

- The introduction of emissions trading of nitrogen dioxide.

## 8.12 Portugal

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### Major achievements during the COST Action

- Determination of Critical Levels and Loads for the Mediterranean Ecosystems.
- Mapping areas at risk of N deposition.
- Network of Portuguese and International research institutes.
- Enlargement of research group on N deposition in Portugal.
- Submission of new research projects on N issues.
- Establishment of interaction with Portuguese environmental agency.
- Political concern increment on N deposition in Portugal.
- Interaction with policy makers.

### Introduction

Air emission inventories in Portugal were initiated in 1989/1990 and first estimates of  $\text{NO}_x$  were made at this time. Only in 1992, under the CORINAIR90 and UNECE/EMEP report was  $\text{NH}_3$  first included in the inventory. At present, emission factors for  $\text{NO}_x$  and  $\text{NH}_3$  are determined from the available set of algorithms reported in EMEP/CORINAIR handbook (EMEP, 2002).

### Major nitrogen issues in Portugal

In Portugal there are approximately 70 air quality monitoring stations measuring permanently  $\text{NO}_x$  (<http://www.qualar.org>), located in urban, suburban and rural areas. Concerning this pollutant both in space and time, the level of information is quite detailed.

According to CLRTAP-Convention on Long-Range Transboundary Air Pollution, Portugal has the compromise to present their  $\text{NH}_3$  emissions in a spatial pattern following a 50 km x 50 km grid. However, at present, APA (Portuguese Environmental Agency) presents the data according to the council level, which is more detailed. Despite this effort, the level of information at spatial dimension is still not adequate to the type of deposition that has been shown to be quite local, most effects occurring at less than 500 m (Pinho *et al.*, 2009). Moreover, there are no  $\text{NH}_3$  monitoring stations at the national level and there are only two  $\text{NH}_4^+$  monitoring stations

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in the continent, one in the north and other in the south of the country (<http://www.meteo.pt/pt/ambiente/atmosfera/>). Thus, the information concerning the air quality and the deposition of  $\text{NH}_3$  is only based on statistical information and air deposition models not validated with instrumental  $\text{NH}_3$  measures in our country.

#### **State of nitrogen and environment in Portugal**

Most part of the  $\text{NH}_3$  emissions is related to agricultural activities (41,5%) or livestock production (39,3%). Knowing that most of our 2000 Natura Network is located in rural areas with high agriculture and livestock activities, the assessment of the impact of  $\text{NH}_3$  on biodiversity and ecosystem function is of high importance for Portugal. Moreover, the Global Strategy for Plant Conservation, that Portugal has also signed, emphasises the need for capacity-building in order to enable the implementation of the targets for 2010 using a flexible framework within which national and regional actions are developed. Thus, there is a need to take the targets into consideration for monitoring and assessing progress of N deposition particularly on Rede Natura 2000 sites.

#### **Research infrastructure in Portugal**

There are no special infrastructures in Portugal fully dedicated to N issues.

#### **Policy links**

In Portugal there are two main institutions that may deal with nitrogen (N) emissions and deposition compliances and their effects on biodiversity that are, respectively: the Environmental Portuguese Agency-APA ([www.apambiente.pt](http://www.apambiente.pt)) and the Institute for Nature and Biodiversity Conservation-ICNB ([www.icnb.pt](http://www.icnb.pt)).

APA is the national entity responsible for the overall coordination of the Portuguese inventory of air pollutants emissions.

#### ***COST Action 729 related activities during the action***

2006 – Portugal was represented by 4 national experts at the UNECE Expert workshop on ammonia. Atmospheric ammonia: detecting emissions changes and environmental impacts. Leith, Edinburgh 4-6 December.

2007 – Portugal was represented by 1 national expert at Nitrogen Cascade in Europe Workshop. Schagen, January 11-12.

2008 – Local organiser of the COST Action 729 – 7th MC meeting. 'Assessing and Managing Nitrogen Fluxes in the Atmosphere – Biosphere system in Europe' Lisbon, April 23-25.

2009 – Portugal was represented by 3 experts at the European Nitrogen Assessment (ENA) April (23-25) meeting in Brussels. ENA represents a process of scientific and policy synthesis that will provide a major review of the role of excess nitrogen on environmental problems.

Portugal was represented by one expert at the Management Committee Meeting held in 2-3 December in Antalya, Turkey.

