SECTION 5

Adding Vegetation Carbon to the RothC Soil Carbon Model

Contents

Adding Vegetation Carbon to the RothC Soil Carbon Model

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Introduction

Sozanska *et al.* 2002 compared estimates of soil carbon for grasslands and other vegetation types using two carbon cycle models. These were BIOTA, a vegetation/soil C cycle model developed at CEH (Centre for Ecology and Hydrology), and RothC, a soil C cycle model developed at Rothamsted and widely applied in different environments. The work envisaged further application of linked models to predict C dynamics under a wide selection of land use types and management practices in the UK. In particular the advantage of using a model with modules describing the plant parts as well as the soil was of interest. These studies showed that with suitable parameter settings the plant carbon modules of Biota were able to generate litter inputs equivalent to those used as inputs to RothC. Hence where climate changes effects on soil carbon are of interest the linked effect of the effect of climate on the plant and litter components would be incorporated.

It was decided that as RothC is well established that additional code should be added, based on Biota, to model changes in plant and litter carbon

This report details the work done to date to integrate the CEH Biota plant carbon cycle model with the RothC v26.3 soil carbon cycle model. This text is not intended as an extensive description of the workings of the models but concentrates on the tasks required to join them smoothly.

Approach to Integration

RothC works on a monthly time-step basis, and obtains plant litter and climate datasets from external text files to drive these time-steps. It outputs a set of time-series soil carbon pool data upon completion.

Biota works on a daily time-step basis, and uses a set of plant parameter files, in conjunction with climate datasets, to drive a plant-growth model and outputs a set of time-series plant pool data upon completion.

The chosen point of interface between the two models is where RothC reads in its plant and climate datasets. The plant litter data is generated by Biota and fed into RothC, and the climate datasets are harmonised so that both models are running with identical data.

Figure 1 illustrates the input and output flows of the RothC, Biota and integrated models:

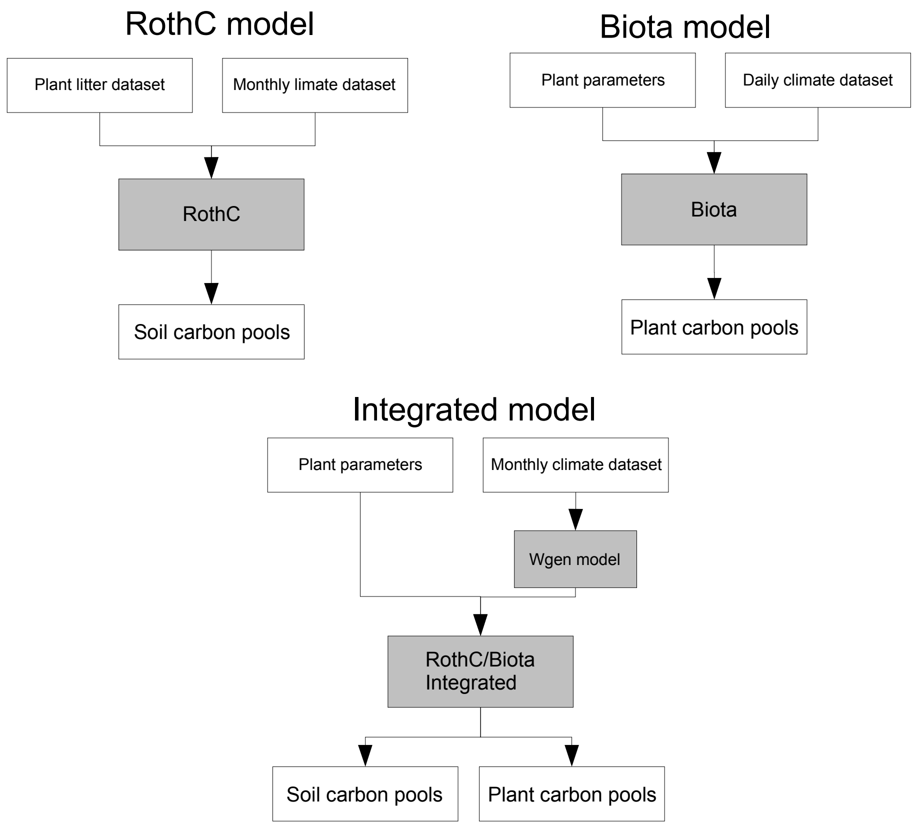

Figure 1. The input and output flows of the RothC, Biota and integrated models:

The integrated model has been constructed in such a way that that is retains the full capabilities to run the RothC model in its original form with all input being provided from simple text files. This is the default mode of operation of the model and the use of the Biota plant module to supply the litter must be explicitly requested.

