

Section 9

RothC-BIOTA v05 plant-soil C turnover model – parameterization and evaluation

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9. RothC-BIOTA v05 plant-soil C turnover model – Parameterization and evaluation.

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9.1. Introduction

The Rothamsted Soil Carbon model has been developed so that it can use the UK soils database to simulate changes in soil carbon, for possible future use in national GHG inventories (Falloon, 2004). The model uses either fitted soil carbon inputs, or crude estimates of carbon returns per month for a range of plant functional types. The limitation of this approach is that the model does not dynamically respond to changes in climate and land-use. In order to simulate such changes, alternative methods of calculating C returns are required, such as those from dynamic plant growth models that respond to atmospheric CO₂ increase, and changes in climate as RothC does for the soil components. One such model is Biota (Wang *et al.*, 1995). BIOTA, a process-based model describing photosynthesis at the canopy level and C transfers in the plant/soil system, has been linked with RothC v26.3 (Coleman *et al.*, 1996), a functional model of C turnover in topsoils. Initial development of the link was presented by Milne *et al.* (2004). In this chapter, we report recent developments of the coupled model, namely improvements in the range of plant functional types (PFTs) and crops included, the efficiency and functionality of the code and the accuracy of the simulations. We report in detail on further improvements of the design, parameterization and initial evaluation of the coupled model.

9.2. Calculating carbon returns to the soil for various crops

The first step in model development for new PFTs and crops is to estimate the proportion of the total dry matter each month that is returned to the soil. This varies greatly among PFTs as well as among different crop types. In order to develop carbon return proportions, so that carbon inputs to the soil each month could be calculated from total plant carbon, relationships between plant carbon and soil inputs from the SUNDIAL agro-ecosystem model (Bradbury *et al.*, 1993, Smith *et al.*, 1996) were adapted and parameterised. This was summarised in an Excel workbook (for transparency of calculation), referred to as the DEBRIS calculator.

In previous work, the BIOTA model was provided with parameters to enable simulation of plant growth for selected arable crops (Milne *et al.*, 2004). These have now been refined and extended to further develop the default parameters quantifying monthly litter production for different crops. The DEBRIS calculator has been used to estimate:

1. proportions of standing plant biomass that are returned to soil as plant debris at monthly intervals during the growing season,
2. proportions of plant biomass removed from the field and incorporated into the soil as crop debris at harvest.

The DEBRIS calculator estimates C additions to soil from different plant components at different growth stages (equation 1). These relationships were developed over a number of years at Rothamsted Research by J.U. Smith, M. Glendening and G. Tuck, on the basis of field measurements provided by A. MacDonald and P. Poulton, and other published field experiments.

The DEBRIS calculator applied a SUNDIAL function (eq 9-1) to estimate monthly C inputs to soil from plant debris. Those estimates were then related to the cumulative C in the growing

plant, to estimate fractions of C in plant biomass that are returned to soil each month. Fractions for each crop are used as BIOTA input parameters in the crop.ini files.

$$C_{inDebris} = C_{inCrop} \times ((C_{ao} - C_{st})/C_{ao}) \times \exp(-kc \times w) \quad \text{eq 9-1}$$

where: $((C_{ao} - C_{st})/C_{ao})$ and kc are SUNDIAL fixed parameters for each crop and w is the number of weeks till harvest [converted to month for use in BIOTA].

At harvest, we applied the SUNDIAL method to estimate the fraction of C in crop biomass removed from field as yield (eq 9-2), and the fraction in cartable crop residues (straw and other crop debris) (eq 9-3). The latter can be added to soil or removed at harvest, which will vary depending on site management.

BIOTA has so far been parameterized for seven crops (Table 9-1), but the DEBRIS calculator will be further applied to define parameters for all crop types including root crops.

$$C_{off} = 0.4(85\%G) \quad \text{eq 9-2}$$

$$C_{cartable} = c5(1 - c6 \times e^{c7G}) \quad \text{eq 9-3}$$

where : G – yield, c5-c7 – SUNDIAL parameters.

