PREDICTING CHANGES IN CARBON STORAGE IN SOILS AND VEGETATION FOLLOWING LAND USE CHANGE : THE NSW ENVIRONMENTAL SERVICES SCHEME, CARBON SEQUESTRATION PREDICTOR.

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Abstract

A Carbon Sequestration Predictor (CSP) has been developed as part of the New South Wales Environmental Services Scheme (ESS). This scheme aims to promote land use change to maximise off-farm environmental benefits, including the mitigation of greenhouse gas emissions. The CSP focuses on predicting carbon (C) sequestration resulting from proposed land use changes that include replacement of annual herbaceous species (crops and pastures) with woody perennial species. Here we report on the principles, operation and outputs of the CSP that aim to inform landholders, policymakers and the public about the potential for C to be sequestered by land use changes in lower rainfall (<800mm) areas of NSW. The CSP is a valuable tool for predicting changes in biomass (trees, shrubs and grasses) and soil C stores associated with a number of land use changes where empirical data are currently sparse. The CSP can be downloaded from http://www.forest.nsw.gov.au/env_services/ess/default.asp or used online at http://www.greenhouse.crc.org.au/calculators/cseq/.

Introduction

A Carbon Sequestration Predictor (CSP) has been developed as part of the NSW Environmental Services Scheme (ESS). This scheme aims to promote land use change to maximise off-farm environmental benefits and is ultimately intended to contribute to the development of a market for such environmental services. In order to objectively assess activities proposed under the ESS, tools including the CSP have been developed to quantify environmental impacts of changes in land management. Other tools are being developed for assessing the environmental impacts of the land use changes in relation to salinity, biodiversity, soil and nutrient retention and management of acid supfate soils.

Extensive areas have been cleared for grazing and cropping on the NSW western slopes and plains. Benson (1999) estimated that almost half the total area had been cleared of native vegetation, amounting to more than 20 million ha of cleared land. One consequence of the clearing has been a reduction in the C stored on these areas due to the release of C as CO_2 as cleared woody vegetation is burnt or decomposes or from soils where land use change results in reduced soil organic matter. Globally, land clearing and fossil fuel burning have resulted in an unprecedented rise in atmospheric CO_2 concentrations over the past century, about 40% of which has been attributed to land clearing. It is believed that the current rapid rise in atmospheric $C0_2$ levels may result in much of Australia becoming hotter and drier due to the enhanced greenhouse effect. Revegetation of cleared agricultural lands is therefore being encouraged as a key component of ESS to remove $C0_2$ from the atmosphere, by sequestering carbon in plant biomass and soils (Whetton, 2001). Revegetation of cleared landscapes using perennial woody vegetation, has the capacity to slow the build-up of CO_2 in the atmosphere by sequestering C in the two principal C sinks - biomass and soil.

The CSP (Version 2.0) predicts the likely changes in both biomass and soil C associated with a number of land use changes and aims to inform landholders, policymakers and the public on the potential for C to be sequestered by certain land use changes in lower rainfall areas of NSW. The principal focus of the CSP is on land use change from annual herbaceous (cropping, pasture) to perennial woody vegetation (commercial and environmental tree plantings) in regions of NSW with rainfall less than 800 mm per year. The tool provides predictions of changes in C stocks in biomass (plants) and soil (organic matter) over two time intervals. A table presents predicted changes in C stocks, 10 years after the land use change. However, many land use changes take a considerably longer time for C storage to reach a new quasi-equilibrium. Therefore, a graph of predicted C changes over 40 years is also provided to indicate the longer-term benefits.

