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Critical Loads and Dynamic Modelling

Year 2 Report - Annex

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SUMMARY

- The first large-scale dynamic model application for UK soils has been undertaken, simulating target loads for five habitat types on sensitive soils at a 1 km^2 resolution for Wales. Model outputs have not yet been fully tested, but initial model simulations suggest that areas of current damage form a subset of those areas currently subject to critical load exceedance, with the greatest deposition reductions required to achieve acceptable chemical status in high-deposition areas of south and east Wales.

- Site specific MAGIC simulations have been validated against long-term soil solution chemistry data for a number of Forest Level II sites. The model appears to perform generally well for upland, acid-sensitive sites, but did not reproduce large short-term chemical fluctuations (possibly related to hydrological fluctuations) and insensitive lowland sites

- New MAGIC calibrations have been undertaken for the Thursley N manipulation site. An assessment of the effects of changing management practices at three heathland experimental sites suggests that biomass removal has an ameliorating effect in terms of nitrogen saturation, whereas turf stripping could accelerate the onset of nitrate leaching by reducing the pool of organic matter available to immobilise incoming nitrogen.

- MAGIC has also been calibrated to the Moor House ECN site, incorporating the effects of climate variations. Results suggest that the large stores of organic sulphur accumulated in peaty soils, although they may have reduced the severity of acidification to date, make these systems highly sensitive to future climate change due to the risk of sulphur remobilisation during droughts.

- A regional MAGIC calibration has been undertaken for the new, North York Moors surface water dataset. Due to severe current levels of sulphate-induced acidification, slow rates of recovery, and the detrimental effects of conifer afforestation at a subset of sites, the model predicts that it may not be possible to achieve acceptable chemical status (ANC > 0) at some sites for many decades.

- No updates have been made to the national steady-state critical load databases. The data are being used for the development and testing of national-scale dynamic modelling for terrestrial habitats.

- The potential impacts of acidification and eutrophication have been assessed using current deposition. The deposition data for 2002-04 indicate that 55.9% of the area of sensitive habitats would be exceeded for acidity and 59.5% for nutrient nitrogen.

- Time series deposition for 1970 and 2020 suggest that the area of sensitive habitats exceeded for acidity would fall by 50% over this time period. Reductions in the area exceeded for nutrient nitrogen (21%) are predicted to be smaller over the same time period. Ammonia deposition is currently making the greatest contribution to both acid and total nitrogen deposition.

Work Package 1: Dynamic Modelling of UK soils

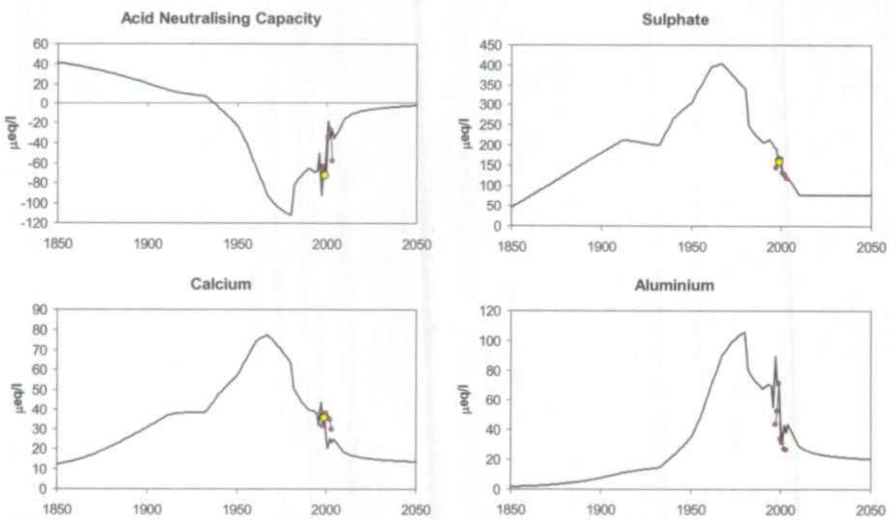
i) Application to specific sites for model testing and development

The dataset of site-specific MAGIC applications has been further tested and expanded [**MILESTONE 1.2**]. Key developments during Year 2 have been:

1. MAGIC recalibration and testing at Forest Level II sites. Sufficiently long time series of annual mean soil solution chemistry are now available for testing model performance at a number of sites. MAGIC was therefore recalibrated to five sites (Figure 1). In each recalibration, marine ion deposition over the monitoring period (an important source of short-term chemical variation) was adjusted based on annual mean chloride concentrations. In all cases, sulphate was modelled conservatively (i.e. unreactive within the catchment) based on a standard deposition sequence scaled to local concentrations. The close correspondence between modelled and observed trends at all sites strongly suggests that this approach is valid (for mineral soils – see Moor House application regarding peats). The success of MAGIC in reproducing the effect of decreasing sulphur deposition on soil solution acidity varied between sites. As might be expected, it appeared most successful at 'acidic' sites (Grizedale, Ladybower and Brianne), where a generally good fit was achieved to ANC. Calcium simulations were reasonable; at all sites an observed decrease in concentrations was reproduced, although the magnitude of change was less well predicted. Calcium concentrations are generally low in these acid-sensitive systems, and sensitive to short-term variations in marine ion deposition and forest uptake; longer records will be required to establish whether there are long-term deviations between MAGIC-modelled and observed calcium concentrations. The other main base cations, sodium and magnesium, were in general better predicted. Finally, model fits for aluminium at these sites (which is not directly calibrated) were generally encouraging.

Figure 1. *Comparison of calibrated MAGIC simulation with annual mean soil solution chemistry measurements at Forest Level II sites (yellow dots indicate calibration targets, red dots are annual means)*

a) Grizedale



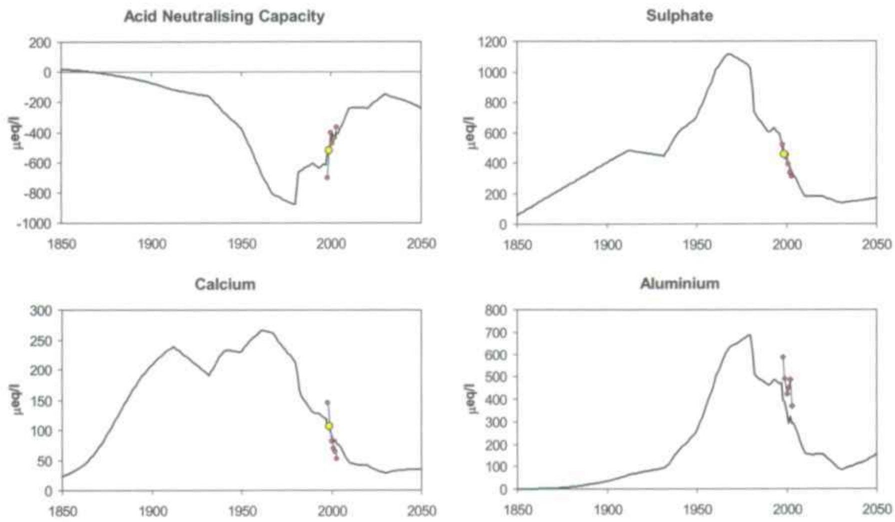
- Three deposition scenarios focused on reductions in sulphur deposition (4.6%, 5.3% and 7.8%) were analysed for the RIA Marine Fuels Directive. The reductions in deposition all gave similar exceedance statistics, with the most stringent scenario (7.8% reduction) resulting in a decrease of 1% (824 km^2) in the habitat area exceeded for acidity compared to the baseline dataset.

- Eight emission abatement scenarios were analysed to give the exceedance statistics for acidity and nutrient nitrogen and help inform the Defra Air Quality Strategy. In addition, air quality objectives for SO_2 and NO_x and the WHO limit for NH_3 concentrations were examined in relation to designated areas. A proposed lower limit for SO_2 (10μg m^{-3}) resulted in <1% of the area of designated sites outside the exclusion zone being exceeded. The NH_3 limit was exceeded in <0.1% of the area of designated sites even when using modelled concentration data for 2020.

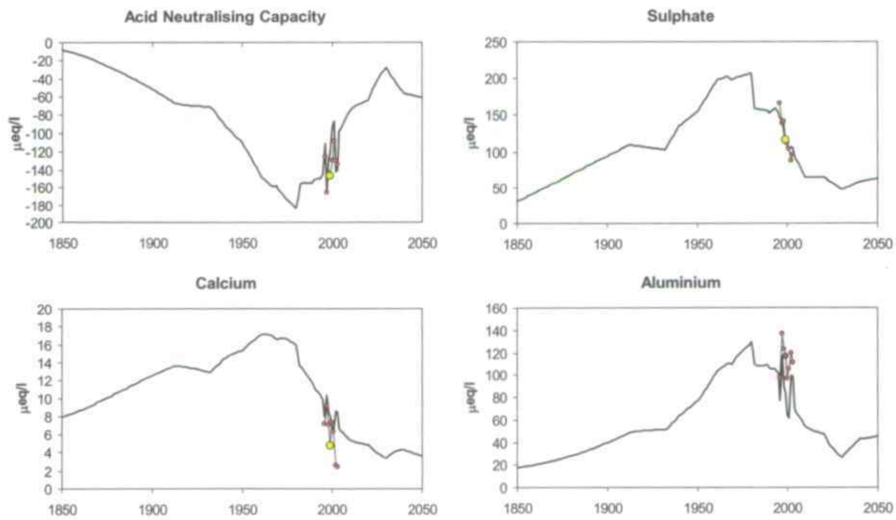
- The 6th meeting of the Joint Expert Group on Dynamic Modelling was organised and held in Brighton, in October 2005. The meeting, together with a preceding workshop, focused on the development of models to predict the effects of nitrogen deposition on plant biodiversity.

- The project has contributed to ICP Integrated Monitoring through assessments of the impact of climate change on recovery from acidification, estimation of MAGIC-derived critical and target loads, and calculation of heavy metal budgets.

