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Trees for carbon sequestration

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Carbon sequestration

Trees remove carbon dioxide from the atmosphere through the natural process of photosynthesis and store the carbon (C) in their leaves, branches, stems, bark and roots. Approximately half the dry weight of a tree's biomass is carbon. One tonne of C = 3.67 tonnes of 'carbon dioxide equivalent' (CO_2-e) – see the box on this page.

Establishing trees on soil that has been depleted of organic carbon by regular cultivation or heavy grazing can increase soil carbon after several years. There may be a short-term loss caused by site preparation.

Trees in forests (including plantations), if well-stocked, typically sequester carbon at a maximum rate between about age 10 and age 20–30. As an indication, at age 30 years about 200 to 520 tonnes CO_2-e are sequestered per ha in forests with productivity ranging from low to high (Australian Greenhouse Office 2001). After this age, if the trees are not harvested, the sequestration rate slows gradually until maturity at about 80 to 100+ years of age, and flattens out from then on as growth is balanced by decay.

Reforesting cleared areas will create carbon sinks to counteract greenhouse gas emissions, and will assist in other aspects of environmental improvement such as salinity control and creation of wildlife habitat.

Estimating sequestration

The carbon sequestration benefit from reforestation is determined by the difference in average carbon stock between the previous land use and the forest or plantation. Generalised predictions of the sequestration rate of reforestation projects cannot be made, since growth (and sequestration) depends on local climate, soil factors and management.

For forests managed for timber production on a long-term plant–harvest–replant cycle, the maximum C stock achieved will not be maintained. In such cases it is more useful to consider the average sequestration benefit of each hectare across multiple rotations (horizontal line in Fig. 1).

A number of computer models have been developed over recent years to estimate the carbon sequestered by forests. Their levels of complexity and required input data vary greatly.

> **Carbon dioxide equivalents (CO_2-e)**
>
> Carbon dioxide equivalents (CO_2-e) provide a universal standard of measurement against which the impacts of releasing (or avoiding the release of or actively sequestering) different greenhouse gases can be evaluated. Every greenhouse gas has a Global Warming Potential (GWP), a measurement of the impact that particular gas has on 'radiative forcing'; that is, the additional heat/energy which is retained in the Earth's atmosphere system through the addition of this gas to the atmosphere.
>
> The GWP of a given gas describes its effect on climate change relative to a similar amount of carbon dioxide. As the base unit, carbon dioxide is 1.0. This allows the greenhouse gases regulated under the Kyoto Protocol to be converted to the common unit of CO_2-e.
>
> *Source: http://www.ieta.org/*

Carbon Sequestration Predictor

Industry & Investment NSW has produced a simple-to-use model, the Carbon Sequestration Predictor (CSP) Version 3.1. This gives predictions of changes in carbon stocks in plants and soil over two time intervals: 10 years (table) and 100 years (table and graph). It is designed for use in areas of NSW with <800 mm rainfall per year (Fortunaso *et al.* 2008).

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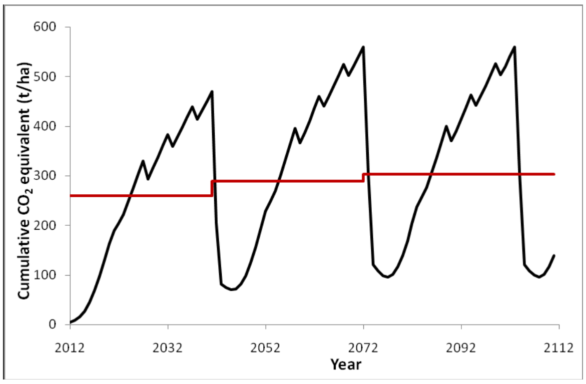

Figure 1. Rotational replant and harvest carbon storage. The red line shows the average carbon stock from each timber rotation. Source: Commonwealth Department of Climate Change

The CSP assists landholders in determining the amount of carbon that is sequestered under different land-use change scenarios. For example, the graph below shows the total amount of carbon, including soil carbon that is sequestered when **annual pasture** is converted to an **environmental planting** (800 trees/hectare), on chromosol soil with a mean annual rainfall of 500 mm.

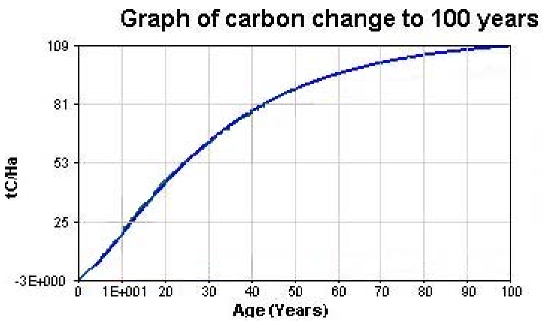

Figure 2. Example graphical output from CSP

The user enters current land use and proposed land use from tables of options, then average annual rainfall, then the soil type from a table of options. A list of site modifiers is provided to adjust predictions depending on local site conditions (such as saline soil or a non-saline water-table accessible to tree roots). As selections are made, a table and graph are simultaneously updated. The table breaks predicted change in carbon into plant biomass and soil organic components.

