CAPER 2019

BOOK OF ABSTRACTS

Edinburgh Centre for Carbon Innovation

8-9th May 2019

Wednesday 8th May

Keynote Presentation

13:10 – 14:00

Avoiding deterioration due to nitrogen deposition by applying ecological measures in Natura 2000 sites: lessons learned in The Netherlands

Bal D.
Senior Policy Officer for Natura 2000 & Programmatic Approach to Nitrogen, Dutch Ministry of Agriculture, Nature and Food Quality

Since the 1980's the need for ecological measures to counteract the effects of nitrogen deposition has been recognized in The Netherlands. Since 1989 the government subsidizes both the scientific research needed (restoration ecology) and the implementation of measures in nature reserves. The strict protection of habitats in Natura 2000 sites made this program even more important. Especially since the Council of State's judgment that no permits can be issued for projects that will cause a further exceedance of critical loads in Natura 2000 sites. The only way out was to relate a permit to both source-oriented measures to reduce the exceedance and appropriate ecological measures to protect (or even enhance) the quality of habitats. This relation is called the Programmatic Approach to Nitrogen and has a legal status since 2015. Several environmental protection organizations went to court, however: they stated that the reduction of deposition is not enough and that the ecological measures are not effective enough. In last year's judgement in this case, the European Court of Justice stressed the importance of scientific certainty. At this moment it is still unknown if the Dutch Council of State will be satisfied by the scientific certainty presented in the Natura 2000 management plans. In the meantime the implementation of ecological measures has been immensely intensified and scientific monitoring and research is being carried out. A new measure that is expected to be approved is the use of rock dust to remineralize heavily acidified soils with silicon. New measures or the adjustments of existing measures have to be approved by expert teams of 'Development and Conservation of Nature Quality' (OBN), a network of experts from research institutes, nature conservation organizations and authorities, and an international review commission.

Session 1. Air pollution impacts on plants and soils.

Chair: Susan Zappala (Natural England)

Wednesday 8th May

14:00 – 14:20

Ozone impacts on respiration and photosynthesis rates in three contrasting forest ecosystems

Ashworth K. [1]; Otu-Larbi F. [1]; Conte, A. [2]; Fares, S. [2] and Wild, O. [1]

1) Lancaster Environment Centre, Lancaster University, UK

2) Council for Agricultural Research and Economics, Research Centre for Forestry and Wood, Viale Santa Margherita 80, 52100 Arezzo, Italy

Dry deposition is the dominant sink for tropospheric ozone and removal rates by vegetated surfaces are several times higher than bare ground. Ozone is a powerful phytotoxin and uptake through the stomata leads to oxidative stress, impairing many physiological processes. This damage reduces photosynthesis and carbon assimilation, induces early senescence and disrupts stomatal functioning. However, the net effect of these various impacts on plant health and growth, and on stomatal control are not well understood. We apply the FORCAsT (FORest Canopy-Atmosphere Transfer) one-dimensional canopy model to investigate the effects of ozone uptake on canopy stomatal conductance, evaporative fluxes and photosynthesis. We implement three widely-used photosynthesis and stomatal conductance models (Jarvis, Ball-Woodrow-Berry and Medlyn) within the FORCAsT framework, and evaluate the ability of the model to reproduce observed evapo-transpiration and Gross Primary Productivity (GPP) at three evergreen forest sites with differing reported sensitivity to ozone: a Holm oak (Q. ilex) forest at Castelporziano Estate, Rome; a Ponderosa pine (P. ponderosa) forest at Blodgett Forest, California; and a boreal forest, dominated by Scots pine (P. sylvestris), at Hyytiälä, Finland. All three sites contribute continuous measurements of plant physiological parameters such as canopy-top latent heat flux and Net Ecosystem Exchange (NEE) to the FLUXNET network, and have observations of ozone concentrations for a number of years. We include species-specific ozone dose-response functions for each physiological model and determine the impact of cumulative ozone damage on physiological processes for a range of assumed ozone threshold values and under different soil water conditions.

Session 1. Air pollution impacts on plants and soils.

Chair: Susan Zappala (Natural England)

Wednesday 8th May

14:20 – 14:40

Closing the global ozone yield gap

Sharps K. [1]; Mills G. [1]; Simpson D. [2] and Pleijel H. [3]

1) Centre for Ecology & Hydrology, Bangor, LL57 2UW
2) Chalmers University, Sweden
3) University of Gothenburg, Sweden

Whilst it is recognised that rapid breeding programmes will have an important role to play in adaptions of crops to a changing climate, the selection of ozone tolerance traits is currently not included in such programmes. This study sets out a case for improving crop yields by closing the ozone-induced yield gap. For the first time, we investigate how the spatial variation and severity of ground-level ozone effects on the yield of 4 staple food crops compares with other abiotic stresses on a global scale. Based on stomatal uptake of ozone (mean of 2010-2012), we estimate that the global yield was reduced annually by 12.4 %, 7.1 %, 6.1 % and 4.4 % for soybean, wheat, maize and rice respectively, with a total of 227 Tg of lost production due to ozone. Our modelling indicates that the highest ozone-induced production losses for soybean were in North and South America whilst for wheat they were in India and China, for rice in parts of India, Bangladesh, China and Indonesia, and for maize in China and the United States. We show that the impact of ozone on crop yield is within the range of concern for other crop stressors. Also, areas with the highest production losses due to ozone were often at risk of high losses from other stresses. Next, we define a crop ideotype with multi-stress tolerance (including ozone) and describe how ozone effects could be included in crop breeding programmes. We also discuss crop management approaches that could be applied to reduce ozone impacts in the shorter term. This global study shows that ozone is an important crop stress, causing yield reductions of staple food crops and comparing in importance with other key stresses. We recommend increased attention to the benefits that could be gained by addressing the ozone yield gap.

