred to as 'silviculture'. Silviculture involves controlling establishment, growth and composition of the forest ecosystem to achieve a desired set of outcomes. Classic silviculture (Troup 1955) refers to management principally in terms of timber production, but the theory and practice of silviculture today takes into consideration the ecosystem composition, structure and function (Barnes *et al*. 1998). Silviculture should ensure sustainable forest management, which is essential for the maintenance of ecosystems supporting tree growth and for allowing a long-term harvesting regime.

In Qld, silviculture in spotted gum forests is generally synonymous with selection logging or 'single tree selection', which typically removes 10–50% of the pre-harvest basal area (Florence 1996). Essentially this system evolved as a response to the composition and uneven-aged structure of many of these forests, the products removed (mostly sawlog) and the need for regular harvests to provide continuous wood supply to industry. However, silvicultural management can also involve thinning to encourage the growth of retained trees. While there is little data available on the effectiveness of thinning in private spotted gum forest we are able to draw on data from state forests to determine the effects of various thinning regimes. Recently established trials on private land (Chapter 4) will allow us to determine the comparability of the results from state forest at some point in the future.

The aim of this document is to provide a summary of historic silvicultural thinning experiments from state forests and to summarise the important findings from these studies. Such a summary was considered necessary to supplement the 'silvicultural guidelines' as much of the information from the historic experiments is not widely available (i.e. it remains in internal documents). In particular we use tree growth data from five long-term thinning experiments in native spotted gum forest to demonstrate differences in growth and stand volumes under differing stockings. These experiments were chosen to represent the eastern, higher rainfall part of the resource (four experiments in the Maryborough region) and the inland, lower rainfall part of the resource (one experiment in the Dalby region) in Qld.

## Experimental details

### Experiment 263HWD (Maryborough region)

This experiment was established in 1970 and was measured up until 1997. The experiment is located in State Forest 958 Gundiah (latitude –25.85, longitude 152.65). The experiment was established in an uneven-aged spotted gum (*Corymbia citriodora* subsp. *variegata*), white mahogany (*Eucalyptus acmenoides*) and ironbark (*E. siderophloia* and *E. crebra*) forest with treatments of:

1. Thinning to a spacing of approximately 7.6 × 7.6 m (173 stems/ha);
2. Thinning to a spacing of approximately 12 × 12 m (69 stems/ha); and
3. Control with no treatment.

While an effort was made to achieve these spacings, actual average densities in 1971 were 68 stems per hectare in the 12 × 12 m treatment, 108 stems per hectare in the 7.6 × 7.6 m treatment, and 359 stems per hectare in the unthinned control.

The experiment was a randomised block design with five blocks each containing the three treatments and four measure plots in each treatment per block (60 plots in total, each 0.091 ha in area). The experiment was located across three separate compartments, each with differing histories of logging. All three compartments were logged prior to establishment of the experiment (last logged in 1966–1970). Thinning treatments were carried out in 1971 by ringbarking and injection of herbicide (2,4,5–T amine in water). Treatment rules for each treatment were specified prior to treatments (outlined in the establishment report for this experiment, i.e. Grimes 1975). Topography varied from flat to undulating with a range of aspects. Average annual rainfall is approximately 1070 mm. Soils are mostly Grey, Brown and Red Kurosols (Isbell 1996) and are generally shallow with loamy surface textures and clay loam to clay textures at 30–40 cm depth.

### Experiment 165DBY (Dalby region)

This experiment was established in 1976 and was last measured in 1997. The experiment is located in State Forest 302 Ballon (latitude –26.35, longitude 151.05). Thinning treatments consisted of:

1. Thinning to a spacing of approximately 8 × 8 m (156 stems/ha);
2. Thinning to a spacing of approximately 10 × 10 m (100 stems/ha);
3. Thinning to a spacing of approximately 12 × 12 m (69 stems/ha);
4. Thinning to a spacing of approximately 14 × 14 m (51 stems/ha); and
5. Control with no treatment.

Actual average tree densities in 1976 were: 51 stems per hectare in the 14 × 14 m treatment, 73 stems per hectare in the 12 × 12 m treatment, 101 stems per hectare in the 10 × 10 m treatment, 137 stems per hectare in the 8 × 8 m treatment, and 352 stems per hectare in the unthinned control treatment.

Plots (0.225 ha in area) with similar pre-treatment basal areas were blocked into four groups, each containing the above five treatments (total of 20 plots). Treatments were randomised within each block. Thinning treatments were carried out by low axe frilling and spraying with herbicide (2,4,5–T amine in water). Competing understorey vegetation was removed with infrequent treatments over time (when deemed necessary).

Unlike experiment 263HWD, this experiment was established in an almost even-aged spotted gum forest (15–35 cm DBH) with few other tree species (e.g. *Eucalyptus crebra, Allocasuarina littoralis, Melaleuca decora* and *Corymbia trachyphloia*). The even-aged stand probably originated from a very intense fire. Some ringbarking (with no herbicide) had taken place in 1961–62, although this was considered to have been largely ineffective (i.e. a poor kill was obtained). Trees with a DBH greater than 40 cm were logged in 1975, prior to experimental treatments being imposed.

The experiment was located on a gentle sandstone ridge. Soils varied across the experiment, but were characterised by shallow depth and large quantities of loose rock in the profile. This experiment was established as an extension of similar experiments in higher rainfall zones. Average annual rainfall at this site is approximately 640 mm.

**Experiment 265HWD (Maryborough region)**

This experiment was located within State Forest 957 Tiaro (latitude –25.75, longitude 152.65) and was established in 1978 and measured up to 1999. The experimental area was ringbarked in 1964 to remove all existing trees. Regeneration and coppice was then allowed to develop and this regeneration was thinned (using Tordon) to:

1. Spacing of approximately 8 × 8 m (156 stems/ha);
2. Spacing of approximately 10 × 10 m (100 stems/ha); and
3. Spacing of approximately 12 × 12 m (69 stems/ha).

The experiment had a randomised design with three plots (0.101 ha in area) randomly allocated to each treatment (nine plots in total). In this experiment, plots were originally established in 1969 but as thinning to the desired stockings did not take place until 1978 we have only used growth data from 1979–1999. This experiment is similar to experiment 165DBY in that it follows the growth of a largely even-aged stand.

There was no control treatment with no thinning in this experiment. The original stand comprised of spotted gum (*Corymbia citriodora* subsp. *variegata*), grey ironbark (*Eucalyptus drepanophylla*), white mahogany (*E. acmenoides*) and Queensland peppermint (*E. exserta*). The area chosen for this experiment had minimal slope and no predominant aspect. Soils were generally shallow with clay subsoils. Average annual rainfall is approximately 1050 mm.

**Experiment 262HWD (Maryborough region)**

This experiment was established in 1968 and measured up to 1999. Growth response was measured after applying treatments of:

1. Spacing of 9.1 × 9.1 m (118 stems/ha) by ringbarking;
2. Spacing of 9.1 × 9.1 m (118 stems/ha) by herbicide (2,4,5–T amine in water);
3. Spacing of 12.2 × 12.2 m (68 stems/ha) by ringbarking; and
4. Spacing of 12.2 × 12.2 m (68 stems/ha) by herbicide (2,4,5–T amine in water).

The experiment was spread across three different state forests (State Forests 57 St. Mary (latitude –25.75, longitude 152.45), 957 Tiaro (latitude –25.75, longitude 152.65), and 958 Gundiah (latitude –25.85, longitude 152.65)) in predominantly regrowth spotted gum forest. Plots (0.162 ha in area) were located across four blocks with four plots in each block (a factorial design). Treatments were allocated subjectively based on pre-treatment densities (i.e. the more widely spaced stands received the wider spacing treatment). There was no control treatment with no thinning in this experiment. The original stand was uneven-aged and varied between blocks and was comprised of spotted gum (*Corymbia citriodora* subsp. *variegata*), grey ironbark (*Eucalyptus drepanophylla*), red ironbark (*E. crebra*), white mahogany (*E. acmenoides*), forest red gum (*E. tereticornis*), gum-top box (*E. moluccana*) and several other less abundant tree species (e.g. *E. exserta, E. propinqua, Angophora leiocarpa, Corymbia intermedia*). Soils are mostly Grey Kurosols (Isbell 1996) with some variation in colour (some Red, Brown and Yellow Kurosols). Average annual rainfall is approximately 1050 mm.

In this experiment ringbarking and herbicide had similar effects and hence we have grouped the ringbarking and herbicide treatments and concentrated only of the two spacing treatments.

**Experiment 258HWD (Maryborough region)**

This experiment was established in 1964 and measured up to 1997. The experiment was established in a relatively even-aged regrowth forest following heavy ringbarking. Treatments in this experiment consisted of:

1. Thinning to stockings varying from 50–111 stems per hectare with retention of the best available stems (referred to as 'thinned' treatment).
2. Routine management, which involved removal of poorest stems only and retention of 235–297 stems per hectare (referred to as 'routine' treatment).

The experiment was located within State Forest 957 Tiaro (latitude –25.75, longitude 152.65). Plots (0.081 ha in area) were paired based on predominant height, stocking and general appearance and one plot in each pair was randomly selected for treatment. Four pairs (eight plots in total) were located in a block layout superimposed on routine treatment with 10 m of isolation surrounding each plot. Thinning was carried out by axe frilling with a distillate solution of 2,4,5–T butyl ester. Given the range of stockings across the thinning treatment this experiment only provides a general comparison between two different degrees of thinning and stand improvement.

The original stand consisted of spotted gum (*Corymbia citriodora* subsp. *variegata*), grey ironbark (*Eucalyptus drepanophylla*) and white mahogany (*E. acmenoides*). Soils are mostly Red Kurosols (Isbell 1996) and average annual rainfall is approximately 1050 mm.

## Analysis

Diameter at breast height (DBH) was measured at various points through time across all of the experiments, so we have focussed our analysis of diameter growth rather than height growth. Stand growth was analysed for all trees with diameters (DBH at 1.3 m) greater than 10 cm. We also analysed only those trees that were present at the start of the experiment, ignoring all recruited stems. This was done to provide an estimate of merchantable growth in the thinned treatments as only potentially merchantable trees were selected for retention in the thinned treatments at the start of each experiment. A mixture of potentially merchantable and unmerchantable trees was retained in the unthinned treatments (certain experiments only). Stem volume ($m^3$/ha) was estimated using one-way volume equations.

Differences in DBH between the first and last measure and volume periodic annual increment were analysed for all of the above experiments using analysis of variance (ANOVA). The assumptions of ANOVA were checked using a normal probability plot of the residuals (to check the assumption of normally distributed data) and a residual plot (to check the assumption of equal variances). Fisher's unprotected least significant difference test was used to investigate differences between individual thinning treatments (where experiments had more than two treatments). Linear regression was used to determine stand growth rates (volume and basal area) over time and to determine whether growth rates differed between various treatments in each experiment. However, for simplicity these statistics are not reported here.

This analysis has only investigated coarse measures of stand growth (all trees in the stand). It is acknowledged that growth rates do vary between different diameter classes (see Bauhus *et al*. 2002) and between the different species occurring in a stand of spotted gum forest.

## Results summary

### Experiment 263HWD

Tree basal area ($m^2$/ha) increased across all three treatments at a similar rate (Figure 3A). It took approximately 20 years for the 12 × 12 m spacing treatment to reach a basal area similar to that at the control site at the start of the experiment, and 15 years for the 7.6 × 7.6 m spacing treatment to reach a basal area similar to that at the control treatment at the start of the experiment. Stem volumes also increased at a similar rate between the different treatments (Figure 3B). At the time of the last measure (1997) the control treatment had volumes of 87.2 ± 3.45 $m^3$/ha, the 7.6 × 7.6 m treatment had volumes of 67.9 ± 3.73 $m^3$/ha, and the 12 × 12 m treatment had volumes of 56.6 ± 3.04 $m^3$/ha.

