# Economy and ecology of emerging markets and credits for bio-sequestered carbon on private land in tropical Australia

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Cutler J. Cleveland
Editor-in-Chief
Ecological Economics

1 April 2007

Dear Professor Cleveland,

I am pleased to submit this analysis and hope that you find it relevant and interesting.

Please note that tables are included in the manuscript.

I hope to make your acquaintance in June, at the NY conference.

Sincerely,

Colin Hunt

# Economic and ecological implications of emerging markets for bio-sequestered carbon in tropical Australia

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**Abstract**

**Australia intends to meet its Kyoto greenhouse gas emissions target – even though it has not ratified the Protocol – and has adopted Protocol rules that specify that carbon stock changes between 2008 and 2012 will be included in the country's accounts. While a national system of carbon emission capping and trading does not exist in Australia, a number of companies are interested in buying the rights to carbon in trees or in planting forests. Most states, that make up the Australian federation, have enacted legislation enabling the recognition of ownership of carbon sequestered in sinks, and because of unilateral action by some states there are carbon markets emerging. In north Queensland reforestation with the aim of augmentating endangered ecosystems and at the same time reducing externalities impacting the Great Barrier Reef World Heritage Area is an official priority. However, such reforestation is heavily subsidised. A question arises whether the emerging carbon markets have the potential to provide an economic incentive for landholders to reforest without recourse to subsidy. A second question, important for policy-making is how**

carbon sequestration costs compare to abatement costs. A third question given that commercial plantations also provide carbon sinks, is whether the goals of carbon sequestration and biodiversity are mutually exclusive or complementary and whether investement in restoration of biodiversity will be jeapordised. Using methodology that allows the comparison of uneven streams of costs and benefits, it is found that – at present prices – payments for sequestered carbon defray only a proportion of costs, providing a level of incentive insufficient to sharply stimulate environmental restoration. If carbon prices were to rise substantially – in the wake of caps on Australian emissions – the outlook for investment in bio-sequestration by the private sector is brighter. However, landowners may prefer the more lucrative monocultures that have poor biodiversity value. A conclusion is that the Australian government and the corporate sector will need to continue to subsidise the augmentation of endangered ecosystems and habita for endangered and rare species.

Key words: carbon sequestration economics, biodiversity, Australia

## Introduction

Australia, like the US, has not ratified the Kyoto Protocol and is therefore excluded from international emissions trading and joint implementation which would stimulate in-country capture of carbon in forest sinks (bio-sequestration).

Nevertheless, Australia still intends to meet its Kyoto target, and has adopted Protocol accounting rules that specify that carbon stock changes between 2008

**and 2012 are to be included in the country's accounts (Australian Greenhouse Office 2006).**

**Given the high rate of increase of emissions from the power generation and transport sectors the Australian government is encouraging *bona fide* bio-sequestration projects (under Article 3.3 of the Protocol) that can contribute to a reduction in the country's emissions. There is no Australia-wide cap and trade system governing emissions. However, corporate activity and unilateral action by states in the Australian federation to cap emissions, thus forcing emitters to seek offsets, has stimulated the emergence of markets for sequestered carbon.**

**The natural forests in the study area, the Atherton Tablelands in the Queensland Wet Tropics (see Figure 1), have been subjected to logging and clearing. The complex notophyll vine (Mabi) forest is listed as "endangered" by the Queensland government and "critically endangered" by the Australian government, having been reduced to 2% of its original extent (Environmental Protection Agency 2007; Department of Environment and Water 2007a).**

**The Mabi forest harbours the "vulnerable" spectacled flying fox (*Pteropus conspicillatus*) (as classified under Australia's *Environment Protection and Biodiversity Conservation Act, 1999*), together with the "rare" Lumholz tree-kangaroo (*Dendrolagus lumholtzi*), green ringtail possum (*Pseudocheirops archeri*) and Herbert river ringtail possum (*Pseudochirulus hebertensis*) (as classified under Queensland's *Nature Conservation Act, 1992*).**

The complex mesophyll vine forest (Hypsi) is less threatened, nevertheless less than 30% remains unaffected by weed invasion and the disturbance effects of logging, and its biodiversity status under Queensland legislation is “of concern”. The Hypsi forest, as well as being habitat for the Lumholtz tree-kangaroo, is also habitat for the iconic southern cassowary (*Casuarius casuarius johnsonii*), listed as “endangered” by the Australian government and is the subject of a recovery plan (Department of Environment and Water 2007b). The augmentation of Mabi forest and cassowary habitat by replanting native species are regional priorities for natural resource management investment. An additional regional priority is the reduction terrestrial threats to the Great Barrier Reef World Heritage Area, in which reforestation has a major role (FNQ NRM Ltd 2005).

