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Enhancing the value of multiple use plantations: A case study from southeast Queensland, Australia

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Abstract

In the 1990s, an expansion of small-scale (farm) forestry in medium to low rainfall areas was considered to be an important part of increasing the national forest estate but it remains a very minor source of timber, largely confined to the higher rainfall areas. In most areas, returns from timber are much less than for alternative land uses, even with low discount rates. If however, there are additional returns from plantation grazing and carbon sequestration and there are other potential management gains, multiple use plantations may be more attractive. The goal of this study is to estimate the net present values of multiple use spotted gum plantations in a medium rainfall area of southeast Queensland.

For the case study, production, carbon sequestration and emissions data were supplemented by formal and informal interviews with landholders, sawmill staff and

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government extension personnel. Forest inventory, biomass and soil sampling, and stakeholder interviews were used as sources of primary data. The costs and benefits data were converted into monetary terms and discounted to produce net present values.

Evaluations in this study identify the optimal rotation age of plantations to be 33-34 years. This is the case if including carbon and stock values, and using either farm- or factory-gate timber prices. The net present value increases significantly however if farmers harvest the trees themselves. In addition, at harvesting age, it was found that carbon and stock had the potential to account for 19.2 percent and 11.4 percent respectively of the total returns from spotted gum plantations. Policy initiatives to support the farm forestry sub-sector should include pricing greenhouse gas emissions and developing and strengthening farmers co-operatives and marketing institutions to enhance farmers' bargaining power.

Keywords: spotted gum plantation, factory gate selling, greenhouse gas emissions carbon values, stock values

Introduction

Forest clearing for pastoral and agricultural production has been portrayed as a historical driver of civilisation and nation-building. In Australia, as in other countries of colonial origin, broadscale clearing has been relatively recent but rapid. Present rates of clearing have decreased from 546,000 ha yr^{-1} in 1988 to 260,000 ha yr^{-1} during 2000 to 2004, with much of that clearance occurring in the state Queensland. The clearing rate is much higher than the average plantation rates of 72,000 ha yr^{-1} during 2003-2008 (AGO 2000; DAFF 2009). There are many motivating factors underlying forest clearing but major drivers include the economic returns triggered by the availability of low-priced land and high profit, immediate profits from crop production, and long-term profits from increased land values (AGO 2000). Recently, due to increased environmental concerns focusing on land degradation and the risk of dryland salinity, the Queensland Government has encouraged farmers to establish hardwood plantations on some degraded ex-cultivation and pasture areas (Brown 2002), however plantations for the production of timber alone are not viable in the medium to low rainfall (600-800 mm yr^{-1}) areas of SEQ (Venn 2005; Maraseni and Cockfield 2011).

There are two major policies that encourage plantations. First, 'Plantation for Australia: The 2020 Vision', whereby the Australian Government wants to increase the national plantation estate to about 3.3 M ha by the year 2020. There has been some progress in this direction but to meet this target small-scale (farm) forestry needs to be promoted in medium to low rainfall (600-800 mm yr^{-1}) areas (Maraseni and Cockfield 2011). At the beginning of this policy, it was expected that farm forestry would comprise up to 12 percent of the 3.3 M ha but it remains a minor part of the national estate, and is largely confined to the recognised industrial-scale plantation zones in the higher rainfall areas (Wood et al. 2001; Bureau of Rural Sciences 2009). There are three ways to increase the competitiveness of small-scale forestry over other land use systems: (1) encouraging famers to plant trees as a silvipasture system and including livestock values; (2) giving incentives to farmers for additional carbon sequestration from plantations; and (3) changing the current dominant practice of selling trees on-farm (farm-gate) to the landholder selling logs to the processing centre (factory-gate) (Garrity 2004; Maraseni and Cockfield 2011; Dawson et al. 2011).

A second policy that could stimulate plantations is the scheme to price greenhouse gas (GHG) emissions which, with appropriate regulations, would increase demand for forest-based sequestration. The Australian Government has passed the Clean Energy Future Plan and intends to introduce an emissions trading scheme aimed at reducing GHG emissions by 80 percent below 2000 levels by 2050. The Plan has allocated $1.7 billion to the land sector for the implementation of an agricultural offset market, the Carbon Farming Initiative (CFI), which allows farmers and land managers to earn carbon credits by storing carbon or reducing GHG emissions on their land. These credits can then be sold to individuals and businesses wishing to offset their emissions. The government is expecting this agricultural initiative to contribute to Australia's unconditional national target of a 5% reduction in GHG emissions by 2020 relative to 2000 levels (Calford et al. 2010).