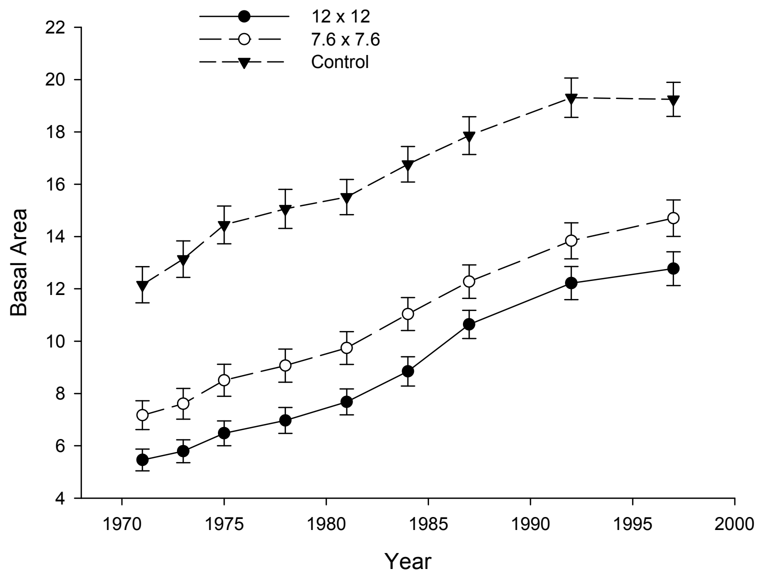



**Figure 3A.** Mean (± SE) basal area ($m^2$/ha) for the different thinning treatments through time at Experiment 263HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

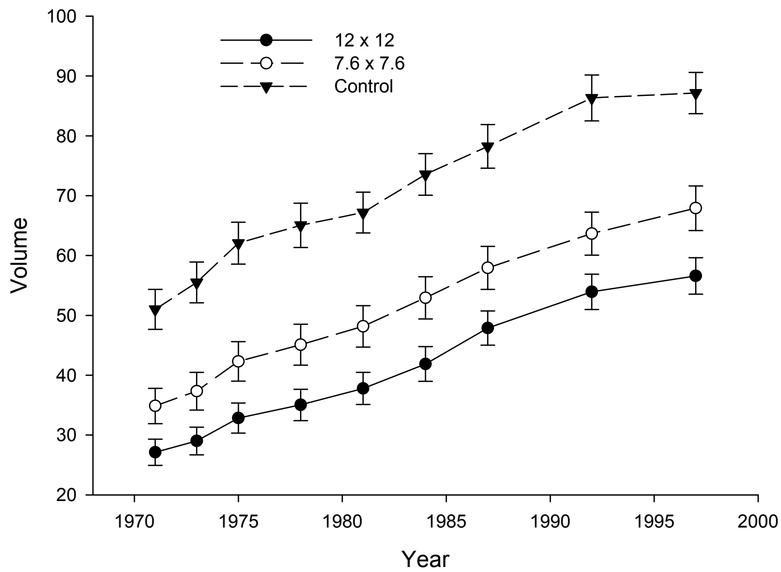



**Figure 3B.** Mean (± SE) volume ($m^3$/ha) for the different thinning treatments through time at Experiment 263HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

For trees that were only present at the start of the experiment (i.e. ignoring all recruited individuals), thinning treatments resulted in a significant improvement in diameter growth ($F_{2,53}$ = 11.19, $P$ <0.001). The unthinned treatment (control) had significantly lower diameter growth than the thinned treatments, which had similar diameter growth (Figure 3C). Annual diameter increments over 27 years were: 0.43 ± 0.03 cm in the 12 × 12 m spacing treatment, 0.38 ± 0.02 cm in the 7.6 × 7.6 m spacing treatment and 0.29 ± 0.02 cm in the control treatment. For initial trees only, average volume increment ($m^3$/ha/year) also differed between treatments ($F_{2,53}$ = 16.11, $P$ <0.001), with highest annual increments in the 7.6 × 7.6 m spacing treatment (1.44 ± 0.06) and lowest increments in the control treatment (0.97 ± 0.06). The 12 × 12 m spacing treatment had intermediate volume increments (1.14 ± 0.07).

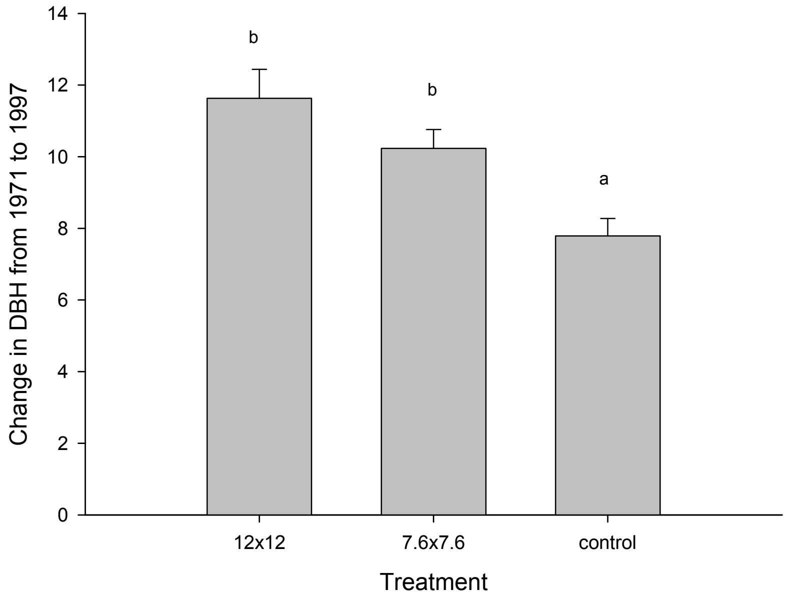



**Figure 3C.** Mean difference in DBH between the first (1971) and last (1997) measures for trees present at the start of the experiment only, across the different thinning treatments. Different letters (a and b) indicate significant differences between treatments ($P$ <0.05).

**Experiment 165DBY**

Tree basal area ($m^2$/ha) increased across all treatments through time (Figure 3D), although there was some indication that basal area at the control site was starting to plateau after 1986. Only the 8 × 8 m thinning treatment had reached similar basal areas to the control site at the start of the experiment (approximately 11.5 $m^2$/ha) after 21 years of growth. Stem volumes increased through time in each of the treatments and the rates of volume increase were similar across all treatments, although there was some tendency of higher volume increases over time in the 8 × 8 m spacing treatment relative to the control treatment (Figure 3E). At the last measure in 1997, stem volumes were highest in the 8 × 8 m spacing treatment (53.4 ± 2.2 $m^3$/ha) and lowest in the 14 × 14 m treatment (30.6 ± 2.1 $m^3$/ha; Figure 3E).

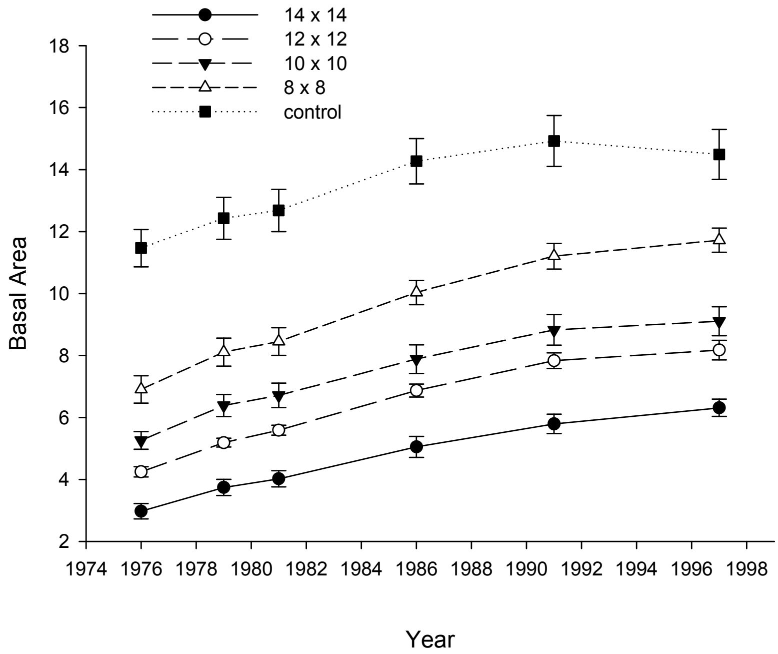



**Figure 3D.** Mean (± SE) basal area ($m^2$/ha) for the different thinning treatments through time at Experiment 165DBY. Data includes all trees with DBH >10 cm recorded through time (including recruits).

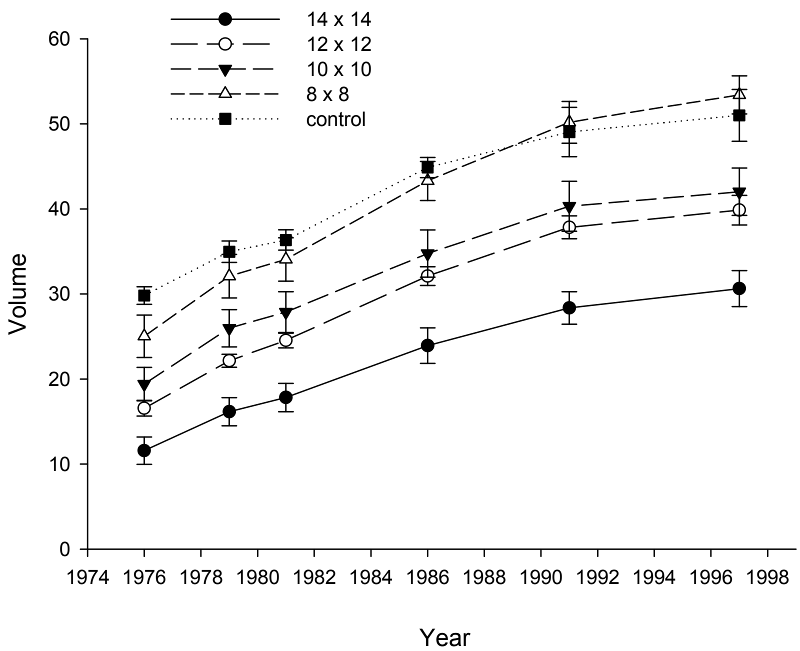



**Figure 3E.** Mean (± SE) volume ($m^3$/ha) for the different thinning treatments through time at Experiment 165DBY. Data includes all trees with DBH >10 cm recorded through time (including recruits).

For trees present at the start of the experiment (i.e. ignoring all recruited individuals), thinning treatments resulted in a significant improvement in diameter growth ($F_{4,12} = 22.44$, $P < 0.001$), with the greater tree spacing (i.e. lower stockings) resulting in the largest increases in diameter growth between first and last measurements (Figure 3F). Annual diameter increments over 21 years ranged from 0.57 ± 0.03 cm in the 14 × 14 m spacing treatment to 0.20 ± 0.03 cm in the control treatment. For initial trees only, periodic annual volume increments also differed between treatments ($F_{4,12} = 3.62$, $P = 0.037$). Average volume increments ($m^3$/ha/year) ranged from 0.88 ± 0.06 at the 14 × 14 m spacing treatment to 1.3 ± 0.02 at the 8 × 8 m spacing treatment.

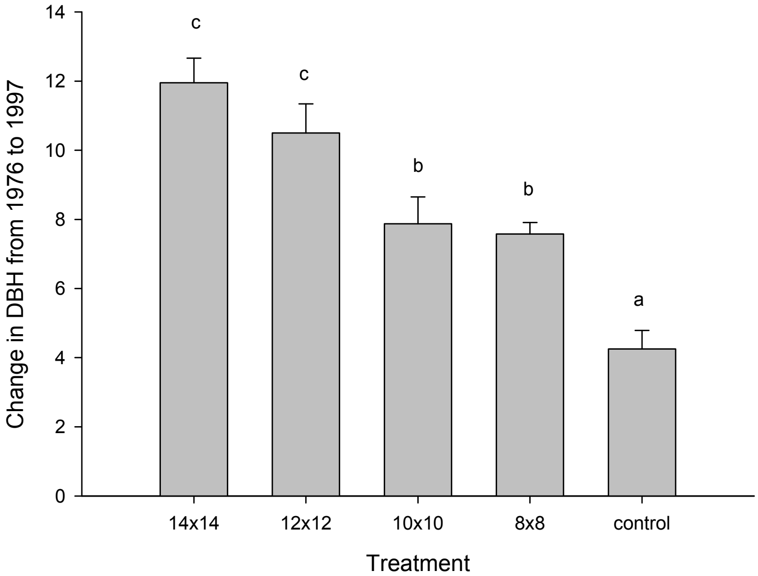



**Figure 3F.** Mean difference in DBH between the first (1976) and last (1997) measures for trees present at the start of the experiment only, across the different thinning treatments. Different letters (a, b and c) indicate significant differences between treatments ($P$ <0.05).

**Experiment 265HWD**

Tree basal area ($m^2$/ha) increased across all treatments through time and there was no difference between the rates of increase between treatments (Figure 3G). Stem volumes also increased at the same rate between treatments (Figure 3H). Volumes increased almost five fold over the 20 years of data collection and at the time of the last measure (1999) the 8 × 8 m spacing treatment had volumes of 50.1 ± 3.70 $m^3$/ha, the 10 × 10 m spacing treatment had volumes of 42.7 ± 3.34 $m^3$/ha, and the 12 × 12 m spacing treatment had volumes of 38.2 ± 2.17 $m^3$/ha.

