Workshop
The Causal Relations of Nitrogen in the Cascade
21 - 23 November 2005, Braunschweig - Germany

Abstracts

Monday 21 November

Session: General introduction on the topic

11.00 - 11.45 ***Invited presentation***: Nitrogen Saturation of Terrestrial Ecosystems: A Revised Framework - *Brigit Emmett*

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The consequences of nitrogen (N) enrichment of terrestrial and freshwater ecosystems is of increasing concern in many areas due to continued or increasing high emission rates of reactive N. Within forest ecosystems, increased nitrogen deposition can result in changes in net primary production, nutrient imbalances, increased soil N transformations and the onset of nitrate leaching. As a guide to understanding the sequence of these changes and their interaction, Aber et al. (1989) proposed a framework which was then revised following a review of experimental results in 1998. Here, this revised framework is extended to cover nitrogen enrichment of grassland and heathland systems and to include recent results from studies of microbial nitrogen transformations using the ^{15}N pool dilution approach. The additions include; (i) an early loss of 'low N value' plant species which has consequences for the N retention capacity of the system, (ii) a delayed decline in soil C:N ratios due to a N-induced increase in carbon sequestration and (iii) a role for increased ammonium availability in suppressing microbial immobilisation of deposited nitrate resulting in the early onset of nitrate leaching.

11.45 - 12.30 ***Invited presentation***: Adverse Impacts of Elevated Nitrogen Inputs on Ecosystems: An Overview - *Wim de Vries*

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This paper presents a short overview of the impacts of elevated inputs of nitrogen on terrestrial and aquatic ecosystems, while other impacts (human health, climate, visibility and materials) are also shortly mentioned (see also de Vries et al., 2004). Effects of nitrogen deposition are now recognised in nearly all oligotrophic natural ecosystems including aquatic habitats, forests, grasslands, oligotrophic wetlands, heathlands and coastal and marine habitats in Europe. An overview of empirical critical loads and

simulated critical loads for major ecosystems in Europe will be presented. N-deposition causes changes in plant species composition and vegetation structure, thus altering the micro-climate, with negative consequences for the resident fauna. An example will be given of Dutch coastal dunes where increased N deposition led to loss of landscape heterogeneity, affecting the prey availability for red-backed shrikes, which completely disappeared. Impacts of nitrogen on forest ecosystems include elevated N leaching, a change towards nitrophilic species, accumulation of N in foliage that may cause nutritional imbalances, affect frost hardiness, cause water stress, and increase the intensity and frequency of insect and pathogenic pests. It may also cause aluminium release by soil acidification and imbalances to base cations causing absolute or relative nutrient deficiencies. Several aspects are exemplified with results from the Intensive Monitoring of Forest Ecosystems in Europe. Elevated N inputs on oligotrophic soft water ecosystems may cause decreased species diversity. As an example, the replacment of characteristic soft-water plant communities like Isoetes, Lobelia and Littorella in Dutch soft waters by Spagnum and Juncus in response to a decrease in pH and an increased NH_4/NO_3 ratio will be shown. Other effects of high ammonium concentrations and low pH are a decline of macro-invertebrate species such as dragonflies and chironomids. In marine areas and coastal systems, high nitrogen loads cause excess algal growth, leading to oxygen-starved (hypoxia) “dead zones,” that are devoid of fish. This will be illustrated for the northwestern shelf of the Black Sea. An overview of all major N effects and their evidence is given in Table 1.

Table 1 Overview of N related effects on ecosystems/ biodiversity and human health in terms of evidence, scientific understanding and scale at which the impacts take place.

Effects	Evidence for effect	Scientific understanding
Species diversity of terrestrial ecosystems		
– plant species diversity	certainly	high
– faunal species diversity	probably	intermediate
Forest vitality impacts due to		
– Nutritional imbalance	certainly	high
– Soil acidification	probably	high
– Increased sensitivity to frost, drought and diseases	probably	intermediate
Water quality and species diversity of aquatic ecosystems		
– Soft water ecosystems	certainly	high
– Coastal /marine ecosystems	certainly	intermediate
Human health		
– Nitrate in drinking water	probably	intermediate
– Ozone and NOx pollution	certainly	high

Reference

De Vries, W., J. Kros, J.W. Erisman and G. J. van Duinen, 2004. Adverse impacts of elevated nitrogen use. In J.W. Erisman et al (2004): The Dutch Nitrogen cascade in the European perspective.

Session:	*Emission*
14.00 - 14.30	Comprehensive Emission Inventories as Tools for Policy Advice - *Ulrich Daemmgen*

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Emissions of trace gases and particles from agricultural activities have to be reported within various international conventions. They describe the level of emissions, in some cases also projections. They may also be useful instruments to detect and quantify emission reduction potentials, if they are detailed enough. Agricultural emissions are reduced at the farm level. The procedure to assess emissions from a single farm may also be used to derive criteria for building permissions. In any case, the procedures used for inventory making and the planning of farm buildings and technical outfit must not be contradictory. The presentation will deal with the requirements for the construction principles of such multi-purpose inventories (degree of detail, mass flow concept, completeness, resolution in time and space, transparability).

14.30 - 15.00 Denitrification and Nitrous Oxide Emission in Agricultural Soils - *Peter Kuikman*

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Denitrification in agricultural soils strongly affects nitrate leaching from soils. Thus, strategies to maintain or increase denitrification may help to achieve the target N standards in ground and surface waters (Nitrate Directive, Water Framework Directive). Possible measures include increasing ground water level, addition of carbon via manures and crop residues, and implementation of wet buffer zones near surface waters. However, the effects of such measures on N_2O emission must also be assessed as denitrification is the major source of this greenhouse gas.
Tracing of ^{15}N labelled fertilizer in a sandy soil indicated low denitrification losses from this soil (<5% of the applied N) and within-profile differences in denitrification end-products, with N_2O produced at 90 cm depth and reduced to N_2 while diffusing upwards (Van Groenigen et al., 2005). Enhancing denitrification in the sub soil to lower N leaching (e.g. by increasing ground water level) is promising, because part of the N_2O is reduced to N_2 while diffusing upwards.
Several laboratory studies provided clues for development en testing of strategies to mitigate N_2O emission from agricultural soils. The total N_2O emission from mineral N fertilizer ranged from 2.1 to 4.0 percent of the N applied and that from pig manures, cattle slurries and poultry manure from 7.3 – 13.9 percent, 1.8 – 3.0 percent and 0.5 – 1.9 percent, respectively (Velthof et al., 2003). The differences between manures are probably caused by substrate availability, i.e. the substrate C in pig manure is better degradable than that in cattle manure.
Total N_2O emission from wheat, maize, and barley residues was low and not significantly different from an untreated soil (Velthof et al., 2002). The total N_2O emission from white cabbage, Brussels sprouts, mustard, sugar beet residues and broccoli ranged from 0.13 to 14.6 percent of the amount of N added as residue in a sandy soil.
In a study with 10 pig manures of different composition (pigs were grown with a different diet) it is shown that denitrification after manure application to soil was positively related to the amount of added volatile fatty acids (Velthof et al., 2005). Ammonia volatilization from stored manure was highest from manures produced with a diet with a high protein content. The effect of manure composition on N_2O emission differed between a sandy and a clayey soil, which is most likely due to interactions with soil properties, such as available C contents and oxygen consumption. These interactions strongly hamper a uniform strategy to mitigate N_2O emission.
In grazed grasslands, the combination of urine patches (high N contents), dung pats (degradable carbon) and treading and trampling by the cattle (compaction; low oxygen) create conditions favourable for denitrification and N_2O emission. Emission from urine-treated soil was much higher than from dung-treated soil and compacted soil. However, compaction or addition of dung increased the N_2O emission from urine with a factor 5 to 8 (Van Groenigen et al., 2005).