2010 – Portugal was represented with 2 national experts on the Workshop on the review and revision of empirical critical loads and dose-response relationships, under the UNECE Convention on Long-Range Transboundary Air Pollution at the Noordwijkerhout, the Netherlands 23-25 June.

Portugal was represented with a national expert on the meeting 12-13<sup>th</sup> May, 2010 in Prague Czech Republic, of the Task Force on Reactive Nitrogen (TFRN) under the Working Group on Strategies and Review of the UNECE Convention on Long-Range Transboundary Air Pollution.

### **Coordination of national projects**

2005-2008 – Managing human activities intensity for water quality in ecological-economic sustainability: the case study of Monfurado. Financing: 84,999 €; Portuguese Government; POCTI/AMB/63160/2004.

*Coordinator:* Cristina Branquinho.

*Objective:* we propose to monitor water quality, namely eutrophication, in an integrated and holistic perspective (combining water physic-chemical analysis, biomonitoring and ecosystem integrity assessment). We also propose to analyse the human activities intensities in same area, in order to find relationships with the first information. Having this relations studied, it is of most importance to optimise relationship between economic system and ecological system in a case-study in the south of Portugal, Monfurado, with regard to aquatic N-pollution. We may estimate which are the ecological costs (in economic language) associated to human activities and also to define acceptable levels of aquatic pollution. We expect to contribute, with this project, to the environmental management, namely, to water quality management in Mediterranean rivers and streams.

2009-2012 – Spheres of Ecosystem Response to Nitrogen (SERN): A case study in a Mediterranean-type ecosystem in southern Portugal. Financed by FCT PTDC/BIA-BEC/099323/2008 (198,332.00 €). Funding entity: Portuguese Government (198,000 €). Coordinated by Cristina Cruz.

*Objective:* the aim of this project is to study the integrated response (atmosphere, soil and biosphere,) of a Mediterranean-type ecosystem to increased atmospheric  $[\text{NH}_3]$ . Our approach will underpin the hierarchy of ecosystem response to N: species composition, ecosystem functioning and services. Consequently, the major issues to be addressed comprise chemistry, microbiology, physiology, ecology and modelling. Apart from the uniqueness of this type of ecosystem and the integrated hierarchical approach proposed, the novelty of the expected results relates with the several perspectives of the effects of increased atmospheric  $[\text{NH}_3]$ : as a driving force in areas of Natura 2000; the importance of the Birch effect on the GHG fluxes between soil and atmosphere; selective response of several soil functions and phylogenetic groups; and mechanisms associated with the tolerance (toxicity) of above ground cover. Integrating all data will result in a conceptual hierarchical model for the response of Mediterranean-type

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ecosystems to increased atmospheric  $[NH_3]$  that is expected to provide valuable management tools for decision makers. Finally, several objectives are integrated within the frameworks of ongoing European Union projects, thus making the Portuguese participation relevant beyond the national level since it would help fill in the gap of the Mediterranean Basin.

2009-2010 – Co-operation with the industry (ADP- Fertilizantes) in order to develop products that increase nitrogen use efficiency. Fertiliser granules were coated with microorganisms resulting in a commercial product that has potential to increase the residential time of nitrogen in the soil and increases the amount of nitrogen that is used by the culture. Coordinated by Cristina Cruz.

### **Results of the COST Action 729 related activities**

#### **Critical levels**

With the support of this cost action lichens were used to determine the critical level of  $NH_3$  in cork-oak woodlands, which was found to be very similar to values determined in other countries and ecosystems using the same group of organisms. Lichens can be used as ecological indicators for determining critical levels of pollutants on ecosystems. When determining the critical levels of pollutants for a given ecosystems it is not possible to test all species, thus, within a precautionary approach, critical levels aim at protecting the more sensitive known species from adverse effects. Lichens are considered one of the most sensitive communities of ecosystems to air pollution, namely N-pollution (Cape *et al.*, 2009).

#### **Critical loads**

Data from epiphytic lichens, on cork oak woodland (*Quercus suber*), under Mediterranean climate, has shown that critical levels for  $NH_3$  are below  $2 \mu g.m^{-3}$  and that critical loads are lower than  $17 kg N.ha^{-1}.yr^{-1}$  (with a background deposition of  $10 kg N.ha^{-1}.yr^{-1}$ ) (Pinho *et al.*, 2009).

