Work Package 1 Task 2:

Evaluation and development of dynamic models for soils and soil-plant systems

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(Soil process models)

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Annual report

WP1, Task 2

a) Evaluation of existing acidification models

i) Model review

A review has been undertaken of dynamic acidification models that have the potential to be applied to terrestrial systems. Although a large number of such models exist, it is clearly impractical, and of little benefit, to attempt to apply all of them. Therefore, a subset of models have been identified which will be applied and evaluated on a site-specific basis.

MAGIC

MAGIC has been widely applied to freshwaters in the UK, and to soils in other European countries. Soils are commonly lumped within the model, but the facility exists to incorporate up to three separate soil horizons. The soil processes in the model are well developed and validated, and include a simple representation of N saturation based on organic soil C/N ratios. Treatment of vegetation is relatively simple (net uptake), although again the facility exists to include more complex vegetation cycling. Advantages of MAGIC include i) existing expertise within the group; ii) relatively low data requirements; iii) a sophisticated optimisation procedure for weathering rates and initial base saturation; and iv) potential for regionalisation.

SAFE

SAFE was developed to model forest soils, and has been widely applied in Europe. A smaller number of applications have been undertaken in the UK, although the companion steady-state model, PROFILE, has been used more extensively. SAFE can incorporate an unlimited number of soil horizons, and includes a full nutrient cycle, although nitrogen saturation is not represented. The model has not been widely applied to non-forest systems, although it should be adaptable. Other processes are largely similar to MAGIC, the key difference between the models being the use of a mineralogy-based estimate of weathering rates. This requires additional site data, but removes the need for optimisation. As with MAGIC, expertise exists within the group in the application of SAFE.

SMART

Processes within SMART, which was developed for terrestrial systems in the Netherlands, are fundamentally similar to those in MAGIC, and differences between models largely arise in their approach to data collection. Whereas MAGIC utilises extensive site-specific data, SMART largely relies on regional databases and default values, and does not include an optimisation procedure. The similarities between SMART and MAGIC suggest that there would be little benefit to applying both models in the UK, however the recent incorporation of the vegetation succession model, SUMO, with the SMART framework, may have potential for application in modelling vegetation responses. This is discussed below.

VSD

The 'Very Simple Dynamic Model' has recently been developed, with the intention of providing an intermediate step between static critical loads, and complex dynamic models, that will be widely applicable at a European level, and will provide input suitable for integrated assessment models. The model is essentially a simplified representation of key processes within the three models above, and like SMART is intended to rely largely on regional-scale databases and defaults. Although there appear to be few benefits to applying the VSD model at a site-specific level, where detailed data exist, it could potentially be of use in providing regional-scale model assessments.

ii) Site application of models

Exploratory applications of MAGIC and SAFE have been undertaken for a data-rich grassland site in the Cyff catchment at Plynlimon, one of the few sites for which long-term soil water chemistry data exist. This is the first time that MAGIC has been applied to three soil horizons. The SAFE application is based on a previous model application to this site by Reynolds (1997) but has been adapted to the new version of SAFE (which includes the nutrient cycling/deposition pre-program MAKEDEP) and to utilise consistent input data with the MAGIC application where possible. The results (Figures X1-X2) suggest that both models are suitable for this form of multi-layer soil application, and that results for the two models are largely comparable. The main discrepancy between the models relates to the different methods used to estimate weather rates; the mineralogy-based method used in SAFE appears to over-estimate base cation supply from this source in the mineral soil.

