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# Analysing the economic potential of forestry for carbon sequestration under alternative carbon price paths

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**November 2008**

Lawson, K., Burns, K., Low, K., Heyhoe, E. and Ahammad, H., 2008, *Analysing the economic potential of forestry for carbon sequestration under alternative carbon price paths,* Canberra, November.

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# Summary

The Commonwealth Treasury has commissioned the Australian Bureau of Agricultural and Resource Economics (ABARE) to estimate the potential increase in afforestation on agricultural land under four hypothetical carbon price scenarios. The carbon price is expressed as dollars per tonne of carbon dioxide (\$/t$CO_2$) and the carbon price path is defined for the period ranging between 2007 and 2100.

The aim of this report is to describe the methodology and assumptions underlying ABARE estimates and analysis and the results from selected scenarios. Assumptions relating to the land available to afforestation and the costs of undertaking these activities are important determinants of the potential for switching from agricultural production to timber plantations or environmental plantings.

ABARE modelled a range of carbon price scenarios for the Treasury. Results are presented here for the CPRS -5 carbon price scenario (in which the carbon price begins at \$20.88/t $CO_2$ in 2010) and the CPRS -15 carbon price scenario (in which the carbon price begins at \$29.10/t $CO_2$ in 2010). In each of these the carbon price is assumed to increase by an average of 4 per cent a year to 2100, The results presented in this report indicate that under the CPRS -5 carbon price scenario the area of agricultural land that is economically suitable for afforestation between 2007 and 2050 is estimated to be 5.8 million hectares. Approximately 47 per cent of this area (2.7 million hectares) is estimated to be environmental plantings. In comparison, the area suitable for afforestation between 2007 and 2050 is estimated to be significantly higher under the CPRS -15 carbon price scenario, reaching around 26 million hectares. Of this, approximately 83 per cent or 21.8 million hectares is projected to be dedicated to environmental plantings.

Given the specific assumptions and the methodology, the estimates presented in this report should be interpreted as conditional projections and not forecasts. However, results presented in this report seem to suggest that the introduction of a carbon price can substantially influence land use change in Australia.

# 1. Introduction

The introduction of a carbon price under the proposed Carbon Pollution Reduction Scheme (CPRS) may be effective in promoting afforestation in Australia and contribute to Australia's emission's target through carbon sequestration. Rates of sequestration will depend on the stringency of the emissions reduction target and hence, the level of the carbon price. However, the rate of afforestation because of the carbon price may potentially affect the attractiveness of agricultural land use activities in Australia. In general, higher carbon prices are expected to decrease the profitability and attractiveness of other land use activities, such as agriculture, in favour of timber plantations and environmental plantings which generate carbon credits under the CPRS.

ABARE has been commissioned by the Commonwealth Treasury to estimate the potential increase in afforestation activity on agricultural land under four hypothetical scenarios and a reference case. The key assumptions underlying ABARE estimates are described in some detail in this report. Assumptions relating to the cost of investment of afforestation and the area of land available for switching are important determinants of the land use conversion. Afforestation activity is assumed to include the establishment of commercial plantations and environmental plantings between 2007 and 2100.

In this report, the impact of two hypothetical carbon price scenarios is examined in detail — the CPRS -5 carbon price (in which the carbon price begins at \$20.88/t $CO_2$ in 2010) and the CPRS -15 carbon price scenario (in which the carbon price begins at \$29.10/t $CO_2$ in 2010). In each of these the carbon price is assumed to increase by an average rate of 4 per cent between 2010 and 2100. The results measure the area of cleared agricultural land in Australia that is economically suitable for afforestation, to the extent that the estimated returns to forestry exceed the estimated land values under existing agricultural activities. The results from the analysis are presented for five periods ranging between 2007 and 2050 for New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania and Northern Territory. The impact of a carbon price is expressed as increases in the economic potential of afforestation on cleared agricultural land. Estimates of the carbon sequestration potential of afforestation are also presented. Results for two additional scenarios — the Garnaut -10 carbon price (in which the carbon price begins at \$25/t $CO_2$ in 2013) and the Garnaut –25 carbon price scenario (in which the carbon price begins at \$45/t $CO_2$ in 2013) are presented in Appendix C.

# 2. Analytical framework

The analytical framework presented in this report is aimed at assessing the potential impact of a carbon price on land use change in the Australian agriculture sector. The framework is spatially explicit, and involves analysing the opportunities for carbon sequestration provided by land use change and afforestation on cleared agricultural land. These opportunities are determined by comparing the net present value (NPV) of returns from forestry investments to the corresponding expected agricultural returns and estimating the potential area of clear agricultural land that is economically suitable for afforestation within each spatial grid cell.

The assumed percentage changes each year to the returns to agriculture and timber over the period 2007-2050 are based on Treasury projections. These changes are applied to both agricultural land values; and the returns and costs associated with timber plantations.

## Assumptions

The model used to undertake this analysis estimates returns from afforestation activity and compares these with ABARE estimates of agricultural returns. The model employs spatial data relating to forestry yields, agricultural land use and distances from timber processing centres to provide state and national estimates of land use change potential. Due to the scale of the analysis, a number of simplifying assumptions are used.

The principal assumptions used in this analysis are:

- There is only a finite area of land available for agriculture and afforestation. The analysis incorporates non-forested land used for all agricultural activities, including minimally adjusted pastures used for livestock production in remote areas of Australia. The extent of new land dedicated to forestry is determined by the relative net present value of afforestation compared to the value of agricultural activities competing for the land.

- The model does not consider possible restrictions on forestry expansion for conservation reasons, the potentially negative environmental impacts of afforestation such as reduced water runoff and rainfall, regional capacity constraints in timber processing or other factors leading to landholder resistance to land conversion. These considerations may significantly limit the increase in forestry activity.

- Additionally, there may be some areas of cleared land in the spatial land availability data set that represents land that was cleared after 1990, and as such would not be available for conversion to a "Kyoto forest." Hence, the areas presented in this paper as being available for conversion to forestry represent an upper bound of that potential.

