Agribusiness Perspectives

Forests as CO_2 Sinks - an Opportunity for Forest Growers?

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Background

Plantation forests offer one choice in the array of options available to provide a sink for carbon dioxide (CO_2). CO_2 emissions have been increasing since the late 19th Century when industrialisation started to utilise stored non-renewable fossil fuels (coal, oil and gas) as a source of energy rather than the traditional fuels (firewood and dung) which are renewable resources.

The impact of increased CO_2 levels has been widely predicted to result in increased temperatures, a change in ocean levels through melting of polar ice caps, and changed weather patterns. Whether increased CO_2 levels will actually cause significant problems to man is not known. Scientists predict temperatures will rise by an average of 2^o Celsius and sea levels by 50 cm by the year 2100 (Fries, 1997). CO_2 levels were clearly higher in previous periods of the earth's history; geological records indicate that large quantities of CO_2 were sequestered into coal, gas and oil during the Carboniferous Period and into limestone deposits as early as the Silurian and Ordovician Periods.

The term "Greenhouse Effect" is scientifically inaccurate. Temperatures increase in a greenhouse, but CO_2 levels are typically very low during daylight hours and commercial growers deliberately release CO_2 into the greenhouse to stimulate growth. High CO_2 levels equate to high rates of net photosynthesis and typically the growth of vegetation is limited by CO_2 levels. Raised CO_2 levels may thus not be a problem to man at least in terms of plant productivity.

The fact remains, however, that the global community does share a common concern over raised CO_2 levels and is seeking ways in which the problem may be slowed or overcome. The most obvious way to reduce CO_2 emissions is to reduce the use of fossil fuels. Alternate energy sources such as nuclear, wind, solar, hydro, wave and biomass provide one type of solution - ie change the source of fuel. The more efficient use of fossil fuels through more efficient vehicles, better mass transit systems, greater use of rail transport and use of more efficient industrial processes is another alternative.

Other methods for reducing energy consumption and, as a consequence, reducing CO_2 emissions, include using materials that use less energy in their manufacture. High-energy materials include steel, concrete and aluminium. The production of 1 tonne of steel releases around 2 tonnes of CO_2 (Forest and Wood Products Research and Development Corporation (FWPRDC), 1996). Solid timber requires a low energy input in its manufacture. Table 1 shows timber stores more than 15 times the amount of CO_2 released during its manufacture, whereas steel, concrete and aluminium store negligible amounts. TOP

Table 1: Carbon released and stored and fossil fuel energy used in the manufacture of building materials

Material	Carbon released (kg / t)	Carbon released (kg / m^3)	Carbon stored (kg / m^3)	Fossil fuel energy (MJ / kg)	Fossil fuel energy (MJ / m^3)
Rough sawn timber	30	15	250	1.5	750
Steel	700	5,320	0	3.5	266,000
Concrete	50	120	0	2	4,800
Aluminium	8,700	22,000	0	435	1,100,000

Source: (FWPRDC, 1997) TOP

Ultimately the problem of using fossil fuels will be resolved economically; as resources are depleted the cost will rise and more efficient methods will be adopted. Ultimately renewable sources of biomass will provide a high proportion of our energy needs and the CO_2 released will be recycled.

One option that is currently being more widely examined is the use of forests, in particular intensively managed forests, both to sequester carbon and to provide an alternative to fossil fuel. A doubling of petrol or diesel prices, for example, would make liquid fuels derived from wood or other forms of biomass an economic proposition.

Industries, which emit large quantities of CO_2, such as coal-fuelled power stations, will have to pay to control their emissions. A ‘carbon credits’ trading system on emissions will allow tradeable permits to be bought and sold among different industries and firms (Cross, 1998). High CO_2-emitting industries will be able to buy carbon credits from carbon storage industries such as plantation forestry in order to reduce the cost of controlling their emissions. TOP

What is the basic chemistry of CO_2?

To gain a simple understanding of the chemistry it is important to go back to the fundamentals. The atomic weights of the three most abundant elements in the atmosphere are:

- Carbon C 12

  Hydrogen H 1

  Oxygen O 16

CO_2 has an atomic weight of 44 (12 + (2*16)). The amount of carbon in one molecule of CO_2 is 27%.

