Financial and economic performance of long-rotation hardwood plantation investments in Queensland, Australia

Tyron J. Venn\textsuperscript{a,b,}\textsuperscript{*}

\textsuperscript{a}School of Economics, The University of Queensland, St Lucia, QLD 4072, Australia
\textsuperscript{b}Queensland Forestry Research Institute, Indooroopilly, QLD 4068, Australia

Received 25 February 2003; received in revised form 23 July 2003; accepted 11 August 2003

Abstract

In Queensland, Australia, there is presently a high level of interest in long-rotation hardwood plantation investments for sawlog production, despite the consensus in Australian literature that such investments are not financially viable. Continuing genetics, silviculture and processing research, and increasing awareness about the ecosystem services generated by plantations, are anticipated to make future plantings profitable and socio-economically desirable in many parts of Queensland. Financial and economic models of hardwood plantations in Queensland are developed to test this hypothesis. The economic model accounts for carbon sequestration, salinity amelioration and other ecosystem service values of hardwood plantations. A carbon model estimates the value of carbon sequestered, while salinity and other ecosystem service values are estimated by the benefit transfer method. Where high growth rates (20–25 m\textsuperscript{3} ha\textsuperscript{-1} year\textsuperscript{-1}) are achievable, long-rotation hardwood plantations are profitable in Queensland Hardwood Regions 1, 3 and 7 when rural land values are less than $2300/ha. Under optimistic assumptions, hardwood plantations growing at a rate of 15 m\textsuperscript{3} ha\textsuperscript{-1} year\textsuperscript{-1} are financially viable in Hardwood Regions 2, 4 and 8, provided land values are less than $1600/ha. The major implication of the economic analysis is that long-rotation hardwood plantation forestry is socio-economically justified in most Hardwood Regions, even though financial returns from timber production may be negative.

\textsuperscript{*}Tel.: +61-7-3346-9456; fax: +61-7-3365-7299.
\textit{E-mail address:} t.venn@mailbox.uq.edu.au (T.J. Venn).

1. Introduction

In Queensland, Australia, only small areas of long-rotation hardwood plantations have been established. This is possibly due in part to the abundant, low-cost supply of large hardwood logs from mature natural forests (Keenan, 1998). However, over the last two decades, large areas of State-owned natural forests have been transferred from the production to conservation estates, resulting in large reductions in supply of hardwood logs. The 1999 South East Queensland Regional Forest Agreement included a commitment for all natural forest logging on State-owned land in the south–east to cease by 2024. These processes appear to have contributed to an increase in enthusi-
asm and optimism about the potential for long-rotation plantations of native hardwood species in Queensland to supply sawlogs to industry. The total area of hardwood plantings in the State grew from 1300 ha in 1994 (National Forest Inventory, 1997) to 20,000 ha (87% privately owned) by June 2001 (Shaw, 2003, personal communication).1 Forestry prospectus companies and the Queensland Department of Primary Industries (DPI), are promoting long-rotation hardwood (primarily eucalypt) plantation investments in the State on the basis of sound financial returns (DPI, 2000; Forest Enterprises Group, 2002).

The optimism surrounding long-rotation hardwood plantations defies the consensus of published literature in Australia, which has, generally reported poor financial prospects for such plantings (FAFPIC, 1989; O’Hara, 1989; Shepherd et al., 1990). It has been argued that hardwood plantations in Australia generally require higher rainfall and soil fertility, and that they are more site-specific than the exotic conifers that dominate the national plantation estate (Shepherd et al., 1990). There are also widely espoused concerns that fundamental wood properties—such as density, strength, shrinkage and growth stresses—may be inferior to those of the natural forest hardwood resource, which may affect market acceptance of plantation hardwoods (Shepherd et al., 1990; Yang and Waugh, 1996). Recent research on eucalypt plantations that had been established in Queensland during the 1960s and 1970s confirmed the long-held negative views about growth rates, timber quality and potential profitability (Leggate et al., 2000). However, these early eucalypt plantings suffered from inadequate site preparation, weed control, fertilisation, thinning, pruning and pest control, and there was a high degree of genetic variability in the unimproved planting stock. Consequently, Lewty et al. (2001) have asserted that the growth, wood quality and financial performance of early eucalypt plantings in Queensland are unlikely to be indicative of the potential for future hardwood plantings in the State.

The Queensland Forestry Research Institute (QFRI) has founded the Hardwoods Queensland research program to support the establishment of high-yielding hardwood plantations, and the transition of the Queensland timber industry from natural forest to plantation hardwood logs. Researchers within Hardwoods Queensland have highlighted two important factors that make a contemporary analysis of the performance of hardwood plantation investments in Queensland warranted. First, while few published data are available, current research and expert opinion suggests that the more intensively managed hardwood plantations established in Queensland since the mid-1990s, some with genetically superior stock, are far more productive than early hardwood plantings. Second, there is a growing awareness in Queensland about the range of ecosystem services that plantation forests can generate when established on cleared agricultural land, although few studies in Queensland have attempted to quantify these non-timber benefits. Non-timber benefits are becoming increasingly important in the decision-making of the Queensland Government (e.g. Environmental Protection Agency, 2001), which is currently the largest plantation grower in the State, and of some potential private investors (perhaps hoping markets will emerge in the future).

