13. Development and testing of coupled soil and vegetation carbon process model (WP 2.9 and 2.10)

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13.1 Overview of models under development

Several models are being developed for soil and plant carbon. Here we give an overview of current model development in the UK with relevance to soil and vegetation carbon. Although these models all describe the plant soil system, their purposes are quite different, so the models will describe processes in different ways. Here we give an overview of these models.

JULES has developed from the land surface scheme Hadley Centre general circulation model (Best, 2005). It has a well developed hydrology sub-model and at present much effort is put into developing the biological component of it through QUEST. In this model, plant cover is described using plant functional types (PFT's). These are vegetation types typical for wide biomes. At present there are 5 PFT's: Broadleaf- and coniferous trees, C_4 and C_3 grasses and shrubs. The model calculates the fraction of each PFT present based on competition and environmental factors (Best, 2005). There may be more PFT's added in the future. Each PFT is described using a set of parameters. The PFTs compete for resources and hence their mix and distribution is estimated within the model. Current work on the model includes introducing an age structure in the vegetation and introducing a nitrogen cycle. As the main focus of the model is to investigate possible effects and feedbacks of global change, fluxes of carbon and water are described mechanistically as far as possible (Cox *et al*., 1999).

ECOSSE has been developed from SUNDIAL, a model developed to predict nitrogen turnover in agricultural systems (Bradbury *et al*., 1993). Recent changes include more soil layers and routines for DOC, methane, nitrous oxide and anaerobic decomposition though these capabilities are still undergoing development (Smith *et al*., 2007). The model has an aboveground component, but the above-ground component has so far only been developed to simulate arable crops and grassland. The soil C and N module of ECOSSE is being coupled to JULES.

RothC-Biota was developed specifically for the carbon inventory. The purpose of this model was to combine two well-developed models to calculate carbon stocks for the carbon inventory. The two models were RothC (Jenkinson *et al*., 1987; Coleman and Jenkinson, 1999) for the belowground carbon, and Biota (Wang and Polglase, 1995) for the aboveground carbon. However, the original Biota could only handle unmanaged trees, so extensive development followed; (Sozanska-Stanton *et al*., 2002; Brown *et al*., 2003; Brown *et al*., 2004). At present the model has three vegetation types: grasses, trees and crops, and fine-tuning of these parameters is in progress. However, the description of the plant types is simpler than in JULES, and plant functional type distribution is prescribed rather than estimated within the model.

13.2 Model testing

See JULES home page (http://www.jchmr.org/jules/index.html) for information on past and current developments of JULES, and evaluation.

The ECOSSE model is still being tested using data from field experiments from the UK and elsewhere. An example from a field site in Finland (Regina *et al*., 2004) is shown in Figure 13-1.

