

# Nitrogen Deposition, Critical Loads and Biodiversity

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## POSTER ABSTRACTS *(at 6 November 2009)*

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**Nitrogen Systems: Policy-oriented Integrated Research and Education (NSPIRE) National Science Foundation Integrated Graduate Education Research Training Grant (IGERT)**

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One of the most difficult yet critical aspects of environmental graduate training is placing research conducted at local and regional scales in a global context and conveying this information to land managers and policy makers. This is exemplified by one of the greatest science and engineering challenges of the 21<sup>st</sup>-century: understanding the complex interactions and the impacts of environmental nitrogen in atmospheric, terrestrial, and aquatic hydrologic systems. Discussions with leaders in government and industry increasingly elicit pleas for students who have not only a strong science foundation, but also have the necessary skills to communicate and work with policy makers. Development of these skills requires first *gaining an interdisciplinary perspective of N cycle processes and the ability to place this in a global context* and second *understanding how to communicate and use scientific research to inform and guide public policy*. Our *vision* is of a novel graduate program that integrates training across the range of disciplines inherent in the nitrogen cycle, including atmospheric science, hydrology, ecosystem ecology, and agriculture, coupled with experiential learning of public policy related to environmental N. This integrative program will produce students better prepared to meet societal needs than current disciplinary approaches. **Thus, our goal is to produce graduates who have a broad and rigorous training in nitrogen cycling who seamlessly integrate nitrogen cycle science for effective communication with public policy makers.** The key features of the program include the following

- N Cycling in the Earth System—interdisciplinary overview of N system science
- Systems dynamic modeling course—introduction to systems modeling applied to N system science and policy
- Policy studio course—immersion in a novel studio course covering policy and regulatory procedures, policy issues, interaction with stakeholders, and development of teamwork and communication skills
- N methods workshop—introduction to multi-phase methods for measuring N in the environment
- Collaborative, team oriented dissertation research projects focused on measurement, modeling and analyses of N cycling in the environment
- Capstone Policy Internship—paid internship for each NSPIRE student placed with a policy-oriented agency or organization either in the U.S. or internationally.

Students who are accepted into the NSPIRE program and make adequate progress on their degree, receive up to two years of support including a \$30,000/year stipend, a tuition waiver and support for a national or international 3 mo policy internship.

For information: <http://igert.nspire.wsu.edu>

**N fertilisation and plant communities in calcareous dry grasslands in southern France: when short-term environmental change induce long-term plant community changes**

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In the region of the “Causse du Larzac”, part of the regional park of Grand Causses, 300 hectares of Causse have been restored since the 1970’s for permanent grazing by a flock of sheep. Permanent monitoring of vegetation was performed since that time in several management contexts (abandonment, fertilized grasslands and non-fertilized grasslands). From the last 2009 survey, we present the changes in species composition and assemblages that have occurred in the N fertilized plots since 1978. Although changes in environmental conditions have been much contrasted in these plots (from 0 to 80kg.ha-1.y-1 of nitrogen for 30 years), changes in plant communities were very progressive, detectable after few years, but still perceptible after 25 years of continuous fertilisation. We discuss our results in the context of N atmospheric deposition and critical loads as regards several points: (1) our ability to detect significant biodiversity changes after long periods of low input of Nitrogen in such ecosystems; (2) the possible interactions with climate events to explain species turnover during these long term changes; (3) the thresholds in community changes due to such nitrogen-climate interaction.

## **Bulk Total Nitrogen Deposition Within Litoral-Highlands County, Croatia, 1996-2008**

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The previous analyses of precipitation within the County area (1) pointed out a specific orography playing an important role in deposition of acidic species: local washout of the atmosphere in the wider urban area of Rijeka, an industrialized city within the Rijeka bay, and higher precipitation depth in the background Highlands District. The paper deals with the time trends in bulk total nitrogen ( $\text{NH}_4^+ + \text{NO}_3^-$ ) deposition at four selected sites: remote Site 1, located on the island of Cres, 100 km south from the urban and industrial Site 2 (Rijeka) at the bottom of the Rijeka bay, while Site 3 is a settlement and Site 4 a resort site located in the highlands area, claimed to suffer from acidic deposition. The lowest deposition of total nitrogen is obtained at the remote Site 1 ( $400\text{-}800 \text{ eq ha}^{-1} \text{ y}^{-1}$ ), while higher values were obtained at urban Site 2 ( $540\text{-}1286 \text{ eq ha}^{-1} \text{ y}^{-1}$ ) due to the local washout of the atmosphere, and highlands Site 3 ( $733\text{-}1384 \text{ eq ha}^{-1} \text{ y}^{-1}$ ) and 4 ( $402\text{-}1799 \text{ eq ha}^{-1} \text{ y}^{-1}$ ) because of higher precipitation depth. The bulk deposition of total nitrogen at the highlands Sites 3 and 4 is below the critical loads for the corresponding soil-vegetation type ( $\text{CL} = 4603 \text{ eq ha}^{-1} \text{ y}^{-1}$ ). In the period 1996-2003 the  $\text{N-NH}_4^+$  participated by  $2/3$  to total-N deposition at all sites, but since 2004 this ratio diminished down to  $1/2$  due to the increase in  $\text{N-NO}_3^-$  deposition. The compensation of  $\text{N-NH}_4^+$  declining trend with  $\text{N-NO}_3^-$  increase results in practically no trend in total - N deposition at all Sites, except Site 4, where the increase is due to  $\text{N-NO}_3^-$  deposition with no significant decline in  $\text{N-NH}_4^+$ .

- (1) Alebic-Juretić A.: Airborne ammonia and ammonium within the Northern Adriatic area, Croatia, *Environmental Pollution*, 154(2008) 349-447

## **Empirical and Modeling Approaches to Setting Critical Loads for N Deposition in Southern California Shrublands**

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Southern California deserts and coastal sage scrub (CSS) are undergoing vegetation-type conversion to exotic annual grassland, especially in regions downwind of urban areas that receive high N, primarily as dry deposition. To determine critical loads (CL) of N that cause negative impacts, we measured plant and soil responses along N deposition gradients, fertilized vegetation at different N levels, and used biomass production output from the DayCent model. N deposition gradients were identified from the CMAQ model and compared with measured N deposition values. CSS receives N deposition as high as 30 kg ha<sup>-1</sup> yr<sup>-1</sup>, while the desert has levels up to 16 kg ha<sup>-1</sup> yr<sup>-1</sup>. Unlike more mesic ecosystems where critical loads are determined by changes in soil chemistry or biogeochemistry, these arid and semiarid ecosystems are subject to increases in exotic species production, loss of native species diversity, and increased fire risk at relatively low CL's. For instance, a gradient survey in CSS showed that exotic grass increased and native plant species and arbuscular mycorrhizal species richness declined by almost 50% above 10 kg N ha<sup>-1</sup> yr<sup>-1</sup>. Fertilization studies in desert creosote bush scrub showed a significant increase in exotic species biomass with 5 kg N ha<sup>-1</sup> yr<sup>-1</sup> in a wet year, and biomass output from DayCent modeling indicated an increased fire risk from exotic grasses with 1 T per ha production during years with moderate to high precipitation at 3-8 kg N ha<sup>-1</sup> yr<sup>-1</sup>. The difference in CL between desert and CSS are related to the different criteria used (diversity loss in CSS, productivity and fire risk in desert) as well as responsiveness of native vs. exotic plant species to N and the degree to which precipitation and soil N limits plant growth in the two vegetation types.

## Nitrogen addition disrupts plant-soil interactions in a pristine old-growth forest in Patagonia, Argentina

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The amount of biological reactive nitrogen has doubled globally in the last century and biodiversity has declined worldwide as a result of human activities. Given the co-occurring changes in nitrogen (N) availability and plant diversity, it is crucial to understand their interactive effects to predict ecosystem response to global change. In particular, evaluating which components of biodiversity have an impact in ecosystem functioning and how they interact with N deposition would give us a better understanding of the mechanisms by which environmental change can operate in natural ecosystems. We evaluated the interactive effects of nitrogen deposition on plant-soil interactions on litter decomposition in an undisturbed old-growth southern beech forest in Patagonia, Argentina. We identified ‘tree triangles’ of each of the three dominant *Nothofagus* species: *Nothofagus dombeyi* (evergreen); *Nothofagus obliqua* (deciduous); and *Nothofagus nervosa* (deciduous), where the intersection of these overstorey canopy trees contributed litter to the forest floor creating a gradient of specific conditions unique to each species. In a factorial experiment of tree triangles, litter type and nitrogen addition, we had two nitrogen addition treatments (0 and 80 kg ha<sup>-1</sup> y<sup>-1</sup>) applied throughout the one-year incubation in the form of slow-release urea. Fresh litter collected from each of the three species was placed in 2 mm mesh litterbags in each of the triangles of their own species (*in situ*) and in the other two species (*ex situ*) with and without nitrogen addition, with five replicates of each treatment. In all tree triangles and in all litter types, nitrogen addition significantly and consistently increased litter decomposition ( $P < 0.0001$ ), ranging in magnitude from 20% to 70%. In addition, nitrogen addition significantly increased nitrogen release from *Nothofagus* spp. litter ( $P < 0.0001$ ). These results are in contrast to the inhibitory effect of nitrogen addition observed in many Northern Hemisphere forests. In addition to these direct effects, nitrogen addition disrupted the demonstrated home-field advantage effects of litter decomposition in this ecosystem (Vivanco and Austin 2008), where litter decomposed significantly faster in its site of origin than in microsites of other tree species. With nitrogen addition, the home-field advantage for litter in its site of origin was erased, with a complete elimination of tree triangle (microsite) effects on litter decomposition. These results demonstrate the range of response in litter decomposition to nitrogen deposition in pristine forests, and additionally highlight the vulnerability of plant-soil interactions to disturbance from global change impacts in natural terrestrial ecosystems.

Vivanco L, Austin AT (2008) Tree species identity alters litter decomposition through long-term plant and soil interactions in a natural forest ecosystem in Patagonia, Argentina. *Journal of Ecology* 96:727-736

## **Biomass Burning in Southeast Asia and Its Impact on Aquatic Ecosystems**

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Atmospheric nutrients have recently gained increased attention as a significant additional source of new nitrogen (N) and phosphorus (P) loading to aquatic ecosystems in tropical regions. The effect of atmospheric nutrients on marine productivity depends on the biological availability of both inorganic and organic N and P forms. Biomass burning is an important source of air pollutants, especially in Southeast Asia (SEA), where the smoke haze phenomenon is a major and recurring problem. Due to recurring forest and peat fires in SEA on a large scale and the abundant rainfall in this tropical region, atmospheric fallout of nutrients, through dry and wet deposition, to aquatic ecosystems is thought to be significant. Atmospheric fluxes of nutrients could contribute a substantial fraction of dissolved N and P species to the euphotic zone, and enhance primary production when nutrients are limited, leading to eutrophication. Currently, limited experimental data sets on atmospheric deposition of N and P species exist for tropical ecosystems in the SEA region. We have recently carried out a series of field and modeling studies to quantify the atmospheric deposition of nutrients such as inorganic and organic forms of N and P during non-hazy and hazy days and to evaluate their effects on the surface water quality. It was observed that the average concentrations of nutrients in aerosols and rainwater increased by a factor of 3 to 8 on hazy days as compared to those during non-hazy days. The occurrences of increased atmospheric deposition of nutrients during haze episodes were found to have negative consequences on receiving aquatic ecosystems with cascading impacts on water quality, and trophic and biogeochemical alterations.

## Examples of alterations in ecosystem stoichiometry and ecosystem-scale effects from N deposition

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Nitrogen deposition and the combination of nitrogen and sulfur deposition in many regions of the world are disrupting biogeochemical cycles and stoichiometric ratios of nutrients. Ecosystem responses can be long-lived. They range from subtle to dramatic, and can either be characterized as eutrophication or acidification responses. We present examples from our research and also from other published studies to illustrate how the changing ratios of nutrients have affected ecosystem structure and food webs. Ongoing depletion of exchangeable soil base cations and continued deposition of inorganic nitrogen has contributed to long-term sugar maple decline in northeastern North America. Loss of soil base cations is also hypothesized to have contributed to the decline in wood thrush numbers due to reproductive failure, since the abundance of calcium-rich prey food (gastropods, isopods, and myriapods) has decreased with soil acidification, making eggshells brittle and subject to breakage. In small freshwater boreal lakes of acidified regions the loss of calcium-rich *Daphnia* spp. was concurrent with reduced inputs of calcium from soil leaching. Calcium-rich daphniids are some of the most abundant zooplankton in many lake systems and their loss will affect food webs. In the Colorado Front Range, where N deposition is higher by an order of magnitude than background values, nitrogen deposition has shifted diatom communities from ultra-oligotrophic assemblages to those dominated now by two species: *Asterionella formosa* and *Fragilaria crotonensis*. As N deposition has increased, in Colorado as well as in Scandinavia, the stoichiometric ratio of nitrogen to phosphorus has shifted such that phytoplankton growth is now P-limited, whereas it was initially N-limited in unimpacted lakes.

## Source Attribution of Eutrophying and Acidifying Pollutants on the UK Natura 2000 network

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Industrial processes may exert a range of different types of impacts on Natura 2000 sites in Europe. The combustion of fossil fuels, in particular, may release large quantities of sulphur and oxidised nitrogen which can then be dispersed and deposited on designated sites, leading to acidification and eutrophication effects. However, deposition of sulphur and nitrogen may also arise as a result of releases from other sources such as transport, domestic or commercial activities, the long-range transport of sulphur and oxidised nitrogen or more locally as a result of ammonia released from agricultural activities. The output from this research provides useful policy insight into the key sources that are contributing to exceedance of site-relevant critical loads for N and acid deposition. Understanding the relative contributions of these different sources can help policy makers decide on the most effective remedial actions that need to be taken to reduce deposition.

The FRAME (Fine Resolution Multi-pollutant Exchange) model, incorporating emission point sources and sectors, was used to provide footprints of nitrogen and sulphur deposition across the UK from 160 sources or groups of sources. The modelling was carried out for the most recently available emissions (2005) and a future emissions scenario for 2020. Using ArcGIS the footprint deposition files were superimposed over the Natura 2000 network boundaries in conjunction with the relevant critical loads for the designated features at each site. The resulting matrix of source attribution by sector, and exceedance statistics for each site, provide a status of the whole UK's Natura 2000 network.