Hardwoods Queensland has funded the study reported here with the joint objective of estimating the potential, financial and economic performance of long-rotation (sawlog) hardwood plantation investments in Queensland.2 The paper assesses financial performance from the grower’s perspective when logs are sold at the stump. Carbon sequestration, salinity amelioration and other ecosystem service values of hardwood plantations are evaluated in predicting the socio-economic performance of hardwood plantations. Three types of investors are likely to play an important role in the establishment of a hardwood plantation resource in Queensland. First, private landholders who own idle or low opportunity cost land. Second, private investors, including plantation prospectus companies, who do not own land. Third, the State Government, which owns land, and

---

1 Principal Policy Officer, Sustainable Resources, Policy Analysis and Industry Development, Department of Primary Industries, Brisbane.

2 The terms ‘hardwood plantation’ and ‘eucalypt plantation’ are synonymous in Queensland forestry and they will be used interchangeably throughout the paper.
may also resume leasehold land and purchase freehold land. Government investors have traditionally been more interested in the socio-economic performance of plantations, prospectus companies and other private investors are likely to focus on financial performance, while the motivations of private landholders establishing hardwood plantations are likely to be somewhere in between.

The paper commences by explaining the logic behind the increased interest in growing hardwood plantations in Queensland. Next, the hardwood plantation regions (Hardwood Regions) of Queensland are illustrated and potential growth rates for hardwood plantations are reported. The methodologies employed for the financial and economic analyses are then described. Estimates of the financial and economic performance of hardwood plantation investments in Queensland follow. A discussion concludes the paper.

2. Rationale for optimism about long-rotation hardwood plantation forestry in Queensland

Recent research has highlighted the potential availability of scores of thousands of hectares of land in southern and northern Queensland that are of sufficiently high quality (rainfall and soils) for hardwood plantation establishment, and where hardwood plantations would provide financially competitive returns with existing agricultural (predominantly pastoral) pursuits (Keenan, 1998; Spencer et al., 1999). While slow growth and low recovery of graded sawn timber has typified early plantings of unimproved eucalypt stock in Queensland, impressive gains in eucalypt plantation productivity have been achieved overseas through matching species to sites, tree breeding and improvement of silvicultural practices (Eldridge et al., 1994; McKenney, 1998). Lewty et al. (2001) have suggested that genetic improvement alone could potentially increase the productivity of future hardwood sawlog plantations in Queensland by between 30 and 50%.

Many Queensland hardwood plantation species have wood properties that uniquely distinguish them from southern Australian plantation eucalypts (Leggate and Muneri, 2000). Existing technologies, including the Durand-Raute spindles lathe (FORTECH, 1994), and the development of composite wood products, such as laminated strand lumber (McNaught, 2002, personal communication)3, provide potential high-value processing options. According to Burns et al. (1999), it is generally accepted that global consumption of wood (excluding fuelwood) will increase at approximately 1–2% per annum over the coming decade, but that the supply of non-pulp hardwood timber will diminish. The once timber rich nations of the Philippines, Thailand and India are now importing timber, Malaysia has begun imposing logging restrictions, and harvesting in Vietnam, Cambodia, Laos and Indonesia is believed to be unsustainable (FORTECH, 1994). Being close to Asian markets, Queensland hardwood plantations appear well-positioned to take advantage of potential market opportunities.

For many small-scale forest growers in Australia, financial returns from timber are a minor motivating factor for plantation establishment, with many non-commercial benefits of forests, such as shade, shelter, land rehabilitation, water table control, wildlife habitat and stock feed being relatively more important (Burns et al., 1999; Emtage et al., 2001; Borsboom et al., 2002). Overseas, the Royal Dutch Shell Group and BP Amoco have invested in large-scale forestry projects for the purpose of obtaining carbon sequestration rights (van Bueren, 2001). Carbon sequestration is also a major motivating factor in the possible establishment of approximately 4500 ha of hardwood plantation in the Aldoga precinct of the Gladstone State Development Area in Queensland (Boden, 2002, personal communication).4 Therefore, plantations are currently being established with consideration given to more than simply the financial returns from timber.

3. Hardwood regions and plantation growth rates in Queensland

The research and development strategy of Hardwoods Queensland recognises that regions within the State differ with respect to climate, soils, land-use

---

3 Senior Research Scientist, Queensland Forestry Research Institute, Brisbane.
4 Co-ordinator, Hardwood Project Development, Queensland Forestry Research Institute, Brisbane.
history and timber industry infrastructure. Consequently, Queensland and northern new South Wales have been divided into 10 Hardwood Regions, as illustrated in Fig. 1. The Western boundaries of the Hardwood Regions are defined by the 600 mm/year isohyet. Field trials testing the performance of many hardwood taxa, silvicultural methods and tolerance to pests and diseases have been established in each of the 10 Hardwood Regions.

