

Calibration of the RothC model to turnover of soil carbon under eucalypts and pines

Keryn Paul and Phil Polglase

CSIRO Forestry and Forest Products, PO Box E4008, Kingston, ACT, Australia. www.csiro.au Email Keryn.Paul@csiro.au

Abstract

An integrated suite of models called FullCAM was developed for full carbon accounting in agriculture and forests at project and national scales. Our objective was to calibrate the RothC sub-model within the FullCAM framework using two long-term forestry experiments where productivity had been manipulated, and archived soil samples were available for analysis of carbon within the various pools described by RothC. Inputs of carbon to soil at these trials were estimated by calibrating FullCAM to temporal data on above-ground growth, litterfall and accumulation of litter. Calibration of RothC was most sensitive to the partitioning of carbon during decomposition of debris between that lost as CO₂ and that transferred to soil. Although rates of decomposition of pools of soil carbon were originally developed in RothC for agricultural soils, these constants were found to be also suitable for soils under plantation systems.

Key Words

Forests, RothC model, soil carbon

Introduction

Establishment of tree plantations may help offset emissions of greenhouse gases, particularly by sequestration of carbon in woody biomass. However, changes in soil carbon following afforestation are generally small and slow (Paul et al. 2002). It may therefore be cost prohibitive to measure any changes directly. An alternative method is to calculate changes in soil carbon using validated models. A complete carbon accounting model, FullCAM, has been constructed by the Australian Greenhouse Office (Richards 2001). This is an integrated suite of models, and RothC can be used to predict turnover of soil carbon.

RothC was originally developed and parameterised to model turnover of organic carbon in arable surface soils from the Rothamsted long-term field experiments (Jenkinson 1990), and more recently has been applied to forests (Coleman et al. 1997; Romanyà et al. 2000; Paul et al. 2003). However, these workers calibrated RothC by adjusting the annual return of plant carbon to match the amount of carbon in soil to a prescribed depth. Others (Jenkinson et al. 1991; Polglase and Wang 1992; King et al. 1997) have used RothC to predict potential response of soil carbon storage under forests to changes in climate and atmospheric CO₂. It was assumed that the ratio of decomposable to resistant plant material (DPM:RPM) was 0.25 for all forests and 0.43 for tropical woodland (Jenkinson et al. 1991). Beyond this assumption, RothC has not been specifically calibrated to simulate turnover of carbon in forest soils.

Methods

Data were collated from two long-term field experiments: a *Pinus radiata* plantation at the Biology of Forest Growth (BFG) experiment in the ACT (Benson et al. 1992), and a *P. radiata* and *Eucalyptus grandis* plantation at the Wagga Wagga Effluent Plantation Project (WEPP) in southern NSW (Myers et al. 1994). Data on stem volume, biomass (total above-ground as well as stem, branch, bark, foliage), leaf area index, fall of leaves and wood were available from both experiments for up to 20 years. At BFG, some data were also available for the biomass of coarse and fine roots. To calibrate RothC, inputs of carbon to soil pools need to be adequately predicted. Values for allocation of biomass to tree components, and rates of litterfall and root slough were adjusted to match rates of biomass accumulation, thus generating inputs of carbon to soil.

Archived soil samples (<2 mm fraction from 0-30 cm depth) were available from BFG when the stand was 11, 21 and 28 years old, and from WEPP when the stand was 1, 3, 5, 7 and 9 years old. Amounts of fine charcoal (assumed to be the inert or IOM), particulate organic carbon (assumed to be the resistant or RPM pool), and total soil organic carbon (TOC) were estimated using MIR methodology described by Skjemstad and Spouncer (2003). The amount of carbon in humus (HUM) was estimated as the difference between total soil carbon and the sum of the IOM and RPM pools. It was assumed that the amount of carbon in the labile decomposable (DPM) and microbial (BIO) pool was initially zero. Calibration was performed by minimising

the total sum of the absolute difference between predicted and observed in TOC, RPM and HUM pools of soil carbon.

Results and Discussion

Efficiency of predictions was sensitive to assumed rates of decomposition of the RPM and HUM pools. Nonetheless best predictions were obtained when their values were unaltered from the original model. No improvements were gained by relating the rate of RPM decomposition to the quality of substrate entering the soil (i.e. the ratio of decomposable to resistant debris). When RothC was calibrated to amounts of carbon within the RPM and HUM pools for all observations, the R^2 value was greater than 0.60, and the line of best fit (when forced through the origin) had a slope close to one (between 0.85 and 0.95).

Although we have successfully calibrated the RothC model for two sites with contrasting carbon dynamics, it needs further independent validation, for example using paired-site comparisons as has been done for agriculture (Skjemstad and Spouncer 2003). Most importantly, we have little information on the partitioning of carbon during decomposition between that lost as CO_2 and the remainder that enters soil. Validation of RothC, and other such models, will require studies that monitor loss of C^{13} - and C^{14} -labelled debris *in situ* to validate the calibrated rates of carbon loss to respiration.

Assumed rates of decomposition of dead roots is another major factor that determines simulated changes in soil carbon. Here we assumed that the resistant fraction was 62% for dead fine roots and was 100% for dead coarse roots. We also assumed that the rate of decomposition of fine and coarse roots followed that of foliage and bark debris, respectively. These assumptions need to be verified.

The RothC model has only been calibrated to predict turnover of carbon within the surface 30 cm of soil. Although this is where soil organic carbon is most concentrated and subject to change, it is possible that deeper soil horizons have the capacity to sequester carbon. Indeed carbon at this depth is older than that near the surface, indicating that it has a greater resistance to decomposition or that the environment at depth is less favourable for microbial decomposition processes (Swift 2001). More information is needed on root input and turnover, and on decomposition of organic matter deeper in soils. Information on the turnover rates of soil carbon within the inert pool is also required.

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