Preliminary results have shown that for 2005 80% of Special Areas of Conservation (SACs) in the UK have at least one feature exceeding their minimum nitrogen critical load, while the figure for acidity exceedance is 75%. By 2020, the percentage of SACs exceeding nitrogen and acidity critical loads is predicted to reduce to 74% and 62% respectively. The scenario for 2020 predicts substantial emission reductions for the major coal fired power stations (reductions of 80% for NO<sub>x</sub> and 90% for SO<sub>x</sub> from 2005). However, despite this, there is not a significant decline in numbers of sites exceeding the critical loads. This is largely because the biggest contribution to exceedance comes from agricultural sources which are predicted to have small emission reductions from 2005 to 2020. Further analysis will look into this in more detail focussing on the spatial importance of source location and site 'nearness' to a source, and also examine the relationship between dry and wet deposition by source sector, as well as oxidised and reduced forms of N.

## **Nitrogen deposition as a threat to the world's protected areas under the Convention on Biological Diversity (CBD)**

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It is now well established that nitrogen deposition is a threat to biodiversity in Europe and North America and an increasing number of studies, using the best available nitrogen deposition estimates from global models, are showing that it is also an increasing threat to biodiversity in other parts of the world. This paper focuses for the first time on overlaying the World Commission on Protected Areas (WCPA)/ International Union for Conservation of Nature (IUCN) Protected Areas (PAs) with global estimates of nitrogen deposition. It shows the protected areas under the CBD where nitrogen deposition estimates exceed 10 kg N/ha/yr and considers what proportion of these areas are either World Wildlife Fund (WWF) G200 ecoregions or Biodiversity Hotspots to give an indication of the potential sensitivity of the protected areas to nitrogen deposition and an estimate of the number of endemic plant species in them. The paper will show overlays for year 2000 data as a baseline and then for 2030 based on a scenario according to 'current legislation'.

Finally, the best currently available information on ecosystem sensitivity for different biomes around the world is used to assess the potential for effects and thresholds for terrestrial plant diversity protection across a latitudinal range of main categories of ecosystems, from Arctic and boreal systems to tropical forests.

**Plant and soil diversity in boreal and temperate Eastern European old-growth forests with high level of soil fertility and ecosystem productivity**

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We have studied vegetation and soil in old-growth forests in European Russia. More than 30 local areas (forestry and natural reserves) have been investigated. A detailed observation of old-growth spruce and spruce-fir forests in North-West and North-East of European Russia showed that the highest plant biomass and the richest soil correlate with the highest plant diversity. It was observed in spruce and spruce-fir forests with domination of tall herbs in ground vegetation and with well expressed tree fall mosaics: plants of different ecological properties occupied the various microsites formed in result of tree falls with uprooting. These forests were found in river valleys as well as at watersheds. Tree fire scorches were absent and carbons in soil were met very rarely and deeply while fire traces were met everywhere in all other boreal forests. We concluded that tall herb spruce and spruce-fir forests with well expressed tree-fall mosaics are the refugiums of boreal forest, which store practically total boreal forest biodiversity. Development of such forests is possible only under the long-term absence of fire and the presence of all plant species seeds from the regional species pool. However, we have not observed the similar correlations between plant diversity and richest soil in the studied old-growth temperate forests. Gaps in knowledge and filed data are discussed.

## **How much is too much? N critical loads and eutrophication and acidification in oligotrophic ecosystems**

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Exposure to progressive inputs of anthropogenic N deposition elicits a series of changes in terrestrial ecosystems associated with both enhancement and inhibition of biogeochemical processes. Initially, growth of plants is enhanced (eutrophication) as the constraint of N supply on NPP is relaxed, sometimes associated with altered dominance of species and gains or losses in diversity. Higher rates of nitrification and leaching of base cations eventually lead to acidification of soils, increases in soluble aluminum, and potentially to decreases in rates of NPP. Increasing evidence suggests that eutrophication may occur to a limited extent in some oligotrophic ecosystems, requiring more sensitive critical load indicators.

Experiments in alpine ecosystems of several mountain ranges, characterized by low rates of N cycling, a flora adapted to low N supply, and acidic granitic parent material, indicate that enhancement of NPP is modest, and the potential for soil acidification is high. At the Niwot Ridge USA-LTER site (ambient deposition 8 kg N/ha/yr) and Rocky Mountain National Park (ambient deposition 4 kg N/ha/yr), increases in NPP are modest (< 10 % increase, lower than interannual variability) with N additions. Soils at Niwot Ridge lose base cations, have increases in extractable aluminum, and significant decreases in pH after 8 years of elevated N inputs (> 20 kg N/ha/year). At an ILTER site in the Western Tatra Mountains of Slovakia, which historically received N deposition > 20 kg N/ha/yr, rates of NPP decreases with increases in N supply, associated with loss of nutrient cations and increases in soluble iron. Taken together, the results from these and other studies suggest minimal biological buffering in alpine ecosystems, and the potential for a rapid transition from minimal eutrophication to acidification.

## **The impact of the form, source and concentration of nitrogen pollution in Mediterranean streams: a biomonitoring system using an aquatic moss**

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Two key sources of reactive N production are produced in intensive agriculture (NH<sub>3</sub> and NH<sub>4</sub><sup>+</sup>). Although the former is an essential element for life, in high concentrations could lead to eutrophication and loss of biodiversity as a consequence. The Millennium Ecosystem Assessment report for Portugal concluded that there are serious problems with water quality in Portugal. Several rivers are heavily polluted from industrial, farming and domestic activities, with eutrophication occurring in some of them. At the same time it identified riparian ecosystems as the most threatened in Portugal, calling attention to the serious problem of their water quality. In 2007 the Portuguese National Institute for Water (INAG) reported that more than 40% of Portuguese rivers are of bad or poor quality status (SNIRH, 2008). In rural areas one of the main causes of eutrophication is agricultural activity (both intensive and extensive), primarily livestock production. At the policy level, the Water Framework Directive (WFD) recommends the adoption of ecological approaches to water quality monitoring, approaching Surface Water Management in a holistic and ecologically integrated manner, privileging ecological functioning and integrated measures over strictly punctual physico-chemical parameters. There are several indicator organisms and communities that have been used to evaluate water quality by means of their biodiversity or through measures of some physiological impact on these indicator organisms. Aquatic bryophytes have been used for long time and in several countries as biomonitors of heavy metal water pollution. Recently, this biomonitor has been used for assessing inorganic N water pollution. Here we show how an aquatic moss transplanted to several streams (40 sampling sites) in two Natura 2000 areas can be used as a biomonitor of both NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> pollution. One site is dominated by livestock production whereas the other is dominated by rice fields. Moreover, we analyzed its nitrogen isotope composition to track its nitrogen source. The results from the form, source and concentration of NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> in the different areas will be related to both the surrounding land-use and the integrity biotic index of the riparian vegetation QBR for Mediterranean areas. Discussion concerning the distance of influence of each land-use to the nitrogen concentration in the streams together with thresholds for the impact of N in the riparian integrity will be presented.

## Patterns of soil O<sub>2</sub> drive denitrification in riparian ecosystems

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Denitrification, the anaerobic reduction of nitrate to nitrogen gases, can be an important “sink” for atmospheric N deposition. Unfortunately, ecosystem-scale estimates of denitrification are rare and poorly constrained. Soil O<sub>2</sub> is an important controller of denitrification, but is rarely measured. We hypothesized that continuous *in situ* measurements of soil O<sub>2</sub> could be a powerful tool for spatial and temporal scaling of denitrification rates and could thus improve ecosystem-scale estimates of this process. From limited field studies, we know that soil O<sub>2</sub> can range from 0-20% within a given ecosystem. Furthermore, detailed microsensor studies of complex soil aggregates suggest this same range (0-20%) can exist within the span of a few millimeters. In this study, we explored: 1) how soil O<sub>2</sub> varied seasonally in wet and dry riparian areas, 2) how this variation in soil O<sub>2</sub> affected denitrification rates, and 3) the potential for using continuous soil O<sub>2</sub> measurements for temporal scaling of point measurements to improve estimates of annual and seasonal denitrification fluxes. We collected continuous measurements of soil O<sub>2</sub> in “wet” and “dry” riparian soils and measured denitrification by removing the background N<sub>2</sub> headspace from intact soil cores, replacing it with a helium/oxygen mixture, and measuring N<sub>2</sub> production over time. We found that soil O<sub>2</sub> varied considerably in the “wet” site, ranging from anoxic conditions when the water table was high in late spring to completely oxic conditions (20% O<sub>2</sub>) during summer when the water table dropped. In contrast, the dry site remained at 20% nearly year round. Bulk soil O<sub>2</sub> strongly controlled denitrification rates in the wet site, but not in the dry site, which only denitrified when nitrate was added. By combining the continuous O<sub>2</sub> measurements with empirical denitrification-O<sub>2</sub> functional relationships, we estimated denitrification to be 13.8 kg N ha<sup>-1</sup> season<sup>-1</sup> in the “wet” site and at or below detection limits in the “dry” site (established by comparison to autoclaved control cores). The combination of continuous soil O<sub>2</sub> data and a simple denitrification-O<sub>2</sub> relationship provided a powerful tool for temporal scaling of this notoriously difficult-to-scale process. Therefore, measurements of O<sub>2</sub>, denitrification and nitrate response experiments may help to identify real hot and cold spots for this important sink for atmospheric N deposition in terrestrial landscapes.

## Factors influencing NH<sub>3</sub> deposition and uptake by plants – other gases

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What happens to NH<sub>3</sub> transferred from the atmosphere to the surface?

From micrometeorological measurements we can estimate the total transfer at some point above the surface, and, assuming negligible loss or gain from particle formation/evaporation between the measurement height and the surface, the flux can be interpreted in terms of deposition or emission to the surface itself. The ‘surface’ however comprises a range of different surfaces – from different heights within the canopy, different stages of senescence, different species making up the canopy, and eventually the litter and soil surfaces. Deposition to and emission from all of these surfaces is possible, and will be at differing rates, and to some extent with different relationship to the temperature, turbulence and other chemicals present in the atmosphere.

Conceptual models of NH<sub>3</sub> exchange have been developed that explicitly take into account the source/sink strength in the apoplast, and surface wetness on leaves (and other surfaces). There has been less work on other co-occurring gases (and particles) and on the dynamics of the processes involved.

One area that has not been explored is the role of oxidants in the atmosphere. If NH<sub>3</sub> is transferred to a leaf surface and exists in solution as NH<sub>4</sub><sup>+</sup> ions, the solution should be in equilibrium with the air, so that NH<sub>3</sub> is released as the surface water evaporates, or as air concentrations fall. In solution, the OH<sup>-</sup> ions that ‘balance’ the reactive dissolution of NH<sub>3</sub> may be neutralised by dissolved acid gases such as CO<sub>2</sub>, SO<sub>2</sub> or HNO<sub>3</sub>. When such solutions evaporate, the equilibria are displaced, and could lead to no net uptake if all the dissolved gases are released back to the atmosphere. Ammonia would be retained by cation exchange (i.e. replaced in solution by another cation from the leaf surface) or by conversion to a non-volatile salt such as sulphate. This implies that co-deposited NH<sub>3</sub> and SO<sub>2</sub> will result in net deposition depending upon the rate of conversion of SO<sub>2</sub> (in solution) to sulphate, i.e. on the availability of oxidants. The rate of oxidation will also be important relative to the residence time of solutions on leaf surfaces, leading to a need for better understanding of dynamical processes in gas and water vapour exchange with wetted vegetation.

## Mitigating Increases in Nitrogen Deposition: The Challenge of Extending Symbiotic Nitrogen Fixation to Cereals and Other Non-legume Crops

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In legume nodules, nitrogen-fixing rhizobia present intracellularly, supplied with energy derived from photosynthesis, fix nitrogen symbiotically. The plant is supplied with biologically fixed nitrogen, usually as ammonia. This minimizes or eliminates the need for inputs of synthetic nitrogen fertilizers. There is a major need to extend this intracellular symbiotic nitrogen fixation capability of legumes to cereals and other major non-legume crops to mitigate the ongoing increases in reactive nitrogen deposition associated with the use of synthetic nitrogen fertilizers. The annual world consumption of synthetic nitrogen fertilizers, manufactured with fossil fuels by the Haber-Bosch process, has averaged 83 to 85 million Mg N in recent years, with nearly 60% of that amount applied to cereal crops, with application rates in North America of 112 Kg N/ha and 113 Kg N/ha in West Europe; a large share of this reactive nitrogen is lost to the environment. The Royal Society Report on *Reaping the Benefits: Science and the Sustainable Intensification of Global Agriculture* (<http://royalsociety.org/document.asp?tip=0&id=8825>) has highlighted the need for research on high-return topics such as nitrogen fixation to provide the dramatic, but sustainable, improvements in crop production urgently required for Global Food Security. Recently we have demonstrated (1) that the naturally occurring nitrogen fixing bacterium, *Gluconacetobacter diazotrophicus*, isolated from sugarcane, can be induced to intracellularly colonize the roots and shoots of maize, rice, wheat, oilseed rape and tomato. Currently experiments are being undertaken to determine the extent to which this non-nodular systemic intracellular colonization by *G. diazotrophicus* will enable symbiotic nitrogen fixation. Any symbiotic nitrogen fixation is likely to result in an ability to reduce inputs of synthetic nitrogen fertilizers (2).

1. Cocking, E.C.; Stone, P.J. and Davey, M.R. (2006) Intracellular colonization of roots of *Arabidopsis* and crop plants by *Gluconacetobacter diazotrophicus*. *In Vitro Cell Dev Biol-Plant* 42, 74-82.

2. Cocking, E.C. (2009) The challenge of establishing symbiotic nitrogen fixation in cereals. In: *Nitrogen Fixation in Crop Production*. Agronomy Monograph 52, 35-63 (American Societies of Agronomy, Crop & Soil Science).

## Challenges in Defining Critical Loads for Nitrogen in UK Lakes

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It is now widely recognised that the deposition of nitrogen compounds can lead to both acidification and eutrophication impacts in upland lakes. While major reductions in sulphur emissions and deposition in the UK have been largely matched by chemical recovery from acidification in surface waters, reductions in emissions of N compounds have not been matched by corresponding reductions in deposition. Furthermore, modelling the effects of N deposition on lakes is complicated by nutrient cycling in the N limited terrestrial ecosystems of upland catchments. Here we explore two related issues in the use of critical loads for N in upland waters:

- 1) identifying potential impacts of nutrient N in naturally nutrient poor systems of conservation importance and links to biodiversity, and
- 2) problems in defining critical chemical limits with respect to reference conditions in upland lakes.