Session 1. Air pollution impacts on plants and soils.

Chair: Susan Zappala (Natural England)

Wednesday 8th May

14:40 – 15:00

Fractions of soil phosphorus and their availabilities to plants in a fertilised lowland heath

Boateng E. [1]; Field C. [1]; Caporn S. [1] and Rowe E. [2]

1) Manchester Metropolitan University, Manchester, UK

2) Centre for Ecology & Hydrology, Bangor, LL57 2UW

The relationships among soil available phosphorus (P), inorganic P fractions and plant (*Calluna vulgaris*) P uptake were investigated in two fertilised heathlands. Soils (0-15 cm) were sampled from long-term nitrogen (N) and phosphorus (P) addition experiments in a UK lowland heath. Available P was determined by deionised water, Mehlich-I and Bray-II extractions. Fractionation of soil P followed a sequential extraction scheme to isolate "active-phosphate" (i.e. P associated with carbonates or soluble-P, Al, Fe, and Ca), as well as two non-labile fractions of inorganic P ("Recalcitrant" and "Residual"). Total P in soils and vegetation samples was determined using *aqua regia* digestion. Total P in the studied soils ranged from 52.7 to 136 mg P kg^{-1} and sequential extraction recovered 80 to 99% of the total P. Water and Mehlich-I extracted P were correlated with soluble-P and tissue P, whereas Bray-II extracted P was correlated with less labile (Al-P and Fe-P) and non-labile fractions of inorganic P. Soluble-P was the only fraction of inorganic P that significantly predicted plant tissue P ($p < 0.001$, $R^2 = 0.738$), suggesting that soluble-P is the form most available for plant uptake. Aluminium (Al-P) and Fe-P dominated inorganic P fractions, representing 28-34% and 17-46% of total P respectively. These fractions were the major contributors to active-P and are presumably most responsible for the replenishment of P in soil solution following plant uptake. Calcium phosphate formed a small fraction (2-3%) of total P, indicating that the studied soils have been intensively weathered. Continuous additions of N and P fertilisers in separate applications largely reduced Al-P and Fe-P concentrations (e.g. 15.4 and 11.6 mg P /kg for Al-P and Fe-P on N plots vs. 23.8 and 28.3 mg P /kg for Al-P and Fe-P on control plots respectively) but together (N+P) significantly increased both forms.

Session 1. Air pollution impacts on plants and soils.

Chair: Susan Zappala (Natural England)

Wednesday 8th May

15:00 – 15:20

Nitrogen damage and signs of recovery in Moninea Bog, Northern Ireland

van Dijk N. [1]; Leith I. [1]; Munzi S. [2]; Finnegan K. [3] and Sutton M.A. [1]

1) Centre for Ecology & Hydrology, Bush Estate, Edinburgh, EH26 0QB

2) Centre for Ecology, Evolution and Environmental Changes, Faculdade de Ciências da Universidade de Lisboa, Portugal

3) Northern Ireland Environment Agency, Belfast

Moninea Bog is located in the southern part of Northern Ireland. It was declared an Area of Special Scientific Interest (ASSI) in 1990 and formally designated as Special area of conservation (SAC) in 2005. The area is especially important for its high cover of Sphagnum moss species and the presence of all three native sundew species. Moninea Bog is surrounded by farmland and a number of sheds were built on a poultry farm directly to the north west of the bog. Concern was raised that the resulting high emissions of ammonia (NH_3) would have an impact on the bog vegetation. In 2007, a detailed study was undertaken. Looking at the results of these field observations, air measurements and bio-indicators, it became clear that the atmospheric ammonia deposition caused severe damage on the vegetation. The farm closed in 2009/2010. In 2017, we returned to the bog to investigate whether there were already signs of recovery. In this presentation, I will show the results of the field observations, air measurements and bio-indicators from the 2007 and the 2017 studies.

Session 1. Air pollution impacts on plants and soils.

Chair: Susan Zappala (Natural England)

Wednesday 8th May

15:50 – 16:10

Nitrogen science and champions: from South Asia to the world

Sutton M.A. [(1)]

1) Centre for Ecology & Hydrology, Bush Estate, Edinburgh, EH26 0QB

Grasping the global nitrogen challenge requires that we link up the multiple opportunities for air quality, water quality, greenhouse gas emissions, biodiversity and other interacting nitrogen related threats. Developing a science agenda can happen at multiple levels from field and landscape, to country, region, and the world. This presentation will outline current progress being made under a recently established South Asian Nitrogen Hub supported by the UKRI global challenge research fund. The developing research agenda highlights the opportunities to make innovative links considering biological responses to nitrogen such as between aerial and aquatic living symbiosis and between agricultural verses engineering solutions. The presentation will highlight how South Asia has acted as a regional champion to develop global attention on the nitrogen cycle through its leadership in developing a Resolution on Sustainable Nitrogen Management, as recently agreed at the 4th United Nations Environment Assembly (UNEA-4) in March 2019.