- Forestry returns are calculated based on an assumption of even aged development, so that an investor will plant an equal area of forest each year. This means that each investor is assumed to own a forest estate, and as such after the first harvest age is reached for the first plantation, the amount of sequestration in each year exactly matches the amount of emissions for that investor. Hence, the investor does not receive any further carbon credits nor do they pay for emission permits after this time.

- All land use change decisions are assumed to be determined by comparing the net present value of returns from afforestation activities to agriculture. The returns from the carbon price are assumed to be received by the landholder on an annual basis. However, no assumptions have been made as to when the returns from agriculture are received by the landholder. Hence, differences in cash flow between the returns to agriculture and forestry are assumed to not affect land use change behaviour.

- There are no assumptions made regarding any endogenous commodity or land price effects arising from the land use changes projected in the model.

- The returns to agriculture are assumed to be unaffected by the implementation of the CPRS. For the emission intensive livestock production in particular, returns may be reduced if agriculture is included in the CPRS.

- The carbon accounting provisions of the Kyoto Protocol are assumed to remain unchanged during the course of the 21$^{st}$ century. Consequently, there is no reportable contribution to mitigation, or emissions removal, by soil toward removal of greenhouse gases from the atmosphere.

- For this analysis, we examine the potential carbon sequestration implications for the entire area that is economically suitable for afforestation. This implies that the areas presented in this report as being available for conversion to forestry represent an upper bound of that potential.

- We assume that the potential rate of afforestation is restricted for each period, such that approximately 75 per cent of the entire economically suitable area is assumed to be converted into forests between 2007 and 2030. The remaining 25 per cent of economically suitable land is assumed to be converted after 2030. This report presents results for the period 2007 to 2050.

- The rate of land use change is based on the estimated rotation length of the forests plantations. These rotation lengths vary across regions in terms of the tree species, the timing of forest thinnings and harvesting. In this analysis, the rotation length of timber plantations is assumed to range from 10 to 35 years. In comparison, equal areas of environmental plantings are assumed to be planted over a 45 year horizon.

## Estimating the returns from agriculture

The vegetation cover data set used for identifying the potential cleared agricultural land in Australia was obtained from the Bureau of Rural Sciences (BRS) and the Department of Climate Change (DCC). In this analysis, the value of the cleared agricultural land represents the opportunity cost of establishing forests. This data is based on 10 year averages of estimated agricultural land values collected through ABARE farm surveys. Spatial datasets of potential agricultural land values for four aggregated industries (grains, livestock, dairy and sugar) were derived by applying a smoothing algorithm to the ABARE data. Further, cleared agricultural land is considered in this analysis to include grasslands and minimally modified pastures.

The average annual growth in land values is informed by Commonwealth Treasury modelling. In this analysis, the average growth in the land values is assumed to range from 4 to 5 per cent per annum across the states of Australia under all scenarios.

## Estimating the returns from afforestation

The NPV of afforestation is determined by calculating the returns under a carbon pricing scheme at an annual real discount rate of 7 per cent over a 50 year time horizon. The 7 per cent real annual discount rate used in this analysis is consistent with guidelines suggested by the Office of Best Practice Regulation (OBPR) (Australian Government 2007). This represents a market weighted average rate, based on before-tax market returns on investment in Australia, after tax returns to consumers and the marginal cost of foreign funds.

The returns from afforestation are assumed to include traditional timber production and the returns from carbon sequestration. Further, the returns from new timber plantations and environmental plantings are distinguished in this report to assist in analysing the impact of a carbon price on land use change.

### *Estimating the returns from timber production*

In this analysis, it is assumed that the return from traditional production is equal to the average mill-door log price receivable in each state. These mill-door log prices are assumed to range from $42/m$^3$ to $71.5/m$^3$ in 2007 (Table 1). The variation in the mill-door log price is attributed to the differences in the demand and supply of softwood and hardwood timber across states. Only one price is estimated for hardwood (broadleaved) and softwood (coniferous) logs. However, these prices are a good approximation of the expected return from native and forest plantations in Australia between 2000-2001 and 2006-2007 (ABARE 2008). Mill-door log prices by state and species are derived from ABARE forest industry survey data.

Table 1: Assumed mill-door price by type in the reference case, 2007

| | | **Hardwood** | **Softwood** |
|---|---|---|---|
| New South Wales | $/m$^3$ | 54.5 | 52.0 |
| Victoria | $/m$^3$ | 62.8 | 59.6 |
| Queensland | $/m$^3$ | 54.5 | 66.8 |
| South Australia | $/m$^3$ | 62.8 | 61.9 |
| Western Australia | $/m$^3$ | 71.5 | 59.6 |
| Tasmania | $/m$^3$ | 60.6 | 61.0 |
| Northern Territory | $/m$^3$ | 67.3 | 42.0 |

Source: ABARE (2008)

The annual increase in returns from timber production in this analysis is informed by Commonwealth Treasury modelling. These returns from timber production are assumed to increase by around 3 to 6 per cent each year across the Australian states. It is also assumed that timber processing industries have the necessary capacity to accommodate any increase in timber production from the forestry sector between 2007 and 2050. However, the feasibility of the timber processing industry to accommodate such an increase is not assessed in this analysis.

Timber plantation investors are assumed to have perfect foresight regarding all price movements. Further, new timber plantations are assumed to be established as even aged estates in this analysis. These estates are assumed to be established at the same rate at which timber is harvested from the plantation. Hence, the volume of carbon sequestrated from the timber plantation throughout the rotation period is equal to the harvested emissions.

Of all land identified as economically suitable for plantations, on the basis of the relative land values, approximately 75 per cent is assumed to be converted into forests between 2007 and 2030. After 2030, the remaining 25 per cent of all land identified as economically suitable for plantations is assumed to be converted into forests. This approach is adopted in order to be consistent with the “Reforestation Best ‘Medium’ Estimate” scenario of the Department of Climate Change (DCC 2007).

