Nitroportugal - Strengthening Portuguese research and innovation capacities in the field of excess reactive nitrogen

Cláudia Marques-dos-Santos Cordovil[1], Tommy Dalgaard[2] and Mark A. Sutton[3]

[1] Research Centre Linking Landscape, Environment, Agriculture and Food (LEAF), School of Agronomy, University of Lisbon, Tapada da Ajuda 1349-017 Lisbon, Portugal. cms@isa.ulisboa.pt.
[2] Department of Agroecology, Aarhus University, Blichers Allé 20, DK-8830 Tjele, Denmark.
[3] NERC Centre for Ecology & Hydrology, Bush Estate, Penicuik Midlothian EH26 0QB Scotland, UK.

Abstract
Nitrogen (N) is a key nutrient, indispensable for the survival of all living organisms on earth, including Man. However, due to human pressure, the N cycle has become the most altered among the element cycles, highlighting the N problem as one of the most pressing environmental issues faced today. Despite the recent work on N in Europe and the rest of the world, Portugal has not so far utilized its full capacity to integrate the available scientific, technical or practical knowledge. NitroPortugal addresses how to improve the Science and technology skills and the scientific output of Portugal, at the same time strengthening the potential for N policy implementation. The project develops around the consensus that N is an emerging issue, that it impacts all the environmental compartments, and has both human health and social implications. This twinning effort on N is divided into five key areas which coincide with the whole N concept WAGES (Water, Air, Greenhouse gases, Ecosystems and biodiversity and Soil) launched by the European Nitrogen Assessment. Based on bringing together existing data on data analysis and on training in new methods for each of the five key topics, a comprehensive analysis will be delivered that prioritizes the key gaps in knowledge. These gaps will then serve as themes for different types of training activities. Emerging questions will feed brainstorming workshops to be held at key points through the project, which will strengthen the Portuguese skills base and enhance peer-review publication. Based on the new skills of the host country team, the basis for preparing a Portuguese Nitrogen Assessment will be obtained that will strengthen Portuguese engagement within the EU and in UNECE Air and Water Conventions. The resulting increase in scientific productivity, associated with strengthened networking between the Portuguese and international partners will be measurable through objective indicators of publication output, policy support and the public engagement.

Key Words: air, ecosystems and biodiversity, greenhouse gases, nitrogen, soil, water

Introduction

In relation to nitrogen, the following five key threats to the environment and issues for further research have been identified by the European Nitrogen Assessment: i) **W**ater quality, ii) **A**ir quality, iii) **G**reenhouse gases, iv) **E**cosystems and biodiversity and v) **S**oil quality (The WAGES concept; ENA, 2011), and is the turning point for the recently initiated NitroPortugal EU twinning project (2016-2019).

In a partnership between The UK (National Environmental Research Council, NERC), Denmark (Aarhus University, AU) and Portugal (School of Agronomy of the University of Lisbon), **NitroPortugal** aims to provide training of the Portuguese partners in the five topics of the WAGES approach, as described in the present paper.

Methods

NitroPortugal will raise the S&T staff skills and scientific productivity of the partners to create a cohesive and comprehensive knowledge working group via the following **types of Training Elements**:

- Training in key research areas of the nitrogen cycle and corresponding scientific production;
- Training on nitrogen integration and synthesis, to build the ground for the elaboration of a *Portuguese Nitrogen Assessment*, which will be addressed both as training as well as science output;
- Training on science interface to national and international policy development, creating an interface to the UNECE-TFRN delivering substantial synergy with the twinning activity.

This is carried out via the following main **Twinning Activities** planned:

Training through exchange missions such as short and medium term visits, online training and workshops;

Increasing scientific production of high impact peer reviewed papers;

Summer schools to ensure knowledge dissemination, rejuvenation of both junior and senior research staff,

and to spread emerging information on the **Mediterranean importance** of the nitrogen challenge;

Stakeholder & policy interface creating new routes for science-user engagement through participatory work-shops, "user tests", with involvement of government institutions, stakeholders, international conventions, and the development of simple messages for the general public.