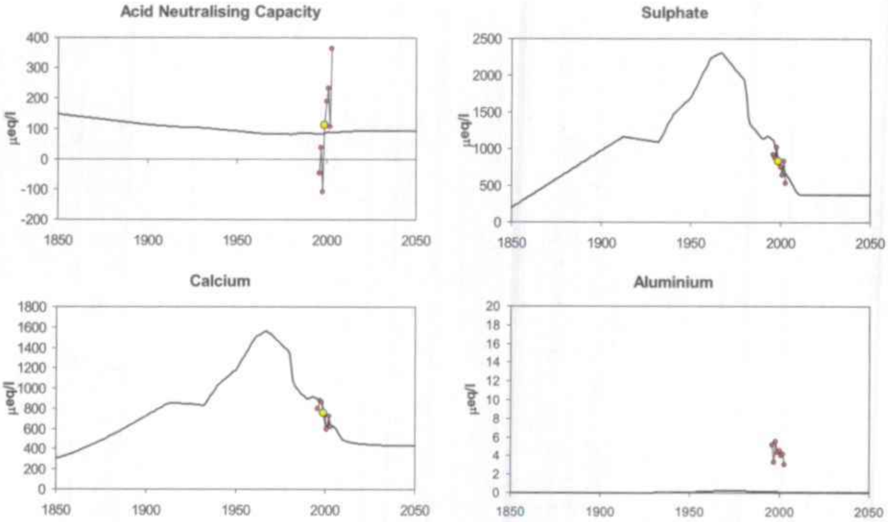
b) Ladybower



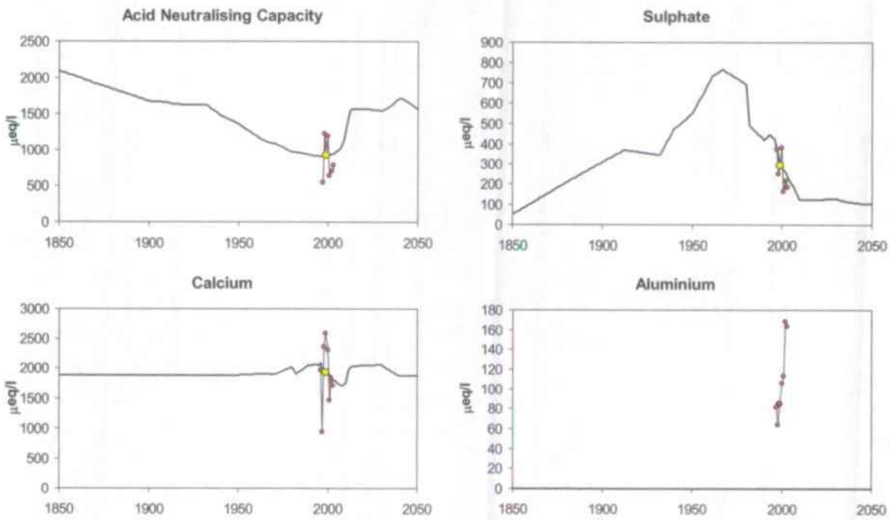
c) Brianne



d) Savernake



e) Thetford

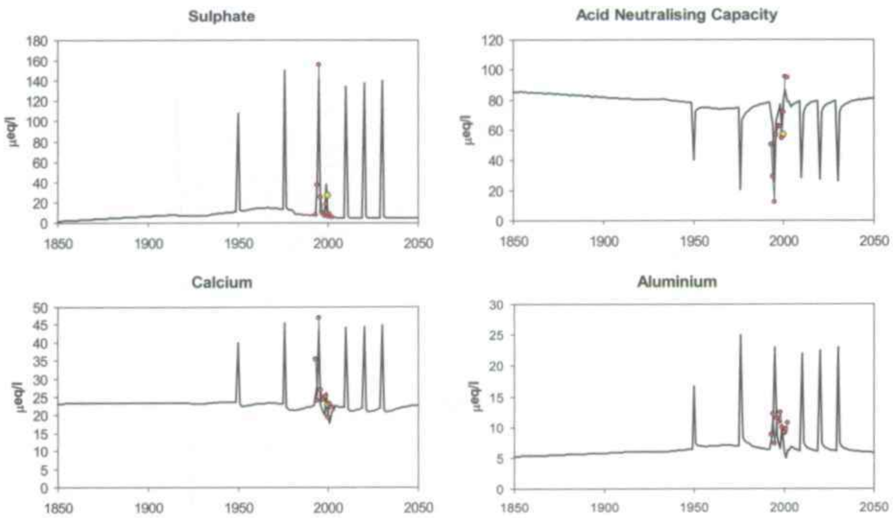


MAGIC simulations for the two non-acid sites, Savernake and Thetford, were generally poorer. Although calcium is well simulated at Savernake, very large short-term variations in ANC are not. Because base cation concentrations at this site are very high, small proportional fluctuations tend to lead to very large ANC fluctuations which MAGIC is unable to simulate. A similar situation is observed for Thetford, where year-to-year concentration fluctuations are extremely large. Since both sites are located in dry areas of southeast England, short-term fluctuations in water flux are likely to have a major impact on solute concentrations, and this has not been included in the MAGIC simulations. It may be possible to improve model performance at low-rainfall sites by incorporating year-to-year hydrologic fluctuations. Although MAGIC failed to reproduce observed aluminium concentrations at these sites, it should be noted that measurements are of total aluminium, whereas MAGIC only simulates the (toxic) inorganic component. At alkaline sites, the unsimulated organic component is likely to comprise most of all the observed aluminium present.

Note that this validation exercise did not provide a test of the nitrogen component of the model, since MAGIC does not currently simulate short term (climatic) fluctuations in nitrate, and available time series are too short to identify any underlying nitrogen 'saturation'. Model calibrations to the N manipulation sites at Ruabon and Budworth (Evans et al., 2006a) and the new calibration to Thursley (below) provide a more useful test of this component of the model.

2. MAGIC calibration to Moor House incorporating drought-induced sulphate flushes. The Moor House ECN site is one of the few UK locations with long-term peat soil solution data. Whilst the assumption of conservative sulphate transport appears valid for mineral soils, this is not thought to be the case for peats, where sulphur can be accumulated in reduced form within organic matter. This store can be remobilised by oxidation if the peat becomes dry, and acid flushes after droughts have been shown to counteract recovery from acidification in Canadian wetland catchments. Monitoring data for Moor House show a similar pattern of near-100% retention of non-marine sulphate during wet years, and large, acidifying sulphate flushes during drought years. MAGIC already contains a 'wetland' sulphur reduction-oxidation component, and this was applied to Moor House, with sulphate re-oxidation triggered when the water table fell below 25cm. The resulting simulation (Figure 2) successfully captures the effect of the 1994, 1999 and more severe 1995 droughts during the ECN monitoring period. Additional severe '1995-like' droughts are (for purposes of illustration) included in the model application in the years 1950, 1976, 2010, 2020 and 2030. The large short-term fluctuations in sulphate concentration provide a robust test of model performance, and the success of MAGIC in reproducing observed variations in base cations and ANC is encouraging. The less effective simulation of aluminium again reflects the omission of organic aluminium complexes from the model application.

Figure 2. *Modelled and observed chemistry of peat soil solution at Moor House, incorporating the effects of sulphate storage and remobilisation during droughts.*



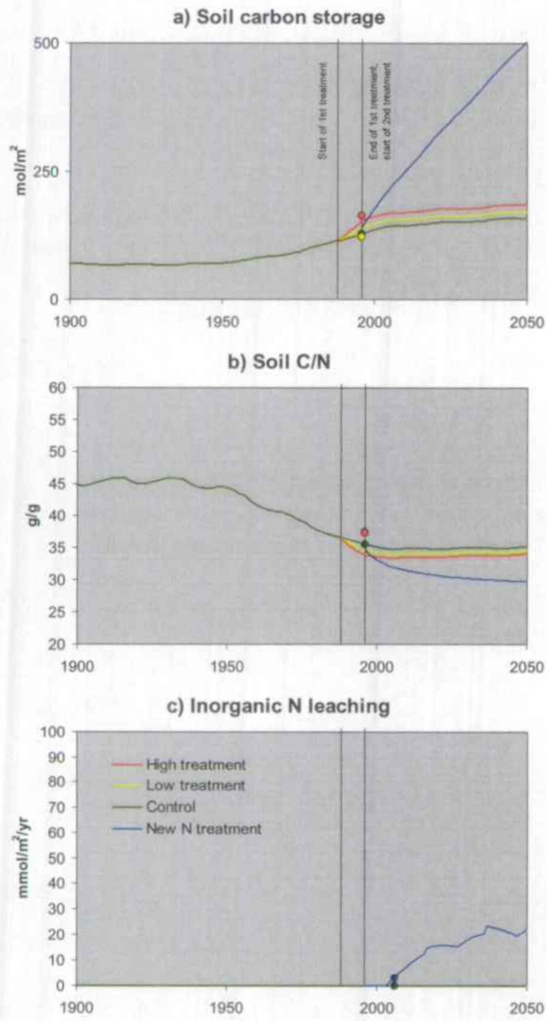
The results of this model application have some interesting implications for acidification and recovery in peatlands. In an average year, because most sulphate is retained, the acidity of soil solution at Moor House will be close to natural background levels. However the gradual accumulation of sulphur in the peats has made the system sensitive to increasingly large (e.g. 1995 vs. 1950) acidic pulses in response to droughts. Because the stores of sulphur in the peat are large, this risk is likely to persist into the future despite reduced sulphur deposition, and to be sensitive to climate change, if drought severity and frequency increase. A final observation based on this application is that the observed 'recovery' trend in ANC (and pH) at Moor House since ECN monitoring began may, if the model simulation is correct, be largely driven by recovery from early-1990s droughts, together with a decrease in marine ion deposition, rather than a reduction in sulphur deposition.

3. Modelling carbon and nitrogen at the Thursley manipulation experiment. In the last Defra Terrestrial Umbrella, a modified version of the MAGIC nitrogen model was applied to the Ruabon and Budworth N-manipulation plots, in which some of the added nitrogen led to carbon accumulation (e.g. through increased plant growth and subsequent litter production), and therefore slower nitrogen saturation. With some soil solution chemistry data now available for the Thursley N-manipulation, a first model application has been undertaken for this site. The model was applied to a) control plots; b) the 'low' 7.4 kg N/ha/yr addition plots, to which $(NH_4)_2SO_4$ was added from 1989 to 1996, with no additions thereafter; c) 'high' 15.4 kg N/ha/yr addition plots, which operated over the same period; and d) 'new' N addition plots, which have been subject to 30 kg N/ha/yr from 1998 to the present day (for the model, these additions were assumed to continue into the future). Detailed soil and vegetation physical and chemical data provided by Sally Power, Imperial

College, were used to parameterise the model. Applications assumed complete removal of above-ground biomass on a 20-year cycle (equivalent to the 'low intensity mow' carried out in the experiment). Two developments on earlier versions of the model were that the (measured) increase in biomass growth under N addition was incorporated in the model, and C and N losses via dissolved organic matter were also incorporated.

Initial results (Figure 3) suggest that Thursley was more or less in balance with regard to nitrogen prior to around 1950. This conclusion is strongly dependent on estimated N loss fluxes (e.g. to long-term soil organic matter accumulation, dissolved organic nitrogen leaching and denitrification) but appears reasonable. With increasing N deposition after 1950, modelling soil C/N decreased, and soil C increased The (relatively small) amount of N added by the 1989-1996 treatments essentially accelerated this process, but was insufficient to trigger nitrate leaching. Compared to measured responses, the model performs well in reproducing the observed accumulation of C in the 'high' treatment. In order to do this, the calibrated ratio of additional C storage to the amount of added nitrogen (C/N_{SEQ}) was higher than that obtained for either Ruabon or Budworth. This could have occurred because the amount of N addition was relatively small (leading to relatively large growth stimulation) or could indicate a transient experimental response (i.e. a lag between the increase in litter production and a subsequent increase in litter decomposition). In addition, the model did not reproduce the apparent *increase* in C/N measured in both 'low' and 'high' N treatments. This increase is surprising, and the result of apparently higher mineral soil C/N beneath the N treatments. Litter C/N, in on the other hand, did decrease in response to treatment, consistent with predictions. Further measurements of soil C and N would be useful for assessing model performance. Applying the calibrated parameters to the more recent and ongoing 30 kg N addition gives substantially greater response in terms of C accumulation, C/N decrease, and also reproduces the apparent onset of nitrate leaching observed in recent soil solution data based on a C/N leaching threshold of 32.5 g/g.