### *Estimating the returns produced by the carbon price*

The returns generated from the carbon price are assumed to be received annually based on the volume of carbon sequestered in that year. The carbon price is assumed to grow on average at 4 per cent per year from 2013 to 2100 and returns from the carbon price received annually by the landholder. The volume of carbon credit returns that may be claimed by a forest owner is assumed to be 100 per cent of the total carbon sequestered in the roots, trunks and branches of the forest planting. A discussion of the methodology used to derive the volume of carbon sequestered by forests is presented in Appendix A.

In regards to timber plantations, carbon credits are obtained from the growth of the plantation until the first harvest age is reached after which it is assumed that net sequestration in the forest is zero. These returns from carbon sequestration are added to the returns from timber production appropriately. The projected amount of carbon sequestrated and emitted from timber plantations is assumed to follow the default assumptions used in the Kyoto Protocol emission accounting methodology. Under the Kyoto Protocol, timber plantation investors are assumed to earn credits each year because of the carbon price. However, these investors must pay for all the emissions sequestrated throughout the plantation cycle upon harvest. In comparison, landholders of environmental plantings receive a return each year because of the carbon price until the forest reaches maximum biomass potential. The maximum biomass potential of these environmental plantings is assumed in this analysis to be 45 years. Further, environmental plantings are assumed to commence sequestrating carbon in the same year as they are established.

### *Cost assumptions*

The cost assumptions relating to the establishment, harvesting and transport of timber plantations and environmental plantings are based on data from NSW Department of Primary Industries (Roberts 2007) and ABARE estimates (Table 2). These costs are assumed to remain constant in the analysis, but are discounted at a rate of 7 per cent each year in the NPV calculations. Further, the cost assumptions presented in Table 2 are based on large-scale investments and may differ considerably from small-scale operations.

Table 2: Cost assumptions, 2007

| | | Timber plantations | Environmental plantings |
|---|---|---|---|
| Establishment | \$/ha | 2500 | 2000 |
| Management | \$/ha | 180 | 0 |
| Harvesting | \$/m$^3$ | 22 | 0 |
| Transport | \$/m$^3$.km | 0.123 | 0 |

Source: ABARE estimates; Roberts (2007)

The establishment costs presented in Table 2 include land preparation, planting and fertiliser application which are assumed to occur only in the year when the forest is established. In comparison, the management, harvesting and transport costs incurred by timber plantations are dependent on the plantation size and amount of logs produced during a specific year.

The environmental plantings regime used in this analysis employ yields based on native vegetation growth in the absence of silvicultural management. Therefore, the cost assumptions presented in Table 2 assumes that there are no ongoing management costs associated with environmental plantings.

## Model scenarios

Three different scenarios are analysed in this report to provide insights into the economic potential of forestry for carbon sequestration under the CPRS. Firstly, a reference case is presented to analyse the interactions between forestry and agricultural land use activities in the absence of any carbon price. Secondly, a carbon price scenario (CPRS -5) is presented in which a \$20.88/t$CO_2$ carbon price is assumed to be introduced in Australia at 2010 and to increase at an average rate of 4 per cent per annum to 2100. Finally, the impact of a relatively higher carbon price scenario (CPRS -15) is examined, in which a \$29.10/t$CO_2$ carbon price is introduced in 2010, increasing the same rate as the previous scenario. The scenarios are further described below.

### *Scenario 1: Reference case*

The reference case is representative of a world where the technological and policy development of Australia progresses along their expected pathways. In the reference case, it is assumed that there are no significant changes to Australia’s policy and technological settings. It is also assumed that a carbon price will not be introduced. However, forest owners are capable of generating a return from the sale of timber logs, which is assumed to increase in value at a rate of around 3 to 6 per cent each year.

### *CPRS -5 Scenario: assumes a \$20.88/tCO₂ carbon price in 2010*

In this scenario a \$20.88/t$CO_2$ carbon price is assumed to be implemented in 2010. Further, this price is assumed to increase by an average of 4 per cent each year to 2100. The carbon permit returns are assumed to be received annually by the landholder. Timber plantation owners are also able to generate an additional return from forestry through the sale of timber logs, with prices the same as assumed in the reference case.

### *CPRS -15 Scenario: assumes a \$29.10/tCO₂ carbon price in 2010*

In this scenario it is assumed that Australia will introduce a \$29.10/t$CO_2$ carbon price in 2010. As in the CPRS -5 carbon price scenario, this price is assumed to increase by an average rate of 4 per cent annually until 2100. The carbon permit returns are assumed to be received annually by the landholder. Timber plantation owners are also able to generate an additional return from forestry through the sale of timber logs, with prices the same as assumed in the reference case.

# 3. Results

This section presents ABARE estimates of the economically suitable area for forest plantations and the associated potential sequestered carbon under three scenarios described earlier for the period 2000-2050. The modelling results suggest that the introduction of a carbon price can significantly increase the economic potential of afforestation in Australia. For comparison, the estimated area of new forest plantations established between 2000 and 2006 are also presented. The large expansion in forest land area between 2000 and 2006 is attributed to a favourable investment environment and strong demand for Australian timber products from overseas (ABARE 2007; BRS 2007). Maps of the land areas identified as being economically suitable for conversion to forestry under alternative carbon price paths are presented in Appendix B. For comparison, the modelling results for the Garnaut carbon price scenarios, where the carbon price is introduced from 2013, are presented in Appendix C.

### *Scenario 1: Reference case*

In the reference case, approximately 610 000 hectares of new plantations are projected to be established between 2007 and 2050 (Table 3). All of these are estimated to be timber plantations, there are assumed to be no returns available to environmental plantations in the absence of a carbon price. Western Australia is projected to have the largest uptake of new forest plantations in the reference case compared to the other states in Australia, with a significant majority being due to an increase in short rotation hardwood investments between 2007 and 2012. Queensland is projected to have the second highest rate of timber plantation investment over the projection period.