Results

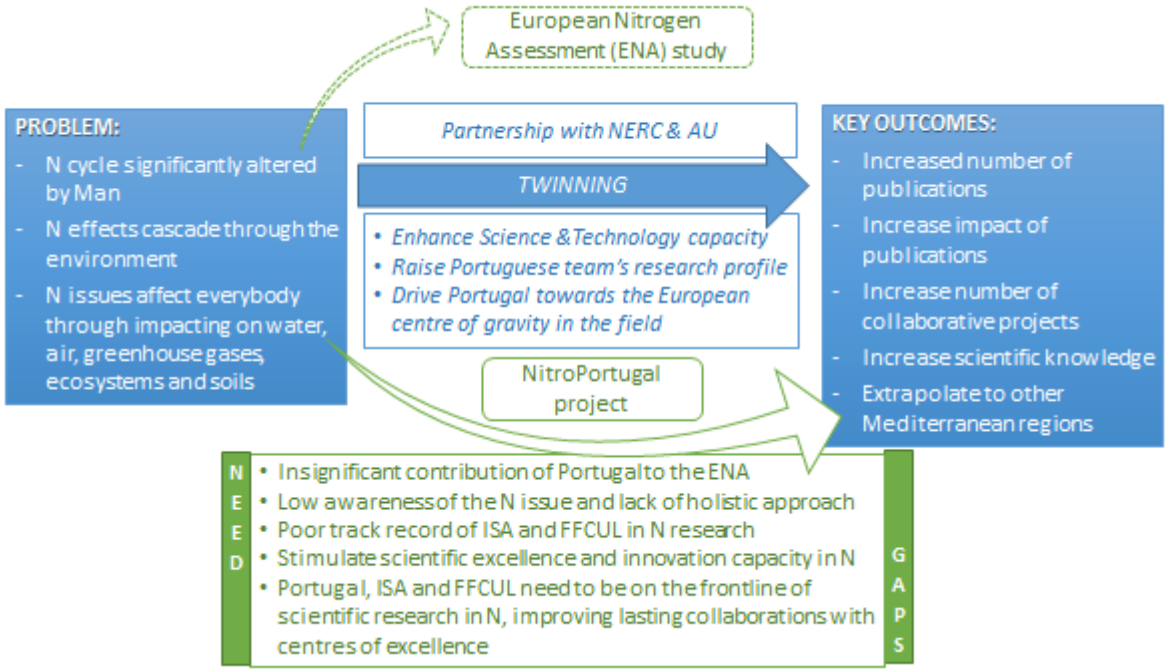

Figure 1. Brief outline of the main project elements – Problem-Need-Gaps-Key outcomes/impacts.

Water quality:

The continuous increase of anthropogenic N in water often surpasses the capacity of aquatic ecosystems to absorb the external input and increases their vulnerability to natural and human related unexpected actions, or even leads to water pollution which poses direct threats to human health and aquatic ecosystems (ENA, 2011). High nitrate concentrations in drinking water are dangerous for human health. In aquatic ecosystems N enrichment enhances eutrophication, which is responsible for toxic algal blooms, water anoxia, fish kills and habitat and biodiversity loss (ENA, 2011). In Portugal as well as across Europe, nitrogen pressures occur over large areas, implying elevated costs for meeting the long-term good chemical and ecological water quality requirements. In Portugal, nitrate vulnerable zones (NVZ) have increased in number (from 3 to 9) and in area, since the first law publication in 1997. This reflects both an increased concern and awareness, but is also a sign that the situation is not improving as much as desired. Therefore a significant part of the Portuguese population could be potentially consuming water with nitrate concentration above the adequate threshold if proper measures are not taken. Furthermore, many aquatic ecosystems are eutrophic or at risk of eutrophication (ENA, 2011).