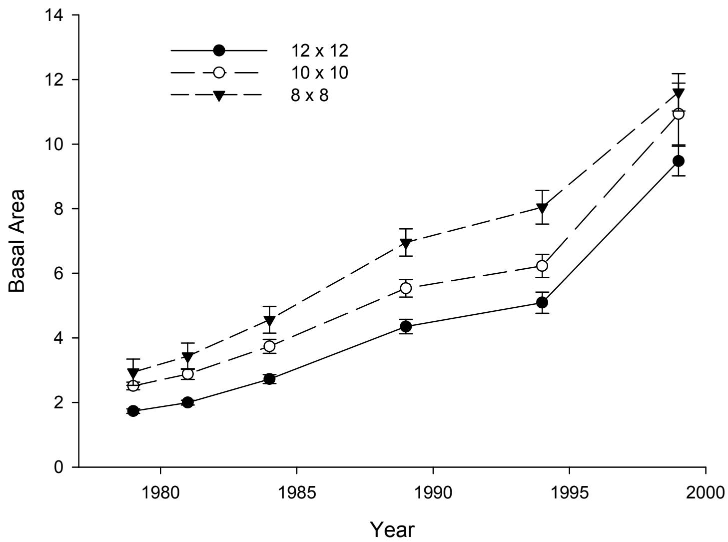



**Figure 3G.** Mean (± SE) basal area ($m^2$/ha) for the different thinning treatments through time at Experiment 265HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

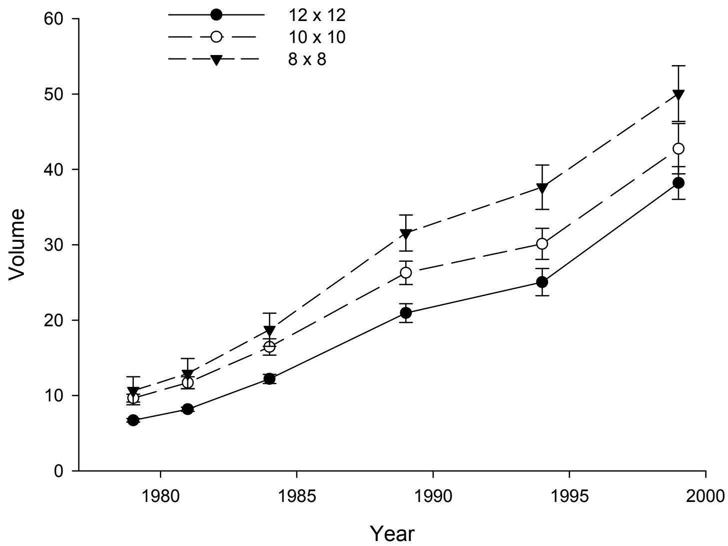



**Figure 3H.** Mean (± SE) volume ($m^3$/ha) for the different thinning treatments through time at Experiment 265HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

For trees present at the start of the experiment, thinning treatments resulted in a significant improvement in diameter growth ($F_{2,8}$ = 9.80, $P$ = 0.029), with the 12 × 12 m spacing treatment resulting in higher increases in diameter growth between first and last measurements (Figure 3I). Annual diameter increments over 20 years were 0.62 ± 0.05 cm in the 8 × 8 m spacing and 0.63 ± 0.04 cm in the 10 × 10 m spacing and increased to 0.78 ± 0.05 cm in the 12 × 12 m spacing treatment. For initial trees only, periodic annual volume increments did not differ significantly between treatments ($F_{2,8}$ = 2.07, $P$ >0.05). Average volume increments across the experiment were 1.35 ± 0.22 $m^3$/ha/year.

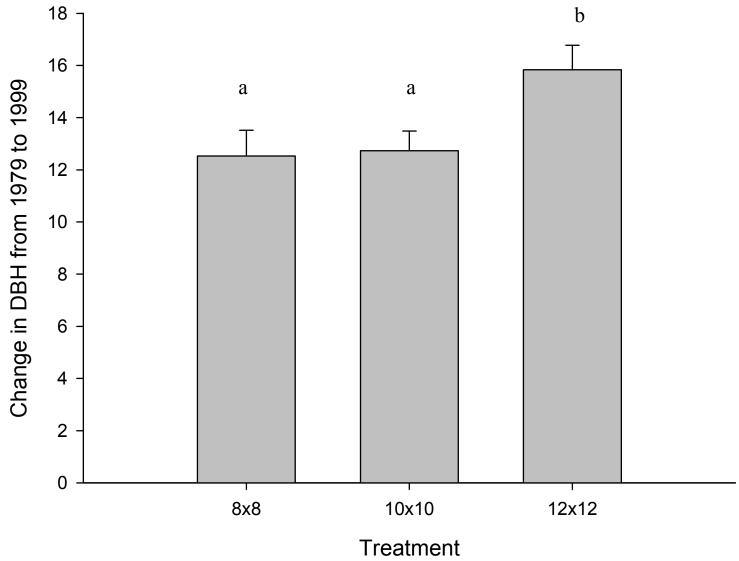



**Figure 3I.** Mean difference in DBH between the first (1979) and last (1999) measures for trees present at the start of the experiment only, across the different thinning treatments. Different letters (a, b) indicate significant differences between treatments ($P < 0.05$).

### Experiment 262HWD

Tree basal area ($m^2$/ha) increased across all treatments through time and there was no difference between the rates of increase between treatments (Figure 3J). Stem volumes also increased at the same rate between treatments (Figure 3K). In 1999 (last measure), the 9 × 9 m spacing treatment had volumes of 63.0 ± 2.69 $m^3$/ha, the 12 × 12 m spacing treatment had volumes of 49.8 ± 3.84 $m^3$/ha.

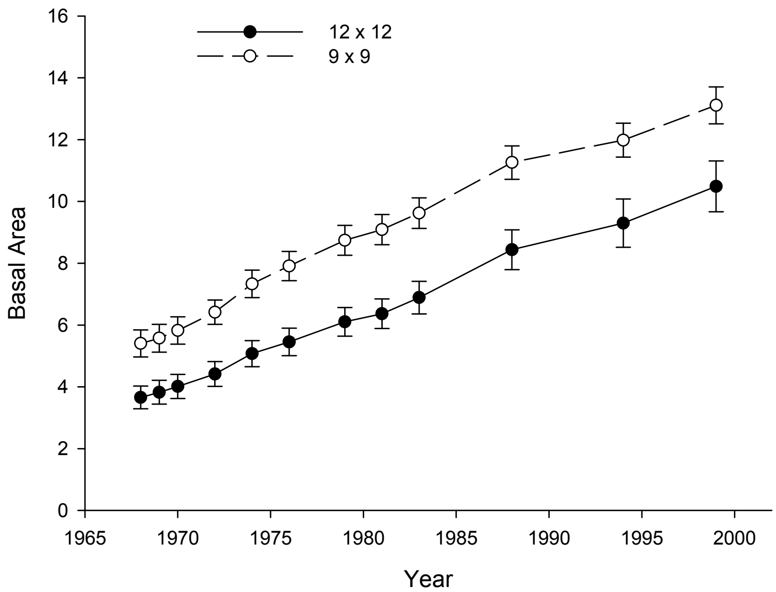



**Figure 3J.** Mean (± SE) basal area ($m^2$/ha) for the different thinning treatments through time at Experiment 262HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

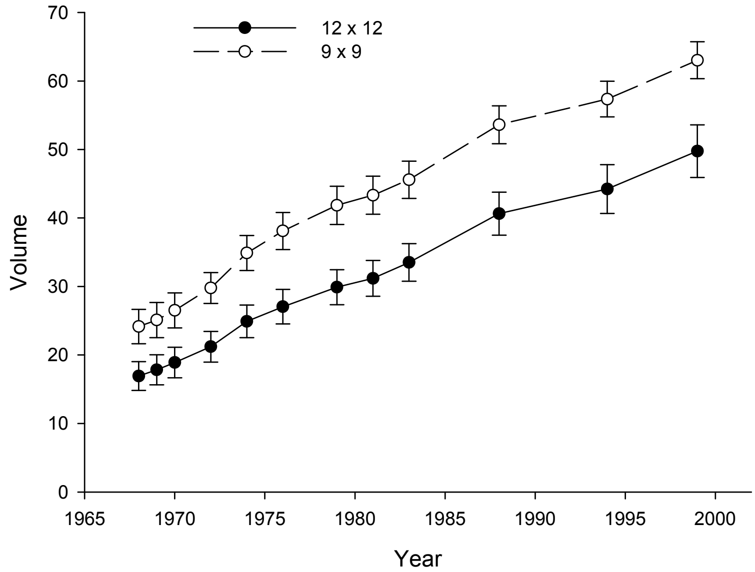



**Figure 3K.** Mean (± SE) volume ($m^3$/ha) for the different thinning treatments through time at Experiment 262HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

For trees present at the start of the experiment, the 12 × 12 m spacing treatment resulted in a significant improvement in diameter growth over the 9 × 9 m spacing treatment ($F_{1,15} = 30.4$, $P < 0.001$; Figure 3L). Annual diameter increments over 31 years were 0.51 ± 0.01 cm in the 12 × 12 m spacing treatment and 0.39 ± 0.02 cm in the 9 × 9 m spacing treatment. For initial trees only, periodic annual volume increments differed significantly between treatments ($F_{1,15} = 7.15$, $P = 0.02$).

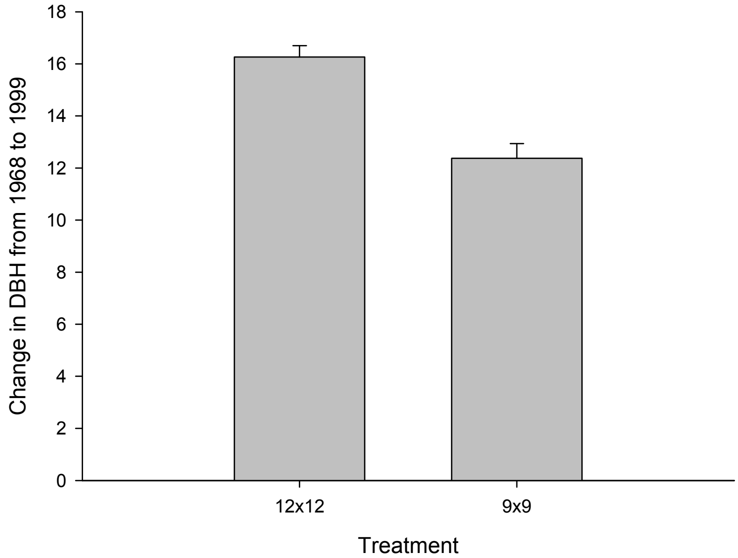



**Figure 3L.** Mean difference in DBH between the first (1968) and last (1999) measures for trees present at the start of the experiment only, across the different thinning treatments. There was a significant difference between the two treatments.

However, average volume increments were higher in the 9 × 9 m spacing treatment ($1.21 \pm 0.07$ $m^3$/ha/year) than in the 12 × 12 m spacing treatment ($0.98 \pm 0.05$ $m^3$/ha/year). The reasons for this are probably related to the greater reduction in stocking (and hence basal area) of initial trees (i.e. mortality) in the 12 × 12 m spacing treatment (an average of $6.2 \pm 2.03$ stems/ha died compared to $4.7 \pm 1.90$ stems/ha in the 9 × 9 m spacing treatment) and may also be related to differences in diameter class distributions (e.g. higher growth of smaller diameter trees) between the two treatments.

**Experiment 258HWD**

Tree basal area ($m^2$/ha) increased across all treatments through time and there was no difference between the rates of increase between treatments (Figure 3M). Stem volumes also increased at the same rate between treatments (Figure 3N). In 1997 (last measure) the thinned treatment had volumes of $65.5 \pm 12.06$ $m^3$/ha and the routine treatment had volumes of $94.0 \pm 10.15$ $m^3$/ha.

