Section 8

Use of the Rothamsted Carbon model, RothC, in deriving the UK Carbon inventory

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8. Use of Rothamsted Carbon model, RothC, in deriving the UK Carbon inventory

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8.1. Background

RothC has been developed to run a the 1km scale and so, potentially, provide detailed information on the change in C stocks under different land-use changes throughout the UK. Direct implementation of RothC into the inventory would be possible but would need substantial modification of the current system. A better course of action might be to test the equivalence of RothC with the current 'coefficient method' in order to see if RothC could inform the choice of coefficients rather than form the hub of the inventory. This would enable us to take a long-term view about how when or if to incorporate RothC into the inventory fully and allow us to evaluate the potential benefits of such an incorporation completely. In this respect we note that the New Zealand inventory employs similar technology and that while the Australian inventory makes use of RothC it has done so by re-writing the code and incorporating this into their reporting system

Figure 8-1 may help to make this clear

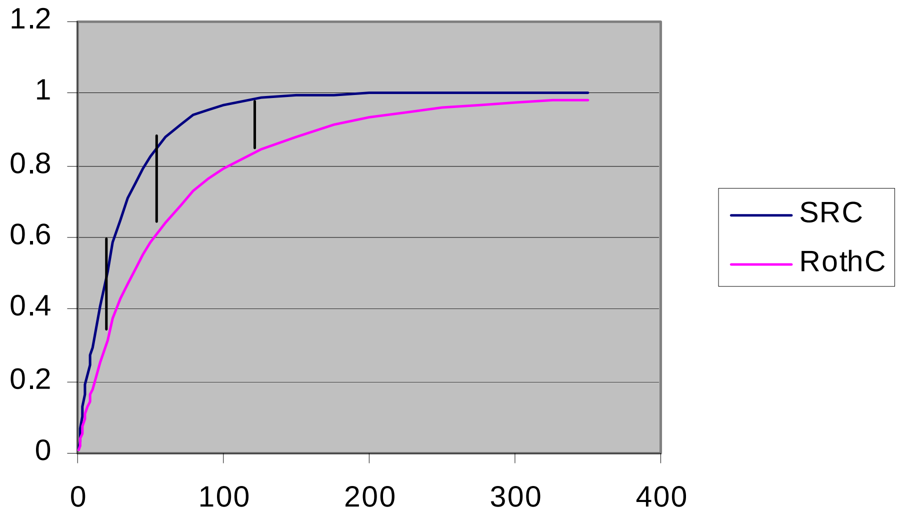

Figure 8-1 Mapping RothC onto a single exponential model in stages

A simple, single exponential model of the decomposition or addition of decomposing crop residues tends to predict a too rapid change in the amount of carbon stored in soil as a result of land-use change. RothC separates soil C into 5 different pools the decomposition of which is controlled by exponential decay. Some pools decompose in parallel with others, most in sequence. The result is a more realistic and versatile description of organic matter dynamics in soil. The price to pay, however, is complexity and our thesis is to see if there is a middle way that is less complex but sufficiently realistic. In Figure 8-1 we have mapped the accumulation of C in soil as a result of land-use change onto that predicted with RothC. Intuitively, then it would seem possible to use RothC to say what the coefficient for a transition described by a single exponential should be at any one time and for how many years that coefficient should be used. The reality is more complex and this report deals with our initial investigations. We hope to report more fully at the end of the next reporting period

8.2. Methods

In order to investigate the possibility of mapping RothC onto the coefficients currently in use in the inventory we looked at a number of situations:

Four land-use changes investigated:

- Pasture to arable
- Pasture to semi-natural
- Pasture to Forest
- Arable to Forest

Several Functions investigated:

