Coal Operators' Conference

Faculty of Engineering and Information Sciences

2005

Economic Returns From Environmental Problems -- Breeding Salt and Stress Tolerant Eucalypts for Carbon Sequestration, Salinity Abatement and Commercial Forestry

G. Dale
Saltgrow Pty Ltd

Recommended Citation

G. Dale, Economic Returns From Environmental Problems -- Breeding Salt and Stress Tolerant Eucalypts for Carbon Sequestration, Salinity Abatement and Commercial Forestry, in Naj Aziz and Bob Kininmonth (eds.), Proceedings of the 2005 Coal Operators' Conference, Mining Engineering, University of Wollongong, 18-20 February 2019
https://ro.uow.edu.au/coal/171

Economic Returns From Environmental Problems — Breeding Salt and Stress Tolerant Eucalypts for Carbon Sequestration, Salinity Abatement and Commercial Forestry

G Dale[1]

ABSTRACT

Carbon sequestration in planted forests provides an immediately available, low cost option to address the greenhouse impacts of coal mining and coal utilisation in a carbon constrained world. In addition, planted forests also offer the opportunity to address other environmental issues, particularly salinity and loss of biodiversity.

Given salinity is characteristically associated with agriculture in the 500 to 700 mm rainfall belt, then where such forests can also produce commercial timber products, they offer the additional opportunity to establish new, diversified rural employment in both timber growing and processing.

In the majority of Australian catchments affected by salinity, where rainfall is generally less than the 700 mm limit to conventional forestry, and where groundwater reserves are often saline, the objective of achieving economically viable forestry production presents a significant challenge.

In 1996, Saltgrow commenced a collaborative breeding program to combine the salt and stress tolerance of *E camaldulensis*, with the growth rate, stem form and wood properties of the commercial species, *E grandis* and *E globulus*. This program aimed to produce trees with the potential for commercial rehabilitation of saline landscapes. Results covering a range of site conditions from Saltgrow's network of over 100 trials around Australia are presented. The opportunity for commercial plantations integrated with agriculture in low to medium rainfall areas to address salinity and sustainability will be discussed. In addition, the significant potential for partnerships between land-rich, cash-poor farmers, catchment management authorities seeking to invest in public good projects that enhance environmental sustainability, and major carbon producing industries with either mandated or voluntary requirements to curtail net emissions will also be discussed.

INTRODUCTION

In the 2001 - 2002 period, Australia exported just over 200 million tonnes of black coal[†]. Based on an average carbon content for black coal of 75 per cent, this represents 150 million tonnes of carbon, or 550 million tonnes of potential carbon dioxide emissions after combustion. Similarly, domestic consumption of black coal in the 2001 - 2002 period was around 72 million tonnes[†], representing potential CO_2 emissions of 198 million tonnes. Black coal combustion accounts for more than 50 per cent of Australia's electric power generation[†].

At the opening of BHP's Dendrobium colliery at Mt Kembla in November 2003, NSW Premier Bob Carr stated that two Australian Coal suppliers had been told by European buyers that they wished to purchase coal with greenhouse offsets[‡]. With ratification of the Kyoto Protocol by Russia on 18 November 2004, and entry into force of the protocol from 16 February 2005, the pressure from overseas coal purchasers for supply of coal together with greenhouse offsets can be expected to increase. All other factors being equal, suppliers that can provide greenhouse offsets at the most competitive price can be expected to enjoy a market advantage. Similarly in Australia, the NSW Benchmarks scheme has placed pressure on NSW power retailers to reduce CO_2 emissions. It is likely that other states will follow this lead.

Numerous technologies exist to improve coal generation efficiency, to capture and store CO_2 following combustion, to achieve demand side efficiencies, and to avoid net carbon emissions via renewable energy generation. Detailed discussion of these alternatives is beyond the scope of this paper other than to say that many of these options remain developmental or cost prohibitive. In contrast, carbon sequestration via planted forests offers an immediately available, cost effective means of providing carbon offsets, either against domestic consumption, or attached to coal exports.

In addition to their carbon sequestration potential, planted forests offer the potential to address many other environmental issues. Salinity currently affects over 5.6 million ha across Australia, and this is projected to increase to 17 million ha by 2050 without intervention (NLWRA, 2000). Of the projected area to be affected, over 13.6 million ha or 80 per cent is agricultural land (NLWRA, 2000).