Presently, most trials are too young and do not adequately cover the range of planting sites available within regions to provide useful growth information for assessment of investment performance. The consensus of recent literature on hardwood plantations in Queensland is that a mean annual increment (MAI) of merchantable timber between 15 m³ ha⁻¹ year⁻¹ and 25 m³ ha⁻¹ year⁻¹ should be achievable in well-managed stands on moist sites (rainfall>1000 mm per annum) (GRO, 1998; DPI, 2000; Leggate et al., 2000). On drier sites (rainfall approximately 700–1000 mm per annum), QFRI growth trials in South–East Queensland are reportedly yielding between 2 m³ ha⁻¹ year⁻¹ and 9 m³ ha⁻¹ year⁻¹. In this study, financial and economic returns have been estimated for plantations with MAIs ranging from 5 m³ ha⁻¹ year⁻¹ to 25 m³ ha⁻¹ year⁻¹ in increments of 5 m³ ha⁻¹ year⁻¹. Table 1 reports expert opinion on potential hardwood plantation MAI by Hardwood Region, with current (largely unimproved) planting stock and modern silvicultural practices. These estimates have been used to project stand biomass of hardwood plantations in Queensland. It would have been preferable to employ growth or yield models, but currently there are no generally accepted models for plantation hardwoods in Queensland.

4. Financial analysis of hardwood plantations in Queensland

The profitability of hardwood plantations are analysed under the assumptions that plantation establishment costs and post-establishment management expenses are incurred by the forest grower, and logs are sold at the stump. Forest growers do not incur harvesting expenses from the commercial thinning and clearfelling operations, however, nor do they share in the returns from value-adding the timber resource. This reflects the current commercial relationship between forest growers and timber processors in Queensland.

4.1. Hardwood plantation species, management and harvest composition

On the basis of potentially high wood quality, market acceptance and yield, DPI-Forestry (c2002) have recommended that hardwood plantations should (initially) focus on the species *Eucalyptus cloeziana* (Gympie messmate), *E. pilularis* (blackbutt), *Eucalyptus argophloia* (western white gum) and *Corymbia citriodora* subsp. *variegata* (spotted gum). For assessment of financial and economic performance, a generic subtropical eucalypt and the hardwood plantation sawlog regime currently recommended by DPI-Forestry (c2002), as outlined in Table 2, have been assumed. Where MAIs of at least 15 m³ ha⁻¹ year⁻¹ are achievable, stands will be clearfelled at age 25, while lower yielding plantations will be harvested at age 30. At clearfall, the trees will have diameters at breast height in excess of 40 cm, making them suitable for sawlogs and poles. The assumed composition of harvested logs at commercial thinning and clearfall is reported in Table 3. Presently, there are limited markets for pruned logs in Queensland, hence no distinction is made between pruned and unpruned sawlogs in the base case. Nevertheless, pruning is undertaken to improve access, minimise fire risk and the potential for disease, and in expectation of clearwood markets developing.

4.2. Cost and stumpage price data

Cost data for long-rotation hardwood plantations are scarce in Queensland, and there is a lack of consistency between the estimates that are available. The cost assumptions detailed in Table 4 have been adopted for the financial model developed in this study from the expert opinions of QFRI and DPI-Forestry research officers (see acknowledgements) and the limited literature (GRO, 1998; DPI, 2000). All monetary values are expressed in Australian dollars, unless otherwise specified.5

---

5 In June 2003 AUD$1 = US$0.60.
Fig. 1. Hardwood Regions in Queensland and northern New South Wales with average annual rainfall. Source: QFRI (2002a).
Land cost is an important factor in the plantation investment decisions of plantation investors, however, it varies considerably throughout the Hardwood Regions of Queensland. Spencer et al. (1999) estimated the approximate average value of land in the South East Queensland Biogeographic Region (approximated by Hardwood Regions 4, 6, 7 and 8) capable of yielding 15–20 m³ ha⁻¹ yr⁻¹ of merchantable timber from hardwood plantations to be approximately $2600/ha. This may be indicative of prices for land that could become available for forestry in many parts of Hardwood Regions 1–4 and 6–8. The cost of higher productivity land and land closer to major settlements in these regions can be $5000/ha–$10 000/ha. In regions 2, 5 and 9, land values are commonly approximately $1000/ha–$1500/ha and in some Western parts can be less than $500/ha.

Little information is available about hardwood plantation log prices in Queensland. According to DPI-Forestry records, the average stumpage paid in 2001–2002 for logs harvested from natural forests on State-owned land in Southern Queensland was approximately $40/m³. However, prices paid for natural forest hardwood logs sourced from private land in Queensland can be as much as twice that paid for logs from State-owned land (GRO, 1998). The mean of the stumpage prices estimated by GRO (1998), DPI (2000) and DPI Rural Business Services et al. (2001) for Queensland hardwood plantation poles, sawlogs and low-value logs have been adopted in this study: $70/m³ for poles; $55/m³ for sawlogs; and $20/m³ for low-value logs.