#### **STSM**

Ms Sim Tang, from the Centre for Ecology and Hydrology, Edinburgh (UK) was in Portugal hosted by Cristina Branquinho, Centre for Environmental Biology (CBA) through a STSM with the topic: relationship of lichen diversity to atmospheric ammonia concentrations in Portugal; STSM Reference Number: COST-STSM-729-732; Period: 24-09-06 to 30-09-06.

Mr Mark Theobald from Technical University of Madrid, Madrid (ES) was in Portugal hosted by Cristina Branquinho, Centre of Environmental Biology (CBA) Faculty of Sciences University of Lisbon (PT) through a STSM with the topic: Inverse dispersion modelling of ammonia emissions from Portugues cattle far. COST STSM Reference Number: COST-STSM-729-5799. Period: Feb. 22 2010 12:00AM to Feb 27 2010 12:00AM; STSM type: Regular (from Spain to Portugal).

Ammonia emitted into the atmosphere from agricultural sources can have detrimental impacts on nearby downwind ecosystems. One such impact is the change in biodiversity leading to a replacement of plant species with a low nitrogen demand with more nitrogen-loving

(oligotrophic) species (e.g. Pitcairn *et al.*, 2003). In a recent study by Pinho *et al.* (2009), lichen diversity was shown to be correlated with measured atmospheric ammonia concentrations downwind of a cattle shed in Portugal. The authors observed that the diversity of oligotrophic lichens decreases with distance from the cattle shed showing that the high concentrations of ammonia near the shed are favoured by these species. This group, which is the based at the host institution of this STSM, were keen to use atmospheric dispersion modelling techniques to assess the spatial distribution of atmospheric ammonia concentrations and nitrogen deposition as well as investigate how the cattle shed emissions vary throughout the year. Mark Theobald is currently doing his PhD at the Technical University of Madrid on the subject of atmospheric dispersion modelling for agricultural sources of ammonia. The Portuguese study site is an ideal case study for Mark's PhD work, since the host group have made a long time series of ammonia concentration measurements, which are useful for assessing model performance in a Mediterranean climate.

### **Nitrogen availability and biodiversity in sites Natura 2000**

IA manipulation of the nitrogen availability in the ecosystem was performed in Arrábida – Mediterranean-type ecosystem. Different nitrogen sources (reduced, oxidised and mixed) were used in 2 levels 40 and 80 Kg N/ha/year. The place is very nitrogen limited (as well as phosphorus). It was observed that one year of nitrogen additions was enough to change the plant composition of the site. An increased in plant biodiversity was in fact observed during the first and the second years of the nitrogen addition. This response of the vegetation was interpreted as nitrogen addition being a relief of the nitrogen stress allowing the appearance of more nitrogen demanding species while the more nitrogen efficient and slow growing plants were still able to grow and develop. A clear tendency for an increment in the number and cover of graminaceous species was clearly observed.

Some species were more affected by the nitrogen source added, while others responded to the amount of nitrogen added. The dominant species in the site is a shrub (*Cistus ladanifer*) that was negatively affected by the nitrogen addition (mainly in the reduced form).

The changes in plant species lead to changes in the below ground communities. As the dominant species forms ectomycorrhiza and the incoming graminaceous form arbuscular mycorrhiza a clear change in the specific composition of these two groups was observed. Specific and functional changes were also observed in the bacteria and archaea communities.

Nitrogen additions did not change the amount of total nitrogen in the soil, or the nitrogen concentration in the plant leaves, but did dramatically increase (5 times) the nitrogen concentration in the plant litter.

### **Soil atmosphere gas exchanges**

The gas exchanges between soil and atmosphere were most studied in a Montado, cork oak (*Quercus suber*) multipurpose forest used to grow animals (cows). The farm has a stable that shelter permanently 200 animals. The barn represents a source point of ammonia emission

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to the atmosphere and creates a gradient of ammonia deposition along the direction of the predominant winds.

It was observed that the influence of the burn was about 200 m, further from the burn the atmospheric ammonia concentration reached background values. The nitrogen input due to the presence of the animals was enough to create a gradient of nitrogen availability that was possible to be detected (stable isotopic analyses) in the tree leaves and in the soil biomass.

A clear gradient of microbial activity was observed with higher activities in the area with higher nitrogen availability.