The favourable soils and climate of the Wet Tropics region of north Queensland result in a quicker growth rate of trees than anywhere else in Australia. However, because the environmental services generated have no market value, and the costs are high, reforestation activities are heavily subsidised.

A question arises whether the emergence of carbon markets has the potential to provide an economic incentive for landholders to reforest without recourse to subsidy.

A second question, given the commercial softwood plantations also provide carbon sinks, is whether the goals of carbon sequestration and biodiversity are mutually exclusive or complementary. Caparrós and Jacqemont (2003) expect that the creation of economic incentives for carbon sequestration by afforestation and reforestation will yield a sub-optimal result of over-planting of fast-growing

**alien species with a potential negative impact on biodiversity. "The Convention on Biological Diversity lacks economic incentives which would ensure that agents will follow the optimal social strategy whereas the Kyoto protocol creates economic incentives" (Caparrós and Jacqemont 2003:155).**

**A third question addressed is how the cost of carbon sequestration in north Queensland compares with abatement costs. This relationship may determine the relative importance that governments place on carbon sequestration as a means of improving carbon accounts.**

## Method

### Estimation of bio-sequestration rates

**Under Kyoto Protocol rules and under Australia's accounting approach (Australian Greenhouse Office 2006) carbon sequestration credits are only available on land cleared of vegetation before 1990. In the modelling of carbon sequestration, the cleared land to be planted with trees is assumed to be under pasture, the now dominant land cover in north Queensland.**

**By synthesising allometric studies, the Australian government has developed predictive models of carbon flows in forest and agricultural systems "fullCAM". Accessible through a "National Carbon Accounting Toolbox" the model predicts for any area of Australia capable of growing trees, the carbon sequestered over time both above and below ground in both mixed species and single species plantings (Australian Greenhouse Office 2006).**

In this study the models are used to compare total carbon (above and below ground) sequestered in reforested plots (environmental plantings mixed species) with afforestation plots (*Araucaria cunninghamii* (hoop pine) monoculture) on the Tablelands of north Queensland. Rates of carbon uptake follow an exponential path in the initial years, then slow with age. The model predicts that in 90 years plus the reforestation captures over 250 tonnes per hectare of carbon. Hoop pine is the softwood monoculture modelled and this captures almost 250 before harvest at 44 years, but decreases with harvest, while unharvested hoop pine sequesters over 350 tonnes of carbon per hectare (see Figures 2 and 3). Under Kyoto and Australian rules only the carbon sequestered in the terrestrial carbon sink is counted. However, it has been estimated (Thamer 2006) that 35% of the hoop pine timber that is harvested (along with its carbon content) is transformed into enduring wood products such as furniture or buildings, while the remaining waste decomposes.

<u>Carbon accounting methodology</u>

The challenge in modelling is to obtain a single number representing the cost-effectiveness of carbon sequestration when this changes annually over a long period.

The methods that can be employed to accomplish this are reviewed by Stavins and Richards (2005). Briefly, the “flow summation” approach or “stock change” method simply divides the tonnes of carbon by the present value of costs regardless of when sequestration occurs. The method implies that the marginal

**benefit of sequestration is increasing exponentially over time. A method that suffers from the same problem is the mean carbon storage method, where the present value of costs is divided by the numerical average annual carbon storage.**

**The discounting approach, which can deal with uneven carbon flows, is adopted in this paper. The marginal benefits of damages avoided by carbon sequestration are assumed to be constant. The benefit of damages avoided and the costs of avoidance are discounted at the same rate. The discounted present value of costs is divided by the discounted present value of the uneven carbon flows to obtain the present cost per tonne of carbon sequestered.**

**The treatment of costs of sequestration**

**Reforestation in the wet tropics of north Queensland is usually carried out on areas of about one hectare on private land. The operation is labour intensive and economies of scale are weak (Catterall and Harrison 2006). Voluntary organisations committed to biodiversity conservation are most often the proponents of restorations, sometimes working in a complementary way with state government departments and local governments. The voluntary organisation contribute their labour which, if imputed, amounts to two thirds of total costs. The financial cost component is most often met by subsidies from the Australian government or the corporate sector. In a study of the costs and benefits of 11 restorations on private land it was found that the average private or landowner contribution to restoration costs (including and imputed labour costs) was $1,000 per hectare, against an average public cost of $56,000 per hectare (Hansel 2006). In this study an imputed, or opportunity cost, of labour**

input by voluntary organisations of $20 per hour is adopted – a locally accepted labour cost.