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15.00 - 15.30 Wetlands as Hot Spots for Greenhouse Gases in Glacial Drift Areas - *Jurgen Augustin*

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Typical of younger glacial drift area which are far common in the northern hemisphere is that a wide spectrum of wetland types of very different acreage is scattered in it. This are primarily the margins of temporary water filled depressions (kettle holes, potholes), riparian areas, and different types of fens (minerotrophic peatlands). They can accumulate enormous C- and N-quantities: up to 630 t C and up to 120 t N per hectare, 10 to 100 times more, than mineral soils contain. Land use, particularly drainage (changed groundwater table) and fertilisation, might have converted a lot of these wetlands into areas of very high biogeochemical activity and thus also in strong sources of greenhouse gases (hot spots). To audit this and its consequences for the significance of glacial shift areas as source for the greenhouse gases methane and nitrous oxide, we carried out long-term gas flux measurements on a wide spectrum of these wetlands in Germany (Brandenburg, Allgäu). Our study sites include margins of wetlands (eutrophic and polytrophic potholes), undisturbed, drained and reflooded fen grassland, and alder swamp forest. Trace gas flux measurements were carried out by the closed chamber method in connection with gas chromatographic system (detectors: ECD, FID).
The trace gas fluxes from fens are affected in very complex way still by a number of further factors apart from the ground water table. As suspected, drained fens sites frequently places a strong source of nitrous oxide, at the same time as a weak methane sink (-1.4 kg CH_4-C*ha^{-1}*a^{-1}) in addition. In particular extremely high nitrous oxide missions resulted on freshly drained peatlands (up to 26.9 kg N_2O-N*ha^{-1}*a^{-1}). However, if the ground water table is constantly low, then extensively used fens function only as weak source of nitrous oxide (0.4 kg N_2O-N*ha^{-1}*a^{-1}). Reflooding of drained and degraded fens caused a further decrease of the nitrous oxide emissions, similarly small emissions showed also virgin fens (0.1 kg N_2O-N*ha^{-1}*a^{-1}). The methane emission reacted always opposite to rising groundwater levels. Only small methane fluxes were to be observed in the shallow drained alder forest and on the rewetted fen meadow (up to 1.7 kg CH_4-C*ha^{-1}*a^{-1}). Complete reflooding always caused a drastic increase of the methane missions (up to 640 kg CH_4-C*ha^{-1}*a^{-1}).
Contrary to the surrounding agricultural area depressional margins represent again very vigorous sources for nitrous oxide (3–130 kg N_2O-N ha^{-1} y^{-1}) and methane (20–2220 kg CH_4 ha^{-1} y^{-1}). In the long run the gas flux rates were mostly controlled by eutrophication, flooding gradient (groundwater level), depth of a colluvial layer, and vegetation zonation.
A weak point of central importance is (unsatisfactory) data to the net CO_2 emission, because it have the strongest influence on the climatic relevance of the wetland sites. In order to get correct estimate of the climatic impact from procedures like the reflooding of fen peatlands we started net CO_2 flux measurements on different wetlands by means of new developed automated chamber approach.
However, the results existing till now point clearly, that any assessment of greenhouse gas emissions from younger glacial drift area disregarding even a small acreage of wetlands influenced by man must result in misleading statements.

16.00 - 16.30 Understanding and predicting Nitrogen Fluxes at the Farm Scale - *Jorgen Olesen*

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When attempting to understand and predict N fluxes in agriculture, it is important to consider that the interactions between N losses occur over a range of scales and vary considerably, depending upon the type of farming. Likewise, the opportunities for management to affect N flows vary between farm types. On arable farms with no livestock, the interactions are mainly at the field scale but as livestock density increases, the farm scale becomes increasingly important. Much N is transferred from field to animal housing in plant products used as animal feed. Most of this is excreted as dung and urine, which passes as manure through a collection and storage system, before being returned to the fields. At each point along this route, there are opportunities for N to be lost to the environment. The interactive nature of N flows is particularly true for cattle farms; the range of management options is large, a large proportion of the animal feed is normally home-grown and the N content of forage crops varies more widely than for grain crops.

Losses of N from agriculture to the environment have traditionally tended to be considered in isolation. However, current EU legislation and international agreements mean that member states must now control losses of several N compounds simultaneously. Legislation relating to specific N compounds includes the Nitrate Directive (NO_3), the National Emission Ceilings Directive (NH_3) and the Kyoto Agreement (N_2O). When considering abatement measures to control one or more N compounds, it is important to take account of the interactions between the N flows that underlie the losses. For example, adopting a new manure application technique to reduce NH_3 volatilisation will increase the amount of mobile N in the soil and could increase both NO_3 leaching and the emission of N_2O, unless other management changes are also made. Management of N in agriculture can also impact on other policy areas such as emission of CO_2 and CH_4, while N losses themselves can be affected by policy measures implemented in other areas (e.g. animal welfare).

Models can be used to describe the interactions of N on a farm and predict the likely consequences of the implementation of a particular abatement measure. Complex dynamic models can describe the underlying processes in some detail but require data that are often difficult to obtain on commercial farms. Simpler, static models using an emission factor approach can operate with fewer data but necessarily compromise the description of the processes. This paper will consider the advantages and disadvantages of the two approaches using the dynamic whole-farm models like the FASSET and FarmGHG models (Berntsen et al., 2003; Olesen et al., 2005) and the simpler FARM-N model (http://www.farm-n.dk). Finally, the paper will consider the extent to which losses of N and methane can be related to farm-scale indicators such as livestock density and N surplus.