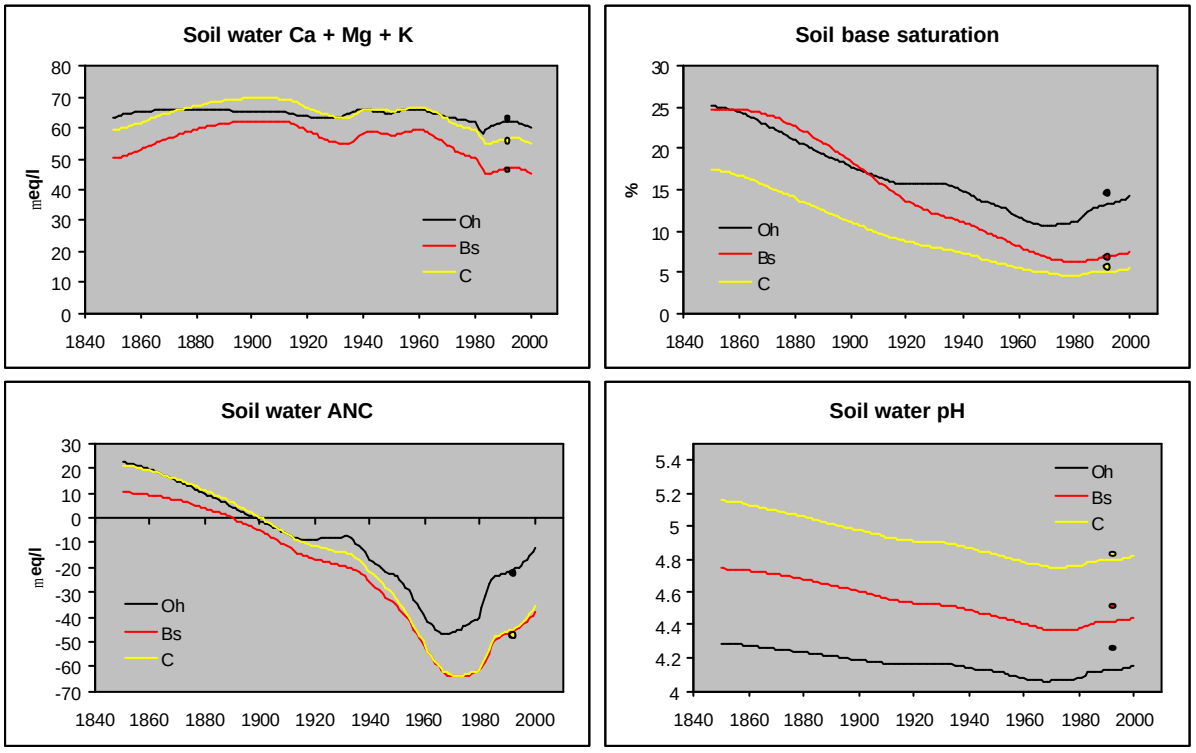

Figure X1. MAGIC simulation for the Cyff grassland site, Plynlimon.

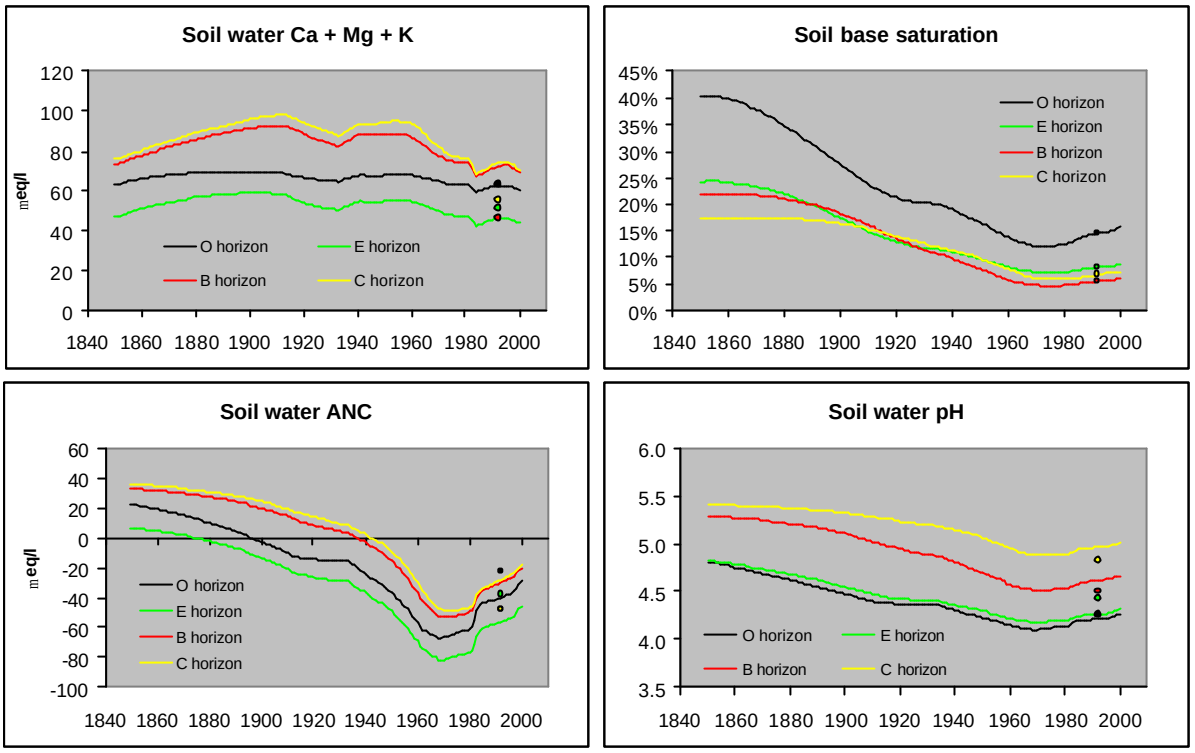

Figure X2. SAFE simulation for the Cyff grassland site, Plynlimon.