As well as unpaid labour in establishment and maintenance there is also an opportunity cost of the replacement of the existing landuse by a carbon sink. Previous studies investigating the past activities and future prospects for increasing reforestation and afforestation in north Queensland (Herbohn *et al* 2000; Harrison *et al* 2004; Harrison and Herbohn 2006) have recognised opportunity costs as an issue, but have not made them explicit. Catterall and Harrison (2006) point out that the cost of reforesting a hectare is the same as a family car at $20,000-30,000. However, adding the cost of agricultural income foregone can increases the cost to that of a luxury car. The importance of including opportunity costs in calculating cost of carbon sequestration is emphasised by Stavins and Richards (2005) who found that cost estimates increased by 2 to 3.5 times in studies that take opportunity cost into account. A similar ratio is found in this study.

The cash or financial costs of reforestation plots in former rainforest landscapes – the cost of seedlings, land preparation and weedicide and amounting to about a third of total costs – are based on the detailed records of a voluntary organisation in north Queensland.

Expansion of hoop pine plantations is one of the “more likely” scenarios for development of plantations given that there is an established resource whose silviculture is well known, and there is a large mill in the region geared to processing (Kanowski *et al* 2005: 362). However, the timber mill servicing the

**study area will only harvest plots in excess of 10 hectares in size or greater because of harvesting diseconomies of smaller plots. There is no unpaid labour involved in establishing the relatively large hoop pine plantations, as there is in the case of restoration plantings, as establishment and maintenance are by contractor.**

**Beef cattle grazing on pasture is the dominant activity replaced by forest. While there are other landuses such as dairy and crops on the Atherton Tablelands – not accounted for in the study – these are likely to be more profitable, and hence have a higher opportunity cost, than beef cattle fattening whose gross margin in the model is $200 per hectare.**

**In this study the displacement of agriculture by plantations and consequent impacts on prices in the forest and agricultural sectors are ignored. If large changes in land use were to be expected then such sectoral benefits and costs would need to be taken into account in estimating costs of carbon sequestration.**

**The opportunity costs of labour and of beef cattle are incurred during year 0 when land is being prepared for tree planting. These year 0 costs are entered at their undiscounted value. The benefits of carbon sequestration of trees planted in year 0 commence at the end of year 1 and occur at the end of each subsequent years for 94 years.**

$$\text{Cost per tonne of carbon} = \frac{\displaystyle\sum_{i=0}^{n} \frac{\textit{cost of sequestration}_i}{(1 + \textit{rate of interest})^i}}{\displaystyle\sum_{i=1}^{n} \frac{\textit{carbon sequestered}_i}{(1 + \textit{rate of interest})^i}} \qquad (1)$$

**Where $i$ = years $0$ to $n$**

**Tree planting cost components**

**Labour opportunity costs of site preparation, tree planting and maintenance for three years after planting are the largest cost components in reforestation followed by the costs of seedlings and herbicide. In north Queensland conditions, grass and weeds pose severe competition for tree seedlings. Intensive weedicide applications are necessary in the year of planting and in the following three years. The competition posed by grass and weeds is countered by planting trees relatively close together, in this case 1.75 metre spacing (or 3,256 trees per hectare) so that a leafy canopy forms in three to four years.**

**The source of variable costs in this study is the records of Trees for the Evelyn and Atherton Tablelands Inc (TREAT) a voluntary organisation dedicated to environmental reforestation and of the Environmental Protection Agency at Lake Eacham Nursery Services. Costs include the opportunity costs of labour at**

**$20 per hour and $30 per hour for specialist staff, plus tree raising and planting costs, and the costs of herbicide. Herbicide and labour costs are incurred in both site preparation and maintenance. The variable cost per tree is $4.25.**

**The analysis of the variable costs of trees by tree spacing shows an exponential rise in costs with tree spacing (see Figure 4). This is derived by number of trees times the cost per tree planted at each spacing.**

**The analysis of cost of maintenance shows the upward trend in maintenance costs with spacing. The cost/maintenance relationship is derived from the experience of TREAT and is costs of materials and labour per hectare of times the number of maintenance treatments required to control weeds satisfactorily (see Table 1 and Figure 5). The cost of maintenance amounts to $7,161 per hectare per year, and is discounted at the rate of 0.05.**

**Figure 6 shows the two sets of data simultaneously. The lowest cost is delivered by a spacing of 1.75 metres between trees i.e. 3,265 trees/hectare and at 2.25 metres between trees. The risks of failure to deliver adequate maintenance, and therefore the risks that tree survival will be jeopardised, increase with the number of years of maintenance required. Therefore the spacing at 1.75 metres is preferred.**

**There is a fencing cost required by the exclusion of cattle from reforested plots and there is an opportunity cost incurred when reforestation replaces cattle grazing.**