NitroPortugal will address these concerns through targeted training activities:

- Assessing the current situation in N water pollution from existing data sources which will be collated, and identifying knowledge gaps. Special attention will be given to the role of nitrates versus other nitrogen forms;
- Assessing available measures to mitigate nitrate and other N pollution for Portuguese soil and climate conditions, including an evaluation of barriers to implementing such measures;
- Modelling nitrate leaching and other N losses to improve water quality;
- Consideration of the relationships between freshwater Eutrotrophication due to N and P (priority) in relations to the challenges faced for the coastal zone.

Air quality:
Atmospheric pollution due to excessive N input contributes to a number of negative effects on ecosystems and human health (ENA, 2011). Nitrogen oxides (NO_x) and ammonia (NH_3) have been reported to contribute to these negative effects not only through primary emissions but more importantly through actions of secondary pollutants such as ground level ozone (O_3, associated to NO_x), and particulate matter (ENA, 2011). The most significant air pollution effects to human health include effects of NO_x, of ground level ozone, and of particulate ammonia and nitrate (NO_3^-). Negative effects to vegetation are mainly due to ammonia, acid deposition and ground level ozone, which impacts biodiversity and water (ENA, 2011; Erisman et al., 2015). While NO_x emissions have been successfully decreased across most of Europe, the same is not true for NH_3. The same is true in Portugal, where the Thematic Strategy on Atmospheric Pollution proposed for the 2000-2020 period a reduction of 52% to NO_x, but only of 9% to NH_3.

NitroPortugal will address these concerns through targeted training activities:

- Assessing the current situation in atmospheric N pollution from existing data sources will be collated, and identifying knowledge gaps. Particular attention will be given to analyzing current capability in monitoring networks and data availability complemented the by the extent of process understanding on Nr, emissions, level and deposition under Portuguese conditions;
- Assessing available measures to mitigate atmospheric N pollution for Portuguese conditions, including an evaluation of barriers to implementing such measures. This will include review in the key major sectors: livestock and crop agriculture as well as transport and combustions;
- Improving the modelling capacity for atmospheric N emissions, transport and deposition, at the national and landscape scale scales (including improving model resolution).

Greenhouse gases balance:
Anthropogenic release of reactive nitrogen (N_r) into the environment is probably one of the important factors impacting the greenhouse gases balance, although there is no accurate estimation on how N gaseous compounds have affected net climate change (ENA, 2011). Reactive nitrogen (N_r) is of fundamental importance in biological and chemical processes in the atmosphere–biosphere system, altering the Earth‟s climate balance in many ways. These include the direct and indirect emissions of nitrous oxide (N_2O) atmospheric N_r deposition and tropospheric ozone formation (O_3), both of which alter the biospheric CO_2 sink, N_r supply effects on CH_4 emissions, and the formation of secondary atmospheric aerosols resulting from the emissions of nitrogen oxides (NO_x) and ammonia (NH_3) (ENA, 2011).

NitroPortugal will address these concerns through targeted training activities:

- Assessing the current situation in greenhouse gas knowledge and data from existing data sources which will be collated, and identifying knowledge gaps. This will be complemented by analysis of the nitrogen based non-greenhouse gas effects on radiative balance drawing on experience from the ENA for effects of N deposition on carbon sequestration, on ozone formation and on aerosol formation under Portuguese conditions;
- Assessing available measures to mitigate nitrous oxide emissions for Portuguese conditions, including an evaluation of barriers to implementing such measures. Particular attention will be given to developing synergies between mitigation of nitrous oxide and other nitrogen forms (e.g. ammonia and nitrates etc);
- Improving the measurement and modelling capacity for greenhouse gas emissions and fluxes.

Ecosystems and biodiversity:
Nitrogen is now one of the main global threats to biodiversity. In particular, atmospheric N_r deposition is recognized as a main driving force affecting biodiversity across the whole range of different ecosystem types, by driving the competitive interactions that lead to composition change and/or making conditions unfavorable for some species (ENA, 2011). Many human activities contribute to perturb the global N cycle and the demand for more food and energy, linked to increasing population and changing living standards, limits the perspectives for a reduction of N emissions into the environment (Erisman et al., 2008).