Table 9-1 Input DEBRIS parameters(proportion of the total cumulative C in the total biomass present in that month) for all seven crops types.

crops	Spring wheat	Spring barley	Winter wheat	Winter barley	Spring oilseed rape	Winter oilseed rape	Field peas
Max. debris input at harvest (1)	0.314	0.194	0.274	0.195	0.366	0.338	0.288
Pre-harvest input (1)							
Jan	0	0	0.598	0.082	0	0.090	0
Feb	0	0	0.496	0.100	0	0.116	0
Mar	0	0	0.318	0.094	0	0.120	0
Apr	0.074	0.428	0.174	0.080	0	0.140	0.138
May	0.066	0.306	0.108	0.120	0.140	0.134	0.162
Jun	0.068	0.322	0.054	0.132	0.122	0.162	0.136
Jul	0.130	0.444	0.044	0.192	0.154	0.332	0.170
Aug	0.146	0.390	0.044	0	0.306	0	0
Sep	0	0	0	0	0	0	0
Oct	0	0	0	0.015	0	0.014	0
Nov	0	0	0.548	0.019	0	0.020	0
Dec	0	0	0.446	0.034	0	0.036	0

9.3. Resolving problems with the coupled model when performing an equilibrium run

RothC-BIOTA v97 was applied to simulate SOC under seven selected cereals (Table 9-1). The results for total SOC, estimated with the soil module (excluding the BIOTA component), using debris inputs based on previous RothC applications, were very low. They ranged from 6.9 tC/ha for soils under field peas to 14.5 tC/ha for soils under winter barley. When the BIOTA component was used, soil C sequestration was increased to 23.5 – 33.1 tC/ha for field peas and winter wheat respectively. The soil carbon stock simulated with the stand-alone version of RothC was very low in comparison with previous RothC results which suggested a total SOC of 33.8 tC/ha simulated for spring barley (Coleman *et al.*, 1996). In this respect, the coupled model apparently performed better. Very low predicted SOC values for RothC in the coupled framework suggested problems with the model structure, which were investigated further. We also observed a very large increase in SOC pools simulated for cereals with the coupled models in the first 10 years. RPM, however, reached equilibrium more slowly (after 100 years in comparison with 30-40 in previous studies). The sudden change of slope in the HUM pool for cereals after 100 years suggested a problem in the coupled model framework (Figure 9-1A).

When annual change in SOC was estimated for each individual year (Figure 9-1B), a rapid drop in SOC was seen after 10, and then 100 years. Those results contrasted with RothC simulation for spring barley and suggested that there might be an artefact associated with the three step process used to assess the equilibrium soil carbon stock.