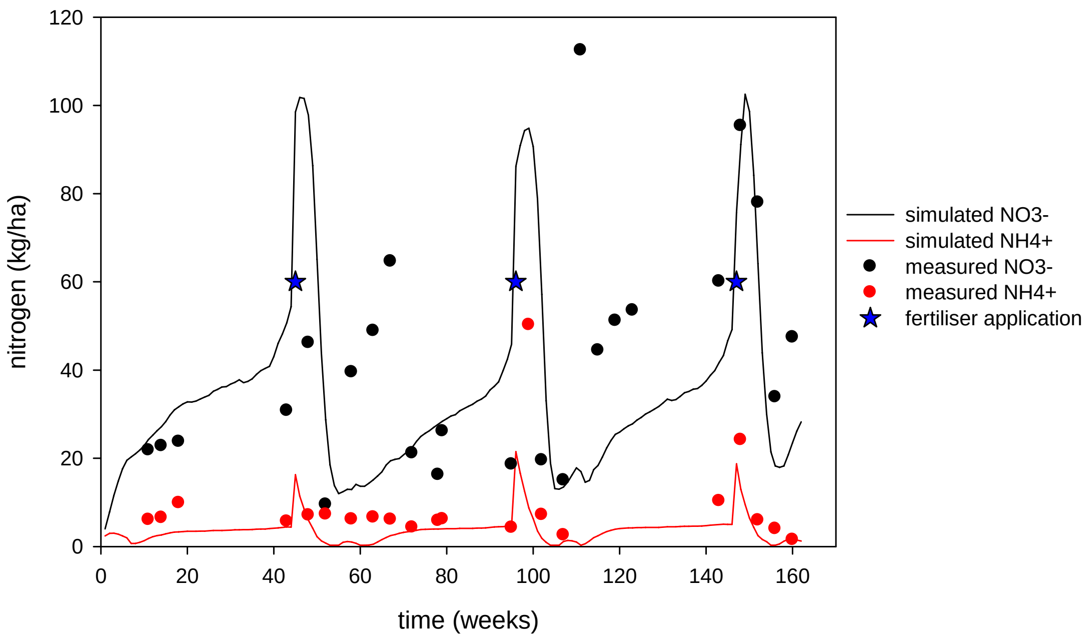

Figure 13-1: Measured and simulated mineral nitrogen in spring barley fields in southern Finland (60°49'N, 23°01'E). Time of fertiliser application is indicated.

RothC-Biota has not been extensively tested yet, although some results of preliminary tests of earlier versions of the model have been presented in previous reports (Sozanska-Stanton *et al*., 2005; Sozanska-Stanton and Smith, 2006). We have also performed a test of the model at a grassland site in Scotland, Sourhope (Figure 13-2). Clearly, more calibration is necessary, but the results seems to indicate that model is rather insensitive to year to year variations in climate, and may need some fine tuning to respond more accurately.

We have also started comparing the results from RothC-Biota to those of JULES. Such a comparison is difficult because JULES calculates which combination of plant functional types that will be present in each time step, whilst in RothC-Biota one plant cover type must be prescribed. Furthermore, the way productivity is calculated is different. Whilst JULES calculates NPP directly, RothC-biota calculates an unlimited NPP first, and then applies various limitations to it. Tests are still preliminary, but Biota and JULES appear to predict similar values for biomass carbon, but the patterns of productivity are quite different (Figure 13-3). Biota seems to predict higher GPP and higher respiration. Further work is underway to understand the differences.

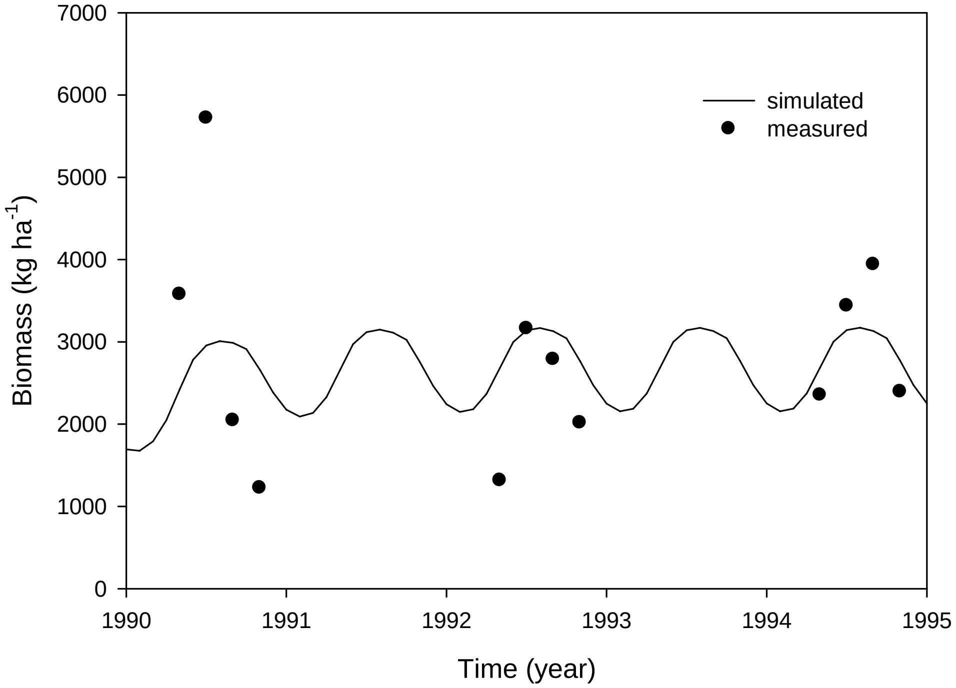

Figure 13-2: Grass aboveground biomass simulated by RothC-Biota compared to measured data from Sourhope, Southern Scotland (Data from Marriott, unpublished).