The CSP can be downloaded from: www.dpi.nsw.gov.au/forests/info/csp.

National Carbon Accounting Toolbox

The currently available prototype of the Commonwealth Government NCAT model, released in 2005, is derived from the National Carbon Accounting System (NCAS). The Government uses the NCAS to calculate emissions and C sequestration from reforestation for the national greenhouse gas inventory. NCAT enables land managers to track greenhouse gas emissions to and removals from the atmosphere (sequestration), and to develop site and management-specific greenhouse gas accounts for any site in Australia. NCAT uses a process model-based approach to biomass and soil carbon stock estimation. It is more comprehensive in scope than the CSP and not as simple to use. It is used on-line or by CD-ROM in order to access databases containing weather and soil records required to generate site-specific predictors.

The Commonwealth Government has continued to invest in the further development of NCAT, aiming to replace the 2005 prototype; it will have a new user-friendly web interface. For more information see: www.climatechange.gov.au/government/initiatives/ncat.aspx

The Greenhouse Effect

Carbon dioxide (CO_2) is a natural greenhouse gas in the atmosphere and is in part responsible for the earth's relatively stable climate. It is a 'greenhouse' gas because it traps heat near the earth's surface, contributing to observed and predicted global warming. Human activities, especially the burning of fossil fuels such as coal and oil and destruction of natural forests, are greatly increasing the level of CO_2 in the atmosphere. Concentrations have risen from about 284 parts per million in 1832 to about 387 ppm in March 2009 (en.wikipedia.org/wiki/Carbon_dioxide). Mean temperature increases between 1° and 6°C have been projected over the next 70 years. Methane and nitrous oxide, produced by agricultural activity and biological processes, are other greenhouse gases with much greater warming impacts per tonne than CO_2. In 2006, Australia's net greenhouse gas emissions totalled 576 million tonnes CO_2-e (Garnaut Climate Change Review 2008 at :www.garnautreview.org.au/chp7.htm).

If the Greenhouse Effect proceeds as predicted, Australia is likely to experience more extreme weather patterns with higher average temperatures, more and longer heatwaves, and reduced rainfall in many parts, especially the south and west of NSW.

Natural and planted forests act as 'sinks' for absorbing CO_2 from the atmosphere. Increasing the area of forests and tree plantations is one method we have available to 'offset' emissions of CO_2.

Emissions trading – New South Wales GGAS

(from Grieve *et al.* 2009)

Emissions trading has been carried out in New South Wales (NSW) under the Greenhouse Gas Reduction (or Abatement) Scheme (GGAS) since 2003. It was one of the first mandatory schemes in the world and is aimed at reducing emissions associated with the use of electricity. Under the scheme electricity providers offset their emissions through purchasing abatement certificates (NGACs) created from reforestation. One NGAC represents 1 tonne of CO_2-e. The GGAS will be terminated when a Federal scheme commences. However, GGAS operating protocols illustrate the requirements and potential benefits for landowners aiming to grow trees for carbon sequestration.

Carbon sequestration projects and markets are heavily regulated, since carbon stored in plantations can be easily lost due to events like fire or harvesting. The buyers of NGACs need to be assured that the carbon remains sequestered and is estimated accurately.

Participation in the market

Abatement producers in the GGAS must be Accredited Certificate Providers. Due to the costs and complexities of managing forests for carbon and the duration of the carbon maintenance obligation (100 years) it is generally appropriate for smaller landholders to contribute their plantings to a ‘pool’ managed by a Certificate Provider, generally called a pool manager.

Key requirements that must be addressed under the Scheme include:

1. Landowners need to transfer control over carbon rights to the pool manager; this is registered on the land titles until removed at the end of the pool’s life.

   A restriction on use covenant is recorded on the land title that gives the Scheme administrator control over the carbon sequestration project and ensures that areas of forest that are destroyed or harvested have to be re-established.

2. Pool managers must describe how they will calculate the number of NGACs represented in forests in their pools. This is done through inventory measurements and models, each of which has associated uncertainties. Regulations require calculation of a range of C-stock values and selection of the value where there is a 70% chance that at least that amount of carbon exists. This discounting due to uncertainty may reduce the quantities of NGACs that can be sold.