Table 3: Reference case – area economically suitable for afforestation, 2000-2050

| | **2000-2006** ‘000 ha | **2007-2012** ‘000 ha | **2013-2022** ‘000 ha | **2023-2032** ‘000 ha | **2033-2042** ‘000 ha | **2043-2050** ‘000 ha | **2007-2050** ‘000 ha |
|---|---|---|---|---|---|---|---|
| Timber plantations | | | | | | | |
| NSW | 42 | 4 | 3 | 2 | 2 | 1 | 12 |
| VIC | 119 | 9 | 7 | 5 | 4 | 3 | 28 |
| QLD | 49 | 21 | 17 | 46 | 43 | 12 | 140 |
| SA | 45 | 9 | 7 | 4 | 4 | 3 | 26 |
| WA | 154 | 190 | 63 | 45 | 45 | 36 | 379 |
| TAS | 91 | 4 | 3 | 9 | 8 | 2 | 26 |
| NT | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | 523 | 237 | 100 | 110 | 105 | 57 | 610 |

The total amount of carbon sequestrated from the additional area of timber plantations projected in the reference case is expected to be around 30.2 Mt of carbon over the period 2007-2050 (Table 4). See Appendix A for details on how the sequestered carbon is estimated. Most of the carbon sequestered between 2007 and 2050 is projected to be from short rotation hardwood investments in Western Australia.

Table 4: Reference case – potential carbon sequestered from land economically suitable for afforestation, 2007-2050

| | **2000-2006** | **2007-2012** | **2013-2022** | **2023-2032** | **2033-2042** | **2043-2050** | **2007-2050** |
|---|---|---|---|---|---|---|---|
| | '000 t | '000t | '000t | '000t | '000t | '000t | '000t |
| Timber plantations | | | | | | | |
| NSW | - | 27 | 112 | 170 | 232 | 230 | 771 |
| VIC | - | 67 | 279 | 436 | 609 | 602 | 1 994 |
| QLD | - | 144 | 601 | 1 419 | 2 622 | 2 695 | 7 481 |
| SA | - | 60 | 251 | 378 | 516 | 511 | 1 716 |
| WA | - | 707 | 2 594 | 3 271 | 4 318 | 4 209 | 15 099 |
| TAS | - | 58 | 244 | 592 | 1 110 | 1 142 | 3 146 |
| NT | - | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | - | 1 065 | 4 080 | 6 266 | 9 407 | 9 389 | 30 207 |

- Not estimated
tonnes of carbon = tonnes of carbon dioxide*12/44

### *Scenario 2: CPRS -5 carbon price scenario assuming a $20.88/tCO_2$ carbon price in 2010*

The introduction of a carbon price in this scenario is projected to increase the area of land economically suitable for afforestation in Australia to around 5.8 million hectares by 2050 (Table 5). Of this, 3.0 million hectares are projected to be timber plantations, and 2.7 million hectares are environmental plantings. A large proportion of the timber plantations are projected to be planted in southern Australia, particularly Tasmania, South Australia and Victoria. In contrast, environmental plantings are projected to be most suitable in the north, particularly Queensland, New South Wales and Northern Territory.

Table 5: CPRS -5 carbon price scenario – area economically suitable for afforestation, 2000-2050

| | 2000-2006 | 2007-2012 | 2013-2022 | 2023-2032 | 2033-2042 | 2043-2050 | 2007-2050 |
|---|---|---|---|---|---|---|---|
| | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha |
| Timber plantations | | | | | | | |
| NSW | 42 | 26 | 73 | 116 | 44 | 34 | 293 |
| VIC | 119 | 45 | 122 | 195 | 74 | 56 | 491 |
| QLD | 49 | 44 | 100 | 168 | 78 | 57 | 447 |
| SA | 45 | 40 | 108 | 234 | 178 | 59 | 619 |
| WA | 154 | 152 | 160 | 84 | 84 | 67 | 546 |
| TAS | 91 | 25 | 73 | 213 | 213 | 126 | 651 |
| NT | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | 523 | 331 | 636 | 1 010 | 670 | 399 | 3 047 |
| Environmental plantings | | | | | | | |
| NSW | - | 33 | 111 | 111 | 111 | 89 | 456 |
| VIC | - | 1 | 2 | 2 | 2 | 2 | 9 |
| QLD | - | 112 | 373 | 373 | 373 | 298 | 1 527 |
| SA | - | 1 | 5 | 5 | 5 | 4 | 19 |
| WA | - | 3 | 8 | 8 | 8 | 7 | 35 |
| TAS | - | 0 | 0 | 0 | 0 | 0 | 1 |
| NT | - | 51 | 169 | 169 | 169 | 135 | 692 |
| AUS | - | 200 | 668 | 668 | 668 | 535 | 2 740 |

- Not estimated

The potential volume of carbon sequestered by these additional forest areas in this scenario is projected to be around 296Mt of carbon over the period 2007-2050 (Table 6), although additional sequestration will occur after this period.

Table 6: CPRS -5 carbon price scenario – potential carbon sequestered from land economically suitable for afforestation, 2007-2050

| | **2000-2006** '000 t | **2007-2012** '000 t | **2013-2022** '000 t | **2023-2032** '000 t | **2033-2042** '000 t | **2043-2050** '000 t | **2007-2050** '000 t |
|---|---|---|---|---|---|---|---|
| Timber plantations | | | | | | | |
| NSW | - | 125 | 1 430 | 4 272 | 6 225 | 6 161 | 18 213 |
| VIC | - | 229 | 2 478 | 7 369 | 10 785 | 10 627 | 31 488 |
| QLD | - | 236 | 1 895 | 5 448 | 8 264 | 8 373 | 24 216 |
| SA | - | 167 | 1 753 | 5 631 | 9 722 | 10 000 | 27 274 |
| WA | - | 676 | 2 847 | 4 691 | 6 489 | 6 486 | 21 189 |
| TAS | - | 223 | 2 608 | 9 812 | 20 508 | 23 756 | 56 906 |
| NT | - | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | - | 1 656 | 13 010 | 37 224 | 61 994 | 65 402 | 179 286 |
| Environmental plantings | | | | | | | |
| NSW | - | 211 | 2 989 | 6 505 | 10 021 | 10 549 | 30 275 |
| VIC | - | 4 | 62 | 135 | 208 | 219 | 628 |
| QLD | - | 442 | 6 268 | 13 641 | 21 015 | 22 121 | 63 488 |
| SA | - | 3 | 48 | 105 | 161 | 170 | 488 |
| WA | - | 6 | 85 | 186 | 286 | 301 | 864 |
| TAS | - | 0 | 6 | 13 | 20 | 21 | 60 |
| NT | - | 143 | 2 031 | 4 419 | 6 808 | 7 167 | 20 568 |
| AUS | - | 811 | 11 488 | 25 004 | 38 520 | 40 547 | 116 371 |