**The total present cost, at the 0.05 discount rate, of reforestation per hectare and taking account of labour opportunity costs is estimated at $30,000 per hectare and where there is labour plus cattle opportunity cost $34,000 per hectare. A comprehensive study of reforestation projects (Catterall and Harrison 2006:12) found similar costs – averaging $26,000 per hectare. However, while this latter estimate includes the opportunity cost of labour it is not discounted and excludes the opportunity cost of alternative land uses.**

**In the case where only cash costs of establishment and maintenance are considered and where the restoration does not replace cattle, the cost of establishment is greatly reduced; nevertheless, this minimum cost is still some $11,000 per hectare.**

**Where timber harvesting is contemplated, trees in plantations need to be widely spaced to obtain maximum growth and maximum value per tree. Two harvests of hoop pine trees each yield 400m$^3$ of millable timber at a farm gate price of $25 per m$^3$ in years 44 and 88; no income is generated by thinnings which are left on the forest floor (Skelton 2007). Tree planting and maintenance includes pruning in years 3 and 47, 6 and 50, 9 and 53, and thinning in years 10 and 54, 13 and 57 and 16 and 70 (Skelton 2007). The cost of hoop pine seedlings is much less than the cost of rainforest trees and only 1,000 or less are planted per hectare. Weed control costs are, however, somewhat greater than for restoration plantings. Where cattle raising is not displaced, the net present cost of establishing and managing commercial hoop pine plantations, at a discount of 0.05, is estimated at $7,700 per hectare.**

**Sources of beef cattle gross margins are the NSW Department of Primary Industries (2006) and Smith (2006). Where cattle grazing is an opportunity cost, cattle grazing is displaced at establishment but is re-introduced into the plantation four years after establishment at half the stocking rate achieved prior to afforestation.**

**The unharvested hoop pine alternative, requiring no thinning or pruning, costs $5,800 per hectare but foregoes timber sales and income from cattle in the plantation.**

**Results**

**Costs of carbon sequestered**

**The cost of carbon sequestered in restoration plots at 0.5 discount rate and where only cash cost are considered is $170 per tonne. The inclusion of opportunity cost of labour and the opportunity cost of the displacement of a beef enterprise from restoration plots increases the total cost to over $500 per tonne of carbon (see Table 1). In the case of the softwood plantation the cost without beef opportunity cost, at 0.05 discount, is $124 per tonne rising to $160 per with beef opportunity cost. At first glance it is surprising that the cost of carbon associated with the periodic harvesting of timber is greater than where the plantation remains unharvested. This same result is obtained by Newell and Stavins' (2000) study of factors affecting the costs of carbon sequestration in the US. However, it is apparent that silviculture costs, incurred relatively early in**

**the life of a plantation (avoided in unharvested plots) that contribute to the cost of carbon, are greater than the distant and therefore more heavily discounted benefits of timber sales.**

**The choice of discount rate has a marked influence on the costs of carbon. In the case of environmental plantings higher discount rates raise costs per tonne of carbon because sequestration is over a long period of time thus its present value decreases with higher discount rates relative to costs that are incurred in the first few years. The discount rate is also influential in determining the costs of plantations. However, a discount rate of 0.25 delivers the lowest cost in the harvested plantation because the tonnes of carbon sequestered is maximised relative to the present costs of maintenance.**

**Comparing sequestration with abatement**

**The cost of sequestering carbon relative to the cost of abatement is important from a policy viewpoint.**

**Australian abatement costs reported are $92 per tonne of carbon through energy efficiency and $59 per tonne through industrial energy efficiency (Next Energy 2004). However, also reported are substantial net benefits (as opposed to costs) from using combined cycle gas turbines for the generation of electricity instead of coal, burning mine waste methane and geo-sequestration of $CO_2$ emitted by coal burning power stations.**

**Also reported by Next Energy (2006) is the cost of carbon sequestered in forestry projects Australia-wide. This suggests that there would be benefits of sequestration where the carbon value of plantations exceeds the agricultural value of the land. However, it has been shown above that in north Queensland carbon credits are presently insufficient to match reforestation or plantation costs even where there are no land or labour opportunity costs attributed.**

<u>Comparison with U.S. carbon sequestration costs</u>

**Reports from the United States, cited by Stavins and Richards (2005) suggest that the cost of sequestration in commercial plantations is between $A38 and $A114 per tonne of carbon, i.e. a somewhat lower range than that found in this study. The cumulative sequestration of 364 tonnes per hectare reported by for permananet (unharvested) loblolly pine in the Mississippi Delta at 80 years (Stavins and Richards 2005:10) is similar to the 350 tonnes sequestered in unharvested hoop pine. It appears that establishment costs are the major reason for the inter-country difference in carbon sequestration costs for pine. In the case of environmental plantings it is obvious that high establishment or opportunity costs or both are responsible for the greater inter-country difference.**