Figure 3. *Modelled changes in soil C and N, and N leaching, in response to ambient and experimental N addition at Thursley.*



4. Model analysis of land-management impacts [MILESTONE 1.5]. The calibrated models for Ruabon, Budworth and Thursley have been used to undertake a trial analysis of the impacts of different land-management practices on rates of nitrogen enrichment. At each site, the base scenario was the continuation of existing practices, i.e. periodic burning at Ruabon, and low-intensity mowing at Budworth and Thursley. For all three sites, a scenario of discontinued biomass removal (i.e. cessation of either burning or mowing) was applied in the future simulation. In addition, for Thursley, a one-off turf-stripping event (equivalent to that which took place at Budworth in 1993, and similar in impact to the high-intensity burn undertaken at Thursley) was also applied to all treatments in 1997.

The results of the different managements, by site and N addition rate, are shown in Table 1. At Ruabon, the discontinuation of periodic burning is predicted to slightly accelerate the rate of N saturation (in terms of N leaching and soil C/N) and to slightly increase soil C accumulation. However the effects of this change, in terms of direct impacts on C and N cycling, appear minor; the impact in terms of possible vegetation change due to lack of management might be more significant, but would require a more detailed plant succession model (such as SUMO) to predict. At Budworth, with a smaller soil C pool and some existing N leaching, the effects of halting mowing appear greater. This is particularly evident for the control plots, where the cessation of biomass removal is predicted to cause a substantial increase in N leaching and a 1.3 unit reduction in C/N ratio. At Thursley the effects of discontinued mowing by 2050 are intermediate between those of the other sites, although interestingly the modelled time series (not shown) suggest that biomass removal in future may be sufficient (under future reduced N deposition) to tip the balance between continued C/N decline, and a slight C/N recovery, in the 'old' plots to which N additions ceased in 1996. Turf-stripping at Thursley also leads to a decrease in C/N, because the C/N ratio of removed litter is greater than that of the underlying soil. As a result, although the total soil C and N stock is reduced, and the enriched litter resulting from experimental N additions removed, the site becomes more susceptible to N leaching; in the short term, a pulse of N leaching is predicted (up to 5 mmol/m2/yr in the 'high' plots). In the longer term, continued biomass removal leads to a recovery of soil C/N and by 2050 N leaching has halted in all 'old' plots. In the 'new' 30kg N addition plots, both turf stripping and cessation of biomass removal are predicted to amplify the effects of ongoing N additions in terms of both C/N ratio and N leaching.

Table 1. *Combined effects of different N addition rates and management practices on the nitrogen and carbon status of Ruabon, Budworth and Thursley N-manipulation sites, in 2050.*

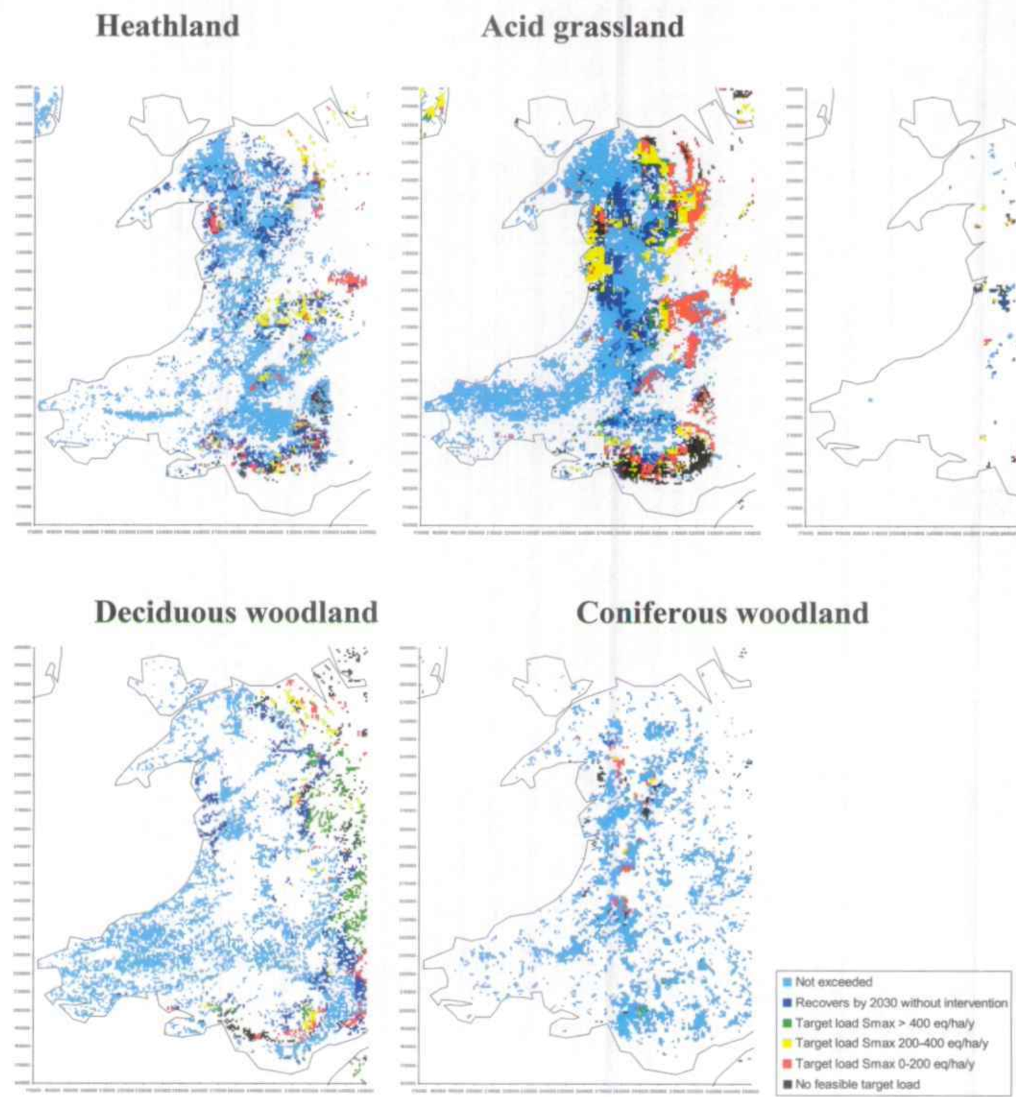
Site	N treatment	Management	N leaching mmol/m2/yr	C/N g/g	C pool mol/m2
Ruabon	Control	Continued burning	0	32.2	968
		No burning from 2000	0	31.8	968
	40kg	Continued burning	36	28.8	1431
		No burning from 2000	39	28.6	1467
	80kg	Continued burning	98	27.4	1855
		No burning from 2000	101	27.3	1888
	120kg	Continued burning	169	26.6	2261
		No burning from 2000	172	26.6	2293
Budworth	Control	Continued biomass removal	6	28.3	311
		No biomass removal from 2008	23	27	340.4
	40kg	Continued biomass removal	53	24.4	433
		No biomass removal from 2008	78	23.9	458
	80kg	Continued biomass removal	176	21.8	646
		No biomass removal from 2008	205	21.7	669
	120kg	Continued biomass removal	378	20.5	939
		No biomass removal from 2008	408	20.4	961
Thursley	Control	Continued biomass removal	0.0	35.1	158
		No biomass removal from 1998	0.0	33.4	197
		Turf cutting in 1998	0.0	33.7	142
	7.7kg* (old plots)	Continued biomass removal	0.0	34.5	171
		No biomass removal from 1998	0.0	33.0	210
		Turf cutting in 1998	0.0	32.8	147
	15.4kg* (old plots)	Continued biomass removal	0.0	34.0	185
		No biomass removal from 1998	0.0	32.7	224
		Turf cutting in 1998	0.3	32.0	152
	30kg (new plots)	Continued biomass removal	21.9	29.7	501
		No biomass removal from 1998	28.7	29.5	549
		Turf cutting in 1998	25.4	29.3	474

*Additions from 1989 to 1996 only. Other treatments continued in forecasts

ii) Model application at the national scale [MILESTONES 1.3 and 1.4]

A major data collation exercise has been undertaken during the year, and a full national dataset for application of a dynamic soils model has been completed. At present, the VSD model, driven from Access, is being used (with a configuration comparable to MAGIC) due to the greater ease of handling large datasets. Input data have been derived wherever possible from the critical loads dataset submitted by the National Focal Centre to the UNECE. For each 1 km square, input data have been derived from defaults for the dominant soil type, and for all vegetation types covering more than 1 hectare. This is directly analogous to the critical loads for each habitat type, calculated at the same resolution. Additional data required by VSD were derived from a survey of representative UK soil types undertaken in the previous Terrestrial Umbrella contract. Base saturation, cation exchange capacity and C/N ratio were affected by vegetation type, and so averages for the soil x vegetation type were used for these parameters. The model was calibrated to present-day base saturation, estimated from data for that soil series. The initial intention in Year 2 of the contract was to apply the model to a small number of small 'regions' (e.g. 20x20 km boxes) to develop protocols for data handling and model parameterisation, and to test outputs. However, in practice it has been possible to apply VSD-Access at much larger spatial scales, and the initial application of the model has been undertaken for all of Wales. Figure 4 shows target loads, by habitat, for achievement of the critical chemical criterion for that habitat in 2030. The initial critical loads dataset has been screened so that only sites with base cation weathering below 1000 eq/ha/yr have been included.

Figure 4. *Preliminary target loads for Wales, expressed as the maximum deposition of S to achieve the habitat-specific target criterion by 2030 (protocol year of 2010, implementation year 2020). Target loads not calculated for 1 km squares with < 1 ha of the habitat or where base cation weathering > 1000 eq/ha/y.*



It must be emphasised that these target load simulations are preliminary, and testing is ongoing. However on first inspection results appear encouraging, with large numbers of achievable target loads. The spatial distribution of target loads appears consistent with critical load exceedance maps, but illustrates that current critical load exceedance does not necessarily equate to current damage; squares where further deposition reductions are necessary in order to achieve recovery to acceptable chemical conditions by 2030 are largely concentrated in areas of either limited buffering (e.g. the Rhinogs in west-central Snowdonia) or areas with a high historic loading of acid deposition (e.g. upland areas adjacent to the South Wales Valleys, and upland areas in eastern Wales). A relatively small proportion of the total habitat area has no achievable target load (i.e. no possibility of ecosystem recovery by 2030).