- Double exponential (parallel model)

$$C = A_2(1-\exp(-k_1 t)) + A_2(1-\exp(-k_2 t)) \qquad \text{eq 8-1}$$

- Sequential single exponentials

$$\begin{aligned} C &= A_1(1-\exp(-k_1 t)); t < t_1 \\ &= A_1(1-\exp(-k_1 t_1)) + A_2(1-\exp(-k_2 t)); t. >= t_1 \end{aligned} \qquad \text{eq 8-2}$$

- Fully flexible exponential fits

$$C = A_2(1-w_1\exp(-k_1 t)) + A_2(1-w_2\exp(-k_2 t)) \qquad \text{eq 8-3}$$

where C is the change in soil carbon, A_1 and A_2 are coefficients representing the change in C stock and k_1 and k_2 are coefficients representing the rate of that change and t_1 is the time at which a transition from one set of coefficients to another takes place.

The four land-uses represent important transitions in land-use. Others will be straightforward to include. As stated above RothC works with a number of pools of C in soil, the decomposition of each being controlled by an exponential decay function. Middle ground with the current methodology in the inventory suggests some sort of multiple exponential but these could be in parallel eq 8-1 or in sequence (eq 8-2, and as in Figure 8-1). Equation eq 8-3 is a more empirical but complete mathematical description that was found to map output from RothC very well. It is difficult, however, to ascribe physical significance to the weighting coefficients w_1 and w_2 in mapping onto the decomposition processes in RothC.

Because the fits with eq 8-2 were less good than expected a fourth model was then evaluated:

$$\begin{aligned} C &= A_1(1-\exp(-k_1t)); t < t_1 \\ &= A_1(1-\exp(-k_1t_1)) + A_2(1-\exp(-k_2t)); t. >= t_1; t < t_2 \\ &= A_1(1-\exp(-k_1t_1)) + A_2(1-\exp(-k_2t_2) + A_3(1-\exp(-k_3t)) \end{aligned} \quad \text{eq 8-4}$$

Which model was best was decided by using a variance ratio (F) test as follows, where ΔRSS is the change in the residual sum of Squares in moving from one model to the next, ΔDF is the change in the number of degrees of freedom and RMS is the residual mean square

F = (ΔRSS / ΔDF) / (RMS most complex model)

This $F_{(\Delta DF,\ DF\ most\ complex\ model)}$ was tested against statistical tables

8.3. Results

In general the three equations eq 8-1 to eq 8-3 could be mapped onto output from RothC well. The more coefficients the better the fit, however. In particular the use of eq 8-2 led to a fitting problem at the transition, as shown in Figure 8-2

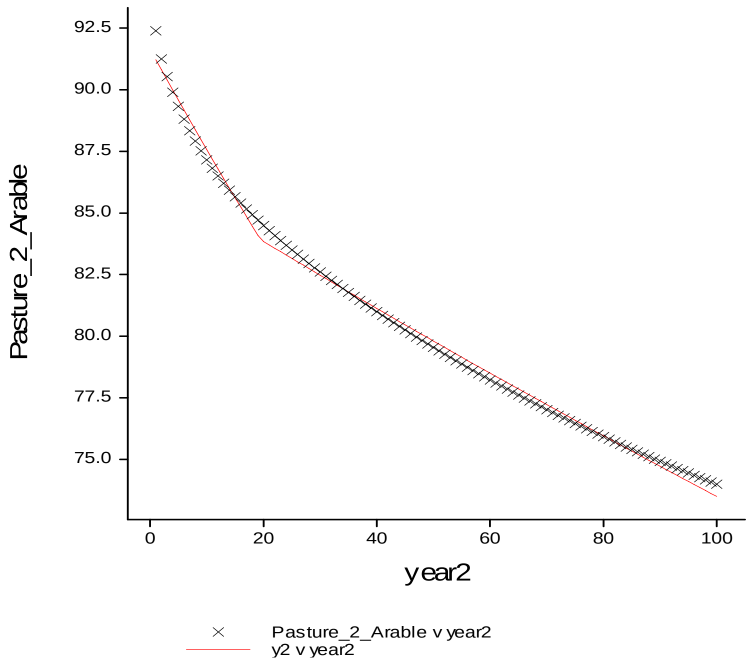

Figure 8-2 Mapping two sequential exponentials onto output from RothC

Moving to three sections appears to solve this problem and fits for all four land-use changes are shown in Figure 8-3