Empirical critical loads for nutrient N have been recommended to protect macrophyte communities of shallow softwater lakes in Europe. The recommended range of 5-10 kgN ha<sup>-1</sup> yr<sup>-1</sup> is exceeded across most of the UK but most oligotrophic lakes are of a different habitat type to those for which empirical critical loads have been recommended. Furthermore, while there is widespread evidence from nutrient bioassay work for N limitation of phytoplankton production in oligotrophic lakes there is little direct evidence to date of impacts on other biological groups in the UK, including macrophytes. A major problem is the lack of data on reference communities in unimpacted lakes and lack of identified “harmful ecological effects” required by the definition of critical loads. There are also fundamental differences in approach between the critical loads employed under the UN-ECE Gothenburg Protocol and the EU Water Framework Directive. We show that there are major challenges in application of critical loads for nutrient N which must be overcome if we are to protect designated sites of conservation interest and maintain, or allow recovery to, the good ecological status required by the EU Water Framework Directive.

## Atmospheric Nitrogen Budget in West African Dry Savannas

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The atmospheric nitrogen budget depends on emission and deposition fluxes both as reduced and oxidized compounds. In this study, a first attempt at estimating the Sahel nitrogen budget for the year 2006 is made, through measurements and simulations at three stations from the IDAF network situated in dry savanna ecosystems. Dry deposition fluxes are calculated from measurements of NO<sub>2</sub>, HNO<sub>3</sub> and NH<sub>3</sub> concentrations and simulated deposition velocities, and wet deposition is calculated from NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> concentration in samples of rain.

Emission fluxes are evaluated including NO biogenic emission from soils, emissions of NO<sub>x</sub> and NH<sub>3</sub> from domestic and biomass fires, and volatilization of NH<sub>3</sub> from animal excreta. Biogenic NO fluxes from soils are simulated in a SVAT model (ISBA), where an algorithm derived from an Artificial Neural Network has been inserted. Emissions of NO<sub>x</sub> and NH<sub>3</sub> from domestic and biomass fires are calculated from satellite data, and volatilization of NH<sub>3</sub> are calculated from animal excreta.

Emission and deposition fluxes at the annual scale are on the same order of magnitude.

When scaled up to the Sahelian region (12°N:18°N, 15°W:10°E), total emissions range from 1.5 to 3.7 TgN/yr and total deposition ranges from 1.3 to 2.1 TgN/yr.

The simulations of biogenic NO emissions made for the year 2006 have been extended from 2002 to 2007. The emissions are compared to deposition fluxes that are presented in a companion paper presented by C. Galy-Lacaux, where measurements of NO<sub>2</sub> concentrations for the same years are shown, at the stations of the IDAF network in West Africa (dry savanna, wet savanna, and forest ecosystems). The purpose of this last part of the study is to assess the impact of the interannual variability in precipitations on the interannual variability in emission and deposition of nitrogen compounds.

## Gaseous nitrogen emissions from Australian cattle feedlots

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Agriculture ranks second to stationary energy as a source of greenhouse gas emissions in Australia accounting for 16.3% of the national total. It is the main contributor of methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O). The national inventory notes that the present growth in N<sub>2</sub>O emissions in Australia is driven in part by increased emissions from the manure of intensively managed livestock. At any one time, 2.4 % of Australia's beef cattle are raised intensively in feedlots. Here, we report emissions of the direct greenhouse gas N<sub>2</sub>O and the indirect greenhouse gases, ammonia (NH<sub>3</sub>) and nitrogen oxides (NO<sub>x</sub>) measured in campaigns in the North and South of the country.

Line-averaged concentrations of N<sub>2</sub>O and NH<sub>3</sub> in the feedlots were measured continuously, circumstances permitting, in campaigns of approximately 10 days in summer and winter at both feedlots in 2007 and 2008. Concentrations of NH<sub>3</sub> were measured with two open-path laser systems and concentrations of both N<sub>2</sub>O and NH<sub>3</sub> were measured with an open-path Fourier transform infrared (FTIR) spectrometer. In 2008, the summer campaign at the southern feedlot was extended for a further 6 months through autumn and winter by using a closed path chemiluminescence analyser to measure concentrations of NH<sub>3</sub> and NO<sub>x</sub>. Emissions of the various gases were inferred from the concentration measurements by a use of a backward Lagrangian stochastic dispersion model. Implementation of the model was achieved through a computer package, WindTrax (Thunder Beach Scientific), which simulates trajectories of "particles" backwards from the sensor. Fluxes are calculated from the numbers of particle touchdowns inside and outside the source area. Required inputs are the geometry of the source area, the location and type of sensor, wind speed and direction, atmospheric stability and statistics of the turbulence.

The overall mean of the N<sub>2</sub>O emissions and its standard deviation were  $1.30 \pm 1.65$  kg N<sub>2</sub>O-N ha<sup>-1</sup> d<sup>-1</sup>. The corresponding figures for the NH<sub>3</sub> observations from all 3 open-path sensors and the closed path analyser were  $95 \pm 36$  kg NH<sub>3</sub>-N ha<sup>-1</sup> d<sup>-1</sup>, and for the NO<sub>x</sub> observations with the closed path analyser,  $1.20 \pm 0.58$  kg NO<sub>x</sub>-N ha<sup>-1</sup> d<sup>-1</sup>. Mosier et al. (1998) suggest that about 1 % of the NH<sub>3</sub> and NO<sub>x</sub> released into the atmosphere is eventually converted to N<sub>2</sub>O after deposition. Using that figure and the above emission data, we estimate a net contribution of N<sub>2</sub>O to the atmosphere from Australian cattle feedlots through emissions of NH<sub>3</sub>, NO<sub>x</sub> and N<sub>2</sub>O itself of 0.42 t CO<sub>2</sub>-e, 75 % of which comes from the indirect greenhouse gases NH<sub>3</sub> and NO<sub>x</sub>. These direct and indirect N<sub>2</sub>O emissions are substantial, more than half as large in terms of CO<sub>2</sub>-e as the emissions of CH<sub>4</sub> from feedlots. Further whole-year studies are needed. As well, the ecological impact of the 99% of the deposited N remaining after emission as NH<sub>3</sub> and NO<sub>x</sub> requires investigation.

**Effect of increased nitrogen availability in Mediterranean-type ecosystems: a case study in a Natura 2000 site in Portugal.**

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The Mediterranean Basin forms a unique ecosystem and is one of the most anthropogenically shaped region worldwide. However they are one of the top five ‘**hottest**’ **biodiversity and endemism hotspots** for vascular plants, and one of the more responsive type of ecosystems to human pressure considering several possible scenarios (water shortage, temperature increase, change of the seasonal pattern). Unfortunately N has not been considered as a threat to these ecosystems and consequently there are not many studies on the effect of increased N availability on their functioning and sustainability.

We are undertaking an integrated field study of the effects of increased N availability in a Mediterranean-type ecosystem in southern Portugal belonging to Natura 2000 (PTCON0010 Arrábida/Espichel), Arrábida has a typical Mediterranean climate, hot and dry summers and mild and wet winters (annual mean temperature of 17.5 °C, annual precipitation ~ 600 mm). N availability has been modified by the addition of 40 and 80 kg N/ha/year in the form of NH<sub>4</sub>NO<sub>3</sub> and 40 kg N-NH<sub>4</sub><sup>+</sup>/ha/year as ammonium chloride (the control plots corresponds to no fertilization). N was added, beginning in January 2007, in three equal applications throughout the year corresponding to distinct seasons, which correlate with distinct biological activities (spring, summer and middle autumn/winter). Each N treatment has three replicates (400 m<sup>2</sup> plots).

One year of N additions were sufficient to induce changes in plant and soil communities (bacterial and AMF communities), and C/N ratios of the litter.

Increased N availability appeared to be targeting specific plant species: ericaceous, evergreen sclerophylls, Summer semi-deciduous (especially *Cistus ladanifer*) and legume shrubs with spines (especially *Genista triacanthos*) increased their plant cover when subjected only to ambient N deposition. On the contrary, when compared to controls, not only did the fertilized plots showed a decreased (negative relative gain) of plant cover for the referred functional groups, but they also increased plat cover of Herbaceous machia plants, Ruderals and Grasses. The C/N ratio of the litter of the dominant species decreased 5 times in the 80 kg N/ha/year in relation to the control. Which may be an initial sign of nitrogen exceedance in the ecosystem.

## Arbuscular mycorrhizal fungal spores, an allied in the quest for targeting increased N availability in Mediterranean-type ecosystems

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Most studies addressing the effects of increased N availability have been undertaken in northern European and American ecosystems. Few have been developed in Mediterranean-type ecosystems. The distinctive seasonality of resource availability (water, nutrients and temperature) reinforces the importance of N availability to ecosystem response. Moreover, Mediterranean basin is one of the top five ‘hottest’ biodiversity and endemism hotspots for vascular plants, and there is a clear gap for scientific based integrative scenarios for management policies in hotspot ecosystems.

We are undertaking an integrated field study (soil, plants and microorganisms) of the effects of increased N availability in a Mediterranean-type ecosystem in southern Portugal. The field site is located in Arrábida (PTCON0010 Arrábida/Espichel) and the experimental design consists mainly of manipulating N availability. N availability has been modified by the addition of 40 and 80 kg N/ha/year in the form of  $\text{NH}_4\text{NO}_3$  and 40 kg N- $\text{NH}_4^+$ /ha/year (the control plots corresponds to no fertilization). N is added in three equal applications throughout the year corresponding to distinct seasons, which correlate with distinct biological activities (spring, summer and middle autumn/winter). Each N treatment has three replicates (400 m<sup>2</sup> plots). N additions began January 2007.

The ecosystem was very responsive to short term increased N availability since one year of N additions were sufficient to induce changes in above (plants) and belowground (soil bacteria and arbuscular mycorrhizal fungi - AMF - spores) communities.

The effects of the N fertilizations on AMF species richness and evenness in relation to the control depended on the N form and dose: fertilization solely with ammonium increased AMF spores richness (from 4.6 to 6.22 AMF species per 100 ml soil) and evenness (from 0.53 to 0.64); fertilization with 40 kg N- $\text{NH}_4\text{NO}_3$ /ha/y decreased AMF spores richness (from 4.6 to 2.40 AMF species per 100 ml soil) and evenness (from 0.53 to 0.19); and fertilization with 80 kg N- $\text{NH}_4\text{NO}_3$ /ha/y had no effect on AMF spores richness (from 4.6 to 4.20 AMF species per 100 ml soil) and evenness (from 0.53 to 0.47).

Most importantly is that AMF spores community responded also in terms of species composition. Morphological evaluation showed the existence of four groups of AMF spores species: 1) those only observed in control plots; 2) those only observed in fertilized plots; 3) those only observed in the plots receiving 40 kg N- $\text{NH}_4^+$ /ha/y solely or with equivalent amount of N- $\text{NO}_3^-$  and; 4) those observed in all treatments. Based on the mutually exclusive nature of the first two groups of AMF spores species (group 1 and 2), these can be further assessed as indicators of low and high N availability, respectively. Taking in consideration the ubiquitous distribution of AMF spores it is surprising the observed clear and drastic effect of nitrogen addition on AMF community.

Changes in AMF spores diversity and composition may reflect changes in AMF community colonizing plant roots. This may have important influences on the efficiency of the mycorrhizal symbiosis in the acquisition of nutrients (namely N and P) and therefore on the relative competitive capacity of co-existing plant species.

## Regional scale modelling of the concentration and deposition of oxidised and reduced nitrogen in the UK

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The Fine Resolution Atmospheric Multi-pollutant Exchange model (FRAME) has been applied to model the spatial distribution of nitrogen deposition over the United Kingdom. The model was found to obtain reasonable agreement with measurements of NO<sub>x</sub> and nitrogen aerosol concentrations in air, as well as wet deposition of ammonium and nitrate. Considerable scatter was evident in the correlation between modelled and measured ammonia gas concentrations, due to the large spatial variability in ammonia emissions. The spatial distribution of ammonia concentrations and spatial separation of agricultural source regions from Natura 2000 sites was significantly improved when the model grid resolution was increased from 5 km to 1 km.

NO<sub>x</sub> emissions in the UK were at a maximum of 951 Gg N in 1970 and fell to 378 by 2005, with a further decrease to 243 Gg N forecast by 2020. These large decreases in emissions have not been matched by similar changes for NH<sub>3</sub> which decreased from 315 Gg N in 1990 to 259 in 2005 and is forecast to fall to 222 Gg by 2020. Modelled wet deposition of nitrogen during this 50 year time period was found to decrease more slowly than the emissions reduction rate. This is attributed to a number of factors including increases in NO<sub>x</sub> emissions from international shipping and changing rates of atmospheric oxidation. The modelled deposition of NO<sub>y</sub> and NH<sub>x</sub> to the UK was found to fall by 52% and 25%, respectively, during this period. The percentage of the UK surface area for which critical loads are exceeded was estimated to fall from 73% to 49% for nutrient nitrogen deposition. Future policies to control emissions of ammonia from agriculture and NO<sub>x</sub> from international shipping will be required to effect further significant reductions in nitrogen deposition.

## **A Comparison of Empirical and Modeled Nitrogen Critical Loads for Mediterranean Forests in California**

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Nitrogen deposition is impacting a number of ecosystem types in California. Here we compare N deposition critical loads (CL) determined for mixed conifer forests in the San Bernardino Mountains in southern California using empirical and various modeling approaches, including simple mass balance (SMB) models for nutrient N and acidification, and the Daycent biogeochemical simulation model. Empirical CL were based on responses across N deposition gradients of lichen community functional groups, nitrate leaching and ponderosa pine fine root biomass. Broad scale CL mapping for the San Bernardino Mountains using the SMB model resulted in nutrient N CL values that were similar but slightly lower than empirical CL values for nitrate leaching. Over the range of elevations and vegetation types considered in the San Bernardino Mountains the SMB modeled CL values ranged from 3.7 to 17.0 kg N/ha/yr for nutrient N. For both the empirical nitrate leaching CL and the SMB model, the CL was lower for chaparral vegetation than for forests. The simulated CL for nitrate leaching estimated by the Daycent model was highly similar to the empirical CL (17 kg N/ha/yr), but the severity and frequency of elevated nitrate leaching was sometimes underestimated by Daycent. The Daycent model was also used to evaluate the efficacy of periodic fire and reduced N deposition as management options to reduce N saturation symptoms. Empirical CL exceedance maps will be shown to indicate the areal extent of the effects of excess N on forests and chaparral ecosystems in California.