In order to test the VSD model, this has also been applied to the Cyff. As this is only a 1-box model, it has been compared to a one-box application of MAGIC to the site. Even using MAGIC-calibrated input data for weathering and cation exchange, some significant mismatches in results are observed in hindcast, particularly for base saturation (Figure X3). The reasons for this discrepancy are currently unclear, and further work will be required before the VSD model is applied more widely.

MAGIC and SAFE are now being parameterised for Aber Forest, and will shortly also be parameterised for the Ruabon heathland site. Parameterised models for data-rich examples of each major vegetation type will the provide a 'template' for applications to other sites, following the collection of data within Task 3.

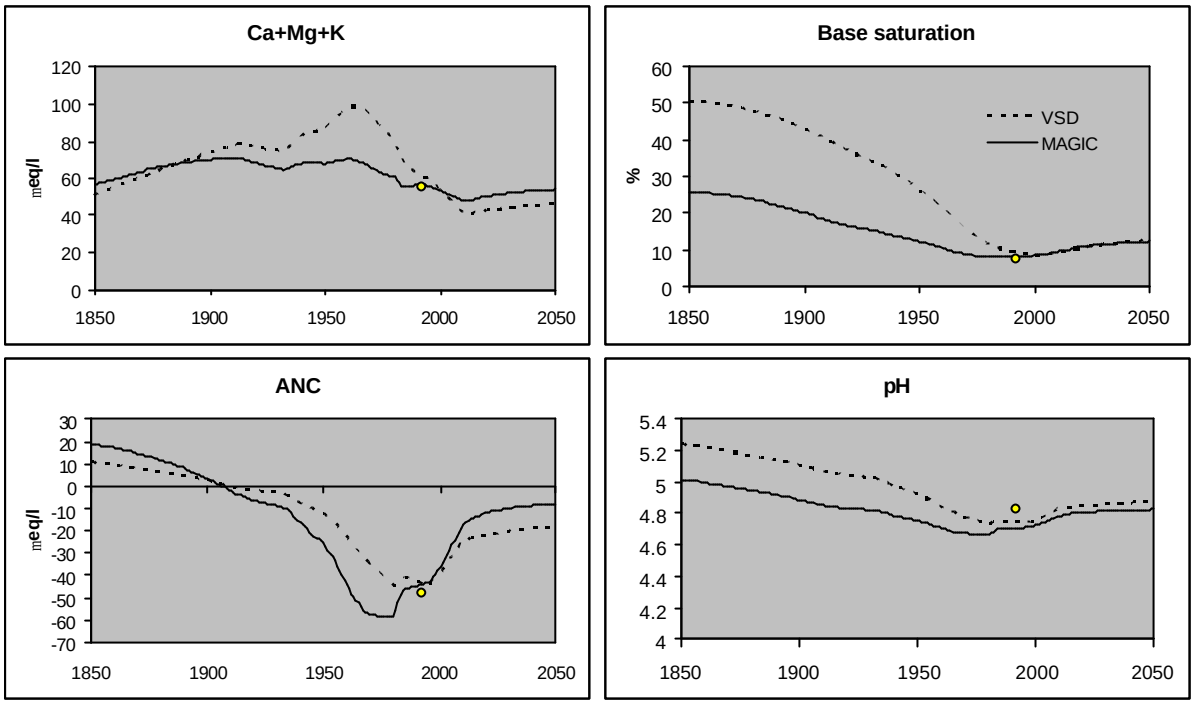

Figure X3. Comparison of single-box MAGIC and VSD applications to the Cyff grassland site, Plynlimon (VSD weathering and cation exchange input parameters based on values calibrated in MAGIC).

b) Evaluation and development of linked soils-statistical vegetation models

The most advanced models currently available to link soil chemical parameters to species occurrence have been developed for the Netherlands, and have been linked to the SMART dynamic acidification model. These include MOVE, which is a simple statistical model relating soil chemistry to species occurrence probability, and SUMO, a dynamic succession model embedded within SMART, which incorporates the effects of grazing and management on the development of vegetation cover, and includes vegetation feedbacks on the biogeochemical model. Arjen van Hinsberg, from RIVM in the Netherlands, has visited CEH Bangor to discuss the use of these models, and both SMART-SUMO and MOVE are now available for use within the umbrella.