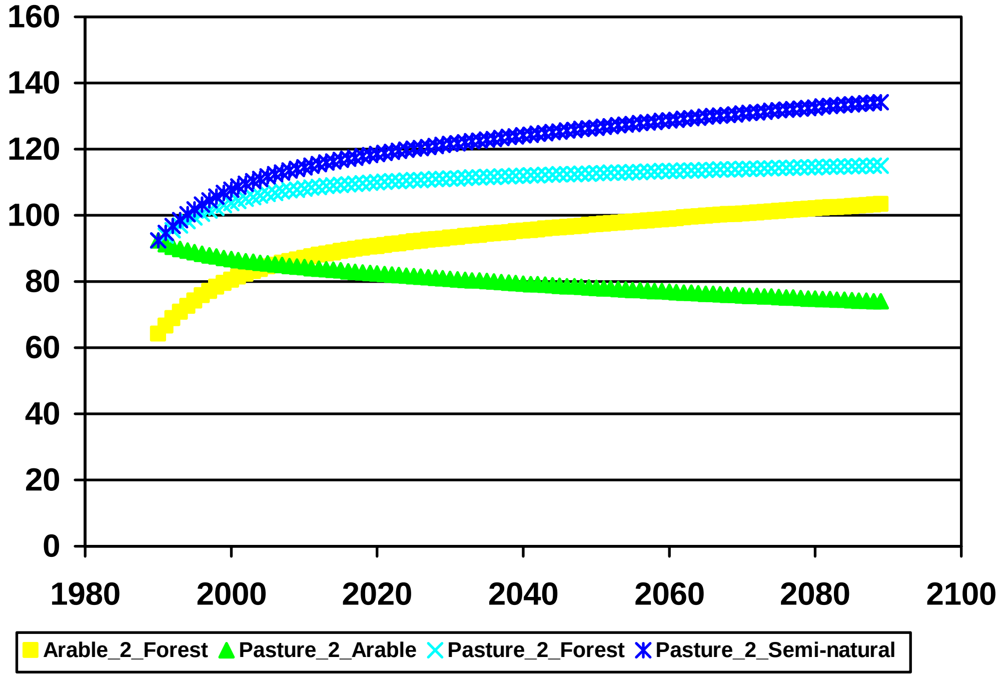

Figure 8-3 Change in C stock with time

Although there a large number of parameters to be determined in order to use eq 8-4 many of these are common among land-use changes and different models. For example the equilibrium values for each land-use will be the same on the same soil type and under the same climate. The start and end values then become common (Figure 8-4).