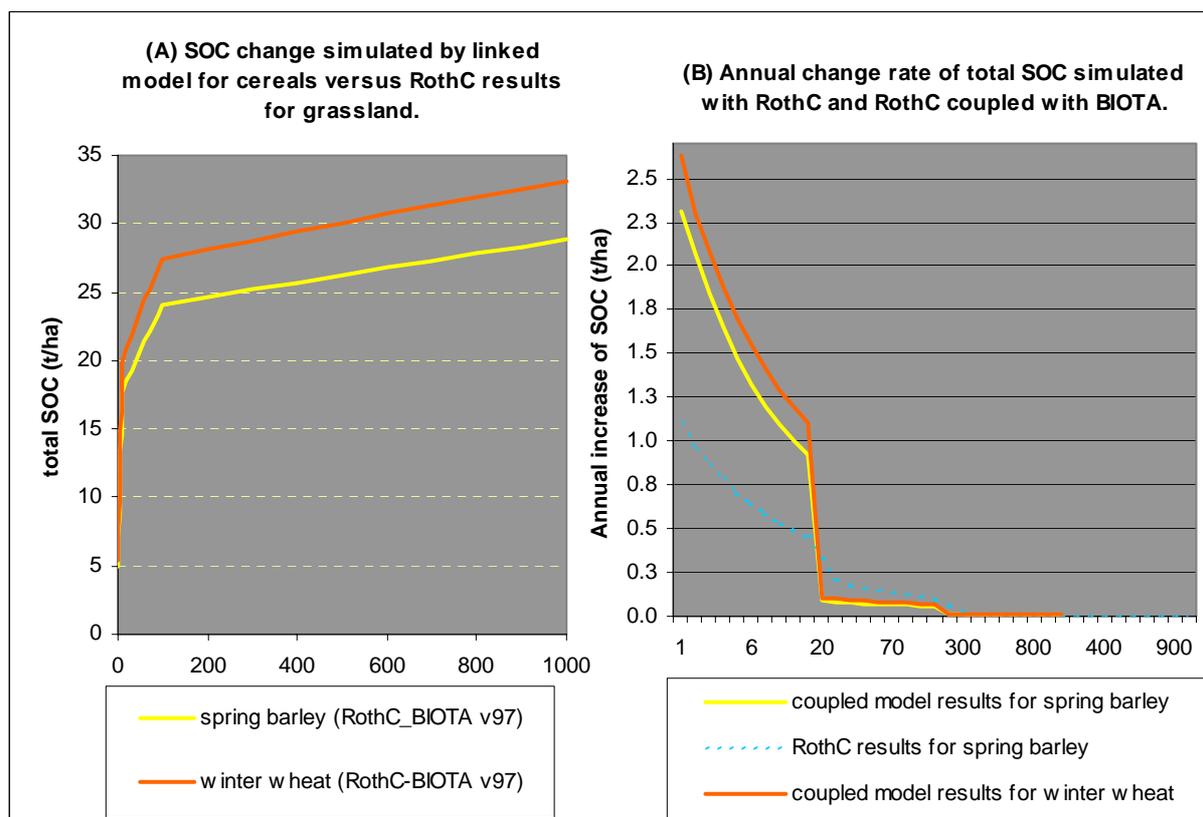


Figure 9-1: RothC-BIOTA v97 simulation of SOC dynamics in soils under winter and spring.

We compared the methods used by the models to reach soil equilibrium. The main difference was the rate of time-step change in the equilibrium run that was closely linked with decomposition and SOC accumulation (details are described in section 9.4.1).

We tested the link between BIOTA and ‘short-term’ RothC with corresponding principal designs. The new link was run for 1000 years. The test showed a great improvement in the annual rate of SOC change and confirmed the source of difference was in the principal design of equilibrium methods in both models (Figure 9-2). This difference was addressed as follows.

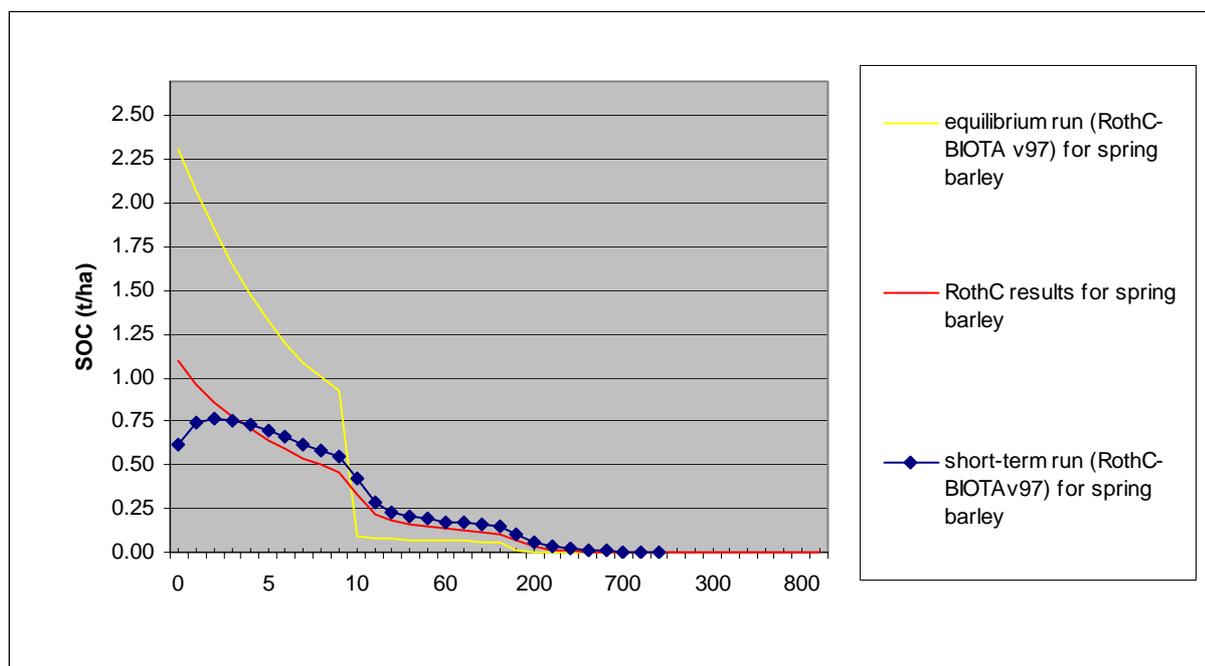


Figure 9-2 Annual rate of SOC change simulated by the coupled models with equilibrium and short-term methods.