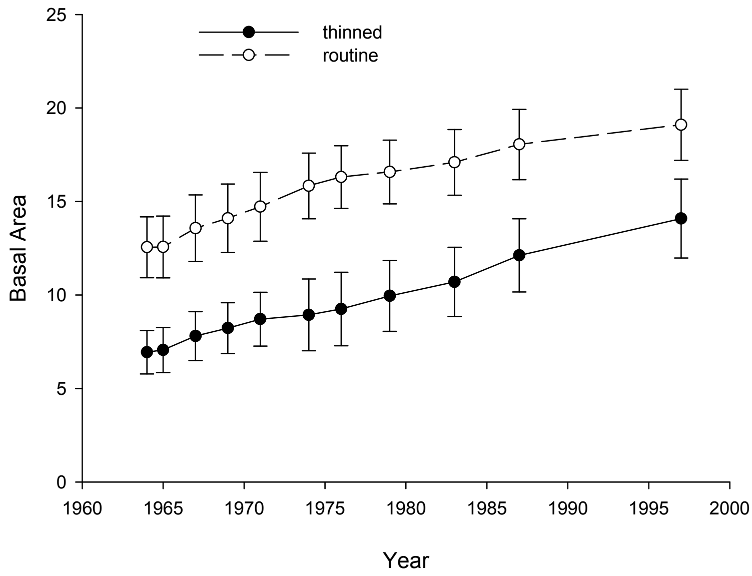



**Figure 3M.** Mean (± SE) basal area ($m^2$/ha) for the different thinning treatments through time at Experiment 258HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

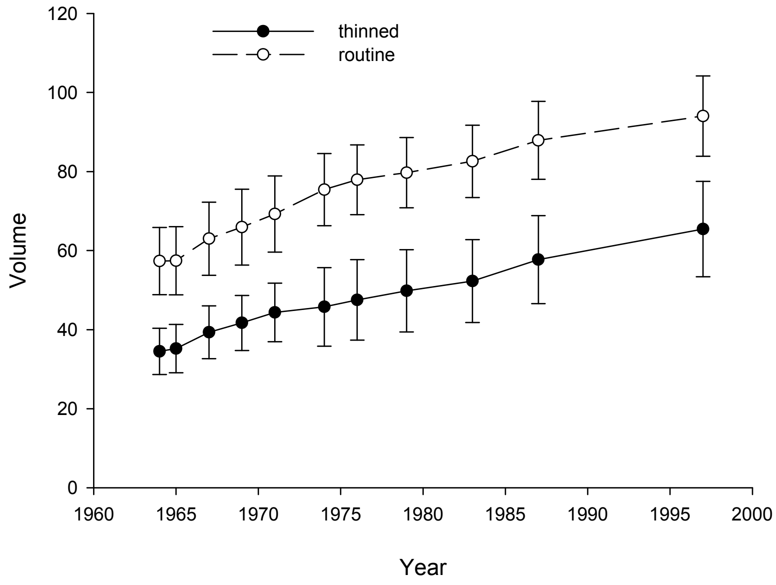



**Figure 3N.** Mean (± SE) volume ($m^3$/ha) for the different thinning treatments through time at Experiment 258HWD. Data includes all trees with DBH >10 cm recorded through time (including recruits).

For trees present at the start of the experiment, the thinned treatment resulted in a significant improvement in diameter growth over the routine treatment ($F_{1,7} = 40.9$, $P = 0.008$; Figure 3O). Annual diameter increments over 33 years were 0.31 ± 0.01 cm in the thinned treatment and 0.20 ± 0.02 cm in the routine treatment. For initial trees only, periodic annual volume increments did not differ significantly between treatments $F_{1,7} = 6.29$, $P > 0.05$). Average volume increments across the experiment were 1.03 ± 0.13 $m^3$/ha/year.

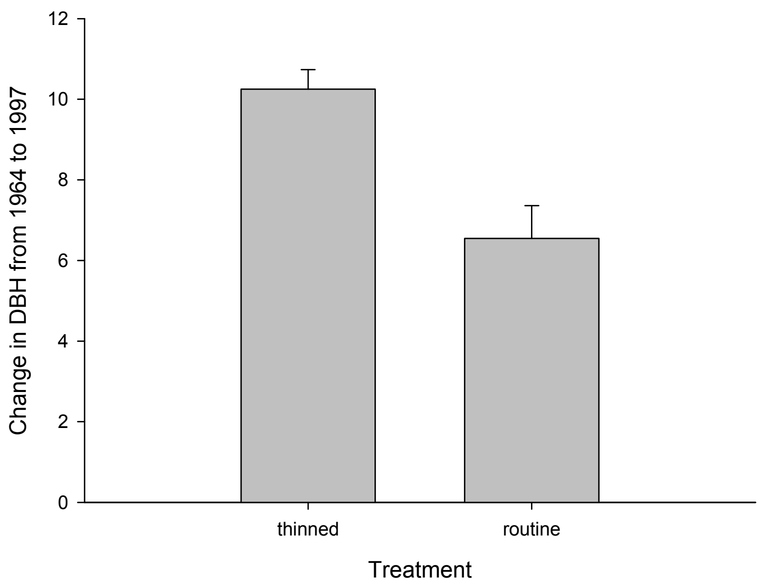



**Figure 3O.** Mean difference in DBH between the first (1964) and last (1997) measures for trees present at the start of the experiment only, across the different thinning treatments. There was a significant difference between the two treatments.

## A general relationship between diameter growth and stocking

Of the five experiments outlined above, only one experiment (Experiment 165DBY) maintained similar stockings (tree densities) through time and contained a range of different stockings (49–453 stems/ha). Using data from this experiment a significant linear relationship was observed ($F_{1,19} = 73.9$, $P < 0.001$; Figure 3P) between diameter growth and stocking (transformed with a logarithm base 10 + 1 transform), which explained 79.3% of the variance in the data.

The experiments outlined above demonstrate that thinning treatments have improved diameter growth on selected stems (i.e. trees retained at the start of each experiment). Hence the relationship between diameter increment and stocking was as expected. Using this relationship we can predict the diameter growth expected for a range of tree stockings (Table 3A). It is likely that a similar relationship exists for the Maryborough region, although growth rates might be slightly greater due to the higher annual rainfall in the Maryborough region. The growth rates reported here might be considered quite low, but are on par with those reported for spotted gum forest on the south coast of NSW (Bauhus *et al*. 2002). It is likely that higher growth rates could be achieved in younger stands (smaller diameter classes) where densities are maintained at low levels (e.g. 100 stems/ha or less), especially in the higher rainfall zones (i.e. MAR >1000 mm). Further analysis is required to determine the relative growth rates for different diameter classes in a given stand.

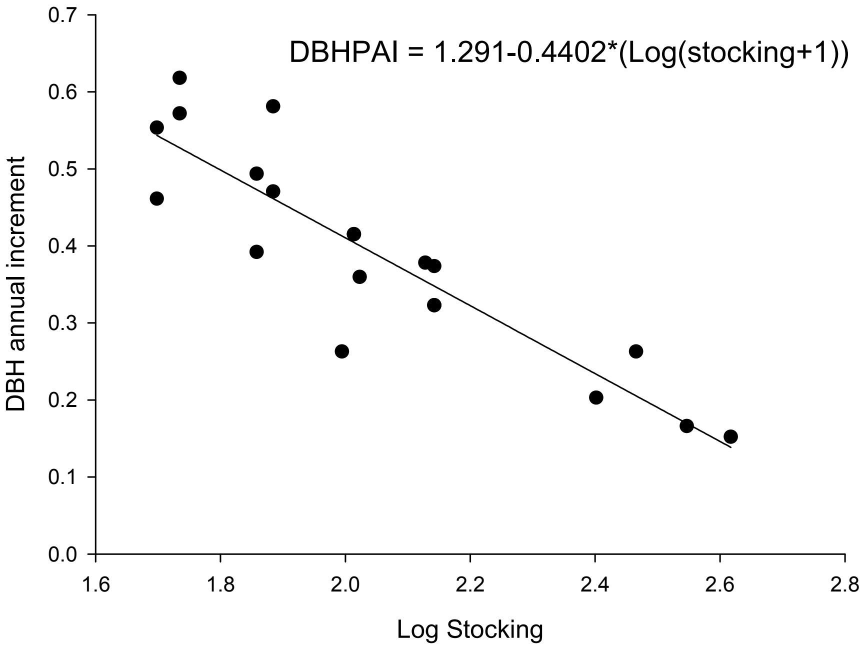



**Figure 3P.** The relationship between diameter increment over the whole data period of Experiment 165DBY and log stocking (log average of initial and final stockings, plus 1). A linear equation was fitted to the data which explained 79.3% of the variance. Data does not include trees that were recruited into the experiment through time.

**Table 3A.** Predicted diameter growth (per year) of selected trees at a range of different stockings. Predictions were based on the relationship in Figure 3P.

| Tree stocking (trees / ha) | Predicted diameter growth (± SE) (cm) |
|---|---|
| 50 | 0.54 ± 0.07 |
| 100 | 0.41 ± 0.06 |
| 150 | 0.33 ± 0.06 |
| 200 | 0.28 ± 0.07 |
| 250 | 0.23 ± 0.07 |
| 300 | 0.20 ± 0.07 |
| 350 | 0.17 ± 0.07 |

## Key findings

In each experiment stand growth increased at similar rates between the various treatments. Hence, where thinning treatments are applied this growth rate is concentrated on the more commercially productive stems (i.e. available site productivity is effectively concentrated on fewer trees). It is important to point out that smaller stand volumes of bigger merchantable trees are often more commercially viable than larger stand volumes consisting of a high proportion of smaller unmerchantable trees. In each experiment the lower stockings (i.e. greater spacing between retained trees) resulted in higher diameter growth rates for trees that were present at the start of each experiment. Across all experiments average diameter growth increments of trees present at the start of each experiment varied from 0.20 ± 0.03 cm per year in the control treatment of the Dalby experiment to 0.78 ± 0.05 cm in the 12 × 12 m spacing treatment of experiment 265HWD. Experiment 265HWD exhibited better growth rates than the other experiments, as this experiment followed the growth of regeneration following the removal of all existing trees (i.e. removal of overstorey competition for resources).

Using data from the Dalby experiment a linear relationship was determined between stocking (log number of trees per hectare) and periodic annual diameter increment, reflecting the finding that higher stocking results in lower growth rates of selected trees in the stand. In summary, active forest management (silviculture) to lower the basal area of unmerchantable trees and maintain productive growing conditions will result in better growth rates of merchantable trees and hence will reduce the period of time between harvests in this forest type.

## References

Refer to page 46–48 of report.

# Appendix 4. Assessment code definitions

## Example of data output.

**Series:** NFQ0099 **Plot:** 1 **Property:** Name

**MGA:** Zone 56 East 382047 Nth 7164543 **Plot area** 0.1 (circular)

| Series | Plot | Tree | Species | Measdate | DBH | Tot Ht | Mch Ht | Mch Cls | Position | Size | Density | Dead Branches | Epicormics | Grimes Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NFQ99 | 1 | 1 | SPG | 16/03/2008 | 29.4 | 25.8 | 10.3 | S | 3 | 4 | 7 | 4 | 2 | 20 |
| NFQ99 | 1 | 2 | SPG | 16/03/2008 | 30.2 | 25.8 | 9.2 | S | 5 | 5 | 6 | 5 | 2.5 | 23.5 |
| NFQ99 | 1 | 3 | SPG | 16/03/2008 | 27.3 | 26.6 | 8.4 | S | 4 | 4 | 6 | 4 | 2.5 | 20.5 |
| NFQ99 | 1 | 4 | SPG | 16/03/2008 | 13.6 | 0.0 | 0.0 | ITD | 0 | 0 | 0 | 0 | 0 | 0 |
| NFQ99 | 1 | 5 | NRI | 16/03/2008 | 54.8 | 0.0 | 0.0 | STD | 0 | 0 | 0 | 0 | 0 | 0 |
| NFQ99 | 1 | 6 | SPG | 16/03/2008 | 18.2 | 0.0 | 0.0 | ITD | 0 | 0 | 0 | 0 | 0 | 0 |
| NFQ99 | 1 | 7 | SPG | 16/03/2008 | 19.2 | 0.0 | 0.0 | STD | 0 | 0 | 0 | 0 | 0 | 0 |
| NFQ99 | 1 | 8 | NRI | 16/03/2008 | 10.1 | 0.0 | 0.0 | SRR | 0 | 0 | 0 | 0 | 0 | 0 |

Notes

Series – Refers to experiment number.
Plot – Refers to plot number.
Tree – Refers to the unique number assigned to each tree in the plot.
Species – Code refers species of assessed tree (Table 4A).
Measdata – Refers to the date that the tree was measured (dd.mm.yy).
DBH – The DBH of the tree in centimetres (Table 4B).
Tot Ht – The total height of the tree in metres (Table 4B).
Mch Ht – The merchantable height of the tree in metres (Table 4B).
Mch Cls – This field is the combination of three assessment variables. In sequence of display they are: (i) merchantable class (Table 4C); (ii) death reason (Table 4D); and (iii) status (Table 4E).

Some experiments had their crown assessed using the Grimes Crown Score (Table 4F; Grimes 1987).