### 4.3. Financial model for hardwood plantations in Queensland

A financial model for hardwood plantations in Queensland, which estimates the land expectation

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cultivate, pre-plant weed control, plant at 1000 stems per ha (sph), post-plant weed control and fertilise</td>
</tr>
<tr>
<td>2</td>
<td>Fertilise and weed control</td>
</tr>
<tr>
<td>3</td>
<td>Non-commercial thin to 450 sph, prune all remaining stems to 3.6 m height</td>
</tr>
<tr>
<td>5</td>
<td>Prune best 200 sph to 6.0 m</td>
</tr>
<tr>
<td>12</td>
<td>Commercial thin to 175 sph</td>
</tr>
<tr>
<td>25–30</td>
<td>Clearfall</td>
</tr>
</tbody>
</table>

Source: Adapted from DPI-Forestry (c2002).
value (LEV) on a per hectare basis, has been developed in a spreadsheet software package. LEV is the net present value (NPV) of an infinite series of plantation rotations and allows for comparison of investments of unequal duration. Another advantage of employing this cost-benefit analysis criterion over others, such as NPV and internal rate of return (IRR) is that LEV represents the highest price forest growers can pay for land (given a particular discount rate and other financial parameters) while still making a profit from plantation forestry. This is particularly beneficial in this study where land values vary considerably throughout the Hardwood Regions. The discount rate for the analysis was set at a real rate (net of inflation) of 7%, which has been commonly adopted for analyses of plantation forestry investments in Queensland (e.g. Spencer et al., 1999; DPI, 2000). The taxation implications of each scenario have not been modelled.

Sensitivity analyses have been performed to assess the influence of changes in parameter assumptions on profitability predictions of the financial model. Also explored is the individual impact that development of a wood composite product manufacturing industry or a market for clearwood could have on the financial viability of hardwood plantations. The former development is modelled with the assumption that the stumpage price for all thinning and clearfall low-value logs increases to $35/m³ (McNaught, personal communication, 2002). A stumpage price of $100/m³ is assumed for pruned logs in clearwood markets.

### Table 3

<table>
<thead>
<tr>
<th>Log type</th>
<th>Composition of harvest (% of harvested merchantable volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial thinning (age 12)</td>
</tr>
<tr>
<td>Pole</td>
<td>0</td>
</tr>
<tr>
<td>Sawlog</td>
<td>0</td>
</tr>
<tr>
<td>Low-value loga</td>
<td>100</td>
</tr>
</tbody>
</table>

*Note*: aLow-value logs include material suitable as salvage sawlogs, pulp, fibreboard, treated posts, pallets and palings.

#### 5. Analysis of the economic performance of hardwood plantations in Queensland

The potential socio-economic values of long-rotation hardwood plantations in Queensland are estimated with respect to carbon sequestration, salinity amelioration, and ‘other ecosystem services’ (a catch-all category). A carbon model is developed to estimate the value of carbon sequestered, while salinity and ‘other ecosystem service’ values are estimated by the benefit transfer method. It is likely that the types and values of ecosystem services generated by long-rotation plantings of native species will exceed short-rotation (Borsboom et al., 2002) and exotic species plantings, however, it is not the intention of this paper to present a comparative assessment.

#### 5.1. Valuation of net carbon sequestration in Queensland hardwood plantations

The present value (PV) of carbon sequestered in an infinite series of hardwood plantation rotations has been estimated from a carbon sequestration model developed to account for the above and below-ground hardwood plantation biomass. Four activities generate carbon flows within the model: plantation establishment; plantation growth; thinning operations (but not pruning); and clearfall harvesting. There are no universally agreed guidelines and little data for modelling soil carbon change in response to reforestation or afforestation (Lamb, 2000). Consequently, as in other recent Australian studies accounting for carbon in forests (e.g. Creedy and Wurzbacher, 2001; Brack and Richards, 2002), change in soil carbon levels after timber crop establishment has not been modelled. Carbon costs associated with growing and harvesting the plantation (e.g. from machinery and
fertiliser) is also excluded from the model. Carbon sequestration in Queensland hardwood plantations is estimated with the equation

\[
C = \sum_{t=0}^{T} (G_{wt} + G_{at} + G_{bt} - H_{wt} - H_{at} - H_{bt}) - (E_s + E_{ab})
\]

where \( C \) = net carbon sequestered per hectare of plantation (tonnes) \( G_{wt}, G_{at}, G_{bt} \) = carbon sequestered per hectare per annum by the net growth of stem wood, non-stem wood above-ground biomass and below-ground biomass, respectively (tonnes) \( H_{wt}, H_{at}, H_{bt} \) = carbon emitted from the decomposition of stem wood, non-stem wood above-ground biomass and below-ground biomass, respectively, following harvest (tonnes) \( E_s, E_{ab} \) = carbon emitted from the soil and pre-existing above and below-ground biomass, respectively, at plantation establishment (tonnes) \( t \) = age of stand in years from establishment to clearfall (0, ..., \( T \)).

The mass of carbon sequestered in plantation biomass is estimated by multiplying the basic density of the biomass by its organic carbon content. For eucalypt species, the Intergovernmental Panel on Climate Change (Houghton et al., 1997) and Lamb (2000) suggested the relevant parameters are approximately 0.5 tonnes/m\(^3\) and 50%, respectively, for all plantation biomass. These parameter estimates have been adopted in this study, although the basic density of the stemwood of subtropical and tropical eucalypts being grown in Queensland may be higher than 0.5 tonnes/m\(^3\) at age 20–30. Total above-ground and below-ground biomass of hardwood plantations has been estimated by multiplying the stemwood biomass by an expansion factor of 1.4 and adopting a root:shoot ratio of 25%, respectively, as recommended by Snowdon et al. (2000) for productive Australian native forest and mature eucalypt plantations.

