CENTRE FOR ECOLOGY & HYDROLOGY
(Natural Environment Research Council)
Project Number C03425
NERC-DEFRA Terrestrial Umbrella – Contract Number AQ0802

Terrestrial Umbrella – Effects of Eutrophication and Acidification on Terrestrial Ecosystems

Annual Report

2009

by
UKREATE

.

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Cite publication as: UKREATE (2009) Terrestrial Umbrella: Effects of Eutrophication and Acidification on Terrestrial Ecosystems for general citations, or Author of chapter (2009) then Title of Chapter. In: UKREATE (2009) Terrestrial Umbrella: Effects of Eutrophication and Acidification on Terrestrial Ecosystems. CEH Contract Report C03425. Defra Contract No. AQ0802.

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Executive Summary

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The Terrestrial Umbrella seeks to provide scientific evidence and support for a series of policy questions regarding recovery from acidification and eutrophication in terrestrial ecosystems. Within the project we have derived specific objectives and deliverables for each policy questions. These are:

Policy question

1. **What is the evidence for the success of policies to reduce emissions of N and S in reducing eutrophication and acidification of terrestrial systems?**

TU objective (WP1): Collate evidence of damage and recovery in the terrestrial systems (soils and vegetation) through data archaeology, re-sampling and analysis of large-scale national or habitat specific surveys

Policy question

2. **Are all forms of atmospheric reactive nitrogen equally damaging to semi-natural habitats and what determines sensitivity to nitrogen?**

TU objective (WP2): Quantify differences between NHy and NOy and dry versus wet deposition impacts through a combination of manipulation experiments and analysis of monitoring data described in WP1

Policy question

3. **What are the most ecological relevant indicators of sensitivity and change**

TU objective (WP3): Analysis of experimental results in combination with spatial surveys to identify most sensitive and ecologically relevant indicators in different habitats and test their robustness.

Policy question

4. **What determines the fate of nitrogen in soils, its short-term and long-term mobilisation, and thus changes in plant species composition?**

TU objective (WP3): Investigate the sensitivity of different soils to N enrichment, and the underlying controls, using a combination of field and experimental studies.

Policy question

5. **What is the likely timing of change in soil chemistry and biodiversity in response to a reduction in N emissions?**

TU objective: Continue to develop ecosystem model chains which link soil biogeochemical models and plant succession and species models.

Policy question

6. **What is the empirical evidence for N impacts and recovery and can models simulate these changes?**

TU objective: Collate data required for testing of linked soil-vegetation model chains involving provision of long-term data from manipulation sites in particular time series data for recovery following cessation of treatments and interaction with management treatments.

Policy question

7. **How will climate change influence the effects of N deposition in terrestrial ecosystems and what are the implications for critical loads?**

TU objective: Investigate the role of climate on N cycling and indicators of N enrichment using two climate change experiments and examine the implications for critical loads using a case study.

Policy issue

8. **Knowledge transfer and Project Management**

TU objective: Support to UK National Focal Centre, response to ad hoc queries from Defra and other agencies, project management including web site, organisation of CAPER conference.

Summary of progress to date is as follows:

There is a large range of activities within this project many of which include data collection, synthesis and modelling. This report describes progress to date after Year 2. Some highlights which have emerged are presented here:

<u>Evidence of change from survey and monitoring</u>

Building on the results of the year 1 survey work, the Scottish datasets for analysis of N deposition impacts have been extended in the last year to include further coverage of alpine and upland *Calluna* heaths. A database of driving variables has been assembled and completed in the last year. This includes information on climatic variables (temperature and rainfall from met office), N deposition (total, reduced, oxidised from CEH) and grazing impacts (domestic herbivore density from EDINA Ag census data and deer density from Macaulay datasets). The next phase of analysis will use these datasets to investigate relationships between drivers and vegetation changes. Continuing analysis of the GB integrated monitoring scheme Countryside Survey, focussed on producing evidence of change in indicators required by the Defra Review of Transboundary Air Pollution (RoTAP) reporting process. Spatial correlations between indicators and total nitrogen deposition were analysed simultaneously with changes in time so that relationships already in place at the time of the earliest survey could be identified. Analyses were carried out by habitat types with differing empirical Critical Loads for N. Anlayses also included data on other possible drivers. This resulted in conservative tests aimed at detecting the unique signal of nitrogen deposition. Results showed that whilst consistent spatial correlations were present throughout the 1978 to 2007 survey data, relationships between cover-weighted Specific Leaf Area and unweighted mean Ellenberg N were already present in 1978 and had not weakened or strengthened in the subsequent 29 years. The same applied to reductions in species richness, forb and bryophyte cover at higher nitrogen deposition in heaths and bogs. Despite these vegetation-type and indicator-specific signs of the historical influence of nitrogen deposition, temporal signals of ongoing change were also seen including reductions in bryophyte cover in semi-natural grasslands and broadleaved woodland, and species richness reduction insemi-natural grassland. Further work is planned by March 2010 to complete estimation of effect sizes and identifying interactions between nitrogen deposition and other drivers. Both sets of results from the Scottish moorland surveys and from Countryside Survey were included in the first draft now of the RoTAP report now out for consultation.

Evidence from experimental approaches

The free air ammonia release experiment (FACE) continues to demonstrate the greater potential for damage to ecosystem biodiversity and service provision when a unit of N is deposited as gaseous ammonia rather than in wet deposition. The scale of the damage continues to increase with the accumulated N dose. The loss of *Calluna* and many lower plant species, together with the increase in *Eriophorum vaginatum* (Cotton grass) and nitrogen tolerant mosses resemble the changes that prevailed in Netherland bogs in the 80s/90s. While *Calluna* appears to be highly sensitive to ammonia other ericoids have a higher tolerance *e.g. Vaccinium myrtillus* (Bilberry)which continues to expand, while after 7 years *Erica tetralix* (Cross leaved heath) has moved from expansion to decline. Adverse effects are now, 5-7 years on, well established with wet deposition, although cover changes are relatively small. Losses of sensitive lichens and mosses have now been quantified when ammonium and nitrate are added in rainfall. Generally the liverwort component seems to be the most tolerant of the lower plants with the reindeer (*Cladonia)* lichens being the most sensitive. Theses cover changes suggest that N deposition is inducing change in species cover and persistence through a combination of eutrophication, changes in competition for resources between species and direct toxicity. This combination of N induced drivers of change may explain why the form of N in wet deposition may be of less importance than the N dose.

A preliminary synthesis of results from the FACE and other long term N addition experiments and N gradient studies show that, although the responses to the manipulations are highly varied, some consistent patterns emerge. Of the biogeochemical changes in the vegetation, **foliar %N** generally responded positively and rapidly to the N treatments (within 2 years) especially within mosses. In the heath and moorland surveys foliar %N was also correlated with the level of N deposition. However, in the grasslands experiments there were typically only modest or no significant responses in tissue N content, a feature consistent with a recent UK grassland survey. Experiments that have examined the impact of wet vs dry and oxidised vs reduced N (Whim and Pwllpeiran) indicate these are also important factors in determining foliar N content.

Indicators of change due to atmospheric deposition

Detailed growth measurements on *Sphagnum capillifolium, Hypnum jutlandicum* and *Pleurozium schreberi* indicate no correlation between N form and N effects on growth despite the significantly greater uptake of reduced N at N doses >24 kg N $ha^{-1}y^{-1}$ in these moss species. Species loss among the lower plants appears to be driven by the accumulated N dose, regardless of N form. The foliar N concentration was found to be sensitive to the density (mass) of the moss, especially in hummock forming *Sphagnum*, and the ability of N to modify moss morphology appears to exacerbate this effect. If the N deposition treatment was reduced (as seen in Ruabon, also NITREX forest experiments) foliar N also fell quickly. Foliar N may thus be a reasonable indicator of current levels of N deposition, rather than long-term ecosystem N enrichment. The foliar ratio of **N:P** tended to increase with N treatment but across some survey work (lowland heath survey and Countryside Survey) this ratio did not change. A number of other foliar measures have been investigated at some sites but require wider testing to assess their broad value as bioindicators. Some exciting research on moss physiology developed at Wardlow and examined also at Ruabon and Budworth suggests that moss phosphatase (PME) activity and certain other physiological measures may be good indicators. Not enough data exist yet to assess the value of **lichen physiology**, **amino acids**, or **metabolomics** as indicators. Biogeochemical indicators may be used to indicate the level of nitrogen deposition to an ecosystem. At some point the indicator may also show ecosystem level responses and ecologically relevant change. Our research shows that across a wide range of N addition experiments a broad level of consistency emerges in indicator responses. However, the best potential indicators show subtle but important differences between ecosystems and the best approach is likely to make use of a small suite of techniques to indicate both the level of deposition and ecological change due to nitrogen pollution.

Development of a synthesis and theoretical framework for effects of N deposition

Ecological responses observed in the long term N addition experiments are diverse and wide ranging and work is nearing completion to synthesise these in a theoretical framework. Recent advances include the emergence of critical interactions of long-term N deposition impacts with heathland management burn or cutting. Recent data suggests that predictions of increasing frequency of summer fire events may have less impact on accumulated soil N stores than expected, and that the floristic and functional recovery of burnt ecosystems will be substantially affected by ongoing atmospheric N inputs. Further evidence also shows that N deposition can hinder recovery from managed cutting suggesting N affected heathlands require more frequent management to counter the ‘ageing’ effect (acceleration towards degenerate phase heather) of the N supply. In grassland experiments that now have cessation of treatments in some plots (to assess recovery), the absence of floristic recovery highlights the inertia of floristic damage in N polluted grasslands and suggests such damage may be long lasting well after reductions in atmospheric deposition rates. At the Forest sites, national chemical trends are indicative of recovery from sulphur deposition and acidification. The recovery is confirmed by pH increase and sulphate, aluminium and manganese decrease in the soil solution at most sites. Significant soil solution NO_3 reduction for the last 12 years under Scots pine forest, in highly N polluted areas corresponds to notable increases in biodiversity of the ground flora and a significantly decrease of Ellenberg N score.

Impacts of nitrogen on soils and water quality

A model - $N^{14}C$ - has been developed that links the plant-soil cycles of nitrogen and carbon thus providing a tool for understanding spatial and temporal patterns in soil and water quality and associated changes in plant diversity and to enable future predictions . The model is simple enough to be parameterised and tested with data that are mostly available from the Terrestrial Umbrella and Countryside Survey (CS) studies, but key additional data in the form of radiocarbon measurements of selected CS soil samples have been added, in order to constrain soil C cycling. $N^{14}C$ has been approximately parameterised for four plant types, coniferous and deciduous trees, shrubs, and grasses. A key attribute of $N^{14}C$ is its description of soil organic matter pools, turning over at different rates. The model accounts reasonably well for observed soil CN ratios and inorganic N leaching. Notably it explains why coniferous forest soils are the most susceptible to nitrate leaching.