## Discussion

### Biodiversity issues

So far this analysis of reforestation and afforestation benefits and costs has ignored the biodiversity benefit accruing from the provision of forest habitat. The failure of the market to generate an increase in endangered ecosystems and habitat for threatened species in north Queensland is recognised by the Australian government which heavily subsidises restorations. The design of restoration plots is aimed to achieve the eventual replication of the rainforest in the shortest possible time. Emphasis is placed on the need to include a large number of native species and, moreover, to enhance the ecological value of the reforestation. For example, seedlings are grown from seeds collected from the same provenance in which environmental plantings are to take place.

Despite an investment of 16.5 million in revegetating some 644 hectares through the Natural Heritage Trust Stage 1 in north Queensland, the rate of increase in habitat achieved by reforestation programs is considered by ecologists to be well below what is required to guarantee the survival of endangered ecosystems or species. Catterall and Harrison (2006) estimate that to recover 30% of the former area of Mabi forest would cost $80 million. But even if financial restraints are removed substantial agricultural opportunity costs remain and these are likely to increase as stocks of marginal land are replanted.

While fauna may be sighted in pure stands of pine, they are less likely to be species that depend on rainforest habitat and, when they are, their presence is

**related to nearby remnant native forest (Catterall and Harrison 2006; Lindenmayer and Fischer 2006)). Both on-site and offsite (for example water quality) biodiversity values are considerably greater for environmental plantings than for hoop pine monoculture (Kanowski *et al* 2005).**

**Incentive to landowners**

**The level of interest among private landowners in establishing small-scale plantations in North Queensland, without a subsidy, is presently very low. Yet the notion persists that small-scale farm forestry will become a significant industry. It has been suggested that impediments to plantation establishment are cultural, lack of public policy initiatives and lack of markets (Herbohn, Harrison and Herbohn 2000). Certainly there is a complete lack of markets for biodiversity. But it is apparent from this study that even when there is a market available for timber (as in the case of hoop pine) the costs of establishment and management exceed the benefits at timber prices offered, even at low discount rates and where landuse opportunity costs are set at zero.**

**The possible benefits from the sale of carbon rights are now compared with the costs of carbon sequestration for different types of plantation and under different opportunity costs assumptions.**

**At a 5% discount rate the lowest cost of carbon sequestered (hoop pine) is some $52 per tonne of carbon where there are no agricultural opportunity costs. Current farm gate prices being offered landowners in Victoria and New South Wales for sequestered carbon are between $36 and $59 per tonne of carbon.**

**Figure 7 shows the average carbon price against cost of carbon established for plantation alternatives.**

**Over the life span of a north Queensland plantations there is a chance of cyclone damage. Landholders are likely to allow for this uncertainty by applying a higher discount rate to future benefits. Table 1 shows that at a 10% discount rate the costs of carbon rise steeply and are well in excess of carbon payments. Cyclone damage to environmental plantings is a less costly threat than to hoop pine, however.**

**Carbon payments could make a difference to the level of environmental plantings in the case where there is a private sponsor, whose grants will go further if augmented by carbon payments.**

**In the future the value of carbon rights might well increase – if for example Australia adopts a cap and trade or carbon tax system of containing its greenhouse emissions and joins a post- Kyoto international protocol.**

**Costs of establishment**

**A question is whether the costs of establishment and management can be lowered to make the economics of planting trees for environmental reasons more attractive to landowners. Catterall and Harrison (2006) suggest that improved technology might enable larger areas to be restored. While environmental plantings are commonly on land that has a low or zero opportunity cost, for example on patches that are costly to work or areas subject to flooding that pose**

**a threat to cattle, larger scale plantings are likely to be more costly if they involve not just marginal land but land with agricultural opportunity costs.**

**The labour-intensive nature of raising rainforest trees and the need for close spacing make it unlikely that major cost savings can be made to reduce the cost below some $14,000 per hectare. If weed control can be mechanised without jeopardising seedling survival rates then the cost of maintenance of some $19,000 may be able to be reduced. However cost of establishing environmental plantings are always likely to be much more than for hoop pine plantations.**

**In southern Australia the cost of establishment of commercial plantations on farms is between $1,000 and $4,000 trees at stocking rates of 1,000 trees per hectare (New England - North West Forestry Investment Group 2002). In this study, the cost of establishment adopted in year 0 is $4,000. Thinning and pruning add another $7,500 per hectare to costs (discounted at 5%). A question is whether north Queensland could attract commercial firms that specialise in establishing and maintaining large-scale plantations at lower cost.**