It is assumed that all pre-existing pasture or crop biomass (above and below-ground) decays in the year of plantation establishment, and that 30% of soil carbon is emitted due to intensive site preparation for plantation establishment (e.g. ploughing and mounding). Estimates of the average carbon content in the biomass and soils of Australian improved pastureland and cropland suggest that plantation establishment will emit 6.3 tonnes C/ha from decaying above and below-ground biomass, and 19 tonnes C/ha from the soil (National Greenhouse Gas Inventory Committee, 1998). At the beginning of each subsequent rotation, site preparation for plantation establishment is assumed to emit the same quantity of carbon. A simple method to account for carbon stored in solid wood products has been adopted from Creedy and Wurzbacher (2001); it is assumed that carbon is instantaneously emitted from short-life products (low-value logs, and wood chips and sawdust recovered as by-products from milling sawlogs), and never emitted from long-life products (sawn timber and poles). Recovery of long-life products from sawlog volume is assumed to be 36%

<table>
<thead>
<tr>
<th>Year</th>
<th>Item</th>
<th>Amount ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total establishment expenses (excluding cost of land)</td>
<td>1900</td>
</tr>
<tr>
<td>2</td>
<td>Weed control</td>
<td>170</td>
</tr>
<tr>
<td>2</td>
<td>Fertilise</td>
<td>130</td>
</tr>
<tr>
<td>3</td>
<td>Non-commercial thinning</td>
<td>280</td>
</tr>
<tr>
<td>3</td>
<td>Ist prune</td>
<td>450</td>
</tr>
<tr>
<td>5</td>
<td>2nd prune</td>
<td>350</td>
</tr>
<tr>
<td>12</td>
<td>Marking for thinning</td>
<td>50</td>
</tr>
<tr>
<td>12</td>
<td>Contingency for commercial thinning costs incurred by landholder</td>
<td>130</td>
</tr>
<tr>
<td>25 or 30</td>
<td>Inventory and analysis prior to clearfall</td>
<td>70</td>
</tr>
<tr>
<td>25 or 30</td>
<td>Contingency for clearfelling expenses incurred by landholder</td>
<td>130</td>
</tr>
<tr>
<td>Annual</td>
<td>Management costs</td>
<td>60</td>
</tr>
</tbody>
</table>

Sources: GRO (1998) and DPI (2000) and personal communication from QFRI and DPI-Forestry research officers (see acknowledgements).
Forest Sawlog Pricing Working Group, 1997). Thinning and clearfelling operations are assumed to result in instantaneous emission of all carbon from the non-stemwood above-ground and below-ground biomass of harvested trees. In reality, these pools would decay over a much longer time period (National Greenhouse Gas Inventory Committee, 1998).

Recent studies of the potential for plantations to sequester carbon in Australia (Burns et al., 1999; Eono, 2001) have adopted a carbon price estimate of $20/tonne (equivalent to $5.45/tonne CO2), which has been adopted in this analysis. As a modelling device for socio-economic analysis, it is assumed that the forest grower receives an annual payment of $20/tonne of carbon sequestered throughout the life of the plantation. However, establishment, thinning and clearfelling operations, which result in carbon emissions, require the forest grower to purchase carbon emission permits at $20/tonne. Adapting Eq. (1), the PV of sequestered carbon over an infinite series of plantation rotations is calculated as follows

$$\text{PV(C)} = \frac{\text{V(C)}}{\left(1 + r\right)^T}$$

where PV(C) = present value of carbon sequestered from an infinite series of plantation rotations ($/ha), V(C) = value of carbon ($/tonne), r = discount rate (%).

5.2. Valuation of salinity amelioration benefits of hardwood plantations in Queensland

The cause of dryland salinity in Australia is accepted to be the replacement of deep-rooted native vegetation with cropping and grazing systems that consume less water, resulting in rising groundwater tables. Dryland salinity is estimated to cost the national economy hundreds of millions of dollars annually in terms of lost agricultural production and damage to infrastructure (Murray-Darling Basin Ministerial Council, 1999). In Queensland, 48 000 ha are currently affected by dryland salinity and 1 M ha could be seriously threatened within 50 years (Task Force established by the Standing Committee on Conservation, 2001). The salinity threatened areas are mostly in the Eastern part of the State, including parts of the Fitzroy (Hardwood Regions 4 and 5), Burnett (regions 4 and 6), Burdekin (south–east of region 2), and the upper Condamine (region 9) Basins, and the lower Mary Irrigation Area (region 4). There is also land at risk of salinisation in Hardwood Region 1, particularly South of Cairns (National Land and Water Resources Audit, 2001). There is minimal salinity risk in Hardwood Regions 3, 7 and 8.