Predicting future changes in plant diversity

Modelling approaches to predict the effects of nitrogen pollution on plant diversity is being developed by linking soil models with habitat suitability models for > 1000 GB plant species. This model chain is called MAGIC-GBMOVE. Previous forecasts using were reasonably accurate when compared to long-term species observations, at least for stable vegetation types. This work package (WP5) aims to improve the accuracy of predictions of species change in response to interacting drivers, and increase the scope of the model chain to cover vegetation succession as this drives much 'natural' change in species change irrespective of air pollution. One example of a new development is that shows promise is the incorporation of climate variables into the GBMOVE model so climate change and its interactions with air pollution impacts can be tested. A method of summarising model outputs (i.e. habitat suitability for all modelled species) into an overall measure of habitat quality based on positive and negative indicator species was also developed. This was presented at the 19th CCE Workshop in Stockholm, May 2009. Further investigations of biodiversity-based measures of habitat quality and damage were requested, and a chapter describing the method has been contributed to the CCE Status Report 2009.

Update of Management activities

The 2009 annual project meeting was held at Manchester Metropolitan University and small workshops for specific issues have been organised to ensure good communication between the project partners. An annual meeting organised by the Committee on Air Pollution Effects Research (CAPER) conference was successfully held at Chancellors (University of Manchester conference facility). Again > 50 scientists and students gathered to discuss the latest research findings on heavy metals, ozone and N. The Ruabon N manipulation site, celebrating 20 years of research, provided a fascinating field visit

The website has been updated and has facility to request data from our database. A more full report is available of the findings to date from the website (UKREATE (2009) Terrestrial Umbrella: Effects of Eutrophication and Acidification on Terrestrial Ecosystems. CEH Contract Report C03425. Defra Contract No. AQ0802.). This project was subjected to a full Defra JCOP audit in 2009 and was passed as complying with all major requirements.

There is a large range of activities within this project many of which include data collection, synthesis and modelling. This report describes progress to date after Year 2 by individual work package.

Work Package 1:
Collate evidence of damage and recovery in the terrestrial systems (soils and vegetation) through data archaeology, re-sampling and analysis of national surveys or data-rich regions

Task Leader: Simon Smart

Centre for Ecology and Hydrology Lancaster

PIs: Simon Smart[1], Lindsay Maskell[1], Andy Scott[1], Andrea Britton[2], Alison Hester[2], Brian Reynolds[3]

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1. Work Package 1

Task Leader: Simon Smart (CEH Lancaster)
PIs: Simon Smart (CEH Lancaster), Andrea Britton and Alison Hester (Macaulay), Brian Reynolds (CEH Bangor)
PIs: Andrea Britton (Macaulay), Brian Reynolds (CEH Bangor)

> **Policy question:** What is the evidence for the success of policies to reduce emissions of N and S in reducing eutrophication and acidification of terrestrial systems?
>
> **Main activity:**
> Collate evidence of damage and recovery in the terrestrial systems (soils and vegetation) through data archaeology, re-sampling and analysis of national surveys or data-rich regions.

Progress to date

Progress has been made on both tasks. Building on the results of the year 1 survey work, the Scottish datasets for analysis of N deposition impacts have been extended in the last year to include further coverage of alpine and upland *Calluna* heaths. A database of driving variables has been assembled and completed in the last year. This includes information on climatic variables (temperature and rainfall from met office), N deposition (total, reduced, oxidised from CEH) and grazing impacts (domestic herbivore density from EDINA Ag census data and deer density from Macaulay datasets). The next phase of analysis will use these datasets to investigate relationships between drivers and vegetation changes.

Further analyses of Countryside Survey data have focussed on producing evidence of change in indicators required by the Report on Transboundary Air Pollution (RoTAP). Spatial correlations between indicators and total nitrogen deposition were analysed simultaneously with changes in time so that correlative patterns already in place at the time of the earliest survey could be identified. Analyses were carried out by habitat types with differing empirical Critical Loads for N. Analyses also included data on other possible drivers. This resulted in conservative tests aimed at detecting the unique signal of nitrogen deposition having factored out other effects. Results showed that, whilst consistent spatial correlations were present throughout the 1978 to 2007 time-series, relationships between cover-weighted Specific Leaf Area and unweighted mean Ellenberg N were already present in 1978 and had neither weakened nor strengthened in the subsequent 29 years. The same applied to reductions in species richness, forb and bryophyte cover at higher nitrogen deposition in heaths and bogs. Despite these vegetation-type and indicator-specific signs of the historical influence of nitrogen deposition, temporal signals of ongoing change were also seen including reductions in bryophyte cover in semi-natural grasslands and broadleaved woodland, and species richness reduction in semi-natural grassland. Further work is planned by March 2010 to complete estimation of effect sizes and identifying interactions between nitrogen deposition and other drivers.

The results from the Scottish moorland surveys and from Countryside Survey were included in the first RoTAP draft.

Task 1.1 – Analysis of spatial and temporal trends of vegetation change at GB scale

Objective

Estimate variation in spatial and temporal abundance in indicator species uniquely explained by drivers (1978-1998 + (2007 if dataset ready)).

Milestone - October 2009

Completed signal attribution for 1978-2007 including estimation of interactions.

Summary of progress to date

Rather than re-analyse individual species changes, effort was diverted into quantifying spatial and temporal relationships between nitrogen deposition and selected indicator variables in the presence of data on other co-varying drivers. Indicator selection was guided by the specification of requirements for the RoTAP drafting process. These analyses have been completed. Estimation of effects sizes, interactions and individual species analyses will be completed in the final phase of the project up to March 2010. Analyses of indicator variables completed in the last year are reported below.

Methods

All analyses of change in indicator variables over *time* were based on a test of the Yr*Total N interaction term having removed variability due to the main effect of year of survey and any covarying effect of change in SOy deposition between 1970 and 1995 (FRAME 5km^2), %cover of intensive agriculture in 1998 (from CS field survey of each 1 km^2), rainfall (long-term annual average, 1969-2000; UKCIP 5km^2). Analyses were also run including change in sheep numbers (1969-2000: AgCENSUS 2km^2) for a subset of plots in upland unenclosed land in Britain. Total N was based on 5km^2 averages of interpolated measured data for 2004-'06 provided by CEH Edinburgh in November 2008. Analyses were carried out by grouping plots based on the sample species composition into Empircal Critical Loads habitat types (see Smart et al 2004). These were heath & bog (hb), semi-natural grasslands (g) and broadleaved woodland (bw). Analysis of species richness excluded bryophytes and lichens. Plant growth forms were analysed as square-root transformed cover and data for bryophytes was centred by the within-year mean to account for potential between-survey differences in bryophyte recording. Bryophyte cover was not tested for the 1998 to 2007 interval because QA survey showed bryophyte records were of poorer quality in 2007. Analyses of the 1998 to 2007 data differed only insofar as a separate test of upland plots with change in sheep numbers present was not carried out because post-foot & mouth changes in density data are not yet available for all years. Also, SOy deposition change was for the period 1970 to 2005.

Mixed-model ANOVA (SAS proc mixed) was used in all analyses. For species richness data a Poisson error model that accounted for overdispersion was used (SAS proc glimmix).

Results

Key points - 78 to 98 changes

- Having analysed change with and without covariates it was apparent that the presence of additional explanatory variables made little difference to the detectability of the Total N signal. This suggests that the signal, whether present or not, was not being confounded with other variables that could have either a) driven observed changes based on some other ecologically plausible mechanism, or b) been intercorrelated simply because gradients of explanatory variables were not well crossed and replicated across GB. Hence all results above were based on analyses that fitted covariates alongside the Yr*Total N term because there was little difference between the two sets of results.

- The role of change in sheep numbers in upland Britain was also tested based on a subset of plots in unenclosed upland squares in the heath & bog and semi-natural grasslands habitat groups. The inclusion of this covariate made no difference to the tests of change in time and in no instance was the partial effect of sheep change significant. This does not rule out its possible importance in explaining spatial differences in vegetation variables or possibly being a significant variable in temporal tests if other intercorrelated variables were removed. This particularly applies to %cover of intensive agriculture in the CS squares, which was generally a highly significant term in explaining temporal and spatial variation in most variables in upland or combined upland and lowland tests. Therefore, to further examine grazing effects, analyses will be re-run excluding intensive land-cover as an explanatory variable.
- We took a unified approach to analysing change in time across 1978-'90-'98, simultaneously seeking correlation with spatial gradients of explanatory variables and testing for overall mean change in time irrespective of position on the Total N gradient. The results showed that across all habitat groups expected spatial correlations (tests of the main effect of Total N) were often found between Total N and vegetation variables (Table 2) and these were more common than significant changes in time that were correlated with position on the Total N gradient (tests of the interaction between Year and Total N) (Table 3).
- The only significant changes between 1978, 1990 and 1998 that were explained by Total N after fitting covariates, were reductions in bryophyte cover in grasslands and woodlands, reductions in species richness in grasslands and reductions in grass cover in woodlands (all greater reduction at higher Total N) (Table 3). No temporal correlations were seen in heath & bog. Note that the change reported in Smart et al (2004) was based on cover-weighted mean Ellenberg N just for the 1990 to 1998 period.

<u>Key points - 98 to 07 changes</u>

- A much larger dataset was available to test for correlations between change in vegetation variables between the two surveys and position on the estimated Total N deposition gradient (Table 1), but the interval was shorter and between just two surveys.
- Having accounted for other covariates, six temporal correlations were detected (Table 3). Four of these were in the semi-natural grasslands where grass cover, forb cover, species richness and cover-weighted SLA all tended to increase most at higher Total N. This is against a background negative spatial correlation between species richness and Total N in the two surveys, which is consistent with Maskell et al (2009) and Stevens et al (2004; 2006), as well as a background positive spatial correlation between cover-weighted SLA and Total N indicating that faster-growing species that can capitalise on higher nutrient availability tend to be more abundant where Total N was higher (Table 2).
- The only other temporal correlations seen in the '98 to '07 interval was a surprising positive correlation between change in Ericoid cover and Total N in heath & bog (Table 3).
- All these analyses will benefit from planned but currently not completed work looking at weather effects during and prior to each survey on the response variables.

Table 1. Numbers of samples available for analysis

1978-'90-'98	1998-'07	Heath & Bog	Grasslands	Broadleaved woodland
1978		282	296	66
1990		527	493	194
1998		584	604	218
	1998	2407	2265	812
	2007	2258	2064	787

Table 2. Spatial correlations – patterns in space. Summary of relationships between N deposition and ecological indicators in Countryside Survey. Arrows ↑↓ indicate direction of response detected; o indicates no response; 'nd' indicates analysis inappropriate.

Response variables	CS78-98 (grasslands)	CS78-98 (heath & bog)	CS78-98 (broadleaved woodland)	CS98-07 (grasslands)	CS98-07 (heath & bog)	CS98-07 (broadleaved woodland)
Species richness [1]	↓	↓	O	↓	↓	↓
Graminoid cover	↑	o	O	↑	↑	↓
Forb cover	o	↓	O	o	↑	↑
Ericoid cover	nd	o	Nd	nd	↑	nd
Bryophyte cover	o	↓	O	nd	nd	nd
Mean Ellenberg N	o	o	↑	↑	o	↑
Cover-weighted Specific Leaf Area	o	↑	O	↑	↑	o

[1] Maskell et al (2009) GCB

Table 3. Temporal correlations – changes in time. Summary of relationships between N deposition and ecological indicators in Countryside Survey. Arrows ↑↓ indicate direction of response detected; o indicates no response; 'nd' indicates analysis inappropriate.