13.3 Next steps

Further work will be on parameterisation of RothC-Biota for different vegetation types. Plant cover types will be selected to be generic, and to use categories that can be distinguished on a large scale. The plan is to include managed and unmanaged grassland, broadleaf and conifer forest, spring and winter cereals and root crops. The model will then be further tested against data and other models. The model will be run for Britain and the results will be compared to the values from the carbon inventory.

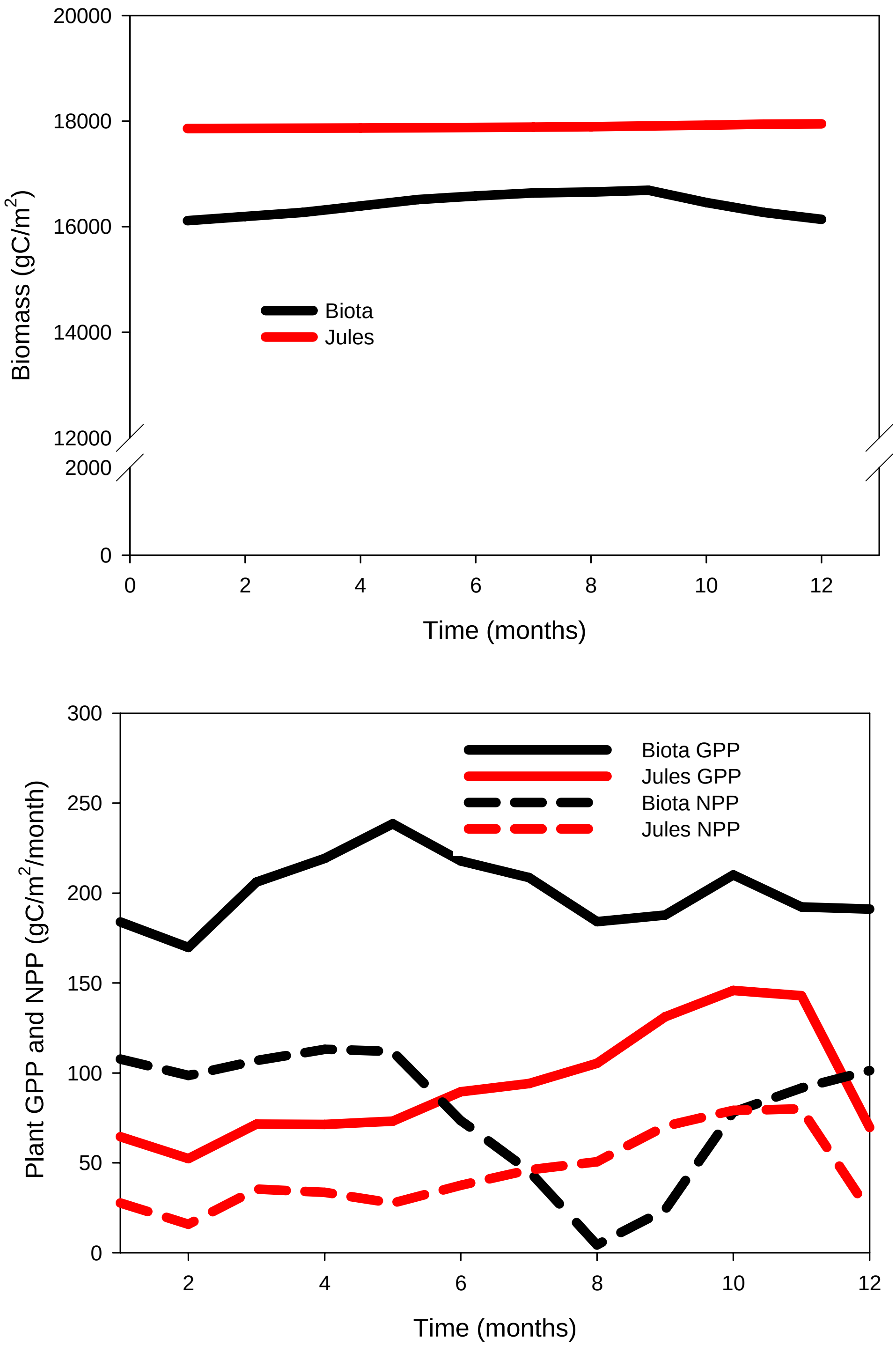

Figure 13-3: Total vegetation carbon, GPP and NPP simulated by RothC-Biota and JULES for Loobos coniferous forest flux tower site, The Netherlands (52°10'4.29"N, 5°44'38.25"E).