**Conclusion**

**While the Australian government has not ratified the Kyoto Protocol, it has nevertheless adopted a policy of meeting its Kyoto greenhouse target. To this end, it has implemented schemes to facilitate the marketing of bio-sequestered carbon, and individual states of the Australian federation and corporations are purchasing carbon rights in plantations on private land.**

**Given that relatively high tree growth rates can be achieved in tropical north Queensland, the paper discusses methodologies for examining the financial and economic costs of sequestering carbon in both environmental and commercial plantations.**

**The economic analysis shows the importance of accounting for opportunity costs. It is found that, at current prices, payments for sequestered carbon are likely to cover a proportion only of reforestation costs, even on land that is marginal for agriculture and therefore carries low opportunity costs. While commercial hoop pine plantations are cheaper to establish than environmental plots their benefits are more uncertain and therefore could be more heavily discounted by investors.**

**Despite the fact that the community and the Australian government have devoted substantial human and financial resources to restoration, the level of augmentation achieved may be insufficient to guarantee the survival of ecosystems and threatened species.**

**The lowest cost carbon was obtained in unharvested hoop pine plantations; costs are lowered by not thinning or pruning and carbon yields are comparatively high. While hoop pine it is a native to north Queensland, it will deliver negligible biodiversity benefits as a monoculture compared with rainforest restoration plantations.**

**It is concluded that there will be a need for the government and the corporate sector to continue to invest in securing biodiversity because present prices for carbon provide an incentive level for sequestration that is unlikely to induce a**

**large increase in environmental reforestation. Moreover, the Australian government is unlikely to subsidise carbon sequestration by reforestation given the lower costs of abating emissions.**

**If carbon prices were to rise substantially to say three or four times present level – in the wake of caps on Australian emissions – then the outlook for private investment in environmental reforestation in north Queensland is much brighter.**

**Acknowledgements**

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**Table 1: Years of maintenance required for environmental plantings by tree spacing**

| Years of maintenance required | Tree spacing, metres |
|---|---|
| 2 | 1 |
| 3 | 1.25 |
| 3 | 1.5 |
| 3 | 1.75 |
| 4 | 2 |
| 4 | 2.25 |
| 5 | 2.5 |
| 5 | 2.75 |
| 6 | 3 |
| 6 | 3.25 |

**Table 2: Carbon sequestered for plantations in north Queensland at various discount rates, tonnes per hectare and cost per tonne***

| | Discount rate | | | |
|---|---|---|---|---|
| | 1% | 2.5% | 5% | 10% |
| **ENVIRONMENTAL PLANTING** | | | | |
| Carbon sequestered (t/ha) | 144 | 102 | 65 | 32 |
| Cash cost ($/t) | 77 | 108 | 170 | 344 |
| Cash plus labour opportunity cost ($/t) | 209 | 170 | 269 | 883 |
| Cash plus beef opportunity cost ($/t) | 162 | 180 | 234 | 413 |
| Cash plus labour, plus beef opportunity costs ($/t) | 293 | 361 | 514 | 952 |
| **HARVESTED SOFTWOOD (HOOP PINE)** | | | | |
| Carbon sequestered (t/ha) | 65 | 82 | 72 | 46 |
| Cash cost ($/t) | 119 | 49 | 124 | 251 |
| Cash plus beef opportunity costs ($/t) | 221 | 154 | 160 | 230 |
| **UNHARVESTED SOFTWOOD (HOOP PINE)** | | | | |
| Carbon sequestered (t/ha) | 232 | 168 | 111 | 60 |
| Cash cost ($/t) | 26 | 35 | 52 | 93 |
| Cash plus beef opportunity costs ($/t) | 54 | 60 | 75 | 110 |

* Note: $ = Australian dollar
t = metric tonne
ha = hectare

**Figure captions**

**Figure 1: Wet Tropics of Queensland**

**Figure 2: Carbon sequestered above and below ground, north Queensland plantations, tonnes per hectare**

**Figure 3: Incremental carbon sequestered above and below ground, north Queensland plantations, tonnes per hectare**

**Figure 4: Cost of trees per hectare of environmental restoration by tree spacing, variable cost $4.25 per tree, 5% discount rate**

**Figure 5: Cost of maintenance per hectare of environmental restoration by tree spacing, 5% discount rate**

**Figure 6: Cost of trees plus maintenance per hectare of environmental restoration by tree spacing, 5% discount rate**

**Figure 7: Costs per tonne of carbon sequestered at 5% discount rate, and price per tonne of carbon**

**Figure 1**
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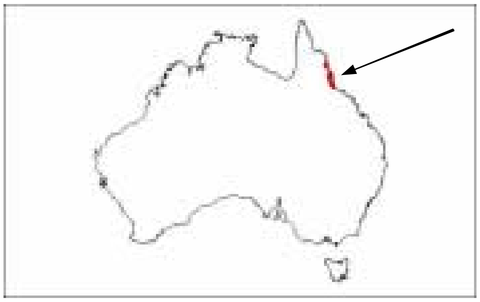
Figure 1: Wet Tropics of Queensland