Operation of the Carbon Sequestration Predictor

The CSP is an interactive model that operates via a series of drop-down menus. From these menus, options are selected to define i) the current land use, ii) the proposed land use, iii) rainfall, iv) soil type and v) a site modifier to adjust for local conditions (Note : all options are defined within the CSP). The selection of each is made from a defined list as follows :

Current land use -	Cropping, Annual pasture, Poor perennial pasture, Degraded native vegetation
Proposed land use -	Commercial planting – fast, Commercial planting – slow, Environmental plantings – fast, Environmental plantings – slow, Managed regeneration, Saltbush, Perennial pasture
Rainfall zone -	<400, 400-600, 600-800, >800 mm year^{-1}.
Soil type -	Hydrosol, Tenosol, Rudosol, Podosol, Sodosol, Kurosol, Kandosol, Chromosol, Vertosol, Ferrosol, Dermosol (after Isbell, 1996).
Site modifier -	None, Salt affected, Non-saline watertable, Lower slopes

Plant biomass carbon predictions

On the basis of the selections that are made, the CSP accesses a series of biomass growth curves (Fig 1). These biomass growth curves were developed using Richard's growth function (Richards 1959). Few empirical data were available to estimate tree C sequestration in rainfall areas <800 mm year^{-1} and most relate to plantings less than 10 years old. Consequently, the number of above-ground biomass growth curves is restricted to eight for woody vegetation and one each for saltbush and perennial pasture (Figure 1). The specific growth curve selected in a particular instance is determined by the parameter selections that are made. Below-ground biomass C was estimated by applying a root:shoot ratio to the above-ground biomass. The root:shoot ratio ranged from 0.2-0.6 between the biomass growth curves, and was determined from empirical, unpublished data. Total biomass was converted to C assuming a C concentration of 50% (Gifford 2000).

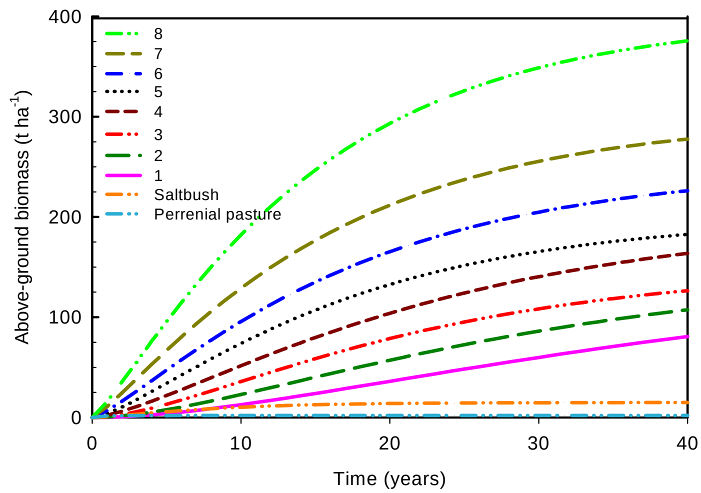

Figure 1. Generic above-ground biomass growth curves for woody vegetation (Curves 1-8), saltbush and perennial pasture.

Soil organic carbon

The dynamics of soil C following land use change in the low rainfall regions of Australia are poorly understood. For this reason, predicting changes in soil organic C following the change from annual herbaceous to woody perennial systems in these areas is especially problematic. To date most studies have focused on the impact of land clearing on soil organic C in this rainfall zone (eg. Murphy *et al.*, 2003), where a decline in soil C has generally been reported. Few have considered C changes resulting from revegetation. To predict changes in soil organic C associated with a proposed land use change, the CSP employs four discrete steps as summarised below. Note that soil C predictions are completely independent of biomass C predictions in this model.

1) Native soil C stock x Current land-use modifier	= Current land-use soil C stock
2) Native soil C stock x Proposed land use modifier	= Proposed land-use soil C stock
3) Change in soil C stock	= Proposed land-use soil C – Current land use soil C

4) Predicted soil C change at 10 and 40 years = *f*(Change in soil C stock and Soil C dynamics)

Values for the *native soil carbon stock* (to 0.3 m depth) for each rainfall and soil type were based on soil C data from undisturbed native vegetation sites held by DIPNR, State Forests of NSW and NSW Agriculture (Banks and McKane 2002). The *current land-use soil C stock* was estimated by applying a current land-use modifier to the native soil C stock , recognising the impact of current management of the site. The current land use modifiers were based on NGGI (1998) with some modification for lower rainfall areas based on Murphy *et al.* (2003). This process assumes that the soil C has reached an equilibrium that reflects the current land use.