Session 2. Metrics and predictions of air pollution effects.

Chair: Stefan Reis (Centre for Ecology & Hydrology, Edinburgh)

Wednesday 8th May

16:10 – 16:30

Predicting topsoil concentrations of five metals in the UK from 1750 to 2100

Tomlinson S.J. (1); Thomas I.N. (2); Carnell E.J. (2); Dragosits U. (2); Dore A.J. (2); Zwagerman T. (2); Harrison S. (1); Pedde S. (1) and Lofts S.(1)

1) Centre for Ecology & Hydrology, Lancaster, LA1 4AP

2) Centre for Ecology & Hydrology, Bush Estate, Edinburgh, EH26 0QB

Soils may be contaminated by metals from a variety of sources including industry, mining, transport and land application of agricultural materials such as manures and fertilisers. Rates of metal contamination, and therefore concentrations in topsoils, are dependent on a host of factors including industrial practice, energy policy, population growth and agricultural intensity. Metals are strongly retained by topsoils, so that proactive management of inputs is needed to prevent contamination reaching levels potentially posing ecological risks, as once this has occurred reduction of concentrations to safe levels may require decades or even centuries. Future projections of metal input rates to soils require development of underpinning scenarios of socioeconomic change in order to derive estimates of trends in the variables directly influencing the input rates.

The Spatially-explicit Projections of Environmental Drivers and impacts project (SPEED) is developing a modelling system to predict present day and future scenario-driven topsoil concentrations of cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni) and Zinc (Zn) for the whole of the rural UK. The project links models of atmospheric deposition (FRAME-HM), soil chemistry (MADOC for pH and organic matter change) and metal accumulation (IDMM). Historic simulations will generate spatial time series of land use, metal inputs to soil (atmospheric deposition, manures, bio-solids etc.) and soil data to allow spatiotemporal predictions of metal concentrations in soil from 1750 and to be evaluated against present-day measurements for use in future scenarios. Socioeconomic change scenarios under development within the project will be used to derive estimates of future input rates to 2100.

This work builds on previous modelling of metal accumulation (Lofts et al., 2013) that shows reasonable predictions of present day concentrations based on historic reconstruction of deposition trends using lake sediment core profiles and deposition data.

Session 2. Metrics and predictions of air pollution effects.

Chair: Stefan Reis (Centre for Ecology & Hydrology, Edinburgh)

Wednesday 8th May

16:30 – 16:50

Are current metrics of air pollution impacts adequate for planning policy responses?

Rowe E.C. [1]; Sawicka K. [1] and Mitchell Z. [2]

1) Centre for Ecology & Hydrology, Bangor, LL57 2UW

2) Centre for Ecology & Hydrology, Wallingford, OX10 8BB

Deposition of nutrient-nitrogen and total acidity, and concentrations of specific gases, have demonstrable effects on ecosystems. Some effects are beneficial. Acidification can slow decomposition and release of greenhouse gases, and limit the release of dissolved organic carbon from soils. Eutrophying pollutants can increase agricultural and forest productivity, thereby reducing net release of CO2. Eutrophication can sometimes increase species-richness in naturally species-poor habitats such as acid grasslands.

On the other hand, atmospheric acidity and nitrogen (N) pollution have damaging effects on particular species. Nitrogen pollution has caused local extinction across the UK of plant and lichen species that are adapted to low-fertility environments. Species lost tend to be those that are small in stature, require high ground-level light availability for at least part of their life-cycle, and are intolerant of competition from fast-growing species. These smaller species are often scarce and threatened, and net effects of air pollution on biodiversity are mainly considered to be negative.

The International Cooperative Programme on Modelling and Mapping (ICP-M&M) has been at the forefront of efforts to predict change in individual species, and to relate these species changes to overall biodiversity targets and metrics. “Biodiversity-based” critical loads have been advocated, to illustrate air pollution impacts at large (e.g. UK) scale in terms of species and habitat changes. However, the proposed metrics are nuanced and require explanation, and may not be appropriate for communicating the scale of the problem and the benefits of pollution control measures. Recent changes within ICP-M&M have led to reconsideration of the biodiversity-based critical loads approach, and may lead to a return to simpler, soil-based metrics as proxies for biodiversity change and recovery. We report on the recent meeting of the ‘Task Force’ for ICP-M&M, and discuss the merits of different approaches to presenting air pollution impacts on biodiversity.

Session 2. Metrics and predictions of air pollution effects.

Chair: Stefan Reis (Centre for Ecology & Hydrology, Edinburgh)

Wednesday 8th May

16:50 – 17:10

Ecologically-meaningful metrics of nitrogen deposition

Payne R. [1]
1) University of York, York, UK

To understand and manage the impacts of N deposition, we need metrics which accurately reflect N deposition pressure on the environment. By far the most widely-used metric is annual nitrogen deposition over either a single year or averaged of a period of up to three years. However, there is evidence that N accumulates in many ecosystems and impacts from low-level exposure can take considerable time to develop. In the UK, recent modelling work by CEH now allows a better understanding of long-term change in N deposition, potentially allowing the development of more meaningful metrics which incorporate this longer-term deposition history. In our study we set out to compare the power of alternative N deposition metrics in explaining spatial variability in vegetation composition in the UK. We assembled 36 individual datasets representing 48,332 occurrence records in 5,479 quadrats from 1,683 sites, and used redundancy analyses to test the explanatory power of 33 alternative N metrics based on national pollutant deposition models. We found convincing evidence for N deposition impacts across datasets and habitats, even when accounting for other large-scale drivers of vegetation change. Our results add to the weight of evidence for N deposition impacts in 'real world' landscapes and provide the first direct evidence for some habitats. As would be expected, there was considerable variability in the explanatory power of metrics between different habitats and datasets. Our results provide strong evidence that metrics which incorporate long-term N deposition explain more variance than metrics which do not, and that metrics which embed critical load values perform more poorly than those which do not. Overall we propose that a thirty-year moving window of cumulative deposition may be the best current alternative.