Other work undertaken for this component of Work Package 1 has included some additional sampling of soils in Scotland. Following analysis of soil sample data collected under the previous Terrestrial Umbrella it became apparent that peaty gley soils had been omitted from the original soil survey in Scotland. Since these soils cover 13.4% of the Scottish land area, 6 set of additional profile samples were collected in January 2006, and analysed for soil chemistry and centrifuge-extractable soil water chemistry. This completes a survey of 138 representative soil samples from across Great Britain for use in parameterising dynamic models. Initially it was intended that these samples would be used to derive cation exchange constants for model parameterisation. However after data analysis, model testing, and enhancements to the VSD model, it is now possible to calibrate these exchange constants to fit measured base saturation. Since base saturation may be expected to vary to some extent within soil types (in part due to the varying exposure of soils to historic acid deposition across the country), higher resolution sampling in future might provide more accurate local calibration targets.

iii) Model development, and application of a predictive vegetation module

The MAGIC model has been extensively revised over the last year in order to meet the requirements of the project, and a new version is now available. Revisions include major changes to the structure of input data files and programs, allowing the model to be run on large datasets using 'best available' data, rather than the full calibration normally undertaken for surface water applications. This should permit MAGIC to be applied to the UK NFC dataset as required. The structure of the model has been adapted to incorporate the effect of N enrichment on carbon accumulation (see application to Thursley, above, and previous applications to Ruabon and Budworth), and with up to three (vertical or lateral) soil boxes in which 'wetland' reduction and oxidation processes can be included. The capacity of the model to simulate the effects of climate change has also been improved, in conjunction with work under the EU Eurolimpacs project.

Data collected from nitrogen isotope studies under the Freshwater Umbrella have provided new insight into the mechanisms controlling N leaching, and the pathways by which deposited N is exported to surface waters. This information will be incorporated in future applications of MAGIC, initially to the AWMN catchments (see below). Two papers on development and testing of the nitrogen component of MAGIC have now been published (Evans et al., 2006a,b) and a further paper demonstrating the importance of vegetation type for the key model relationship between C/N ratio and N leaching has been accepted for publication (Rowe et al., in press).

The development of linked soils-vegetation models during Year 2 was focused around the workshop on nitrogen and biodiversity modelling organised for Defra by the Joint Expert Group on Dynamic Modelling. Prior to this workshop, a major review and analysis (Rowe et al., 2005) addressed the following issues:

- Process understanding and models of nitrogen in soils
- Mechanisms and measures of nitrogen impacts on plant species occurrence
- Existing models for predicting nitrogen impacts on plant species occurrence
- Interactions between nitrogen deposition and other environmental drivers
- Future research requirements, and potential for harmonisation of models across Europe

Subsequently, members of the consortium have also contributed to a more detailed report on modelling the biodiversity impacts of nitrogen deposition (de Vries et al., in prep.). Close collaboration has been maintained with work being undertaken for the Terrestrial Umbrella by Dr Simon Smart, and a paper on the completed GBMOVE model is also being prepared for submission. Full application of GBMOVE to outputs from MAGIC (site specific applications) and VSD (national-scale applications) will undertaken following testing and validation of MAGIC and VSD outputs.

Work Package 2: Dynamic Modelling of UK Freshwaters

i) Development and validation of the MAGIC model

The key developments to the MAGIC model itself are described above. Additional work has been undertaken to improve the quality of input data used for modelling. Much of this work was completed in Year 1 and described in the first annual report. Some additional data has been added to the nitrogen uptake database, confirming that Norway spruce and Sitka spruce, two species which dominate many conifer plantations, have the highest rates of N uptake. These data will enable more accurate predictions of the effects of conifer planting on soil and water chemistry.

During the reporting year the Macaulay Institute has been responsible for generating the parameters necessary for MAGIC applications at the 22 AWMN sites. Soil data has been extracted from a new, high resolution database developed at the Macaulay, and carbon pools have been calculated as part of an on-going exercise with existing data, and data from a SEERAD funded project which quantified soil carbon stocks at a UK scale [**MILESTONE 2.3**]. Although more work is necessary in this particular area, the parameters to be applied to the model application are the best currently available. To date, MAGIC has been calibrated for three Scottish AWMN catchments using an improved, two-box model formulation, and a manuscript has now been submitted on this work [Aherne et al., submitted; **MILESTONE 2.4**]. Some delay to the calibration of the remaining sites has been necessary due to periods of parental leave for two members of the consortium, but is now ongoing.

ii) Extension and presentation of regional MAGIC applications

Major progress was made in this area during Year 1 of the project, in order to deliver target loads for surface waters in February 2005, in response to the CCE Call for Data. At this time, MAGIC was calibrated to a total of 320 catchments covering seven sensitive regions across the UK. During Year 2, a further 50 catchments have been calibrated based on the North York Moors dataset compiled under optional work package B [**MILESTONE 2.6**]. As noted previously in the report on this work (Evans et al., 2005), streams in the region were found to be highly acid, due to extremely high sulphate concentrations and limited soil buffering capacity. This is reflected in the MAGIC simulations (Figure 5), which suggest a very severe level of acidification since the 1950s, and only partial recovery to present day. Note that many streams had a very low ANC in 1850. This in part reflects the low buffering capacity of the soils, but it should be noted that some anthropogenic S deposition was assumed to occur at this time, so these do not represent true 'reference' conditions. As noted previously, conifer forestry appears to have greatly exacerbated the effects of acid deposition in terms of present day chemistry (including nitrate leaching) and again this is reflected in MAGIC simulations (Figure 6). These suggest that, prior to forest planting in the latter part of the 20th century, these catchments were on average slightly less acid than the areas still covered by moorland, but that afforestation led to severe acidification thereafter.

In terms of future recovery, the MAGIC simulations suggest only a partial improvement in water chemistry, with median ANC stabilising at around -50 μeq/l after 2050 in response to Gothenburg protocol emissions reductions. Even with deposition reduced to background levels, median ANC is still predicted to remain

Figure 5. *Median MAGIC-modelled ANC for 50 streams in the North York Moors, 1850-2050*

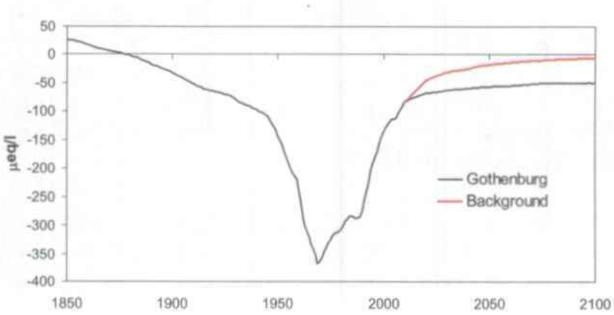
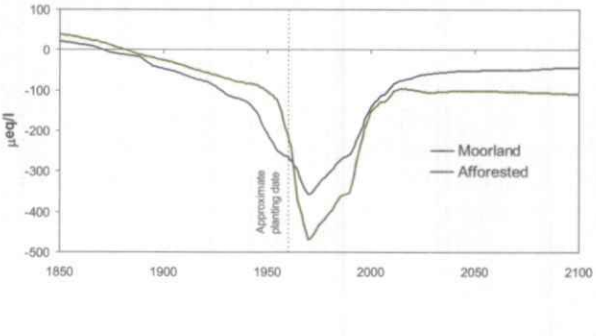


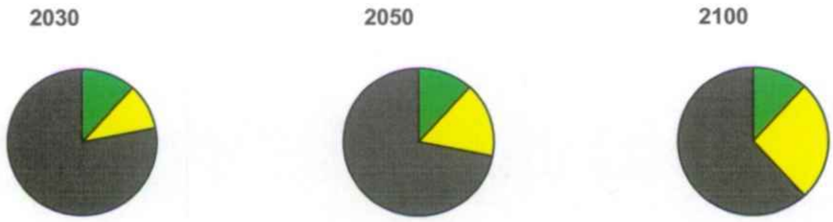
Figure 6. *A comparison of median MAGIC-modelled ANC in moorland and forest streams, North York Moors*



negative in 2100, suggesting that recovery will be extremely slow in the region. It is noteworthy that recovery under the Gothenburg protocol will be greater and sustained in moorland catchments, whereas some re-acidification is predicted for forested catchments (Figure 6).

Because of the slow and incomplete recovery, even if deposition is reduced to background levels, a very high proportion of the North York Moors streams have unachievable target loads, even with the least stringent target chemistry (ANC 0) and target year (2100) (Figure 7). This represents a more pessimistic prediction than for any of the regions previously modelled, and for which target loads were submitted in 2005. If these predictions are correct, they raise considerable cause for concern regarding the current and future chemical and biological status of these waters. However it must be noted that all MAGIC calibrations are based on the assumption that the single water samples (collected in March) provide a representative estimate of annual mean water chemistry; further sampling at other times of year would be beneficial in testing this assumption, and if necessary refining MAGIC calibrations.

Figure 7. *Proportion of North York Moors sites having acceptable chemistry (green), achievable target loads (yellow) or no possibility of recovery (black), based on a target ANC of zero, and target years of 2030, 2050 and 2100.*



iii) Prediction of biological response to chemical change

Empirical relationships between probability of occurrence of an acid-sensitive indicator stream invertebrate species, *Baetis rhodani*, and stream ANC, were developed under the previous Freshwater Umbrella contract by Dr Steve Juggins, University of Newcastle. The relationships have been used to predict biological change from MAGIC-simulated ANC change for a set of streams in the Conwy catchment, North Wales. This work has now been published (Evans et al., 2006c). Completion of this component of the work programme, and of Milestone 2.5, is reliant on the completed calibration of the AWMN catchments, and will take place during autumn 2006.

Work Package 3: Coordination of critical load activities

The national critical loads of acidity and nutrient nitrogen were significantly revised and updated in 2003 and 2004; no further changes have been made to the data sets since February 2004. The UK NFC has kept a watching brief on developments over the last year by attendance at the Acid Rain conference in 2005 and at the CCE Workshop and ICP Mapping and Modelling (M&M) Task Force meetings in April 2006. The current focus of developments is on dynamic models, particularly those that consider nitrogen impacts on biodiversity. The development of dynamic models in the UK is reported on under Work Packages 1 and 2. Jane Hall has also attended APRIL (Air Pollution in London) group meetings, the annual meeting of Defra contractors involved in deposition modelling and a meeting to discuss progress with the Air Quality Strategy (see WP5).

The national deposition data based on measurements (i.e., CBED data) are now revised and updated on an annual basis by CEH Edinburgh. In parallel with this exercise the NFC calculate the exceedances and maintain a record of the trends in exceedance over time based on the CBED data. The results of this exercise are reported on in Work Package 5. These exceedance statistics also include information on the area of designated sites in exceeded areas. These areas are based on a 1km gridded version of the polygon boundaries of the designated sites, since at present this is the quickest and simplest mode of generating the exceedance statistics. The conservation agencies are continually updating their databases of designated sites; to avoid constantly updating the data we use, we update our data sets on an annual basis only. The data were last updated in May 2005 and are currently being updated for 2006 at the time of preparing this report. In previous years we have used the boundary data of SSSIs, SACs and SPAs; for 2006 we are additionally including RAMSAR sites. Final completion of this task [**MILESTONE 3.2**] will be possible as soon as the Welsh data are available. The designated area data have also been used in the assessment of exceedance of critical levels (air quality objectives) as part of the Defra Air Quality Strategy (see WP 5).