Reforestation activities are eligible on a voluntary basis under the CFI. The government will issue carbon credits (annually or every five years) to the forest owners, based on the volume of carbon sequestered in that period, less five percent that is set aside for what it referred to as the carbon risk reversal buffer (Burns et al. 2011). All permanent plantings (both long rotation, between 25 and 45 years rotation, hardwoods and carbon plantings) established on or after 1 July 2007 are eligible for carbon credits (Burns et al. 2011). The long rotation hardwood can be harvested at any time, but any emissions units received to that time must be handed back in order to 'offset' the emissions that are released back into the atmosphere. This requirement is in place for 100 years (DCCEE 2010). Furthermore, carbon offsets generated by plantations must meet the integrity standard that they are additional and permanent, and are measurable and can be verified (Burns et al. 2011). The demand for forestry sinks however is dependent on the stringency of any emissions trading scheme, and the rate at which emitters substitute other inputs and technologies for those that result in greenhouse gases. The inclination to provide forest sinks also depends on production costs, including transaction costs, preferences for non-forest land uses, and returns from timber.

Some studies have explored the possible impact of carbon price on reforestation activities (Lawson et al. 2008; Burns et al. 2009; Maraseni and Cockfield 2011). Lawson et al (2008) and Burns et al. (2009) only consider biomass (carbon) sequestration values but do not consider GHG emmissions related to the use of farms inputs such as agrochemicals, fuels and machinary.

Maraseni and Cockfield (2011) compared the returns from Queensland plantation species, including GHG values, with returns from other land use systems. They considered all sources and sinks of GHG emissions related to: production, packaging, storage, transportation and applications of all agrochemicals, machinery and fuels; urine, dung and cattle burping; soil carbon; biomass carbon; and biologically fixed nitrogen. However, their estimation was based on the farm gate price of trees. This is because the common practice in Australia is for contractors to thin and harvest and farmers receive a stumpage price for trees. The contractors do not usually disclose harvesting costs (ANU 2005).

This current research hypothesizes that the farmers could significantly increase their plantation benefits by including grazing values (silvipasture system) and selling logs directly to the factory. The goal of this study is therefore to estimate returns and optimal rotation ages of spotted gum (*Corymbia citriodora*, subspecies Variegata) plantations in a medium rainfall area of southeast Queensland, by including grazing (stock) and GHG values, and with landholders selling logs directly to the factory. This is not the typical approach investigated in forestry papers: by way of contrast, the paper investigates how silvipastural systems can be promoted by including GHG values.

A brief snapshot of Australia's plantations

Of the 149.4 M ha of forest about 2/3rd or 100 M ha is woodland (up to 50 percent crown cover) – only about 1/3rd what most people consider to be 'forest' (>50 percent crown cover) (DAFF, 2010). Plantations cover about 1.97 M ha— 1.32 percent of Australia's total forest cover. Recently, three major changes have become apparent in the Australian plantation sector: a move out of softwood and into hardwood; a shift from public to private forest resources; and the transition from previously small-scale farm forestry to large managed investment scheme (MIS) plantations. The proportion of hardwood plantations has increased from 15 percent in 1994 to 74 percent in 2003 and about 95 percent in 2008 (DAFF 2009). In total, around 48 percent of the current total plantations area is hardwood (DAFF 2009). Likewise, the proportion of private plantations has increased from 30 percent in 1990 to 46 percent in 1999 and >64 percent in 2008 (National Forest Inventory, 2004; DAFF 2009). Similarly, in 2007, over 26 percent of the total plantation estate was under MIS ownership, and until 2008 such schemes have funded over 80 percent of new plantations (DAFF 2009). However, very recently, many MIS operations ceased, mainly due to the economic recession of 2008 (Nichols et al. 2010) and the abandoning of the tax incentives previously permitted under the Income Tax Assessment Act 1997.

Although the plantation area in Queensland is small compared to the national area (about 13 percent or 251,000 ha out of 1.97 M ha), the general pattern of plantations is similar. Until 2002, only around 13 percent of the total planted area was hardwood and 87 percent was softwood. However, in 2008, the trend was reversed; of the total planted area of 10,300 ha, >96 percent (9,900 ha) was hardwood and about 4 percent (400 ha) was softwood (DAFF, 2009). Our research species, spotted gum, is the most prioritised (over 60 percent) hardwood tree species for plantation in Queensland (Huth et al., 2004). Of the 3.42 M ha of cleared land evaluated for plantation in the South East Queensland Regional Forest Agreement (SEQRFA) region, 2.72 M ha met the slope (<20 percent) and size (>10 ha) constraint, and 73 percent of that land was found to be suitable for spotted gum (Queensland CRA/FRA Steering Committee 1998).

Research methods

The study area is the Kingaroy district of southeast Queensland which was selected because it is: 1) where plantations have been encouraged by the Queensland Government; and 2) in a medium rainfall area of inland southeast Queensland, which makes it a target area for hardwood plantations as the region is considered to be the most favourable location outside the high rainfall areas nearer the coast. In other words, if multiple use forestry is not profitable in the study site area, it is unlikely to be so in most other areas in this climatic zone. The soil at site is classified as a Red Ferrosol according to the Australian Soil Classification of Isbell (2002). Elevation at Kingaroy is 441 m above sea level. The climate is classified as subtropical, with long summers and mild winters. Annual rainfall varies from 339 to 1430 mm, with an average of 781 mm, and the yearly average maximum temperature is 24.7°C, while the yearly average minimum is 11.4°C.