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16.30 - 17.00 From Land Use to Farm Types: Availability and Potential of Agricultural Information at European Scale - *Adrian Leip*

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THOMAS HECKELEI[2] AND WOLFGANG BRITZ[2]

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International obligations as e.g. the reduction of greenhouse gas emissions under the Kyoto Protocol (United Nations Framework Convention on Climate Change) as well as European legislation like the nitrate directive (Council Directive 91/676/EEC) require the assessment of the agricultural practices and their effects on the environment. As the recommended procedures to derive for example greenhouse gas emissions from agricultural soils are associated with a huge uncertainty range, the development of reliable independent estimates is needed. Process-based models are adequate tools that can be used, for example, in the frame of GHG inventories in the near future. But the accuracy of simulated fluxes with process-based models such as DNDC (Denitrification Decomposition) Model (Li et al., 1992) is largely dependent on the quality of input data. The model showed especially sensitive to the soil organic matter (SOM) content of the soils. If no *a priori* information is available, the range of calculated fluxes is determined by the range of SOM occurring in the administrative region, for which statistical information is available. Uncertainties by a factor of 10 or more are common (Mulligan, 2004). Spatial disaggregation of the statistic information would help in reducing and specifying the area that is used by a certain activity. The consequence is a reduced range within input data and a decrease in the uncertainty of simulated fluxes of N_2O and other environmentally relevant fluxes of nutrients (ammonia emissions, nitrate leaching, carbon sequestration, etc.).

In the frame of the project CAPRI-*DynaSpat* we developed a procedure to estimate cropping patterns for about 80000 homogeneous spatial mapping units (HSMU) for EU-15. The aim of building HMSUs is the definition of areas where similar conditions for crop growing from a natural as well as a technical point of view can be assumed. Also, the environmental conditions that lead to high or low emissions of greenhouse gases or other pollutants are regarded as similar. The HSMUs are built from three major data sources: the European Soil Database V2.0 (European Commission, 2004) with about 900 Soil Mapping Units, the CORINE Landcover map (ETC-TE, 2000) , and a Digital Elevation model (CCM DEM 250, 2004). One HSMU is defined as the intersection of a soil mapping unit, one of 11 agricultural or mixed agricultural CORINE land cover classes and 7 non-agricultural classes where some agricultural activities are occurring, administrative boundaries at the NUTS 3 level, and the slope according to the classification 0 degree, 1 degree, 2-3 degrees, 4-7 degrees and 8 or more degrees.

Statistical information is obtained at the regional NUTS 2 level from the CAPRI database. In this database, statistical information from different EU-wide datasets (ESTAT, DG AGRI, etc.) are checked on their completeness and inherent consistency to make them useable for modelling purposes (CoCo database, see Britz et al., 2002). In the case of data gaps or controversial data, the problems are fixed with a well defined algorithm staying as close as possible to the original data source.

The problem to be solved is to find the driving factors that determine the share of agricultural land use within each of the HSMUs. Possible parameters are social factors (traditions, policies …), economic factors (markets, industry, infrastructure, …), and natural factors (climate conditions, soil quality, topography). As we are speaking on the distribution of land use choices *within* a region (about 220 NUTS 2 regions are defined in EU-15, which however vary considerably in size), social and economic variations can be assumed to have no strong impact and are neglected because of pragmatic reasons. To assess the impact of natural factors, each HSMU is linked to an attribute table containing information obtained from climate data (mean monthly temperature, temperature sum, duration of the vegetation period, precipitation) (Van der Goot and Orlandi, 1997/2003), the topography (slope and elevation, CCM DEM 250, 2004) and the European Soil Map (several parameters of interest, European Commission, 2004) .

The Land Use / Cover Area Frame Statistical Survey (LUCAS, European Commission, 2003a) is a unique data set that can be used for investigating the relationship between location factors and land use. The data set contains information on land cover and land use of about 100000 geo-referenced points in EU-15, from which about 38% belong to one of 34 agricultural classes. We use the results of the LUCAS surveys

from the years 2001/2002 and 2003 to regress the available environmental information against the crop share in a region. The regression is done separately for each region and CORINE land use class. The size of the area to be included in the analysis must on one hand be small to assure representativeness for that specific region but on the other hand must be large enough to contain a statistically significant sample of LUCAS observations for the specific crop. Both the size of this “window” and the selection of the parameter to be used in a regression equation that will further be used to estimate crop shares in the region are determined iteratively (Kempen et al., 2005).
The analysis is done individually for each of the 30 crops considered on the basis of a “Locally Weighted Binomial Logit Estimation”. The Binomial Logit Model (e. g. Green, 2000) simulates the probability that at a certain point a crop e.g. soft wheat is grown as function of a set of pre-defined parameters. The coefficients required for the model are determined with a maximum likelihood (ML) estimator maximizing the probability that the observations at the LUCAS points are realized. To account for the possibility that other factors than the natural conditions influence the choice of farmers to grow a specific crop, for example the presence of a sugar refinery, each LUCAS point is assigned with a weight in the ML estimation that decreases with increasing distance from the region (Cleveland et al., 1988). The optimal bandwidth defining the size of the “window” is selected on the basis of the Schwartz criterion (Schwartz, 1978). Obviously, the bandwidth will be smaller for crops which are frequently observed (e. g. soft wheat) than for those which occur only occasionally (e. g. “other cereals”) and therefore the infrastructural factors can be expected to be reflected in the estimates for the major crops only.
If the thus-derived model for estimating crop shares is applied to the NUTS 2 regions, the total crop share will not match the available land because each crop has been simulated separately without a direct link to land availability. Consistency with the available statistical information is obtained with the Bayesian highest posterior density (HPD) estimator (Heckelei et al., 2005) using a covariance matrix calculated according to Green (2000).
An example of the resulting disaggregated land use map is shown in Figure 1 for grassland in the Lombardy region. The quality of the product has been validated with information of the Farm Structure Survey 2000 (European Commission, 2002) for those countries where data at the NUTS 3 level are available.