Salinity is generally regarded as resulting from clearing of native deep rooted perennial vegetation and its replacement with annual crop and pasture species. This vegetation change, and the associated differences in plant water-use, has lead to an altered water-balance and rise in groundwater tables, ultimately bringing salt stored deep in the soil profile to the surface. Commercially driven tree production systems developed for large areas of the current crop and pasture zones of the Murray Darling Basin is one of three pillars of on-ground action recommended to halt the growth of salinity and loss of native biodiversity in Australia's land and river systems (Stirzaker *et al*, 2000).

However, in the majority of catchments affected by salinity, where rainfall is generally less than the 700 mm limit to conventional forestry, and where groundwater reserves are often saline, the objective of achieving economically viable forestry production presents a significant challenge.

The XYLONOVA Research and Development Program commenced in 1996 with the aim of developing salt and drought tolerant eucalypt hybrids for establishing commercial plantations under low rainfall conditions and on saline, and waterlogged land. The program's primary objective was to combine the salt and drought tolerance plus timber characteristics of *Eucalyptus camaldulensis* with the growth rate, wood quality and form of *E grandis* and *E globulus*. To date 1333 novel varieties have been developed, and over 100 trials and 300 separate planting sites have been established across Australia.

This paper reports on the results of these trials under two different landscape conditions. The results are reviewed in the context of the opportunity for commercial plantations integrated with agriculture in low to medium rainfall areas to address salinity, carbon sequestration and sustainability. In addition, the potential for partnerships among land-rich, cash-poor farmers, catchment management authorities seeking to invest in public good projects that enhance environmental sustainability, and major carbon producing industries with either mandated or voluntary requirements to curtail net emissions will also be discussed.

---

[1] Saltgrow Pty Ltd, PO Box 575, Qld.
Email: glenn.dale@saltgrow.com.au

[†] http://www.australiancoal.com.au/

[‡] http://www.nafi.com.au/news/view.php3?id=729

MATERIALS AND METHODS

Site type 1 – Shallow saline watertable with saline irrigation

In 1998, the first Saltgrow trial was established at Mt Scobie, near Kyabram in northern Victoria. It comprises 217 genotypes from two *E camaldulensis x E grandis* families and four *E camaldulensis* x *E globulus* families. This trial is a single tree plot, incomplete block design with five replicates and a single irrigation treatment using pumped saline groundwater.

The site forms part of a salinity control experiment testing conjunctive water use as a form of integrated on-farm salt management. The trial is located within the draw-down zone of a groundwater pump, and is used to dispose of the saline water extracted by the pump. Irrigation with low salinity water continues on surrounding dairy pasture. The trees are located in an area which had become too saline for continued pasture production, with a soil salinity of approximately 8 to 12 dS/m (ECe). The predominant soil type in the trial area is a Goulburn Loam (a grey-brown loam with a subsoil of yellowish-brown medium to heavy clay), with a tongue of Congupna Clay (grey, gilgaied clay with a heavy clay subsoil) traversing the trial.

The site was irrigated with fresh water for five months following establishment. In the second irrigation season (October 1999 to March 2000), groundwater was diluted 1:1 with fresh water to achieve an EC of 5 dS/m. From the start of the third irrigation season (October 2000) and for all subsequent irrigation seasons, the site has been irrigated with undiluted groundwater at 10 dS/m. As a genetics trial, irrigation with saline water exposes all trees to the same level of salinity.

Mean annual rainfall in the area (Kyabram) is approximately 465 mm, and mean annual evaporation is about 1606 mm. Applied irrigation provides the equivalent of approximately 400 to 600 mm of rainfall, bringing the annual total to around 865 mm. Watertable depth across the site varies between 0.4 and 1.85 m.

Site type 2 – Medium to low rainfall, non-saline recharge sites

In August 2000, a series of six species trials, each comprising 84 hybrid clones and seven unimproved pure species judged as 'best bets' for low/medium rainfall areas, was established in conjunction with State Forests of NSW throughout the western slopes of NSW from Wagga in the south to Boggabri in the north. Pure species used in the winter rainfall trials were *E cladocalyx*, *E camaldulensis*, *E sideroxylon*. *Corymbia maculata* and *Acacia mearnsii*. In the intermediate and summer rainfall trials, *E cladocalyx* and *C maculata* were replaced by *E argophloia* and *C variegata* respectively. The trials span the gradient from winter maximum rainfall, through even annual rainfall to summer maximum rainfall. Rainfall across the six sites ranges from 531 to 707 mm. Other key climatic data are summarised in Table 1.