The climate data

The base climate data used by the integrated model comes from the CRU Climatology datasets and has the following climatic variables in *monthly* format:

Integrated model climatic data requirements

- Fraction of wet days
- Rain per wet day (mm)
- Minimum temperature (degrees Celsius)
- Maximum temperature (degrees Celsius)
- Solar Radiation (MJ/m2/day)
- Relative humidity (%)

The Biota plant carbon module requires daily data to run, the format of which is shown below:

Biota module climatic data requirements

- Rainfall (mm)
- Maximum temperature (degrees Celsius)
- Minimum temperature (degrees Celsius)

- Solar radiation (MJ/m2/day)
- Vapour pressure (kPa)
- Day length (s)

In order to derive such data from the CRU dataset a subsidiary climatic module, the *ITE Global Weather Generator* (GWG), is included within the model. This model is a stochastic daily weather generator parameterised to operate at the half-degree scale for the Earth's terrestrial surface. This was an ideal solution as the CRU dataset and the GWG was the method being used to derive daily data for the stand-alone Biota plant model. The output and unit conversion from the CRU data to the required Biota units is handled internally by the GWG by means of a handful of settings.

The RothC soil carbon module has a much simpler set of climatic requirements, as shown below:

RothC module climatic data requirements

- Temperature (degrees Celsius)
- Rainfall (mm)
- Pan evaporation (mm)

The temperature value for the RothC code is simply derived in the integrated model as the average of the CRU minimum and maximum temperature, and the rainfall from the simple calculation:

rainfall in month = days in month * rain per wet day * fraction of wet days

using the appropriate number of days for the month concerned.

The pan evaporation figure required for the RothC model was derived using the *Thornthwaite method* and its set of equations to generate a monthly time series. This small set of equations uses the air temperature and the number of daylight hours to give a very good set of values for pan evaporation. It takes the following form:

$$PET = 1.6L_d\left(\frac{10T}{I}\right)^a$$

where

- PET is potential evapotranspiration in cm/month - to get a per day amount, we assume there are 30 days per month, so PET in mm/day = PET*10 (mm/cm)/30 (days/month)
- T is average temperature for the day or month in ^{o}C
- L_d is daytime hours in units of 12, for example if there are 10 daytime hours, then L_d=10/12
- I is the annual heat index that is computed from the monthly heat indices $I = \sum_{j=1}^{12} i_j$ where i_j is computed as $i_j = \left(\frac{T_j}{5}\right)^{1.514}$
- a = $6.75\mathrm{x}10^{-7}I^3 - 7.71\mathrm{x}10^{-3}I^3 + 0.01792I + 0.40239$ or: $a = \frac{1.6}{100}I + 0.5$

The integrated model can be used without providing Biota plant litter input to the soil, but with the CRU climate dataset to provide the climatic input as an alternative to the original RothC files. This provides a good method of testing the effects of using the calculated pan evaporation equations described above.

Plant module details

The plant (based on Biota) module is fully parameterised in order to allow a wide range of plant types to be implemented. The types of plant can be broadly categorised into two:

> *Unmanaged*
> These are plant types that will be parameterised by natural lifetimes and death rates.
>
> *Managed*
> These are plant types that will be parameterised according to how they are farmed, harvested, etc

These two categories are conceptual, there is no actual framework in the model that distinguishes the two types explicitly. The following is a detailed list of the specific plant types that the model is able to function with, along with their major input data requirements (note that all plant types will have some type-specific information such as growth rates, leaf conductance, etc which are not elaborated on here – this list concentrates on the *cycle* as opposed to the physical plant):

1. **Grass**
   Grass can be both managed, and unmanaged.

Unmanaged grass
Requires 12 natural loss fractions (one per month) . This loss is passed into the RothC soil module as above-ground litter.

Managed grass
Requires the same natural loss fractions as unmanaged grass, one or more mowing dates and two further parameters indicating:

a) fraction of "leaves" removed by mowing

b) fraction of removed "leaves" remaining as detritus (input to soil module above-ground litter)

2. **Crops**
   Crops are always managed, and are divided into two sub-types, cereal and root. Both require the following parameters:

   a) planting date

   b) harvesting date

   Both sub-types have natural biomass loss spread across the growing season, calculated by taking a fraction of the total biomass at harvest date and distributing it under a curve. This loss is passed to the soil module as above-ground litter.

For cereal sub-types, the roots at harvest time are passed to the soil module as below-ground litter. Root crops are of course removed.

3. **Coniferous trees**
   Can be managed, or unmanaged.

   Unmanaged coniferous trees
   Requires 12 natural loss fractions (one per month). This loss is passed into the RothC soil module as above-ground litter

   Managed coniferous trees
   Requires the same natural loss fractions as unmanaged coniferous trees, as well as:
   a) harvesting date (expressed in years since planting date)

   b) fraction of leaves passing to soil module above-ground litter

   c) fraction of stems passing to soil module above-ground litter

   d) fraction of roots passing to soil module below-ground litter

4. **Broadleaf trees**
   Can be managed, or unmanaged.