## Rainfall and Throughfall $NH_4^+$ and $NO_3^-$ Deposition in Some Brazilian Rainforests

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### Abstract

A comparison of nitrate and ammonium deposition through rainwater and throughfall water among different types of rainforests is presented. The data were obtained from three small forested catchments: 1) northeast area of Amazonia – a rainforest (51°59'1.5 "W; 00°55'57.1 "N) with annual deposition of 0.99 kg  $NH_4^+$  ha<sup>-1</sup>.y<sup>-1</sup> and 3.02 kg  $NO_3^-$ .ha<sup>-1</sup>.y<sup>-1</sup> (AMF); 2) southeast area of the state of São Paulo preserved forest (23°13'28 "S; 45°05'15 "W) with annual deposition of 8.20  $NH_4^+$  ha<sup>-1</sup>.y<sup>-1</sup> and 4.08 kg  $NO_3^-$  ha<sup>-1</sup>.y<sup>-1</sup> of ammonium and nitrate respectively (AFC) and 3) southeast area of São Paulo an urban forest (23°39'S; 46°37'W) with annual deposition of 15.2  $NH_4^+$  ha<sup>-1</sup>.y<sup>-1</sup> and 52.3 kg  $NO_3^-$ .ha<sup>-1</sup>.y<sup>-1</sup> (AFP). At the Amazonian site (AMF) the field work was done from June 1993 until June 1997 and in the two sites on the southeastern region of São Paulo state, which is on the Atlantic forest domain the studies were conducted from September 1999 until September 2001. The forest soil input derived from throughfall was: 3.37 kg.  $NH_4^+$  ha<sup>-1</sup>.y<sup>-1</sup> and 3.85 kg  $NO_3^-$  ha<sup>-1</sup>.y<sup>-1</sup> for the AMF site, 3.74 kg.  $NH_4^+$  ha<sup>-1</sup>.y<sup>-1</sup> and 4.08 kg  $NO_3^-$  ha<sup>-1</sup>.y<sup>-1</sup> for AFC site and 14.5 kg  $NH_4^+$  ha<sup>-1</sup>.y<sup>-1</sup> and 40.5 kg.  $NO_3^-$  ha<sup>-1</sup>.y<sup>-1</sup> for the AFP site. The rainfall water in the AMF site has basically two components: maritime and biogenic being the biogenic dominant. Throughfall net input at this site indicates that it is derived from the rainfall-canopy interaction pointing out that this vegetation does not absorb those ions. However,  $NO_3^-$  is mainly derived from rainfall water since the net input is lower than 30% of the total input. Ammonium content in throughfall is enriched in relation to rainfall by about 2.5 folds which indicate that for this site ammonium is mainly derived from the canopy. A comparison between AMF results with AFC show that ammonium input through rainwater is higher at Atlantic AFC forest than the one found at Amazon AMF being the nitrate input equivalent at both sites. When the urban forest (AFP) nitrate input is considered ten fold larger input than the one for AFC is observed which a consequence of vehicular emission. The inputs either by rainfall or by throughfall for the three sites presented variations between the wet and dry periods which were partially attributed to the lower amount of rainfall during the dry season and partially to the vegetation cover characteristics. For AFC the deposition rates are lower than for AFP (46% for  $NH_4^+$  and 91% for  $NO_3^-$ ) with a  $NH_4^+$  absorption by the canopy mainly during the rainy period being a small amount of  $NO_3^-$  transferred from the canopy to throughfall during the rainy season. At AFP the deposition rates from the rainfall are high compared with the others however, with no substantial transfers of those ions for the throughfall. At AFP  $NH_4^+$  is absorbed by the canopy during the dry season and transferred during the rainy one while  $NO_3^-$  is absorbed along the year with high rates. These observed variations on deposition, absorption and transference of those ions probably reflects the composition and functioning of the plant communities present on these different sites.

## Dry and Wet Atmospheric Nitrogen Deposition in West Central Africa

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This work is part of the IDAF (IGAC/DEBITS/Africa) programme which started in 1995 with the establishment of 10 measurement sites representative of major African ecosystems. The objectives of the programme are to study wet and dry deposition fluxes, to identify the relative contribution of natural and anthropogenic sources and factors regulating these fluxes. In this way, the IDAF activity is based on high quality measurements of atmospheric chemical data (gaseous, precipitation and aerosols chemical composition) on the basis of a multi-year monitoring.

The main objective of this paper is to present the first estimation of the atmospheric nitrogen deposition budget in Africa based on experimental measurements over a 10 year period. To estimate atmospheric nitrogen deposition fluxes, including both wet and dry processes, we compiled the IDAF nitrogen data (gas, particles, rain) obtained from the measurement network for the period 1997-2007. In western and central Africa, we studied a transect going from dry savanna to humid savanna and forest. Results will be compared to South African IDAF sites representative of a rural and an industrialized semi-arid savanna. Presenting the dry deposition in gaseous and particulate forms associated with wet deposition, this study will allow to estimate (i) the relative contribution of dry and wet deposition processes and (ii) the total nitrogen deposition at regional representatives sites in Africa. The total nitrogen deposition is estimated to be around 6 kg N.ha<sup>-1</sup>.yr<sup>-1</sup>, 6.5 kg N.ha<sup>-1</sup>.yr<sup>-1</sup> and 13 kg N.ha<sup>-1</sup>.yr<sup>-1</sup> respectively over dry savanna, humid savanna and over the forest. These values should be taken with caution and we estimated the uncertainties on the budget to be around 30%. If the estimations of wet deposition fluxes are known within a 10 % margin, dry deposition fluxes present larger uncertainties mainly due to dry deposition calculation. It is also important to note that our budget don't take into account all nitrogenous species, especially organic nitrogen species. An important result highlighted by this budget is the importance of dry deposition processes in west central Africa, especially for nitrogenous gaseous compounds. In dry savanna and forest, the relative contribution of dry deposition is about 60 %. In the wet savanna the contribution is around 53 %.

## Effects of Nitrogen addition and mowing management on acidic grassland after 3 years

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Atmospheric nitrogen deposition is one of the components of global change driving to eutrophication and acidification to ecosystems. Several studies have shown a decline of species richness along gradients of atmospheric nitrogen deposition, especially in acidic grasslands. But these studies have not been confirmed in experimental evidences. This plant diversity decline could be explained by mechanisms like the competition for light or the toxicity of nitrogen. The aims of the study are to determinate the effects of increasing N-addition on biomass and species richness and to examine the possible mitigation effects of more frequent biomass removal. The study tries to elucidate mechanisms behind potential plant diversity changes with an investigation of the competition for light.

The study consists in an N-addition experiment started in 2007 on an acidic grassland of *Violion caninae* community in south west in France characterized by low pH around 5.0 and low atmospheric nitrogen deposition (8.9 kgN ha<sup>-1</sup> yr<sup>-1</sup>). We manipulated an increasing amount of total nitrogen in the form of NH<sub>4</sub>NO<sub>3</sub> (0, 35 or 70 kgN ha<sup>-1</sup> yr<sup>-1</sup>) and a cutting frequency, one or two cutting per year, in a factorial design.

After 3 years, a significant effect of cutting has been shown. Cutting treatments point out a decrease of total biomass with two cuttings per year. There is a marginally significant effect between cutting and nitrogen on total biomass with no more effect of cutting at the highest level of nitrogen addition. Light measurements confirm significant effect of cutting that is a decrease of the percent of light extenuation by plant cover with two cuttings. There is a temporal effect of nitrogen on light extenuation, but no evidence of persistent impact of nitrogen addition on cover species. Indeed nitrogen effects are only visible on plant phenology with a higher percent of light extenuation at the beginning of the season vegetation in absence of nitrogen. Nitrogen additions show no effect on biomass but a marginally significant effect on species number, suggesting a decline in species richness in relation to nitrogen increase.

At this stage of experimentation, our results are consistent with a toxicity hypothesis to explain changes in biomass and species number. On the other hand, no evidence of competitive exclusion has been shown. Mitigation effects via more frequent cuttings leave unresolved with only a non significant tendency to gain plant between one and two cuttings per year at the highest level of nitrogen.

## **Predicting lichen-based critical loads for nitrogen deposition in temperate forests**

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Critical loads (CLs) define the quantitative exposure to one or more pollutants below which significant harmful effects on sensitive elements of the environment do not occur, according to present knowledge. CLs generated for epiphytic lichens, a most nitrogen(N)-sensitive component, may convey general protection from N deposition to forested ecosystems. Using multiple linear regression, we related epiphytic-lichen community composition of northwestern North American temperate forests to total N deposition from the Communities Multi-Scale Air Quality (CMAQ) model. Sensitive lichen scarcity was associated with CLs of 3-9 kg N /ha/y. CLs increased with precipitation across the landscape, perhaps from pollutant dilution or leaching. Replication of previously published US and European CLs using our model suggests a consistent relationship between N deposition, precipitation and temperate forest lichen-community composition. This relationship may be used to predict nitrogen CLs in other temperate forests.

## **Nitrogen biogeochemistry research at Fernow Experimental Forest, West Virginia, USA: soils, biodiversity, and climate change**

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Nitrogen (N) saturation arises when atmospheric inputs of N exceed biological N demand, resulting in loss of  $\text{NO}_3^-$  in streams, accompanied by the loss of nutrients (Ca and Mg) that are essential to forest health. Previous studies have shown that some watersheds the Fernow Experimental Forest (FEF), West Virginia, USA, are among the more N-saturated sites in North America. Research from the Gilliam laboratory at Marshall University (West Virginia, USA) began focusing specifically on N biogeochemistry in 1993 with establishment of plots at FEF to carry out long-term *in situ* (“buried bag”) incubations in three watersheds: two control (WS4, WS7) and one treatment (WS3). This was done in conjunction with the Fernow Watershed Acidification Study, established by the USDA Forest Service in 1989 to treat an entire watershed (WS3) with aerial applications of 35 kg N/ha/yr. The initial period (1993-1995) exhibited increases in rates for all watersheds, but especially in treated WS3. This period has been followed by declines in net nitrification, which is consistent with current declines in stream  $\text{NO}_3^-$  and has been especially pronounced in WS3 since 1998. Also during this time, sampling of the herbaceous layer (vascular plants  $\leq 1\text{m}$  in height) has revealed pronounced changes in response to N treatments on WS3, especially in the increase of the shade-intolerant *Rubus* spp. Future work will investigate the effects of freezing on soil N dynamics. Preliminary results indicate that freezing exacerbates the symptoms of N saturation already seen in soils at FEF, further increasing already high rates of net nitrification.

**Ammonia Emissions in the US: Assessing the role of bi-directional ammonia transport within vegetation canopies using the Community Multi-scale Air Quality (CMAQ) model**

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Ammonia emissions are calculated based on recent emission factors. However, scientific uncertainty exists in the determination of ammonia (NH<sub>3</sub>) emissions, with current inventories overestimating by up to 20%. In addition to the lack of continuous NH<sub>3</sub> emissions analysis and the limited spatial and temporal scope of current NH<sub>3</sub> emissions factors, air quality models do not accurately represent all NH<sub>3</sub> atmospheric processes. Recent advancements suggest that the bi-directional transport of NH<sub>3</sub> within and above vegetation canopies may account for some of these uncertainties. Ammonia emissions for the Southeast and Midwest United States (US) are adjusted using the Community Multi-scale Air Quality (CMAQ) model. Seasonal crop and commercial fertilizer application data from the National Nutrient Loss & Soil Carbon (NNLSC) Database are used to provide additional input information to the bi-directional (compensation point) NH<sub>3</sub> flux option of the CMAQ model (version 4.7). We then estimate the difference in ammonia concentrations in the Midwest and Southeastern US due to the NH<sub>3</sub> bi-directional flux option; and estimate N deposition in the regions.

## Freshwater Species Assessments

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This poster will provide a brief overview of the Global Freshwater Biodiversity Assessment, a collaboration between IUCN's Species Programme, Conservation International, and NatureServe. The Global Freshwater Biodiversity Assessment programme will evaluate the conservation status of freshwater fishes, mollusks, crabs, odonates (dragonflies and damselflies), and selected groups of freshwater plants, totalling about 28,000 species. These species provide a representative view of the ecology and conservation status of freshwater ecosystems. Each species assessment includes information on taxonomy, distribution, populations, habitat and ecology, utilization, livelihoods values, major threats, conservation measures, and risk of extinction. The collected distribution data for each species are converted into digital geospatial data and mapped to drainage basins. All data are distributed publicly through IUCN's *Red List of Threatened Species*. The results of the assessments can be used to inform planning and conservation decisions by identifying regions with species of high vulnerability (i.e., levels of threat) and irreplaceability (i.e., levels of endemism) as well as by identifying species and entire ecosystems of high service value (i.e. supporting livelihoods and human well-being at a local to global level). The assessments represent an important tool in support of research on the global impacts of nitrogen deposition on freshwater biodiversity.

### **GLOBIO 3**

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The UNEP World Conservation Monitoring Centre, UNEP-GRID Arendal and the Netherlands Environmental Assessment Agency have developed the GLOBIO 3 model. GLOBIO 3 uses quantitative relationships between environmental pressure factors and biodiversity, based on state-of-the-art knowledge from literature. Pressure factors comprise changes in land use (agriculture, forestry and settlements), climate change, infrastructure, fragmentation and nitrogen deposition. By combining results related to individual pressures, the overall change in biodiversity is calculated in terms of mean species abundance (MSA) and the extent of ecosystems. This measure of mean species abundance (MSA) is similar to the Biodiversity Integrity Index (Majer and Beeston, 1996) and the Biodiversity Intactness Index (Scholes and Biggs, 2005) and can be considered as a proxy for CBD indicators (UNEP, 2004). Effects of nitrogen deposition were calculated by combining global deposition maps, maps of critical loads (Bouwman, VanVuuren et al. 2002) and dose response relationships between critical load exceedance and species loss (CCE, 2008).

## **Fluxes of inorganic nitrogen in forest ecosystems from Romania**

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High levels of nitrogen depositions to forests can determine nutrient imbalances and move the ecosystem toward nitrogen saturation in the long term.

That was the reason why we monitored the fluxes of ammonium and nitrate in bulk deposition, throughfall and percolation water in 4 forest ecosystems from Romania. During 1998 – 2006, nitrogen fluxes decreased or remained relatively constant at the two plots located in the mountains, at more than 1000 m altitude, and increased at the two plots situated at less than 600 m altitude, in south Romania, in regions with high influences from industry and agricultural activities.