These six trials were established on non-saline recharge areas, where rainfall not used by annual crops and pastures leaks past the rootzone. Over time, this leakage contributes to a rise in the watertable and leads to salinity outbreaks in downslope areas. The re-establishment of trees in recharge areas aims to prevent rainfall leaking to the watertable, preventing or limiting the spread of salinity.

RESULTS

Site type 1 – Shallow saline watertable with saline irrigation

Figure 1 illustrates the significant gains in stem volume achieved by the hybrids over their pure species parents in the Mt Scobie trial at six years (72 months). For the *E camaldulensis x E grandis* hybrid, the mean volume of all clones is 102 per cent greater than the volume of the best of the two pure species parents. Selection of the top ten per cent of clones increases this yield gain to 203 per cent. For the *E camaldulensis x E globulus* hybrid the volume gain is more pronounced, with the mean stem volume of all clones being 295 per cent greater than the volume of the best of the two pure species parents. Selection of the top ten per cent of clones increases this yield gain to 516 per cent.

Survival of the top ten per cent of *E camaldulensis x E globulus* and *E camaldulensis x E grandis* clones is 100 per cent and 95.6 per cent respectively, compared to pure *E globulus* (five per cent) and pure *E grandis* (24.6 per cent) (data not shown). In contrast to pure *E globulus* and *E. grandis*, survival of pure *E camaldulensis* is 100 per cent, confirming the salt tolerance of this species, but the growth rate, projected at an average to year ten of 3.7 m^3/ha/yr, is well below the commercially viable threshold of around 15 m^3/ha/yr.

Site type 2 – Medium to low rainfall, non-saline recharge sites

While the mean stem volume of both hybrid types was similar to that for the other hardwood species, when compared to the best performing pure hardwood species, (River Red Gum – *E camaldulensis*), the top ten per cent of *E camaldulensis x E globulus* and *E camaldulensis x E grandis* clones performed 63 per cent to 67 per cent better respectively, while the top clone of each hybrid performed 64 to 82 per cent better.

TABLE 1

Key climatic data for medium to low rainfall, non-saline recharge trials. Decile 1 rainfall means that there is a ten per cent chance that the annual rainfall will be at or below this figure.

Station	Mona Vale	Tuffnell Park	Lui Station	Winston Park	Silsoe	Emerald Hills
Locality	Wagga	Junee	Mudgee	Molong	Quirindi	Gunnedah
Rainfall seasonality	Winter	Winter	Even	Even	Summer	Summer
Av annual rainfall (mm)	584	531	675	707	685	619
Decile 1 rainfall (mm)	418	367	430	467	458	377
Lowest min temp (°C)	-6.3	-5.0	-8.3	-8.8	-6.7	-5.6
Highest max temp (°C)	44.8	46.1	42.2	42.3	41.8	43.3
Days <0°C	22.1	24.8	38.5	66.4	31.1	9.8
Days >35°C	18.2	18.2	13.3	12.5	19.6	22
Annual evap (mm)	1825	1825	1752	1825	1934	1934