The soil C stock of the proposed land use is then predicted based on the native soil C stock and a *proposed land use modifier*. The Proposed land use modifier predicts what the new long-term soil C equilibrium will be under the proposed land use. Subtracting the current land use C from the proposed land use C value gives the predicted long-term change in soil C associated with the particular land use change. The dynamics of soil C change were obtained by the selection of an appropriate soil change curve (Figure 2). Curves 1 and 2 produce an initial 10 % decline in the current soil C before increasing soil C toward the new equilibrium. These curves are used when trees are established on pasture. However, the evidence for an initial decline in soil C is largely derived from data from higher rainfall studies (> 800 mm) (eg. Paul *et al.* 2002). In the absence of data from the lower rainfall areas the current version of the CSP adopts a conservative approach and shows an initial decline in soil C. Curves 3 – 5 produce increasingly more rapid rates of increase in soil C stock. The selection of a curve is based on the particular land use change being undertaken. The curve applicable for the land use change is applied to the predicted change in soil C stock to predict the temporal pattern of soil C change.

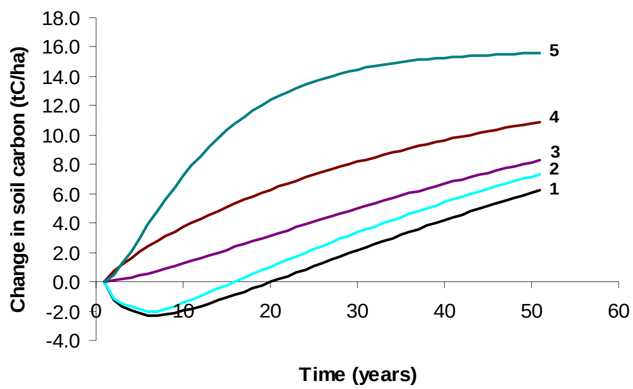

Figure 2. Representation of the soil carbon change dynamics following land use change.

Output from the Carbon Sequestration Predictor

As selections are made, a table and graph output are generated (Figure 3) which are simultaneously updated where selections are changed. Once the appropriate group of selections has been made the predicted change in C stocks at 10 years is shown. The table breaks total predicted change in C into biomass (above- and below-ground plant biomass C) and soil organic C. The graph plots the same data but over a 40 year period to give an indication of the longer term changes in C stocks.

Conclusions

The CSP has been developed under the NSW Environmental Services Scheme to inform landholders, policymakers and the public about the potential for C to be sequestered by land use changes in the lower rainfall (<800mm) areas of NSW. The CSP predicts changes in biomass (trees, shrubs and grasses) and soil C stores associated with a number of land use changes with an emphasis on changes from annual herbaceous to perennial woody vegetation. Its operation is simple and logical and in the absence of detailed data relating to C sequestration in the lower rainfall zones of NSW and Australia, we provides a valuable tool for C storage prediction. As new data become available this tool can and will be modified and improved. The CSP can be downloaded from http://www.forest.nsw.gov.au/env_services/ess/default.asp or used online at http://www.greenhouse.crc.org.au/calculators/cseq/.

Carbon Sequestration Predictor

Output : Table

Predicted carbon change after 10 years

Biomass	28.6	t/ha
Soil	-2	t/ha
Total	26.6	t/ha

Output : Graph

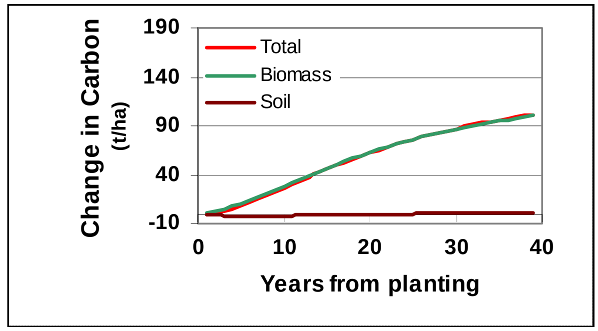

Figure 3. Outputs from the Carbon Sequestration Predictor.
Predicted changes in C stocks at (a) 10 years and (b) over the 40 years following the land-use change.

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