- Not estimated
tonnes of carbon = tonnes of carbon dioxide*12/44

### *Scenario 3: CPRS -15 carbon price scenario assuming a $29.10/CO2 carbon price starting in 2010*

Under the CPRS -15 carbon price scenario, the area of agricultural land economically suitable for afforestation in Australia is projected to be around 26 million hectares by 2050, with 83 per cent of this being environmental plantings (Table 7). The small additional timber plantations under this scenario compared to the CPRS -5 carbon price scenario reflects the constraints on timber plantation areas, particularly the distance of sites from processing centres and minimum yield requirements. The large increase in environmental plantings relative to the CPRS -5 scenario reflects the substantial difference in carbon price between the two scenarios and the therefore the improved profitability of environmental plantings. Most of the timber plantations are projected to be established in southern Australia, while environmental plantings are expected to be established predominantly in eastern Australia.

Table 7: CPRS -15 carbon price scenario – area economically suitable for afforestation, 2000-2050

| | **2000-2006** | **2007-2012** | **2013-2022** | **2023-2032** | **2033-2042** | **2043-2050** | **2007-2050** |
|---|---|---|---|---|---|---|---|
| | '000 ha | '000 ha | '000 ha | '000 ha | '000 ha | '000 ha | '000 ha |
| Timber plantations | | | | | | | |
| NSW | 42 | 37 | 107 | 179 | 81 | 59 | 464 |
| VIC | 119 | 83 | 235 | 378 | 146 | 109 | 950 |
| QLD | 49 | 34 | 71 | 112 | 42 | 33 | 293 |
| SA | 45 | 67 | 191 | 394 | 278 | 101 | 1 031 |
| WA | 154 | 172 | 218 | 111 | 111 | 89 | 700 |
| TAS | 91 | 40 | 121 | 353 | 353 | 209 | 1 076 |
| NT | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | 523 | 433 | 943 | 1 526 | 1 011 | 601 | 4 514 |
| Environmental plantings | | | | | | | |
| NSW | - | 581 | 1 938 | 1 938 | 1 938 | 1 550 | 7 945 |
| VIC | - | 6 | 21 | 21 | 21 | 16 | 84 |
| QLD | - | 775 | 2 583 | 2 583 | 2 583 | 2 067 | 10 591 |
| SA | - | 35 | 117 | 117 | 117 | 94 | 481 |
| WA | - | 96 | 319 | 319 | 319 | 255 | 1 308 |
| TAS | - | 0 | 0 | 0 | 0 | 0 | 1 |
| NT | - | 102 | 342 | 342 | 342 | 273 | 1 400 |
| AUS | - | 1 596 | 5 320 | 5 320 | 5 320 | 4 256 | 21 812 |

- Not estimated

In this scenario, the potential level of carbon sequestration in the economically suitable areas is estimated to be 885Mt of carbon over the period 2007-2050 (Table 8), although there will be significant additional sequestration after this period. Sequestration from environmental plantings dominates the level of sequestration across all decades, accounting for around 70 per cent of the total carbon sinks over the entire period to 2050.

Table 8: CPRS -15 carbon price scenario – potential carbon sequestered from land economically suitable for afforestation, 2007-2050

| | **2000-2006** | **2007-2012** | **2013-2022** | **2023-2032** | **2033-2042** | **2043-2050** | **2007-2050** |
|---|---|---|---|---|---|---|---|
| | '000 t | '000 t | '000 t | '000 t | '000 t | '000 t | '000 t |
| Timber plantations | | | | | | | |
| NSW | - | 161 | 1 925 | 5 902 | 8 960 | 9 066 | 26 016 |
| VIC | - | 391 | 4 636 | 13 993 | 20 603 | 20 366 | 59 989 |
| QLD | - | 182 | 1 332 | 3 710 | 5 347 | 5 269 | 15 840 |
| SA | - | 251 | 2 898 | 9 316 | 15 718 | 16 083 | 44 266 |
| WA | - | 712 | 3 386 | 5 773 | 8 045 | 8 072 | 25 987 |
| TAS | - | 326 | 4 040 | 15 320 | 32 066 | 37 158 | 88 910 |
| NT | - | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | - | 2 024 | 18 218 | 54 014 | 90 739 | 96 013 | 261 008 |
| Environmental plantings | | | | | | | |
| NSW | - | 1 832 | 25 956 | 56 493 | 87 029 | 91 610 | 262 920 |
| VIC | - | 30 | 427 | 929 | 1 431 | 1 506 | 4 322 |
| QLD | - | 2 034 | 28 810 | 62 704 | 96 597 | 101 681 | 291 826 |
| SA | - | 63 | 888 | 1 933 | 2 978 | 3 135 | 8 997 |
| WA | - | 162 | 2 293 | 4 991 | 7 689 | 8 094 | 23 229 |
| TAS | - | 1 | 8 | 17 | 27 | 28 | 81 |
| NT | - | 225 | 3 180 | 6 922 | 10 664 | 11 225 | 32 216 |
| AUS | - | 4 346 | 61 562 | 133 989 | 206 415 | 217 279 | 623 591 |

- Not estimated
tonnes of carbon = tonnes of carbon dioxide*12/44

## The sensitivity of different land types to land use change

The majority of the economically suitable areas for these types of afforestation are estimated to be on grazing land. Grazing land is generally more sensitive to changes in relative profitability/returns because they have lower levels of profitability relative to other agricultural activities such as sugar or horticulture. However, there may be potential for land use change on all agricultural land types if the relative returns from forestry increases. The higher returns from forestry can be caused by an increase in demand for Australian wood products or if a higher carbon price is introduced. Similarly, the relative return of afforestation may increase if the return of other land use activities declines. These declines may be a result of lower productivity on agricultural land caused by various factors including changes in the price of agricultural goods.