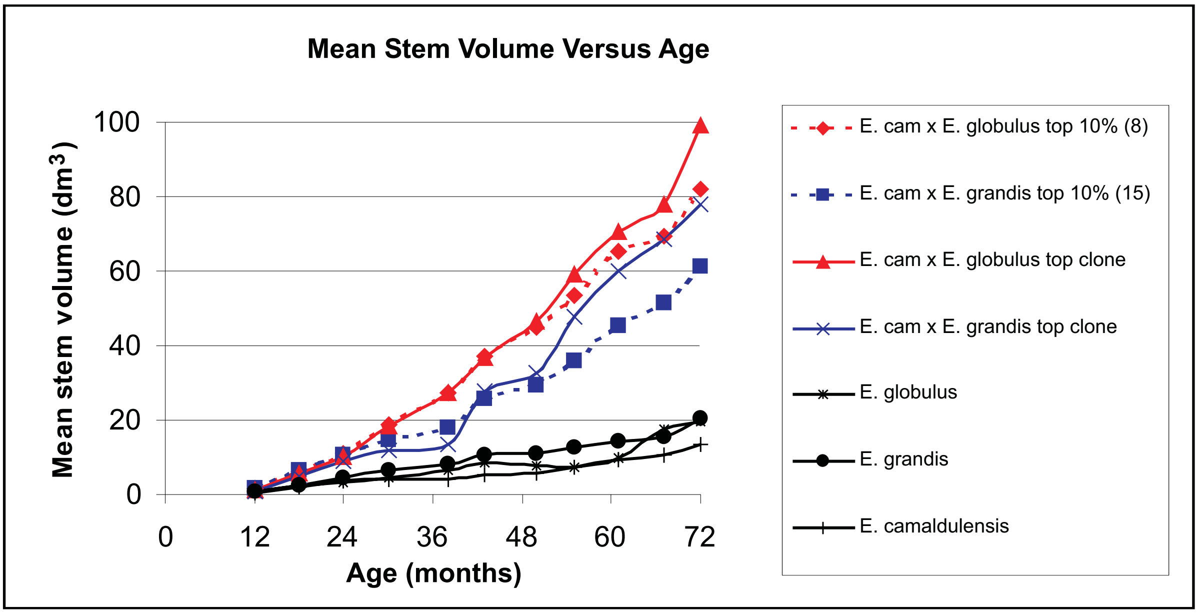

FIG 1 - Growth curve to 72 months of age for mean stem volume at Mt Scobie. Growth curves for the top clone and the top ten per cent of clones of both the *E camaldulensis x E grandis* and *E camaldulensis x E globulus* hybrids are shown in comparison to the growth curves of their pure species parents, *E grandis*, *E globulus* and *E camaldulensis*. The stem volume growth of the hybrids is significantly greater than that of any of their pure species parents.

FIG 2 - Three-and-a-half-year-old stand of Saltgrow hybrids at Mt Scobie in northern Victoria. Note the salt encrustation on the bare scalded area in the foreground.

DISCUSSION

Genetic improvement of Eucalyptus for commercial productivity in low/medium rainfall and saline site conditions

The exploitation of heterosis has been one of the major successes of plant breeding in the 20th century (Cooper and Merrill, 2000). The results of this work indicate the potential for a similar revolution in eucalypts for forestry in stressed environments. Through inter-specific hybridisation and the incumbent capacity to exploit and re-package the wealth of natural genetic variation available among inter-breeding eucalypt species, substantial improvements have been achieved in adaptation and productivity.

The Mt Scobie trial site presents soil conditions that would typically be considered stressful for growth of non-halophytic tree and crop species: shallow watertable (0.5 to 1.05 m) leading to problems with root zone aeration; moderately saline groundwater (7.5 to 8.5 dS/m) having direct osmotic and toxicity impacts; saline soil conditions at the soil surface (ECe 4.7 to 7.1 dS/m) and in the active rootzone area (ECe up to 12 dS/m at 0.5 m), again having osmotic and toxicity impacts; medium to heavy clay texture restricting root penetration, soil aeration and plant water availability; and high subsoil pH (7.5 to 8.8 at 0.5 m and below) leading to problems with nutrient availability. These site conditions are typical of many saline degraded areas of the Murray-Darling Basin, and the Shepparton Irrigation Region in particular, presenting conditions unsuitable for agricultural crops which are typically restricted to soils of less than 2 dS/m (Ghassemi *et al*, 1995).

Under the stressful conditions of the Mt Scobie site, significant heterosis is displayed by both hybrid types relative to their respective mid-parent means. For stem volume at 72 months, the gain in the mean performance over the better of the two pure species parents was between 102 per cent for the *E camaldulensis x E grandis* hybrids and 295 per cent for the *E camaldulensis x E globulus* hybrids. The practical implication of this result is that an increased level of timber production can be achieved in the hybrids under shallow saline watertable conditions compared to naturally occurring pure species.