Biodiversity seems to be a relatively sensitive criterion that is clearly linked to a measurable adverse effect of N at ecosystem level. Biodiversity is simultaneously the target and the indicator of the effects of N in ecosystems. Understanding how biodiversity reacts to increasing N and how this affects ecosystem resilience and ecosystem services may lead us to the development of integrated and long-term ecological indicators of the effects of N in biodiversity.

NitroPortugal will address these concerns through targeted training activities:

- Assessing the current situation in ecosystem and biodiversity effects from excess nitrogen, by collating data from existing data sources, and identifying knowledge gaps;
- Addressing the extent to which sensitivity differences can be identified between different forms of nitrogen deposition (e.g. wet deposition of N versus dry deposition of N; oxidized N vs reduced N forms) under Portuguese conditions and consideration of gap analysis in designing priorities for future research;
- Improving the S&T capacity for e.g., state-of-the art experiments on the effects of N on sensitive Portuguese habitats and species, gradient studies and upscaling plus modelling initiatives.

Soil quality:

Soil fertility/quality is threatened by over fertilization, both with chemicals and animal manures, and excess atmospheric N_r deposition which also acidifies natural and agricultural soils. There are negative consequences of high N inputs to the soil in plant production, in soil biodiversity, but excess N_r may also pollute atmosphere and water due to emission of undesirable compounds from the soil. Nitrogen is indispensable for plant production, and the use of synthetic fertilizer generally affects agricultural soils positively by enhancing soil fertility and allowing crop growth. However, the application of fertilizers and manures, associated with atmospheric acid deposition, leads to **soil acidification** which causes organic matter decline under certain conditions, affects soil biota, reduces crop and forest growth, and may increase micronutrient availability in soil and leachates (ENA, 2011). Soil is one compartment strongly involved in **nitrogen pollution swapping** as it is directly connected to water and air pollution. Noxious effects of excess N_r into the environment reduce crop production and produce high social costs.

NitroPortugal will address these concerns through targeted training activities:

- Assessing the current situation on existing data relating to soils to establish key concerns for a nitrogen assessment of Portuguese soils;
- Assessing the potential for N losses under current N fertilization practice in Portugal and identifying measures for the reduction of losses through increasing N use efficiency;
- Improving modelling capacity for predicting behavior of different soil types with regard to N retention and loss interacting closely with related efforts to water and air;
- Improving the capacity for analyzing soil biology, to enable the systematic assessment of the Portuguese situation.

Conclusion

In summary, the planned twining activities will prepare the ground and kick-off the *Portuguese Nitrogen Assessment* process, improve S&T skills and help raise the scientific productivity of the Portuguese team to the highest levels. At the same time the activities will build the basis to ensure durable networking between the partners of this consortium beyond the life of the project, while establishing an effective interface with national and international policy makers and stakeholders. The international partner institutions (NERC, ÅU) will also benefit by increasing their knowledge of Mediterranean conditions, which is still not sufficiently understood compared with other temperate biomes.

The project will enable the integration and publication of existing fragmented knowledge on nitrogen in relation to environment, the food system and health, together with a gap analysis of key research priorities. The fact that better nitrogen management can deliver so many co-benefits for food, energy and environment, shows how this must become an urgent priority for global society in the near future.

References

ENA 2011. The European Nitrogen Assessment, Cambridge University Press. http://www.nine-esf.org/ENA

Erisman J.W., Sutton M.A., Galloway J.N., Klimont Z., Winiwarter W. 2008. How a century of ammonia synthesis changed the world. *Nature Geoscience* 1, 636-639.

Erisman J.W., Galloway J.W., Dise J.B., Sutton M.A., Bleeker A., Grizzetti B., Leach A. and de Vries W. (2015) *Nitrogen: Too much of a vital resource*. WWF Science Brief. World Wide Fund for Nature NL. Zeist, The Netherlands. ISBN 978-90-74595-22-3.