Response variables	CS78-98 (grasslands)	CS78-98 (heath & bog)	CS78-98 (broadleaved woodland)	CS98-07 (grasslands)	CS98-07 (heath & bog)	CS98-07 (broadleaved woodland)
Species richness	↓	o	o	↑	O	o
Graminoid cover	o	o	↓	↑	O	o
Forb cover	o	o	o	↑	O	o
Ericoid cover	nd	o	nd	nd	↑	nd
Bryophyte cover	↓	o	↓	nd	nd	nd
Mean Ellenberg N	O[1]	O[1]	o	o	O	o
Cover-weighted Specific Leaf Area	o	o	o	o	O	o

[1] Change in cover-weighted Ellenberg N detected in Smart et al (2004)

References:

Maskell et al (in press) Nitrogen deposition causes widespread loss of species richness in British habitats. Global Change Biology.

Smart et al (2004) Detecting the signal of atmospheric N deposition in recent national-scale vegetation change across Britain. Water Air and Soil Pollution: Focus 4, 269-278.

Stevens et al (2004) Impact of nitrogen deposition on the species richness of grasslands. Science, 303, 1876-1879.

Stevens et al (2006) Loss of forb diversity in relation to nitrogen deposition in the UK: regional trends and potential controls. Global Change Biology 12, 1823-1833.

Task 1.2: Habitat specific trends: Changes in moorlands and wetlands in Scotland

Progress against Milestones:

Milestone 5: Task 1.2 Carry out moorland fieldwork, data input and analysis. October 2008 (12 Months).

Fieldwork and data entry for this milestone have been completed along with analysis of diversity and composition trends and spatial and temporal analysis in relation to N deposition. Multi-driver analysis remains to be done now that required driver information has been collated into a GIS. Further analysis is planned for autumn/winter 2009/10 aiming for first paper submission by end of 2009.

Milestone 6: Task 1.2 Carry out wetland fieldwork, data input and analysis. October 2009 (24 Months). Field survey work and data input have been completed and checked, along with chemical analysis of water, sediment and soil samples. Analysis of the data is planned for autumn 2009.

Progress to October 2009

Task 1.2 focuses on quantification of change in Scottish moorland and wetland systems and assessment of the role of different drivers, including land management, climate change and nitrogen deposition. This is being done through a targeted re-survey of sites for which archive vegetation description data (from 1960's and 1970's) are held. The first year of the project focussed on moorlands with 407 plots re-surveyed. This dataset has now been extended through addition of data from a PhD student working on a re-survey of Derek Ratcliffe's plots and from the survey of alpine heaths carried out under the previous Terrestrial Umbrella, improving coverage of the north-west of Scotland and of the upper altitudinal range of *Calluna* heaths respectively. The final dataset now comprises 525 plots with 292 species recorded.

While the main aim of this project is to determine the relative role of the three key drivers (climate, N deposition, land use) in driving vegetation change over the last 40 years, analyses of the new enlarged data set have so far focussed on quantifying and describing change in terms of diversity and composition, while a spatial database of driver information was being developed. This is now complete and includes information on climatic variables (temperature and rainfall from met office), N deposition (total, reduced, oxidised from CEH) and grazing impacts (domestic herbivore density from EDINA Ag census data and deer density from Macaulay datasets). The next phase of analysis will use these datasets to investigate relationships between drivers and vegetation changes.

Analyses to date have shown trends of increasing species richness but decreasing diversity across most heathland types, similar to those identified in alpine habitats (Britton *et al* 2009). Overall, a significant richness increase of 2.3 species per plot (P<0.001) was seen between 1970s and 2007 with the biggest increases in wet heath (3.0 species) and alpine heath (2.7 species). Blanket bog species richness changed least (+ 2.1 species). Changes in richness were primarily driven by bryophytes and, to a lesser extent, higher plants. Lichens had no significant change in richness overall, but increased in alpine heath. Within-plot diversity (Shannon index) showed a small but significant (-0.06; P<0.01) decline across all heathland types, this was mainly due to a highly significant decline in alpine heath diversity (-0.22; P<0.001) and small decline in blanket bog (-0.08; P<0.05) while other heath types remained unchanged. Cover changes were also analysed for the main species groups and heath type combinations (Table 4). Overall lower plants showed the greatest changes with a highly significant increase in moss cover and decline in lichen cover. Increases in moss cover were consistent across all heathland types with significant increases in dry heath and blanket bog. Lichen declines were equally consistent across heath types with the greatest change seen in alpine and dry heath where lichens were initially most abundant. For the higher plant groups a variety of trends were seen; herbs declined significantly in all heath types except moist and wet heath while dwarf shrub cover declined on all heaths except alpine heath where there was a strong, significant increase. Graminoid cover showed the biggest change of all the higher plant groups, increasing in all except moist heaths, but with the biggest increase in blanket bog. Investigation of cover and frequency changes for individual species revealed the two common mosses *Rhytidiadelphus squarrosus* and *Pleurozium schreberi* to have shown the biggest increases.

An analysis of N deposition effects on species richness and cover was carried out for the initial 407 plot dataset before expansion. This indicated that whilst there were few relationships between N deposition and cover changes, there were significant relationships between richness change of most plant groups and N deposition, although the amount of variability explained remained relatively low. Stronger relationships were found between the spatial pattern of richness and cover of groups in either the new or archive data and N deposition, with lichens being the groups most consistently negatively impacted by N deposition. These analyses will now be repeated using the new, expanded, dataset to see if trends and relationships are the same across a wider range of plots.

Fieldwork in 2008 and 2009 focussed on wetland habitats. Two distinct wetland types; upland springs (NVC M32, M33, M37) and lowland *Carex* dominated swamps (NVC S9-11, S19, S27 & S28) were targeted. In total, 122 plots were successfully re-located and re-recorded; 44 springs and 78 swamps. Sediment, water and plant samples (*Philonotis fontana* in springs, *Menyanthes trifoliata* and *Carex rostrata* in swamps) were collected from the majority of sites and have been analysed for a suite of determinants including C, N and P content. This data will allow an analysis of the degree to which nutrient enrichment of the habitat reflects atmospheric deposition vs. local nutrient inputs.

Publications & Talks:

Britton, A.J., Beale, C.M., Towers, W. & Hewison, R.L. (2009) Biodiversity gains and losses: evidence for homogenization of Scottish alpine vegetation. Biological Conservation 142, 1728-1739.

Hester A.J., Britton, A.J. (2008) A snapshot in time: 40 years of change in some upland plant communities. Talk to Aboyne Garden Club October 2008.

Table 4. Cover change for all species groups by habitat. Significance of change from t-test.

Species group	**All plots**	**Alpine heath**	**Blanket bog**	**Dry heath**	**Moist heath**	**Wet heath**
	n = 525	*n* = 119	*n* = 115	*n* = 194	*n* = 41	*n* = 48
All highers	+0.06 ns	+7.14 ***	-0.46 ns	-2.83 *	-5.43 *	+1.69 ns
Trees & shrubs	+0.23 *	+1.12 **	+0.01 ns	-0.14 ns	+0.11 *	+0.19 ns
Dwarf shrubs	-1.25 ns	+5.71 **	-3.04 *	-3.36 *	-1.16 ns	-5.31 *
Graminoids	+2.39 ***	+1.41 ns	+3.83 **	+2.50 **	-4.33 ns	+7.69 ***
Herbs	-1.28 ***	-1.09 ***	-1.23 **	-1.78 ***	+0.04 ns	-0.92 ns
Pteridophytes	-0.03 ns	-0.01 ns	-0.04 ns	-0.05 ns	-0.09 ns	+0.03 ns

All bryophytes	+3.29 ***	+1.71 ns	+1.88 ns	+4.93 ***	+5.91 *	+0.37 ns
Mosses	+3.85 ***	+1.95 ns	+3.77 *	+5.06 ***	+4.34 ns	+1.98 ns
Liverworts	-0.57 **	-0.24 ns	-1.90 ***	-0.13 ns	+1.57 ns	-1.61 *
Lichens	-3.21 ***	-8.31 ***	-1.37 *	-2.05 ***	-0.43 ns	-2.36 ns

Task 1.3

This task was abandoned after year one with agreement of the Defra Project Manager and remaining resources channeled into WP3 field survey

Work Package 2:
Quantify differences between NHy and NOy and dry versus wet deposition impacts through a combination of manipulation experiments and linkage to analysis of monitoring data described in WP1

Task Leader: Lucy Sheppard
Centre for Ecology and Hydrology Edinburgh

PIs: Lucy Sheppard[1], Ian Leith[1], Sanna Kivimaki[1], Owen Davies[2], Bridget Emmett[3] Mike Pilkington[3] , Simon Smart[4], and T. Mizunuma[1]
[1]Centre for Ecology and Hydrology Edinburgh, [2]ADAS Pwllpeiran, [3]Centre for Ecology and Hydrology Bangor, [4]Centre for Ecology and Hydrology Lancaster, M

2. Work Package 2

Task Leader: Lucy Sheppard (CEH Edinburgh)
PIs: Ian Leith (CEH Edinburgh), Owen Davies (ADAS) and Simon Smart, Bridget Emmett (CEH Bangor), and Simon Smart ((CEH Lancaster)

> **Policy question:**
> Are all forms of atmospheric reactive nitrogen equally damaging to semi-natural habitats and what determines sensitivity to nitrogen?
> Is some N more 'damaging' and what determines sensitivity?
>
> **Main activity:**
> Quantify differences between NHy and NOy and dry versus wet deposition impacts through a combination of manipulation experiments and linkage to analysis of monitoring data described in WP1

Task 2.1 – Differential effects of reduced versus oxidised and wet versus dry N in wetlands.

PIs: Lucy Sheppard, Ian Leith (CEH Edinburgh) + students: S. Kivimaki Mizunuma T.

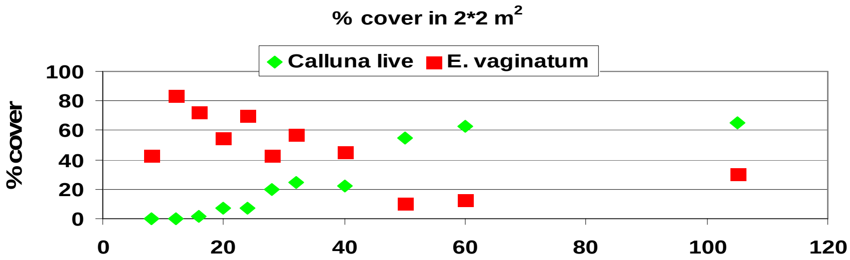
Overall deliverable*:*
Assessment of the relative importance of reduced versus oxidised N (peer reviewed paper on indirect versus direct effects of N deposition by form) and evaluation of long-term ammonia exposure on the CLE_{NH3}.
Milestones to date: Task 2.1 Oct. 2009
Submission of paper, maintain wet and dry treatment regime and soil and vegetation chemistry evaluations and re-evaluation of long-term species response to ammonia. Completion of vegetation surveying, sampling and soil, soil water sampling.
Delivery to date: Paper submission still delayed. Treatments maintained, soil and plant cover measurements completed and chemical and statistical analysis underway, for completion by end of contract. Evidence of N form effects provided to ROTAP and COST Natura 2000 meeting.