Poster Presentation

Wednesday 8th May

17:10 – 17:20

Ozone tolerance found in *Aegilops tauschii* and synthetic wheat

Brewster C. [1]; Hayes F. [1] and Fenner N. [3]
1) Centre for Ecology & Hydrology, Bangor, LL57 2UW
2) Bangor University, Bangor, LL57 2DG

Ground level ozone is an air pollutant which acts as an important abiotic stress on many important crops. Modern wheat cultivars (Triticum aestivum L. AABBDD) appear increasingly sensitive, with mean yield reductions in the northern hemisphere estimated at nearly 10%. In this study three of the genome donors of bread wheat, T. urartu (AA), T. dicoccoides (AABB), and Aegilops tauschii (DD) along with a modern wheat cultivar (T. aestivum 'Skyfall'), a 1970s cultivar (T. aestivum 'Maris Dove'), and a line of primary Synthetic Hexaploid Wheat (AABBDD), were grown in 6L pots of sandy loam farm soil in solardomes (Bangor, North Wales) and exposed to a weekly regime of low, medium and high concentrations of ozone over a 3 month period. Measurements were made at harvest of shoot biomass and grain yield. Contrary to previous findings, Ae. tauschii (DD) appears ozone tolerant with no significant effects of ozone on total shoot biomass, total seed head weight, or 1000 grain+husk weight even under high ozone levels. In comparison T. urartu (AA) had a significant reduction in 1000 grain+husk weight, under both medium and high ozone (-26%). T. dicoccoides was affected by ozone but not significantly. The older cultivar, 'Maris Dove', had a significant reduction in seed head biomass (-9%) and 1000 grain weight (-11%) but was less sensitive than the more recent cultivar 'Skyfall' which had significant reductions in its total seed head biomass (-21%) and 1000 grain weight (-27%) under high ozone. Notably, the line of primary Synthetic Hexaploid Wheat was ozone tolerant, with no effect of ozone on total grain weight (-1%) and only a 5% reduction in 1000 grain weight even under high ozone levels. Further research is required to assess the use of synthetic wheat to develop ozone tolerant cultivars.

Poster Presentation

Wednesday 8th May

17:20 – 17:30

Atmospheric N input to a designated site in Northern Ireland: modelling and measurement

Thomas I.N. [1]; Carnell E.J. [1]; van Dijk N. [1]; Tang Y.S. [1]; Stephens A. [1]; Dore A.J. [1]; Sutton M.A. [1] and Dragosits U. [1]

1) Centre for Ecology & Hydrology, Bush Estate, Edinburgh, EH26 0QB

The effects of atmospheric nitrogen (N) pollution pose a substantial threat to many protected sites in Northern Ireland, where thresholds for impacts of N deposition and ammonia (NH_3) concentration on sensitive vegetation are frequently exceeded. This study focuses on one such site, Ballynahone Bog SAC/ASSI/RAMSAR, where annual modelled NH_3 concentration exceeds the critical level for lichen and bryophyte species of the active raised bog habitat present.

The work presented aims to quantify the atmospheric N input to this site at a landscape scale, through a combined measurement and modelling approach. In addition to existing atmospheric NH3 monitoring network of 8 passive samplers on the bog itself, a further 9 sampling sites were situated in a 10 km by 10 km landscape study area surrounding the bog. In addition, vegetation samples from the bog are currently being analysed to provide quantifiable information on the impact of N pollution on species present, building on existing observations of vegetation damage. In parallel, modelling is being carried out to quantify emission density in the area surrounding the bog, with atmospheric concentration and deposition modelling to follow. A key outcome of the project is to share knowledge of impacts to the bog and consider how spatial targeting of measures may help to mitigate and prevent further damage.

This study has been funded by the Northern Ireland Department of Agriculture, Environment and Rural Affairs and the Northern Ireland Environment Agency.

Poster Presentation

Wednesday 8th May

17:30 – 17:40

Integrating UK environmental networks to monitor air pollution impacts on terrestrial and freshwater ecosystems: a new initiative

Tang Y.S. [1]; Benham S. [2]; Monteith D. [3]; Rennie S. [3]; Rowland C [3]; Norris D. [4]; Hayes F. [4]; Jones L. [4]; Keane R. [5]; Holdsworth J. [5]; Boorman D. [4]; Rowe E. [4]; Hernandez Martin C. [1], Leaver D. [1]; Taylor P. [1]; Vincent K. [6]; Conolly C. [6]; Stroud A [7]; Vowles D. [7], Braban C.F. [1] and Sutton M.A. [1]