**Table 4A**. Definition of species codes.

| Species Code | Common Name | Species | Qld Spp No |
|---|---|---|---|
| CP- | White Cypress Pine | *Callitris glaucophylla* | 1120 |
| BBX | Brush Box | *Lophostemon confertus* | 156 |
| BGL | Brigalow | *Acacia harpophylla* | 974 |
| BKS | Forest Oak / Black Sheoak | *Allocasuarina littoralis* | 1159 |
| BOK | Bulloak | *Allocasuarina luehmannii* | 1091 |
| BRI | Broad-leaved Red Ironbark | *Eucalyptus fibrosa* | 1042 |
| BSP | Spotted Gum | *Corymbia henryi* | 1351 |
| BWT | Curracabah / Black Wattle | *Acacia concurrens* | 995 |
| CAS | Casuarina | *Casuarina sp* | 1161 |
| EPL | Grey Gum | *Eucalyptus longirostrata* | 2083 |
| FRG | Forest Red Gum | *Eucalyptus tereticornis* | 395 |
| GBX | Grey Box | *Eucalyptus moluccana* | 957 |
| GGM | Grey Gum | *Eucalyptus biturbinata* | 1012 |
| GIB | Grey Ironbark | *Eucalyptus drepanophylla* | 1038 |
| GMS | Gympie Messmate | *Eucalyptus cloeziana* | 1081 |
| GRG | Grey Gum | *Eucalyptus propinqua* | 1011 |
| GRI | Grey Iron Bark | *Eucalyptus siderophloia* | 1037 |
| GTI | Gum Topped Ironbark | *Eucalyptus decorticans* | 1039 |
| MBA | Moreton Bay Ash | *Corymbia tessellaris* | 536 |
| NRI | Narrow-leaved Red Ironbark | *Eucalyptus crebra* | 1043 |
| QPM | Queensland Peppermint | *Eucalyptus exserta* | 1111 |
| RBA | Rough Barked Apple | *Angophora floribunda* | 910 |
| RBW | Red Bloodwood | *Corymbia intermedia* | 396 |
| RDA | Red Ash | *Alphitonia excelsa* | 480 |
| ROS | Rose Sheoak | *Allocasuarina torulosa* | 393 |
| SBA | Smooth Barked Apple | *Angophora leiocarpa* | 911 |
| SBX | Swamp Box | *Lophostemon suaveolens* | 893 |
| SGU | Spotted Gum | *Corymbia citriodora subsp. citriodora* | 1014 |
| SLI | Silver-leaved Ironbark | *Eucalyptus melanophloia* | 1044 |
| SPG | Spotted Gum | *Corymbia citriodora subsp.variegata* | 1027 |
| SPG | Spotted Gum | *Corymbia maculata* | 3121 |
| SRG | Slaty Red Gum / Narrow-leaved Red Gum | *Eucalyptus seeana* | 1018 |
| TRP | Turpentine | *Syncarpia glomulifera* | 397 |
| TWD | Tallowood | *Eucalyptus microcorys* | 1177 |
| WAT | Wattle | *Acacia spp.* | 1906 |
| WMY | White Mahogany | *Eucalyptus acmenoides* | 1063 |

**Table 4B**. Definition of measured variables.

| Variable | Definition |
|---|---|
| Total Height | Distance from the ground to the tallest live point of the tree. |
| Merch Height | Height from the ground to the highest merchantable point of the bole. Based on straightness and defect - not size. |
| Crown Break | Height from the ground at which the bole terminates and the crown begins. Not based on merchantability. |
| DBH | The diameter of a tree outside of the bark at 1.3 m off the ground on the uphill side of the tree (Normally breast height) |
| BA | The cross sectional area of the bole of a tree. Foresty BA is generally at 1.3 m above the ground. Commonly expressed as sq m of basal area for a given land area. |

**Table 4C**. Merchantability (Merch) class definition.

| Merch. Class | Definition |
|---|---|
| S | Potential sawlog |
| U | Useless by either form or species |
| R | Other Product / fencing, sleepers |
| I | Between useless and sawlog /Small tree retained for future stocking |
| # | Tree was removed/died at a previous measure |

**Table 4D.** Death reason codes.

| Death Reason | |
|---|---|
| L | Logged |
| T | Treated |
| O | Other natural causes |
| S | Smashed at logging |
| C | Crushed - by falling stag (not at logging) |
| H | Other human causes |
| F | Fire |
| W | Wind |
| D | Drought |
| E | Lightning |
| R | Retained / Alive |

**Table 4E**. State definitions.

| Status | |
|---|---|
| D | Dead at this measure |
| R | Recruit at this measure |

**Table 4F**. Grimes Crown Score codes (Grimes 1987).

| | |
|---|---|
| Position | |
| 5.0 | All crown open, both upper surface and sides exposed to direct sunlight |
| 4.0 | Upper crown surface entirely exposed, some side competition |
| 3.0 | Part of upper crown exposed, mostly side light |
| 2.0 | Some side light only |
| 1.0 | No side light |
| Size | |
| 5.0 | Perfect (wide deep roughly circular) |
| 4.0 | Good (slight faults, lop sided etc.) |
| 3.0 | Satisfactory (satisfactory silviculturally) |
| 2.0 | Poor (remove in thinning) |
| 1.0 | Very poor (useless) |
| Density | |
| 9.0 | Very dense |
| 7.0 | Dense |
| 5.0 | Average |
| 3.0 | Sparse |
| 1.0 | Very sparse |
| Dead Branches | |
| 5.0 | Nil |
| 4.0 | Branchlets dead |
| 3.0 | Small growing branches dead |
| 2.0 | Most of main growing branches dead |
| 1.0 | All main growing branches dead |
| Epicormics | |
| 3.0 | Nil to slight (growth concentrated on branch extremities |
| 2.5 | Slight |
| 2.0 | Moderate |
| 1.5 | Severe on crown or stem |
| 1.0 | Severe on crown and stem |
| Grimes Total | |
| Score | Aggregate for all values |

# Appendix 5. Description and early data summary for monitoring plots established in private native forest.


## Authors: S. Swift, D. Osborne and B. Hogg


## NFQ 1 - Rathdowney

### Site description

Experiment 1 NFQ is located in the Qld and NSW border ranges near Rathdowney (Figure 10). The experimental site is surrounded by native forest on the upper slopes and hills, while the lower slopes and plains have been cleared for grazing and cultivation.

The forest cover at this site is mixed dry sclerophyll forest dominated by spotted gum and is generally typical of forests within both the property and the broader landscape. The site was heavily stocked and contained a large percentage of suppressed stems. There was a commercial logging operation in 2007 which removed some of the overwood prior to establishment of the current trial.

There are two replicated blocks at this experiment. Replicate 1 is mapped as being non-remnant forest while replicate 2 is mapped as regional ecosystem 12.9/10.2 which is described as an open-forest or woodland of *Corymbia citriodora*, usually with *Eucalyptus crebra* on sedimentary rocks (Sattler and Williams 1999).

Replicate 1 has a slope of 1–5° with a southerly aspect while replicate 2 has a slope varying between 2–13° with a northerly aspect. The soils were classified as Red or Yellow Kurosols (Isbell 1996). The site has been managed for both timber production and grazing.

Long term mean annual rainfall, measured at the Rathdowney post office is 889 mm.

### Design and methodology

This trial was established to investigate the effect of three stocking treatments on tree growth. The treatments selected were: (i) 50–75 stems per hectare; (ii) 100–150 stems per hectare; and (iii) an unthinned control (Table 5A). The experiment consisted of six plots laid out as two replications of the three treatments. The continuous forest cover enabled the use of large square plots. The thinned plots have a gross plot area of 1.0 ha with a nett (measure) plot area of 0.25 ha while the control (unthinned) plots have a 0.42 ha gross area and a nett plot area of 0.06 ha.

The treatments were imposed on 7.02.2008. Treatments were carried out with a combination of chainsaw and brush-cutter thinning followed by the application of Tordon DS ™ to the cut stumps of removed stems.

The retained trees ≥10 cm DBH were assessed and identified with a stainless steel tag carrying a unique number. The control plots had all stems >5 cm DBH uniquely identified and assessed.

### Results

The plot was initially measured on 6.02.2008. The subsequent measure was carried out on 17.03.2010 and a summary of the data from both measures is presented in Table 5A.

**Table 5A**. Plot data from the 2008 and 2010 measures at NFQ1.

| Plot Number | Treatment (st/ha) | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|---|
| | | 2/2008 | 3/2010 | 2/2008 | 3/2010 | 2/2008 | 3/2010 |
| 1 | 50–99 | 68 | 88 | 12.5 | 14.3 | 1.0 | 1.7 |
| 2 | 100–150 | 124 | 136 | 14.1 | 17.0 | 3.0 | 4.2 |
| 3 | Control | 832 | 1088 | 9.1 | 9.4 | 7.9 | 10.6 |
| 4 | 50–99 | 72 | 72 | 17.9 | 22.0 | 3.0 | 3.6 |
| 5 | 100–150 | 132 | 136 | 18.4 | 21.6 | 4.5 | 6.2 |
| 6 | Control | 816 | 832 | 11.8 | 12.4 | 11.9 | 13.1 |

## NFQ 2 - Esk

### Site description

Experiment 2 NFQ is located in the Brisbane Valley near Esk (Figure 10).

The site was previously cleared to encourage pasture growth, however recent management practices have resulted in development of dense spotted gum regeneration and the landowner recognising the potential for timber production, was keen to allow experimental work on the property.

The site was originally mapped as remnant forest however requests by the landowner to have the mapping re-assessed resulted in the site being re-mapped as ‘cleared’ (Sattler and Williams 1999).

The site has a slope of less than 8° with a southerly aspect. The soils were classified as a Red Kandosol (Isbell 1996) at the top of the ridge to a Yellow Kurosol (Isbell 1996) on the lower slope. The experimental site is surrounded by spotted gum and ironbark native forest on the upper slopes and hills. The lower slopes and plains have been cleared for grazing and cultivation.

Long term mean annual rainfall, measured at the Esk post office is 921 mm.

### Design and methodology

The experiment consisted of 12 plots laid out as three replications of four treatments. The four stocking treatments were: (i) 75 stems per hectare; (ii) 120 stems per hectare; (iii) 200 stems per hectare; and (iv) unthinned control (Table 5B).The continuous forest cover enabled the use of square plots. The thinned plots have a gross plot area of 0.49 ha with a nett (measure) plot area of 0.16 ha, while the control (unthinned) plots have a 0.25 ha gross area and a nett plot area of 0.04 ha.

Due to the high initial stocking, the thinning operation was undertaken in two stages. The initial treatment operation was undertaken on 7.02.2008. The stumps were allowed to coppice until 21.11.2006 when a foliar application of Garlon®™ (4.4 ml/l) and Spraymate LI 700®™ penetrant surfactant (3.6 ml/l) was carried out. This application resulted in a successful kill of the smaller sized coppice only; the surviving larger coppice was killed on 01.03.2007 using Garlon®™ (5.9 ml/l) plus Spreadwet 600®™ wetting agent (0.14 ml/l).

The second stage of the experimental silvicultural treatment operation to thin the plots to the required stocking was carried out on the 06.02.2009 with a combination of chainsaws and brush cutter followed by the application of Tordon DS ™ mix (20:1) to cut stumps.

Trees >2 cm DBH retained following the second stage of treatment were assessed and identified with a stainless steel tag with a unique number.

### Results

The plot was initially measured on 16.05.2007. Individual trees were not identified until a measure at the completion of the second stage of treatment (06.02.2009). Initial data reported in the commencement report (Swift and Osborne 2008) was collected prior to the final thinning treatment. The trial was measured after this final thinning in 2009 and this data should now be used as the baseline from which all treatment effects should be measured. Data shown in Table 5B shows the data from both the 2009 and 18.03.2010 measures.

**Table 5B**. Plot data from the 2009 and 2010 measures at NFQ2.

| Plot Number | Treatment (st/ha) | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|---|
| | | 2/2009 | 3/2010 | 2/2009 | 3/2010 | 2/2009 | 3/2010 |
| 1 | 75 | 75 | 75 | 12.8 | 15.5 | 1.0 | 1.5 |
| 2 | 200 | 200 | 200 | 11.5 | 13.6 | 2.3 | 3.1 |
| 3 | 100 | 119 | 119 | 11.6 | 13.9 | 1.3 | 1.8 |
| 4 | Control | 1975 | 1975 | 6.4 | 7.2 | 8.4 | 10.4 |
| 5 | 100 | 131 | 131 | 10.9 | 12.8 | 1.3 | 1.8 |
| 6 | 75 | 75 | 75 | 11.7 | 13.5 | 1.1 | 1.3 |
| 7 | Control | 650 | 650 | 8.8 | 9.7 | 7.3 | 8.1 |
| 8 | 200 | 206 | 206 | 11.3 | 13.0 | 2.3 | 3.0 |
| 9 | 200 | 200 | 200 | 11.4 | 13.2 | 2.2 | 2.8 |
| 10 | Control | 1225 | 1225 | 6.5 | 7.3 | 4.7 | 5.9 |
| 11 | 75 | 75 | 75 | 11.2 | 12.8 | 0.8 | 1.0 |
| 12 | 100 | 138 | 138 | 12.0 | 13.9 | 1.7 | 2.2 |

## NFQ 3 - Miva

### Site description

Experiment 3 NFQ was located 10 km north west of Gunalda and 35 km north west of Gympie near the locality of Miva (Figure 10) in an advanced spotted gum regrowth forest.