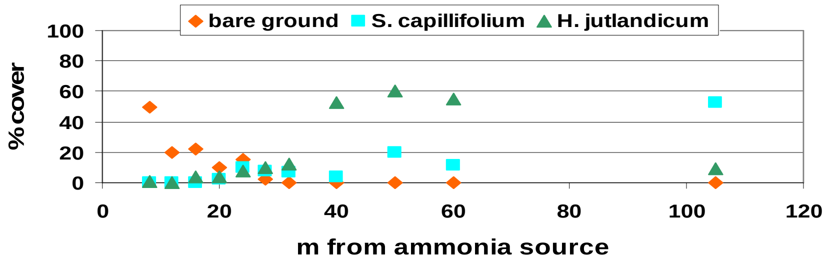
Progress to date
Nitrogen additions as ammonia, ammonium and nitrate have provided 'real world' N deposition to a peatland ecosystem since 2002. Along the free air ammonia release transect, which provides an exponential concentration gradient, the distance over which detrimental effects are observed continues to expand. *Eriophorum* spp have flourished, *Vaccinium myrtillus* has increased and significant amounts of bare peat have been exposed. Species hitherto showing a degree of tolerance to ammonia, *Erica tetralix* and *Hypnum jutlandicum* are now declining. The changes resemble those seen in rural Netherlands since the 80's where ammonia concentrations were high. The loss and breakdown of vegetation has removed a physical barrier, subjecting peat to increased wind speeds, drying out and the potential for oxidation. Measurements are underway (Phd student Magnus Kelly) to evaluate effects on soil C. Visible effects of ammonium and nitrate, providing equivalent N deposition in rain water (wet deposition), are only apparent in small areas, ie not on the scale seen along the ammonia transect. However, detailed measurements on permanent quadrats are starting to reveal loss of lower plant cover and biodiversity in response to wet deposited N. Detailed growth measurements on the most abundant mosses, *Sphagnum capillifolium, Hypnum jutlandicum* and *Pleurozium schreberi* indicate negative effects of wet N above 20 kg N ha^{-1}

y^{-1}, although despite significant differences between the forms in N uptake the effects of the form of N on growth are mostly non significant.

1. Species cover assessments undertaken in 2009 have revealed a significant decline in lower plant species in response to ammonia. Losses of Cladonia are no longer confined to *C. portentosa*, the limited occurrences of *C. arbuscular* and *C. rangiferina* have now disappeared. The ericoid *Erica tetralix* appears damaged and is now in decline near the ammonia source, whereas *Empetrum nigrum* and *Vaccinium myrtillus* are increasing, together with *Eriophorum vaginatum* which now dominates near the ammonia source.
2. Ammonia driven species loss has not translated into loss of species diversity as sensitive species have been replaced by more N tolerant species with the effect of ammonia acting partly through changes in competitive advantage. The invading higher plant species reflect the surrounding species pool and the presence of facilitators *e.g.* rabbits. The new mosses are from those species that colonise bare peat eg. *Campylopus* and *Dicranella spp.*.
3. Moss growth data all show significant negative effects of increasing N dose, reductions ranging from 30 to 70% for productivity in *S. capillifolium*. No significant growth differences between reduced or oxidized N were found, (p values ranged between 0.1 and 0.2). The absence of significant form effects on moss growth contrasted the differences in tissue N concentrations in response to N form that were significant at the high N dose.
4. N sensitive species show a greater tolerance to N in wet than dry deposition (ammonia). Thus the cumulative N dose threshold is greater when the N is supplied in wet deposition.
5. Detrimental effects of wet deposition have taken > 5 years to show.
6. Results suggest at least among the lower plants the form of N in wet deposition is less important than the cumulative N dose.
7. Soil C, N and CN measurements indicate increases in both C and N but with no clear dose or form effects, although there was a significant form by dose interaction with significant increases in % C at the highest oxidized N dose. The CN ratio has fallen from 41 to 35 in response to N addition. Acetic acid extractable P was not affected by N additions whereas the stronger sulphuric acid (Truog reagent) extractant showed a 200% reduction in available P at the highest N dose indicating depletion of the available P.

Fig. Changes in the cover of Calluna and E.vaginatum mosses and bare ground along the ammonia release transect after 7 years of treatment.





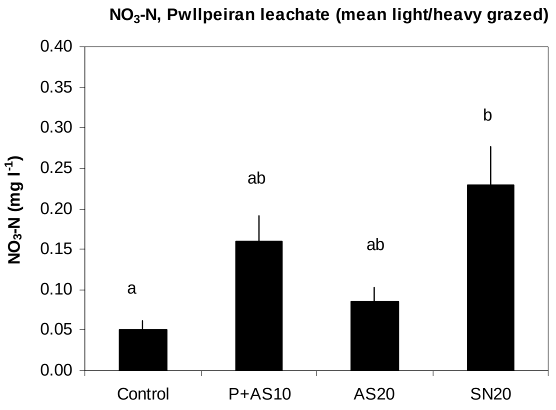
Task 2.2 Differential effects of reduced versus oxidised N in acid grasslands and the modifying effects of management, grazing.

PI: Bridget Emmett (CEH Bangor), Owen Davies (ADAS), Mike Pilkington +?.

Overall deliverable:
Comparison of feedbacks from oxidised versus reduced N mediated changes in soil chemistry on species composition change in acid grassland.
Milestone: Task 2.2 Oct. 2009
Continuation of N applications and repair and testing of soil water sampling equipment Completion of soil water analysis
Delivery to date: N applications have been maintained and soil water (sw) samplers repaired and 1 year of data collected and chemical analysis undertaken. Results are presented below. A repeat botanical survey has also been carried out. Results from soil water samplers have been analysed and are presented below. All data has been delivered to the UKREATE database and results included in the TU analysis of experiments and survey for the RoTAP draft report. Two papers are in preparation from this 10 year experimental study summarizing results to date.

- Sodium nitrate additions at 20 kg N ha^{-1} yr^{-1} significantly ($P < 0.05$) increased leachate nitrate concentrations based on the grazing regime average.
- The equivalent effect of ammonium sulphate additions (at 20 kg ha^{-1} yr^{-1}) did not significantly raise ammonium concentrations in the leachate, although they did increase.
- As an average of both grazing regimes, the concentration of total N (total inorganic N (NH_4-N + NO_3-N) + organic N) was increased approximately equally by both oxidised and reduced forms of N addition ($P < 0.05$ in each case).
- Overall grazing reduced total N concentrations in soil leachate ($P < 0.05$) although this effect was not significant at any specific N treatment.

Other effects to date
- Ammonium sulphate additions significantly raised concentrations of sulphate in leachate and sodium nitrate additions significantly raised concentrations of sodium in leachate.
- pH was raised in response to sodium nitrate and lowered by ammonium sulphate additions.
- Grazing significantly reduced concentrations of both potassium and calcium in leachate.



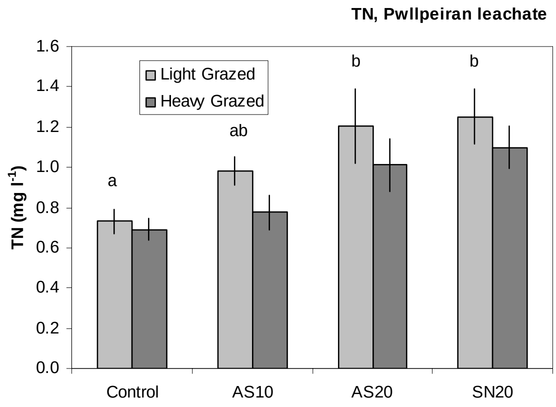


Fig 1. Most recent effect of N additions on nitrate concentrations (average of two grazing regimes) in leachate at Pwllpeiran and effects of grazing on total N (DON + NH_4-N + NO_3-NN. **Key to N additions** Control = no N additions, P+AS10 = ammonium sulphate additions at 10 kg N ha^{-1} yr^{-1} plus single addition of phosphate at 20 kg P ha^{-1} yr^{-1} applied in June, 2000,AS20 = ammonium sulphate additions at 20 kg N ha^{-1} yr^{-1} **,** SN20 = sodium nitrate additions at 20 kg N ha^{-1} yr^{-1}

Task 2.3 Analysis of CS data – by habitat and functional type. PI: Simon Smart (CEH Lancaster)

Overall deliverable*:*
Assessment of the relative importance of N form and other key drivers in reported change in vegetation, plant trait groups and soil parameters at the GB scale.

Milestone: Task 2.3 Oct. 2009
Derivation, where possible, of trait profiles uniquely associated with the impacts of N form, grazing pressure and climate change.

Delivery to date: Progress has continued to be delayed by the demands of Countryside Survey in the past year, in particular the production of the country-level summary reports. The trait database has now been completed and all analyses will be completed by the end of the project. Major new analyses were undertaken to further explore the relative importance of oxidized versus reduced nitrogen. These have thrown up important questions that need further work before they can be presented.

Work Package 3:
Analysis of experimental results in combination with spatial surveys to identify the most sensitive indicators for both N deposition and N enrichment

Task Leaders: Simon Caporn and Nancy Dise
Manchester Metropolitan University

PIs: Bridget Emmett[1], Gareth Phoenix[2], Jonathan Leake[2], Sally Power[3], Lucy Sheppard[5], Ian Leith[5], Andrea Britton[6] and Rachel Helliwell[6]
[1]Centre for Ecology and Hydrology Bangor, [2]University of Sheffield, [3]Imperial College London, [4]Manchester Metropolitan University, [5]Centre for Ecology and Hydrology Edinburgh, [6]MLURI.

Work Package 3

Task Leaders: Simon Caporn and Nancy Dise (MMU)
PIs: Bridget Emmett (CEH), Gareth Phoenix (Sheffield), Jonathan Leake (Sheffield) Sally Power (Imperial), Jacky Carroll (MMU), Lucy Sheppard (CEH), Ian Leith (CEH), Andrea Britton (Macaulay), Rachel Helliwell (Macaulay).

> **Policy question:** What are the most ecologically-relevant indicators of sensitivity to nitrogen (N) deposition and of ecosystem change due to N saturation?
>
> **Main activity**: Analysis of experimental results in combination with spatial surveys to identify the most sensitive indicators for both N deposition and N enrichment.

Task 3: Indicators of nitrogen deposition and ecosystem change due to nitrogen saturation

Milestones to date:
Data synthesis from UKREATE manipulation sites.(12 months)
Regional survey: laboratory analyses and data synthesis (24 months)

Delivery to date: A preliminary analysis has been carried out and contributed to the ROTAP vegetation chapter meeting (23.10.08) and drafts of the ROTAP report (Spring 2009). We expect the full dataset analysis to be completed by end of 2009 along with a draft of the paper synthesising indicators from the UKREATE experiments and surveys. The field survey is now complete and analysis of data underway. A 6 month extension for submission for this Task was agreed with last Defra Project Manager

Methods and Results:

Data synthesis: In year 1 we collated from our partners data on ecosystem change in response to the nine nitrogen manipulation experiments in the UKREATE network. The sites are: moorland (Ruabon), lowland heath (Thursley and Budworth representing warmer, drier and cooler, moist types respectively), montane heath (Culardoch), bog (Whim), acid grassland (Pwllperian, Wardlow) calcareous grassland (Wardlow), sand dune (Newborough). These were augmented with data from completed surveys of lowland heath, moorland, dune slacks and forests. Results were classified into:

Vegetation chemical changes; Litter chemical changes; Soil chemical changes; Soil process changes.