Few studies have attempted to quantify the non-timber benefits of tree planting in areas affected by dryland salinity. A literature review revealed three studies in different regions of New South Wales and Victoria, Australia, which estimated the PV of a single rotation of trees as a salinity amelioration mechanism within the range of $400/ha–$13 000/ha (Cacho, 2001; Theiveyanathan et al., 2001; Wilson Land Management Services and Ivey ATP Agricultural Consulting and Management Services, 2002). The PV of damage costs per hectare of agricultural land affected by salinity in Queensland (in terms of lost agricultural production, damage to local infrastructure and downstream damage to urban and industrial land) is predicted to be lower, on average, than in south–eastern Australia (Hajkowicz and Young, 2002). Therefore, it is assumed that the PV of salinity amelioration benefits of a single rotation of a hardwood plantation in a salinity threatened catchment of Queensland is at the low end of the range at $400/ha. Furthermore, it is assumed that each successive plantation rotation in an infinite series of rotations has a salinity amelioration benefit equivalent to $400/ha at plantation establishment. A single value has been adopted for all of Queensland because of the scarcity of empirical studies in Queensland and the lack of consensus about which parts of the landscape could generate greater salinity amelioration benefits if planted to trees, i.e. higher rainfall recharge sites where higher MAIs are likely or lower rainfall discharge sites where lower MAIs are likely.

5.3. Valuation of ‘other ecosystem services’ of hardwood plantations in Queensland

A classification of 23 types of ecosystem functions, providing a much larger number of goods and services
has been described by de Groot et al. (2002). It is likely that accounting only for the carbon sequestration and salinity amelioration benefits of plantation forests will greatly underestimate the value of plantation forest ecosystem services to society. However, only the most preliminary attempts have been made to value most ecosystem services (e.g. Costanza et al., 1997). Evidence is emerging that the value of at least some ecosystem services generated by plantation forests are lower, perhaps considerably lower than the value generated by natural forests, due to their relative lack of biological and structural diversity (e.g. Hobbs et al., 2003).

When raw material production and climate regulation (accounted for elsewhere in this study), and food production and recreational values of temperate forests (which are likely to be negligible in Queensland hardwood plantation forests) are deducted from the Costanza et al. (1997) estimate of ecosystem service values generated by natural temperate forests, a residual value of US$103/ha/year is obtained. Nationally, van Bueren and Bennett (2000) estimated the Australian population was willing to pay the equivalent of AUS$50/ha/year\(^7\) for 20 years for the landscape aesthetic values of bushland protected or farmland restored to bushland, as distinct from their species conservation or watershed restoration values. This estimate is approximately 29% of the Costanza et al. (1997) residual value. In this study, ‘other ecosystem service’ values for all Hardwood Regions are assumed to be the lower of these two estimates, i.e. AUS$50/ha/year.

### 6. Financial and economic performance of hardwood plantations in Queensland

Table 5 reports the estimated financial (timber value only) and economic (timber plus ecosystem service values) LEV of Queensland hardwood plantations. Predictably, plantation profitability is highly sensitive to plantation MAI. It is estimated that a MAI exceeding 15 m\(^3\) ha\(^{-1}\) year\(^{-1}\), coupled with low land purchase costs or low opportunity costs are necessary for hardwood plantations to be financially viable in Queensland. For example, on sites where a MAI of 25 m\(^3\) ha\(^{-1}\) year\(^{-1}\) is achievable, an investor interested in financial returns could only pay up to $2300/ha for land. The discussion of rural land values in the Hardwood Regions of Queensland indicates that in general, long-rotation hardwood plantations are unlikely to be financially viable when the value of land is accounted for.

Carbon sequestration, salinity amelioration and other ecosystem service values are added sequentially and cumulatively to financial LEV in Table 5. These values raise the socio-economic performance substantially above the projected financial performance. While plantations achieving a MAI of 15 m\(^3\) ha\(^{-1}\) year\(^{-1}\) are not financially viable, they are economically justified. Notably, the economic LEV of plantations growing at a MAI of 10 m\(^3\) ha\(^{-1}\) year\(^{-1}\) is close to zero. Investors giving consider-

---

\(^7\) van Bueren and Bennett (2000) estimated that on average, an Australian household was willing to pay AU$0.07/10 000 ha of bushland protected or farmland restored. Australia has 7.2 M households.
ation to the economic benefits of hardwood plantations would be justified in paying up to $5000/ha for land in Queensland capable of growing plantations with a MAI of 25 m³ ha⁻¹ year⁻¹.

6.1. Sensitivity analyses of plantation investment performance with respect to parameter estimates

Figs. 2–6 illustrate the sensitivity of financial and economic LEV to the discount rate for plantations with MAIs of 5–25 m³ ha⁻¹ year⁻¹. For example, Fig. 4 indicates that at a discount rate of 4%, the financial and economic LEV of a plantation growing at 15 m³ ha⁻¹ year⁻¹ are $3300/ha and $6400/ha, respectively. The discount rate at which the LEV schedule equals zero is the IRR of an infinite series of successive plantation crops.

The sensitivity of financial and economic LEV to changes in selected parameter values has been undertaken for stands with MAIs from 10 m³ ha⁻¹ year⁻¹ to 20 m³ ha⁻¹ year⁻¹, and is reported in Tables 6 and 7, respectively. Sensitivity analyses have been performed with plausible optimistic and pessimistic parameter values or percentage changes provided by experts and the literature search from which the base case parameter values have been obtained. Uncertainty surrounding the economic value of the salinity amelioration and ‘other ecosystem service’ values of plantation forests is reflected in the wide interval selected for the sensitivity analyses.