There is some anecdotal evidence (old ringbarked stumps) that the property was previously cleared for grazing, probably in the early 1900s. Due to the even age of the stand it appears likely that farming was abandoned around the 1930s and the forest has regenerated from that point. The forested area is typical of many of the private forests in the region and had been subjected to heavy diameter limit harvesting with little or no subsequent management until purchase by the present owners in the late 1990s who now manage for timber production, grazing and habitat values.

The site was classified under the regional ecosystem classification as 12.9/10.3 *Eucalyptus moluccana* ± *Corymbia citriodora* on Cainozoic and Mesozoic sediments (Sattler and Williams 1999). The conservation status of this ecotype is classed as 'of concern'.

At this site there are two replicates and both are located on undulating topography with slopes less than 10°. Six plots have a northerly aspect while two plots have a southerly aspect. There were two soil types at this site and these are both acid duplex soils (Kurosols) (Isbell 1996).

Long term mean annual rainfall, measured at Theebine is 975 mm.

**Design and methodology**

This trial was established using some existing plots from a previous trial. The existing plots were part of a demonstration trial initiated in July 1999. The site is now used by PFSQ to demonstrate sustainable management in private native forests.

This trial aimed to investigate the effects of four stocking treatments: (i) 70 stems per hectare; (ii) 100 stems per hectare; (iii) 200 stems per hectare; and (iv) unthinned control (Table 5C). The experiment consisted of eight plots laid out as two replications of the four treatments. The continuous forest cover enabled the use of large square plots. All plots have a gross plot area of 1.0 ha with a nett (measure) plot area of 0.16 ha.

The treatments were applied in September 1999. There were problems with finding enough suitable stems in the 200 stems per hectare treatment and the retained numbers were closer to the 100 stems per hectare treatment (Table 5C). In July 2006, trees that had not been killed by the 1999 treatment were retreated with Tordon®.

Following the thinning treatment all trees ≥10 cm DBH were measured and assessed. Retained trees were identified with a stainless steel tag carrying a unique number. There has been some recruiting of stems since initial establishment and a number of the treatments now have a similar stocking.

**Results**

The trial was initially measured on 19.07.2006, the subsequent measure was carried out on 23.03.2010. Data from both measures are presented in Table 5C.

**Table 5C**. Plot data from the 2006 and 2010 measures at NFQ3.

| Plot Number | Treatment (st/ha) | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|---|
| | | 7/2006 | 3/2010 | 7/2006 | 3/2010 | 7/2006 | 3/2010 |
| 7 | 200 | 112 | 112 | 27.5 | 29.3 | 7.4 | 8.0 |
| 8 | Control | 300 | 300 | 22.8 | 23.8 | 13.7 | 15.0 |
| 9 | 100 | 100 | 100 | 28.0 | 30.3 | 6.6 | 7.7 |
| 10 | 70 | 100 | 100 | 29.3 | 31.7 | 8.1 | 9.2 |
| 11 | Control | 193 | 194 | 26.7 | 28.1 | 12.2 | 13.4 |
| 12 | 100 | 112 | 112 | 22.0 | 23.7 | 4.9 | 5.6 |
| 13 | 200 | 143 | 144 | 28.3 | 29.6 | 10.2 | 11.0 |
| 14 | 70 | 106 | 112 | 25.8 | 30.0 | 6.0 | 9.2 |

## NFQ 4 - Gundiah

### Site description

Experiment 4 NFQ is located in the Mary Valley 50 km north of Gympie and 14 km south west of Tiaro near the township of Gundiah (Figure 10).

This property has been managed for over 60 years for both timber and grazing production. Management of the spotted gum forests on this property has been cross-generational with the potential for timber sales to offset grazing downturns realised by the property owners.

The majority of the research site was classified under the regional ecosystem classification as non-remnant forest with two plots located in an area classified as RE12.3.11 - *Eucalyptus tereticornis*, *E. siderophloia* and *Corymbia intermedia*, sometimes with spotted gum as a minor species, on alluvium or flat to undulating plains with sandy surfaced texture contrast soils (Sattler and Williams 1999). The conservation status of this ecotype is classed as 'of concern'. All plots were situated in spotted gum dominant forests.

The aspect of the experiment is variable (four plots had a south easterly aspect, two plots had a south westerly aspect, one plot had an easterly aspect and another plot had a north westerly aspect). The topography is undulating with slopes less than 6°. The soils were classified as Red Dermosols or Brown Kurosols (Isbell 1996). The experimental site is surrounded by native forest on the upper slopes and hills while the lower slopes and plains have been mostly cleared for grazing and cultivation.

Long term mean annual rainfall, measured at Gundiah is 1043 mm.

### Design and methodology

This experiment consisted of eight plots each with differing treatments. The experiment aimed to measure the range of stockings across the property with stockings of 12, 31, 88, 144, 175, 206 and 425 stems per hectare (Table 5D). There was no replication of treatments at this experiment.

The continuous forest cover enabled the use of large square plots. The gross plot area was 0.25 ha with a nett (measure) plot area of 0.16 ha. The lack of replication means that this experimental site will be of benefit in broad scale analysis of all established plots and provides plots at the lower and upper end of the stocking range.

The retained trees ≥10 cm DBH were assessed and each is identified with a stainless steel tag with a unique number.

**Results**

The trial was initially measured under this project on 08.09.2008, the subsequent measure was carried out on 29.03.2010. Data from both measures are presented in Table 5D.

**Table 5D**. Plot data from the 2008 and 2010 measures at NFQ4.

| Plot Number | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|
| | 9/2008 | 3/2010 | 9/2008 | 3/2010 | 9/2008 | 3/2010 |
| 1 | 144 | 144 | 18.3 | 19.5 | 4.1 | 4.6 |
| 2 | 206 | 206 | 23.4 | 23.9 | 11.5 | 11.8 |
| 3 | 175 | 175 | 19.2 | 19.6 | 7.0 | 7.2 |
| 4 | 425 | 413 | 15.5 | 15.9 | 11.8 | 12.0 |
| 5 | 31 | 63 | 20.7 | 14.5 | 1.3 | 1.6 |
| 6 | 206 | 188 | 21.5 | 20.6 | 11.8 | 9.5 |
| 7 | 13 | 13 | 34.6 | 35.9 | 1.5 | 1.5 |
| 8 | 88 | 88 | 41.6 | 42.0 | 12.7 | 13.0 |

## NFQ 5 - Gin Gin

**Site description**

Experiment 5 NFQ is located 12 km south west of Gin Gin in the Wide Bay - Burnett region (Figure 10).

This site was classified under the regional ecosystem classifications (Sattler and Williams 1999) as non-remnant forest and consist mostly of spotted gum dominant open woodlands to open forests with a mixture of other species including *Eucalyptus crebra*, *Alphitonia excelsa* and understorey dominated by acacia (at varying density). The research area was previously cleared for grazing. Past and current management aims to integrate timber production with grazing in suitable areas. In the productive areas of the property, spotted gum regeneration has been allowed to develop for the purposes of timber production. The forest was previously logged *circa* 1998 and the resulting stand was silviculturally treated.

Three plots at this site have a westerly aspect with the remaining plots having a predominantly northerly influence. The degree of slope varies between plots but is generally less than 10°. The low hilly terrain results in undulating to moderately steep slopes in some gully areas. Nine plots are on a Clastic Rudosol soil (Isbell 1996). The remaining four plots are on a different soil type which appears more consolidated. The experiment site is surrounded by regrowth native forest which is mapped as remnant (Sattler and Williams 1999).

Long term mean annual rainfall, measured at Moolboolaman is 937 mm.

**Design and methodology**

This trial aimed to measure the range of stockings across the property with stocking rates of 80, 120, 160, 180, 192, 200, 252 stems per hectare and unthinned control plots with up to 1403 stems per hectare (Table 5E). The experiment consisted of 13 plots of varying size and shape due to the broken nature of the forest cover. Eleven plots were circular with a gross area of 0.21 ha and a net (measure) plot area of 0.05 ha. The other two plots were square plots with a gross area of 0.36 ha with a nett (measure) plot area of 0.25 ha.

The site was commercially logged *circa* 1998 and the resulting stand was silviculturally treated in November 2006. The silvicultural treatment (thinning) used a tomahawk and calibrated tree injection gun using the chemical Tordon DS® diluted in water at a ratio of 1:4.

The retained trees ≥10 cm DBH were measured, assessed and each was identified with a stainless steel tag carrying a unique number.

**Results**

The trial was initially measured under this project on 12.09.2008, the subsequent measure was carried out on 16.03.2010. Data from both measures are presented in Table 5E.

**Table 5E**. Plot data from the 2008 and 2010 measures at NFQ5.

| Plot Number | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|
| | 9/2008 | 3/2010 | 9/2008 | 3/2010 | 9/2008 | 3/2010 |
| 1 | 120 | 120 | 16.5 | 17.7 | 2.6 | 3.0 |
| 2 | 180 | 180 | 17.2 | 18.4 | 4.8 | 5.4 |
| 3 | 120 | 120 | 11.1 | 11.8 | 1.2 | 1.4 |
| 4 | 80 | 80 | 15.4 | 16.4 | 1.8 | 2.0 |
| 5 | 160 | 140 | 22.7 | 18.8 | 9.5 | 5.1 |
| 6 | 902 | 882 | 9.0 | 9.3 | 6.8 | 7.0 |
| 7 | 120 | 1163 | 9.6 | 9.8 | 9.8 | 10.1 |
| 8 | 1243 | 1243 | 10.0 | 10.3 | 12.5 | 13.1 |
| 9 | 120 | 120 | 18.8 | 19.8 | 3.4 | 3.8 |
| 10 | 200 | 201 | 13.2 | 11.1 | 2.9 | 2.0 |
| 11 | 1403 | 1404 | 4.9 | 5.7 | 5.8 | 5.2 |
| 12 | 192 | 192 | 10.9 | 11.7 | 3.7 | 3.9 |
| 13 | 252 | 252 | 10.9 | 12.0 | 5.1 | 5.5 |

## NFQ 6 - Gayndah

**Site description**

Experiment 6 NFQ is located 22 km south east of Gayndah in the Burnett region (Figure 10).

The research sites have been classified under the regional ecosystem classifications (Sattler and Williams 1999) as either non-remnant (three blocks) or regrowth (one block) and consist mostly of spotted gum dominant open woodlands to open forests with a mixture of other species including *Eucalyptus crebra* and *E. moluccana*.

The site was previously cleared for grazing. Management aims to integrate timber production with grazing in suitable areas. In the low productive areas of the property, spotted gum regeneration has been allowed to develop for timber production and it was in these areas that experimental plots were located.

The aspect of the experiment varies between north, east and south. The topography is undulating with slopes variable but all less than 10°. The soils were described as either Brown Kurosol or Brown Sodosol (Isbell 1996), although one block (three plots) was on a very rocky knob and soil was unable to be described. The property has been managed for both timber production and grazing. The landscape surrounding the experiment site is covered by native forest (RE12.9–10.3, Sattler and Williams 1999).

Long term mean annual rainfall, measured at the Brian Pastures Research Station is 692 mm.

## Design and methodology

This trial aimed to investigate the effects of three stocking treatments: (i) 50 stems per hectare; (ii) 100 stems per hectare; and (iii) an unthinned control (Table 5F). The experiment consisted of 12 plots laid out as four blocks of with three plots in each block. The broken nature of the forest cover at this site required the use of circular plots. Plots have a gross area of 0.24 ha with a nett (measure) plot area of 0.1 ha.

The spotted gum in this area was all young regeneration but was not contiguous in the landscape. At the request of the landholder each block consisted of two treatment plots of the same stocking and a control plot. The treatment operation was undertaken on 13.06.2008. Treatment was carried out using a tomahawk and calibrated tree injection gun using the chemical Tordon DS® diluted in water at a ratio of 1:4 and applied at a rate of 1 cc per cut.

The retained trees >10 cm DBH were measured, assessed and each was identified with a stainless steel tag carrying a unique number.