Initial results of the tests revealed important methodological differences between RothC and BIOTA in reaching equilibrium state. RothC estimates decomposition of organic plant material and C content of the four active organic pools in a framework of an exponential time increase function i.e. model results are output for years 1-10, 20, 30, 40,...100, 200, 300,..1000, 2000,...and 10000. This method is used in all versions of RothC (Coleman *et al.*, 1996) and it was originally designed to reduce the processing time. Currently, simulating decomposition processes at yearly time-steps, as is done in BIOTA, only marginally increases PCU run-time (running RothC this way for 10000 years takes only minutes in comparison with some detailed physical models with PCU run-time of hours and days). Close-coupling of RothC and BIOTA requires corresponding rates of plant growth (simulated by BIOTA) and decay of dead plant material in soil (RothC). In order to run the coupled model, the old equilibrium calculation routines were discarded and the ‘new approach’ taken was to adopt the method used by the ‘short-term’ RothC model. We initially retained the original assumption of soil reaching equilibrium after 10000 years. The model code was developed on the basis of the new GIS-RothC version 2003 (Smith *et al.*, 2005a, Smith *et al.*, 2005b), which was adopted for this project (more details in section 9.5). The new equilibrium approach was applied to the existing model subroutines (SETSIM and RUNC14 instead of previously used SETEQ and RUNTOEQ) as presented in Appendix 0.

After running the model for 10000 years it became apparent that soil organic pools reach equilibrium earlier than 10000 years; DPM in < 10 years, RPM in < 100, BIO in < 1000 and HUM < 3000 years. To reduce the PCU run-time a flexible algorithm was introduced to estimate the exact time for all the soil pools to reach equilibrium in site-specific conditions, based on no further increase in total SOC over a number of years. An algorithm was developed that monitors the change of SOC until it differs by less than 0.001 tC/ha in successive years, when the equilibrium state is reached. The threshold level is currently being tested.

9.4. Inclusion of spatial functionality adopted from GIS-RothCv03.

The new RothC-BIOTAv05 is based on the spatial model GIS-RothCv03, used to make spatial simulations for whole countries and continents (Smith *et al.*, 2005a, Smith *et al.*, 2005b). The code of the coupled plant-soil C model retains the spatial functionality, which will enable its applications to site and regional studies. We have developed a site version of this model (SITE_MODEL), which is linked to the regional RothC (GIS_MODEL). A transfer between the two model types is controlled in the MAIN model with a simple loop and variable *space* set to ZERO for this project. We also set LUCODE to agricultural land (=1), so that the same GIS-RothC routines could be applied directly to a site-scale. This is an advantage for future spatial applications of the coupled models, as no further code developments are necessary due to its multi-scale functionality. Further changes required for the site-scale code involved input of site-specific data in the form of a self-explanatory text file (INPUT_REF.TXT) presented in Appendix A.2. Model RothC-BIOTAv05 is called using the command line:

```
biotarothc -rothc <input_ref.txt> -biota biota.ini <crop.ini> -cruclimate
<climate.mon> -pladd <biota_pladd.txt>
```

A description of the command line is presented in Appendix A.3.

The command line was designed to test the link between the models and the effect of different climatic data sets. This will be retained in future for the user to decide on the best site-specific method. The options below give guidelines for using the different model functions.

9.4.1. Stand-alone RothC with ‘fitting-to-equilibrium’ option

This can be applied for the equilibrium runs, when there is measured SOC at equilibrium. It would enable the model results to be tuned to a specific equilibrium level. ‘Fitting’ option is switched automatically, when measured SOC > 0 in INPUT_REF.TXT.

This function can use site measurements of climate for individual years of the ‘short-term’ model. All the weather files need to be named in INPUT_REF.TXT.

9.4.2. RothC with BIOTA using site climate.

When measured monthly weather data are used, the model results can be considerably improved. The climate variables listed in <NAME>.MON are accordingly:

1. Fraction of wet days in a month (%)
2. Average Rain per wet day (mm)
3. Maximum temperature (°C)
4. Minimum temperature (°C)
5. Solar Radiation (MJ/m²/day)
6. Relative Humidity (%)
7. Pan evaporation (mm)

9.4.3. RothC with BIOTA using CRU climate.

When there are no measured weather data other sources should be considered. We use the Climate Research Unit (CRU) data (<http://www.cru.uea.ac.uk/cru/data/hrg.htm>) that provide all the required inputs for both models. The Weather Generator with an in-built CRU dataset of BIOTA can be applied to estimate the input data given above, based on the site location in the U.K.