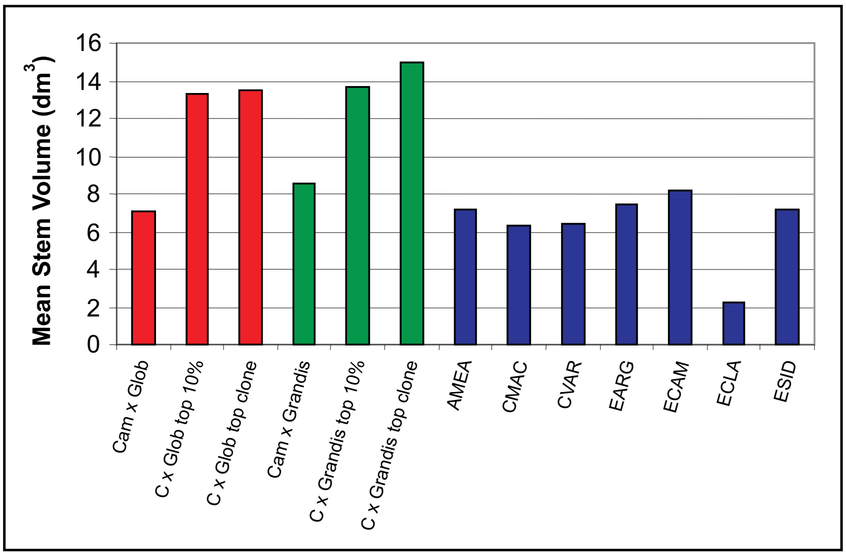

FIG 3 - Mean stem volume of seven 'best bet' pure hardwood species compared to: (a) the clone mean, (b) the top ten per cent of clones, and (c) the top clone of both the *E camaldulensis x E globulus* and *E camaldulensis x E grandis* hybrids at 45 months of age. Results are averages across six dryland sites through western NSW.

However, the improvement of the hybrids relative to pure species alone is not adequate justification to support commercial adoption unless the absolute growth rates exceed a minimum, commercially viable level. Comparison of the mean performance of the top ten per cent of clones from each hybrid with highly productive forest stands in non-saline areas indicate growth rates at Mt Scobie are on track to achieve a productivity of around 20 to 30 m^3/ha/yr, well above the threshold productivity required for a positive return on investment. Assuming the growth rate of the hybrids continues to follow the same trend as exhibited to date, then they might be expected to achieve a commercially attractive harvest yield when grown under poor quality site conditions.

Similarly, the NSW recharge site trials, spanning a rainfall range of 530 mm/yr to just over 700 mm/yr, present conditions typically considered below the usual rainfall threshold for commercial tree cropping in Australia (700 mm/yr). For forestry purposes, low rainfall in southern Australia is defined as <600 mm/yr; medium rainfall as 600 to 800 mm/yr, and high rainfall as >800 mm/yr (Harwood and Bush, 2002). Salinity in Australia predominately occurs in the 400 to 700 mm rainfall belt, and as such, species suitable for commercial reforestation of recharge areas of saline catchments need to be both tolerant of drought and water-use efficient to grow well in moisture limited conditions. The results of the NSW dryland salinity trials indicate that Saltgrow hybrids show improved performance relative to pure species under low/medium rainfall conditions.

Together, the Mt Scobie and NSW recharge trial results indicate that Saltgrow hybrids display a broad spectrum of stress tolerance, and are able to achieve high rates of growth relative to other commercial eucalypt species in low to medium rainfall and saline areas. These attributes make the hybrids a viable option for integrating commercial forestry into agriculture – one of the key actions required to address salinity.

Carbon sequestration in planted forests

Planted forests capture and store carbon from the atmosphere both directly in the woody and non-woody biomass (roots, branches, leaves and stem), and indirectly in the soil and forest litter. After harvesting, some carbon is released to the atmosphere, but modelling by the Australian Greenhouse Office indicates that much of the stored soil carbon is retained and increases over time though successive rotations. In addition, if timber is used in products such as house framing, then a proportion of stored carbon is locked out of the atmosphere for a longer period than the life of the forest itself.

Figure 4 illustrates the output from the carbon accounting model, CamFor, for a theoretical stand harvested on a rotation of 30 years, with periodic thinning, and achieving a mean annual increment of around 6 to 8 m^3/ha/yr in each rotation. It can be seen from this figure that although the stand is harvested and replanted each 30 years, and that carbon stored in the trees and tree debris returns to zero at the end of each rotation, there is a continuing increase in both soil carbon and carbon stored in timber products.

Figure 5 illustrates the theoretical carbon profile for a eucalypt plantation estate planted at 1000 ha/yr up to a total area of 20 000 ha. The timber volume is assumed to grow at an average rate of 15 m^3/ha/yr, with harvesting on a cycle of 20 years. It can be seen from Figure 5 that a plantation, even when harvested on a regular rotational cycle, creates a pool of stored carbon since, in any one year, an amount equal to only one/rotation age of the entire estate (in this instance 1/20th) is harvested and not actively sequestering carbon.