There is some research from the same sites, which estimate different parameters. The types of parameter, method and key results, used for this study, are summarised in Table 1 immediately below. Those methods not discussed in this present research are discussed in following sections.

[Table 1 here]

In case of soil carbon, our study (Maraseni et al., 2008) estimated that the increment of soil carbon in spotted gum plantation in ex-pasture is 1.4 percent per year. In fact, the newly established plantations at the research site are consist of a silvipastoral system that includes nitrogen fixing legumes along with exotic and native grasses species planted as an intercrop along with the spotted gum. The accumulation of soil C is higher when there are N_2-fixing species present (Paul et al. 2002). Therefore, in our study area, SOC increment rates seem a little bit higher than in other studies. However, in line with our findings, most of the studies in Australia, with some reservations, report that soil carbon increases after the establishment of hardwood plantations on agricultural land (Paul et al. 2002; Paul et al. 2003). However, the conversion of pasture to pine has in general resulted in a loss of soil carbon (Ross et al. 2002; Richards et al. (2007). In Kingaroy, Richards et al. (2007) investigated the SOC dynamics under a hoop pine plantation established on a former rainforest site. They found no real increase in SOC over many years. This may be caused by a reduction of the surface area of fine roots, loss of soil aggregates, and lower input of carbon from fine-root turnover under pines.

Timber grades and their factory gate prices

In Australia, logs price are based on their grades. The proportion of different grades of logs at different ages and their factory gate prices were based on advice from managers of the Wondai Sawmill, the main sawmill in the Kingaroy region, where 90 percent of the timber processed is spotted gum. Most of the harvested logs were used for saw logs. The Sawmill, following Queensland State Government regulations, categorises three different types of logs for valuation: compulsory logs, optional logs and landscape logs. Compulsory logs are high quality logs that the sawmill must accept as part of their volume allocation. The price of compulsory logs is \$A170 m^{-3} at factory (Table 2). The optional logs are lower quality logs and their price \$140 m^{-3} at factory. Landscape logs are usually less than the acceptable diameter and so the price is very low, \$90 m^{-3} at factory.

[Table 2 here]

The predicted volume and average diameter at breast height (DBH) of logs under bark (UB) and percentage of different types of log at different ages are taken from Maraseni et al. (2011). At age 26, the average DBH of trees are around 41 cm, increasing to around 55 cm by year 40. The percentage of compulsory logs and optional logs are directly related to DBH, whereas the percentage of landscape logs is inversely related to DBH. At the 26th year, the percentage of compulsory logs is around 76% which increases to 78% at 40 years. The percentage of landscape logs at age 26 years is around 9% and decreases to 5% at the 40th year.

Cost of plantations and stock

All the costs of plantations up to harvesting age are summarised in Table 3. Costs are largely in the first four years of the establishment period (around \$2077 ha^{-1}). The major spending is for hilling and ripping (\$150 ha^{-1}), seedlings production (\$750 ha^{-1}) and transportation (\$250 ha^{-1}), labour for the plantation operation (\$170 ha^{-1}) and fertilisers (\$137 ha^{-1}) in the first year, the first thinning and form pruning (\$355 ha^{-1}), and the second thinning and tidying-up operation (\$390 ha^{-1}). As noted above, as trees are usually harvested by contractors or sawmillers, the farmers may not often know the harvesting cost. Therefore, we did extensive modelling for estimating harvesting and transportation costs of plantations, which is discussed in following section.

[Table 3 here]

Harvesting and transportation costs of timber

The working hours of harvesting and transportation operations and their tentative costs are modelled in the following sections. The basic concepts of all formulae used in modelling were derived from FAO Forestry (1992). However, values of different coefficients of the different formulae were decided on the basis of real information and discussion with experts (please see acknowledgement for details). The contract rates of machines were taken from different experts and average value of all was taken for the studies.

From modelling, Maraseni et al (2009) found that the optimal spacing for spotted gum in the study site region, after a second thinning, is around 250 trees ha^{-1}. Therefore, all the calculations are based on 250 trees ha^{-1}. Equation 1 was developed for the estimation of harvesting time.

T = a + 2 b D ……………………………………………………(1)

where, 'T' is the harvesting time per tree in minutes, 'b' is the minutes per unit diameter (cm) and the 'D' is the diameter (cm).

The coefficient 'a' is the time interval between two cuts (that is, time for preparing the next cut). This formula assumed that the cut-time and time to fell the cut tree into an appropriate position is equal; therefore, 2bD (bD + bD) was needed. In this case, the research had to model harvesting costs of trees for different ages for finding optimal rotation age. As there was DBH information for all ages (from growth modelling), it was easy to do so by using the above formula. For example, if harvesting spotted gum at age 29, the average DBH (at 1.37 m height) and volume of trees is around 44.7 cm and 1.07 m^3 respectively. Maraseni *et al.* (2007b) found that the tapering rate of a spotted gum tree is 0.97 cm m^{-1}. Therefore, the diameter (D) at the bottom felling part is around 46 cm. According to experts, 'a' would be around 0.25 minutes and 'b' would be 0.005 minute per cm diameter. Therefore;

T = 0.5 + 2 * 0.005 (46 cm) = 0.71 minute per tree= 2.96 hr (ha^{-1})

Equation 2 was developed for the estimation of de-limbing and bucking time (using a power chain saw).