## Diversity of shrubtree layer in a Brazilian Cerrado under N, P and N plus P addition

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The Brazilian Cerrado is characterized by a complex vegetation mosaic ranging from grasslands to woodlands and is the second most extensive plant formation in South America. Agricultural and cattle ranching activities led to the conversion approximately 50% of the original Cerrado area (2 million km<sup>2</sup>) in the last four decades. The aim of this study was to compare the diversity of shrub-tree layer in fertilized and unfertilized plots in a cerrado *stricto sensu* area in Central Brazil. The experiment was conducted in 16 plots of 15 x 15 m arranged in a completely randomized design with tree fertilization treatments (+ N, + P, + NP), and an unfertilized treatment (control) in the Reserva Ecológica do Instituto Brasileiro de Geografia e Estatística (RECOR –IBGE), Federal District, near Brasília. Vegetation surveys were performed during January and July 2008 including all trees and shrubs with circumference > 5 cm at soil height. Indices of diversity of Shannon (H'), evenness of Pielou (J') and similarity of Sørensen were calculated. Control plots presented 479 individuals of 47 species, belonging to 29 families. In N plots, 461 individuals were registered, belonging to 53 species and 34 families while 448 individuals of 54 species from 31 families were registered in P plots and 336 individuals of 40 species, belonging to 24 families in NP plots. The N (H'=3.20; J'=0.80) and NP (H'=2.89; J'=0.78) plots showed lower Shannon (H') and Pielou (J') indices relative to the control plots (H'=3.40; J'=0.88). The Sørensen floristic similarity was high between fertilized and control plots but decreased in the following order: P plots (0.81), N (0.78) and NP (0.76) plots. Fertilization shifted species density and dominance patterns in comparison to unfertilized plots. N and NP addition decreased the evenness, species diversity and provided the less floristic similarity relative to the control plots. Density and dominance changes resulted in differences in species importance values among treatments. Simultaneous addition of N and P affected density, dominance, richness and diversity patterns more significantly than addition of N or P separately.

## Leaf litter decomposition and nutrient release under N, P and N plus P additions in a Savanna in Central Brazil

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Brazilian Cerrado (savannas of Central Brazil) is the one of world's diversity hotspot due to its biodiversity, high endemism level and rapid loss of habitats. The expansion of cattle ranching and mechanized agriculture since 70's has led to the conversion of large extensions of native areas resulting in the fragmentation of native areas and in intensive use of fertilizers. The aim of this study was to determine leaf decomposition and nutrient release in a cerrado *sensu stricto* under N, P and N plus P addition. This vegetation type is characterized by a continuous grass layer and a woody layer of trees and shrubs varying in cover from 10 to 60%. The experiment was carried out in an area located in the Ecological Reserve of the Instituto Brasileiro de Geografia e Estatística, near Brasília (15° 56' S, 47° 53' W). Soil is characterized as Oxisols, acidic, with high Al levels and low cation exchange capacity. Total precipitation was 1667 mm in 2006 and 1183.7 mm in 2007. Air temperature ranged from 10.1 °C and 31.9 °C during the study period. Between 1998 and 2006, 100 kg. ha<sup>-1</sup>.y<sup>-1</sup> of N (N treatment), P (P treatment) and N plus P (NP treatment) were applied to sixteen 225m<sup>2</sup> plots, arranged in a completely randomized design. Litterfall was collected in the end of dry season (September 2006) and oven dried (60 °C) until constant weight. Litter bags with 10 g of leaf litter were incubated *in situ* for 473 days to determine decomposition rate. N and P concentrations and mass loss were measured during the incubation process. N plots leaf litter did not alter the decomposition rate in relation to that in control plots. Leaf litter decomposition rates increased in P (+ 18.6 %) and NP (+27.4 %) plots, where there was a greater N (in NP plots) and P (in P and NP plots) initial concentration in litter relative to the control plots (p<0,05). N treatment leaf litter had the highest N mass loss, and together with NP treatment, the smallest P mass loss. N addition increased N mass loss, while the combined addition of N and P resulted in an immobilization of N in leaf litter. When the nutrients are supplied separately, there is greater mass loss of N with N addition, and greater mass loss of P with P addition compared to that observed when N and P are supplied together. The results indicate if the availability of P is not increased proportionally to the availability of N, the losses of N are intensified.

## **Dynamic Modelling of Forest Growth at Different Levels of Nitrogen Deposition and Climate Change, Ecosystem Model EFIMOD as an Example**

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Projected climate change scenarios for the Central European Russia boreal and temperate forests generally predict warmer and somewhat drier conditions. Consequently, a problem of quantification of the effects of climate change on forest growth and changes of carbon and nitrogen turnover in the forest-soil system and harvesting on C budget in forest ecosystem has arisen. The forest ecosystem model EFIMOD has been undertaken for mixed coniferous-broadleaf forests in central Russia. The EFIMOD model has been developed for analyzing of carbon and nitrogen turnover in boreal forest ecosystems. Nitrogen dynamics is crucial in boreal zone due to poorness of forest ecosystems, soil, first of all, in nitrogen. General scheme of the model includes N deposition, N leaching and dissolved organic nitrogen dynamics. The EFIMOD model was applied for different case-studies in Russia, Canada, Finland, Sweden, Germany, Czech Republic etc. Applications show considerable effect of N deposition for forest growth. Effect is nonlinear due to mentioned components of nitrogen balance. Possible links with other models such as SAFE, MAKEDEP etc. are discussed. The EFIMOD integration of both vegetation and soil processes into a forest-soil model permits feedback between the vegetation and soil. This provides a dynamic representation of vegetation and soil parameters and allows for a simulation of carbon and nitrogen dynamics with stand development. Case-studies for forest territories in Moscow and Kostroma (four hundred kilometers north-east from Moscow) areas in Central Russia have been chosen. Two scenarios of silvicultural regimes were compiled: natural development and cuttings in correspondence with local forest practice. A set of scenarios with climate change using HADCM3 model was compiled for the simulation. EFIMOD application shows that climate warming and harvesting significantly influence the pools of tree biomass and soil C. In general forest productivity grows and soil resource decreases. Increasing of soil nutrition due to more intensive deliverance of mineral nitrogen to vegetation as a result of climate changes is the main reason of this new balance. Difference between dynamics of forest and soil carbon is more distinct at natural development. Species composition at natural development in both case-studies is shifting to the more nitrophilous trees. Cuttings are smoothing these processes. The detailed results show that climate changes have indirect impacts to the processes in forest-soil system. Effects of N deposition for forest growth and biodiversity at different systems of cuttings are shown. Gaps in knowledge and experimental data are also displayed.

**Nitrogen deposition in background areas monitored by the epiphytic lichen (*Hypogymnia physodes*) and the mosses (*Hylocomium splendens* and *Pleurozium schreberi*) in Finland in 1985-2005**

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Monitoring of nitrogen deposition was started in 1985 by the epiphytic lichen and then carried out by the carpet forming mosses at 5-year intervals in 1990, 1995, 2000 and 2005. The samples were collected from the permanent monitoring sites established as a part of the 8<sup>th</sup> National Forest Inventory in the Finnish Forest Research Institute. Originally there were 3009 monitoring sites covering the whole country. Finland is located between latitudes 60°N and 70°N. The ground is covered with snow average for 100-230 days.

The nitrogen concentrations were the highest in the southern part of the country with decreasing trend on moving northwards. The average varied depending on the latitude from 1.26% to 0.7 %. The highest value was measured in 1990, 2.2% of the dry weight. The concentrations were very small especially in northern Finland representing true background areas and well reflected measured nitrogen deposition.

The results indicate that the forests in the Southern Finland are subject to nitrogen pollution while the concentrations in the North are at the lowest level in Europe. Responses of boreal forest ecosystems to N addition, the trend between 1985 and 2005 and differences within two moss species and the epiphytic lichen will be discussed.

## The tree phenology strategies explain the photosynthetic nitrogen characterization in the Brazilian savanna?

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The cerrado Biome is structural and functionally complex where species with different strategies of water and nitrogen use occur, with seasonal climate which affects carbon balance and growth. In this study our objectives were evaluate the seasonal dynamics of the gas exchange and nitrogen investment into photosynthetic apparatus in the dominant tree species occurring in the Vassununga State Park, São Paulo State. Three species were chosen: *Anadenanthera falcata* (Benth.) Speg, Legumiosae, Mimosoideae; *Xylopia aromatica* (Lam.) Mart., Annonaceae; and *Myrcia lingua* (O.Berb) Mattos, Myrtaceae. The gas exchange was evaluated with infra-red gas analyzer (Li-Cor 6400), leaf area (SLA) was evaluated through scanner and the software Leaf Area Measurement (Version 1.3) and the leaf dry mass was evaluated in scale (Shimadzu, Model ELD 300). The leaf nitrogen concentration was analysed by mass spectrometer and the photosynthetic nitrogen was calculated according to von Caemmerer *et al.* (1994), which is based on leaf nitrogen concentration, Rubisco carboxylation velocity ( $V_c$ ) and SLA. Data was analysed with Winstat statistical package, light curves were fitted with a non-rectangular hyperbola and Rubisco activity was calculate according to Sharkey *et al.* 2007. The measurements were done in the summer (January) and in the winter (July) of 2006. Based on the phenological and physiological traits, it was possible to characterize a gradient between species: *M. lingua*, evergreen, dominates the lower strata, showed low SLA,  $A_{max}$  and  $A_{mass}$ ; *X. aromatica*, a semi deciduous species, dominates the intermediate strata, showing medium SLA and high  $A_{max}$  and  $A_{mass}$ ; *A. falcata*, a deciduous species, dominates the canopy, showing high SLA,  $A_{max}$  and  $A_{mass}$ . In relation to the nitrogen investment to photosynthesis (% total leaf nitrogen), *A. falcata* showed 27% and 78%, *X. aromatica* 40% and 24%, and the *M. lingua* 80% and 14%, in the summer and in the winter, respectively. These results indicate that non deciduous species invested more nitrogen in photosynthesis in the summer, in agreement with higher photosynthetic assimilation in this season. The increased proportional investment in photosynthetic nitrogen in the winter observed in the deciduous species suggests that, besides the absolute decrease in total leaf nitrogen, the remobilization of compounds (including N compounds) in the beginning of leaf senescence, somewhat preserved photosynthetic nitrogen from withdrawn. This remnant N content was probably responsible for the increased  $V_c$  observed in the winter.

BIOTA/FAPESP

## **N-Print: a Tool that Links Resource Consumption to Critical Load Exceedances**

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There is a growing body of scientific knowledge on how humans influence the N cycle as well as how the altered N cycle then impacts both humans and ecosystems. However, advances in science are far ahead of the policy, stakeholder, and public's understanding of the importance of nitrogen issues. We present a tool called N-Print that can help bridge this gap. Here we will show the first results of N-Print and its potential role in raising awareness for nitrogen.

The overarching goal of N-Print is to encourage the more efficient use of nitrogen to decrease its environmental impact while maintaining its benefits. N-Print aims to raise awareness about nitrogen and to help consumers, producers, governments, and universities understand how they can reduce their nitrogen emissions. The intended uses include education for the general public, improvement of best management practices for producers, policy development for government agencies, and research for universities.

The N-Print tool is a modeling system that is made up of four integrated components that describe the sources of nitrogen, its flows to receptors, and its effects on the environment through threshold exceedances. The first module, the N Calculator, is a nitrogen footprint model that shows an individual consumer how much nitrogen his or her activities release to the environment. The second module, N Loss, spatially defines where these nitrogen emissions are released and the form that they take. The third module, N Dispersion, employs modeling techniques to determine how the nitrogen emissions to the air, soil, and water may circulate through the environment. The final module, N Exceedances, then makes the spatial connection between how much nitrogen enters the environmental system and the resulting ecological and human health impacts. An example of the latter is the critical load exceedance.

The N Calculator found that the average per-capita N footprint in the Netherlands is similar to that of the United States, at 44 kg N/yr and 46 kg N/yr, respectively. For both the Netherlands and the US footprints, food production accounts for about 35 kg N/yr, of which 28 kg N/yr is lost to the environment prior to food consumption and 7 kg N/yr is lost to the environment after food consumption. The difference between the US and Netherlands footprints is mostly due to the housing sector, as the US housing footprint is about 3 kg N/yr and the Netherlands housing footprint is about 1.5 kg N/yr. The remaining portion of the N footprint in each country is lost to the environment from the mobility, goods, and services sectors.

More information and the N Calculator can be found at: [www.n-print.org](http://www.n-print.org).

## Nitrogen Deposition and Plant Foliar N Indicate Accelerated Atmospheric Reactive N Pollution over China

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Nitrogen (N) deposition is an important component in the global fixed nitrogen cycle, which has threatened the stability and biodiversity of terrestrial and marine ecosystems worldwide. Nitrogen deposition rates have leveled off in most developed countries since late 1980s with the implementation of stricter legislation to limit atmospheric pollution. However, the magnitude and distribution of N deposition are basically unknown in China, despite the fact that China has become one of the most polluted countries on Earth with continuously fast economic growth since early 1980s. Assessing whether nitrogen deposition has been significantly increased by anthropogenic sources in China, and whether this situation could be affected by reduction on the environment, is critically important in evaluating the impact of China's economic advancement during the last thirty years on the global environment. Here we provide evidence of accelerated nitrogen deposition over China, reflecting serious reactive N pollution, and that this is having a marked impact on non-agricultural ecosystems. In spite of some scatter in our dataset, both inorganic N bulk deposition and plant foliar N concentrations show strong increasing trends with time ( $p < 0.001$ ) in China, with average annual increase of  $0.55 \text{ kg N ha}^{-1}$  and  $0.44 \text{ g N kg}^{-1}$ , respectively, between 1980 and 2006. Our results suggest that China has been experiencing increasingly serious atmospheric reactive N pollution since the 1980s. This increase is largely attributed to the expansion of agricultural and industrial production, especially the overuse of N fertilizer, the rapid increase in livestock production, the number of vehicles, and power plants, all of which have been part of the rapid economic development and urbanization in China over the last 30 years.

**Key words:** Air pollution, reactive N species, N deposition, China

## Ammonium absorption and cations leaching from the canopy of a sugarcane agro ecosystem under acid rains precipitation

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Acidic rains heavily loaded in ammonium are characteristic of Central Northern Venezuela, a region currently cropped with sugarcane plantations.