Figure 5 also shows that although the annual carbon sequestration for each hectare is around 34 tonnes of CO_2 and that rate of annual plantation establishment is flat at 1000 ha/yr, the profile of cumulative sequestration for the estate pool up to year 19 is geometric, being the sequestration from 1000 ha in year one, the accumulation of year one plus that of 2000 ha in year two and son on.

The scale of forestry required to address salinity and provide useful carbon sinks

In contrast to high rainfall production forestry, forestry for the aim of both reduction of groundwater recharge and direct treatment of discharge sites will require the targeted re-introduction of trees as a mosaic in the rural landscape. However, for trees to exert an appreciable effect on regional groundwater tables, the sum of areas planted as a mosaic across the landscape must reach a scale rivalling Australia's existing plantation resource in high rainfall areas. The scope of reforestation envisaged by the Murray Darling Basin Commission Salinity Reforestation Bank is in the order of

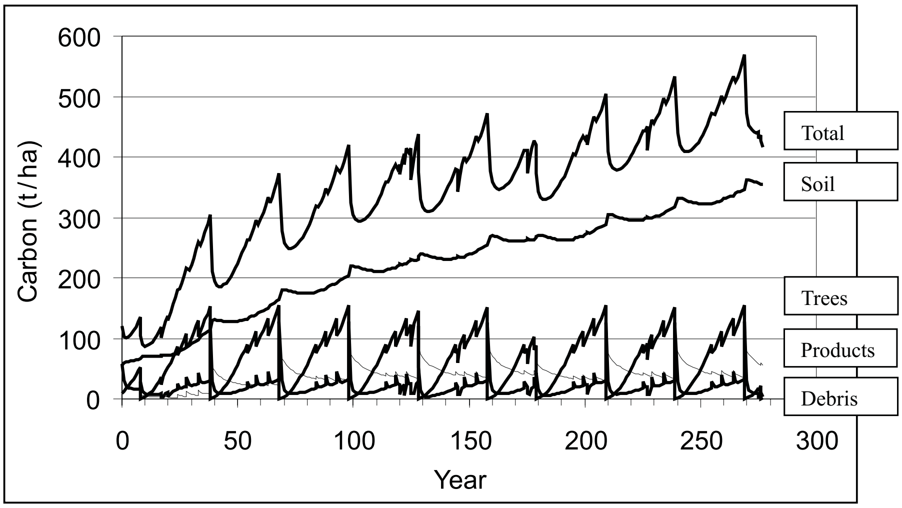

FIG 4 - Cumulative carbon sequestered (mass/ha) as predicted by the carbon accounting model CamFor, for a theoretical plantation managed on a 30 year cycle for a mixture of solidwood and other timber products, with replanting following each harvest. The reduced rate of carbon sequestration in year 179 simulates the effect of a catastrophic fire in part of the plantation area (source: http://www.greenhouse.gov.au).

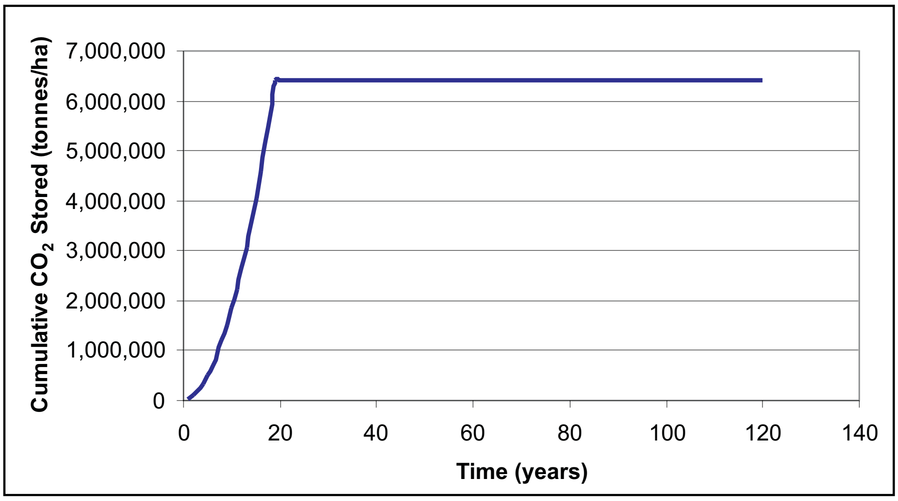

FIG 5 - Cumulative carbon pool for a eucalypt forest under the following assumptions: average growth rate of stemwood = 15 m^3/ha/yr; annual planting rate = 1000 ha/yr; harvest rotation = 20 years with each hectare replanted in the year following harvest.