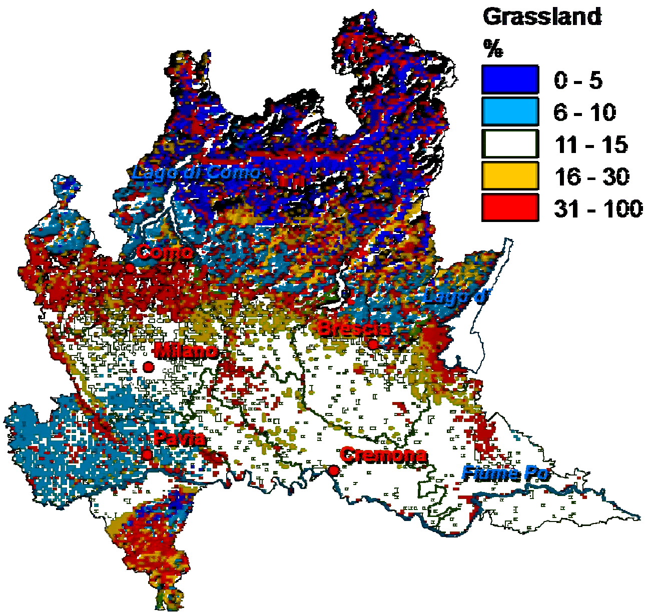

Figure 1: Disaggregation result for grassland in the Lombardy region

The methodology developed has proven to be rather robust and at the same time flexible. The map will be the basis for application of process-based models in the frame of the projects CAPRI-*DynaSpat* and NitroEurope-IP. Extensions to spatialize crop yield and fertilizer application rates are currently evaluated. An application of the methodology to distribute farm types according to the FADN farm typology (European Commission, 2003b) is planned in the frame of the SEAMLESS-IP project.

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17.00 - 17.30 Indirect N_2O Emission due to Atmospheric Nitrogen Deposition - *Albert Bleeker*

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Nitrous oxide (N_2O) is a potent greenhouse gas produced in soils and aquatic systems. The UNFCCC requires participants to report 'indirect' N_2O emissions, following from agricultural N losses to ground- and surface water and N deposition on (other) ecosystems due to agricultural sources. Indirect N_2O emission due to atmospheric N deposition is presently not reported by the Netherlands. In this paper we quantify the consequences of various tiers to estimate indirect N_2O due to deposition for a country with a high agricultural N use and discuss the reliability and potential errors in the IPCC methodology. This includes a review of the emission factor, using various country-specific (activity) data but also an assessment of the validity of the underlying assumptions and the potential role of N losses from other anthropogenic sources. IPCC requires that indirect N_2O emissions due to anthropogenic atmospheric N deposition are attributed to the emission source. Therefore, indirect emissions are derived from national N emissions, not from N deposition. We calculated indirect N_2O emissions due to Dutch anthropogenic N emissions to air by using official Dutch N emission data as input in an atmospheric transport and deposition model in combination with land use databases. Next, land use-specific emission factors were used to estimate the indirect N_2O emission. This revealed that 1) for a country like the Netherlands most agricultural N emitted is deposited on agricultural soils and not on natural (forest) ecosystems, 2) indirect N_2O emission are ~30% higher because more specific emission factors can be applied that are higher than the IPCC default.

Tuesday 22 November

Session:	*Transport - Exchange - Deposition*

09.00 - 09.30	Soil - Atmosphere N_2O and CH_4 Exchanges in Mediterranean Sclerophyllous Woodlands as affected by Global Change - *Simona Castaldi*

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Mediterranean ecosystems are among the most heavily and early utilized by man, and, as a result, are frequently severely impacted by anthropogenic activities. According to global change scenarios, they are predicted to experience sever alteration of precipitation and fire regimes.
Sclerophyllous woodlands are typical environments of the Italian peninsula. They occur at different succession stages, from trees to shrubs (maquis) and the more degraded garrigue, depending on the level of anthropic disturbance (fire, coppicing, pasture) and on natural conditions.
These ecosystems present some natural features which make them areas of low impact, with respect to their contribution to the increase of the atmospheric concentrations of N_2O and CH_4. The warm and dry climate and the particular edaphic conditions result in well aerated soils, which are thus good sink for CH_4. On the other hand, being these ecosystems typically N and P limited, little soil mineral N is available for nitrification and denitrification processes, which, together with a good aeration status of the soil, makes N_2O emissions being almost absent in these environments. However, the intensification of rain events and the alteration of fires regimes, as well as, changes in soil use and management have the potential to make these environments becoming sources of green house gases.
We will report data on N_2O and CH_4 soil-atmospheric exchange, from different Mediterranean sclerophyllous woodlands subject to manipulation such as precipitation regime, and fire intensity. Implications for Mediterranean ecosystem vulnerability to these and other disturbance will be discussed.

09.30 - 10.00	The Role of Atmospheric Nitrogen in the Baltic Sea Eutrophication - *Anita Lewandowska*

ANITA LEWANDOWSKA

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Eutrophication of the Baltic environment is now identified as one of the most serious problems. It affects biodiversity, fish stocks as well as human health and the recreational use of marine coast. The effects of eutrophication are clearly visible in the Polish coastal zone in the form of intensified algal blooms. Poland is the major country that influence the nutrients loads into the Baltic Sea, even that between 1985 and 2000, the total discharges from point sources and losses from diffuse sources into surface waters of the Baltic Sea within the Polish territory decreased by about 30 % for nitrogen. In 2000, the total riverine nitrogen load entering the Baltic Sea amounted to 830 000 tones. The bulk (81%) of this load was discharged by monitored rivers and almost 30% of total emission of nitrogen compounds was still discharged via rivers from the territory of Poland.

Also atmospheric deposition contributes significantly to the input of many natural and anthropogenic substances into the Baltic Sea. The emission of NO_x in last 10 years decreased in Poland by 34% and of ammonia by 37%, but their concentrations, especially in the case of nitrogen dioxide in the atmosphere are not decreasing. Estimates have shown that the input of nitrate and ammonium via the atmosphere to the Baltic Sea is of the same magnitude than the input by rivers. The problem is getting more and more important because of growing numbers of cars in Poland in the last decades. Ammonia can be emitted into the atmosphere also from diffuse sources – mainly agriculture. Such a huge reverine load of nitrogen as well as the atmospheric deposition create biological production and eutrophication of the Baltic Sea.

Our investigation are concentrated on short and long-term fluctuations of chemical composition of aerosols, atmospheric precipitation and surface sea water in the coastal zone and off-shore. From experiments done in over a dozen years we could observe the great interaction between sea and land air masses and thus their impact on the chemical composition of atmosphere e.g. aerosols. We focus also on seasonal and daily cycle of nitrogen species in the air, since meteorology and emission changes over the year and day- night happen. But we still don't know how efficient are land sources in the case of NO_x and NH_3 in the presence of emission changes described above.

The rain composition showed us the important problem with the acidification About 80% of annual deposition in the coastal Baltic zone is acidic with the average value of pH equal to 5,14. In connection with this some questions arises e.g.: if the sea salt is the element, which can cause neutralisation of acid deposition in the coastal zone and if nitrogen species deposited from the air can stimulate the primary production in the Baltic Sea?