Please note: print Figure 1 in greyscale

**Figure 2**

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Figure 2

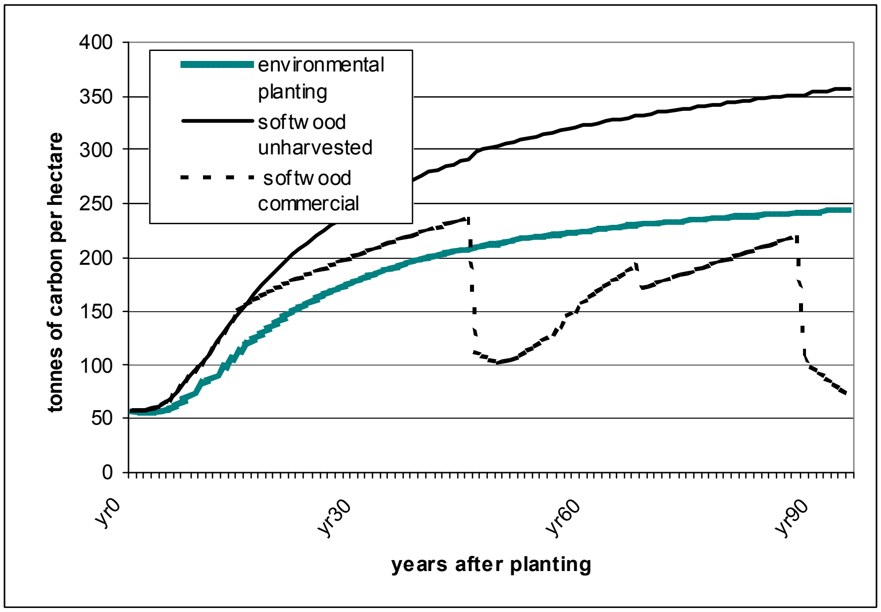

**Figure 3**

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Figure 3

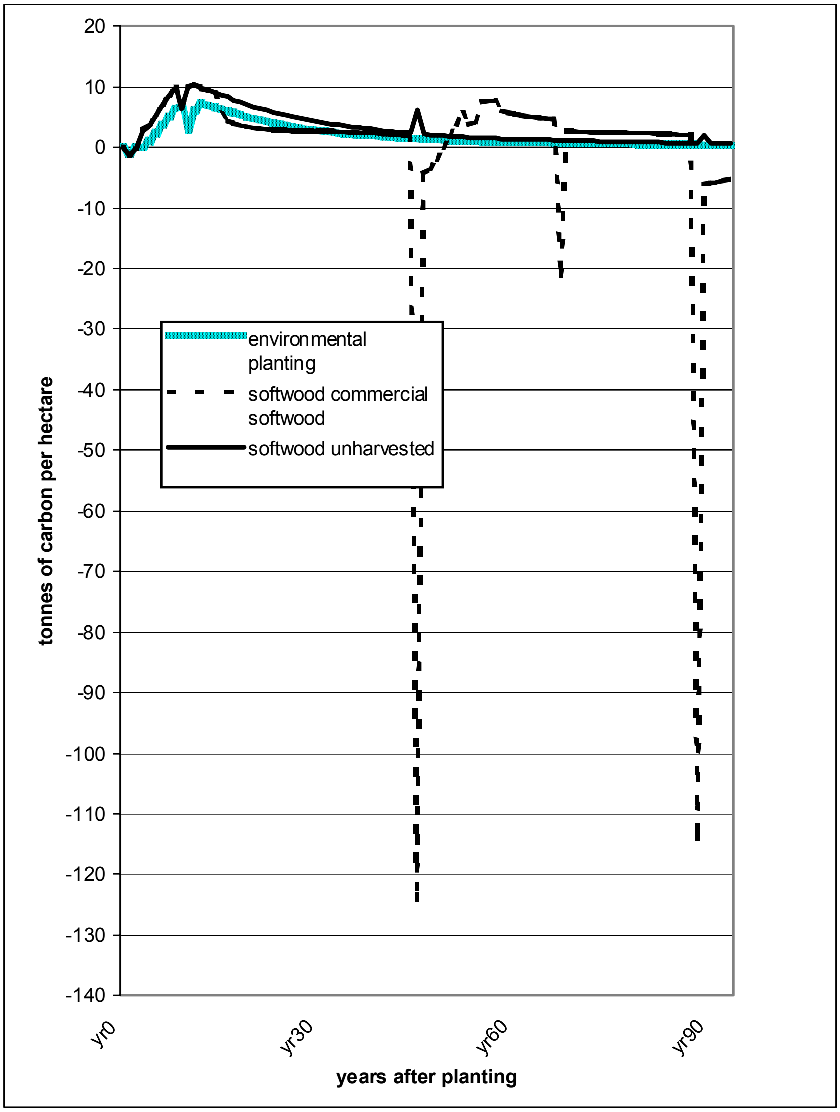

**Figure 4**
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Figure 4