9.5. Initial evaluation and sensitivity analysis – a case study for spring barley.

The coupled model was run to equilibrium for the seven crops so far parameterised (Table 9-2) with Rothamsted climate. The climate input data, listed above in MON file, were based whenever possible on site measurements (temperature, pan evaporation). Those inputs were provided by `roth.dat`, weather input file to RothC that represents long-term monthly averages measured at Rothamsted weather station. The climate variables that were not available from the site source were obtained from CRU. This design of the monthly climate input ensured consistency throughout different simulation types for the testing of the coupled model.

There was a considerable improvement in total SOC simulated with RothC in the new coupled framework, which were comparable with measurements (section 9.3). RothC simulated higher SOC when soil carbon additions were estimated by BIOTA (Table 9-2). The overall increase in total SOC corresponded with larger monthly plant additions as estimated by BIOTA, compared to the inputs suggested by previous applications of RothC in which the soil carbon returns were estimated by fitting the model to match the measure soil carbon value. As expected, winter crop systems show higher rates of C accumulation than spring crops due to a longer growing season and hence a longer period during which the plants are adding carbon to the soil. For spring barley, however, the coupled model results at equilibrium (annual plant additions and total SOC) were ~ 25% higher than for winter barley. This was probably caused by much higher % debris input to soils estimated with DEBRIS Calculator (Table 9-1).

To evaluate the above simulations it was necessary to simulate C soil dynamics in continuous crop systems. RothC-BIOTA v05 was run for the Hoosfield Continuous Barley Experiment at Rothamsted in the south-east of England. The coupled model was applied to simulate C dynamics on un-manured plot. Spring barley has been grown on that plot since 1852, with the exception of 1913, 1934, 1943 and 1967 when it was fallow. Currently, the coupled model can simulate only continuous crops, with no land use change, so the fallow years could not be reflected in these simulations.

RothC-BIOTA was run for 1414 years before soil reached equilibrium SOC of 62 tC/ha (Figure 9-3). The model results were overestimated due to much higher monthly carbon inputs to the soil than suggested by fitting the stand-alone RothC to the measured SOC data. The BIOTA module estimated total plant additions in the growing season¹ at 1.73 tC/ha ('tuned' inputs to RothC suggest 0.66 tC/ha is required). At harvest², when 1.74 t C/ha of plant biomass was removed from the field, with the assumption that 50% of straw was removed with the grain, the remaining 1.16 tC/ha of plant material was added to the soil (straw, chaff and dead roots). This suggests a fresh yield of 5.12 t/ha, which was very close to the south-east average of 5.3 t/ha (MAFF, 1998).

Following the initial simulation, the coupled model was tested with different debris inputs during the growing season and at harvest. The following scenarios were simulated to test the sensitivity of the model to residue management:

1. spring barley inputs during the growing season with (a) 50% straw removed, (b) 75% of straw removed and (c) 100% of straw removed at harvest,

¹ Growing season here refers to the period from the second month of plant growth to the last month but one.

² Harvest month with all the carbon inputs to the soil due to harvest

2. spring wheat inputs during the growing season with (a) 50% straw removed, (b) 75% straw removed and (c) 100% straw removed at harvest.

Debris inputs during the growing season estimated with BIOTA for spring wheat were exactly the same as those suggested for Hoosfield spring barley by RothC (0.66 tC/ha). Scenario 2c (spring wheat debris return parameters with 100% of the straw removed) provided the best fit for Hoosfield, with annual debris input of 1.47 tC/ha and total SOC at equilibrium of 33.8 tC/ha (Figure 9-3). RothC-BIOTA was more sensitive to debris inputs during the growing season, with a proportional increase of C sequestration in the range 50% for the higher debris inputs (scenario 1c) (Table 9-3). That difference would increase by a further 30%, when half amount of straw was incorporated into soil at harvest (scenario 1a) (Table 9-3). In summary, model proved very sensitive to debris inputs, particularly at harvest.