A summary of highlights of the data synthesis is given below.

Vegetation change
Foliar %N generally responded positively and rapidly to the N treatments (within 2 years) especially within mosses; in heath & moorland surveys correlated with N deposition, but not in grassland surveys. The form of N deposition can influence % foliar N. Foliar N may thus be a reasonable indicator of current levels of N deposition, rather than long-term ecosystem N enrichment. The foliar ratio of **N:P** tended to increase with N treatment but across some survey work (lowland heath survey and Countryside Survey) this ratio did not change.

Physiological markers in moss - leaf phosphatase (PME) activity and certain other physiological measures may be good indicators of increased N supply, but need wider testing.

Litter

In some ecosystems the changes in foliar N were reflected in increased **litter %N**. Extracellular enzymes such as **phosphatase** (PME) were generally highly active in the litter layer and surface soils and at some of the sites these have been measured. Consistently, PME activity increased with N treatment However, the moorland and lowland heath surveys found that the PME was not as strongly related to N deposition as in the experiments.

Extractable NH_4^+ in litter and surface soils often increased after N addition in the experiments Extractable NH_4^+ dropped quickly after N supply was reduced (Wardlow and Ruabon) and so may be a reasonable indicator of recent deposition. In the moorland survey extractable NH_4^+ was correlated with nitrogen deposition but this was not the case in the lowland heath survey.

Soil changes

Several other measurements are of potential value as indicators but were found not to change consistently across the sites/surveys or to respond but only at the highest N dose rates in the manipulation experiments. These require further testing.These included: **nitrogen leaching base cation depletion** and **net N mineralization, nitrification, microbial immobilisation, denitrification and mineralisable N.**

New Bioindicator survey research: The pilot surveys of selected habitats carried out in the 2004 -7 Terrestrial Umbrella included lowland heath and the Moorland Regional Survey. These generated information on soil-plant nutrient and physiological indicators and established a potential link between chemical indicators of nitrogen deposition and ecological change. Promising indicators from the pilot surveys and other work within the group include bryophyte species richness, N accumulation in bryophytes and physiological responses in bryophytes. The focus of this year's (2009) TU WP3 was a field survey where these indicators were tested across a larger range of habitats encompassing lowland and upland heath, sandunes, acid grasslands and also blanket and raised bogs. Over the summer 2009 detailed survey work has been undertaken at 125 sites where higher and lower plant diversity was recorded and samples of soil, moss, plant litter and plant tissue taken. Sites were chosen to represent broad ranges of nitrogen deposition and climate. In addition, over 100 plots across the TU nitrogen manipulation sites have been surveyed and sampled. These will provide a benchmark to the broader habitat surveys with sites that have well documented responses to nitrogen deposition and accumulation.

The field survey stage of WP3 is now complete and all survey data has been received by MMU. The next phase of the project is the laboratory analysis of the plant and soil samples collected. This has commenced and will continue throughout Autumn 2009. Initial results of the species survey work is expected by the end of November 2009 and a comparison of this with key plant and soil chemical and physiological indicators by early 2010. The final report for the survey and recommendations of suitable bioindicators for different habitats will be completed by February 2010.

Discussion: Collation of data from the UKREATE nitrogen addition experiments has enabled us to examine a wide range of potential biogeochemical indicators (at least 20) that may be used to reliably indicate elevated nitrogen deposition and actual or potential ecological change. The ecosystems studied, along with regional surveys of some of these, represent many of the major ecosystem types in the UK. Given the variety, it is not surprising that likely candidate indicators differ across ecosystems. For example, in many of the systems, the simple measure of foliar %N is a reliable marker of N accumulation but this is not consistently true (e.g. grassland plants). However, in all the experiments where phosphatase activity (in soil or moss) was tested its activity has increased in response to N. Probably the best approach will be to adopt a small suite of indicators that can be used over a range of ecosystems.

More detailed analysis of the likely indicators will explore their level of change in relation to important aspects of the current experiments that differ from site to site such as the duration, the concentration and the nitrogen form. Further research in WP3 in 2009 has tested a smaller selection of priority indicators in regional field surveys, relating where possible to known levels of ecological change.

Policy Implications Biogeochemical indicators may be used to indicate the level of nitrogen deposition to an ecosystem. At some point the indicator may also show ecosystem level responses and ecologically relevant change. Research in this Workpackage shows that across a wide range of N addition experiments a broad level of consistency emerges in indicator responses. However, the best potential indicators show subtle but important differences between ecosystems and the best approach is likely to make use of a small suite of techniques to indicate both the level of deposition and ecological change due to nitrogen pollution.

Work Package 4:
Investigate the sensitivity of different soils to N enrichment, and the underlying controls, using a combination of field and experimental studies

Task Leader: Ed Tipping
Centre for Ecology and Hydrology Lancaster

PIs: Bridget Emmett[1], Nick Ostle[2], Steve Hughes[1], Alwyn Sowerby[1], Robert Mills[1]
[1]Centre for Ecology and Hydrology Bangor, [2]Centre for Ecology and Hydrology Lancaster

Work package 4

Task Leader: Ed Tipping (CEH Lancaster)
PIs: Bridget Emmett (CEH Bangor), Nick Ostle (CEH Lancaster), Steve Hughes (CEH Bangor), Alwyn Sowerby (CEH Bangor)

> **Policy question:**
> What determines the fate of nitrogen in soils, its short-term and long-term mobilisation, and thus changes in plant species composition?
>
> **Main activity**:
> Investigate the sensitivity of different soils to N enrichment, and the underlying controls, using a combination of field and experimental studies.

The research in this Work Package was due to begin in April 2008. The approach proposed in the original submission was to carry out detailed studies of N cycling in four specific soils, and to attempt to define functional soil pools and their dynamic interactions. The results were anticipated to improve understanding of the links between soil C and soil N, and especially to support modelling work in the Dynamic Modelling Umbrella which requires increased knowledge concerning the controls on N immobilisation and release.

However, developments since the proposal was made, especially in the Countryside Survey (CS), suggested a better way to address the issue of how N availability is related to C cycling. We therefore proposed a major variation to WP4, in which CS data and samples, analysed for natural-abundance ^{14}C, would permit a much broader perspective of N:C linkages, more useful in the national-scale assessment required to support policy. This variation was agreed with the Defra Project Officer.

Task 4.1 – Identifying links between plant and soil type, soil carbon, and nitrogen cycling. PIs: Bridget Emmett (CEH Bangor), Nick Ostle (CEH Lancaster), Rob Mills (PhD student, CEH Bangor)

Milestone
The original WP had a single milestone, which was the delivery of *an assessment of tools available to quantify available carbon and N retention rates in soils*, due in June 2009. The revised deliverable is *quantification of soil organic matter turnover in different plant-soil combinations, related to N cycling.*

Delivery to date

The contract variation required detailed planning of soil sampling and analysis, completed in 2008. We took into account CS results, the availability of samples from CS, and the need for an analysis strategy. We processed 55 soil samples from CS plots, covering Aggregated Vegetation Classes (AVC) 3, 4, 5, 6, 7 and 8. The last five are sensitive to the effects of N deposition, while AVC 3 (fertile grassland) was included to obtain comparative information about organic matter turnover in systems high in N, due to fertiliser and manure applications. There are rather few CS sites for woodland (AVC 5 and 6), but we have other data for 25 UK deciduous sites, already analysed for ^{14}C, that can be used. In addition, we took duplicate samples of soils from TU study sites and CEH Carbon Catchments. The final total number of ^{14}C data available for the modeling analysis will be c. 120, which represents a major resource with respect to the characterization of soil organic matter turnover. As of September 2009, all the soil samples have been processed and submitted for analysis at the NERC RadioCarbon Facility, East Kilbride. Results have been returned for all the CS and TU samples. The remainder will be delivered during the next 3 months. We already have sufficient data to proceed with modeling.

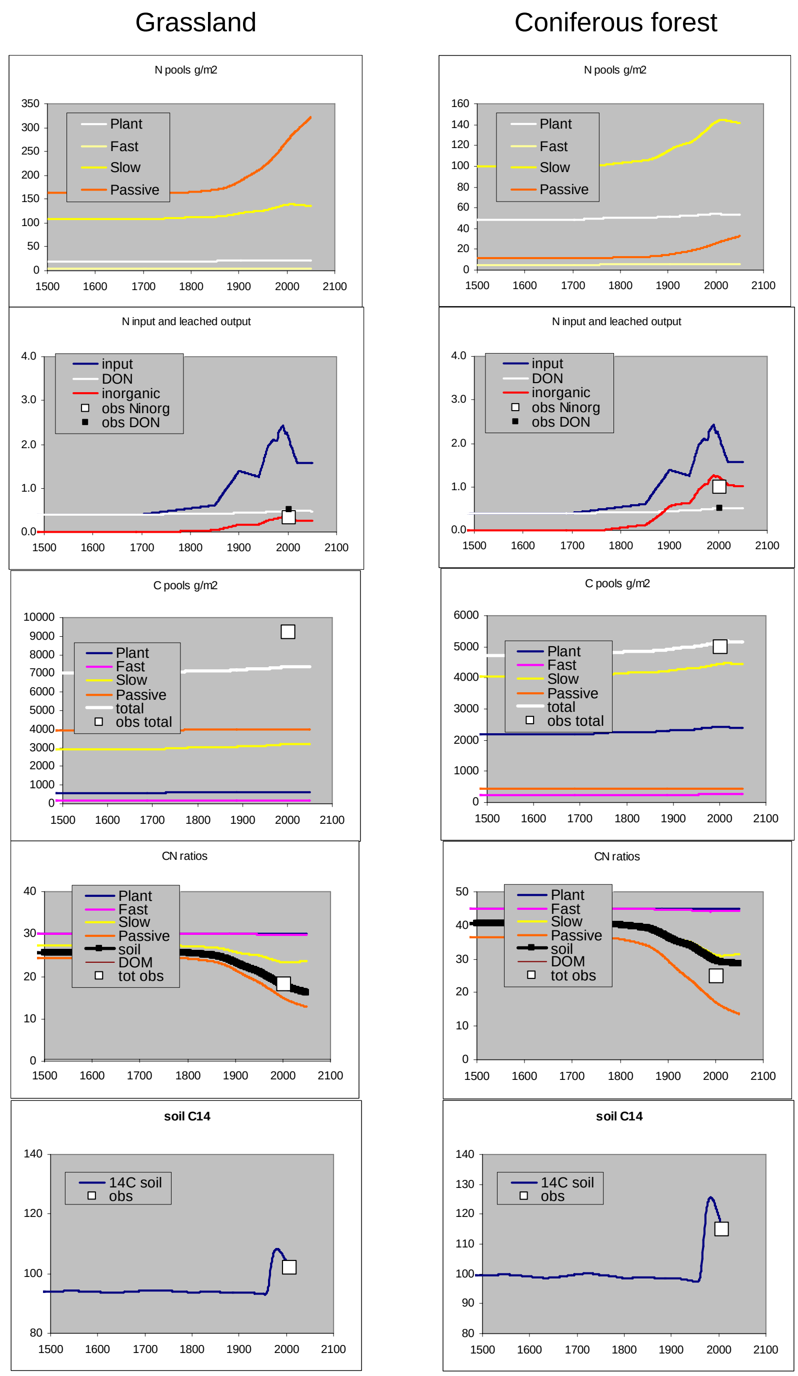
A new model - N14C - has been developed, specifically to use the data available from TU and CS work, and with the capability for national-scale application. The key features are:

- C incorporation into biomass is determined by available N.
- Litter C and N enter three soil organic matter (SOM) pools (Fast, Slow, Passive) which turn over at different rates (1 year, 20 years, 1000 years).
- Each SOM pool can immobilize inorganic N.
- N is lost from the soil in either dissolved organic (DON) or dissolved inorganic (DIN) forms.
- Plants differ in their CN ratios and the proportions in which they produce the different litter types.