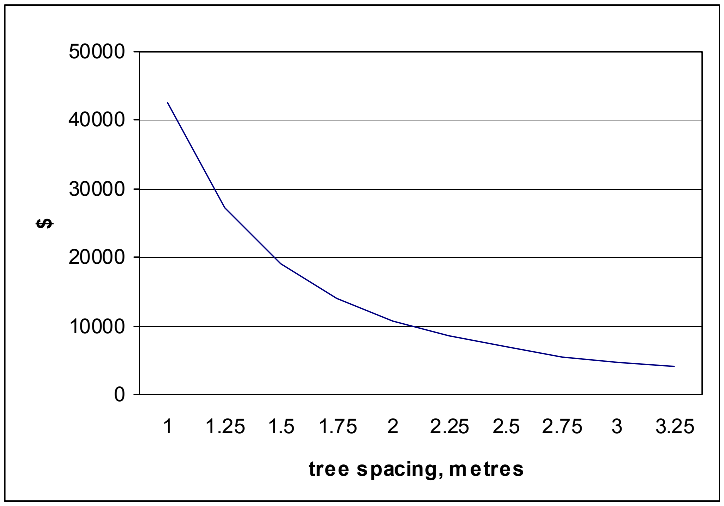

**Figure 5**

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Figure 5

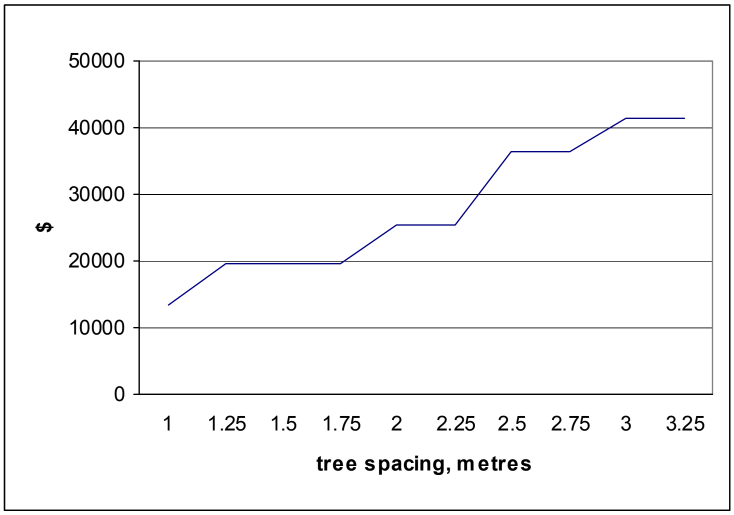

**Figure 6**

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Figure 6

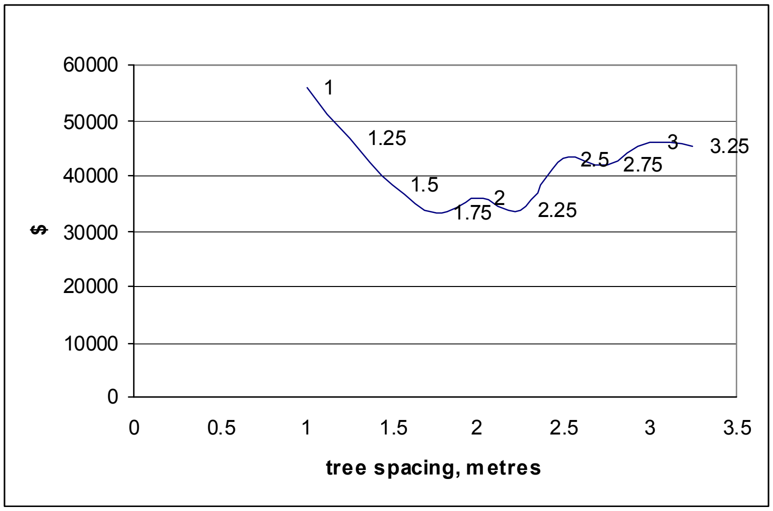

**Figure 7**
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Figure 7