Table 9-2 Annual inputs of dead plant matter into soil and total SOC after 1000 years of simulation with RothC and the coupled models.

crops	RothC		RothC-BIOTA	
	user-defined debris (tC/ha)	SOC (tC/ha)	debris calculated by BIOTA (tC/ha)	SOC (tC/ha)
winter wheat	0.92	26.3	2.24	63.0
spring wheat	0.52	14.2	2.54	47.2
winter barley	1.87	52.3	2.04	45.8
spring barley	1.83	42.2	2.89	63.9
winter oilseed rape	1.19	36.3	2.82	79.2
spring oilseed rape	1.08	24.4	2.77	58.3
field peas	0.74	17.9	1.82	40.0

The 'short-term' coupled model simulated SOC remaining at the equilibrium level, while the measurements suggested a slow loss of C caused by fallow years. This effect of land use change was simulated better by RothC with 'fitted' debris inputs. The coupled model cannot presently simulate that land use change, but the function is currently being developed.

Table 9-3 Sensitivity of the coupled model to different debris inputs.

Model run	% straw removed at harvest	Annual plant additions (t C/ha)	SOC (t C/ha)
Site measurement	-	-	33.8
RothC (site climate)	-	1.63	35.9
RothC (CRU climate)	-	1.63	35.9
Monthly debris additions defined for spring barley			
RothC-BIOTA	50%	2.89	61.9
RothC-BIOTA	75%	2.64	56.7
RothC-BIOTA	100%	2.39	51.5
Monthly debris additions defined for spring wheat			
RothC-BIOTA	50%	2.11	49.1

RothC-BIOTA	75%	1.79	41.9
RothC-BIOTA	100%	1.47	34.8

9.6. Current focus and future developments.

In the first instance we need to reconcile the BIOTA and RothC inputs so that a match to the measured SOC can be achieved. Overestimation of SOC stock at equilibrium could be due to:

- a) total C in biomass being too high from BIOTA – we will test this by comparing to estimates of total biomass / C in biomass during the growing season – this will be done by harvest index and yield in the absence of measured data, but measured data will be sought,
- b) too much C being returned from the crop biomass to the soil – this could be the result of incorrect relationships from SUNDIAL. This could be remedied by tuning the C return proportions calculated by DEBRIS so that the inputs match the measured SOC – this will only be done when we are sure BIOTA is not overestimating total crop biomass C.

More tests are being carried out at present, with the equilibrium threshold still being tested and the model still being developed to simulate crop rotations. All of the coding procedures need to be finalized soon to enable model evaluation in different cropping systems. The current model can simulate only continuous crops, while most long-term experiments are for various crop rotations. Further steps will involve detailed evaluation of the model in different agricultural systems with real climate inputs. Further parameters need to be derived from the literature to evaluate the current model parameters describing plant additions at harvest.