# 4. Conclusion

The results generated using the spatial framework suggests that Australia's agriculture sector may experience an increase in land use change in favour of new afforestation in a carbon constrained policy environment. However, these results are highly dependent on specific assumptions. In particular, the inclusion of grasslands and minimally adapted pastures greatly expands the available land area.

Three scenarios were analysed in this report to determine the impact of assumed carbon price paths on agricultural land use change activity. In the reference case, which assumed no carbon price in Australia, the area of land economically suitable for afforestation activity between 2007 and 2050 was projected to be around 610 000 hectares. However, the introduction of a \$20.88/t$CO_2$ carbon price path from 2010 was estimated in this report to increase the economically suitable area for afforestation to around 5.8 million hectares. These new plantings are a combination of both timber plantations and environmental plantings. In comparison, it is estimated that approximately 26 million hectares of agricultural land would be economically suitable for afforestation if a \$29.10/t$CO_2$ carbon price path is introduced by 2010.

The level of the carbon price will influence the share of land dedicated to environmental plantings. Under a \$20.88/t$CO_2$ carbon price path, less than half of the economically suitable land (around 2.7 million hectares) was suitable for environmental plantings, with the remaining 3.0 million hectares being suitable for timber plantations. In comparison, under a \$29.10 /t$CO_2$ price path, more than 80 per cent of the economically suitable land area (around 21.8 million hectares) is estimated to be suitable for environmental plantings, with the remaining 4.5 million hectares being dedicated to timber plantations.

In both carbon price scenarios, it was estimated that the majority of new plantings established between 2007 and 2050 would occur in Queensland and New South Wales. The high uptake of new afforestation in these two states could potentially be due to the large areas of available land, and highly productive grazing land located within these regions.

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# Appendix A: Estimating the carbon sequestration in forests

The carbon sequestration potential of the new forest planting within each grid cell is determined by equation 1:

$$SC = M \times (1+RSR) \times BC \qquad (1)$$

where *SC* is the estimated sequestered tree carbon (tC/ha); *M* is the maximum obtainable aboveground biomass (t/ha); *RSR* is the carbon sequestered by the planting's root in comparison to its shoot (assumed to be 0.25); and *BC* is the conversion rate of biomass into carbon (assumed to be 50 per cent). The maximum aboveground biomass (*M*) is assumed to be a function of the National Carbon Accounting System Forest Productivity Index (*FPI*) as follows:

$$M = (6.019 \times (FPI)^{1/2} - 5.2912)^2 \qquad (2)$$

In this analysis, the cumulative growth of a planting, expressed as an increase in biomass at age *a* is calculated using equation 3:

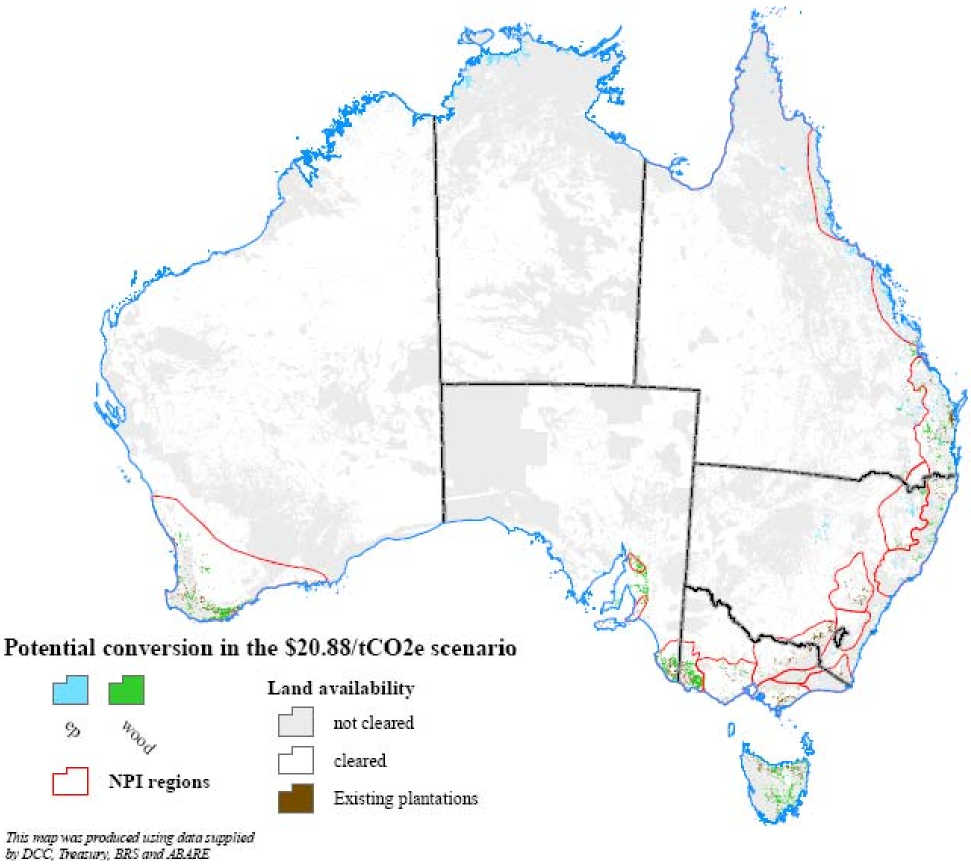
$$M_a = M \times e^{(-2G+1.25)/a} \qquad (3)$$

Where $M_a$ is the cumulative growth in biomass at age *a*; *a* is the age of the forest in years; and *G* is the age of the forest in which the maximum biomass increment is reached (assumed to be 10 years in this analysis). The marginal growth in biomass each year is calculated by subtracting $M_{(a-1)}$ from $M_a$. Similarly, the carbon sequestered in each year is derived by substituting the annual growth in biomass of the environmental planting into equation 1. The productivity values used in the analysis are estimates from the median quartile of the potential biomass within the relevant area. The relevant area is determined by intersecting the survey region boundaries with the 2001/02 (version 3) national land use map of Australia compiled by the Bureau of Rural Sciences.