13.4 References

Best, M. (2005). JULES Technical Documentation. Hadley Centre.

Bradbury, N.J., A.P. Whitmore, P.B.S. Hart, and D.S. Jenkindon. (1993). Modelling the fate of nitrogen in crop and soil in the years following application of ^{15}N-labelled fertilizer to winter wheat. *Journal of Agricultural Science* **121**, 363-379.

Brown, T.A.W., R. Milne, P. Smith, and M. Sozanska-Stanton. (2003). Adding vegetation Carbon to the RothC Soil Carbon Model. p. 5:1-5.8. *In* R. Milne (ed.) *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities*. Defra, Global Atmosphere Division, CEH, Edinburgh.

Brown, T.A.W., R. Milne, P. Smith, and C. Zhang. (2004). Adding Vegetation Carbon to the RothC Soil Carbon Model. p. 4.1-4.16. *In* R. Milne, and D.C. Mobbs (eds.) *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities*. Defra, Global Atmosphere Division, CEH, Edinburgh.

Coleman, J.S., and D.S. Jenkinson. (1999). *ROTHC-26.3 Model description and windows users guide*. IACR – Rothamsted, Harpenden Herts AL5 2JQ.

Cox, P.M., R.A. Betts, C.B. Bunton, R.L.H. Essery, P.R. Rowntree, and J. Smith. (1999). The impact of new land surface physics on the GCM simulation of climate and climate sensitivity. *Climate Dynamics* **15**:183-203.

Jenkinson, D.S., P.B.S. Hart, J.H. Rayner, and L.C. Parry. (1987). Modelling the turnover of organic matter in long-term experiments at Rothamsted. *INTECOL Bulletin* **15** 1-8.

Regina, K., E. Syvasalo, A. Hannukkala, and M. Esala. (2004). Fluxes of N_2O from farmed peat soils in Finland. *European Journal of Soil Science* **55**:591-599.

Smith, P., Smith, J.U., Flynn, H., Killham, K., Rangel-Castro, I., Foereid, B., Aitkenhead, M., Chapman, S., Towers, W., Bell, J., Lumsdon, D., Milne, R., Thomson, A., Simmons, I., Skiba, U., Reynolds, B., Evans, C., Frogbrook, Z., Bradley, I., Whitmore, A., Falloon, P. (2007). *ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions. Final Report*. SEERAD Report. ISBN 978 0 7559 1498 2. 166pp.

Sozanska-Stanton, M., and P. Smith. (2006). RothC-BIOTA v05 plant-soil turnover model. p. 7.1-7.21. *In* R. Milne, and D.C. Mobbs (eds.) *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities*. Defra, Global Atmosphere Division, CEH, Edinburgh.

Sozanska-Stanton, M., P. Smith, R. Milne, and T.A.W. Brown. (2002). Linking Soil and Vegetation Carbon in Dynamic Models. p. 127-137. *In* R.Milne (ed.) *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities*. Defra, Global Atmosphere Division, CEH, Edinburgh.

Sozanska-Stanton, M., C. Zhang, T.A.W. Brown, R. Milne, and P. Smith. (2005). RothC-BIOTA v05 plant-soil C turnover model - parameterisation and evaluation. p. 9.1-9.14. *In* R.Milne, and D.C.Mobbs (eds.) *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities*. Defra, Global Atmosphere Division, CEH, Edinburgh.

Wang, Y.P., and P.J. Polglase. (1995). Carbon Balance in tundra, Boreal forest and humid tropical forest during climate-change - Scaling-up from leaf physiology and soil carbon dynamics. *Plant Cell Environ*. **18**, 1226-1244.