Optimistic stumpage prices are sufficient for plantations growing at a MAI of 15 m³ ha⁻¹ year⁻¹ to be financially justified where land values are less than $1580/ha. Pruning stems and developing markets for clearwood is shown under particular circumstances, to be an effective means of raising the profitability of hardwood plantations in Queensland. If clearwood logs can be sold at $100/m³, pruning is financially justified when the yield of clearwood logs at clearfall is greater than 20% of stand volume and plantation growth rates exceed 10 m³ ha⁻¹ year⁻¹. For example, where a clearwood market exists, a pruned plantation yielding 15 m³ ha⁻¹ year⁻¹, of which 40% is clearwood, has a financial LEV of $548/ha, compared with -$16/ha when only 20% of the yield is clearwood. In the latter case, the landholder would be better off not pruning the stand, which returns a financial LEV of $242/ha.

The development of a wood composite manufacturing industry that is willing to pay higher stumpage prices for low-value logs from thinning and clearfall operations is found to raise financial returns almost to the same level as the development of clearwood markets. The joint development of clearwood markets

![Fig. 2. Sensitivity of LEV to the discount rate when MAI is 5 m³ ha⁻¹ year⁻¹.](image-url)
and a wood composite product manufacturing sector (not tabulated) is estimated to raise the financial LEV of hardwood plantations growing at a MAI of 15 m$^3$ ha$^{-1}$ year$^{-1}$ to $1579/ha.

7. Discussion

On the basis of expert opinions about likely growth rates in specific Hardwood Regions, this financial analysis indicates that long-rotation hardwood plantation establishment should be centred in Hardwood Regions 1, 3 and 7 when the sole aim is profitable timber production. However, there is a scarcity of low-cost (<$2300), high-yielding (20–25 m$^3$ ha$^{-1}$ year$^{-1}$) land in these regions, which is necessary for such investments to be profitable. The high value of land throughout much of Hardwood Regions 1, 3 and 7 is likely to preclude large-scale private investment in long-rotation hardwood plantations, even under optimistic timber market conditions. Therefore, expansion of the hardwood plantation estate in these regions is

![Fig. 3. Sensitivity of LEV to the discount rate when MAI is 10 m$^3$ ha$^{-1}$ year$^{-1}$.](image)

![Fig. 4. Sensitivity of LEV to the discount rate when MAI is 15 m$^3$ ha$^{-1}$ year$^{-1}$.](image)
likely to be dependant on rural landholders with relatively low opportunity cost land (i.e. grazing rather than cropping lands), who are motivated by socio-economic and not purely financial objectives. Slow growth rates (5–10 m$^3$ ha$^{-1}$ year$^{-1}$) throughout most of Hardwood Regions 5, 6 and 9 mean that long-rotation hardwood plantations are also unlikely to be financially viable in these regions, despite relatively low land values.

The combination of moderately high growth rates (15 m$^3$ ha$^{-1}$ year$^{-1}$) and, generally, lower rural land values (compared with regions 1, 3 and 7), suggests that the potential for large-scale private investment in long-rotation hardwood plantations in Queensland may be greatest in Hardwood Regions 2, 4 and 8. Although returns are negative in the base case, the sensitivity analysis indicates that optimistic stumpage prices, or the joint development of clearwood markets and a plantation hardwood wood composite processing industry are sufficient for plantings in these regions to become financially justified where land values are less than about $1600/ha. Forestry research and policy formulation that facilitates these timber market and processing developments in Hardwood...
Table 6
Sensitivity of financial performance of Queensland hardwood plantations to selected model parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter value</th>
<th>LEV ($/ha) by MAI (m³ ha⁻¹ year⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
<td>Pessimistic</td>
</tr>
<tr>
<td>Establishment expenses ($/ha)²</td>
<td>1600</td>
<td>3000</td>
</tr>
<tr>
<td>Optimistic</td>
<td>–100</td>
<td>+25</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>(no prune)</td>
<td></td>
</tr>
<tr>
<td>Pruning expenses (%)</td>
<td>+100</td>
<td>–25</td>
</tr>
<tr>
<td>Annual management expenses ($/ha)c</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>Optimistic</td>
<td>–817</td>
<td>–2593</td>
</tr>
<tr>
<td>Pessimistic</td>
<td>1437</td>
<td>1761</td>
</tr>
<tr>
<td>Stumpage price of low-value logs ($/m³)d</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Clearwood market developed (%)e</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Clearfall harvest composition (%)f</td>
<td>40%:60:10</td>
<td>10:50:40</td>
</tr>
</tbody>
</table>