With developments in GIS technology (from UNIX-based ArcInfo to PC-based ArcGIS) it is now becoming easier and quicker to perform spatial analysis using vector polygon data than was previously possible. CEH have agreed to fund the development of GIS methods for their application to critical loads research. We will determine which processes can be run from ArcGIS with minimal modifications, and develop models/scripts for those processes that require conversion. We will focus on:

(i) Methods to assess the number of designated sites (rather than just the area) where critical loads or levels are exceeded.
(ii) Methods used to calculate critical load exceedance statistics – currently based on C-programs linked to a suite of programs in ArcInfo macro language (AML).
(iii) Methods for the conversion of data from the Irish Grid to the GB grid and vice versa, as required for the use of deposition and other data sets.

The NFC has also been involved in other projects that are of relevance to this Defra contract:

(i) Uncertainty in critical load assessment models: project funded by the Environment Agency, examining the uncertainties in critical loads at the site-specific, regional and national scales (Skeffington et al, 2006).
(ii) Assessing the risks of air pollution impacts to the condition of Areas/Sites of Special Scientific Interest in the UK: project funded by JNCC to consider the options for assessing the potential risks from acidification and eutrophication (in terms of critical loads and exceedances) to designated sites (Hall et al, 2006a)

Work Package 4: National Focal Centre for Critical Loads and Dynamic Modelling

i) To maintain the UK's national critical loads and dynamic modelling databases

As explained in WP3 there have been no updates to the national critical loads database since February 2004. The national 1km data are maintained and securely stored in a UNIX environment with access via ArcInfo and ArcGIS GIS packages. A copy of the data as submitted to the CCE in February 2004 is maintained within an MS Access database. In addition a new MS Access database has been created, based on the CCE data submission, but with the additional input parameters required for the running of dynamic models for any 1km grid square of the UK to assist in the development and testing of national scale modelling under WP1(ii).

ii) To provide relevant data on critical loads and dynamic modelling to the UNECE's Coordination Centre for Effects (CCE)

On 24th October 2005 the CCE announced an ***optional*** call for data (critical loads for acidity eutrophication or heavy metals, and data on dynamic modelling of acidification), requesting NFCs to provide a statement of intent by 2[nd] December and deliver data by 31[st] January 2006. The UK NFC contacted relevant Defra contractors and agreed not to make a data submission on the following grounds:

- No updates had been made to the national steady state critical loads for acidification and eutrophication since the data submission in February 2004.
- Dynamic modelling outputs for acidity (freshwaters) were submitted to the CCE in February 2005 and were consistent with the steady-state data submitted in 2004. There was insufficient time to obtain all the data required and calculate steady-state critical loads for other freshwater sites for which dynamic models could be applied.
- No updates had been made to the national critical loads for heavy metals since the data submission in December 2004.

[Note that, since no new data submission was required, **DELIVERABLE 4.3** was no longer applicable. The update to the UK Dynamic Modelling database, **MILESTONE 4.2,** was completed prior to the data submission in February 2005]

At the CCE workshop and ICP MM Task Force meetings in April 2006 it was recommended that there should be a voluntary call for data on critical loads for nitrogen impacts on biodiversity later in 2006 for submission of data to the CCE in Spring 2007 (see item (iv) below).

iii) To maintain a website and to make data readily available

The UK NFC web site (http://critloads.ceh.ac.uk) has been maintained and updated as necessary and still provides a key contact point for those seeking information on the methods used as well as those requiring data. Copies of the critical loads and exceedance maps are now accessible more readily on the web site, without having to search the various Status Reports or other documents. These will continue to be updated as exceedance maps are revised using the latest CBED deposition data (see WP5). Reports on dynamic modelling activities are now also available on the web site.

Future developments:

- The NFC makes the habitat distributions, critical loads and exceedance (based on 5th percentile critical loads) data available to users via a password protected 'file transfer protocol' (ftp) site. The data are issued free of charge under a CEH licence agreement. In the coming year the data will be made available directly from the NFC web site; this development has been delayed due to internal discussions about the CEH data licence agreements.
- The structure and content of the web site will be reviewed.
- New sections will be added to the web site to provide information on (a) uncertainties in critical loads and exceedances; (b) site-specific critical loads.

(iv) Head of UK NFC and representation at UNECE meetings

Jane Hall, as head of the NFC attended the UNECE CCE workshop and ICP M&M Task Force meeting in April 2006. The CCE workshop was also attended by Chris Evans and Bridget Emmett (CEH Bangor) and by Sam Baker (Defra). The CCE workshop made the following recommendations (of relevance to this contract) to the Task Force:

- To establish (fix) the status of the current European database of acidification and eutrophication for use in the 2006/2007 protocol review.
- A 2-track approach to the development of nitrogen critical loads for impacts on biodiversity, consisting of:
  (a) Track 1 (2006-2007): Voluntary involvement of NFCs, including:
    - Preliminary application of a broader range of critical limits in SMB modelling to address biodiversity in terrestrial ecosystems.
    - The exploration of simple dynamic modelling applications for eutrophication.
    - The comparison of modelled and empirical critical loads and their exceedances.
    - The improvement of databases for more complex modelling.

  (b) Track 2 (2007-2008): NFCs to focus more on the implementation of more complex modelling of the effects on biodiversity that are directly or indirectly caused by air pollution.
- To conduct in 2006-07 a voluntary call from contributions from NFCs to test and review new critical limits and methods in simple steady-state and dynamic modelling applications as described in CCE workshop background document (de Vries et al, in prep.) and in relevant chapters of the Mapping Manual.

Recommendations from the Task Force (TF), of relevance to this contract are summarised below:

- TF Encouraged NFCs to continue comparing EMEP base cation deposition data to their national estimates and report on these items at the next TF meeting. NB. the UK was one of 14 countries who had carried out a comparison or intended to do so in the near future.
- TF Encouraged other NFCs to follow the six countries (including the UK) which had already linked national high-resolution deposition models to the EMEP scale model and

analyzed the resulting critical load exceedances, and report on these items at the next TF meeting.

- The CCE announced that the new merged (CORINE land cover and SEI data) land cover map for Europe based on the EUNIS habitat classification would be available from the SEI in April / May 2006. The TF invited NFCs to compare their national data with the merged data set and report discrepancies to the CCE. NFCs encouraged to use these data in the test phase of the development of biodiversity critical loads for nitrogen.
- TF recommended that AAE (average accumulated exceedance) should be the measure to use in gap closures, and the area exceeded should also be presented.
- TF confirmed the necessity of applying dynamic models to assess time delays of risks to ecosystems where target settings lead to depositions that continue to exceed critical loads.
- TF requested NFCs to carry out studies on biases (i.e., systematic differences in how countries calculate critical loads, egg, selection of ecosystems, criteria) and uncertainties of critical loads, separately for acidification and eutrophication.
- TF agreed the recommendation from the CCE workshop for the voluntary call for data.
- TF encouraged NFCs to contact their local "habitat experts" to learn more about regionally defined biological endpoints, making use of the ongoing SEBI2010 process.
- TF invited NFCs to suggest modifications to the background nitrogen document (de Vries et al, in prep.) to the CCE in Spring 2007 (well in advance of the next CCE Workshop).
- TF encouraged NFCs to undertake studies on the interaction between climate change effects and acidification and eutrophication processes, including sensitivity studies of potential scenarios (bias evaluation), and to report on them at the next TF meeting.
- Recommended NFCs to further assess the implications of the revised draft rules for the use of their data under CLRTAP (copy available from ICP M&M web site).

A list of future relevant meetings was also drawn up:

- 23/24 May 2006, Charlottesville, USA: U.S. Multi-Agency CL Workshop
- 9 - 10 October 2006, Bergen, Norway: Workshop on Confounding Factors
- 13 - 18 October 2006, Obergurgl, Austria: ESF/LFUI Conference on NH_3
- 25 - 27 October 2006, Sitges, Spain: 7th JEG Dynamic Modelling meeting
- November 2006, Netherlands ESF NinE Workshop: The Nitrogen Cascade in Europe
- 4 - 6 December 2006, Edinburgh, UK: NH_3 Workshop
- 19 - 21 March 2007, Wageningen, Netherlands: NH_3 Conference
- 23 – 27 April 2007 (provisional), Sofia, Bulgaria: CCE Workshop and ICP M&M Task Force meeting

Full copies of the minutes and supporting documents from the meetings are available from the CCE and ICP M&M web sites (CCE: http://www.mnp.nl/cce/. ICP M&M: http://www.oekodata.com/icpmapping/)

Work Package 5: Scenario analysis and advice to Defra and devolved administrations

(i) Critical load assessments

Critical load exceedance statistics have been calculated using measured (i.e., CBED data from CEH Edinburgh) and modelled (FRAME) deposition together with the national critical loads data for February 2004. The results are summarised under the headings below.

CBED current deposition

Deposition for 2001-2003

In April 2005 the average deposition data for 2001-2003 became available; the full exceedance statistics by habitat and country and based on these data have previously been reported to Defra. Subsequently the area of designated sites (based on the 2005 data described in WP3) within exceeded areas were calculated and are summarised in Tables 2 and 3 below.

Table 2. *Acidity exceedance statistics for designated sites in the UK**

Site type	Area (km^2)*	Exceeded area (km^2)	% exceeded area
SSSIs	16740	11536	68.9
SACs	10860	7600	70.0
SPAs	8531	5774	67.7

Table 3. *Nutrient nitrogen exceedance statistics for designated sites in the UK**

Site type	Area (km^2)*	Exceeded area (km^2)	% exceeded area
SSSIs	21061	14191	67.4
SACs	14625	9144	62.5
SPAs	12119	7081	58.4

* *These are the areas of designated sites that occur in 1km grid squares for which critical loads for terrestrial habitats are mapped.*

When interpreting these results it should be noted that the total area of the UK represented by the critical loads maps for acidity and nutrient nitrogen differs for the following reasons:

- The number and type of habitat mapped nationally for each effect (acidity, nitrogen) differs, with more habitats being mapped for nutrient nitrogen than for acidity.
- The methods used to map the habitat distributions may differ for acidity and for nutrient nitrogen. For example, for nutrient nitrogen it is necessary to set different critical load values to wet and dry dwarf shrub heathland and hence additional data are required to identify the separate habitat distributions.
- The calculations of acidity and nutrient nitrogen critical loads require different input data sets.

Therefore when the national maps are derived many different data sets are combined, and each varies in its coverage of the UK, resulting in different areas being represented on the final maps for acidity and nitrogen, in some cases even for the same habitat. For further information on the methods used refer to Hall et al, (2003, 2004).

When using these national critical load maps to make an assessment of the designated areas at risk, a simple approach has been adopted. The total area of designated sites being assessed is taken as the area of sites within 1km squares of the UK for which acidity or nutrient nitrogen critical loads data are available (for terrestrial habitats). The area considered to be at risk is calculated as the area of sites within 1km squares of the UK for which the relevant critical loads for any of the terrestrial habitats are exceeded. No assessment is made of site areas in regions of the country for which no critical loads data are available.