1) Centre for Ecology & Hydrology, Bush Estate, Edinburgh, EH26 0QB
2) Forestry Commission, Alice Holt Lodge, Farnham, GU10 4LF
3) Centre for Ecology & Hydrology, Lancaster, LA1 4AP
4) Centre for Ecology & Hydrology, Bangor, LL57 2UW
5) Natural England
6) Ricardo EE
7) Defra

A new integration of the UK's environmental networks to monitor air pollution impacts on terrestrial and freshwater ecosystems will be undertaken for the first time in 2019. This will report on air pollution impacts on a representative range of terrestrial and freshwater ecosystems, as specified under Article 9 of the revised National Emissions Ceilings Directive (NECD, 2016/2284). The main focus is on linking SO_X, NO_X, NH_3 and ground level ozone to acidification, eutrophication and ozone damage, complemented by modelling of the extent to which critical loads and levels are exceeded across the EU. Established long-term national networks such as the ICP, ECN, UWMN and UKEAP with relevant air quality and ecosystem measurements are central to delivering the evidence. Extensive data from field surveys such as the Countryside Surveys and National Plant Monitoring schemes are also important as they capture important changes across the country. The new UK network will report data to the European Environment Agency for the very first time this year. In collaboration with the data providers, a major data collection and synthesis exercise is presently under way to meet the 1st July reporting deadline. The integrated dataset will provide a baseline against which any changes and recovery in ecosystem response to emissions reductions under the NECD may be assessed, and provides a unique opportunity for developing integrated long-term ecosystem research in the UK and across Europe.

Poster Presentation

Wednesday 8th May

17:40 – 17:50

Effects of acidity on DOC in peatland soil extracts, pore water and surface litters

Pschenyckyj C. [1]; Clark J.M. [2]; Shaw E.J. [2]; Griffiths R.I. [3] and Evans C.D. [4]

1) Northumbria University, Newcastle upon Tyne

2) Forestry Commission, Alice Holt Lodge, Farnham, GU10 4LF

3) Centre for Ecology & Hydrology, Wallingford, OX10 8BB

4) Centre for Ecology & Hydrology, Bangor, LL57 2UW

Over the past 30-40 years, dissolved organic carbon (DOC) concentrations have increased in soil solutions and surface waters in many acid-sensitive areas of Europe and North America. This has been linked to recovery from acidification of soils in response to decreasing levels of atmospheric pollution. Evidence from radiocarbon dating suggests that DOC in surface waters is typically derived from recently photosynthesised organic matter such as plant litter and exudates, yet there is little information on the pH-sensitivity of organic matter solubility, or its decomposition, in litter layers. Based on data collected at four established field pH-manipulation experiments in upland areas of the United Kingdom, we examined the sources, composition and acid-sensitivity of DOC export from the litter and upper organic horizons of two major soil types, peats and peaty podzols. We found that litter generated nearly three times more DOC than the organic soil horizons, consistent with radiocarbon evidence that recently senesced plant material is a major source of DOC export. Yet DOC in litter had comparatively low specific ultraviolet light absorbance (SUVA254), suggesting that much of this material may be relatively biodegradable, and DOC concentrations in litter were found to be insensitive to pH change. By contrast, DOC in the upper organic soil horizons of both peats and podzols had a high SUVA254, implying that this material is relatively resistant to biodegradation and that the mobility is more sensitive to acidity, and DOC concentrations were strongly related to experimentally manipulated pH. We conceptualise the process of DOC export from these systems within this poster. Our results suggest that widely observed increases in surface water DOC in areas undergoing recovery from acidification are due primarily to physicochemically mediated controls on organic matter solubility, rather than biologically mediated changes in DOC production or decomposition.

Poster Presentation

Wednesday 8th May

17:50 – 18:00

Peering into the hidden world: photosynthetic microbes as functionally-significant indicators of peatland degradation and restoration

Burkitt A. [1]; Hughes C. [1]; Andersen R. [2]; Coupar A. [3]; Hancock M [4] and Payne R. [1]
1) University of York, York, UK
2) University of the Highlands and Islands
3) Scottish Natural Heritage
4) RSPB

Peatlands are an important ecosystem, providing a wide range of ecosystem services including carbon sequestration. Little is known about the diversity and functional role of photosynthetic microbes within these ecosystems. Changes in the communities and functions of these microbes may allow their use as indicators of degradation and the effectiveness of restoration in peatlands. I plan to use the long term air pollution experiment at Whim Bog to develop a suite of methods to investigate photosynthetic microbes in peatlands and their responses to environmental changes.

Thursday 9th May

09:00 – 10:00

Public engagement in air pollution impacts science: panel presentations and open forum discussion

Chair: Mark Sutton (Centre for Ecology & Hydrology, Edinburgh)

Panel: *Jenny Hawley (Plantlife), Felicity Hayes (CEH Bangor), Dave Reay (University of Edinburgh)*

Session 3. Public health & pollution mitigation.

Chair: Mat Heal (University of Edinburgh)

Thursday 9th May

10:00 – 10:30

The agriculture chapter of Scotland's climate change plan 2018-2032

McWhinnie K.
Scottish Government, lead policy official Agricultural Climate Change

Agriculture is a source of greenhouse gas emissions but it also contributes to climate change mitigation through areas that are not defined as agriculture through tree planting and renewable energy generation. Emissions reduction can be complex within agriculture due to their inherent nature within in food production, both livestock and plant. Through the agricultural chapter of the Scottish Climate Change Plan 2018 – 2032 our focus is on maximising efficiency, this can be achieved by taking a holistic approach to protecting and enhancing our soil, optimising land use, tackling livestock disease, utilising the latest technology, maximising input efficiency such as nitrogen based fertilisers and turning wastes into resources.