Most organic compounds that are common in plants and animals have a structure $C_nH_{2n}O_n$. Glucose, a simple sugar, has the structure $C_6H_{12}O_6$. In the simplest form the atomic weight of common organic compounds is $C_1H_2O_1$ or 12 + 2 + 16 = 30. The amount of carbon in one molecule of a simple sugar is 12/30 or 40%.

In many cases the oxygen component is slightly less than the simple model; $C_6H_{12}O_6$ for example is the formulation of glucose while $C_{12}H_{22}O_{11}$ is the formulation of sucrose and the amount of carbon is typically closer to 43%. **TOP**

What happens in gas exchange?

Two processes operate simultaneously in plants.

Photosynthesis converts carbon dioxide and water, in the presence of energy from sunlight, into a simple sugar and oxygen is released as a by-product.

$CO_2 + H_20 = C_1H_2O_1 + O_2$

or 1 tonne of carbon (in CO_2) produces 1 tonne of carbon (in sugar)

Respiration (Oxidation) reverses the process and converts sugar and oxygen back to carbon dioxide and water; energy is derived in the process. Both plants and animals depend on photosynthesis in plants which uses sunlight as the energy source to combine carbon dioxide and water to produce carbohydrates. Breaking down carbohydrates through respiration is the mechanism used by both plants and animals to provide energy as required. **TOP**

How much carbon dioxide is produced?

The major anthropogenic source of greenhouse gas emissions are combustion of fossil fuels (5.5 billion tonnes of carbon per year worldwide) and land use change (1.6 billion tonnes of carbon per year worldwide) (AACM, 1997). Australia produces a total of 275 million tonnes of CO_2 annually, which is equivalent to 74.4 million tonnes of carbon (SEC Vic, 1989). It is estimated that the amount of CO_2 produced in transport is 68.5 million tonnes/annum, equivalent to 18.7 million tonnes of carbon per annum. The electricity industry alone is estimated to produce 124 million tonnes of CO_2 per annum, which is equivalent to 33.5 million tonnes of carbon (it should be noted some of electricity produced is used in transport) (SEC Vic, 1989).

Of the 7.1 billion tonnes of carbon emitted worldwide each year, 4.5 billion tonnes are absorbed by oceans and by biological processes, especially photosynthesis by plants. Nearly 3 billion tonnes of carbon accumulate in the earth's atmosphere every year. **TOP**

How much can a forest take up?

The quantity of carbon dioxide that can be sequestered into biomass depends on the type of forest, its rate of growth and the ultimate fate of the wood or other biomass harvested.

Natural forests tend to be in a state of equilibrium with growth being balanced by decay. This equilibrium may be disturbed, for example by fire, and this sudden loss of CO_2 tends to be followed by a period of growth and net sequestration until a steady state is again reached.

Forests which are to be locked up and not used for wood production will pass from a period of active growth when CO_2 is actively sequestered into the biomass, to a period when they mature and growth and decay are in balance. As trees die and the crowns of large trees become less dense, the amount of dead mass on the forest floor can increase substantially and the forest may be a net producer of CO_2. A new equilibrium is reached when net CO_2 production and sequestration are in balance.

Forests which are regularly harvested will continue to sequester carbon as long as growth continues. When a forest is thinned there will be a short period while the remaining trees occupy the available space and slash from harvesting breaks down. If a forest is clearfelled and replanted there will be a period while trees are being re-established when carbon sequestration may be low or even negative (eg when there is a lot of slash left on site which is breaking down).

Only by continuing to grow a forest and removing the biomass in the form of wood or other product can the forest continue to play a role in carbon sequestration.

The amount of carbon that can be sequestered depends on the rate of growth and the species involved; highest rates are achieved by well managed, fast growing species on good soils in high rainfall areas. The lowest rates of carbon sequestration are where rainfall is low, soils are poor, management is poor and slow growing species are used. **TOP**

The growth of all biological organisms tend to follow a similar growth pattern. A number of models have been suggested but that presented in Barson and Gifford (1989) is an assymetrical sigmoidal form and closely matches actual biomass production data. The function takes the general form:

- W = A*exp(-b*exp(k*t))

  where

  W is the total amount of carbon sequestered (tonnes/ha)

  t is time in years

  A is the asymptotic value of W

  b and k are constants

In a project undertaken for Environment Australia two of the authors (Borough and Bennett) took this basic model of growth and fitted known patterns of growth in forest plantations in Australia. The form of the general model was modified slightly by the addition of an adjustment to force the value of W to be zero at time zero. The general form of the function was thus:

- W = A*exp(-b*exp(k*t)) + z

  where

  W is the total amount of carbon sequestered (tonnes/ha)

  t is time in years

  A is the asymptotic value of W

  b, k and z are constants

Five eucalypt and three pine "growth classes" were modelled based on published and unpublished above-ground biomass data and then converted to total carbon equivalents (including roots). The "growth classes" used are broad groupings which reflect combinations of rainfall, species selection and type of management. Table 2 shows how these are grouped. **TOP**

Table 2: Key factors used in determining growth classes

Rainfall (mm/a)	Species	Management	Growth Class
400-600	Fastest Growing	Planting	E4
		Direct Seeding	E4
		Natural Regeneration	n/a
	Local Species/provenance	Planting	n/a
		Direct Seeding	E5
		Natural Regeneration	E5
600-800	Fastest Growing	Planting	E2 or P2/P3
		Direct Seeding	E3
		Natural Regeneration	n/a
	Local Species/provenance	Planting	E3
		Direct Seeding	E4
		Natural Regeneration	E5
800 +	Fastest Growing	Planting	E1 or P1/P2
		Direct Seeding	E2
		Natural Regeneration	n/a
	Local Species/provenance	Planting	E2
		Direct Seeding	E3
		Natural Regeneration	E3/E4

These models were used to predict the amount of carbon that could be sequestered over time. In Figure 1 the cumulative amount of carbon sequestered is shown over a 30 year period. In Table 3 the amount of carbon sequestered annually by each growth class type is shown for selected years. **TOP**

Figure 1: Quantity of carbon sequestered over time by range of pine and eucalypt (E) and pine (P) growth classes

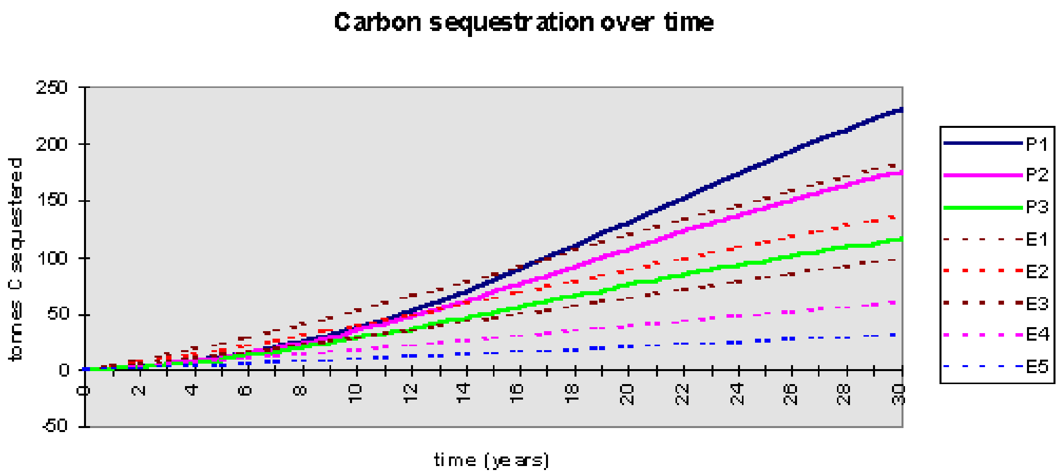

Table 3: Quantity of carbon sequestered annually by a range of pine and eucalypt growth classes.

		Year					
CAI	**Scenario**	**1**	**5**	**10**	**15**	**20**	**25**
C t / ha /yr	**E1**	4.2	5.2	6.2	6.7	6.8	6.5
	E2	3.2	3.9	4.6	4.9	5.0	4.9
	E3	2.4	2.8	3.2	3.5	3.6	3.5
	E4	1.5	1.7	2.0	2.1	2.2	2.1
	E5	0.8	0.9	1.0	1.1	1.1	1.1

	P1	1.3	3.2	6.6	9.4	10.7	10.3
	P2	1.4	3.1	5.6	7.4	7.7	7.0
	P3	1.4	2.6	4.1	4.9	4.8	4.1

TOP

Eucalypts, at least as represented by the faster growing species on high rainfall sites, grow rapidly initially and reach a peak, somewhere around age 15. Pines, however, grow more slowly initially but, by age 15 exhibit a higher rate of carbon accumulation reaching a maximum somewhere around age 20. In the short term (10 -12 years), fast grown eucalypts will sequester more carbon but in the long term (20 - 30 years) pines will be superior.