T = a + c ……………………………………………………..(2)

where, 'T' is the de-limbing and bucking time per tree in minutes, 'a' is assumed to be one minute (time for walking between two felled trees and preparing to cut) and 'c' is de-limbing and one bucking cut time per tree (including the time to walk from the bottom of the tree to the buck point), which is assumed to be two minutes. Therefore, the total de-limbing and bucking time for 250 (ha^{-1}) trees would be around 12.5 hr.

Equation 3 was developed for the estimation of skidding time. This includes the time (T) for travel unloaded, hooking, travel loaded and unhooking time.

T = a N + b x…………………………………………………..(3)

where ‘a’ is the combined time for hooking and unhooking per log (i.e., 1.5 minutes), ‘N’ is number of logs carried at a time (assumed four), ‘b’ is the minutes per round trip distance (minutes/metre) and ‘x’ is the one way distance (the average distance from harvesting point to log yard). Considering the area of plantation, ‘x’, is assumed to be 200 metre. Equation 4 was used to calculate ‘b’ as per the unitary method.

b = (V1 + V2)/(V1V2)..(4)

where ‘V1’ is travel speed loaded and ‘V2’ is travel speed unloaded. In this case, ‘V1’ is assumed as 75 metres per minute (4.5 km hr^{-1}) and ‘V2’ as 150 metres/minute (9 km hr^{-1}). Therefore, ‘b’ would be around 0.02 minutes/metre and total skidding time for 250 logs (ha^{-1}) would be around 10.42 hr.

Equation 5 was developed for the estimation of crosscutting time (using a power chain saw for one cut).

T = a + c N…………………………………………...….(5)

where, ‘T’ is the cross cutting time per log in minutes, ‘a’ is the time per log that is not related to its diameter such as walking between logs and preparing to cut another log and ‘c’ is the time per cut and ‘N’ is the number of cuts in each log. We assumed ‘a’, ‘c’ and ‘N’ as 1 minute, 0.5 minutes and 1 cut respectively. Therefore, the total crosscutting time for 250 log (ha^{-1}) would be around 6.25 hr.

A John Deere D-series Forwarder (1710D model) was used for loading logs from log yard and transportation and unloading to them Wondai Sawmill (35 km distance). The round trip travel time (T) was calculated by using Equation 6.

T = a + b x ……………………………………………….(6)

where ‘a’ is combined time for loading and unloading and ‘b’ is the hour per round trip km and ‘x’ is the one-way distance. The coefficient ‘b’ is calculated as Equation 7.

b = (V1 + V2)/(V1 V2)……………………………………….(7)

where ‘V1’ is travel speed unloaded and ‘V2’ is travel speed loaded.

A D-series truck (D1710) can carry 17 t (or 23 m^3) per trip (23 m^3 x 739 kg m^{-3} = 17 t). The haul distance from plantation site (Kingaroy) to Wondai Sawmill is around 35 km. It was assumed that the unloaded truck can travel 90 km/hr and a loaded truck can travel 60 km hr^{-1}. The combine sorting and loading time is 30 minutes and combined unloading and piling time is around 20 minutes per load. So the time taken for each trip (or for 23 m^3) would be around 1.972 hr {T = (40 + 20)/60 + {(90 + 60)/(90*60)}35= 1.972 hr).

Costs and benefits of plantation due to addition of stock

In order to estimate the net result of grazing amongst plantations, the specific additional costs and benefits in the plantation are considered. The income from stock is dependent on price, live weight gain and stocking rates. Farmers in the study site suggest that the beef price averages \$2 kg^{-1} live weight with the average weight gain being 250 kg/head/yr. Livestock are excluded until the plantation is three years old. In year 4, 27 cattle are grazed in two rotations for a total period of 94 days (stocking rate of 0.286 ha^{-1}). From years 4-11 the stocking rates decrease by 2.5% yr^{-1}, to 0.24 head ha^{-1}. At year 12, after the second thinning at the 11^{th} year, the stocking rate would return to 0.29 ha^{-1}. After that the stocking rates decrease constantly to 0.14 head ha^{-1} at age 26 and continue at that level until harvest.

Additional costs of plantations include: establishment costs in the first year of $251 per head for seeds (planting operations and establishment of watering system); selling costs of $13.49/head, annual health costs of $5.87 per head, $2 per head per yr for ear tags , an annual electricity cost of $2.96 per head and an annual maintenance cost $104 per head. The net return from stock was estimated for individual years and then discounted to get present values from stock. The discount rate for all values, including GHG values, was 6 percent. This enables the estimation of various production scenarios with optimal rotation ages for the plantations.