Nitrogen inputs (ammonium and nitrate) in precipitation waters are considered of great importance in the N economy of natural ecosystems; on the contrary in agro systems those inputs are of lesser importance when compared with the N requirements to crop production. However, in some areas atmospheric deposition highly loaded in N as a consequence of industrial and agricultural activities can contribute in a significant proportion to crop nutrition.

The nitrogen and other nutrients dissolved in rainwater might be retained by the crop-canopy (mainly in leaves); in this case a natural fertilisation occurs, whereas a reverse process takes place when ions and compounds are leached from the canopy to the throughfall waters. The magnitude of the foliar leaching depends on plant conditions such as plant age, physiological state, plant composition and morphology, but also in frequency, duration, and intensity and chemical composition of the rainwater.

In this contribution we analyzed the chemical changes in acid rains heavily loaded in N after passing through the canopy of a sugarcane field.

The study site was located in a sugarcane farm near San Felipe, Yaracuy state, Venezuela (10°29'44''N and 68°31'44''W).

Four plots of 300 m<sup>2</sup> within an experimental area of 4.5 ha cropped with *Saccharum officinarum* were selected to install the collectors of rain, throughfall and leaching waters. The study corresponds to the analysis of the second and third ratoons of two sugarcane varieties.

The soil is a Mollisols, with a pH of 7.4, moderate to high CICE and N content 0.1-0.2 %. All the rainwaters collected were acid (3.54-4.52). The pH of the acid rain increased after the passage through the canopy, which is in accordance with the significant amount of cations leached from the leaves.

Ammonium was the predominant N form in the precipitation water with a mean value of 1.29 µg L<sup>-1</sup>. N-nitrate forms in most of the analysed months were no detectable. The nitrogen inputs for wet and dry deposition in the agro system were high compared with other ecosystems (26.3 kg ha<sup>-1</sup> yr<sup>-1</sup>, mostly in the ammonium form). This is probably due to the high agricultural activity in the area, the local burning of the sugarcane before cropping, and the location of the experimental area nearby petrochemical industrial activities and fertiliser producer industries.

Although nitrates were leached in throughfall waters, the balance accounted for important N fertilisation of the leave canopy through ammonium absorption. On the contrary, throughfall waters were enriched in bases compared with precipitation waters meaning a significant cations lessivage from leaves particularly of magnesium due to the acidic water leaching of the canopy.

**Nitrogen Deposition Effects Team (N-DET) at the Spanish Research Council CSIC (Madrid, Spain)**

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Nitrogen (N) pollution is known to be of major concern and is related with global biodiversity losses. Despite this, little is known about its effects on Mediterranean ecosystems. In October 2007 we established six replicated blocks in different but close open patches dominated by *Rosmarinus officinalis* L. (rosemary), a well-developed biological soil crust (BSC), and therophytes during the short growing season, in a kermes oak (*Quercus coccifera*) scrubland from central Spain, each one consisting in four 2.5 x 2.5 m plots separated by two perpendicular crossed 1-m buffer stripes (24 plots in total). Each plot was randomly assigned to four different N treatments (0, 10, 20 and 50 kg N ha<sup>-1</sup> year<sup>-1</sup>) over the background deposition, all but the latter (about two times above the upper limit calculated) in the context of predicted 2050 deposition scenarios for Mediterranean ecosystems. N is being applied monthly during all the year as a 2 L solution of NH<sub>4</sub>NO<sub>3</sub> using a sprayer. Additionally, in autumn 2008 half of the plots were seeded with seeds of the nitrophilous species *Diplotaxis muralis* (L.) DC. These seeds were harvested at the end of the spring 2008 from disturbed areas located in the surroundings of our site. We hand-seeded the northern half of each randomly selected seeded plot with a density of 8000 seeds m<sup>-2</sup>. We have several results that show how a relative short time after the beginning of this experiment was enough for vegetation to show clear patterns associated with the reduction of two autochthonous annual forbs, while the seeded one and thought to be potentially invasive was enhanced. With this field experiment, the first related with N pollution in Central Spain, we expect to fill a gap of knowledge of the effects of this global change factor on Spanish Mediterranean ecosystems, which are typically limited by N, and to contribute to a better understanding of ecosystem response to N deposition in a global scale.

## Land use change impact on soil nitrogen content and trace gas fluxes: From a deciduous tropical dry forest to agricultural land and abandoned shrub land

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Developing-world agriculture is expanding rapidly; however, there is little information on its effect on nitrogen cycling from these regions. This gap is critical for trace gas emissions (such as NO<sub>x</sub>, N<sub>2</sub>O and CO<sub>2</sub>), whose emissions are driven by microbial processes likely increased by hot climates, and also for the fate of nitrogen as runoff and leaching in these areas. Latin America is expanding the agriculture frontier rapidly. In Venezuela the most affected areas are savannas and dry forests. In this study, in order to assess the impact of changes in nitrogen loads from these Venezuelan ecosystems, we established a comparison between trace gas fluxes and soil nitrogen content from a deciduous tropical dry forest (DF), agricultural lands fertilized with 100 kgN ha<sup>-1</sup> under tillage (T) and non tillage (NT) and an abandoned shrub land (FA) at one of the largest cereal producers in Venezuela during the growing season. The agricultural land and abandoned shrub land were established 50 and 3 years prior the experiment, respectively. The unfertilized evaluated areas receive a nitrogen input from wet deposition of about an order of magnitude smaller than the amount received from fertilization in the agricultural lands. In general, we found an order of magnitude larger N<sub>2</sub>O emissions from the agricultural lands (T = 31 ± 79 ngN cm<sup>-2</sup> h<sup>-1</sup> and NT = 52 ± 135 ngN cm<sup>-2</sup> h<sup>-1</sup>) than the dry forest (5 ± 9 ngN cm<sup>-2</sup> h<sup>-1</sup>) and abandoned shrub land (2 ± 6 ngN cm<sup>-2</sup> h<sup>-1</sup>). Although N<sub>2</sub>O fluxes were not significantly different between T and NT site, the latter showed larger emission values. The tilled site had the largest NO<sub>x</sub> and CO<sub>2</sub> fluxes (19 ± 41 ngN cm<sup>-2</sup> h<sup>-1</sup> and 89 ± 108 mgC cm<sup>-2</sup> h<sup>-1</sup>, respectively) in comparison to NT site (6 ± 10 ngN cm<sup>-2</sup> h<sup>-1</sup> and 33 ± 43 mgC cm<sup>-2</sup> h<sup>-1</sup>), dry forest (6 ± 12 ngN cm<sup>-2</sup> h<sup>-1</sup> and 25 ± 12 mgC cm<sup>-2</sup> h<sup>-1</sup>) and abandoned shrub land (4 ± 10 ngN cm<sup>-2</sup> h<sup>-1</sup> and 25 ± 8 mgC cm<sup>-2</sup> h<sup>-1</sup>). Soil ammonium and nitrate concentrations were about 10 times larger in T and NT sites than in FA and DF sites. There was more nitrate than ammonium in all sites. The total soil inorganic nitrogen (TIN = NH<sub>4</sub><sup>+</sup> + NO<sub>3</sub><sup>-</sup>) concentrations from the agricultural sites ranged from 2 to 190 mg.N g.d.s.<sup>-1</sup> and were an order of magnitude larger the unfertilized soils (FA and DF) (range of TIN concentration was between 2 and 16 mg N g.d.s.<sup>-1</sup>). From the 100 kg N ha<sup>-1</sup> applied fertilizer in the agricultural lands we found that the crop nitrogen use efficiency takes about 30% in the T and NT sites, 5% is lost as reactive nitrogen gases (N<sub>2</sub>O, NO<sub>x</sub> and NH<sub>3</sub>) and the remaining 65% gets lost as leaching and runoff from these sites. Our study suggests that rivers and groundwater are the more susceptible ecosystem service affected in the evaluated region.

## Effects of nutrient additions on the diversity of the herbaceous-subshrub layer of a Brazilian savanna (Cerrado)

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Brazilian Cerrado (savannas of Central Brazil) is the one of world's diversity hotspot due to its biodiversity, high endemism level and rapid loss of habitats. It is estimated that the number of herbaceous species is four times higher than that of woody species. The present work investigated the effects of nutrient additions on the diversity herbaceous-subshrub layer of a Brazilian savanna (cerrado *strict sensu* - this vegetation type is characterized by a continuous grass layer and a woody layer of trees and shrubs varying in cover from 10 to 60%). The experiment was carried out in an area located in the Ecological Reserve of the Instituto Brasileiro de Geografia e Estatística, near Brasília (15° 56' S, 47° 53' W). Soil is characterized as Oxisols, acidic, with high Al levels and low cation exchange capacity. Between 1998 and 2006, N (N treatment), P (P treatment), N plus P (NP treatment) or Ca (Ca treatment) were applied to twenty 225m<sup>2</sup> plots, arranged in a completely randomized design. Each plot was subdivided in nine subplots, three of which were randomly chosen for inventory of herbaceous-subshrub layer using line-intercept method (5m transect was marked, totalizing 15m per plot and 60m for each treatment). Shannon's diversity index was calculated and compared by the Hutchseon's t test. Soil samples (0-10 cm) were collected for chemical analyses (pH(H<sub>2</sub>O), pH(CaCl<sub>2</sub>), %C, organic matter, total nitrogen, P, K, Ca, Mg, Al, Fe, N-nitric e N-amoniacal. Canonical Correspondence Analysis (CCA) was used to analyze the relationship between species distribution and environmental variables.

The floristic diversity between the treatments was significantly different ( $p < 0,01$ ). NP treatment presented the lowest richness (48 species and  $H' = 1.65$ ) probably because the high cover of the exotic C4 grass *Melinis minutiflora* P. Beauv and of the native C3 grass *Echinolaena inflexa* (Poir) Chase. P treatment had 64 species and  $H' = 2.29$ , showing a high cover of *E. inflexa* e *M. minutiflora* too. N treatment presented 66 species, had  $H' = 1.91$  and high cover of *E. inflexa* but *M. minutiflora* was absent. Ca treatment had 69 species and  $H' = 3.23$  with lower cover of *E. inflexa* e *M. minutiflora*. Control treatment showed the highest richness of all, 90 species and  $H' = 2.40$  with a high cover of *E. inflexa* what can explain its relatively low diversity index in comparison to Ca treatment. Ca and Control treatments had the lowest cover of *M. minutiflora* and the highest diversity values. Canonical correspondence analysis (CCA) showed significant correlations between soil chemical properties and species distribution. Organic matter content, Ca, Mg, Al and Fe presented a high redundancy (Variance Inflation Factor > 20). Sites with higher levels of nitrogen differed from those with higher P concentrations. P, K and C% were significantly correlated to species distribution in the area. Spatial distribution of species was strongly related to the nutrients additions. The addition of N and P increase the coverage of alien species and exclude native species.

## Competition alters responses of juvenile woody plants and grasses to N addition in Brazilian savanna (Cerrado)

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Savanna ecosystems are characterized by the coexistence of shrub-tree layer and a grass layer. Changes in the distribution of these plant life forms due to differential responses to N addition might have several consequences to ecosystem functioning. In the present study, saplings of three woody species were grown in mono and mixed cultures with one of the dominant Cerrado grasses (*Echinolaena inflexa*) in a greenhouse experiment, with and without addition equivalent to a deposition of 20 kg N/ha/year. The hypotheses tested were that (1) woody plants are more efficient in gaining N per root biomass compared to the grass, what should lead to reductions in N content or biomass in grass individuals in the presence of the saplings, whereas these parameters would not change or increase in the saplings; (2) saplings would benefit from the increased N availability more than the grass, and (3) that the responsiveness of plants to N addition depends on the type of competition (inter or intraspecific). Interspecific competition tended to reduce root and shoot biomass of juvenile plants and grasses, however, significant effects were found, mainly, on root morphology. Compared to plants in monoculture, under interspecific competition the total root length and total fine root length diminished in two of the woody species and in grass, and root biomass was also reduced but only in one of these woody species. Compared to the control, N addition increased root diameter, total length and biomass in two of the woody species, mainly in monoculture. The higher N availability reduced the negative effects of interspecific competition, especially in the juvenile woody plants, increasing root biomass to similar levels found in the monocultures. N addition did not affect aboveground biomass and woody plant N content (foliar, root and stem) in the same extent. In contrast, the higher N availability increased the grass N content (root and shoot) and the ratio of total plant N content per root biomass in monoculture. Apparently, N addition did not affect grass individuals in mixed culture. The results pointed out that competition between saplings of woody plants and grasses is an important factor driving plant allometry and morphology during the first stages of development in cerrado environments. The enhancement of N availability might, in some cases, minimize effects of competition, increasing the potential competitiveness of some woody species. The consequences of such changes in the competitive ability of plants in a long term, however, still have to be evaluated. On the other hand, the results suggest that the responsiveness of plants to N deposition is highly influenced by the type of competition (intra- or interspecific) and models of vegetation dynamics in response to air pollution should take it into account.

## Nitrogen Fertilizer Equivalency of Selected Organic Materials in the Central Highlands of Kenya

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Nitrogen (N) is the plant nutrient taken up in the greatest quantities by crops and is also the nutrient most frequently limiting to plant growth in smallholder farms in Africa due to its high susceptibility to losses especially by leaching. In Kenya, continuous cropping has led to rapid deterioration of soils and diminished capacity of soils to supply N. Locally available organic materials could be used to curb this problem but the challenge is to identify organic materials that can act as alternative sources of N, with high N use efficiency, as well as economically feasible. This study was carried out to determine fertilizer N equivalency values of five organic materials in biomass transfer systems in a maize (*Zea mays*) monocrop. Field trials were carried out in two contrasting sites, a humid and dry zone, in central highlands of Kenya between 2005 and 2006. The organic materials were *Calliandra calothyrsus* (calliandra), *Tithonia divesifolia* (tithonia), *Lantana camara* (lantana), *Mucuna pruriens* (Mucuna) and cattle manure. Rainfall varied over the seasons with some seasons receiving amounts that below normal. Nitrogen fertilizer equivalencies were estimated only in good seasons and had a correlation coefficient of >85%. Tithonia, cattle manure and calliandra recorded high fertilizer N equivalency of more than 100% in the humid site. Mucuna, on the other hand recorded lower N equivalencies in all seasons. In the dry site, manure and lantana recorded the highest fertilizer N equivalency. Similarly, higher maize yields were obtained in treatments with organics compared to sole mineral N fertilizer treatments especially in the dry site because the organics enhanced conservation of moisture. This study showed that in areas experiencing erratic or low rainfall, organic inputs would be better option for enhancing crop productivity compared to mineral fertilizers. In addition, tithonia, manure, lantana and calliandra can be used as sources of plant N.

