The following supplement accompanies the article

Stratification of climate projections for efficient estimation of uncertainty and variation using weather-driven models

David A. Elston*, Mike Rivington, Cairistiona F.E. Topp, Shibu Muhammed, Jacqueline M. Potts, Adam Butler, Helen Kettle, Nikki J. Baggaley, Robert M. Rees, Robin B. Matthews

*Corresponding author: david.elston@bioss.ac.uk

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DNDC

DeNitrification and DeComposition (DNDC, see Li et al. 1992, Li et al. 2000) is an ecosystem model that describes C and N cycling in agricultural systems, and is recognized for its strengths in predicting C sequestration and greenhouse gas emissions. DNDC has been validated against numerous field data sets around the world (Frolking et al. 1998; Xu et al. 2003; Saggar et al, 2007) and has been used to compare contrasting N management practices on C sequestration and net greenhouse gas exchange. The DNDC model is process based with three components; firstly there is a component which simulates soil climate and soil organic matter decomposition; secondly there are sub-models for nitrification, denitrification and fermentation which predict emissions of CO_2, N_2O and CH_4 emissions; and thirdly there is a crop growth sub-model that predicts annual yield. We used DNDC to simulate plant-environment interactions for intensively managed semi-permanent grasslands. Inputs to the model are soil descriptions, crop physiology parameters, descriptions of farm management practices and daily weather data, where the inputs used were precipitation, maximum and minimum temperature. The inputs of fertilizer were based on recommended practice for silage production, and hence 96 kg N ha^{-1} was applied on the 26 March, 60 kg N ha^{-} was applied on 8 June, and 50 kg N ha^{-} was applied on 10 August. The 2nd and 3rd applications were after the grass had been cut for silage on 1 June and 5 August. Although the yields from each of the two cuts per year were recorded, we report here the analysis of total annual yields.

PALM

PALM (Matthews and Pilbeam 2005; Matthews 2006, Shibu et al. 2012) is an agent-based model operating at the level of a catchment, which contains a number of decision-making entities (e.g. farm households) located on a landscape made up of a number of heterogeneous land units, each of which contains routines to simulate its water balance, carbon and nitrogen dynamics over time. Organic matter decomposition is simulated by a version of the CENTURY model, while water and nitrogen dynamics are simulated by versions of the routines in the DSSAT crop models. The soil processes are simulated continuously, and vegetation types (crops, weeds, trees) can come and go in a land unit depending on its management. Decisions made by the household agents result in actions which may influence the fluxes of water, carbon and nitrogen within the landscape. The model is modular, in that it is possible to run just the agent-based part of it: alternatively, the soil, tree, crop and weed modules can be run as separate stand-alone programs if so desired. For this project, we used the tree module parameterized for willow. Model inputs include daily weather data (precipitation, minimum and maximum temperatures and solar radiation), soil and tree physiology parameters and management information. No fertilizer or irrigation was applied throughout each simulation period (30 years). For each simulation, during the winter in the first year, stooling (or cut back) was carried out to initiate multiple sprouts in the following spring. Successive wood harvests (or coppicing) were taken at three-yearly intervals. Soil variables (organic carbon, NO_3-N, NH_4-N and soil moisture) were reinitialized at the start of each simulation.

CropSyst

CropSyst (Stöckle et al. 2003) is a multi-crop and multi-year daily time step crop growth simulation model, capable of representing a wide range of cropping systems in many parts of the world, including the United Kingdom (Rivington et al 2006, Rivington et al 2007). The model simulates soil water, crop-soil water and nitrogen budgets, crop phenology, canopy and root growth, yield and biomass production and organic residue decomposition. Biomass gain is based on crop transpiration and transpiration-use efficiency, an approach that has been shown to be more robust than the radiation capture and radiation-use efficiency approach used by other models (Stöckle et al. 2008). Inputs to the model are weather data (daily precipitation, minimum and maximum daily temperature and solar radiation), soil and crop physiology parameters, and management control parameters. The accumulation of thermal time (growing degree days, GDD) controls crop phenological development and management events can be automated with timings set in relation to crop phenology. For this project, we used CropSyst to predict yield of spring barley. Sowing date was kept constant (15^{th} March), and the simulations set up so that the crop was not nitrogen limited. The period between the start of each year and sowing was fallow, but with representative management (ploughing, harrowing and fertiliser application) prior to sowing. Soil water content was set at field capacity for the particular soil at each grid square on the 1st January each year.

Informing the models with soil data

Each of the 5km squares was intersected with the 1:250,000 National Soil Map of Scotland (Soil Survey of Scotland Staff 1981) and the Land Cover of Scotland 1988 (LCS88) data sets (MLURI, 1993). The area of the soil map units within each grid square which was under arable land cover (LCS88 classes 100- 107 and mosaic classes 305, 335 & 605*)* was then calculated. The area of each soil series was then calculated based on the percentage of soil series in each map unit from the Scottish Soils Knowledge and Information Base - SSKIB (Boorman et al. 1995; Gottschalk et al. 2010; Lilly et al. 2004). The properties for the most extensive soil series under arable (or cultivated) land for each 5km square were then extracted from the SSKIB as follows.

- Texture: median percentage clay (<2 μm), silt (2-50 μm) and calculated sand (50-2000 μm) as (100-(*Silt*+*Clay*)).
- Hydraulic properties: saturated water content [Theta 0, %], field capacity [Theta 50, %], wilting point [Theta 15 000, %], (derived from a set of pedotransfer functions developed for great Britain (Cranfield University 2008), saturated hydraulic conductivity [cm/day] derived from the HYPRES pedotransfer functions (Wösten et al. 1999) and bulk density [gcm^{-3}] (Gottschalk, et al. 2010).
- Chemical properties; median pH, carbon [%] and nitrogen [%] (Lilly et al. 2004).

If the square did not contain any arable land*,* the area classified as cultivated (LCS88 classes 5, 7, 90- 93 and mosaic classes 353 & 453) was used instead.

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