Results

This section discusses four different types of optimal rotations, which could be utilised to determine the age at which trees should be cut to maximise production objectives: (1) optimal rotation age for maximum economic return from timber (T) values; (2) optimal rotation age for maximum economic return from timber and stock (T+S) values; (3) optimal rotation age for maximum economic return from timber, stock and carbon (C1 scenario) values (T+S+C1; and (4) optimal rotation age for maximum economic return from timber, stock and carbon ((T+S+C1 & C2) values.

C1 and C2 represent two different carbon scenarios. Following the Kyoto Protocol, the C1 scenario, the most pessimistic emissions scenario, assumes that the harvested forest products will emit carbon immediately in the atmosphere after harvesting. In fact, carbon may be locked up in a range of forest products over time (Haripriya 2001). As noted, spotted gum is used for flooring and decking products, the life span of which is around 90 years (Jaakko Pöyry 2000). Similarly, the soil carbon gain due to plantations may not drop to the same level of zero age plantations after harvesting the trees, as significant amounts of residues will be left on the ground after harvesting. Therefore, the C2 scenario assumes that at least 40 percent of the gained soil carbon and harvested product carbon will be stored for another 46 years (as suggested in Cacho et al. 2003).

Cacho et al. *(* 2003) mentioned that the decay pattern of carbon of CO_2 is complex, as it decays quickly over the first 10 years, gradually over the next 100 years, and then very slowly over hundreds of years before ending in the ocean sediments. Because of this pattern, it is necessary to find the age at which the area under the decay curve of CO_2 up to 100 years is equivalent to the sequestration of the same amount of CO_2, as it is this which gives the total amount of carbon staying in the atmosphere in 100 years. This age, referred to as equivalence time (Te), is found to be 46 years (Cacho et al. 2003).

Optimal rotation age for maximum economic yield from timber

The combined NPVs from timber, stock and carbon values are shown in Figure 1. When the average DBH of trees approaches 28 cm at age 14, it becomes possible to get some cash by selling logs. However, since the costs are higher than the benefit, the NPV from timber would be negative up to age 17 (NPV of Timber, Figure 1). Age 18 would be the break-even age when NPV of costs and NPV of benefits are equal. After that the NPV from timber starts rising and approaches the maximum (around \$4785 ha^{-1}) at year 31. Therefore, this is the age at which trees could be cut for maximum timber benefit. After this age, the NPV starts to decline and approach zero at age 68 and therefore become negative at that point.

Optimal rotation age for maximum economic return from timber and stock

If the plantation is managed as a silvipastoral system, with grazing permitted after three years the combined NPV of plantation and stock would remain negative until the 15th year, because the start-up costs for grazing add additional time. Since the combined NPV ($5570.7 ha^{-1}) is maximised at age 32, this is the harvesting age of the plantation, if we consider both timber and stock values. The range of positive values of NPV from timber and stock would be 16 to 80 years, compared with 18 to 68 years in timber (only). The NPV from stock (pasture) plays a significant role in increasing the range of positive values.

[Figure 1 here]

Optimal rotation age for maximum economic return from timber, stock and carbon values

As in the previous case, the combined NPV of plantation, stock and carbon (T+S+C1) remains negative until the 16th year. However, the amount of NPV would be slightly higher than before. The negative NPV until the 16th year is due to the higher initial cost of plantation, and higher emissions from machines, fuels and agrochemicals and the accumulation of lower amounts of soil and biomass carbon. After the 15th year, the combined NPV continues to be positive and never returns to zero even at 100 years. The range of positive NPV values increases significantly and it would be even higher if the C2 scenario is also considered.

The combined NPV approaches a maximum at age 33 in both (T+S+C1 and T+S+C1&C2) scenarios. It is around $6383.5 ha^{-1} in the T+S+C1 scenario and around $6873.8 ha^{-1} in the T+S+C1+C2 scenario (Figure 1 Table 4). The NPV gain from carbon at this age is around $829.3 in the T+S+C1 scenario and $ 1319.6 in the T+S+C1+C2 scenario. The returns gain from carbon continues to increase after 33 years, but due to a lower rate of increase in NPV from the timber value the combined NPV is reduced. Therefore, age 33 would be the optimal harvesting age of plantations, if timber, stock and carbon values were to be considered.

Discussions

A previous study by Maraseni and Cockfield (2011) discussed net returns of plantations with a farm gate price. In order to find the net benefits of selling timber to the factory and its impacts to the optimal rotation ages it is better to compare our results with the Maraseni and Cockfield (2011) results. In order to discuss this, two scenarios for the forest owner/manager are developed: (1) the current practice of selling trees from farm as business as usual; and (2) selling logs directly to the sawmill as an optimistic scenario. The business-as-usual scenario assumes current equipment and practices will remain constant over time and the farmers would receive a stumpage price on their farm. The optimistic scenario assumes that farm forestry will advance towards a commercial scale and farmers will sell logs directly at the processors and unlike the business as usual scenario, the harvesting and loading and transportation costs will be borne by farmers.