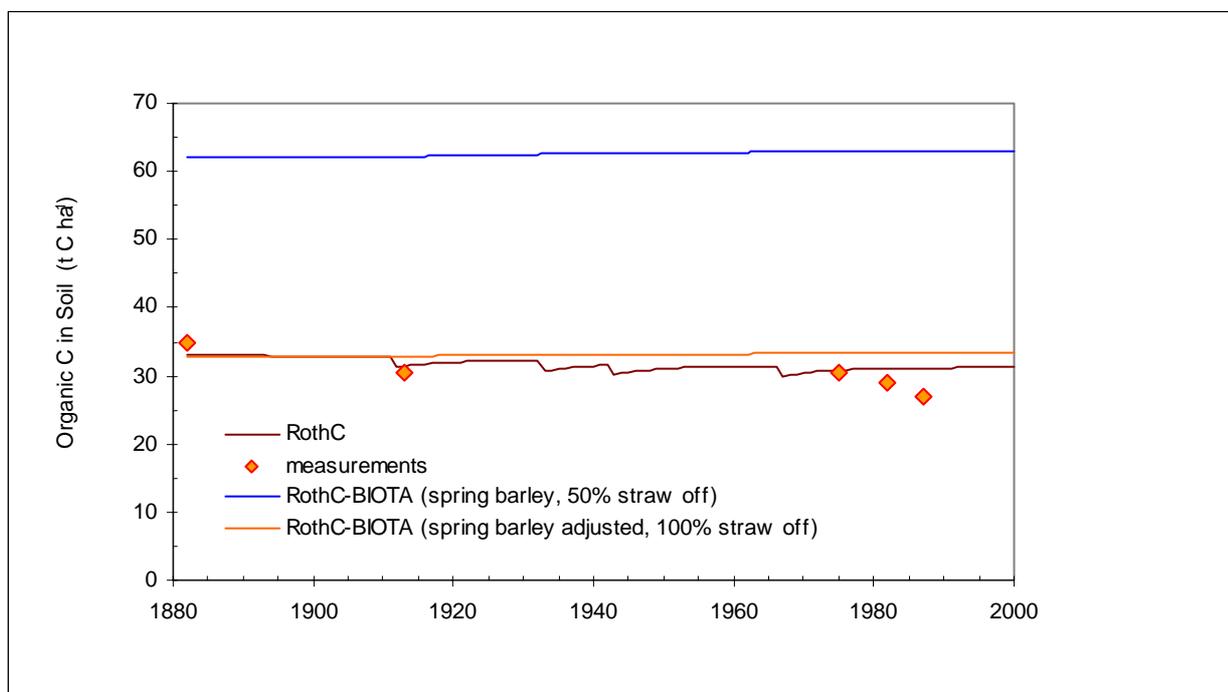


Figure 9-3 RothC 'short-term' simulation results for Hoosfield, with and without BIOTA component.

9.7. References

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9.8. Appendices

A.1. New Equilibrium code.

```

SUBROUTINE SETSIM(INYEAR)
C
C Sets up simulation
C
      IMPLICIT NONE
      INTEGER I, INYEAR
      REAL*8 T, TP, TF
C Common Blocks
C
      INCLUDE 'FILES.FOR'
      INCLUDE 'GIS.FOR'
      INCLUDE 'MAIN1.FOR'
      INCLUDE 'MOD1.FOR'
      INCLUDE 'MOD2.FOR'
      INCLUDE 'MOD4.FOR'
C
C Set values
C Type of simulation
      IF(EQUIL .EQ. 1) THEN
          ICAREQ=1      !Equilibrium run
      ELSE
          ICAREQ=0      !short-term simulation
      ENDIF
C No bomb effect
      IBOMB=1
C Starting year of simulation
      ISYEAR=INYEAR
C Run simulation for 200 years by default
c      NYEARS=200      !changed to 200 - GS 17/05/05
C Output results in last year
      IOUT=1
C Do not output monthly values
      MONCAR=0
C Start month = January
      MSTART=1
C
C Set fixed parameters for current land-use
C
      DO 10 I = 1,5
          FPLANT(I) = 0.0
10    CONTINUE
      FFYM(1) = 0.49
      FFYM(2) = 0.49
      FFYM(3) = 0.0
      FFYM(4) = 0.0
      FFYM(5) = 0.02
      FDEC1(3) = 0.46
      FDEC1(5) = 0.54
      FPDEC1(4) = 0.46
      FPDEC1(5) = 0.54
      DECOMP(1) = 10.0
      DECOMP(2) = 0.3
      DECOMP(3) = 0.66
      DECOMP(4) = 0.66
      DECOMP(5) = 0.02
      FPLANT(1)=DRRAT/(1+DRRAT)
      FPLANT(2)=1/(1+DRRAT)
      T=FDEC1(3)+FDEC1(5)          !WHAT ARE THESE USED FOR, JO?
      TP=FPDEC1(4)+FPDEC1(5)      !WHAT ARE THESE USED FOR, JO?
      TF=FPLANT(1)+FPLANT(2)      !WHAT ARE THESE USED FOR, JO?