1.5 million hectares within the 500 to 800 mm rainfall zone, or just 4.2 per cent of the land area of this zone. This scale of reforestation, the associated scale of capital investment, and the trend of natural resource management agencies to leverage limited public funds with private investment, virtually dictates, in most situations, that such forests provide economic returns in order to encourage and sustain the scale of capital investment required.

Improvements in productivity achieved by Saltgrow hybrids under stressed environmental conditions should enable commercially viable growth rates to be achieved in the key areas requiring reforestation. Current projections are that Saltgrow hybrids can achieve harvestable logs of 40 to 50 cm diameter in 20 to 25 years. Further improvements in clonal selection may reduce this period, while developments in sawmilling and veneering technology may reduce optimum log sizes and rotation lengths.

Fortuitously, the need for large-scale reforestation to control salinity is fully consistent with the requirement for development of a critical resource mass to supply any industry based on processing of wood and fibre products. While hardwood sawmilling operations (currently based exclusively on native forests) can operate on a resource of as little as 5000 ha (RIRDC, 1996), an internationally competitive softwood sawmill requires a minimum resource base in the order of 38 000 ha (RIRDC, 1996). It is likely that a similar scale of resource will be required to support hardwood mills based predominately on new plantation timber resources, and that such mills will need to be integrated to produce a range of products that fully utilise the wood fibre entering the mill gate. Integrated timber processing operations would also utilise residues for products such as biomass energy generation, which in turn will contribute to meeting Australia's renewable energy targets.

Similarly, large areas of plantation must be established to offset even a small proportion of CO_2 emissions from combustion of coal, or to provide offsets for export coal. For a project such as BHP Billiton's Denrobium colliery yielding around one million tonnes of thermal coal/year, potential CO_2 emissions equate to around 2.75 million tonnes per year. For a plantation with a mean annual timber increment of 15 m^3/ha/yr and a harvest rotation length of 20 years, the average annual carbon sequestration assuming a planting rate of 1000 ha/yr up to a total estate of 20 000 ha will be in the order of 337 000 tonnes of CO_2/ha/yr over the first 19 years. This equates to an offset of just over 12 per cent of potential annual CO_2 emissions from combustion of Denrobium thermal coal. While clearly, timber plantations alone cannot hope to achieve carbon neutral coal production, they can potentially make a significant contribution to offsetting carbon emissions within the scope of the reductions required by Kyoto restrictions. The significance of this lies in the realisation that timber plantations can begin to offer this benefit today, and continue to offer this benefit for the next 20 to 30 years until such time that all potential timber land resource is occupied. While the potential capacity for carbon sequestration in plantations is finite, the 20 to 30 year window of opportunity they provide may allow the time necessary for alternative technologies with much greater carbon abatement capacity, such as geo-sequestration and improved efficiency renewable energy, to be developed to a cost effective level.

A further benefit of large-scale plantations integrated with agriculture, in addition to providing salinity and carbon sequestration benefits together with commercial timber, will be the flow-on benefit to rural communities. Such plantations can be expected to create new regional industries and jobs in forestry contracting, timber harvesting, sawmilling and value added processing. This in turn will have flow-on benefits to service and support industries, and provide a diversified source of income to landholders, either through lease payments on land, or participating in the returns from tree growing. The net environmental and economic benefits for a single 20 000 ha resource catchment managed over a period of 40 years, has an estimated net present value in the magnitude of A$ 23 million (using a discount rate of eight per cent). This does not include the social benefit arising from the arrest of rural decline, stimulation of new regional jobs and industries, and the maintenance or improvement in farm productivity and sustainability.