Net present values (NPV in $ ha^{-1}) from timber (T), stock (S) and carbon (C1 and C2) in critical years in business as usual and optimistic scenarios are given in Table 4. The optimal ration ages of plantations for timber value, timber plus stock values and timber plus stock plus carbon values (T+S+C1) in the business as usual scenario were found to be 31, 31 and 34 year, respectively. The respective NPVs in given rotation ages were $2100 ha^{-1} (timber alone at age 31), $2878.8 ha^{-1} (timber plus stock at age 31), $3700 ha^{-1} (timber plus stock plus carbon at age 34).

[Table 4 here]

On the other hand, the optimal rotation age for maximising timber (only) NPV in the optimistic scenario is 32 years at which total NPV is around \$4786 ha^{-1}. The inclusion of stock grazing in a plantation does not change the optimal rotation age, but the combined NPV increases to \$5571 ha^{-1}. The optimal rotation age of plantation for timber, stock and carbon values would be the 33rd year and the consequent NPVs would be around \$6383 ha^{-1} and \$6873 ha^{-1} in the T+S+C1 and T+S+C1+C2 scenarios, respectively.

The net increase in NPV due to stock (\$789 ha^{-1}) and carbon values of \$829 ha^{-1} from C1 and \$490 ha^{-1} from C2 scenarios for the business-as-usual and optimistic scenarios are the same. Therefore, the decrease in the optimal rotation by one year in the optimistic scenario compared to business-as-usual scenario could be due to the greater effect of timber benefits rather than carbon benefits.

In the business-as-usual scenario, the actual harvesting cost, and loading, transportation and unloading costs are implicit. From the difference between stumpage price and factory gate price it was indirectly revealed that this cost is around \$70 m^{-3}. Our results show that the explicit costs for the plantation owner could be much lower than that. This finding is partially supported by three case studies in southeast Queensland (Ryan and Taylor 2001). Ryan and Taylor (2001) found that the landowner could get a net extra benefit of \$28 m^{-3} by employing a miller to saw the logs and then sell the sawn product himself. If the landowner mills and sells his timber using a portable sawmill the net return will increase by \$142 m^{-3} (Ryan and Taylor 2001).

In the interface of timber, stock and carbon markets there are several exogenous factors that may affect the estimated rotation age and NPV of plantations. In particular, the factors affecting the costs and benefits of given farming activities could be influential. An increase in harvesting costs and any additional cost during the harvesting period would suggest a need for a longer rotation. If the timber, cattle and carbon prices increase, there will be an incentive for early harvesting and therefore the rotation age will shorten.

In our case, the most sensitive parameters for an economic return from plantations are timber price, carbon price and discount rates. A one percent decrease in timber price reduces the NPV of plantations at harvesting age by 1.2 percent. As a plantation is a net sink of GHG, increased or reduced carbon prices will have either positive or negative outcomes. For example, reducing carbon prices by one percent reduces the plantation NPV by 0.2 percent. Similarly, if the discount rate increases, the rotation ages and plantation NPV will decrease. For example, if the discount rate increases to 7 percent from currently assumed 6 percent, the optimal rotation age would decrease to 30 years. At this age, the combined plantation NPV will be reduced by 37 percent. If the discount rate further increases to 8 percent, the optimal rotation would be reduced to 28 years and the NPV by 65 percent. In plantations most of the costs are incurred in the early ages while the benefits come only at point of harvest. Therefore, benefits are more heavily discounted than costs. Since timber price is the greatest single contributor to plantation value, the total net present value, as well as optimal rotation, decreases drastically with increasing discount rates.

Conclusions

This study estimated the net present values and optimal rotation ages of spotted gum plantations in medium to low rainfall region of southeast Queensland with the consideration of factory gate price of logs and then compared these results with those obtained from farm gate prices paid for trees. The optimal ration age of timber, timber plus stock and timber plus stock plus carbon in both conditions (either selling trees from farm or logs to the processing centre) were found to be similar (33-34 years), but the net present values in all cases increased significantly if farmers harvested trees themselves and sold logs to the processing centres. The maximum possible net present value from plantations in the ‘farm gate selling’ and ‘factory-gate’ selling’ scenarios would be around \$4185 ha^{-1} and \$6873 ha^{-1}, respectively. Therefore, farmers are losing a lot from the current practice of selling trees on-farm. In addition to that, at the age of 33 (optimal rotation age), carbon and stock account for 19.2 percent and 11.4 percent of the total returns from spotted gum plantations, so multiple use plantations will be more attractive to landholders.

This shows that there is a good chance of promoting small-scale forestry and meeting the Federal Government’s 2020 plantation target of 3.3 M ha, if farmers are encouraged to sell logs to the factory rather than from the farm gate, and farmers are provided with incentives to adopt ‘carbon friendly’ land uses. If farmers are selling 'carbon friendly' timber, they may also be able to gain further market advantage through certification and labelling programmes (Cadman 2003). The formation and strengthening of farmers’ co-operatives and institutions and the enactment of CPRS would be helpful in this direction. This would require some cultural and structural changes however, given that farm forestry is generally a minor activity relative to crop and livestock production. Landholders may not have easy access to harvesting equipment and might be reluctant to make the investment. Furthermore, harvesting and handling logs would involve the acquisition of new skills, including new safety skills. Nonetheless, publicising the potential economic benefits would help overcome these potential impediments.