   The calculation method must also give estimates of the total C stock over the life of the pool, defined as the first year that NGACs are created to 100 years after the last NGAC is created. The pool must be maintained at the projected level for 100 years, compensating for losses in parts of the pool.

3. While the pool is increasing its C stocks, managers must report events that reduce the stocks. When stocks are no longer increasing, reporting will describe how stocks are being kept secure.
4. Risks to the pool are described, as well as measures to control these risks.
5. Systems must be in place to manage documents relating to management of the pool, compliant with Australian Standard AS ISO 15489.1–2002.

Pool managers would retain part of the revenue from NGAC sales to cover the operating costs plus a profit margin.

Financial and physical risks

Predicting carbon prices for 60 or more years into the future is guesswork. Prices per NGAC (i.e. per tonne CO_2-e) have fluctuated, from $8–10 in 2004, to $14 in 2006, to around $5 in 2009. Estimates of annual returns from carbon-trading from a small environmental planting of 4 ha in Central-west NSW varied greatly, from profit to loss.

Physical risks include fire (first and foremost), insects and drought. Apart from dispersing the plantings over a wide area to reduce the risk of losing many to a fire, there is little one can do to completely avoid most risks of this type.

Contractual risks include collapse of the trading scheme itself, or of a pool manager. The former is unlikely since any national scheme would be backed by legislation and regulated.

The risk of not being able to sell encumbered land depends on future prices and degree of community support. A scheme that delivers high prices may positively affect property values.

For landholders considering participation in a scheme such as GGAS, it is probably best at this stage to wait and see the details of the national scheme, which is intended to replace the GGAS.

More information on GGAS can be found at http://www.greenhousegas.nsw.gov.au.

Greenhouse Friendly

This is a voluntary scheme that operates all over Australia. In contrast to the GGAS, carbon sequestration is required to be maintained for 70 rather than 100 years. It does not require registration of carbon rights or restrictions on use over land titles. There is no requirement to discount estimates of C-stocks for uncertainty. However, this scheme does require demonstration of ‘additionality’ – participants have to demonstrate that the planting being done to generate carbon credits is in addition to business as usual. For example, credits could not be claimed for a plantation established primarily for timber production.

National Carbon Pollution Reduction Scheme

The Federal Government proposed establishing a national Carbon Pollution Reduction Scheme (CPRS) by 2011. As at February 2010, the CPRS has yet to be passed into legislation. The following information outlines aspects of the proposed scheme.

The 'White Paper' (December 2008) which outlines the scheme's design has identified forestry as a voluntary 'opt in' sector under the scheme, meaning that eligible entities within the sector have the option of participating in the scheme.

The CPRS was proposed as a 'cap and trade' scheme, with aggregate emissions capped at a level consistent with environmental objectives. The number of tradeable carbon pollution permits (similar to NGACs) would be equal to the scheme cap, e.g. if the cap is set at 100 million tonnes of CO_2-e in a year, 100 million permits would be issued in that year.

Eligible reforestation

Under the CPRS only reforestation as defined under the Kyoto Protocol was proposed to be eligible to generate offsets. The definition is: 'direct human-induced conversion of land that was clear of forest at 31 December 1989 to forested land.' It must be a forest/plantation of trees with a potential height of at least two metres, have a crown cover of at least 20 percent and cover an area greater than 0.2 hectares. Areas where natural revegetation has been encouraged by the removal of suppressive activities such as grazing or weed control might not be included.

Native forest management was not proposed for inclusion at the commencement of the Scheme, raising fears that some plantations might be maintained un-harvested to increase C stocks, thus increasing the demand for timber from natural forests.

Forest Entities

Accredited Forest Entities under the proposed scheme included landowners, certain leaseholders and certain carbon property rights holders.

Forest Entities needed to monitor their emissions and sequestration. It was proposed that emissions and removals would be estimated using the NCAT. NCAT will be updated as new information for different forest types and new management practices become available.

Issue of permits

Carbon permits were proposed to be issued on an 'average crediting' basis, stand by stand, for the projected net greenhouse gas removals (sinks less sources) up to a permit limit for each planting. For harvested plantations the permit limit was based on the average cumulative net sequestration to the end of rotation over the long term of 100 years (about three rotations). See Fig. 3 for representation of a harvested plantation re-established over multiple rotations.

In such a case forest entities could generate permits during the initial growing phase (yellow bars) and will have to surrender permits for net emissions that lead to a change in permit limit (e.g. if the land is cleared and not replanted). The yellow dashed line is the permit limit. The blue dashed line represents a 'risk of reversal' buffer. This creates a reserve to help protect entities against the exposure posed by emissions from natural disasters like fire, storm, insect damage, etc. It would be in the form of a small deduction when permits were issued.