## Results

The experiment was initially measured on 11.06.2008; this was followed by a silvicultural thinning operation on 13.06.2008. The subsequent measure was carried out on 24.03.2010. Data from both measures are presented in Table 5F.

**Table 5F**. Plot data from the 2008 and 2010 measures at NFQ6.

| Plot Number | Treatment (st/ha) | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|---|
| | | 6/2008 | 3/2010 | 6/2008 | 3/2010 | 6/2008 | 3/2010 |
| 1 | 100 | 100 | 101 | 19.9 | 20.6 | 4.4 | 4.6 |
| 2 | 100 | 100 | 101 | 19.6 | 20.0 | 4.2 | 4.3 |
| 3 | Control | 160 | 161 | 15.0 | 15.7 | 3.0 | 3.3 |
| 4 | 100 | 100 | 101 | 12.7 | 14.2 | 1.3 | 1.6 |
| 5 | Control | 290 | 291 | 15.7 | 16.5 | 6.6 | 7.2 |
| 6 | 100 | 100 | 101 | 16.7 | 18.5 | 2.3 | 2.8 |
| 7 | 50 | 50 | 50 | 23.4 | 25.7 | 2.3 | 2.7 |
| 8 | 50 | 50 | 50 | 23.5 | 26.5 | 2.2 | 2.8 |
| 9 | Control | 240 | 241 | 16.9 | 17.8 | 6.3 | 6.9 |
| 10 | 50 | 50 | 50 | 19.1 | 21.7 | 1.5 | 1.9 |
| 11 | 50 | 50 | 50 | 15.9 | 17.7 | 1.0 | 1.2 |
| 12 | Control | 300 | 301 | 13.7 | 14.3 | 4.6 | 5.1 |

## NFQ 7 - Gayndah

### Site description

Experiment 7 NFQ is located 22 km south east of Gayndah in the Burnett region (Figure 10).

This experiment is located on the same property as experiment 6 NFQ but is situated in a different stand type. The site has been classified under the regional ecosystem classification as 12.12.5 - *Corymbia citriodora*, *Eucalyptus crebra* open forest on mesozoic to proterozoic igneous rocks (Sattler and Williams 1999). The site was a spotted gum dominant, open forest. The plots were located in remnant forest which was treated as part of a demonstration project funded by AgForests and Burnett Mary Regional Group (BMRG). The forest had a high basal area and was over-stocked, resulting in a high proportion of suppressed stems and trees with poor crowns and a relatively low total tree height. Some difficulty was experienced in selecting 100 suitable stems per hectare for retention in the experimental plots. Current management aims to integrate timber production with grazing in this area.

The experiment site is surrounded by remnant native forest with some non-remnant regrowth areas in the lower landscape. Slope across the site is variable but less than 10° with the aspect ranging between the north and east. The soil was classified as Bleached-Leptic Tenosol (Isbell 1996).

Long term mean annual rainfall, measured at the Brian Pastures Research Station is 692 mm.

### Design and methodology

This experiment consisted of six plots laid out as two replications of three treatments. Treatment stocking rates were: (i) 50 stems per hectare; (ii) 100 stems per hectare; and (iii) an unthinned control (Table 5G). The experiment uses circular plots with plot size altered to ensure that there was a minimum of 10 measure trees per plot. The 50 stems per hectare plots have a gross area of 0.39 ha and a nett area of 0.2 ha, the 100 stems per hectare plots have a gross area of 0.24 ha and a nett area of 0.1 ha and the control plots have a gross area 0.09 ha and a nett area of 0.05 ha. The thinned plots have 10 m isolation and the control plots have 5 m isolation.

The treatment operation was undertaken on 13.06.2008. Treatment was carried out using a tomahawk and calibrated tree injection gun using the chemical Tordon DS® diluted in water at a ratio of 1:4 and applied at a rate of 1 cc per cut.

The retained trees >10cm DBH were measured, assessed and individually identified with a stainless steel tag carrying a unique number.

**Results**

The experiment was initially measured on 14.05.2008; this was followed by a silvicultural thinning operation on 13.06.2008. The subsequent measure was carried out on 24.03.2010. Data from both measures are presented in Table 5G.

**Table 5G**. Plot data from the 2008 and 2010 measures at NFQ7.

| **Plot Number** | **Treatment (st/ha)** | **Stocking (st/ha)** | | **Mean DBH (cm)** | | **Retained BA ($m^2$/ha)** | |
|---|---|---|---|---|---|---|---|
| | | 5/2008 | 3/2010 | 5/2008 | 3/2010 | 5/2008 | 3/2010 |
| 13 | 100 | 100 | 101 | 25.7 | 26.5 | 5.4 | 5.7 |
| 14 | 50 | 50 | 50 | 22.9 | 24.5 | 2.1 | 2.4 |
| 15 | Control | 460 | 461 | 17.7 | 18.1 | 12.5 | 12.9 |
| 16 | Control | 540 | 541 | 16.4 | 16.9 | 12.2 | 13.1 |
| 17 | 100 | 100 | 101 | 21.1 | 22.4 | 3.6 | 4.0 |
| 18 | 50 | 50 | 50 | 22.0 | 23.4 | 1.9 | 2.2 |

## NFQ 8 - Kingaroy

**Site description**

Experiment 8 NFQ is located 34 km north west of Kingaroy in the south Burnett region (Figure 10).

The sites has been classified under the regional ecosystem classification as 11.7.6 - *Corymbia variegata* or *Eucalyptus crebra* woodland on Cainozoic lateritic duricrust; with a vegetation management status of 'not of concern' (Sattler and Williams 1999). The site was a spotted gum dominant (almost monoculture), open forest with isolated occurrences of *Eucalyptus crebra*. The trial site was last logged during the late 1980s. The harvest was heavy with the smaller stand fraction also being targeted. This previous logging was possibly carried out in the 1950s or 1960s. There was no evidence of previous silvicultural treatment in the plots.

The experiment has a predominantly easterly aspect. Replicates 1 and 2 are located on what appears to be the better parts of the site with a slope of about 3°. Replicate 3 was located on a rockier part of site where the stand tends to be of a more clumpy nature and with a slope of 6°. The soil was classified as Brown Chromosol (replicates 1 and 2) or Grey Sodosol (replicate 3) (Isbell 1996). The site is managed for both timber production and grazing.

The site is surrounded by remnant native forest amidst large areas of previously cleared land. There are patches of regeneration and regrowth occurring across the property.

Long term mean annual rainfall, measured at the property is 720 mm.

**Design and methodology**

This trial aimed to investigate the effects of three stocking treatments: (i) 100 stems per hectare; (ii) 200 stems per hectare; and (iii) a control (Table 5H). The experiment consisted of nine plots laid out as three replications of the three treatments. The experiment uses circular plots with plot size altered to ensure that there was a minimum of 10 measure trees per plot. The 200 stems per hectare plots and control plots have a gross area 0.09 ha and a nett area of 0.05 ha. The 100 stems per hectare plots have a gross area of 0.24 ha and a nett area of 0.1 ha. The 100 stems per hectare plots have 10 m isolation while the 200 stems per hectare and control plots have 5 m isolation.

The treatment operation was undertaken on 16.07.2008. Treatment was carried out using a tomahawk and calibrated tree injection gun using the chemical Tordon DS® diluted in water at a ratio of 1:4 and applied at a rate of 1 cc per cut.

The retained trees >10cm DBH were measured, assessed and individually identified with a stainless steel tag carrying a unique number.

**Results**

The experiment was initially measured on 15.07.2008; this was followed by a silvicultural thinning operation on 16.07.2008. The subsequent measure was carried out on 18.03.2010. Data from both measures are presented in Table 5H.

**Table 5H**. Plot data from the 2008 and 2010 measures at NFQ8.

| **Plot Number** | **Treatment (st/ha)** | **Stocking (st/ha)** | | **Mean DBH (cm)** | | **Retained BA ($m^2$/ha)** | |
|---|---|---|---|---|---|---|---|
| | | 7/2008 | 3/2010 | 7/2008 | 3/2010 | 7/2008 | 3/2010 |
| 1 | 100 | 100 | 100 | 29.8 | 30.5 | 7.2 | 7.5 |
| 2 | 200 | 200 | 200 | 27.3 | 27.6 | 12.8 | 13.0 |
| 3 | Control | 301 | 301 | 24.1 | 24.6 | 17.1 | 17.7 |
| 4 | Control | 361 | 341 | 22.1 | 23.1 | 16.5 | 16.9 |
| 5 | 200 | 200 | 200 | 26.1 | 26.7 | 11.9 | 12.5 |
| 6 | 100 | 100 | 100 | 32.4 | 33.4 | 8.8 | 9.3 |
| 7 | 200 | 200 | 200 | 26.3 | 26.6 | 12.6 | 12.9 |
| 8 | Control | 381 | 381 | 19.8 | 20.3 | 13.0 | 13.6 |
| 9 | 100 | 100 | 100 | 26.2 | 27.2 | 5.5 | 6.0 |

## NFQ 9 - Taroom

### Site description

Experiment 9 NFQ is located 45 km north west of Taroom in Central Queensland (Figure 10).

The research sites have been classified under the regional ecosystem classification as 11.5.9d - *Corymbia citriodora* and/or *Eucalyptus crebra* woodland on Cainozoic sand plains/remnant surfaces (Sattler and Williams 1999). The plots were located in remnant forest which has been previously logged over the past 100 years. Logging operations had been carried out in the 1920s and 1930s for bridge timber and then the area was logged again in the early 1950s and 1960s for mill timber. A pole sale was carried out in 1983 but no timber has been removed since.

The site is situated in broken topography with slopes less than 10°. Replicate 1 has a northern aspect and replicate 2 has a southerly aspect. The soils at this site are classified as Grey Kurosols (Isbell 1996). The property is managed for both timber production and grazing. The lower slopes and valleys were brigalow/bottle tree scrub types, mostly cleared for agriculture and grazing. The spotted gum was situated in the mid slope position and the density declines up the slope and lancewood (*Acacia shirleyi*) becomes the dominant species. Total tree height was relatively low compared to spotted gum forests in higher rainfall areas.

Long term mean annual rainfall, measured at Broadmere is 640 mm.

### Design and methodology

This experiment consisted of eight plots laid out as two replications of four stocking treatments: (i) 50 stems per hectare: (ii) 100 stems per hectare; (iii) 130 stems per hectare; and (iv) an unthinned control (Table 5I). Circular plots were used and plot size was altered by treatment to ensure that there were a minimum of 10 measure trees per plot.

The control plots have a gross area of 0.1 ha and a nett area of 0.05 ha. The 127 st/ ha plots have a gross area of 0.13 ha and a nett area of 0.07 ha. The 100 stems per hectare plots have a gross area of 0.24 ha and a nett area of 0.1 ha and the 50 stems per hectare plots have a gross area of 0.39 ha and a nett area of 0.2 ha. The 100 and 50 stems per hectare plots have 10 m isolation and the control and 127 stems per hectare plots have 5 m isolation.

The treatment operation was undertaken on 15.10.2008. Treatment was carried out using a tomahawk and calibrated tree injection gun using the chemical Tordon DS® diluted in water at a ratio of 1:4 and applied at a rate of 1 cc per cut.

The retained trees ≥10 cm DBH were measured, assessed and individually identified with a stainless steel tag carrying a unique number.

### Results

The experiment was initially measured and thinned on the 14 and 15.10.2008. The subsequent measure was carried out on 17.03.2010. Data from both measures are presented in Table 5I.

**Table 5I**. Plot data from the 2008 and 2010 measures at NFQ 9.

| Plot Number | Treatment (st/ha) | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|---|
| | | 7/2008 | 3/2010 | 7/2008 | 3/2010 | 7/2008 | 3/2010 |
| 1 | 50 | 50 | 50 | 22.2 | 23.1 | 2.0 | 2.1 |
| 2 | Control | 361 | 361 | 18.9 | 19 | 11.4 | 11.6 |
| 3 | 100 | 100 | 101 | 22.1 | 22.3 | 3.9 | 4.0 |
| 4 | Control | 481 | 481 | 19.1 | 19.3 | 15.8 | 15.9 |
| 5 | 50 | 50 | 50 | 16.1 | 16.8 | 1.2 | 1.3 |
| 6 | 100 | 100 | 101 | 18.1 | 18.7 | 2.8 | 3.0 |
| 7 | 127 | 127 | 127 | 25.6 | 26.8 | 6.9 | 7.6 |
| 8 | 127 | 127 | 127 | 22.8 | 23.5 | 5.5 | 5.9 |

## NFQ 10 - Coombell

### Site description

Experiment 10 NFQ was located 15 km south of Casino in northern NSW (Figure 10).