# Appendix B: Potential landuse conversion to forestry under alternative carbon price paths

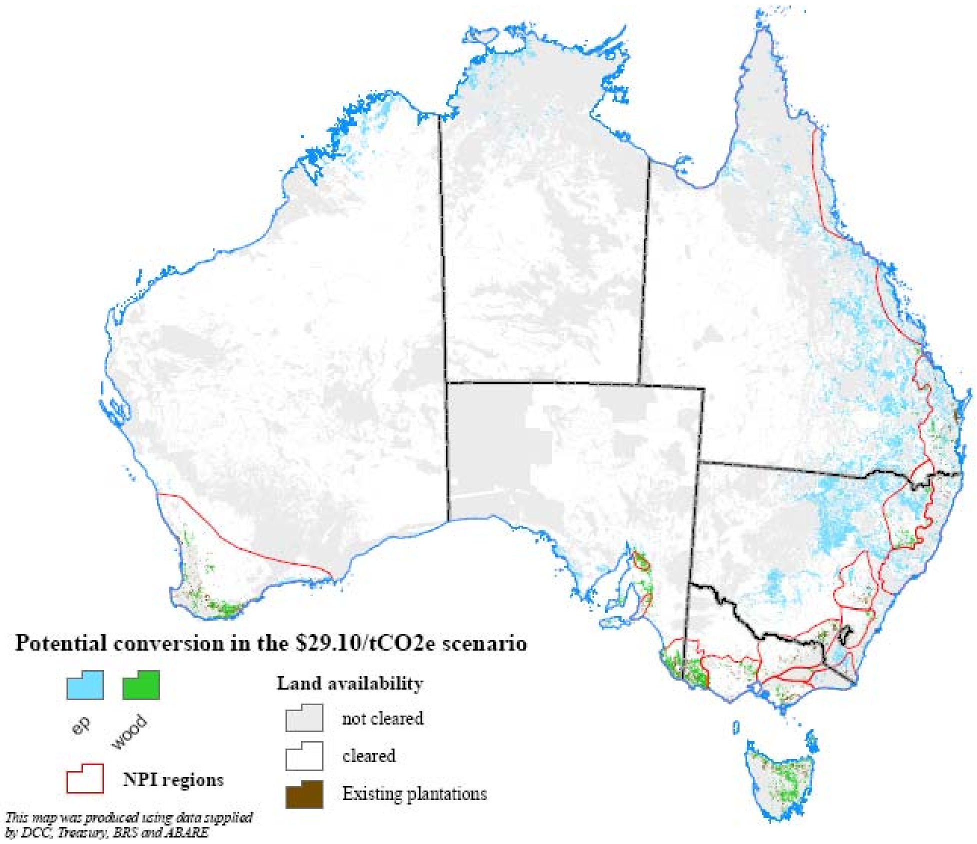
In this Appendix, maps of the potential landuse conversion to forestry under alternative carbon price paths are presented.

Figure 1: Potential land use conversion to forestry under the CPRS -5 carbon price path




Source: This map was produced using data supplied by DCC, Treasury, BRS and ABARE

Figure 2: Potential land use conversion to forestry under the CPRS -15 carbon price path




Source: This map was produced using data supplied by DCC, Treasury, BRS and ABARE

# *Appendix C: Economically suitable areas and potential carbon sequestration under Garnaut scenarios*

ABARE has undertaken additional scenarios for the Garnaut Review Team which has also been incorporated into the Treasury modelling. The analysis for the additional scenarios utilises the same modelling framework and cost assumptions. The carbon price paths for the Garnaut scenarios are as follows:

Garnaut -10: carbon price of \$25/t$CO_2$ introduced in 2013.
Garnaut -25: carbon price of \$45/t$CO_2$ introduced in 2013.

In all scenarios the carbon price was assumed to increase by an average of 4 per cent a year to 2100.

Table 9: Garnaut -10 scenario –area economically suitable for afforestation, 2000-2050

| | **2000-2006** | **2007-2012** | **2013-2022** | **2023-2032** | **2033-2042** | **2043-2050** | **2007-2050** |
|---|---|---|---|---|---|---|---|
| | '000 ha | '000 ha | '000 ha | '000 ha | '000 ha | '000 ha | '000 ha |
| Timber plantations | | | | | | | |
| NSW | 42 | 4 | 100 | 156 | 58 | 45 | 363 |
| VIC | 119 | 9 | 195 | 307 | 113 | 85 | 709 |
| QLD | 49 | 21 | 114 | 180 | 69 | 53 | 437 |
| SA | 45 | 9 | 123 | 254 | 183 | 63 | 632 |
| WA | 154 | 190 | 164 | 88 | 88 | 71 | 602 |
| TAS | 91 | 4 | 96 | 278 | 278 | 164 | 819 |
| NT | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | 523 | 237 | 792 | 1 262 | 789 | 482 | 3 562 |
| Environmental plantings | | | | | | | |
| NSW | - | 0 | 344 | 344 | 344 | 275 | 1 308 |
| VIC | - | 0 | 6 | 6 | 6 | 5 | 21 |
| QLD | - | 0 | 578 | 578 | 578 | 462 | 2 195 |
| SA | - | 0 | 10 | 10 | 10 | 8 | 39 |
| WA | - | 0 | 28 | 28 | 28 | 22 | 107 |
| TAS | - | 0 | 0 | 0 | 0 | 0 | 1 |
| NT | - | 0 | 182 | 182 | 182 | 145 | 691 |
| AUS | - | 0 | 1 148 | 1 148 | 1 148 | 918 | 4 362 |