All of those problems are still under very low understanding for the atmosphere over the polish coast and sea and we should carry on them in the future. The problem is, that in Poland only about 100 air monitoring stations exist, which continuously carries out pollution emission measurements to control the air quality, including NO_x and NH_3 concentrations.

10.00 - 10.30 Consequences of N deposition on biosphere-atmosphere exchange of N and C trace gases in forests: results and modelling studies - *Klaus Butterbach-Bahl*

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Since decades forests in Central Europe are receiving atmospheric nitrogen inputs exceeding by far the N demand due to forest growth. Nitrogen additions have led to changes in the C/N ratio of soil organic matter, changes in forest growth, and ground vegetation composition. Moreover, increased nitrate leaching and changes in the magnitudes of exchange rates of environmental important trace gases were observed as consequences of increased nitrogen deposition. In the framework of various field measurements at different forest sites across Europe, we observed that N deposition reduced the uptake of atmospheric CH_4 and markedly increased emissions of NO and N_2O by forest soils. At least at some sites N trace gas emissions from forest soils have been found to have the same magnitude as emissions from intensively fertilized arable soils. Also effects on microbial N cycling processes such as nitrification and denitrification were found. The results of these field and laboratory studies were used for developing and testing of the biogeochemical model PnET-N-DNDC. By use of this model, national and EU wide inventories of N trace gas exchange between forest soils and the atmosphere were calculated. The calculations show that N deposition is a major factor affecting rates of N trace gas emissions from forest soils. But other factors such as soil properties and meteorological conditions can at least in some areas partly overrule N deposition effects on N trace gas exchange mostly on costs of increased rates of nitrate leaching.

11.00 - 11.30 Integrating Nitrogen Dynamics at the Landscape Scale - *Mark Sutton*

MARK SUTTON

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Atmospheric ammonia is an air pollutant with both local, regional and international impacts. Much attention has focused on developing the science to develop international policies to reduce the transboundary pollution aspects. This has required the development of mapped emission inventories, atmospheric chemistry, transport and deposition models, and models for thresholds of expected ecological effects.

These developments represent a success story for science-policy interaction. For example, the signing of the Gothenburg Protocol and the National Emission Ceilings Directive represent the first time that international emission controls on ammonia have been agreed. By contrast, it is recognized that these agreements are not enough, and that more needs to be done to reduce emissions to levels that do not exceed, so called "critical loads" above which damage to habits occur. There are many effects, but the most relevant one for terrestrial ecosystems is that extra nitrogen from deposited ammonia favours nitrophytic plant species at the expense of ones succeeding under oligotrophic (nutrient limited) conditions.

One of the main failings of these agreements is that they are based on e.g. 50 km resolution maps, and miss the landscape level variability in ammonia emisssions and deposition. The main source of ammonia emission is livestock agriculture, so that the sources occur in rural landscapes in intimate mixture with the receiving ecosystems, such as forests, semi-natural grasslands and bogs. Nearness to source (e.g. 0-2 km) introduces a huge spatial variability in the deposition and exceedance of the critical loads. Explict GIS emission-dispersion models with a 20 m - 50 m resolution show that the exceedances are so large that it is realistically impossible to protect all ecosystems across Europe while maintaining livestock agriculture in its present form.

If it is accepted that not all ecosystems can be protected, the debate shifts to identify the priorities for protection from atmospheric deposition. A major point here to consider is the existence of the Habitats Directive, which gives an extremely high degree of protection to sites designated as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). Article 6 (3) of the habitats directive provides for a precautionary approach where the onus is on developers to demonstrate that there would be no adverse effect on these sites. This leads to a new thinking on ammonia abatement which focuses on spatial planning of agricultural activities in rural landscapes. It raises questions like: how wide should atmospheric buffer zones be? Can trees be used sacrificially to help recapture emissions? How can one prove that there will be no adverse effect of a development? How can agriculture be brought into the planning process? The talk will finish with a case study of a recent Planning Appeal on whether to permit a new poultry farm adjacent to a heathland SAC.

11.30 - 12.00 Estimation of Nitrogen Flux between the Atmosphere and Aquatic/Terrestrial Ecosystems in Hungary - *Szilvia Kugler*

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Exchange processes at the boundary of the biosphere and the atmosphere involve the wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) ions, the dry deposition of nitrogen dioxide (NO_2), nitric acid (HNO_3) and nitrate, ammonium particles (NO_3-, NH_4^+), as well as the emission of nitric oxide (NO) and nitrous oxide (N_2O). In the case of ammonia gas (NH_3) emission from surfaces (plant tissues, water) and the dry deposition takes place parallel.

Terrestrial ecosystem. For determination of deposition of nitrogen compounds the wet flux was calculated from the ammonium and nitrate concentrations measured in the wet-only, monthly precipitation samples between 1999 and 2000 at Hortobágy National Park above a semi-natural grassland. Dry deposition was inferred using the atmospheric concentration data and the dry deposition velocities determined for grass surface. Net flux of ammonia was detected between 2000 and 2002 by the profile method. Soil emission of nitrous oxide was determined from July 2002 to December 2004, by the chamber method at Bugac National Park with the same surface characteristics as above (emission of nitric oxide is negligible in comparison with nitrous oxide). Results are given in Table 1:

Table 1.

Compound	Wet deposition	Dry deposition	Emission	Net deposition
	(kg N ha^{-1} yr^{-1})			
NH_4^+-N	2.6	0.5		
HNO_3-N		3.2		
NO_3^--N	2.1	0.8		
NO_2-N		0.0		
N_2O-N			1.2	
NH_3-N		4.6		
Total N	4.7	9.1		**12.6**

Aquatic ecosystem. With a surface area of 600 km^2 and a mean depth of 3 m, Lake Balaton is the largest lake in Central Europe. Dry deposition of nitrate and ammonium particles were inferred using the atmospheric concentration data measured in 2002 and 2003 and by dry deposition velocities from the literature. Wet deposition was previously determined by long-term measurements. Dry fluxes of nitric acid and ammonia gas were determined by daily concentration samplings. With the knowledge of the concentration and the calculation of the equilibrium concentration (only in case of ammonia) it was possible determine the turbulent fluxes knowing the deposition velocities with the help of a resistance model using standard meteorological data. Model has been tested with the gradient measurements. Samplings were carried out in three separate two-week campaigns between summer 2002 and spring 2003 at two levels (2.8 m and 12.3 m above the water surface). Results are given in Table 2:

Table 2

Compound	Wet deposition	Dry deposition	Emission	Total deposition
	(kg N ha^{-1} yr^{-1})			
NH_4^+-N		0.11		
HNO_3-N		1.4		
NO_3^--N		0.08		
NO_2-N		0.36		
N_2O-N			???	
NH_3-N		0.36		
Total N	7.2	2.3		**9.5**

12.00 - 12.30 Trends of Nitrogen in Air and Precipitation in Europe - a comparison of EMEP Model Results and Observations - *Hilde Fagerli*

HILDE FAGERLI[1] AND WENCHE AAS[2]

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A major aim of EMEP (Cooperative Programme on the Long Range Transmission of Air Pollutants in Europe, http://www.emep.int) is to support governments with scientific guidance on the causes of air pollution concentrations and depositions within Europe. The work within EMEP was initiated with a focus on reducing sulphur air pollution, but it was soon realized that nitrogen posed a threat as serious as that of sulphur. Recently, health impact aspects due to particulate matter have become more in focus, and ammonia emissions are the gaseous precursor of ammonium aerosols that can be transported over long distances and affect particulate matter (PM) levels over thousands of kilometers. The EMEP model (documented in Simpson et al. 2003 and Fagerli et al. 2004) results are an essential input to the RAINS integrated assessment model, and have been crucial to a number of UN-ECE Protocols and the European Union National Emission Ceilings Directive. It is essential that the model responds correctly to emission changes (e.g. in concentrations and depositions), and one way to test this is through it's ability to reproduce trends.

The large changes in emission regimes in Europe the last 20 years have led to changes in the atmospheric residence time of nitrogen as the reduced sulphur concentrations in air has been followed by less formation of ammonium sulphate and relatively more formation of ammonium nitrate. Further, more rapid oxidation of NOx through homogenous oxidation with OH and O_3 has been suggested to contribute to nonlinearities in the oxidized nitrogen budget (Fowler et al, 2005).

In this paper we perform trend analysis for EMEP sites with nitrogen measurements in air (and precipitation) from 1990(1980) to 2002 using the Mann Kendall method. The results are compared to an analysis of EMEP model results at the same sites. In order to separate the effects of inter annual meteorological variability and emission changes (especially in SOx) we have performed model experiments where 1) meteorology has been kept constant, 2) emissions have been kept constant and meteorology varied and 3) SO_x emissions have been kept on the 1980 level whilst other emissions and meteorology have been varied. Both model and measurement results show that oxidized nitrogen in air has a slightly less pronounced downward trend than reduced nitrogen in air, despite larger reductions in NO_x than in NH_3 emissions in most parts of Europe. This can be explained by the nonlinearities in the chemistry caused by the reductions in sulphur emissions. The downward trend for oxidized nitrogen in precipitation deviates somewhat from the observed trend, suggesting that there are processes causing non-linearities in the nitrogen budget that are still not completely understood.

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Long term trends in sulphur and nitrogen deposition in Europe and the cause of non-linearities. D. Fowler, R. I. Smith, J. Muller, J. N. Cape, M. Sutton, J. W. Erisman and H. Fagerli. To appear in: ACID RAIN 2005 Conference Proceedings, Water Air Soil Pollution: Focus, 2005

Session: Effects

14.00 - 14.30 Does Organic Nitrogen play a significant role in the Nitrogen Cycle of Temperate Ecosystems? - *Lutz Breuer*

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The global nitrogen (N) cycle has been dramatically changed since the invention of inorganic fertilizer production in early 1900. As a result of increased fertilizer usage over the last century human input of N into the global terrestrial N cycle has more than doubled. Regions with intensive agricultural production, industrialized countries and densely populated areas have to deal with a large set of environmental problems that are tightly related to this increased N application. N excess creates problems in almost all types of ecosystems and ecosystem spheres and dramatically altered ecosystem services. A broad variety of N compounds contribute to atmospheric pollution (NOx, ammonia), climate change (N_2O), soil and water acidification, eutrophication (NO_3^-), toxification (NH_4^+, NO_2^-), drinking water quality (NO_3^-), and losses of ecosystem diversity. Within the last decades of environmental research, substantial effort has been put into the investigations of anorganic N compounds and the decisive role these components play in the aforementioned environmental problems.
Recently, organic nitrogen compounds have also attracted more and more interest in the research of the overall terrestrial N cycle. The direct use of amino acids as a N source has for example been shown for both, plants[1] and soil microbes[2]. It was further demonstrated that organic nitrogen is involved in N_2O trace gas evolution[3]. The contribution of dissolved organic N to total N export has been proven to be 50 % and more for a variety of nutrient-poor South American catchments[4]. The underlaying question is, whether such patterns have also occurred in nowadays nutrient-rich ecosystems, for example in temperate European catchments. There is a growing debate, whether "some standard thinking about how nature deals with nitrogen in soils and waters needs to be re-evaluated"[5-7].
Here, we present results of two investigations in mesoscale river catchments of Hesse, Germany, that contribute new information to this debate. The basis hypothesis of the investigatios are, that (1) organic N substantially contributes to total N export of these catchments, and (2) that landscape information can be used to predict the ratio of organic to anorganic N in these catchments. In the first case study, monthly snapshot sampling (transect measurements) are conducted along various stretches and subcatchments of the Schelde and Aar river. Water samples are measured for anorganic N (NO_3^-, NH_4^+, assuming that NO_2^- can be neglected) and total N. Organic nitrogen is calculated as the difference of total N and anorganic N. Information on land use, population, soil, geology and climate derived from an extensive GIS analysis is then

used in a multiple regression analysis to predict spatio-temporal dependency of anorganic and organic N export. The second case study uses public available data on organic and inorganic N export from approx. 70 Hessian catchments. Based on catchment characteristics provided by environmental agencies and a comprehensive GIS analysis, functional units of catchments with a distinct ratio of organic to anorganic nitrogen are derived. Information to deduce functional units comprise data on population, density and layout sewage treatment work systems, land use and fertilizer rates on the county level.

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14.30 - 15.00 Separating the effect of Pollution, Climate Change, Wildlife and Forest Management on Forest Production and Ground Vegetation Biodiversity - *Salim Belyazid*

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The ForSAFE-VEG model can be used to estimate the individual contribution to ecosystem effect from nitrogen pollution, acidification, soil moisture, temperature, wind chill exposure, light and shading by trees, grazing by animals, competition between plants, above ground for light and below ground for water and nutrients. The model has been initially tested and validated at 16 integrated level II forest monitoring sites across Sweden, and it can be shown that the basic model concept is successful in predicting observed vegetation composition and its change. The model integrates 42 ground vegetation plant groups and 5 tree groups, each representing its class of plants. The project research questions are:

• Separating the environmental effects of acidic deposition, nutrient nitrogen, climate change, wildlife dynamics and forest management on forest growth and ground vegetation biodiversity using the integrated ForSAFE-VEG model.