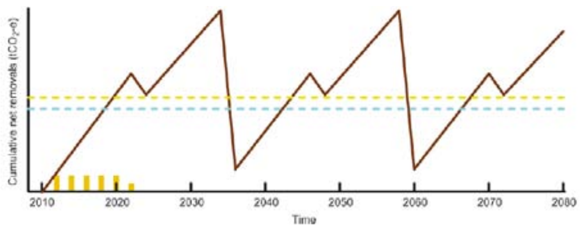

Figure 3. Commercial plantation re-established over time. Yellow dashed line represents permit limit; blue dashed line represents risk of reversal buffer. Source: Federal Govt CPRS White Paper.

In the case of plantings grown for non-harvest purposes (environmental reasons), forest entities could generate permits for sequestration as long as the trees were growing. They would surrender permits if land was converted to a non-forest use – see Fig. 4 (blue dashed line represents permit limit including the risk of reversal buffer).

For already established forests, permits would only be issued for any net removals of greenhouse gas from the atmosphere from 1 July 2010 once carbon stocks were greater than 2008 levels. The inclusion of the 2008 baseline was designed to ensure there was no incentive to clear plantations in 2009/2010 to receive permits for increases in net C-sequestration from plantation establishment.

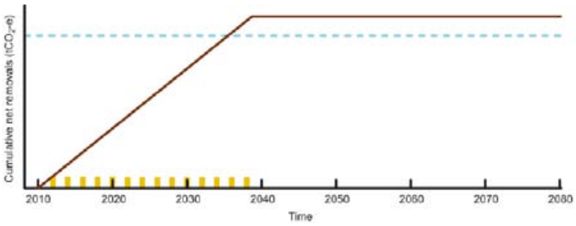

Figure 4. Plantations grown for non-harvest purposes. Blue dashed line is risk of reversal buffer. Source: Federal Government CPRS White Paper.

Price of carbon emission permits

The price per emission unit was proposed to be capped at $10 per tonne CO_2-e for the first year, and was then expected to rise to over $20. The cap, however, would not apply to permits generated from reforestation projects.

More information on the CPRS can be found at http://www.climatechange.gov.au/whitepaper/index.html

National Carbon Offset Standard

In November 2009 the Federal Government released detail of the NCOS, to commence from July 2011. As at February 2010 the NCOS had not been passed into legislation. This standard was intended to provide confidence and consistency to the voluntary offset market.

Eligible offset activities were those that cannot be counted by Australia towards its current Kyoto Protocol commitments. This included management of forests planted prior to 1990, revegetation, and soil carbon management in crop land and grazing land.

Details of methodologies for determining offset credits have yet to be announced.

For more information see http://www.climatechange.gov.au/government/initiatives/carbon-offset.aspx

Planting trees for sequestration

Tree plantings for carbon sequestration do not need to be of particular kinds or to be done on any particular type of site. Plantings carried out for wood production or salinity control on eligible land could 'double' as carbon sinks under the proposed CPRS. Because there are requirements for carbon plantations to remain viable and grow well over a long timeframe, careful attention to establishment and care of the growing plantation are vital. Details of site preparation for plantation establishment, tree planting methods and aftercare will be available in a new Industry & Investment NSW publication on farm forestry, expected to be released in early 2010.

Containerised seedlings ('tubestock') are more expensive than direct seeding but they have proven to be more reliable, with higher survival rates and (if planted well) less susceptibility to windthrow.

Planting densities will vary depending on whether the plantation is to be a long-term carbon store or is to be harvested. For plantings to produce sawlogs, high density planting (about 800–1100 per ha) would be used to encourage good form and to increase the number of suitable trees available for selection as crop trees. Such plantations need to be thinned quite heavily over time to encourage log growth. If the aim is to maximise long-term sequestration, high initial stocking (probably over 1000 per ha) may be used, with periodic thinning mainly to prevent growth suppression and death. Alternatively, a wider spacing may be appropriate to increase growth rate, at the expense of form, but in this case nearly all planted seedlings would need to survive and grow vigorously.

Tree species selection will be largely dictated by the purpose of the plantation – generally local species for environmental plantings, and often non-local species for timber production. Naturally, they must be suited to the site conditions. Promising commercial species in lower rainfall areas of NSW include:

- slightly salt-tolerant: spotted gums (*Corymbia* species) and *Eucalyptus cladocalyx*;
- moderately salt-tolerant: *Casuarina cunninghamiana*, *E. argophloia, E. camaldulensis, E. sideroxylon, E. tricarpa, Pinus pinaster, Pinus radiata*;
- highly salt-tolerant: *E. occidentalis*.

Marcar and Crawford (2004) include a comprehensive account of many commercial and environmental species tolerant of various levels of soil salinity.

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