Deposition for 2002-2004

The full exceedance statistics by habitat and country and based on the deposition data for 2002-2004 have also previously been reported to Defra. The results are summarised below (Tables 4 and 5) alongside the results for the 2001-2003 data for comparison. It should be noted that the data for 2001-2003 included nitric acid which was not measured in earlier years, and in 2002-2004 the data additionally include aerosol deposition resulting in some small apparent increases in the area exceeded compared the 2001-2003. However, the accumulated exceedances have decreased showing an overall reduction in the magnitude of exceedance. The areas of designated sites within exceeded habitat areas will be calculated in the near future when the updated boundary data are complete (see WP3).

Table 4. *Acidity exceedance statistics for the UK*

Broad habitat	Habitat area (km^2)	Exceeded area (km^2) [percentage exceeded]		Accumulated Exceedance (keq year^{-1})	
		2001-2003	2002-2004	2001-2003	2002-2004
Acid grassland	153334	12232 [79.8%]	12347 [80.5%]	1081529	1028396

Calcareous grassland	1808	0	0	0	0
Dwarf shrub heath	24703	9805 [39.7%]	10128 [41.0%]	564884	520802
Bog	5463	3408 [62.4%]	3336 [61.1%]	256185	226180
Montane	3054	2520 [82.5%]	2731 [89.4%]	183732	196280
Coniferous woodland*	8377	5612 [67.0%]	5777 [69.0%]	605502	624260
Broadleaved woodland*	7452	5188 [69.6%]	5277 [70.8%]	749269	700282
Unmanaged woodland	4011	2363 [58.9%]	2429 [60.6%]	276664	262738
Freshwaters	7790	1646 [21.1%]	1601 [20.6%]	131725	120058
All habitats	77991	42773 [54.8%]	43627 [55.9%]	3849490	3678997

* managed woodland

***Table 5**. Nutrient nitrogen exceedance statistics for the UK*

Broad habitat	Habitat area (km^2)	Exceeded area (km^2) [percentage exceeded]		Accumulated Exceedance (keq $year^{-1}$)	
		2001-2003	2002-2004	2001-2003	2002-2004
Acid grassland	15421	8847 [58.0%]	9053 [59.4%]	364888	332318
Calcareous grassland	3577	2822 [78.9%]	2216 [61.9%]	111696	69863
Dwarf shrub heath	24820	8035 [32.4%]	8301 [33.4%]	331339	296093
Bog	5541	2347 [42.4%]	2345 [42.3%]	166313	145383
Montane	3129	2784 [89.0%]	2898 [92.6%]	126491	136971
Coniferous woodland*	8385	7594 [90.6%]	7795 [93.0%]	861195	881761
Broadleaved woodland*	7482	7288 [97.4%]	7341 [98.1%]	1380872	1308940
Unmanaged wood**	3296	3147 [95.5%]	3164 [96.0%]	568939	544725
Atlantic oak***	822	750 [91.3%]	797 [96.9%]	70369	77131
Supralittoral sediment	2128	666 [31.3%]	355 [16.7%]	14907	6613
All habitats	74422	44279 [59.5%]	44264 [59.5%]	3997008	3799801

* managed woodland

** N effects on ground flora

*** N effects on epiphytic lichens

Time series deposition

For this study the exceedance statistics based on the 2001-2003 CBED deposition were compared against exceedance statistics derived using FRAME modelled deposition for 1970 and 2020, where the FRAME output was calibrated using the 2001-2003 CBED data for consistency. FRAME was also run to generate deposition data for 1980 and 1990, but critical load exceedances were not calculated using these data. A summary of the results together with exceedance maps were included in the 2006 final report to Defra on the FRAME model (Dore et al, 2006). The exceedance statistics are summarised below by country (Table 6) and by habitat for the UK (Table 7).

***Table 6**. Exceedance statistics by country*

Country	% habitat exceeded for acidity:			% habitat exceeded for nutrient N:		
	1970	2001-03	2020	1970	2001-03	2020
England	82.7	72.1	63.3	96.9	93.1	85.3
Wales	95.7	81.6	67.8	93.7	87.4	75.2
Scotland	91.0	42.6	24.1	50.9	37.5	24.6
NI	89.9	71.3	59.7	85.4	82.0	70.4
UK	89.4	54.8	39.4	69.1	59.5	48.1

Table 7. *Exceedance statistics by habitat for the UK*

Broad habitat	% habitat exceeded for acidity			% habitat exceeded for nutrient N		
	1970	2001-03	2020	1970	2001-03	2020
Acid grassland	97.9	79.8	66.4	70.4	58.0	38.9
Calcareous grassland	38.8	0	0	93.2	78.9	52.4
Dwarf shrub heath	95.9	39.7	21.7	42.4	32.4	21.3
Bog	98.1	62.4	43.8	55.9	42.4	39.5
Montane	99.9	82.5	56.7	98.9	89.0	71.4
Coniferous wood (managed)	93.1	67.0	49.6	97.3	90.6	83.9
Broadleaved wood (managed)	82.4	69.6	57.2	98.9	97.4	96.2
Unmanaged woods*	84.1	58.9	42.8	98.0	95.5	93.7
Atlantic oak (epiphytic lichens)**	-	-	-	98.3	91.3	70.8
Freshwaters***	59.5	21.1	12.0	-	-	-
Supralittoral sediments****	-	-	-	51.2	31.3	17.6
All habitats	89.4	54.8	39.4	69.1	59.5	48.1

* for nutrient nitrogen unmanaged woodland separated into areas considering (a) the effects of N on ground flora, and (b) into the Atlantic oak class for the effects of N on epiphytic lichens.
** for acidity the areas of Atlantic oak are included in the unmanaged woodland
*** critical loads only calculated for acidity
**** critical loads only calculated for nutrient nitrogen

For acidity the total area of sensitive habitats exceeded fell by almost 35% between 1970 and 2001-03, and is predicted to fall to less than half the area exceeded in 1970 by 2020. Reductions in the habitat areas exceeded for nutrient nitrogen are also significant, but smaller than those for acidity, with a predicted reduction of 21% between 1970 and 2020. However, for the woodland habitats the areas exceeded for nutrient nitrogen show much smaller decreases over this time period (egg, only ~4% for unmanaged woodland); this is largely due to the dominant role of dry deposition of ammonia to tall vegetation.

The exceedance results clearly follow the reductions seen in emissions and deposition between 1970 and the present day. For the year 1970, sulphur accounted for over half of the total acid deposition to forest. During the period 1970-1990, oxidised nitrogen accounted for 30% of the total nitrogen deposition to forest. However, for a recent emissions year (2005), reductions in emissions of SO_2 and NO_x mean that NH_x is making the greatest contribution to both acid deposition (64%) and total nitrogen deposition (78%) to forest. Without future reductions in ammonia emissions, NH_x deposition is forecast to increasingly dominate acid and total nitrogen deposition (Dore et al, 2006).

RIA Marine Fuels Directive

Exceedance statistics were calculated for four scenarios to provide information to ENTEC (Defra contractors) in relation to the RIA Marine Fuels Directive. The scenarios consisted of a baseline for the year 2007 and three comparative scenarios with 4.6%, 5.3% and 7.8% reductions in sulphur deposition. The scenario deposition was generated at CEH Edinburgh using the FRAME model. The exceedance statistics were reported to ENTEC and to Defra. As the focus was on reductions in sulphur, nutrient nitrogen exceedances were only calculated for the baseline scenario. These reductions in the sulphur deposition had a very small impact on the area of habitats exceeded: the area exceeded for acidity for the most stringent scenario (7.8% reduction) resulted in the "protection" of 824 km^2 more habitat area than the baseline, equating to a difference of 1% in the habitat area exceeded. The accumulated exceedance for this scenario was 2.4% lower than that of the baseline scenario, showing that the magnitude of exceedance had also decreased.

Defra Air Quality Strategy

The UK Air Quality Strategy (AQS) sets air quality standards and objectives for eight key pollutants, two of which (SO_2 and NO_x) are responsible for acidification and eutrophication. In addition to assessing the potential impacts of deposition scenarios, air quality (AQ) objectives for the protection of vegetation and ecosystems from the gaseous concentrations of these pollutants were also examined. No AQ objective has been set for NH_3 and therefore the critical level for NH_3, recommended by ICP Vegetation and WHO, was used. The results of this study were published in a report to Defra (Hall et al, 2006b) as one of the supporting documents for the AQS during its consultation period. The results are summarised below.

Deposition scenarios and critical load exceedances

CEH Edinburgh provided the FRAME model predictions for the scenarios required for the AQS and also provided an analysis of the emissions, concentration and deposition data in the report (Hall et al, 2006b). Critical load exceedances were calculated for the years 2001-03 (CBED data), 2010 and 2020. For acidity, 54.8% of UK sensitive habitats are exceeded for 2001-03, decreasing to 39.4% in 2020. For nutrient nitrogen there is a slightly smaller decrease over this time period, from 59.5% exceeded in 2001-03 to 48.1% in 2020, reflecting the smaller reductions expected in nitrogen deposition.

Eight emission abatement scenarios were considered and compared with the 2020 baseline. The eight scenarios gave similar results (Table 8); differences in the habitat areas exceeded were only 0.8% for acidity and 2.2% for nutrient nitrogen. Overall, Scenario B (Euro high) with the large reductions in nitrogen deposition gave the lowest areas exceeded for both acidity and nutrient nitrogen and for all countries within the UK. Scenario N (shipping emission reductions) gave the smallest reduction in areas exceeded for acidity in England and NI, and in all countries for nutrient nitrogen since nitrogen deposition was only decreased by 1.7% for this scenario. However this scenario gave the greatest reduction in area of exceedance in Scotland. However, the results need to be interpreted with care; the area of habitat exceeded can be the same for different scenarios, but the magnitude of that exceedance can differ. The accumulated exceedance (AE) integrates both the area exceeded and the magnitude of exceedance, but different combinations of these two parameters, such as a large area with a small exceedance, or a small area with a large exceedance, may give the same AE value.