It is important to appreciate the difference between a tonne of carbon and a tonne of CO_2. As mentioned earlier, the amount of carbon in a molecule of CO_2 is 27%. Thus 3.7 tonnes of CO_2 is equivalent to 1 tonne of carbon.

How many ha?

If Australian transportation produces 68.5 million tonnes of CO_2 per year this is equivalent to 18.7 million tonnes carbon. If all this carbon were to be sequestered by actively growing trees at the rate of 5 tonnes of carbon per year, the amount of forest required would be 3.7 million ha. If all the CO_2 Australia produced was to be sequestered, the forest area required would be 14.9 million ha.

If the world produces 5,500 million tonnes of CO_2 per year from fossil fuel combustion, this is equivalent to 1485 million tonnes carbon. If all this were to be sequestered at 5 tonnes carbon per year, the amount of forest would be 297 million ha. Even if Australia took on 1% of the world's CO_2, 3 million ha of fast growing plantations would be required. It is clear that Australian forest growers can play a major role in sequestering the CO_2 of Europe and North America. **TOP**

What is carbon sequestration worth?

The price likely to be paid for carbon creditscould vary over time depending on either the legislative requirement to account for CO_2 produced or for a market advantage for a product which promotes the environmental value of its actions in CO_2 sequestration.

Dobes (1996) calculated the marginal cost in terms of \$/tonne CO_2 ranging from \$1.76 to \$5.18. This is equivalent to \$6.50 to \$19.20/tonne C. Indications from other sources suggest \$10/tonne is likely but \$20/tonne is not unreasonable.

At an average rate of 5 tonnes C/ha/yr, growers could see their forest incrementing \$100/ha each year from carbon alone. The potential of this additional return to forestry is very substantial. **TOP**

What might be done?

There are two elements that need to be put in place before growers can expect a market for the carbon sequestration they are able to supply. The first element is regulatory; governments need to develop a regulatory framework that specifies the rules that should apply. The second element is the development of an effective trading mechanism that allows carbon dioxide emitters to enter into contracts with forest growers to sequester carbon dioxide.

Regulatory Framework

At the Kyoto Climate Change conference, the States Parties agreed to include trading regimes within the measures to be taken to attack the problem (see Convention Article 16 bis). The Parties are now busily working on regimes that might be acceptable to take back to a meeting later in 1998.

The Australian Department of Primary Industries and Energy, Greenhouse Challenge Office, recently commissioned the development of a Workbook on Carbon Sinks. The purpose of the workbook was to "..assist companies...to incorporate sinks in their inventories..". This Workbook will be an important step in assisting to set the parameters for a regulatory framework that seems likely will emerge. **TOP**

Carbon Trading

Within the private sector there are currently a number of schemes in the pipeline to set up mechanisms to permit trading in carbon. These schemes need to have the following elements:

- mensuration to quantify the amount of carbon sequestered or likely to be sequestered
- certification to issue carbon certificates and provide assurance to purchasers and regulators that the due processes have been complied with
- access to a group of carbon emitters who need to secure carbon credits
- access to a group of forest growers who can deliver carbon sequestration
- a trading system which allows carbon certificates to be traded

As trading will be international and the quantity of carbon to be sequestered is so huge, it is likely that the bulk of the carbon sinks will be created in the southern hemisphere. For a country like Australia, with a stable political system, a well established legal and land tenure system plus relatively cheap land, there appears to be considerable promise for a trading system to be established which will benefit land holders in Australia. Indeed the emergence of a sinks trading system could be of profound significance in pushing along the development of commercial private forestry to the level that might see the 2020 Vision Statement (Plantations 2020 Vision Implementation Committee, 1997) actually realised. **TOP**

CONCLUSION

The carbon sequestered by fast growing forests appears likely to be a value that has previously not been recognised. At this stage there is no mechanism to allow carbon producers and forest growers to link but carbon trading mechanisms are likely to develop in the short to medium term. Already companies producing carbon emissions are seriously talking to emerging trading entities while land holders are gearing up for the large-scale plantings that would be necessary to achieve anything like an impact on this world-wide problem.

Depending on the price, forests as carbon sinks may well become a major factor to be considered in forest economics and future forest management regimes will need to be adjusted accordingly.
TOP

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