   Unmanaged broadleaf trees
   Requires 12 natural loss fractions (one per month) , tuned to budburst and leaf fall dates. This loss is passed into the RothC soil module as above-ground litter.

   Managed broadleaf trees
   Requires the same natural loss fractions tuned to budburst/leaf fall as unmanaged broadleaf trees, as well as:
   a) harvesting date (expressed in years since planting date)

   b) fraction of leaves passing to soil module above-ground litter

   c) fraction of stems passing to soil module above-ground litter

   d) fraction of roots passing to soil module below-ground litter

Initial investigations of model output on unmanaged grass

One of the main concerns about the integration of the two models was that the plant additions figures generated by the Biota plant module would be a reasonable first-approximation match for the "real" input data as used by the standard RothC soil model.

To test this, an initial grass parameter file was designed and the output compared with the original RothC data. The RothC additions are static, and the same every year whereas the Biota-provided ones are modelled each year, and the figures shown here are an average.

It should be noted that the Biota figures here are properly seasonal, with the litter generated being dependant on a number of factors affecting plant growth and subsequent litter availability, for example the climatic variables.

Figure 3 shows the soil pool values for a run of the RothC model between the years 1876 and 1991, and Figure 4 the same for the integrated model.

Future work required before release of new version of RothC with integrated plant modules.

- Further testing of the integrated model code for different vegetation types
- Construction of test parameter set for each vegetation type
- Comparison of outputs from old and new version of RothC using field data (SOMNET likely to be useful source)

References

G. Sozanska, P Smith, R. Milne, and T. A.W. Brown (2002) Linking Soil and Vegetation Carbon in Dynamic Models. In: *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities.* Annual report for DEFRA Contract EPG1/1/160 (Ed. by R. Milne).

Month	Biota	RothC
Jan	0	1.0
Feb	0	1.0
Mar	0	1.0
Apr	0.18415	1.0
May	0.16307	1.0
Jun	0.14505	1.0
Jul	0.12857	1.0
Aug	0.11402	1.0
Sep	0.1076	1.0
Oct	0	1.0
Nov	0	1.0
Dec	0	1.0

Table 1: Plant additions from the Biota module and the original RothC measured data (t/ha)

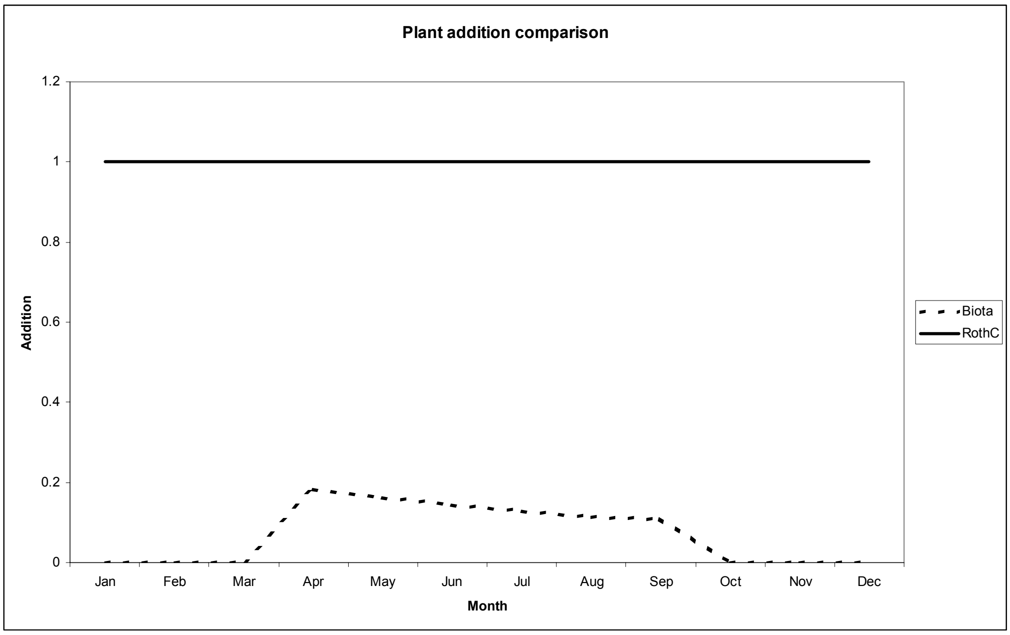

Figure 2: Plant additions from the Biota module and the original RothC measured data