***Table 8**. Deposition scenarios and exceedance statistics for the Air Quality Strategy*

Scenario	Description	Deposition budgets [% reduction from base]		% habitat area exceeded	
		NO_y (kT N)	SO_x (kT S)	Acidity	Nutrient N
Baseline	2020	72.7	87.5	39.4	48.1
A	Euro-low: traffic reductions	68.8 [5.4]	87.5 [0]	38.7	46.8
B	Euro-high: traffic reductions	64.2 [12]	87.5 [0]	37.9	45.6
C	Early Euro-low: traffic reductions	68.6 [5.6]	87.5 [0]	38.7	46.7
K	Large Combustion Plant	66.5 [9]	87.5 [0]	38.2	45.7
N	Shipping reductions	71.5 [1.7]	82.6 [5.9]	38.5	47.8
O	Early Euro-low & LEV*	67.8 [6.7]	87.5 [0]	38.6	46.5
P	Early Euro-low & SCP**	67.9 [6.6]	86.2 [1.5]	38.5	46.5
Q	Early Euro-low & LEV & SCP	67.2 [7.6]	86.2 [1.5]	38.4	46.3

* Low Emission Vehicles

** Small Combustion Plant

Assessment of the AQ objectives for ecosystems and vegetation

This assessment was based on identifying and calculating the areas of designated sites (rather than critical load broad habitats) where the AQ objectives were exceeded. Assessment of the air quality objectives for SO_2 (20µg m^{-3}) and NO_x (30µg m^{-3}) identify some areas (typically <1%) where the objectives are exceeded in 2003 for designated sites falling outside the "exclusion zone". Areas are classified as being outside the zone if they are more than 20km from agglomerations and 5km from motorways, other urban areas and industrial installations. The concentration data used for the AQS report included 1km and 5km resolution data that included urban areas (i.e., areas within the exclusion zone). Therefore this result is in contrast to reporting under the EU Daughter Directive (DD) in which no exceedance is recorded. However, the reporting for the DD is based on 30km resolution mean concentration data calculated for rural areas only to prevent the influence of any urban area appearing unrealistically large on adjacent vegetated areas.

The potential impact of reducing the SO_2 objective to 10µg m^{-3} was also examined using 1km and 5km concentration data; this resulted in some small areas of exceedance but represented <1% of the areas of designated sites outside the exclusion zone. For NH_3, the objective of 8µg m^{-3}, as recommended by the World Health Organisation and ICP Vegetation, was investigated. This was exceeded in only a few areas, coinciding with <0.1% of the area of designated sites in the UK, both for 2002 and 2020.

(ii) Dynamic modelling assessments

No dynamic modelling scenario assessments were requested during the year.

(iii) Provision of advice/information to Defra and the devolved administrations

The NFC responds to requests from Defra and the devolved administrations (and also the Conservation Agencies) for advice, information, data (egg, exceedance statistics) and maps. In recent months exceedance statistics and/or maps have been provided for:

- Defra headline indicators for sustainable development
- Defra e-Digest of Environmental Statistics
- SEPA State of the Environment Report.

Work Package 6: Chairmanship of the UNECE Dynamic Modelling Expert Group

The report of the 2004 meeting of the Joint Expert Group was delivered to the 24th session of the WGE in September 2005 [**MILESTONE 6.2**]. The 6th JEG meeting was organised and held in Brighton in October 2005 [**MILESTONE 6.3**] . The aims of the workshop were to:

- Review the outcome of the 2004 call for dynamic modelling outputs
- Consider the potential for using dynamic model outputs within the forthcoming review of the Gothenburg Protocol
- Assess progress on linking dynamic biogeochemical models with models of biological damage and recovery
- Consider the potential for model applications incorporating both climate change and emissions reduction scenarios
- Discuss the Work Plan for 2006 and 2007.

As already noted, an preceding workshop was held, with additional support from Defra, on dynamic modelling of nitrogen and its impacts on biodiversity, and the JEG also reviewed the outcomes of this workshop. 20 conclusions and recommendations were agreed, and included in a report which has now been circulated to members of the JEG, and submitted to the WGE [**DELIVERABLES 6.3, 6.4**].

Plans have been made for the 7th meeting of the JEG, in Sitges on October 25-27 2006, and initial invitations have been circulated. The meeting will consider the following:

- Effects-based approaches for the review and possible revision of the Convention protocols.
- Current status of dose-response functions and stock at risk.
- Links between field observations and both target and critical loads.
- Determination and evaluation of key nitrogen and heavy metal processes for dynamic modelling.

Work Package 7: National Focal Point for ICP-Integrated Monitoring

M7.4 Completion of database for 2004
M7.5 Data transmission to EDC Helsinki
M7.6 Attendance at ICP-IM Task Force

The ICP-IM database for 2004 has been completed, and data transmitted to the ICP-IM Programme Centre (Finnish Environment Institute) [**MILESTONES 7.4, 7.5**]. The ICP-IM task force meeting in May was attended by Mike Hutchins [**MILESTONE 7.6**]. Minutes of the meeting and drafts annual reports are on the ICP-IM Programme Centre website: http://www.environment.fi/default.asp?contentid=17110&lan=en.

As stated in the Feb 2006 interim report, a paper on dynamic modelling of climatic effects has been accepted for publication by Science of the Total Environment, and now published (Wright et al., 2006). In addition, a stand-alone piece of work based on site-specific modelling of the Afon Hafren has been reported to ICP-IM and forms Chapter 4 of the draft annual report (Hutchins and Jenkins, 2006 -see link above) [**DELIVERABLE 7.2**]. This work has involved the following:

- Re-calibration of MAGIC model against 1998 data and use of updated information to model impact of future forecasted deposition
- Comparison of MAGIC-derived critical loads with those available for the site using FAB in recent submissions. The MAGIC-derived critical load for the Hafren, which make use of weathering rates taken from the MAGIC calibration, is approximately 5% lower than the FAB estimate.
- Calculation of loads of S and N to achieve future streamwater target chemistry for a range of years. For the Hafren, the recovery delay time to achieve a stream ANC of 20 μeq L^{-1} is rapid (< 5 years) and achievable under UK NECD deposition projections. MAGIC predicts that ANC will deteriorate slightly towards 2100. However, as ANC is predicted to remain above critical levels throughout, a target load function for 2100 shows deposition levels significantly above the current UK NECD projections for the Hafren (which are 0.776 and 0.075 keq ha^{-1} yr^{-1} for total N and non-marine S respectively).

Further future applications of MAGIC and calculation of target load functions for ICP-IM will be specified when appropriate and will take advantage of ongoing improvements to the model with a view to reporting to ICP-IM and WGE in 2007.

In addition, work on heavy metal budgets has been undertaken using data from the Allt a'Mharcaidh ICP-IM site. A report on the work, led by Lage Bringmark, SLU Sweden, was submitted to the WGE Executive Body in Dec 2005. A summary of this work is included in Chapter 3 of the ICP-IM draft annual report. It is hoped that the work will be submitted to a refereed journal later in summer 2006.

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SID 4

Annual/Interim Project Report for Period July 12 2005 to July 11 2006.

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Project details

1. Defra Project code: CPEA 19
2. Project title: Critical Loads and Dynamic Modelling for Acidity and Nitrogen
3. Defra Project Manager: Samantha Baker
4. Name and address of contractor: Centre for Ecology and Hydrology
   Orton Building, Deiniol Rd
   Bangor
   Gwynedd
   Postcode LL57 2UP
5. Contractor's Project Manager: Christopher Evans
6. Project: start date .... 12 July 2004
   end date .... 11 July 2007

Scientific objectives

7. Please list the scientific objectives as set out in the contract. If necessary these can be expressed in an abbreviated form. Indicate where amendments have been agreed with the Defra Project Manager, giving the date of amendment.

Terrestrial dynamic modelling: Site-based model testing; method development, testing and application of models at the national scale; incorporation of improved nitrogen, climate change and management controls in the model; prediction of changes in vegetation due to atmospheric deposition
Freshwater dynamic modelling: Model validation at long-term monitoring sites; extension of regional surface water model applications; prediction of biological recovery.
Critical loads: Management of UK Critical Loads NFC; maintenance and updating of critical loads dataset and website; provision of critical load and dynamic model data to UNECE Coordination Centre for Effects.
Scenario analysis: Provision of critical load and dynamic model scenario assessments to Defra on request
Contribution to international activities: Chairing of UNECE Joint Expert Group on Dynamic Modelling; UK NFC for ICP-IM programme.

Summary of Progress

8. Please summarise, in layperson's terms, scientific progress since the last report/start of the project and how this relates to the objectives. Please provide information on actual results where possible rather than merely a description of activities.

The following summary and listed progress in relation to milestones cover the period since the half-year report was submitted in Feb 2006. The appended report covers the full one-year reporting period.

WP1. Dynamic Modelling of UK soils. MAGIC validation runs have been carried out for Forest Level II plots with long-term soil solution monitoring data, and show generally good agreement between modelled and observed recovery from acidification. MAGIC has also been applied to the Moorhouse ECN site, replicating climate-related seasalt variation and drought-induced sulphate flushes. This suggests that much of the apparent 'recovery' at this peatland site may in fact be climate-related. Model upscaling work has included the creation of a national input dataset in Access, based on the critical loads input dataset, from which the updated Very Simple Dynamic (VSD) model can now be applied. Trial regional model runs have been undertaken for a 100 km^2 area of NE Wales, and outputs compared to MAGIC-calibrated simulations from Ruabon experimental site, located within the square. Further testing is ongoing.The MAGIC model itself has now been substantially upgraded for the project, to include new N dynamics, and the capacity to run large (i.e. national-scale) batch runs.

WP2. Dynamic Modelling of UK freshwaters. A major MAGIC recalibration of all existing regions was undertaken for the Feb 2005 CCE data submission during the last reporting period. A manuscript comparing UK and Scandinavian modelling results is in preparation. Data for the new North York Moors region have also been collated prior to MAGIC application. MAGIC has been recalibrated to three Scottish AWMN catchments for model validation, using an improved 2-box model formulation (a manuscript has been submitted on this work). N uptake has been included in the model, and a new set of carbon pool estimates English and Welsh catchments has been derived from National Soils Research Institute data. Some concerns have been identified with individual soil types and these are being addressed; for now, existing C pool estimates will be retained.

WP3. Coordination of critical load activities. No updates have been made to the national steady-state critical loads database. The NFC maintains a watching brief on developments in critical loads research. National databases of the areas of designated sites, including RAMSARs, are in the process of being updated for use under WP5.

WP4. National Focal Centre for Critical Loads and Dynamic Modelling. It has not been necessary to submit any data to the CCE in the last year. The current national data are being used for the development and testing of national-scale dynamic modelling for terrestrial habitats. The NFC web site is being maintained and there are plans for its further development. The NFC represented the interests of the project and Defra at the Task Force meeting of the UNECE ICP on Mapping and Modelling.

WP5. Scenario analysis and advice to Defra and devolved administrations. Critical load exceedance statistics (area, percentage, accumulated exceedance) by habitat and country have been generated using (a) deposition data for 2002-04; (b) time series data for 1970 and 2020; (c) scenarios for the RIA Marine Fuels Directive; (e) scenarios for Defra's Air Quality Strategy. For the latter exceedance of air quality objectives (gaseous concentrations) were also assessed.

WP6. Chairmanship of the UNECE Dynamic Modelling Expert Group. The final report of the 2006 Joint Expert Group, and the report of the workshop on nitrogen and biodiversity modelling, have been submitted to the WGE. A date has been set and initial invitations issued for the 2007 meeting in October.

WP7. National Focal Point for ICP-Integrated Monitoring. The project has contributed to ICP Integrated Monitoring through assessments of the impact of climate change on recovery from acidification, estimation of MAGIC-derived critical and target loads, and calculation of heavy metal budgets.

Amendments to project

9. Are the current scientific objectives appropriate for the remainder of the project?................ **YES** ☒ **NO** ☐

If **NO**, explain the reasons for any change giving the financial, staff and time implications.