Notes:
²Optimistic and pessimistic establishment costs reflect large-scale plantings on flat sites and smaller-scale plantings on relatively steep sites, respectively.
³No pruning (–100%) is examined because, with the present lack of clearwood markets in Queensland, pruning may not be financially justified.
⁴Pessimistic annual management fee approximates the management fees of timber plantation prospectus companies operating in Queensland (e.g. Forest Enterprises Group, 2002).
⁵Optimistic and pessimistic stumpage prices approximate current stumpage prices paid for hardwood timbers from natural forests in Queensland on private land and state-owned land, respectively.
⁶Proportion of merchantable volume sold as clearwood (base case = 0%). Clearfall harvest volume consists of 40% clearwood 20%, pole, 20% sawlog and 20% low-value log in the optimistic case, and 20% clearwood, 20% pole, 40% sawlog and 20% low-value log in the pessimistic case.
⁷Clearfall harvest composition is % poles:% sawlog:% low-value log obtained from merchantable timber volume in m³ per hectare.
<table>
<thead>
<tr>
<th>Parameter value</th>
<th>LEV ($/ha) by MAI (m$^3$ ha$^{-1}$ year$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimistic</td>
</tr>
<tr>
<td>Value of carbon ($/tonne C)</td>
<td>30</td>
</tr>
<tr>
<td>Value of salinity amelioration ($/ha paid at establishment)</td>
<td>1000</td>
</tr>
<tr>
<td>Value of ‘other ecosystem services’ ($ ha$^{-1}$ year$^{-1}$)</td>
<td>100</td>
</tr>
</tbody>
</table>
Regions 2, 4 and 8 could be critical for encouraging large-scale hardwood plantings in Queensland.

The financial analysis reveals the high importance of continued research into tree breeding, genetics, silviculture and wood quality to ensure future Queensland hardwood plantations are capable of achieving higher merchantable yields on lower productivity (and land value) sites. This analysis also indicates that, for pruning operations in hardwood plantations to be financially viable, high growth rates and timely pruning (to minimise the knotty core and maximise clearwood production) are necessary. Even if clearwood markets develop for plantation hardwood logs in Queensland, pruning operations are unlikely to be income maximising for forest growers in Hardwood Regions 5, 6, 9, and the western parts of regions 2, 4 and 8, because of slow stand growth. However, this conclusion does not account for the potentially increased risk of disease, crowning fires and higher management costs associated with unpruned stands.

The major implication of the economic analysis is that plantation forestry in Queensland could be socio-economically desirable on sites that have, generally, been regarded as marginal for hardwoods because of low timber yield. While long-rotation hardwood plantations for timber production alone are not profitable in Hardwood Regions 2, 4, 6, 8 and eastern parts of 5 and 9, they are economically justified where the land has low opportunity cost. Indeed, under optimistic assumptions about ecosystem service values, the economic LEV of hardwood plantations in these regions approximates current land values. QFRI (2002b) have identified 16.4 M ha of cleared freehold and leasehold land in a broad area approximated by Hardwood Regions 5, 6 and 9, with high suitability for establishment of *E. argophloia* plantations. When timber and ecosystem service values are added to the potential regional employment and income benefits, a strong case could be made for an investor with socio-economic objectives to establish long-rotation hardwood plantations in these regions.

There is growing awareness that economic incentives, such as land rates rebates and taxation deductions, have a role to play in converging the private and social valuation of forests to ensure that socio-economically efficient levels of forest cover are maintained. If ecosystem service payments are made to forest growers in recognition of the positive externalities of hardwood plantations, then plantation forestry would provide a considerably more profitable private investment opportunity. Some of the estimates of ecosystem service values adopted in this paper may serve as a starting point for negotiations between hardwood plantation growers and governments about ecosystem service payments to Queensland forest growers.

This research has highlighted that information about the ecosystem service values of plantation forests globally, and in Queensland specifically, is scarce. Given the increasing awareness and requirement to account for ecosystem service values, and the contribution that these values can make to the profitability of plantation forestry, there is a need for future research to identify and quantify, both spatially and temporally, the types and values of ecosystem services provided by plantation forests in Queensland.

The paper provides contemporary information for potential Queensland hardwood plantation investors. The financial and economic performance of hardwood plantations in Queensland has been assessed assuming the present relationship between forest growers and timber processors; i.e. forest growers ‘look forward’ as far as the mature tree, and processors ‘look backward’ as far as the log on the ground. The need for an integrated approach to the growing and utilisation of plantation eucalypts is being argued by QFRI, and it is anticipated that this will deliver financial gains to both growers and processors of plantation hardwoods. This proposition is to be examined in a forthcoming study.

**Acknowledgments**

The author would like to thank the Hardwoods Queensland program of QFRI for funding this research. The support, assistance and advice provided by QFRI officers Dr Garth Nikles, Mr Bill Leggate, Dr Michael Kennedy, Mr Andy McNaught, Dr Russell Haines, Dr Mark Lewty, Dr Marks Nester and Mr David Boden, and Mr Neil Halpin and Mr Russell Garthe from DPI-Forestry, in deriving the parameters for the financial model, is greatly

---

8 Hardwood plantations in regions 5, 6 and 9 are economically justified under optimistic assumptions about ecosystem service values.
appreciated. The guidance provided by Dr Beverley Henry of the Queensland Department of Natural Resources and Mines in estimating the carbon sequestered by Queensland hardwood plantations is also acknowledged. Finally, the author would like to extend his gratitude to Dr Steve Harrison from the University of Queensland and two anonymous referees for many helpful comments on earlier versions of this paper.

References


Queensland Forestry Research Institute, 2002b. A Study on the Potential for Hardwood Plantations in the Western Hardwoods Region. A report to the Timber Task Force, Department of State Development. QFRI, Agency for Food and Fibre Sciences, DPI, Brisbane.