**Key words:** *Calliandra calothyrsus*, cattle manure, Dry and humid sites, *Lantana camara*, *Mucuna pruriens*, *Tithonia divesifolia*

**Photosynthetic pigment production and physiological status of the green algal foliose lichen *Cladonia foliacea* are affected by simulated N pollution and resource spatial heterogeneity in a Spanish semi-arid Mediterranean ecosystem**

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Nitrogen (N) pollution effects are related to anthropogenic activities such as food production and energy use, and it is currently affecting nutrient cycling and competitive plant-plant interactions in terrestrial ecosystems. The majority of field experiments related to N pollution studies have been conducted in temperate areas or Californian Mediterranean-type ecosystems, while the real effects on Spanish Mediterranean ecosystems remain unknown. Here we present firsts results of our N fertilization experiment, conducted in a semi-arid Mediterranean ecosystem, where plant community is dominated by sclerophyllous species, and where the biological soil crust (BSC) community is well developed and especially important for ecosystem functioning. We analysed pigment production and chlorophyll fluorescence of one selected lichen species (*Cladonia foliacea*) one (autumn 2008) and one and a half (spring 2009) year after the beginning of the experiment. *C. foliacea* pigment chlorophyll *a* and neoxanthin production were significantly and dose-related affected by N treatments and, although chlorophyll fluorescence was not statistically affected, trends were found suggesting negative effects of N pollution in the lichen physiological status. There was a clear seasonal effect on pigment production, with more pigment accumulation in spring compared to autumn, and with water stress playing a potential key-role in photo-protective pigments accumulation. Additionally, Fe was determinant for *C. foliacea* physiological status and Cu explained satisfactorily lutein content. We propose further research including natural gradients and some eco-physiological bioassays in order to detect early effects related to N pollution in water-limited Mediterranean ecosystems using BSC as bioindicators.

## Impacts of Nitrogen and Sulfur Deposition on the Growth of Red Spruce and Sugar Maple in the United States

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Nitrogen (N) and sulfur (S) deposition in forest systems can have positive or negative impacts on tree growth. The growth of many forests is limited by N availability, and therefore N and S deposition may stimulate or “fertilize” growth. However, N and S additions can sometimes be greater than that required by trees and negatively impact tree health. In cases where N and S deposition exceeds the critical acid load of a site, tree health and growth may be reduced directly and indirectly due to soil nutrient imbalances caused by leaching of base cations from the soil. To determine the relationships between N and S deposition and tree growth, analyses comparing the growth of sugar maple and red spruce and N deposition and critical load exceedances in the United States (U.S.) were conducted. Sugar maple and red spruce were selected as the test species because both have been shown to experience decline in areas of high N and S deposition. Critical loads were calculated using the simple mass balance model and a Bc/Al chemical indicator value of 10.0, and were compared against 2002 N and S deposition to estimate critical load exceedance. Annual individual tree volume growth for sugar maple and red spruce were obtained from the U.S. Forest Service Forest Inventory and Analysis (FIA) database. Linear regression analyses were conducted to determine the relationships between tree growth and N deposition and tree growth and critical load exceedance. Sugar maple growth was found to have a positive and significant ( $p = 0.0005$ ) relationship with N deposition in plots where the critical load had not been exceeded by deposition, suggesting a “fertilizer” effect of the deposition. In contrast, both sugar maple and red spruce showed a negative growth response on sites where N and S deposition exceeded the critical load, indicating that growth may have been impaired by the acidifying deposition in these locations. In the analyses of all plots across the full ranges of the two species, critical loads were found to be exceeded in at least 80% of sugar maple plots in 13 of 24 states and in 100% of red spruce plots in 5 of 8 states. These results suggest that the health of sugar maple and red spruce may be compromised in multiple locations throughout their natural ranges in the U.S.

## **Calibrating Nitrogen concentration in lichens with ammonia emissions and deposition at regional scales**

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The impact of Nitrogen (N) in ecosystems is a growing concern, leading to increasing demands for policies aiming at the identification and mitigating of its effects. However, there is a missing link between the predictions made by N-deposition models, at broad scales, and the actual N deposition on sensitive areas of ecosystems, that occur at a much lower scale.

The use of biomonitors could provide that link, more specifically the nitrogen concentration [N] in lichens, whose higher values have been associated to areas with more intensive agriculture activities, could be used to model the deposition of N in ecosystems with a high spatial detail. Although Nitrogen in lichens was measured in several works, we still need to compare the levels of N obtained from models produced by biomonitoring and the models based on N emissions or deposition. The aim of this work is to develop a link between the N concentrations in lichens and the [N] estimated from N-emissions and N-deposition models. With this we will be able to develop an important ecological tool by translating the information based on lichens to the atmospheric environment.

We have done so in two large regional areas with a typical Mediterranean climate, located in Portugal with different land-uses: i) urban and industrial areas, ii) extensive and intensive agriculture, iii) several important natural protected areas. In those regions we have measured [N] in lichens and interpolated it for the entire region using geostatistics. As emission estimation we used census data on the number of animals and area occupied by agriculture activities obtained from land-cover map. As deposition measures we used NH<sub>3</sub> concentrations measured using ALPHAS.

The first question addressed was if the [N]-lichen patterns were related to emission estimates. This was done using two estimation approaches, both considering agriculture as the main NH<sub>3</sub> source: i.) at a broad scale, estimating ammonia emissions from parish-level information on the number of animals; this provided us a robust measure of ammonia emissions (because it is based on real census data) but is reported only at very large spatial scale; and ii.) using land-cover information from satellite data, considering the area occupied by intensive and extensive agriculture; this provided a less robust approach (because it is dependent on accuracy of satellite classification), but present a high spatial resolution. For both scales of analysis it was confirmed that there was a significant correlation between [N] in lichens and emission estimates calculated both from cattle census data and from area occupied by agriculture. However there was no correlation with artificial areas, excluding NO<sub>x</sub> as N source for lichens. These results confirmed that [N] in lichens were reflecting the N-emissions mostly from NH<sub>3</sub>. Secondly we aimed at relating [N] in lichens to deposition measures. This will allow us to use [N] in lichens as a tool to assess the areas under the impact of N greatly enhancing the resolution of N-deposition models at a local and regional scales of analysis.

## **An Overview of Research and Environmental Monitoring Associated with Calculations of Critical Loads in the United States Forest Service**

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The United States Forest Service (USFS) has been involved with critical loads research and their application to forest and rangeland management since the late 1980s. These activities have been associated primarily with the monitoring of atmospheric pollution, long-term studies of forested watersheds, forest health monitoring, and the management of wilderness areas. Of particular interest has been the potential for interactive effects of air pollution with both climate and land-use change on forest health and water quality. Research efforts have focused on the development of empirical, static (mass balance), and dynamic modeling tools to calculate critical loads for levels of acidic deposition, nitrogen, and ozone. The USFS is in a strong position to conduct critical loads research due to its active participation with several environmental monitoring networks (e.g., the National Atmospheric Deposition Program) and its own long-term research facilities (e.g., Experimental Forest and Rangeland sites, affiliation with the Long Term Ecological Research sites and National Environmental Observatory Network). Moreover, the Forest Service is unusual among Federal agencies in that it has both a land management and research mission. This poster will provide several examples and case studies of the ongoing research, monitoring, and application of critical load measurements to forest and rangelands in the United States.

## **Wetland ecosystem and impact of nitrogen deposition on soil-aquatic environment for fish-crop diversity in the regions of Indian sub-continent**

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Soil and water are the integral part of global natural resources, determined greatly wetlands and its biodiversity. Survival of human civilization is inextricably linked with wetlands which sustained economic stability of hundreds million of people. And this swampy environment of the carboniferous period produced and preserved many of the fossil fuels on which we greatly depend now, for this James (1995) has rightly termed as 'Nature's kidney' of the world. In north-eastern part of Indian sub-continent have chains of rivers, tributaries, canals, oxbow lakes, which have a pivotal role in the regions for rural agricultural-fisheries productive system. Indiscriminate use of added nitrogen fertilizer by the farming communities resulted increasing level of N deposition, sometimes in critical level in soil and aquatic environment. Analyzed data of field studies on balanced nitrogen management (INM) on fish-crop diversification under varied wetland ecosystem (deep, semi-deep, temporary) resulted a sustainable productive system vis-a-vis existence of favourable physico-chemical properties of soil [organic carbon and organic matter, available ( $\text{NH}_4^+\text{N}$  &  $\text{NO}_3^-\text{N}$ ) and total N], respectively. Analysis of such wet bodies represents the water characteristics [ $\text{CO}_3^-$ ,  $\text{HCO}_3^-$ ,  $\text{NO}_3^-\text{N}$ ] is most responsive for fish-crop integrated system, may be quite adaptable and favourable for effective utilization of this vast waste wetlands for the mankind's safely. All the characters of both soil and water were also significantly influenced by the depth and duration of submergence under this investigation.

**Key words:** Wetland ecosystem, fertilizer N, soil and water quality, fish-crop diversity and productivity

## Wet Deposition of Nitrogen at Different Locations in India

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Daily wet deposition samples are being collected at Pune (regularly), and other locations (for limited period) representing different environments (i.e., Urban, rural, Industrial, high altitude, marine, traffic etc.) in India. All the rain water samples were analysed for pH, conductivity, anions (Cl, SO<sub>4</sub> and NO<sub>3</sub>) and cations (NH<sub>4</sub>, Na, K, Ca and Mg). The wet deposition data for Pune for the period 2000-2007 and for the other locations for the different time periods during 2001- 2007 are considered in this study. Also, the wet deposition fluxes of Nitrogen along with the other major ionic constituents for 10 GAW (Global Atmospheric Watch) locations in India for a period of 8 years during 2000 – 2007 will be presented.

In general, the rain water was found to be in alkaline range in India. Out of 10 GAW stations, the 8 years average pH was slightly acidic (pH 5.15 – 5.36) at only three locations. At the remaining 7 locations the pH was alkaline (pH > 5.65). This alkaline nature is due to high dust levels. Neutralization factors indicated that Ca is the major neutralizing cation in wet deposition. Ca concentrations were higher in N and NW regions and lower in southern and NE regions. Non-sea salt component and back trajectory analyses showed that Ca and SO<sub>4</sub> aerosols were transported to Indian sub-continent from North African and Gulf countries. Long term trend analyses (two decades) in the ionic composition at Pune showed the increasing trend of SO<sub>4</sub>, NO<sub>3</sub> and decreasing trend of Ca and pH. The wet deposition fluxes were estimated for all the ionic components including Nitrogen. The eight year average annual wet deposition of Nitrogen for 10 locations varied between 4.7 and 34.3 Kg/ha/y and yearly depositions varied between 1.8 and 57 Kg/ha/y. At all the locations, the NO<sub>3</sub> – N depositions were higher compared to NH<sub>4</sub> – N. At some of the locations, even though the concentrations are low, the depositions were higher due to the high rainfall amounts. Temporal variation of wet depositions of Total Nitrogen, excess SO<sub>4</sub>, Ca and pH of rain water at the 10 GAW locations in India will be presented. In regional perspective, the excess SO<sub>4</sub> - S deposition was higher at an industrial location and the Nitrogen deposition was higher at a traffic junction in Pune region. At an high altitude rural location (Sinhagad) nearby Pune, the concentrations of excess SO<sub>4</sub>, NO<sub>3</sub> and NH<sub>4</sub> were lower but their depositions were higher due to higher rainfall amounts. The total Nitrogen deposition at four different locations in Pune region varied from 10.4 to 13.2 Kg/ha/y.

## Atmospheric dry deposition of ammonia and particulate ammonia in the North China Plain

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Atmospheric ammonia and particulate ammonium (in PM<sub>10</sub>) were measured at six sites (two suburban and four rural) in the North China Plain (NCP) from August 2006 to September 2009. The annual mean concentrations of ammonia and ammonium were 12.9  $\mu\text{g N m}^{-3}$  (ranging from 7.3-19.9  $\mu\text{g N m}^{-3}$ ) and 9.0  $\mu\text{g N m}^{-3}$  (ranging from 4.3-14.4  $\mu\text{g N m}^{-3}$ ), respectively. Both ammonia and particulate ammonium concentrations were higher at the rural sites than at the suburban sites, implying the importance of agricultural sources for reduced reactive N species. Higher ammonia concentrations were observed in April, July, August and October, the major N fertilization seasons. It suggested that ammonia emission from N fertilizer application was an important source of atmospheric ammonia in the NCP. Particulate NH<sub>4</sub><sup>+</sup> was highly correlated with particulate SO<sub>4</sub><sup>2-</sup> and NO<sub>3</sub><sup>-</sup> at all sites. The total concentrations of secondary species (NH<sub>4</sub><sup>+</sup>, SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup> and Cl<sup>-</sup>) accounted for 25.8-29.2% and 36.3-43.8% of the PM<sub>10</sub> concentrations at the suburban and rural sites, respectively. Based on the measured ammonia and ammonium concentrations and their deposition velocities taken from literatures, the annual mean NH<sub>x</sub> (NH<sub>3</sub> plus NH<sub>4</sub><sup>+</sup>) dry deposition rate was 22.2 kg N ha<sup>-1</sup> among the six sampling sites. The high NH<sub>x</sub> concentrations and dry deposition rates in the NCP indicated agricultural sources contributed substantially to air pollution and should be considered in environmental N nutrient input.

**Keywords:** atmospheric nitrogen, agricultural emissions, PM<sub>10</sub>, secondary particles

**Peat bogs: Does enhanced reactive nitrogen deposition threaten their sustainability via effects on carbon sequestration, is N form important?**

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Peatlands cannot sustain themselves if they can't sequester carbon, a vital ecosystem service. If decomposition/mineralization rates start to exceed productivity, gradually their area and functionality will decline. Recently, shrinkage and reductions in peat depth have been occurring in response to anthropogenic activities. However, responses to specific anthropogenic drivers such as enhanced N deposition and the roles of different N forms, along side interactions with climate change, have still to be resolved. Nitrogen is a key plant and microbial growth nutrient, with the potential to increase carbon assimilation and decomposition. Thus, the consequences of changing nitrogen availability are tightly coupled to the biogeochemical cycling and sequestration of carbon via growth, which also drives changes in species composition/functionality.