• Evaluate possible ramifications for policies concerning acid deposition, eutrophying deposition of nitrogen, global climate change mitigation and forest management and harvesting strategies.

The results will be delivered in a number of peer-reviewed articles and a PhD thesis during 2006.

15.00 - 15.30 Relation of Nitrogen Deposition and Stand Structure in Northwest German Forest Ecosystems - *Henning Meesenburg*

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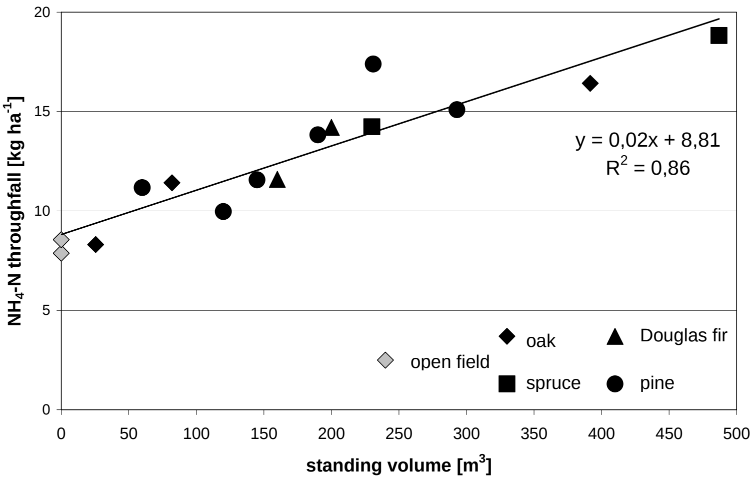
Atmospheric deposition is an important source of elements for forest ecosystems. Due to their large extension into the atmosphere, trees are the major interface for the exchange of substances between atmosphere and soil. Therefore, the structure of forest stands is an important characteristic for the deposition process. However, relatively little is known about quantitative relations between stand structure and deposition rates. The effect of stand structural parameters on atmospheric deposition of nitrogen (N) was studied at forest stands in Northwest Germany. The area is characterized by high emissions of reduced N due to animal husbandry. Throughfall fluxes of N species and other major ions were investigated in 13 stands of different tree species and structural phases. Total deposition has been calculated by means of canopy budget models (Ulrich 1994, Draaijers and Erisman 1995). For each of the investigated stands, stand height, diameter at breast height, basal area, volume, canopy closure and leaf area index (LAI) were measured. Close relations have been found between N fluxes in throughfall and standing volume, stand height and mean diameter of the forest stands (Fig. 1). Most other major ions showed also significant relations to these parameters. Unexpectedly, no relation between N fluxes and canopy closure or LAI was found. In contrast to other studies (e.g. Meesenburg et al. 1995), there was no difference between the investigated tree species. The stand structural parameters, which show close relations to N fluxes in throughfall can easily obtained for the whole forested area of a certain landscape through forest inventories. Thus, the relations between these parameters and N fluxes can be used as transfer functions for the regionalization of the N input into larger areas.

Figure 1 Relation between NH_4-N fluxes in throughfall and standing volume of forest stands in Northwest Germany



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16.00 - 16.30 Modelling Effects on Biodiversity by Eutrophication and Acidification with BERN - *Philipp Hubener*

PHILIPP HÜBENER AND ANGELA SCHLUTOW

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As a Signatory to the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone, Germany's responsibilities is to contribute work-products towards the fulfillment of the medium-term work plan of the UNECE Working Group on Effects (WGE). The challenge is to include, in future models, more ecological indicators when establishing environmental cause-effect relationships and determining Critical Loads. In order to better integrate ecosystematic connections, the BERN (Bioindication of ecosystem regeneration within natural conditions) model was developed on the basis of empirical compilations, performed within a well monitored region of Germany.

Nearly all biological components in a natural or semi-natural ecosystem depend on a harmonious balanced relationship with the essential nutrients, which include nitrogen (N), phosphorus (P) and carbon (C), as well as base cations (Bc: sum of calcium [Ca], potassium [K] and magnesium [Mg]) and the supply of water and temperature. Indicators of the endogenic change are characterized by the change of the vegetation structure. Plant communities contain the highest and most exact level of information. Therefore from community structure, one can draw more exact information about the site parameters than from the average of the optimum values of the plant species.

The BERN model database includes in the first stage only the fundamental niches of the plant species with their blurred thresholds of the suitable site parameters (base saturation, C/N-ratio, soil moisture, length of vegetation period and continentality index). Quite the combination of the site factors which influence the vegetation vitality results in a really possibility for plant existence. In the second stage the really niche of the whole plant community had been modelled by combining the fundamental niches of the constant plant species with the minimum operator of the fuzzy logic. The real existing combinations of site factors are classified to site types.

This database enables the user of the BERN-model to assess the current regeneration ability, to quantify the critical limits and critical loads of natural and semi-natural plant communities, to determine the dynamic change of vegetation structure in the past and future depending on history and future scenarios of using, depositions and climate change and to determine the future options of regeneration targets. Presently the database contains about 220 plant communities and 1040 species and covers all regular site types in Germany.

Until now the BERN model was coupled with the geochemical models SMB, VSD and SAFE to predict the change of the vegetation structure in a changing environment. Because the BERN model has an open interface, it can be coupled with any other biochemical model like SMART2 as long as the changing soil parameters base saturation and C/N ratio is calculated.

16.30 - 17.00 Effects of different Forest Conversion Practices on Nitrogen Fluxes in an N-saturated Spruce Forest Ecosystem - *Nicolas Bruggeman*

N. BRÜGGEMANN, K. BUTTERBACH-BAHL, R. GASCHE, H. PAPEN

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A long-term experiment with the purpose of quantifying the effect of conversion of an approx. 110-year-old N-saturated spruce forest (Höglwald) into a beech forest by clear-cutting and

selective cutting, respectively, with subsequent planting of beech saplings on greenhouse gas exchange and nitrate leaching has been run since 1999. Soil C- and N-trace gas exchange (CO_2, CH_4, N_2O, NO, NO_2) has been monitored at the two differently treated sites and additionally at an untreated spruce control site since then in five replicates with hourly (NO, NO_2) or two-hourly time resolution (CO_2, CH_4, N_2O), using fully automatic measuring systems. Nitrate concentrations in leached water have been monitored on a weekly basis. N_2 losses through denitrification were determined regularly in the laboratory on soil cores taken in the field.
The results of the first years of the experiment reveal that the clear-cutting treatment led to much higher N_2O and N_2 emissions, and also to higher nitrate leaching to the groundwater as compared to the selective cutting treatment. However, NO emission rates as well as CH_4 uptake rates were strongly reduced after clear-cut, whereas they were still at a comparably high level at both the selective-cutting and at the control site.
As an effect of the very high N_2O emissions at the clear-cut site during the first years of the experiment, the total sink strength of the forest for greenhouse gases over a period of 80 years was calculated to be reduced by approx. 35 % by clear-cutting as compared to approx. 24 % by selective cutting. This finding cannot be neglected in the context of the Kyoto protocol when dealing with forests as sinks for greenhouse gases.