Potential for partnerships between farmers, catchment management authorities and major carbon producing industries

The scale of reforestation required to both address salinity and provide useful carbon sinks will require significant capital investment. The Murray Darling Basin Commission have estimated an investment requirement of A$ 17 billion over the next 50 years to develop an estate of 1.5 million ha in the Murray-Darling Basin alone. Full funding for such investment from catchment boards, even where economic returns are attractive, is undoubtedly impractical. At the same time, the task is unlikely to be achieved by land-rich, cash-poor farmers, the custodians of the land on which re-introduction of trees is required, given the long investment periods to realise returns from forestry. This opens the opportunity for partnerships between catchment authorities, landholders and investors able to absorb the cash-flow profile of forestry investment, where most expenses are incurred at the start of a rotation and returns at the end. Given this nature of forestry investment, major carbon producing industries who can directly benefit from the annual accumulation of a carbon pool, who have long investment horizons, and operate at a scale with the capacity to absorb long periods of investment prior to realising a return, are ideally suited as investors in such projects.

From such a partnership, each party stands to gain significantly. Farmers can provide the land on which re-introduction of trees is required to achieve benefits to downstream land managers, water users and native ecosystems. At the same time farmers making land available for tree planting may benefit from lease fees, giving them certainty of annual income from a portion of their property, and from the direct on-site benefits of tree establishment including: shade and shelter for stock; windbreaks for crops, pastures and stock; habitat for natural predators - allowing reduced insecticide use; and direct return of degraded land to productive use.

Catchment management authorities, mandated with repair and improvement of the natural resources within their jurisdiction, benefit from the ability to leverage limited government funds with private investment in public good projects that enhance environmental sustainability, achieving a larger scale of land-use change than they could with public grant funds alone.

Finally, major carbon producing industries as investors receive long-term returns from: harvesting of timber products; the goodwill of facilitating public good environmental works; stimulating rural economies; and, carbon sequestration credits at a net profit over the life of the project. The carbon credits that can be generated from forestry investment can, in turn, be offset against emissions by purchasers, potentially providing a market advantage, particularly where purchasers are subject to carbon emission constraints.

CONCLUSIONS

Improvements in productivity achieved by Saltgrow hybrids under stressed environmental conditions should enable commercially viable growth rates to be achieved in the key areas requiring reforestation for salinity abatement. The scale of reforestation required to address salinity is consistent with the scale of plantation required to supply world competitive scale timber processing facilities and at the same time, this scale of plantation establishment can make a significant contribution within the scope of the reductions required by Kyoto restrictions to offsetting the potential carbon emissions from combustion of Australian mined coal. The significance of this capacity lies in the realisation that timber plantations can begin to offer carbon sequestration benefits today, and continue to offer this benefit for the next 20 to 30 years, providing a window of opportunity that may allow the time necessary for alternative technologies with much greater carbon abatement capacity to be developed to a cost effective level. Significant opportunity exists for major carbon dioxide emitting industries to partner in projects with salinity and other environmental benefits, including carbon offset credits at a net profit over the life of the project.

ACKNOWLEDGEMENTS

The support of the landowners of the trial sites; Lewis and Josie Watson, Jim and Helen Dumareq, Will and Marg Howard, Rod and Pam Williams, Ned and Di Coombes, Brett Blackmore, and Geoff Symonds is gratefully acknowledged, as is that of State Forests of New South Wales and the numerous collaborators in more recent trials. The research work was funded by the XYLONOVA Research and Development Syndicate.

REFERENCES

Cooper, M and Merrill, R E, 2000. Heterosis, its exploitation in crop breeding, in *Proceedings QFRI/CRC-SPF Symposium: Hybrid Breeding and Genetics of Forest Trees* (Compiled by H S Dungey, M J Dieters and D G Nikles), pp 316-329 (Department of Primary Industries: Brisbane).

Ghassemi, F, Jakeman, A J and Nix, H A, 1995. *Salinisation of Land and Water Resources: Human Causes, Extent, Management and Case Studies,* 526 p (University of New South Wales Press: Sydney).

Harwood, C and Bush, D, 2002. Breeding trees for the low rainfall regions of southern Australia, JVAP Research Update Series No 4, 23 p.

National Land and Water Resources Audit, 2000. Australian dryland salinity assessment 2000: extent, impacts, processes, monitoring and management options, National Land and Water Resources Audit, Canberra, 129 p.

RIRDC, 1996. Commercial farm forestry in Australia: development of a strategy framework, Rural Industries Research and Development Corporation, Canberra, 120 p.

Stirzaker, R, Lefroy, T, Keating, B and Williams, J, 2000. A revolution in land use: emerging systems for managing dryland salinity, CSIRO Land and Water, Canberra, 24 p.