Session 3. Public health & pollution mitigation.

Chair: Mat Heal (University of Edinburgh)

Thursday 9th May

11:00 – 11:20

The influence of leaf traits and external factors to maximise particulate matter removal in urban areas

Corada K. [(1)]**; de Nazelle A.** [(1)] **and Bell N.** [(1)]

1) Imperial College London, London, UK

Green infrastructures (GI) improve air quality via deposition of particulate matter (PM) on leaves. The accumulation of PM on leaves depends on species-specific characteristics such as leaf shape, leaf size and leaf texture, and external factors such as location and weather parameters. Although these characteristics are vaguely known by researchers, they have not yet been systematically reviewed. The research aims are to identify the main leaf traits and external factors that can influence the PM removal and demonstrate the impact of considering these features to remove high PM concentrations.

Three systematic literature reviews were carried out. Street trees, green walls and green roofs were the GI chosen for analysis. Articles published between 2000 and 2018 in English journals were searched in scientific databases. Studies carried out in city sampling areas with real weather parameters (excluded computer modelling) and laboratory data to measure PM concentrations on leaves which identified the effectiveness of leaf traits/external factors for removing PM were the selection criteria used.

The results showed, despite a lack of consensus on optimal species selection for PM removal, some leaf traits stand out as being most helpful to maximise the PM removal such as a high number of trichome, roughness, needle leaf shape and evergreen species. The vegetation location and precipitation, also, should be considered to maximise the PM removal effect by vegetation.

This research summarises for the first time what is known from the literature about leaf traits and external factors that can influence the PM removal. While other elements, such as pollen counts, BVOCs emissions and street morphology, must also be considered, this research contributes to informed decision-making for more health-promoting urban environments through the optimisation of benefits expected from GI. Future research will examine the specific location for green species in order to remove, efficiently, high concentrations of PM.

Session 3. Public health & pollution mitigation.

Chair: Mat Heal (University of Edinburgh)

Thursday 9th May

11:20 – 11:40

Relationships between occurrence of epiphytic lichens and atmospheric NO_x and SO_2 concentrations – urban case studies from Helsinki, southern Finland

Manninen S. [1]; Vierikko K. [1] and Komppula B. [2]

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2) Finnish Meteorological Institute, P.O. Box 503, FI-00101 Helsinki, Finland

Acidophytic macro lichens growing on tree trunks are known to be sensitive to both sulphur (S) and nitrogen (N) deposition. The role of SO_2 as a factor affecting lichens negatively is considered minor today in most of the cities in Europe and North America due to reduced emissions, whereas the emissions of NH_3 from agricultural activities and those of NO_x from traffic and energy production still contribute to high deposition of reactive N compounds. We scored occurrence of epiphytic lichens on Scots pine (Pinus sylvestris) trunks in forests (38 sites) and on the trunks of deciduous trees (Acer, Betula, Fraxinus, Populus, Quercus, Sorbus or Tilia) in parks (12 sites) in the Helsinki metropolitan area, where NO_2 concentrations range from 4 to > 50 µg m^{-3} yr^{-1} and SO_2 concentrations from 1 to 4 µg m^{-3} yr^{-1}. Lichen N and carbon (C) contents were also analysed from samples collected from Scots pine trunks. The number of acidophytic (oligotrophic) species on Scots pine trunks was negatively correlated with ambient NO_2 and SO_2 concentrations. The frequency of most acidophytes also decreased especially with increasing NO_2 concentration, while that of green algae + Scoliciosporum chlorococcum increased. The total N content of Hypogymnia physodes increased with increasing bark ammonium (NH_{4+}-N) concentration and the C:N ratio of the species decreased both with increasing air NO_2 concentration and bark NH_{4+}-N concentration. The total frequency and number of nitrophytic species, or those of oligotrophs, on deciduous tree trunks were not correlated with ambient NO_2 or NO_x concentrations, despite correlations at p <0.1 in the case of some individual species. However, the total frequency of nitrophytes and the number of nitrophytic species on Q. robur trunks decreased with increasing ambient SO_2 concentrations. Critical levels for NO_2 and SO_2 will be discussed.

Session 3. Public health & pollution mitigation.

Chair: Mat Heal (University of Edinburgh)

Thursday 9th May

11:40 – 12:00

Measures for mitigating ammonia: assessment of the effects of Rural Development Programme for England (RDPE) environmental land management schemes on air quality

Carnell E.J. [1]; Misselbrook T.H. [2]; Tomlinson S.J. [3]; Thomas I.N. [1]; Sawicka K. [4]; Rowe E. [4]; Sutton M.A. [1] and Dragosits U. [1]

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4) Centre for Ecology & Hydrology, Bangor, LL57 2UW

The effects of atmospheric nitrogen (N) deposition are evident in terrestrial ecosystems worldwide, with eutrophication and acidification leading to significant changes in species composition. In recent decades, policy interventions in the UK have led to substantial reductions in N deposition from nitrogen oxide emissions. By contrast however, ammonia (NH_3) emissions from agriculture have slightly increased over the past decade and UK agri-environment schemes have typically focused on promoting biodiversity and improving water quality, rather than tackling issues causing N deposition.