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Table 1: Methodology and key results of previous studies utilised in for this study

Estimation of:	Methods	Results
Optimal spacing of spotted gum plantations****	Growth modelling using Non Linear Estimation Module of STATISTICA Software	250 trees per hectare after second thinning.
Optimal rotation age of spotted gum plantations*	By estimating net present values for each possible harvesting ages	Optimal rotation depends on types of values considered (timber only, timber plus stock, timber plus stock plus GHG)
Grass and timber biomass*	Stratified Random Sampling	Varies by ages of plantations. At age 34, above and underground biomass is 468 t/ha.
Soil, surface litter & particulate organic matter**	Pair soil sampling, and chemical analysis using isoprime isotope mass spectrometer	Annual increment of soil carbon planted in ex-pasture is 1.4%.
GHG emissions due to use of farm machinery***	Information about type, weight, lifespan & proportion of lifespan used for a hector of forestry activity was collected and a formula was developed.	In 34 year GHG emissions related to farm machinery is 1940.8 $kgCO_2eha^{-1}$
GHG emissions due to use of agrochemicals and fuels***	Amount and types of agrochemicals and fuels were collected from landholders and their emissions factors were taken from various sources.	In 34 year GHG emissions related to agrochemicals and fuels are 19751 $kgCO_2eha^{-1}$ and 14029 $kgCO_2eha^{-1}$, respectively.
GHGs from cattle*	Total number of cattle was taken from grazing calendar and emissions factors were taken from from various sources.	Emissions vary cattle number. Urine and faeces: 383 $kgCO_2e\ yr^{-1}$ $head^{-1}$ Burping: 1380 $kgCO_2eyr^{-1}$ $head^{-1}$
Cost and benefit data*****	Formal and informal interviews with landholders, agronomists, sawmill staff and government extension personnel.	Discussed later

Sources:*Maraseni and Cockfield (2011); **Maraseni *et al*. (2008); ***Maraseni *et al*. (2007a); ****Maraseni *et al*. (2011); and *****Maraseni *et al*. (2009)

Table 2 Percentage and prices of compulsory, optional and landscape logs of spotted gum at various ages at Kingaroy

Types of log	Various types of log at different ages (%)				Price of log at factory ($/m3)
	26 yr	30 yr	35 yr	40 yr	
Compulsory	76	76.6	77.3	78	170
Optional	15	15.6	16.3	17	140
Landscape	9	7.8	6.4	5	90
DBH cm (UB)*	41.5	45.7	50.6	54.6	
Tot volume/ha*	217.4	284.8	369.2	452.2	

Source: Wondai Sawmill Staff; *Maraseni *et al*. (2011)

Table 3 Different types of costs for spotted gum plantation in Kingaroy, Queensland

Year	Activity	Items	Cost per unit	Quantity	Tot ($/ha)
1	Site survey	Consulting hour	60		60
1	Ripping and hilling	Machine hire	150	1	150
1	Pre-planting weed control	*Roundup* (lt)	5	3	15
		Fuel and oil	0.41	3	1.23
		Parts & repairs	1.5	3	4.5
1	Planting	Seedlings	0.75	1000	750
		Transport seedling	0.25	1000	250
		labour	17	10	170
		Fertiliser (BigN,kg)	0.606	226	137
1	Post plant slashing	Fuel and oil	0.41	3	1.23
		Parts & repairs	1.5	3	4.5
1	Weed spraying (spot spray from 4w motorbike)	labour (hr)	17	2	34
		Roundup (lt)	5	2	10
	Cost of motorbike operation	Fuel and oil	0.41	3	1.2
		Parts & repairs	1	3	3
1	Form pruning	labour	17	4	68
Total yr 1 cost					1659.7
2	Weed spraying (spot spray from 4w motorbike)	labour (hr)	17	2	34
		Roundup (lt)	5	2	10
	Cost of motorbike operation	Fuel and oil	0.41	3	1.2
		Parts & repairs	1	3	3
	Maintenance slashing	Fuel and oil	0.41	3	1.23
		Parts & repairs	1.5	3	4.5
Total yr 2 cost					53.93
4	Maintenance slashing	Fuel and oil	0.41	3	1.23
		Parts & repairs	1.5	3	4.5
4	Thinning-1 (800 to 400 trees)	labour-thinning	17	11.03	187.5
4	Low pruning	labour	17	10	170
Total yr 4 cost					363.2
7	Carry-up pruning	labour	17	16	272
12	Thinning-2 (400 to 250 trees)	labour-marking			50
	Felling/delimbing/bucking (saw)	labour	17	14.70	205.8
	Tidying operation	labour	17	8	136
Total yr 12 cost					391.8
At 34 yr	**Harvesting operation (estimate vary by age), given example is for 34 yr**				
	Felling (Bouncher)	Bouncher (hr)	155	2.96	458.8
	Delimbing & bucking (saw)	labour	17	12.5	212.5
	Skidding (grapple skidder)	Skidder	110	10.42	1146.2
	Cross cutting (chain saw)	labour	17	6.25	106.3
	Loading/unloading & transportation to sawmill	Hired-truck ($/m3)	9.4325	352.36	3324
	Tidying operation	labour	17	10	170