The property has been managed for timber production with light selective logging, targeting the removal of dying, damaged and suppressed stems carried out as needed. Current management aims to integrate native forest timber production with grazing. Fire is applied at 10 year or greater intervals as a tool to manage pasture productivity and forest regeneration.

This experiment is situated across several spotted gum dominated ecosystems including Clarence Lowlands Spotted Gum (ecosystem 24) and Lowlands Spotted Gum – Box (ecosystem 75) (FORECO Mapping, 1999). The research sites have been classified under the CRAFTI Floristic Vegetation Mapping Layer (DECC 1999) as either 'spotted gum dominant' or 'spotted gum complex – grey gum, grey ironbark, mahogany complex' and consist mostly of spotted gum dominant forest with a mixture of other species including *Eucalyptus siderophloia*, *E. moluccana* and *Corymbia gummifera*.

The topography is relatively low. Most plots had slopes varying between 0–2°, with the steepest slope of 4° at one plot. Aspect also varied across the site with some plots having no aspect and others being either southerly or northerly.

The soil was classified as Grey Kurosol (Isbell 1996). The property has been managed for timber production, grazing and horticulture. The experiment site is surrounded by spotted gum forest mostly on the slightly elevated rises but extends with varying associations across the lower/wetter soil types. Some low lying areas have been cleared for agriculture.

Long term mean annual rainfall, measured at Upper Mongogarie is 1040 mm.

### Design and methodology

The landholder established a series of over 40 inventory plots to provide data on the productivity and resource availability for the property. This experiment was established using some of the previously established plots and consisted of two replications of five stocking treatments: (i) 100 stems per hectare; (ii) 150 stems per hectare; (iii) 200 stems per hectare; (iv) 250 stems per hectare; and (v) unthinned control (Table 5J). Each plot is circular and has a nett area of 0.1 ha. Trees previously measured and able to be identified have retained the unique identifiers assigned by the landholder.

The treatment operation was carried out on the 24.02.2009 and the 2008 measure data was updated to reflect this treatment operation. The silvicultural treatment (thinning) used a tomahawk and calibrated tree injection gun using the chemical Tordon DS®.

The retained trees ≥10 cm DBH were measured, assessed and individually identified with a stainless steel tag carrying a unique number.

**Results**

The experiment was initially measured on the 24.09.2008. The subsequent measure was carried out on the 11/05/2010. Data from both measures are presented in Table 5J.

**Table 5J** – Plot data from the 2008 and 2010 measures at NFQ10.

| Plot Number | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|
| | 9/2008 | 5/2010 | 9/2008 | 5/2010 | 9/2008 | 5/2010 |
| 1 | 250 | 250 | 29.4 | 29.5 | 19.2 | 19.4 |
| 2 | 420 | 420 | 24.7 | 25.5 | 24.8 | 26.3 |
| 3 | 180 | 180 | 32.3 | 32.9 | 17.1 | 17.7 |
| 4 | 260 | 260 | 23.7 | 24.3 | 14.1 | 14.8 |
| 5 | 100 | 100 | 36.8 | 37.9 | 11.8 | 12.4 |
| 6 | 420 | 420 | 18.6 | 19.2 | 14.1 | 15.0 |
| 7 | 150 | 150 | 25.9 | 26 | 10.4 | 10.7 |
| 8 | 100 | 100 | 20.9 | 21.6 | 4.0 | 4.2 |
| 9 | 210 | 200 | 30.8 | 31.6 | 18.5 | 18.6 |
| 10 | 160 | 160 | 23 | 23.8 | 8.9 | 9.3 |

## NFQ 11 - Bonalbo

**Site description**

The property is located 8 km north east of Bonalbo in the Richmond Range area of northern NSW (Figure 10).

The research area was located in remnant forest which had been previously logged over the past 100 years. Large areas of the original forest had been cleared on the lower slopes and flats for agriculture and are currently under eucalypt plantation, with the remnant forest tending to be on the steeper ridges. These steeper areas have not been cleared and consist of tall closed forests in the gullies with tall open forests on the ridges.

The owner from 1992 to 2007 only harvested selected grey gum posts however, some logging was carried out by the previous owner before 1992 (probably more than 20 years ago). The site is relatively broken with steep spurs running down to the cleared lower flats. There are several vegetation types across the site with the spotted gum occupying the spurs and ridge tops. This is replaced with *Eucalyptus microcorys, E. acmenoides, E. saligna, E. longirostrata, Lophostemon confertus* and *Syncarpia glomulifera* subsp. *glomulifera* on the lower slopes and gullies.

The 'CRAFTI Floristic Vegetation Mapping Layer' (DECC 1999) is very detailed around the trial site area with most plots being classified into different groups. However, all plots can be described as 'spotted gum complex' and consist mostly of spotted gum dominant wet sclerophyll forest typical of the Richmond Range spotted gum forest ecosystem (FORECO, 1999).

All plots have a southerly aspect with varying slopes of less than 8°. The soils were classified as Grey or Brown Kurosols (Isbell 1996). The site is typical of the better spotted gum country and the intention is that the site be managed to increase timber production with future potential for grazing as the plantation estate develops.

Long term mean annual rainfall, measured at the Bonalbo post office is 1020 mm.

**Design and methodology**

The experiment consisted of six circular plots laid out as two blocks with three plots in each replication. These plots were situated in remnant forest dominated by spotted gum. Treatments were assigned based initial stocking. No thinning treatments were applied because the plots were due to be logged. Logging was carried out in 2009 at all plots, but at varying intensities (Table 5K).

Circular plots were used with a gross area of 0.16 ha with a nett (measure) plot area of 0.1 ha. There was 5 m isolation around each nett plot.

The retained trees ≥10 cm DBH were measured, assessed and individually identified with a stainless steel tag carrying a unique number.

**Results**

The trial was measured on the 15.10.2008. A subsequent measure was carried out under this project on 12/05/2010. This measure was completed post logging. Data from both measures are presented in Table 5K.

**Table 5K.** Plot data from the 2008 and 2010 measures at NFQ 11.

| Plot Number | Treatment (st/ha) | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|---|
| | | 10/2008 | 5/2010 | 10/2008 | 5/2010 | 10/2008 | 5/2010 |
| 1 | >500 | 650 | 550 | 21.4 | 22.7 | 28.4 | 26.7 |
| 2 | <500 | 470 | 400 | 25.6 | 24.7 | 31.8 | 25.4 |
| 3 | >500 | 570 | 420 | 26.6 | 25.4 | 37.8 | 25.4 |
| 4 | <500 | 490 | 370 | 25.0 | 25.7 | 31.5 | 25.8 |
| 5 | >500 | 520 | 390 | 25.7 | 27 | 32.1 | 26.5 |
| 6 | >500 | 560 | 490 | 23.0 | 22.3 | 27.1 | 22.1 |

## NFQ 12 - Nanango

### Site description

Experiment 12 NFQ was located 12 km north east of Nanango in the South Burnett region (Figure 10).

The site is generally grazed all year; however cattle have been excluded in this area since 2006 to allow spotted gum regeneration to develop. The harvest history includes sawlog harvests in 1968 and 1988. The trial site was last logged in 2006. Following the harvest, trees that were surplus to stocking requirements and not suitable for commercial harvest were silviculturally treated.

The research site has been classified under the regional ecosystem classification as 12.11.6 - *Corymbia variegata*, *Eucalyptus crebra* open forest on metamorphics ± interbedded volcanics with a vegetation management status of 'not of concern'. (Sattler and Williams 1999). The site is a spotted gum dominant open forest with isolated *Eucalyptus crebra*.

The topography is undulating with slope varying between 3–6°. Four plots have a westerly aspect, one plot has a northerly aspect and another plot has a southerly aspect. The soil was classified as Grey Kurosol (Isbell 1996). The site is surrounded by large areas of previous cleared land with low to moderate densities of regeneration and regrowth.

Long term mean annual rainfall, measured at Kia Ora Sandy Ridges is 764 mm.

### Design and methodology

This experiment was originally established as a demonstration site and consisted of six plots laid at a range of stocking rates: 76, 100, 108, 120, 140 and 212 stems per hectare. The continuous forest cover enabled the use of large square plots. The plots have a gross area of 1.0 ha with a nett (measure) plot area of 0.25 ha.

The thinning operation was undertaken on 27.07.2006. Treatment was carried out with a combination of chainsaw and brush-cutter thinning followed by the application of Tordon DS™ mix (20:1) to cut stumps or tomahawk calibrated tree injection gun using the chemical Tordon DS® diluted in water at a ratio of 1:4 and applied at a rate of 1 cc per cut.

The retained trees >2 cm DBH were measured, assessed and individually identified with a stainless steel tag carrying a unique number.

### Results

The trial was measured on the 24.11.2008. The subsequent measure was carried out on 29.01.2010. Data from both measures are presented in Table 5L.

**Table 5L**. Plot data from the 2008 and 2010 measures at NFQ 12.

| Plot Number | Stocking (st/ha) | | Mean DBH (cm) | | Retained BA ($m^2$/ha) | |
|---|---|---|---|---|---|---|
| | 10/2008 | 1/2010 | 10/2008 | 1/2010 | 10/2008 | 1/2010 |
| 1 | 108 | 152 | 26.8 | 21.2 | 6.4 | 6.8 |
| 2 | 120 | 156 | 22.3 | 18.9 | 6.0 | 6.3 |
| 3 | 212 | 244 | 15.8 | 15.0 | 6.6 | 6.9 |
| 4 | 140 | 220 | 14.3 | 11.7 | 3.1 | 3.5 |
| 5 | 76 | 172 | 23.0 | 13.7 | 3.4 | 3.8 |
| 6 | 100 | 192 | 24.6 | 15.8 | 5.1 | 5.5 |

## NFQ 13 - Boonah

### Site description

Experiment 13 NFQ was located in the Qld and NSW border ranges near Boonah (Figure 10).

Previous owners extensively cleared the vegetation for grazing purposes resulting in a patchy relatively young spotted gum (*Corymbia citriodora*) and ironbark (*Euclayptus crebra*) mixed regrowth forest. The site appears to have been logged since 2000 and some ironbark regeneration has been treated out since 2005. For the purposes of the experiment, trees treated within the past 2–3 years of the original measure were included in the original standing basal area. The site is mapped as cleared by Sattler and Williams (1999).

All plots have a northerly aspect. Slopes vary between plots but are less than 15°. The soils were classified as being either Red or Yellow Sodosols (Isbell 1996). The site is surrounded by native forest on the upper slopes and hills with cleared areas for grazing and cultivation on the lower slopes and plains.

Long term mean annual rainfall, measured at the Maroon is 864 mm.

### Design and methodology

This experiment aimed to measure a range of stockings across the property. Plot stocking rates of 80, 100, 120 and 160 stems per hectare and an unthinned control were implemented (Table 5M). The experiment consisted of nine plots with various spacings dictated by the quality of the stand.

The broken nature of the forest cover required the use of circular plots arbitrarily located to minimise edge effects. The plots have a gross area of 0.97 ha with a nett (measure) plot area of 0.05 ha.

The treatment operation was undertaken on 29.08.2008 using tomahawks and calibrated tree injection guns using the chemical Tordon DS® diluted in water at a ratio of 1:4 and applied at a rate of 1 cc per cut.

The retained trees >10cm DBH were measured, assessed and identified with a stainless steel tag carrying a unique number. All stems >5 cm DBH were uniquely identified and assessed in the control plots.

**Results**

The trial was measured on the 27.08.2008. The subsequent measure was carried out on 17.03.2010. Data from both measures are presented in Table 5M.

**Table 5M**. Plot data from the 2008 and 2010 measures at NFQ13.

| **Plot Number** | **Stocking (st/ha)** | | **Mean DBH (cm)** | | **Retained BA ($m^2$/ha)** | |
|---|---|---|---|---|---|---|
| | 10/2008 | 3/2010 | 10/2008 | 3/2010 | 10/2008 | 3/2010 |
| 1 | 160 | 160 | 23.9 | 26.3 | 7.6 | 9.2 |
| 2 | 120 | 120 | 18.1 | 21.3 | 3.1 | 4.3 |
| 3 | 80 | 80 | 23.0 | 25.9 | 3.4 | 4.3 |
| 4 | 100 | 100 | 19.0 | 21.3 | 2.9 | 3.7 |
| 5 | 180 | 180 | 22.3 | 23.8 | 7.3 | 8.3 |
| 6 | 140 | 140 | 20.8 | 22.8 | 5.4 | 6.3 |
| 7 | 120 | 120 | 23.5 | 25.6 | 5.3 | 6.3 |
| 8 | 120 | 100 | 20.4 | 21.7 | 4.2 | 3.9 |
| 9 | 1142 | 1123 | 10.8 | 11.6 | 11.7 | 13.2 |