This study aimed to assess the NH_3 mitigation potential of all measures made available under existing agri-environment schemes in England. Of ~800 measures assessed in the study, 16% were considered to provide a quantifiable benefit in terms of NH_3 reductions. As existing schemes were, with very few exceptions, not targeted at NH_3, co-benefits estimated were relatively small overall. The main exceptions under current (i.e. early 2018) schemes and grants are the Farming Ammonia Reduction Grant scheme (FARG) and the Countryside Productivity Scheme (CPS), where tailored measures such as covering slurry stores and enabling low-emission land spreading of slurries were estimated to be very effective.

Government strategies to improve air quality in the UK (e.g. A Green Future: Our 25 Year Plan to Improve the Environment and Defra's Clean Air Strategy) are increasingly ambitious and with future environmental land management schemes currently in development, the findings of this study suggest that measures need to be specifically designed to reduce NH_3 in order to achieve substantial emission reductions.

This project was funded by Natural England with support from the Rural Development Programme for England, for which Defra is the Managing Authority, part financed by the European Agricultural Fund for Rural Development: Europe investing in rural areas.

Session 3. Public health & pollution mitigation.

Chair: Mat Heal (University of Edinburgh)

Thursday 9th May

12:00 – 12:20

Assessing avoided air quality-induced premature mortality from agricultural interventions

Thakrar S. [(1)]**; Hill J.D.** [(1)]**; Tessum C.W.** [(2)]**; Goodkind A.L.** [(3)]**; Tilman G.D.** [(1)]**; Polasky S.** [(1)]**; Domingo N.** [(1)]**; Colgan K.** [(1)]**; Marshall J.D.** [(1)]**; Clark M.** [(4)]**; Smith T.** [(1)]**; Hunt N.D.** [(1)] **and Mullins K.A.** [(5)]

1) University of Minnesota, Minneapolis, U.S.A.
2) University of Washington, Seattle, U.S.A.
3) University of New Mexico, Albuquerque, U.S.A.
4) University of Oxford, Oxford, U.K.
5) Lumina Decision Systems

Session 4. Modelling of pollution emissions, deposition, and impacts.

Chair: Rob Kinnersley (Environment Agency)

Thursday 9th May

13:30 – 13:50

Dispersion modelling of ammonia emissions from vehicles and prediction of air quality impacts at designated sites

Virdo J. [1]; Coulon A. [1]; Adams T. [1]; Rose R. [1] and Carslaw D. [1]

1) Ricardo Energy & Environment, The Gemini Building, Fermi Avenue, Harwell, Didcot, OX11 0QR

This presentation will draw on recent dispersion modelling studies undertaken in support of Habitats Regulations Assessments (HRAs) for strategic and local development plans. These studies assessed the impacts of increased vehicle emissions on designated sites in terms of the airborne concentrations of oxides of nitrogen (NO_x) and ammonia (NH_3), as well as the deposition of acid and nutrient nitrogen. While there are sources of uncertainty involved with any type of dispersion modelling, the process for modelling NH_3 vehicle emissions poses some additional challenges. Firstly, the emission factors describing the amount of NH_3 emitted by vehicles have not been studied to the same extent as emission factors for other vehicle pollutants, such as NO_x or particulate matter (PM_{10}, $PM_{2.5}$), and there is generally less confidence in the field regarding the accuracy of the existing emission factors. Secondly, while it is standard practice to compare dispersion model results with real-world monitoring data in order to verify and, if necessary, adjust the model's performance, there are relatively few monitoring sites for NH_3 with which to compare model results. As a typical example, the model domain for a local plan (i.e., the area covered by a single local authority) might contain 10 to 40 NO_2 monitoring locations, 1 to 5 PM_{10} monitoring locations, and just 1 or no NH_3 monitoring locations. This presentation will consider the approaches that are available for modelling vehicle emissions of NH_3, given these sources of uncertainty, and the overall impact these might have on the results of an HRA study. The presentation will also discuss some recent work undertaken by Ricardo Energy & Environment in addressing these two sources of uncertainty, in supporting the HRA for the update to a local authority development plan in an area with multiple European sites.

Session 4. Modelling of pollution emissions, deposition, and impacts.

Chair: Rob Kinnersley (Environment Agency)

Thursday 9th May

13:50 – 14:10

Modelling the concentration of ammonia and deposition of nitrogen in the UK and exceedance of critical loads and levels

Dore A.J.; Smith R.I. (1); Rowe E.C. (2); Sawicka K. (2); Flynn L. (1); Cameron D. (1); Vieno M. (1); Fowler D. (1); Tang Y.S. (1); Braban C. (1); Sutton M.A. (1); Dragosits U. (1) and Reis S. (1)

1) Centre for Ecology & Hydrology, Bush Estate, Edinburgh, EH26 0QB

2) Centre for Ecology & Hydrology, Bangor, LL57 2UW

Critical loads and levels are threshold values for atmospheric deposition and concentration respectively above which harmful effects may occur to natural ecosystems. The concentration of ammonia in the atmosphere and deposition of nitrogen to the surface was calculated with the FRAME atmospheric chemistry transport model. Nitrogen deposition was compared with CBED data which uses an inferential approach based upon the interpolation of measured concentrations in air and precipitation.