The model is run from steady-state pristine conditions (in 1500) until the present, driven by changing N depositional inputs. N14C has been parameterised using TU and other data, and the new ^{14}C results, for four representative, averaged, plant types, i.e. grassland, deciduous and coniferous forest, and shrubland. The increasing N deposition causes biomass, litter production, and SOM to increase. Soil CN decreases, and DIN leaching increases but to different extents depending upon the plant type, with conifer-soil systems being especially prone to DIN leaching.

The following Figure compares outputs and observations for grassland and coniferous forest. The results highlight a number of model predictions:

- The passive pool is the major form of SOC and SON in the grassland, whereas the slow pool dominates in the forest.
- The CN ratio of the forest soil is higher than that of the grassland, but the leaching of DIN is greater in the forest (for similar N deposition), showing that CN ratio is not in general a predictor of leaching or availability.
- Plant and soil carbon increased more noticeably in the forest due to the fertilizing effect of N deposition, because the grassland SOM sequesters N more effectively.
- The ^{14}C panels show how the soil accumulated "bomb carbon" due to weapons-testing in the min-20th Century. The higher ^{14}C in the coniferous forest soil reflects the greater rate of C cycling than occurs in the grassland soil.



Objectives

The remaining objectives for this WP are:

- Obtain the ^{14}C data for the few remaining samples.
- Compute soil carbon mean residence times for each individual sample. Use the data for CS soils to investigate relationships with N availability, expressed as mineralisable N, and measurements of mineralisable C.
- Test the N14C model with independent data sets, including experimental manipulations.

Work Package 5:
Continue to develop ecosystem model chains which link biogeochemical models of soil processes and plant succession with species occurrence models.

Task Leader: Ed Rowe

Centre for Ecology and Hydrology Bangor

PIs: Simon Smart[1], Lindsay Maskell[1], Ed Rowe[2], and Salim Belyazid[3]

[1]Centre for Ecology and Hydrology Lancaster; [2]Centre for Ecology and Hydrology Bangor; [3]Belyazid Consulting and Communication

5. Work Package 5

Task Leader: Ed Rowe (CEH Bangor)

PIs: Ed Rowe (CEH Bangor), Simon Smart, Andy Scott and Lindsay Maskell (CEH Lancaster)

Subcontractor: IVL (Sweden)

> **Policy application:**
> Development of model chains to forecast likely timing of change in soil chemistry and biodiversity in response to a reduction in N emissions
>
> **Main activity:**
> Continue to develop ecosystem model chains which link biogeochemical models of soil processes and plant succession with species occurrence models.

Objectives

- To improve a model chain forecasting plant species occurrence from soil chemistry dynamics and pollutant deposition
- To extend this model chain to include:
  a) modules for plant growth and vegetation management and succession
  b) effects of local species pools

Milestones for Oct 09

5.1 (deferred) Bayesian calibration approach applied to current Ellenberg versus soil variable regression models. **Partially met**, due to prioritisation of CS2007 reporting; report on alternative calibration approaches available (Butler and Smart, 2009). Delivery: March 2010.
5.1 Set up and test uncertainty and sensitivity analysis on MAGIC+GBMOVE model chain. **Not met**, due to to prioritisation of CS2007 reporting. Now being carried out in association with Trevor Page and Duncan Wyatt of Lancaster University. Delivery: December 2009.
5.2 (deferred) Assembly of trait databases, BRC 10km square species pool data and computation of estimated abundance for invasives and native potential dominants. **Not met**, due to prioritisation of CS2007 reporting. Delivery: March 2010.
5.2 Hypothesis tests completed and appraisal of the risk assessment approach. Not met, due to prioritisation of CS2007 reporting. Delivery: March 2010.
5.3 Review available existing modelling tools and investigate their compatibility. **Met.**
5.3 Implement the model integration. Relate the outcome at this stage to results and developments of parallel ongoing projects in Sweden, Denmark and possibly Switzerland. **Not met**, due to delays in preparing a non-forest version of FORSAFE-VEG. Delivery: March 2010.

Overview of progress to date :

One paper accepted and one submitted to international peer-reviewed journals; two workshop presentations, at CCE Working Group on Effects and COST 729 meetings (see below).

Methods:

The effects of nitrogen pollution on plant diversity can be forecast by linking biogeochemical process models with habitat suitability models. Previous forecasts using the GBMOVE species occurrence model driven by the MAGIC soil chemistry model were reasonably accurate when compared to long-term species observations, at least for stable vegetation types. This work package aims to improve the accuracy of predictions of species change in response to interacting drivers, and increase the scope of the model chain to cover vegetation succession. The GBMOVE model is being refined by uncertainty analysis, re-calibration and testing against large spatial datasets, in particular new Countryside Survey 2007 (CS2007) data. An invasibility module will be developed, and a plant growth and vegetation succession module is being incorporated into the model chain. The main development route for this module is to adapt the ForSAFE-VEG model chain for UK habitats, and for non-forest habitats, but stand-alone vegetation modules such as SUMO will also be assessed. Modelling frameworks were assessed for their ability to facilitate the integration of models and data.

Results and Discussion:

a) Improvement of model chain

Re-fitting of relationships between mean Ellenberg score and abiotic variables, a component of the GBMOVE model, has been delayed due to prioritization of Countryside Survey reporting. An assay for mineralisable nitrogen was applied to 700 cores from those CS2007 "X" plots for which data are available since 1978. A paper describing results from the CS2007 pilot study was rejected by Journal of Vegetation Science on statistical grounds. A re-analysis of the data revealed more clearly why mineralisable N considerably improved predictions of mean Ellenberg N, increasing the proportion of explained variance from ca. 60% to ca. 90%. Mineralisable N measured by the new flushing method described a component of the variation in Ellenberg N that was orthogonal to that described by a set of s strongly correlated soil properties (pH, bulk N/C ratio and water content (Figure 5.1). This suggests that the measure may be useful as an indicator of N exposure, as well as helping to improve model accuracy.

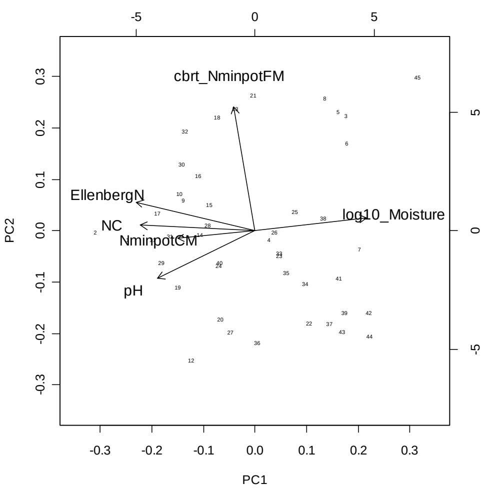


Figure 5.1 PCA plot of mean Ellenberg N and selected abiotic variables in the CS2007 pilot study. In prep. for Journal of Vegetation Science. Ellenberg N = mean Ellenberg N score for present species; cbrt_NminpotFM = mineralisable N measured by new flushing method, cube root transformed; NC = N/C mass ratio; NminpotCM = mineralisable N measured by conventional two-extraction method; pH = pH in water; Moisture = g water / g fresh soil.

Uncertainty analyses of the VSD-GBMOVE model chain will be carried out using methods being developed in ongoing projects analysing uncertainties in VSD and MAGIC. Testing of CliMOVE, the version of GBMOVE in which three climatic parameters are fitted as well as the other abiotic parameters, has focussed on predicting change in habitat suitability for heather in the CLIMOOR droughting and warming experiment (Figure 5.2).

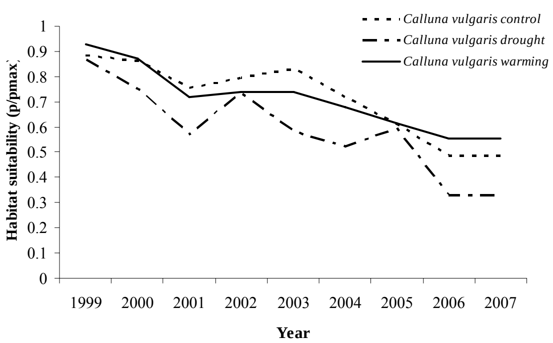


Figure 5.2. Predicted change in habitat suitability for heather (*Calluna vulgaris*) in the Climoor experiment control, droughted and warmed treatments.

b) Adaptation of FORSAFE-VEG to UK and non-forested systems

To develop capacity to predict changes in vegetation type, the ForSAFE-VEG model is being adapted for UK species and for non-forested ecosystems. Work this year has focused on three aspects:

a) implementation of a simplified growth module accounting for carbon and nutrient cycles in ground vegetation, enabling simulation of non-forest sites;

b) model set up for grassland experimental manipulation sites (e.g. Pwllpeiran), to evaluate data availability and the model's biogeochemical performance;

c) parameterisation of VEG to simulate changes in the ground vegetation for UK terrestrial ecosystems.

It was decided to focus on grassland rather than forested sites to ensure that the capability of ForSAFE-Veg can be extended to non-forested systems before the end of the project. , and data on forest characteristics, management and soil properties including mineralogy have been collated. To simulate competition for light, nutrient elements and water, seven plant functional types (PFTs) have been identified. All plant species will be assigned to one of these PFTs. The relative dominance of the PFTs will depend on the composition of the ground vegetation as predicted by the VEG model. The PFT model will thus be driven by species composition as predicted from the effects of abiotic factors on individual species.

The VEG module dynamically simulates interactions between species on the basis of their competitive strength. Competitive strength is in turn calculated according to the environmental conditions using a set of response functions. In the UK, the GBMOVE set of models provides an empirical basis for assigning environmental thresholds and optima for individual species. We have developed methods for deriving VEG parameters from the GBMOVE models, allowing VEG to be applied to the majority of the UK flora using a consistent and empirical approach (e.g., Figure 5.3).