```

9-12

```
C
C Set all active soil pools to zero ready for equilibrium run
C
      IF(ICAREQ .EQ. 1)THEN
          DO 660 I=1,5
              SOIL(I)=0
660      CONTINUE
          ENDIF
          END
C
C Equilibrium run - new method using alorythm check
C
      CALL CALC1
      CALL BPCALC
      TOTCEQ=0
      TOTIN=0
      ISTARTYR=1
      ISTOPYR=10000

      last_TOTIN = -9999
      equilibrium_threshold = 0.001

      do equilibrium_loop = 1, ISTOPYR, 100

          CALL RUNC14(TOTCEQ,TOTIN,equilibrium_loop,equilibrium_loop+100)

          if (abs(TOTC-last_TOTIN) .lt. equilibrium_threshold) then
              exit
          end if

          last_TOTIN = TOTC

      end do

!      End program if we didn't find equilibrium
      if (equilibrium_loop .eq. ISTOPYR+1) then
          write(*, *)'***** Could not find equilibrium after ', equilibrium_loop 1,
' years'
              stop
          end if

      TOTCEQ = TOTC

SUBROUTINE RUNC14(tceq,tcin,startyr,stopyr)
C
C
C Running Carbon model with varying radiocarbon activity
C
C      IMPLICIT NONE
C
C
C ** Common Statements
C
      INCLUDE 'GIS.FOR'
      INCLUDE 'MAIN1.FOR'
      INCLUDE 'MOD2.FOR'
C      INCLUDE 'MOD3.FOR'           !Used by GIS model only - ENABLE WHEN NEEDED
(02/2005)
      INCLUDE 'MOD4.FOR'
      INCLUDE 'MOD10.FOR'         !Replaces MOD3.FOR for SITE model (02/2005)
      INCLUDE 'TOTALS.FOR'
C
C
      REAL*8 tcin,tceq
      INTEGER*4 startyr,stopyr,NYPRINT,K,M,I
      MON=MSTART
      NYPRINT=0
C
C Do calculation for NYEARS years
```

```

C
  NYEARS=stopyr
  DO 20 K=startyr,stopyr
    IYEAR=IYEAR+1
    NYPRINT=NYPRINT+1
C
C Set this years weather data
C
  CALL GETENV(K)      !This replaced GETMET subroutine for GIS (02/2005)
C
C calculate (1) monthly rate modifying factors (2) set transition matrices
C
  CALL RATEF

  IF ((SPACE .EQ. 0) .AND. (IYEAR .EQ. 1)) THEN
    CALL INFOOUT
  ENDIF

  CALL SETMAT

C
C Do calculation for 1 year
C
  DO 10 M=1,12
    tcin=tcin+PLADD(MON,LUCODE)+FYMADD(MON,LUCODE)+tceq
    tceq = 0.0
C
C Calculate amount in soil carbon compartments for this month
C
  CALL MONAA

C
C If printing results, calculate totals ready for printing, and output results
C
  IF((NYPRINT.LE.MONCAR).OR.
& (MON.EQ.MEND.AND.IOUT.EQ.1).OR.
& (MON.EQ.MEND.AND.IOUT.EQ.2.AND.K.EQ.NYEARS).OR.
& (MON.EQ.MEND.AND.IOUT.EQ.2.AND.K.EQ.NYEARS/2))THEN
    BIO = SOIL(3) + SOIL(4)
    CO2 = tcin - TOTC
c    ICOUNT = ICOUNT + 1      !Is this needed ? Jo (icount(2)?)
    CALL PCAR
    IF (space .EQ. 0 .and. ICAREQ .EQ. 1) CALL CQOUT
    IF (space .EQ. 0 .AND. ICAREQ .eq. 0) CALL C14OT
  END IF

C
C Move on to next month
C
  MON=MON+1
  IF(MON.GT.12)THEN
    MON=1
    ISYEAR=ISYEAR+1
  END IF

C
C Save C in soil pools for output and calculating C after land use change
C
  DO 5 I=1,6
    IF(M.EQ.12)SOILC(K,I,LUCODE)=SOIL(I)
  5  CONTINUE
  10  CONTINUE

C
  20  CONTINUE

C
  RETURN
  END SUBROUTINE

```

A.2. Revised RothC input file.

Input data for RothC linked with BIOTA (RothC-BIOTA v05)

Site information:

clay % - 23.4
 soil depth (cm) - 23.0
 Measured C at equilibrium (t/ha) - 35.0
 Year of measurement - 1882

Equilibrium run:

weather file - roth.dat
 land use file - lmfefeq.dat

Short-term run:

weather land use nr_years
 lines - 1
 roth.dat lmtestsb.dat 200

A.3. Multi-functionality of simulation procedures.

Description of the command line:

- rothc** - should be always selected for running the model, **<input_ref.txt>** file contains all input data and names of data files necessary for RothC (eg. climate data and land management data);
- biota** – informs the model that BIOTA plant-module will run and estimate plant debris additions to soil instead of pre-defined plant additions in land management file, **biota.ini** is the BIOTA parameter file, **<crop.ini>** contains parameters defined for the current crop;
- cruclimate** – informs the model (BIOTA) about the monthly climate input data **<climate.mon>** that are used by the Weather Generator to estimate daily weather data required by BIOTA;
- pladd** – option that should be used when an output of plant debris, simulated by BIOTA, is needed, **<biota_pladd.txt>** is the name of the output file;