The FRAME model was found to obtain satisfactory agreement with measurements of annually averaged NH_3 concentration and precipitation concentrations from the UK National Monitoring Networks. The results of the model showed that the 1 μg m^{-3} critical level for NH_3 (for sensitive species) was exceeded across 60 % of the UK land area and the 3 μg m^{-3} critical level (for all other species) was exceeded for >3 % of the land area. CBED generally gave higher estimates of both wet and dry deposition than FRAME. Comparison of the area of ecosystems with exceedance of critical loads for nitrogen deposition calculated with the two different deposition data sets for the three year average 2010-2012 was 63 % for CBED and 42 % for FRAME.

The nitrogen deposition and exceedance of the ammonia critical level and critical load for nitrogen deposition for the four regions of the UK are presented and uncertainty in estimates of processes driving critical load exceedance in the uplands (wet deposition) and in agricultural areas (NH_3 dry deposition) are discussed.

Session 4. Modelling of pollution emissions, deposition, and impacts.

Chair: Rob Kinnersley (Environment Agency)

Thursday 9th May

14:10 – 14:30

AmmoniaN2K: Ireland, ammonia and Natura 2000 sites

Kelleghan D. (1); Hayes, E.T. (2); Everard, M. (2) and Curran, T. P. (1)

1) University of the West of England, U.K.

2) University College Dublin, Dublin, Ireland

The Republic of Ireland has a strong tradition of agricultural production, which is the primary source of atmospheric ammonia across the European Union. As an EU member state Ireland is beholden to a number of EU directives which require the protection of sensitive habitats and the reduction of ammonia emissions. Reported emissions for Ireland in 2016 exceed the limit set for ammonia, which without additional abatement techniques is likely to continue increasing due to expanding livestock numbers under Food Wise 2025. Mapping Ammonia Risk on Sensitive Habitats (MARSH) modelling conducted by the AmmoniaN2K project considered all publicly available sources of atmospheric ammonia in Ireland. This highlighted c. 81 % of Natura 2000 sites may exceed the UNECE annual critical level of 1 µg NH_3 m^{-3}, at which impacts occur on lichen and moss species. And 6 % of Natura 2000 sites may potentially exceed the UNECE annual critical level of 3 µg NH_3 m^{-3}, which impacts higher plants. The critical level of 3 µg NH_3 m-3 has an uncertainty of 2 – 4 µg NH_3 m^{-3}, where impacts can occur at 2 µg NH_3 m^{-3}, 34.3% of Natura 2000 sites may exceed this concentration. Additionally, the AmmoniaN2K project has identified an additional 760 below Industrial Emission Directive threshold intensive agriculture units in the Republic of Ireland. The contribution of such intensive houses to a Natura 2000 site could potentially have a higher impact than large licensed farm's further away. Contributions from intensive agriculture units to impacts on Natura 2000 sites needs to be considered in combination with ambient concentrations from Ireland's extensive, growing dairy and beef industry in addition to slurry spreading. The AmmoniaN2K project has identified a number of gaps currently limiting Ireland's ability to adequately comply with European Directives, which need to be urgently addressed.

Session 4. Modelling of pollution emissions, deposition, and impacts.

Chair: Rob Kinnersley (Environment Agency)

Thursday 9th May

14:30 – 14:50

Impact of ammonia emission reduction scenarios on predicted N deposition and effects at designated sites in Northern Ireland

Dragosits U. [1]; Carnell E.J. [1]; Tomlinson S.J. [2]; Dore A.J. [1]; Thomas I.N. [1]; Rowe E. [3]; Sawicka K. [3]; Misselbrook T.H. [4]; McIlroy J. [5] and Carolan R. [5]

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Northern Ireland's sensitive habitats and designated sites receive substantial atmospheric nitrogen (N) input from local, regional and transboundary sources of ammonia (NH_3, mainly from agricultural sources) and nitrogen oxides (NO_x, mainly from combustion sources, including transport/industry). In recent decades, policy interventions in the UK have led to substantial reductions in NO_x emissions. However, NH_3 emissions from agriculture have decreased much less, with some sources increasing over recent years.

This study assessed the potential impact of key mitigation measures, including low-emission manure spreading, improvements to livestock housing and diet, slurry store covers, extended cattle grazing season, etc., at different levels of ambition (25-100% implementation). The greatest emission reductions were associated with slurry application. Individual measures (with implementation levels deemed potentially achievable) were combined into scenario options, with combinations giving reductions of 13-26% compared to a 2016 baseline. One scenario was selected for high-resolution atmospheric dispersion/deposition modelling and assessment of critical loads and critical levels exceedance for nutrient N deposition. Overall, NH_3 emissions were estimated to reduce by 24% (1-10 kg ha^{-1} yr^{-1} over most source areas, but >10 in some areas and <1 in remote areas), with average concentration reductions of >0.1-1 µg NH_3 m^{-3} (>1 in highest concentration areas, <0.1 away from sources/mitigation). N deposition to low-growing semi-natural habitats (e.g. bogs) was estimated to decrease substantially, by >1-8 kg N ha^{-1} yr^{-1}, and Accumulated Average Exceedance (AAE) reduced by 2 kg N ha^{-1} yr^{-1} for SACs on average (3 kg N ha^{-1} yr^{-1} for ASSIs). These are all substantial reductions from a very high baseline. However many sites remain in exceedance of their critical loads, and an approach including additional spatially targeted measures, optimising mitigation where most needed, is likely to achieve better outcomes for designated sites at a lower overall cost than region-wide only measures.