Contractors cannot alter scientific objectives without the agreement of the Defra Project Manager.

Progress in relation to targets

10. (a) List the agreed milestones for the year/period under report as set out in the contract or any agreed contract variation.

It is the responsibility of the contractor to **check fully that all milestones have been met** and to provide a detailed explanation when they have not been achieved.

Milestone		Target date	Milestones met	
Number	Title		In full	On time
M1.2	Completion of dataset for new site-specific model applications	Oct 2005	✓*	✓
M1.3	Creation of database for national-scale modelling	Oct 2005	✓	✓
M1.4	Trial 'regional' soils model applications and testing	Mar 2006	✓	✓
M1.5	Model analysis of land-management impacts	Mar 2006	✓	✓
M2.3	New estimates for catchment C and N pools	Oct 2005	✓	✓

M2.4	Model validation runs for AWMN sites	Mar 2006	**	**
M2.5	Testing of biological predictions at AWMN sites	Mar 2006	**	**
M2.6	Initial MAGIC calibration to all regions	Mar 2006	✓	✓
M3.2	Updated SSSI, SAC, SPA data	May 2006	✓	✓
M4.2	Updates to UK dynamic modelling database	Jan 2006	✓	✓
D4.3	Respond to CCE call for data	Feb 2006	No response required	
D5.2	Critical load and dynamic model assessments	2005 on request	✓	✓
M6.2	Report on 5th JEG Meeting delivered at WGE	Aug 2005	✓	✓
M6.3	*6th JEG Meeting organised and held*	Oct 2005	✓	✓
D6.3	Draft report on 6th JEG Meeting completed	Nov 2005	✓	✓
D6.4	Final report on 6th JEG Meeting submitted to WGE	May 2006	✓	✓
D7.2	Final report on DM and climate interactions to WGE	Aug 2005	✓	✓
M7.4	Completion of database for 2004	Oct 2005	✓	✓
M7.5	Data transmission to EDC Helsinki	Nov 2005	✓	✓
M7.6	Attendance at ICP-IM Task Force	Apr 2006	✓	✓

(b) Do the remaining milestones look realistic? .... **YES** ☒ **NO** ☐
If you have answered **NO**, please provide an explanation.

Notes on milestones and deliverables above:

* Dataset will continue to be expanded as further data become available (e.g. Whim and Thursley experimental sites, where soil solution sampling began in 2005).

**Milestones partially met (see Annex), but completion delayed due to periods of parental leave by two members of the consortium. Remaining work for this element of the work programme will be completed by autumn 2006; no adjustments to the work programme are required.

Project costs and staffing input

11. In this reporting period what was:

approved project expenditure	£ 156257
actual project expenditure	£ 168943
approved staff input (days)	406
actual staff input (days)	419

Publications and other outputs

12. (a) Please give details of any outputs, e.g. published papers/presentations, meetings attended during this reporting period.

Reports produced during the reporting period (full year)

Rowe, E.C., Moldan, F., Emmett, B.A., Evans, C.D., and Hellsten, S. (2005). Model chains for assessing impacts of nitrogen on soils, waters and biodiversity: a review. Centre for Ecology and Hydrology/ASTA Programme report for the 6th meeting of the Joint Expert Group on Dynamic Modelling under the Working Group on Effects of the Convention on Transboundary Air Pollution. 63 pp.

Hall, J., Dore, A., Heywood, E., Broughton, R., Stedman, J., Smith, R.I. & O'Hanlon, S. (2006). Assessment of the environmental impacts associated with the UK Air Quality Strategy. Report to Defra 2006. 106pp.

Hall, J., Ullyett, J., Evans, C., Rowe, E., Aherne, J., Helliwell, R., Ferrier, R., Jenkins, A. and Hutchins, M. (2005). UK National Focal Centre report. In: Posch, M., Slootweg, J., Hettelingh, J-P. (eds.) European critical loads and dynamic modelling. CCE Status Report 2005. Netherlands Environmental Assessment Agency, Report 259101016/2005. Bilthoven, Netherlands. p158-160.

Joint Expert Group Meeting on Dynamic Modelling: Summary report on the sixth meeting prepared by the organisers. Report to the Working Group on Effects of the Convention on Transboundary Air Pollution.

Workshop on Nitrogen Processes and Dynamic Modelling. Summary report on the meeting prepared by the organisers. Report for the Joint Expert Group on Dynamic Modelling of the Working Group on Effects, Convention on Transboundary Air Pollution.

Hutchins, M. and Jenkins, A. Use of dynamic modelling forecasts of streamwater chemistry to derive future target loads for N and S in atmospheric deposition. Chapter 4, ICP-IM Annual Report, http://www.environment.fi/default.asp?contentid=17110&lan=en.

Papers accepted for publication during the reporting period

Hall, J., Ullyett, J., Wadsworth, R.A. & Reynolds, B. The applicability of national critical loads data in assessing designated sites. Water, Air and Soil Pollution: Focus.

Rowe, E.C., Evans, C.D., Emmett, B.A., Reynolds, B., Helliwell, R.C., Curtis, C.J., and Coull, M.C. Vegetation type affects the relationship between soil carbon to nitrogen ratio and nitrogen leaching. Water, Air and Soil Pollution.

Papers published during the reporting period

Evans, C.D. (2005) Modelling the effects of climate change on an acidic upland stream. Biogeochemistry, 74, 21-46

Evans, C.D., Caporn, S.J.M., Carroll, J.A, Pilkington, M.G. Wilson, D.B., Ray, N., Cresswell, N. (2006). Modelling nitrogen saturation and carbon accumulation in heathland soils under elevated nitrogen deposition. Environmental Pollution, 143, 468-478.

Evans, C.D., Cooper, D.M., Juggins, S., Jenkins, A., and Norris, D. (2006). A linked spatial and temporal model of the chemical and biological status of a large, acid-sensitive river network. Science of the Total Environment, 365, 167-185

Evans, C.D., Reynolds, B., Jenkins, A., Helliwell, R.C., Curtis, C.J., Goodale, C.L., Ferrier, R.C., Emmett, B.A., Pilkington, M.G., Caporn, S.J.M., Carroll, J.A., Norris, D., Davies, J., Coull, M.C. (2006) Evidence that soil carbon pool determines susceptibility of

semi-natural ecosystems to elevated nitrogen leaching. Ecosystems, 9, 453-462.

Wright, R.F., Aherne, J., Bishop, K., Camarero L., Cosby, B.J., Erlandsson, M., Evans C.D., Forsius, M., Hardekopf, D.W., Helliwell, R., Hruska, J., Jenkins, A., Kopáček, J., Moldan, F., Posch, M., and Rogora, M. F. (2006). Modelling the effect of climate change on recovery of acidified freshwaters: relative sensitivity of individual processes in the MAGIC model. Science of the Total Environment, 365, 154-166.

Meetings attended

Workshop of the Co-ordination Center for Effects, Bled

Task Force Meeting of the ICP on Mapping and Modelling, Bled

Joint Expert Group on Dynamic Modelling and workshop on nitrogen modelling, Brighton

Working Group on Effects, Geneva

Defra Ammonia Research Coordination meeting, IGER, Devon

Acid Rain 2005 Conference, Prague

Biogeomon Conference, Santa Cruz

Air Pollution Research in London (APRIL): October 2005 & January 2006

Posters and presentations

J. Aherne, R.C. Helliwell, A. Lilly, R.C. Ferrier, A. Jenkins. Dynamic modelling of the acidification process: the two soil-layer approach. Poster, Acid Rain Conference, Prague.

C.D. Evans, E.C. Rowe, C.J. Curtis, R. C. Helliwell, B. Reynolds, B.A. Emmett and M.C. Coull. Can organic soil C/N ratios be used to predict inorganic nitrogen leaching in acidification models? Presentation, Acid Rain Conference, Prague.

C.D. Evans, B. Reynolds, O. Kaste, R. Wright, F. Moldan. The potential influence of changing climatic extremes on acidic episodes and recovery from acidification. Poster, Acid Rain Conference, Prague.

C.D. Evans. Report from the workshop on nitrogen processes and dynamic modelling. Presentation, CCE Workshop, Bled

C.D. Evans, D. Monteith, P. Chapman, J, Clark. Dissolved organic carbon, sulphur and nitrogen: Is everything connected to everything else? Presentation, Biogeomon Conference, Santa Cruz

J. Hall, J. Ullyett, R.A. Wadsworth, B. Reynolds. The applicability of national critical loads data in assessing designated sites. Presentation, Acid Rain Conference, Prague.

R.C. Helliwell, C.D. Evans, M.C Coull, A. Jenkins, R.C Ferrier, B. Reynolds, J. Davies, J. Aherne. Predicting the potential recovery from acidification in response to reduced nitrogen deposition across the UK: a new approach to model parameterisation. Poster, Acid Rain Conference, Prague.

F. Moldan, J. Aherne, C. Evans, R. Helliwell, V. Kronaas, T. Larssen, M. Posch. Target load functions and scenario analysis for recovery of acidified surface waters in Europe.

Poster, Acid Rain Conference, Prague.

R.F. Wright, J. Aherne, K. Bishop, L. Camarero, B.J. Cosby, C.D. Evans, D. Hardekopf R. Helliwell, J. Hruska, A. Jenkins, F. Moldan, M. Posch, M. Rogora. Modelling the effect of climate change on recovery of acidified freshwaters: relative sensitivity of individual processes in the MAGIC and SMART models. Poster, Acid Rain Conference, Prague.

(b) Have opportunities for exploiting Intellectual Property arising out of this work been identified? .... YES ☐ NO ☒
If **YES**, please give details.

(c) Has any other action been taken to initiate Knowledge Transfer? .... YES ☐ NO ☒
If **YES**, please give details.

Future work

13. Please comment briefly on any new scientific opportunities which may arise from the project.

Some future priorities for work in this area are considered to be:

1. Development of a model framework linking models of nitrogen, carbon, acidity, plant growth and biodiversity change.
2. Improved representation of key feedbacks and interactions within the MAGIC model, such as feedbacks between DOC and acidity, between N immobilisation and organic matter accumulation, and the role of sulphate release from wetlands as a climate-dependent delay to recovery in peats
3. Development of a spatially distributed version of MAGIC, in order to predict specific areas of vulnerability to N-induced biodiversity change within the landscape, e.g. within designated sites
4. Generation of biodiversity-based critical loads for nitrogen
5. Prediction of the impacts of climate change on critical loads, and on modelled timescales of recovery from acidification and nitrogen saturation.
6. Large-scale model validation, e.g. against Countryside Survey data
7. Extension of MAGIC applications for surface waters to the full Freshwater Critical Load dataset
8. Development of a tool to predict long term changes in the chemical and biological status of unmodelled UK surface waters by 'matching' with modelled sites

Declaration

14. I declare that the information I have given is correct to the best of my knowledge and belief.

Name	Christopher Evans	Date	19 July 2006
Position held	CEH Project Manager		

The Centre for Ecology and Hydrology is the UK's Centre of Excellence for research in the land-based and freshwater environmental science.

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