Wednesday 23 November

10.00 - 10.30	Title not known yet - *Zbigniew Klimont*

Not yet available

11.00 - 11.30	Why did Nitrogen Management fail within Various Policy Arenas - *Peringe Grennfelt*

Not yet available

11.30 - 12.00	Work on Nitrogen Effects in CLRTAP - *Till Spranger*

TILL SPRANGER

Federal Environmental Agency (UBA)
Dessau, Germany

The UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) has been rather successful in reducing air pollution in Europe. But many remaining problems are closely connected to nitrogen emissions into the atmosphere. Consequently, nitrogen effects are one main focus of the effects-oriented activities under CLRTAP, including the International Cooperative Programme on Modelling and Mapping Critical loads and Levels and Air Pollution Effects, Risks and Trends (ICP M&M). This presentation provides a brief overview of work on nitrogen effects, focusing on present and future challenges facing ICP M&M.
These include:

- (approaches to model) strong links and feedbacks to biological processes and climate change (carbon and water budgets)
- choice of biodiversity effects indicators, dose/effect relations, and critical limits
- land use change and scale effects IAM extension and/or other policy advice formats?

Session: Emission

Impact of nitrogen fertilization on loss of nitrogen from agricultural system - *Triin Teesalu*

T. TEESALU, A.. TOOMSOO, T. LAIDVEE, P. KULDKEPP

The nitrogen mass balance for a long-term field experiment in 1995 was calculated. The trial was established as three-field crop rotation (potato- spring wheat-spring barley) on sandy loam *Fragi Stagnic Albeluvisol* at Eerika research station, Tartu in Estonia. The organic fertilizer treatments were followings: 1) without organic fertilizer; 2) farmyard manure given for potato and 3) different alternative organic fertilizers: beet leaves (40 t ha $^{-1}$) + straw (4 t ha^{-1}) for potato, beet leaves (40 t ha $^{-1}$) for spring wheat and straw (4 t ha^{-1} + 35 kg N ha^{-1}) for spring barley. The organic fertilizer treatments were divided into five mineral nitrogen fertilizer treatments (N-0; N-40; N-80; N-120; N-160). The idea was to use data of input with fertilizers and output with yields on one hand and of data the nitrogen statement in humus layer on other hand for calculation the difference, considering that this should denote result of the loss of nitrogen from agricultural system. Though there was not possible to distinguish the nitrogen amounts and forms loosed through emission to atmosphere neither to hydrosphere. The nitrogen balance (input-output) was related with changes of nitrogen content in soil.

Farm-N internet model of farm N flows - *Nicholas Hutchings*

Projection of NO_x, N_2O and NH_3 emission limits at regional level in Poland for fulfilling national obligations of international conventions and EU NEC directive - *Janina Fudala*

JANINA FUDALA, STANISLAW HLAWICZKA, EWA STRZELECKA-JASTRZAB, MARIAN CENOWSKI, BRONISLAWA DYDUCH

Institute for Ecology of Industrial Areas, Katowice, Poland

The realisation of national sustainable development and environmental protection strategy is a part of international strategy based on the same roles. It needs to take into account an international commitments and obligations on the atmospheric emission reduction of several pollutants. These two aspects – external and internal in the implementation of national sustainable development and environmental protection strategy must be taken into account also in the region and local strategies. While the internal aspects of regional and local sustainable development can be defined, the external aspects (international) not always are perceptible. Therefore they should be clearly defined as an input information for development of effective regional or local sustainable development strategy and environmental protection.

As an introduction the trends of emission NOx , NH_3 and N_2O will be presented as well as their effects of acidification of the environmental compartments. Then the range of emission reduction above mentioned pollutants up to the year 2010 will be discussed. In consequence the main presentation will focused on the method of determination the regional emission limits for different pollutants covered by international conventions, protocols and EU NEC directive, which must be reached in the year 2010 and which allow Poland to meet an international obligations on the national total emissions in this year. The spatial resolution of the emission limits by emission source categories will also presented. Such approach will help regional and local authorities for better monitoring of annual emissions, maintenance of restructuring of emission sources and development such economic sectors, which will be friendly for environment and allow to meet the regional and local limits.

Session: *Transport - Exchange - Deposition*

Investigating possibilities for a local ammonia policy - *Willem Asman*

WILLEM A.H. ASMAN

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Atmospheric ammonia is partly deposited close to sources and is partly converted to particulate ammonium, which is transported over long distances before it is deposited. Information will be presented on the possibilities and limitations to reduce the deposition to nearby nature reserves for a country with a relatively high emission density, such as Denmark.

Atmospheric nitrogen concentrations in Finland: trends vs. emission reductions - *Tuomas Laurila*

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Finland is located in the gradient region between the less polluted high northern latitudes and the densely populated areas of Europe where emission densities of nitrogen oxides and ammonia are high. Atmospheric concentrations and wet deposition of nitrate and ammonium observed in Finland reflect this emission pattern. North of the Arctic Circle the atmospheric concentrations of total nitrate (gaseous HNO_3 and particulate NO_3^-) and total ammonium (gaseous NH_3 and particulate NH_4^+) are nearly one order of magnitude smaller than in the southern part of the country. This gradient is clear in nitrate and ammonium concentrations in precipitation as well. Using the EMEP (European Monitoring and Evaluation Programme) and GAW (Global Atmosphere Watch) atmospheric concentration and wet deposition data, we detect a declining trend of concentrations up to the middle 1990's. Since that concentrations have remained more or less unchanged. The total Finnish anthropogenic NOx emissions have decreased only by 23 % between 1990 and 1999, and thereafter remained stable in spite of the declining road traffic emissions. The reported ammonia emissions have decreased by 13 % between 1990 and 2000, but the emission data are less accurate. In this presentation we analyse trends of atmospheric concentrations and depositions data and make a comparison between these observations and reported emissions.

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