The gas exchanges between the soil and the atmosphere were very dependent on the water availability in the soil. Under suitable water availability the cork oak forest was behaving as a sink of methane, however the increase in nitrogen availability increased methane emissions, showing the importance of the C/N relation in the soil towards microbial activity. At the moment work is being developed to study the interaction of nitrogen availability with methane emissions, and the microbial activities associated.

#### **PhDs**

2010 – Silvana Munzi. European PhD in Science and Technologies Applied to the Environment. University of Siena. Faculty of Maths, Physics and Natural Sciences. 'Sensitive organisms (lichens) as monitors of biological effects of nitrogen pollution'. Supervisor Stefano Loppi, and co-supervisor Cristina Branquinho. PhD Erasmus Student in Portugal.

2010 – MS. Pedro Pinho, PhD in Applied Ecology in Faculty of Sciences University of Lisbon 'Modelling lichen communities: key ecologic factors in a changing environment' SFRH/BD/17880/2004. Supervised by Cristina Máguas and Cristina Branquinho.

2011 – Teresa Dias, ecosystem responses to increased availability of reactive nitrogen: applicability of a model on 'nitrogen saturation' in ecosystems like bogs and in the Mediterranean. SFRH/BD/25382/2005 Supervised by Cristina cruz and Lucy Sheppard.

#### **Scientific and policy implications**

The impact of Nitrogen on biodiversity is not a priority subject for our conservation biology governmental authority, ICNB ([www.icnb.pt](http://www.icnb.pt)). Thus, N deposition is never considered as a threat/pressure in habitats status reporting, habitats limitation, or as a factor for conservation management. Nevertheless, some protected areas Natura 2000 are located in areas where the  $\text{NH}_3$  deposition is between 1 and 1,6  $\text{ton.km}^{-2}$  (Martins-Loução *et al.*, 2011).

#### **Future outlook**

An international consortium was established to present an Erasmus Mundus Joint Doctorate (1) to form doctoral candidates who are able to face the challenge of improving nitrogen management, increasing nitrogen use efficiency in order to maintain food and energy security, while decreasing the health and environmental impacts of that use; (2) to contribute to a better

integration and a global assessment concerning the nitrogen management in the biosphere linking the fragmented knowledge that exists at the moment on many of the areas. This is only possible in a multidisciplinary team of nitrogen experts working in transversal research projects and establishing a committed and creative platform towards knowledge based decisions, which is the basis of the present consortium. This EMJD is based on a broad consortium putting together different regions of the world: Europe, South America, China, under different socio-economic growth and economical needs, and including universities: Universidade de Lisboa, Portugal, University of Amsterdam, the Netherlands, University of York, UK, Universidade de São Paulo, Brazil, China Agriculture University, China, research centres: Centre for Ecology and Hydrology, UK, Energy Research Centre of the Netherlands, the Netherlands, industry: International Fertilizer Association, Euro Mediterranean University, non-governmental association: Liga para a Protecção da Natureza, Portugal, and governmental sectors, such as International Nitrogen Initiative. The launching of this programme will allow doctoral candidates to develop co-operation between institutions of different countries, different sectors – academia, research, industry, governmental and non-governmental institutions – and to work together towards the development of integrative projects on N management.

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## 8.13 Spain

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### Major achievements during the COST Action

- Integration of information on greenhouse gas processes at national scale.
- Increased understanding of nitrification and denitrification processes in Spanish soils and their influence on emissions of nitrogen oxides.
- Development of crop management strategies (organic fertilisers, drip irrigation etc.) to reduce emissions of nitrogen oxides from soils.
- Quantification of the potential of nitrification inhibitors to reduce emissions of nitrogen oxides from Spanish soils.
- Quantification of the potential of urease inhibitors to reduce emissions of ammonia and nitrogen oxides.
- Quantification of ammonia emissions from diverse sources including the use of micrometeorological techniques.

### Introduction

#### Major nitrogen issues in Spain

##### *Rising emissions*

National emissions of  $\text{NH}_3$  and  $\text{NO}_x$  have been increasing since 1990 (the base year for the National Emissions Ceilings Directive). Ammonia emissions have risen by 25% during the period 1990-2007 and  $\text{NO}_x$  emissions have risen by 17% in the same period. Reported emissions in 2007 were 20% above the emissions ceiling for  $\text{NH}_3$  (353 Gg) and 63% above the emissions ceiling for  $\text{NO}_x$  (847 Gg). In the same period national annual greenhouse gas (GHG) emissions