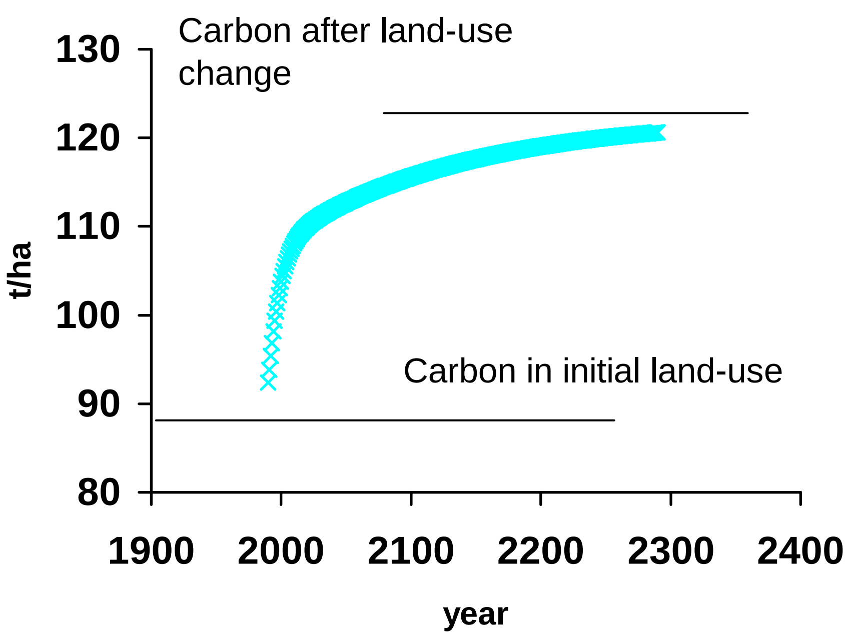

Figure 8-4 Change in soil C relative to equilibrium values

It appears likely that the transition times (t_1 and t_2) are similar for all land-use transitions investigated so far but that they differ depending upon whether carbon is increasing with land-use change or decreasing (Figure 8-5)

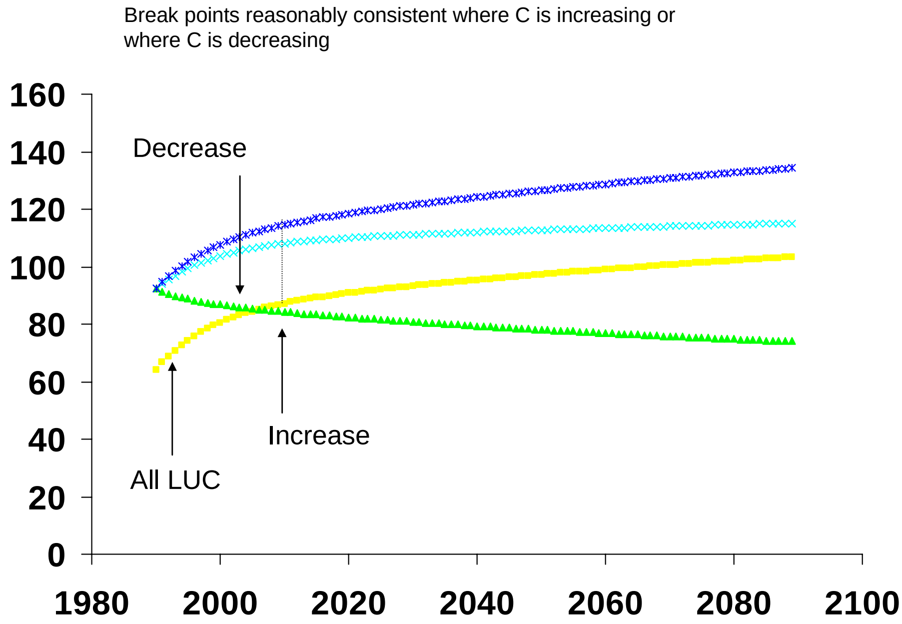

Figure 8-5 Location of break points during change in soil C as a result of land-use change

8.4. Discussion

All of Eqs eq 8-1 to eq 8-4 map to RothC reasonably well. eq 8-1 has the advantage of simplicity and fits better than eq 8-2. eq 8-3 fits very well but is difficult to tie into reality. Eeq 8-4 fits better than eq 8-3 with parameters that have physical meaning but is more complex than either eq 8-1 or eq 8-2.

A further advantage of eq 8-4 over eq 8-1 is that the parameters appear to be consistent over different land-use changes. Subsequent work will focus on confirming that this is indeed so. An important issue here is that of accuracy. The effect on the inventory of small errors such as that introduced by eq 8-2 needs to be investigated but it must be remembered that the deviation shown in Figure 8-1 is of a simpler model from RothC. eq 8-2 may be perfectly adequate in the face of real information we have on land-use change. However, there is still the issue of stability of parameters to consider and here we expect eq 8-4 to be best model.