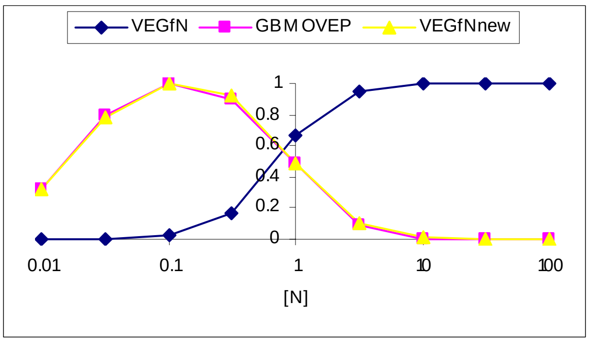


Figure 5.3. Re-fitting of VEG model for *Agrostis capillaris* with respect to nitrogen concentration in soil solution (mg N L^{-1}) using the GBMOVE N function. GBMOVEP = GBMOVE function mapped onto typical concentration range; VEGfN = original VEG function for this species; VEGfNnew = new VEG function for the species, obtained by fitting using the Generalized Reduced Gradient algorithm.

c) Modelling framework

Modelling frameworks aim to ease the technical challenges of interfacing models and databases, and thereby focus attention on the scientific issues. Criteria for assessing modelling frameworks were outlined, and potential frameworks assessed, in the first year of the project. Development of modules to be used in the TU model chain will continue in FORTRAN. The GBMOVE model has been implemented in Access along with routines to calculate mean habitat suitability for habitat-specific groups of indicator species.

d) Interpretation of model outputs

The UNECE-CCE is increasingly interested in developing indicators of pollutant effects that directly measure effects on biodiversity, for use in setting damage thresholds in the Critical Loads approach. A habitat quality index *HQ* has been defined to summarise effects on positive and negative indicator species as defined in Common Standards Monitoring guidance. Since it uses the entire list of indicator species, the *HQ* index does not rely greatly on predictions of environmental suitability for rare species, which are less likely to be available than predictions for more common species. The method was presented to the 19th CCE Workshop in Stockholm, May 2009. This generated considerable interest, and a chapter describing the method was requested for the CCE Status Report 2009.

Publications and talks:

Rowe, E.C., Smart, S.M. and Emmett, B.A. (in press) Defining a biodiversity damage metric and threshold using Habitats Directive criteria., In: Proceedings of COST 729 Nitrogen Deposition and Natura 2000 Workshop, Brussels, 28-20 May 2009.

Smart, S.M., *et al.* (submitted) Empirical realized niche models for British higher and lower plants - development and preliminary testing. Journal of Vegetation Science.

de Vries, W., *et al*. (in press) Use of dynamic soil-vegetation models to assess impacts of nitrogen deposition on plant species composition and to estimate critical loads: an overview. Ecological Applications.

Butler, A. and Smart, S., 2009. Comparative test of methods to develop niche models for British vegetation. Interim technical report. Biomathematics and Statistics Scotland.

Rowe, E.C. 2009. Habitat quality: A single metric for defining biodiversity damage using Habitats Directive criteria. Presentation at meeting of CCE Working Group on Effects, Stockholm, May 2009.

Rowe, E.C., Emmett, B.A. and Smart, S.M. (submitted) Habitat quality: A single metric for defining biodiversity damage using Habitats Directive criteria. In: Hettelingh J-P et al., CCE Status Report 2009.

Work Package 6:

Collate data required for testing of linked soil-vegetation model chains from long-term manipulation sites, in particular time series data for recovery following cessation of treatments and interaction with management treatments. Interpret findings to understanding of impacts, rate of recovery and modifying factors

Task Leader: Gareth Phoenix[1] and Bridget Emmett[2]

[1]University of Sheffield

[2]Centre for Ecology and Hydrology Bangor

PIs: Elena Vanguelova[1], Simon Caporn[2], Jacky Carroll[2], Nancy Dise[2], Jonathan Leake[3], Gareth Phoenix[3], Sally Power[4], Lucy Sheppard[5], Ian Leith[5], Alwyn Sowerby[6], Andrea Britton[7], Rachael Helliwell[7]

[1]Forest Research, [2]Manchester Metropolitan University, [3]University of Sheffield, [4]ImperialCollege London, [5]Centre for Ecology and Hydrology Edinburgh, [6]Centre for Ecology and Hydrology Bangor, [7]MLURI

6. Work Package 6

Task Leaders : Gareth Phoenix (Sheffield) & Bridget Emmett (CEH Bangor)
PIs: Elena Vanguelova (Forest Research), Simon Caporn, Jacky Carroll, Nancy Dise (Manchester Metropolitan University), Jonathan Leake and Gareth Phoenix (University of Sheffield), Sally Power (Imperial College London), L. Sheppard (CEH Edinburgh), Ian Leith (CEH Edinburgh). A. Sowerby (CEH Bangor), Andrea Britton and Rachel Helliwell (Macaulay Institute)

> **Policy question:**
> What is the empirical evidence for N impacts and recovery and can models simulate these changes?
>
> **Main activity:**
> Collate data required for testing of linked soil-vegetation model chains from long-term manipulation sites, in particular time series data for recovery following cessation of treatments and interaction with management treatments. Interpret findings to increase understanding of impacts, rate of recovery and modifying factors.

Objectives:
(1) Provision of data sets for the testing and development of linked soil-vegetation ecosystem models (WP5)
(2) Interpret findings to increase understanding of impacts, rate of recovery and modifying factors.
(3) Produce a synthesis paper reviewing the current understanding of ecosystem responses to N (based on UKREATE sites) drawing out the most important unifying responses.

Milestones
Start new data collection.; Provision of site data (set 2, table 6.1.2). (12 months)
Continued data collection and provision of essential datasets (set 1, table 6.1.1) (24 months)

Progress against milestones

Task: What is the empirical evidence for N impacts and recovery and can models simulate these changes?

Delivery of objectives to date
New and existing data continues to be submitted to the UKREATE database adding to that submitted last year (*Objective 1*). Following previously reported delays, Manchester Metropolitan University (Ruabon and Budworth sites) and CEH Bangor (Peaknaze site) have now submitted data that was outstanding at the last report, though CEH Edinburgh (Whim site) and Forest Research (Forest sites) are still delayed due to staff time pressures. A summary of the data submitted to date, and progress on data submission by each site is provided in Table 6.1. Collection of new data required to improve existing model runs has been underway at all sites with most data now collected (*Objective 1*). However, it is likely that most sites will not have this new data submitted to the database by the October 2009 delivery date due to time needed to finish analysing samples and process data (i.e. since actual sample collection for most will only just have finished in October). Imperial (Thursley site) and Sheffield (Wardlow sites) will have delayed delivery of the 18 month time course of soil water chemistry due to their delayed starts in this (reported previously).

Analysis of data from the UKREATE database has been used to draw out unifying effects (*Objectives 2*) across sites. This proved more challenging than anticipated but is now approaching completion. Draft text of the review paper (*Objective 3*) contributed to the RoTAP vegetation chapter. Draft text is due to be distributed to co-authors for comment in October. The review paper will include the analyses from *Objective 2*. Despite the delays outlined above, it is anticipated that all objectives will be completed by the end of contract.

Milestones to date

Milestone 43, "*Start new data collection and provision of site data*" Deliverable by Oct 2009: Mostly complete bar the delay in submission of existing data by two partners and late initiation of 18 month data series at two sites as detailed above. Milestone 44, "*Continued data collection and provision of essential datasets*" Deliverable by Oct 2009: Collection of data is on target (bar the partial completion of the late running 18 month series at the sites mentioned above). However, data submission for most sites is likely to miss the October 2009 target (as detailed above).

Methods and Results

Current activities at the UKREATE sites are too numerous and diverse to describe in detail since each site's main activities are largely dependent on which datasets are being collected. However, a brief overview of some recent activities is provided here. At Thursley, N additions continue to affect the recovery dynamics of higher and lower plants, following the severe summer fire in 2006. Despite the loss of a substantial proportion of soil nutrient stores during the fire, treatment-related differences in soil microorganisms and associated differences in nutrient availability are still apparent, as are the effects of N additions on above- and below-ground carbon stores. At the Wardlow grasslands, detailed vegetation surveys have revealed continued decline in forb abundance in both the calcareous and acidic grasslands under N deposition, with no sign still of floristic recovery in the "recovery" plots despite 4 years following cessation of treatments. At the Forest sites, national chemical trends are indicative of recovery from sulphur deposition and acidification. The recovery is confirmed by pH increase and sulphate, aluminium and manganese decrease in the soil solution at most sites. A further clear signal of declining sulphur deposition is the continuous decline in tree leaf sulphur and aluminium contents. Evidence from the Level II long term Intensive forest monitoring of significant soil solution NO_3 reduction for the last 12 years under Scots pine forest, in highly N polluted areas such as Thetford, corresponds to notable increase in biodiversity of the ground flora and a significantly decrease of Ellenberg N score (Vanguelova et al, 2009). At Climoor and Peaknaze vegetation measurements have recently been undertaken and analysis of that data is underway. Soil water chemistry measurements are ongoing. The upland heath experiment at Ruabon reached a landmark 20 years of N treatment and while there no obvious adverse effect on the dominant heather vegetation, there were numerous other changes within the ecosystem. Recent vegetation monitoring found reduced cover and variety of lichens and bryophytes due to added N, but no significant changes in the composition of higher plants in the stand which is still dominated by *Calluna*. At both Ruabon and Budworth (lowland heath) recent analyses of the soil carbon stores found increases in C storage, particularly in the upper horizons, due to added N. The possible benefits of nitrogen deposition for carbon accumulation within the system have to be set against the negative impacts on biodiversity and the potential for N leaching (shown earlier at both sites). At Budworth, the highest N treatment continues to show poor recovery from the managed cut 7 years ago (autumn 2002).

Policy implications

Critical interactions of long-term N deposition impacts with management burn or cutting are now emerging. Recent data from Thursley lowland heath suggests that predictions of increasing frequency of summer fire events may have less impact on accumulated soil N stores than expected, and that the floristic and functional recovery of burnt ecosystems will be substantially affected by ongoing atmospheric N inputs. Furthermore, at Budworth, the highest N treatment continues to show poor recovery from the managed cut 7 years ago (autumn 2002), which reinforces the view that N affected heathlands require more frequent management to counter the ‘ageing’ effect of the N supply. In the Wardlow grassland systems, the absence of floristic recovery following cessation of treatments highlights the likely slow recovery of polluted grasslands in the UK even with considerable declines in N deposition rates. Further work continues to reinforce the evidence that for *Calluna* dominated ecosystems (heathlands, bogs), while wet deposition increases *Calluna* biomass across most sites, considerable damage results from dry deposited NH_3. This suggests the lack of decline in NH_3 deposition in the UK may result in continued damage and future reductions in NH_3 emissions appear essential if damage to *Calluna* dominated systems is to be reversed.

TABLE 6.1: Progress on data submission by site

	T	W	R	B	Wa	Wc	P	C	F	Cl	Pk
Vegetation surveys	√	d	√	√	√	√	√	√	d	√	√
Biomass or shoot growth	√	d	√	√	√	√	√	√	d	√	√
Plant chemistry	√	d	√	√	√	√	√	√	d	√	√
Soil extractable NO_3^-, NH_4^+	√		√	√	√	√				√	√
Soil sol^n or leached NO_3^-, NH_4^+	d	d	√	√	√	√	√	√		√	√
Leached organic N					√	√	√	√	d	√	√
Soil pH	√	d	√	√	√	√	√	√	d	√	√
Soil moisture	d	d	√	√				√	d	√	√
Soil total N	√	d	√	√	√	√		√	d	√	√
Soil total C	√	d	√	√	√	√	√	√	d	√	√
N mineralization rates	√		√	√	√	√	√	√		√	√
Nitrification	√		√	√	√	√	√	√		√	√
N_2O production	√	d			√	√	√			√	√
Respiration		d	√	√						√	√
Extractable base cations	√				√	√	√	√	d	√	√
Total base cations					√	√		√	d	√	√
Extractable non-bases (Al, Fe, Mn)					√	√	√		d	√	√
Total non-bases (Al, Fe, Mn)					√	√		√	d	√	√
Usefull additional data: CEC; DOC, DON, SO_4^- Cl, Ca, Mg, K, Na; Litterfall C,N,P		d	√	√			√	√	d		
PME activity	√	d	d		√	√					
Soil extractable PO_4^-	√	d	d		√	√					
Drought injury	√	d	d								

√ = data submitted. d = data available but submission delayed (see text for details). Sites are T=Thursley, W=Whim, R=Ruabon, B=Budworth, Wa=Wardlow acidic, Wc=Wardlow calcareous, P=Pwllpeiran, C= Culardoch, F= ICP Forests, Cl= Climoor, Pk=Peaknaze.