- Not estimated

Table 10: Garnaut -10 scenario – potential carbon sequestered from land economically suitable for afforestation, 2007-2050

| | **2000-2006** '000 t | **2007-2012** '000 t | **2013-2022** '000 t | **2023-2032** '000 t | **2033-2042** '000 t | **2043-2050** '000 t | **2007-2050** '000 t |
|---|---|---|---|---|---|---|---|
| Timber plantations | | | | | | | |
| NSW | - | 27 | 1 323 | 5 274 | 7 875 | 7 851 | 22 350 |
| VIC | - | 67 | 2 683 | 10 621 | 15 926 | 15 793 | 45 091 |
| QLD | - | 144 | 1 619 | 5 619 | 8 308 | 8 260 | 23 951 |
| SA | - | 60 | 1 442 | 5 930 | 10 364 | 10 688 | 28 485 |
| WA | - | 707 | 3 164 | 5 015 | 6 872 | 6 835 | 22 593 |
| TAS | - | 58 | 2 262 | 11 522 | 25 212 | 29 565 | 68 620 |
| NT | - | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | - | 1 065 | 12 493 | 43 982 | 74 558 | 78 992 | 211 090 |
| Environmental plantings | | | | | | | |
| NSW | - | 0 | 3 912 | 11 024 | 18 136 | 19 629 | 52 701 |
| VIC | - | 0 | 89 | 249 | 410 | 444 | 1 193 |
| QLD | - | 0 | 5 478 | 15 438 | 25 398 | 27 490 | 73 805 |
| SA | - | 0 | 59 | 168 | 276 | 298 | 801 |
| WA | - | 0 | 153 | 431 | 709 | 767 | 2 059 |
| TAS | - | 0 | 4 | 11 | 19 | 20 | 54 |
| NT | - | 0 | 1 294 | 3 647 | 6 001 | 6 495 | 17 437 |
| AUS | - | 0 | 10 989 | 30 969 | 50 948 | 55 144 | 148 050 |

- Not estimated

tonnes of carbon = tonnes of carbon dioxide*12/44

Table 11: Garnaut -25 – area economically suitable for afforestation, 2000-2050

| | **2000-2006** | **2007-2012** | **2013-2022** | **2023-2032** | **2033-2042** | **2043-2050** | **2007-2050** |
|---|---|---|---|---|---|---|---|
| | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha | ‘000 ha |
| Timber plantations | | | | | | | |
| NSW | 42 | 4 | 117 | 197 | 94 | 67 | 479 |
| VIC | 119 | 9 | 317 | 500 | 187 | 140 | 1 154 |
| QLD | 49 | 21 | 53 | 80 | 26 | 22 | 202 |
| SA | 45 | 9 | 250 | 504 | 351 | 126 | 1 240 |
| WA | 154 | 190 | 256 | 129 | 129 | 103 | 808 |
| TAS | 91 | 4 | 135 | 388 | 388 | 230 | 1 145 |
| NT | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | 523 | 237 | 1 128 | 1 800 | 1 176 | 688 | 5 028 |
| Environmental plantings | | | | | | | |
| NSW | - | 0 | 3 521 | 3 521 | 3 521 | 2 817 | 13 381 |
| VIC | - | 0 | 65 | 65 | 65 | 52 | 247 |
| QLD | - | 0 | 3 989 | 3 989 | 3 989 | 3 191 | 15 159 |
| SA | - | 0 | 244 | 244 | 244 | 195 | 925 |
| WA | - | 0 | 610 | 610 | 610 | 488 | 2 317 |
| TAS | - | 0 | 2 | 2 | 2 | 1 | 7 |
| NT | - | 0 | 525 | 525 | 525 | 420 | 1 997 |
| AUS | - | 0 | 8 956 | 8 956 | 8 956 | 7 165 | 34 033 |

- Not estimated

Table 12: Garnaut -25 scenario – potential carbon sequestered from land economically suitable for afforestation, 2007-2050

| | **2000-2006** ‘000 t | **2007-2012** ‘000 t | **2013-2022** ‘000 t | **2023-2032** ‘000 t | **2033-2042** ‘000 t | **2043-2050** ‘000 t | **2007-2050** ‘000 t |
|---|---|---|---|---|---|---|---|
| Timber plantations | | | | | | | |
| NSW | - | 27 | 1 397 | 5 779 | 9 173 | 9 445 | 25 821 |
| VIC | - | 67 | 4 231 | 17 152 | 25 839 | 25 678 | 72 968 |
| QLD | - | 144 | 702 | 2 523 | 3 674 | 3 619 | 10 662 |
| SA | - | 60 | 2 528 | 10 894 | 19 021 | 19 610 | 52 114 |
| WA | - | 707 | 3 820 | 6 586 | 9 199 | 9 240 | 29 553 |
| TAS | - | 58 | 3 107 | 16 054 | 35 192 | 41 287 | 95 699 |
| NT | - | 0 | 0 | 0 | 0 | 0 | 0 |
| AUS | - | 1 065 | 15 785 | 58 989 | 102 099 | 108 879 | 286 817 |
| Environmental plantings | | | | | | | |
| NSW | - | 0 | 27 912 | 78 662 | 129 411 | 140 068 | 376 053 |
| VIC | - | 0 | 692 | 1 950 | 3 207 | 3 472 | 9 320 |
| QLD | - | 0 | 26 561 | 74 852 | 123 144 | 133 286 | 357 843 |
| SA | - | 0 | 1 110 | 3 127 | 5 145 | 5 568 | 14 950 |
| WA | - | 0 | 2 788 | 7 858 | 12 927 | 13 992 | 37 564 |
| TAS | - | 0 | 23 | 64 | 106 | 114 | 307 |
| NT | - | 0 | 2 805 | 7 905 | 13 005 | 14 076 | 37 792 |
| AUS | - | 0 | 61 890 | 174 418 | 286 945 | 310 576 | 833 829 |

- Not estimated
tonnes of carbon = tonnes of carbon dioxide*12/44