Peatlands are widespread in northern regions of Europe, areas with low levels of N deposition, often  $\ll 5$  (-10)  $\text{kg N ha}^{-1}\text{y}^{-1}$ , the Critical Load for bogs, so should we be concerned about enhanced nitrogen deposition? Evidence suggests that sensitivity to N is strongly determined by historical and current N deposition in tandem with the environmental factors that constrain carbon assimilation, growth rates and species composition. Peatlands generally occur in environments that restrict growth, are cold, wet and acidic with low levels of available nutrients. The vegetation has evolved to tolerate low nutrient availability and many components of the species pool are unable to up regulate their C assimilation in response to elevated nitrogen deposition. Thus peatlands, their biodiversity and function and the services they provide may well be threatened by even very modest increases in their ambient nitrogen deposition. In the context of peatland ecosystems that have evolved over millennia, the increases in reactive nitrogen deposition observed over recent decades represent a huge **stepwise** change, even if the N dose appears very small. Because the carbon balance at these sites is particularly important in buffering rising  $\text{CO}_2$  levels and because of their potential nitrogen sensitivity, understanding nitrogen effects on carbon processing in peatlands is crucial.

We provide a snapshot of some key responses that underpin the carbon economy of a peat bog in the Scottish Borders where nitrogen deposition in the dry reduced form (ammonia) and wet deposition as either oxidised or reduced N ( $\text{NaNO}_3$  and  $\text{NH}_4\text{Cl}$  respectively) has been manipulated over the last 7 years. Using realistic deposition scenarios, where wet deposition is coupled to precipitation patterns, and dry deposition to wind direction, N deposition has been increased by 2, 3 and 7 times the relatively low (UK) background deposition of  $8 \text{ kg N ha}^{-1}\text{y}^{-1}$ .

Per unit N deposited ammonia gas drives species loss, *Sphagnum capillifolium* and *Calluna* at a considerably faster rate than wet N, leading to breakdown of the vegetation cover and the loss of functionality. Both reduced and oxidised nitrogen in wet deposition, even at the lowest N dose, accelerated loss of  $\text{CO}_2$ -C from this bog and had a detrimental effect on *S. capillifolium*. GHG emissions of methane (by ammonia and nitrate) and nitrous oxide (by ammonia) were also enhanced.

## **Nitrogen and phosphorus additions negatively affect tree species diversity in tropical forest regrowth trajectories**

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Nutrient enrichment is increasingly occurring in many tropical ecosystems, but there is little information on how tropical tree diversity is affected. To examine dynamics in tree species biomass and diversity in a young successional forest, we re-measured trees annually before and for six years after additions of nitrogen (N) and phosphorus (P) in abandoned Amazonian cattle pastures. Nitrogen and P each stimulated growth of the dominant pioneer, *Rollinia exsucca* (Annonaceae), while N also stimulated growth of two other species. Overall, N or P addition reduced tree assemblage evenness and delayed tree species accrual over time, likely due to competitive monopolization of resources by the few species responding to nutrient enrichment. While growth rates were elevated for only 2 years post-nutrient addition, shifts in relative species growth and reduced assemblage evenness persisted for >3 years post-nutrient addition, favoring nutrient-responsive pioneer and early-secondary species.

Surprisingly, N+P effects on tree biomass and species diversity were weaker than N-only and P-only effects, because remnant pasture grass biomass increased dramatically in response to N+P addition, preventing an expected positive N+P synergy for the trees. In conclusion, N or P enrichment may reduce the diversity of coexisting species and delay species accrual during structurally and functionally complex tropical rainforest secondary succession.

## Changes In Soil Nitrogen And Microbial Population Under Organically Managed Rice-Wheat Greengram Cropping System

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The management of soil nitrogen is critical for maintaining a productive organic farming system especially when exhaustive system like rice-wheat system is taken up. No one source of nutrient usually suffices to maintain productivity and quality control in organic system. In addition, the inputs to supplement nutrient availability are often not uniform and presenting additional challenges in meeting the nutrient requirement of crops in organic systems. With this concept, a field experiment was conducted at the research farm of Indian Agricultural Research Institute, New Delhi, India during 5 wet and dry seasons of 2003-08 in rice-wheat-green gram cropping system. In this experiment different treatments comprising organic amendments such as Blue Green Algae (BGA) @ 2.0 kg / ha, Azolla @1.0 tonne / ha, Vermicompost and Farm Yard Manure (FYM) @ 5.0 tonne / ha applied alone or in combination were tested in organic crop production. These treatments were compared with total control (N0P0K0) and recommended dose of fertilizer (N80P40K40). In wheat crop Azotobactor replaced Azolla, but other treatments remained same. Bio mass of green gram was incorporated in soil after picking of pods and wheat was sown using zero tillage practice.

Total nitrogen content in soil (0-15 cm) was found to be continuously built up over the period of five years due to the organic farming through the combined application of four organic amendments. Total N content in absolute control plots declined sharply due to the continuous depletion of N by the crops. Soil organic carbon (SOC) contents also showed the same trends as total soil N contents and SOC were correlated. A built up in soil organic carbon up to 0.92% due to the application of four amendments from the initial level of 0.46% was recorded during this period. SOC declined up to 0.34% and 0.22% due to chemical fertilizer application and absolute control, respectively over the same period.

Microbial population (CFU/g of soil x10<sup>5</sup>) of Actinomycetes, Bacteria, Fungi and blue green algae (BGA) increased from 74, 203, 14 and 3 in 2003 to 312, 615, 85 and 93, respectively in 2008, due to the application of four organic amendments. Increase in microbial population caused notable increase in Dehydrogenase Enzyme Activity and phosphatase enzyme in organic treatments over the years as compared to control and recommended dose of chemical fertilizer.

Results revealed a significant enhancement in grain yield of basmati rice and wheat over total control due to the application of different organic amendments applied alone or in combinations. The mean grain yield of 4.43 and 3.68 t ha<sup>-1</sup> of rice and wheat, respectively obtained under combined application of four organic amendments was at par with the yield recorded under recommended dose of chemical fertilizer application. No serious incidence of any insect pest or disease was recorded in organically grown rice and wheat crops.

It was concluded that addition of four organic amendments (BGA, Azolla, FYM and Vermicompost) could maintain proper level of soil nitrogen and organic matter and give the optimum yield of organic Basmati rice and wheat.

## **Applying Bayesian Belief Network ideas to quantifying Ecosystem Services**

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The Ecosystem Services concept highlights the benefits of a holistic approach to rural land management using combinations of socio-economic and biophysical data. The assessments combine data from different sources, measured at different spatial scales and of different qualities. The challenge CEH faces is to bring together our biophysical information for complex ecosystems in a form that retains the relevant detail but can be successfully integrated with socio-economic data.

The Bayesian framework theoretically can pull together disparate information and is increasingly used by socio-economists for this task. We focus on how useful these frameworks are for typical biophysical data held within CEH using examples from Loch Leven and ECN.

**Soil nitrogen dynamic and green house gas fluxes (CO<sub>2</sub>, N<sub>2</sub>O e CH<sub>4</sub>) in two watersheds with different land cover (forest and pasture), southeast Brazil.**

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The Atlantic forest is one of the most threatened tropical ecosystem in the world, and considered priority for conservation policies. Today the native vegetation is reduced to less than 8% of its original area and due to the fast change in land cover, and use, there is a clear lack of deep knowledge on its ecological dynamic. Green house gas emissions are particularly under studied, in spite of the great interest the subject has raised nowadays. The main objective of this work was to evaluate the nitrogen dynamic and GHG (N<sub>2</sub>O, CO<sub>2</sub> e CH<sub>4</sub>) fluxes in two small catchments, with contrasting land cover – forest and pasture – in southeast Brazil. The GHG fluxes were higher in the pasture in comparison to the forest, with a positive correlation to temperature (in particular CO<sub>2</sub>). Positive soil-atmosphere fluxes of CH<sub>4</sub> were also observed in the pasture site, indicating changes in the decomposition dynamic with the forest replacement. There was statistical significant difference in the N<sub>2</sub>O fluxes from forest to pasture, with higher values in the later. Forest fluxes varied, throughout the study period, from  $-0,17 \pm 0,06 \text{ ng N cm}^{-2} \text{ h}^{-1}$  a  $0,73 \pm 0,04 \text{ ng N cm}^{-2} \text{ h}^{-1}$ , while in pasture a higher fluctuation in fluxes were observed, with the pick value ( $9,29 \pm 0,44 \text{ ng N cm}^{-2} \text{ h}^{-1}$ ) happening in November. These results contradicts the hypothesis that the emission of gaseous nitrogen resulting from forest soils would be greater than pasture, since pasture soils tend to be limited in nitrogen, and contrasts with previous observation in the Amazon region, where forest N<sub>2</sub>O fluxes in “terra-firme” forests were always higher than in pastures.

## Quantifying Atmospheric Nitrogen Deposition On Lowland Heathland: A Synthesis Of Long Term Data From Thursley Common

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Elevated rates of nitrogen deposition can lead to the eutrophication of sensitive terrestrial ecosystems and the associated change in plant community characteristics and ecosystem function. Since 1989, a series of nitrogen manipulation experiments have been carried out at Thursley Common NNR, a lowland heathland in Surrey. Current experiments include an ongoing N addition study and a recovery experiment. The ongoing experiment, started in 1998, shows large and significant effects of N addition (0 or 30 kg ha<sup>-1</sup> yr<sup>-1</sup>) on *Calluna* growth, flowering and canopy development, detrimental effects on understory lichen and bryophyte abundance, as well as strong effects on soil chemistry, nutrient cycling and the soil microbial community. Following a severe summer fire in 2006, vegetation re-growth was strongly stimulated in plots receiving additional N. Analysis showed that, despite the intensity of the fire, treatment-related differences in soil nutrient stores and availability persisted, driving observed patterns in vegetation regeneration.

The recovery experiment, now in its 13<sup>th</sup> year, has monitored vegetation growth and soil chemistry since N additions ceased in 1996 (0, 7.7 or 15.4 kg ha<sup>-1</sup> yr<sup>-1</sup>, 1989-1996). During this time, persistent effects of former N treatments have remained, with treatment-related differences still seen in terms of *Calluna* growth, lichen abundance and soil chemistry. Interestingly, the severe fire of 2006 has increased the size of the persistent N signal, with larger effects of former N treatments apparent in 2008 than in recent years. This poster summarises the main patterns and trends seen at Thursley over the past 10 years.

## Physical disturbance determines effects from nitrogen enrichment on boreal plant community

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1. Human induced perturbations of ecosystems rarely occur in isolation. Nitrogen (N) enrichment of ecosystems often occurs in combination with land-use related disturbances and interactive effects are considered to be both common and important. Despite this, the importance of such interactive effects is often poorly known.
2. We tested the hypothesis that there are interactive effects between N enrichment and physical disturbances, and that N enrichment can predispose boreal forest plant communities to increased sensitivity to physical disturbance. To test this we evaluated effects of N enrichment on forest understorey vegetation in full-grown (undisturbed) and in clear-felled (disturbed) boreal forest.
3. Our results show that the N effect on the plant community was strongly dependent on the disturbance caused by removal of the overstorey tree canopy and that the two perturbations interacted although they were temporally separated. In full-grown undisturbed forests, there were small or no residual effects on plant community composition from N addition nearly 30 years ago. In contrast, forests exposed to N addition and subsequently disturbed by clear-felling had lower species diversity, higher Ellenberg N values, lower abundance of dwarf shrubs (30-70%), and higher abundance of grasses and herbs (100-400%) than forests only exposed to clear-felling.
4. *Synthesis.* Our study highlights the importance to consider interactive effects of multiple disturbances when evaluating environmental changes in plant community composition. We suggest that N enrichment predispose plant communities to increased sensitivity to secondary disturbances. The predisposing nature of N enrichment implies that effects on plant communities may appear small, short-lived, or even absent until it is exposed to a disturbance that implements the full effect of the enrichment. Most studies that have evaluated effects of N enrichment on forest understorey vegetation have not considered interactive effects with secondary disturbances, and may thus have underestimated the full effect of enrichment. Hence, forest understorey vegetation may be more sensitive to N enrichment than presently thought.

## **An intercomparison of models used to simulate the atmospheric dispersion and deposition of agricultural ammonia emissions**

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Ammonia emitted into the atmosphere from agricultural sources can have an impact on nearby sensitive ecosystems either through elevated ambient concentrations or dry/wet deposition to vegetation and soil surfaces. Short-range atmospheric dispersion models are often used to assess these potential impacts on semi-natural ecosystems and a range of different models are used for these assessments depending on the location and experience of the assessors. However, until now there has not been an intercomparison of the different models, for the case of ammonia dispersion from agricultural sources. This paper presents an intercomparison of some models commonly used for this type of assessment (ADMS 4; AERMOD; LADD and OPS-st). This intercomparison shows that there are significant differences between the concentration predictions of the models and some of these differences appear to be consistent independent of the scenario modelled. When applied to two case study farms in Denmark and the USA the performance of the models is variable with some models performing “acceptably” for one case study and not the other (according to the performance measures used). The models generally performed better for long averaging periods (e.g. one year) than for short periods (e.g. one week). Although there are insufficient field data to evaluate the deposition predictions of the models, it is expected that the accuracy of model predictions will be less than that of the concentration predictions.

## **Regional scale nitrogen budgets from Agriculture sector in India and environmental implications**

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In this study, we present nitrogen budgets at a regional scale from agriculture sector in India. Much of the excess nitrogen inputs in the Indian region are related to agriculture. We quantified soil surface nitrogen loads for agroecological zones (AEZ's) in India using mass balance approach. We estimate nearly 35.0 Tg of nitrogen inputs from different sources, with output nitrogen from harvested crops of about 21.0 Tg. The soil surface nitrogen balance, estimated as inputs minus outputs, is found to be about 14.4 Tg surplus from the agricultural land of India. Livestock manure constituted a major percentage of total inputs (44.0%), followed by inorganic fertilizer (32.4%), atmospheric deposition (11.86%) and nitrogen fixation (11.58%). Nitrogen balance varied from deficit to surplus for different states and agroecological zones. Soil surface N balance for agricultural lands showed a surplus of about 14.4 Tg. The lowest N loads were found for AEZs in the Eastern Himalaya, with 19 kg/ha surplus, and highest surplus in AEZ's with 111 kg/ha in Deccan plateau and the south India. Environmental implications of these excess nitrogen loads in India will be discussed in addition to some best management practices to reduce these loads from the agriculture sector.