Source: Up to age 12 are from Maraseni *et al.* (2009) and after that from modelling as discussed in *Harvesting and transportation costs of timber* section

Table 4 Net present value ($ ha⁻¹) from timber, stock and greenhouse gases in Kingaroy, Queensland

Age	Timber	Timber & Stock	Timber, Stock & C1	Timber, Stock & C2+C2	NPV from Stock	NPV from C1	NPV from C2	Total gain from C1&C2
Farm gate price (business as usual scenario; Maraseni and Cockfield, 2011)								
30	2091.4	2865.0	3593.7	4102.5	773.6	728.7	508.8	1237.5
31	2099.6	2878.8	3641.5	4144.9	779.2	762.7	503.4	1266.1
32	2093.8	2878.2	3674.4	4171.6	784.4	796.3	497.2	1293.5
33	2075.1	2864.5	3693.8	4184.1	789.3	829.3	490.3	1319.6
34	2045.0	2839.0	3700.8	4184.7	794.0	861.8	483.8	1345.6
Factory gate price (Optimistic scenario; current study)								
31	4785.5	5564.6	6327.3	6830.7	779.1	762.7	503.4	1266.1
32	4786.3	5570.7	6366.9	6864.2	784.4	796.3	497.2	1293.5
33	4764.8	5554.2	6383.5	6873.8	789.3	829.3	490.3	1319.6

Note: C1 scenario assumed that the harvested forest products would emit carbon immediately in the atmosphere after harvesting and C2 scenario assumed that 40 percent of the gained soil carbon and the harvested product carbon would be locked for another 46 years.

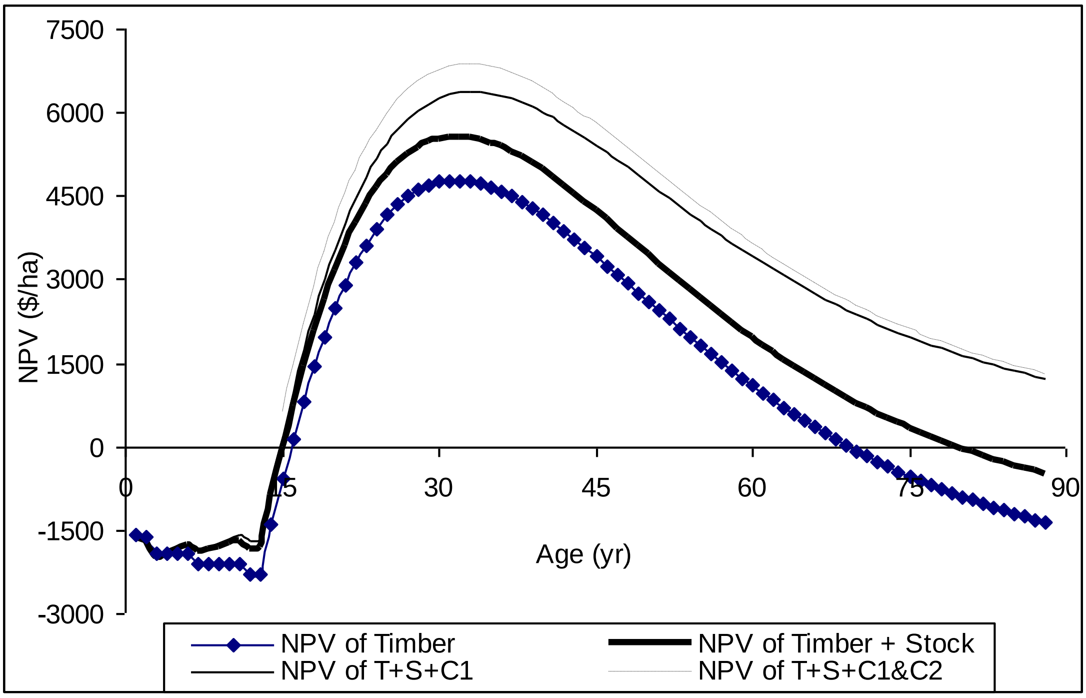

Figure 1 Net present values (NPV in $ ha⁻¹) from timber (T), stock (S) and carbon (C1 and C2). Note: T+S+C1 scenario assumed that the harvested forest products would emit carbon immediately in the atmosphere after harvesting and T+S+C1 & C2 scenario assumed that 40% of the gained soil carbon and the harvested product carbon would be locked for another 46 years.