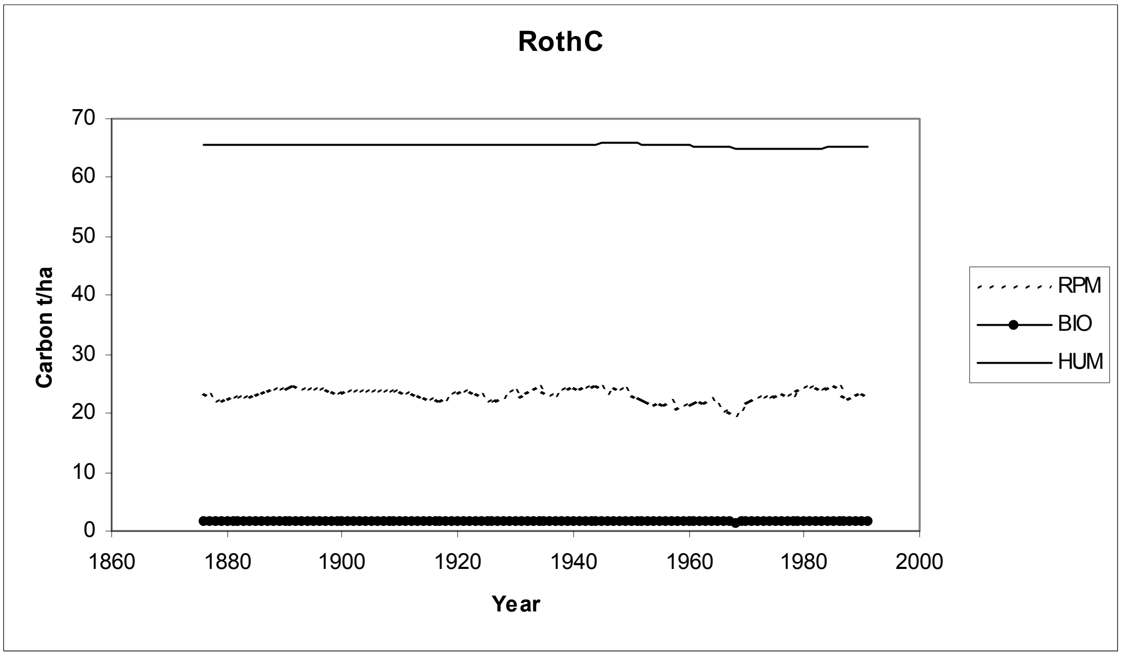

Figure 3: Soil pool values for RothC model

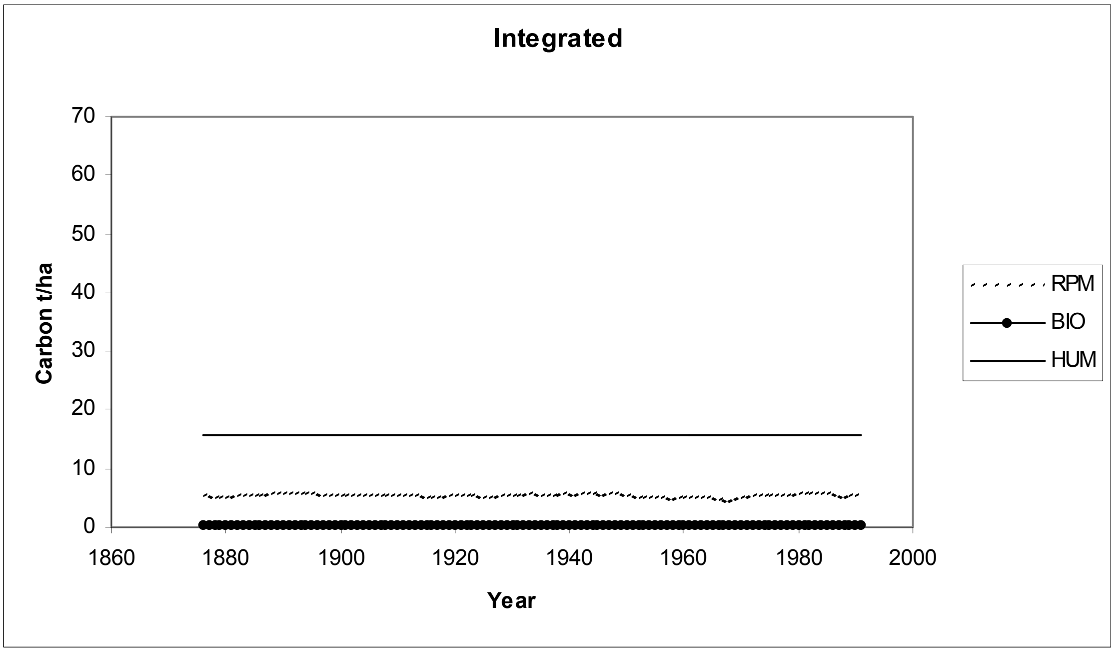

Figure 4: Soil pool values for the Integrated model