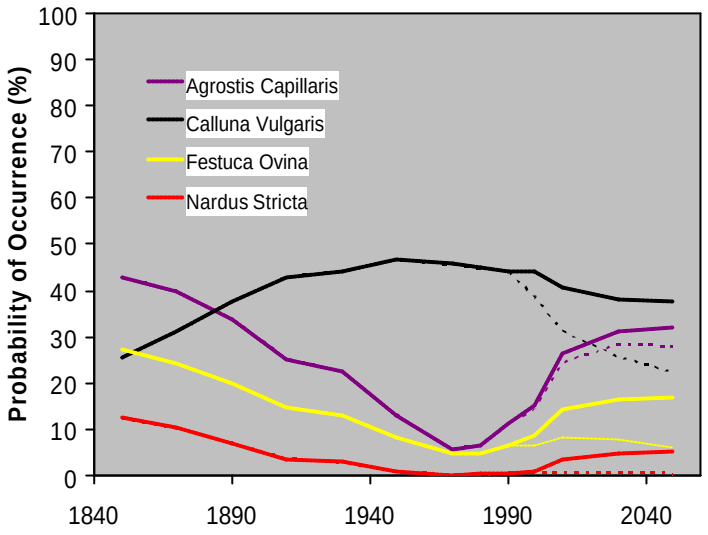

Figure X4. Evaluation of MOVE for the Cyff moorland site, based on SAFE model outputs. Dotted lines show the effect of trebling N availability in forecast.

The MOVE model can utilise soil pH and N availability data from any dynamic model, and has therefore been tested using SAFE outputs from the Plynlimon moorland site (see Figure X4). The results, which suggest a shift from grass to heather dominance due to acidification, do not appear particularly realistic, since they do not take account of grazing pressures which have maintained the site as grassland. There are also concerns that the relationships developed for Dutch ecosystems may not be fully applicable to the UK, and comparable species response curves are now being developed for the UK [**See text from Merlewood**]

To incorporate the effects of management, the use of SMART-SUMO is now being evaluated. This model requires data on historic (and future) site management, but can otherwise be applied using the same data as other biogeochemical models. The SUMO component predicts plant biomass in each of seven broad vegetation classes, and the output data from this model can then be entered into MOVE, to predict individual species occurrence. It is hoped that this model will provide a more realistic simulation of vegetation response for UK ecosystems.

d) Evaluation of N saturation/leaching models

As for acidification models, a large number of models are available to model nitrogen processes. Some of these models are not considered suitable for this project as they are designed primarily for agricultural systems (e.g. SoilN) or would be difficult to parameterise for more than a few sites (e.g. MERLIN). Therefore, work will focus on three models, of which two (MAGIC and SAFE) are also being used to model acidification. MAGIC contains a nitrogen saturation function based on soil C/N ratio. The use of a C/N control within MAGIC, particularly for moorland systems, is currently being assessed within a number of GANE projects, and the results of these projects will be used to direct the use of this model within the umbrella. The SAFE model incorporates a more detailed nutrient

cycle for N, but does not at present include a representation of N saturation, and its utility for N modelling will therefore be assessed further before it is used in this area.

Finally, the PnET-CN model will be evaluated for forested systems. This model was developed for the Northeastern US, and links carbon and nitrogen cycles in the vegetation and soil. By modelling forest growth and nutrient cycling as a function of climate and N availability , rather than based on assumed growth sequences, it differs considerably from the other models assessed, and provides potential to examine the interacting effects of climate change and atmospheric deposition on forest growth and soil N leaching. Following a visit to CEH Bangor by Christine Goodale from the Woods Hole Ecosystem Research Centre, PnET-CN has been installed and parameterised for Aber Forest, and will be evaluated for this site prior to wider application. The extension of the model to non-forest systems will also be considered. The potential utility of two recent extensions of the model will also be evaluated; these are PnET-BGC, which includes other major ions, and PnET-TRACE, which incorporates a more detailed representation of N dynamics, with multiple soil N pools.