Work Package 7:
Investigate role of climate change N cycling and indicators of N enrichment using two established climate change experiments

Task Leader: Alwyn Sowerby
Centre for Ecology and Hydrology Bangor

PIs: Alwyn Sowerby[1], Bridget Emmett[1] and Elena Vanguelova[2]
[1]Centre for Ecology and Hydrology Bangor, [2]Forest Research

Work Package 7 Task Leader: Alwyn Sowerby

Objective:
The aim of this work package is consider the impact of climate change on the flow and uptake of N through terrestrial ecosystems, as well as the impact of potential change in location of receptor (i.e tree species). There are two tasks within the work package, Task 7.1 uses two established climate change experiments to identify the impact of warming and repeated summer drought on the N cycle and indicators of N enrichment. Task 7.2 aims to identify the potential importance of change of location of receptor as a result of changing forestry policy and adaptation measures designed to address the threats of climate change, on the uptake of N and nutrients and the implication to Critical Load for acidity and N for woodland.

Milestones - Delivery to date
Oct 2008 (47) Maintenance of experiment, all climate change treatments have been operational throughout 2007-2009., completed. (Task 7.1)
Oct 2008 (Milestone 51) Generation of maps of current tree species distribution and current yield class for the study areas, completed. (Task 7.2)
Oct 2009 (48) Report on plant species change and start of all biogeochemical measurements, this is delayed by a few months, the data has been collected we just need to collate and analyse it. (Task 7.1)
Oct 2009 (Milestone 52) Scenario analysis and maps of current/most suitable species distribution and current/future yield class for the study area, due for completion by 31st Oct 2009. (Task 7.2).

Task 7.1 – The influence of climate change on the N cycle and indicators of N enrichment in upland heathland and grassland PI: Alwyn Sowerby (CEH)

Methods
The Climoor and Peaknaze experimental sites utilise automated roof technology to produce warming and summer drought treatments (Beier *et al*. 2004). In conjunction with funding from the Nitroeurope project (www.nitroeurope.eu), routine measurements of key fluxes and indicators of N enrichment are continuing.

Results and Discussion
We have completed collection of an 18 month data set of the key biogeochemical and vegetation measurements for both sites, including NO_3 and NH_4 leaching (Figure 1), N_2O flux as well as other fluxes related to the C cycle (e.g. soil respiration). We have also collected meteorological and abiotic data for the site, as well as plant diversity, biomass and foliar-N concentrations for the dominant species at the sites. We are still collating and analysing plant biomass data for the plant measurements, but have secured raw data for both Climoor and Peaknaze. At Peaknaze, initial analysis of plant biomass data shows a widespread die-back of *Empetrum nigrum*, which, on average, made up 30% of the overall total plant biomass at the site when baseline measurements were carried out in 2005 (Figure 2), We need to carry out further analysis of the data, however this die-back appears to have had a significant impact on N cycling at the site, for example we have observed approximately a two-fold increase in nitrate concentrations in soil solution (data not shown).

Implications

Work in this task will assess the magnitude of change and response of critical N processes in response to climate change (warming and drought) and how this compares to natural variability.

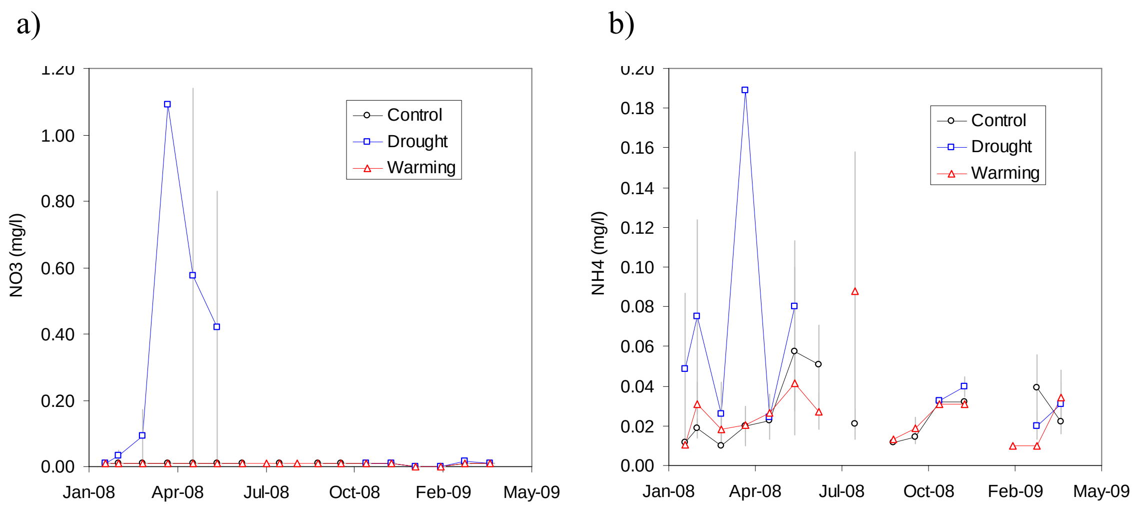


Figure 1 – a) NO_3 concentration and b) NH_4. in soil water run-off from the Climoor experimental plots, error bars show the standard error of the mean, n=3.

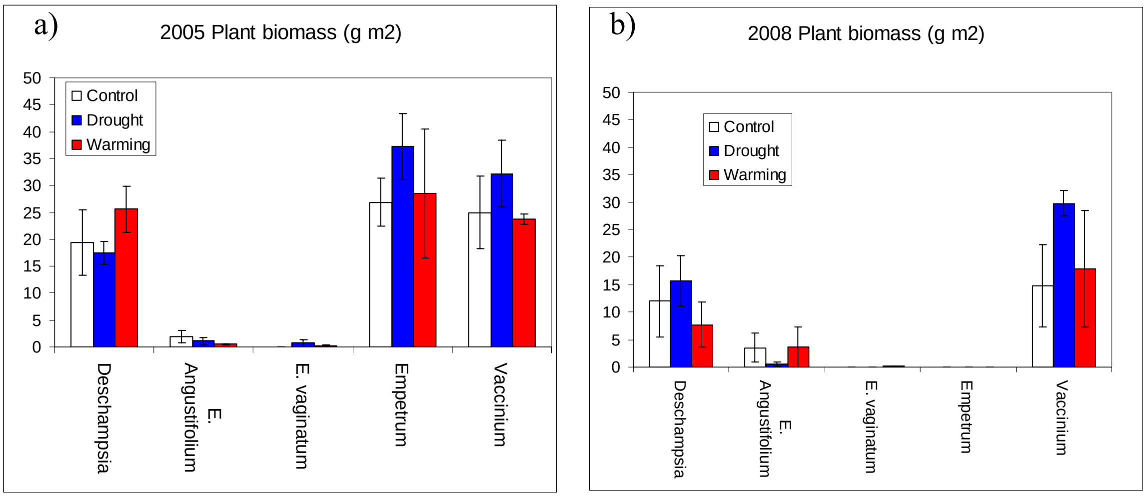


Figure 2 – Measurements of plant biomass in experimental plots at the Peaknaze fieldsite show a widespread die-back of the shrub *Empetrum nigrum* . a) Baseline measurements carried out in 2005, b) repeated measurements in 2008.

Task 7.2 An assessment how climate change may affect critical loads for woodlands
PI: Elena Vanguelova (Forest Research)

Methods

A GIS approach using also Ecological Site Classification (ESC, Pyatt *et al*., 2001) are used to bring together predicted changes in species, flows and uptake for a selected woodland to identify the relative magnitude of climate change on critical load exceedance.

References - Beier, C., Emmett, B.A., Gundersen, P., Tietema, A., Penuelas, J., Estiarte, M., Gordon, C., Gorrison, A., Llorens, L., Roda, F., Williams, D. (2004) Novel approaches to study climate change effects of terrestrial ecosystems in the field – drought and passive night time warming. Ecosystems, 7(6), 583-597.

Results and Discussion

To date, current maps of tree species for the two sites have been generated from FC sub compartment database. Milestone 52 (see above) will be completed by 31st Oct 2009.

Implications

The work under this task will be put into context to enable better predictions of the woodland areas endangered by pollution in the fate of changing climate. If impacts are shown to be marked, the results will also provide the evidence base to support and guide Defra in bringing about the necessary change in future emission control to protect England's woodlands.

References - Pyatt, G., Ray, D. and Fletcher, J. (2001). An Ecological Site Classification for Forestry in Great Britain. Bulletin 124. Forestry Commission, ISBN 0 85538 418 2.

Work Package 8:
Provision of management, advice and support on an ad hoc basis, support of CAPER conference

Task Leader: Bridget Emmett

Centre for Ecology and Hydrology Bangor

PIs: B. Emmett[1], Lucy Sheppard[2] and Mike Ashmore[3]

[1]Centre for Ecology and Hydrology Bangor, [2]Centre for Ecology and Hydrology Edinburgh, [3]University of York

8. **Work Package 8**

Task Leader: Bridget Emmett (CEH Bangor)
PIs: Mike Ashmore (U. York), Lucy Sheppard (CEH Edinburgh), Brian Reynolds (CEH Bangor)

Policy question:
Knowledge transfer to help support and inform policy development.

Main activity:
Provision of management, advice and support on ad hoc basis, and support of CAPER conference.

Milestones
Effective management of TU, knowledge transfer and liaison with UK NFC (12 and 24months)
Organisation of annual CAPER meeting (12 and 24months)
Review of empirical critical loads, in the specific context of evidence of differential effects of reduced and oxidised N (24 months)

Task 8.1 – Management support and knowledge transfer

The 2nd annual meeting was organised at MMU and focussed on synthesis talks bringing together the existing data and knowledge. This has enabled the UKREATE team to present our findings to a series of RoTAP meetings and provide written text for the RoTAP report. Planned activities for all WPs was also reviewed and timetables and responsibilities checked and agreed. A report to the project manager was submitted. The last annual meeting is planned for November at Bangor.

A full audit for Defra was carried on the Terrestrial Umbrella in Year 2. It was found to pass all requirements of the Joint Code of Practice with only a few suggestions for improvement.

Task 8.2 – Organisation of CAPER conference

A second highly successful CAPER conference was organised at Manchester Metropolitan University. There was over subscription for places demonstrating the high regard with which this meeting is held.

Task 8.3 – Assessment of the validity of mapping values of empirical loads in the UK

This is in progress and will be reported in the final report.