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Report on methods (esp. inverse modelling and dispersion models) for estimating fluxes at landscape scale

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NitroEurope – Component 4: Verification measurement protocol

Atmospheric concentration and flux measurements

1. Purpose of the Measurements

The measurement of atmospheric gas concentrations provides a method of verifying the predictions of the atmospheric dispersion sub-model of NitroScape. In an indirect way, they can also be used to verify modelled emission fluxes since the atmospheric dispersion model uses these fluxes as inputs. The measurement of fluxes (land-atmosphere exchange) on the other hand can be used to verify the emission or deposition fluxes predicted by the ecosystem sub-models (arable, pasture, semi-natural etc.). Within Component 4 of NitroEurope it is proposed that measurement of the following gases will be made across the 6 study landscapes: ammonia (NH₃), nitrous oxide (N₂O), methane (CH₄) and nitrogen dioxide (NO₂). NB. not all of these gases will be measured at all sites.

2. Measurements of Concentrations

Atmospheric concentrations can be highly variable, both spatially and temporally. Measurement methods range from the very simple (e.g. passive samplers) to the complex (e.g. laser spectroscopy). The type of method used will depend on the species to be measured, spatial and temporal resolution required and the resources available. Three measurement approaches will be used: spatial variability, continuous point and mobile measurements.

2.1. Spatial variability measurements

2.1.1. Measurement techniques

Ammonia

Due to the high spatial variability of concentrations, it is necessary to measure at a relatively large number of locations. For this reason, it is only possible to use a low-cost method sampling at a relatively long time resolution. Passive samplers such as diffusion tubes are the most suitable for this task. There are two types that are planned for use in Component 4: CEH ALPHA samplers [1] and Gradko diffusion tubes [2]. Due to different techniques being used for different study areas, an intercomparison exercise is necessary.

Nitrous oxide and methane

These two gases have been grouped together because the measurement technique that is currently being developed is used for both species. Due to the multiple sites required for this measurement, low-cost methods need to be used. The most suitable method is bag sampling. Aluminium foil bags are slowly filled with atmospheric air using a small pump during the sampling period. The concentrations of N₂O and CH₄ in the balloon are then measured in the lab and correspond to the mean atmospheric concentrations at measurement location during the sampling period.

2.1.2. Measurement strategies

All measured concentrations need to be referenced to the coordinates of the measurement location, preferably with a Geographical Information System (GIS)

Ammonia

Samples will be placed at a height of 1.5 m above the ground (a standard air quality monitoring height) at a number of locations. The exact number of location required will depend on the size of the study area and the strength and distribution of NH₃ sources. For example, few locations are needed far from sources where concentrations are close to background whereas more locations are needed close to strong sources (e.g. livestock houses) where large horizontal concentration gradients are expected. Near strong sources it is useful to have linear transects away from the sources. A minimum of 10 locations are recommended for each study area although some areas will have many more. Ideally samples should be exposed in triplicate (i.e. three samplers at each location) because this allows the identification of a contaminated sample. Samples should be changed monthly, stored in a cold room (e.g. 2-4 °C) after exposure and sent for analysis as soon as possible.

Nitrous oxide and methane

Concentrations of N₂O and CH₄ are less spatially variable than NH₃ and, therefore, fewer measurement locations are required – a minimum of 5 locations per study area are recommended. The inlet should be at a height of 1.5 m and it is beneficial to co-locate the measurements with NH₃ concentration measurements.

2.2. Continuous point measurements

2.2.1. Measurement techniques

For some of the study areas, continuous measurement systems will be used to give accurate, high time resolution measurements of NH₃ (and possibly other gas) concentrations.

Ammonia

The type of system used will depend on the resources and expertise of the researchers in that country. Example systems include, wet-denuder systems (e.g. AMANDA [3]), laser absorption spectroscopy (e.g. tunable diode laser (TDL) [4]) and photo-acoustic instruments. Ideally these measurements should be made at the same height and location as one of the spatial variability measurements to allow an intercomparison.

2.2.2. Measurement strategies

Ammonia

Continuous measurements should be made during the NitroScape modelling period for the respective study area. Ideally measurements should be made continuously throughout the entire period but resources or equipment failure may make this impossible. Periods of nitrogen management activities (e.g. manure spreading) should be the priority periods in which to measure.

2.3. Mobile measurements

Where resources allow, mobile measurements (i.e. from a moving vehicle) of gas concentrations will be made at several study areas. This will allow the analysis of the spatial variability of concentrations at short time scales.

2.3.1. Measurement techniques and strategies

All gases

Accurate, high temporal resolution instruments will be driven along a pre-determined route within the study area and the trajectory coordinates and the corresponding concentrations are recorded to a computer. The actual routes used will depend on the features of the study area. For example, a typical route may be a circuit around a source region within the study area. The timing of the measurements should correspond with nitrogen management events in the study area and the frequency of the trajectories will depend on the resources available.

3. Measurements of Fluxes

Measurements of land-atmosphere exchange fluxes can be done using a variety of techniques, all of which require significant resources (equipment, expertise and time). Due to these constraints, fluxes cannot be measured at all study areas and where they are possible, they are normally measured at a single location. These measurements have the benefit of allowing the verification of fluxes predicted by a single ecosystem model.

3.1. Continuous point measurements

3.1.1. Measurement techniques

Ammonia

The most suitable method to use will depend on resources available at each study area. Three main approaches can be used:

1. *Aerodynamic gradient methods* use concentration measurements at multiple heights above the surface combined with vertical profiles of wind speed, temperature and water vapour pressure to determine the average vertical flux within the profile height range. Examples of this method are the AMANDA and COTAG systems [5].
2. *Eddy covariance (EC)* methods require a fast accurate concentration measurement (e.g. by laser spectroscopy) and correlate this with the vertical component of the wind to obtain the vertical NH_3 flux at the height of measurement.
3. *Relaxed eddy accumulation (REA)* methods measure the concentration of NH_3 within both the up- and down-drafts of the passing air. Combining these concentrations with the standard deviation of the vertical wind component gives the vertical NH_3 flux at the height of measurement.

Nitrous oxide and methane

Two types of methods can be used to measure fluxes of N_2O and CH_4 ; chamber measurements [6] and eddy covariance [7]. In chamber measurements, the build-up of N_2O and CH_4 within a sealed chamber placed on the ground is measured by taking a sample of the chamber air and analysing the concentrations using a suitable method (e.g. gas chromatography or TDL).

3.1.2. Measurement strategies

All gases

Continuous measurements should be made during the NitroScape modelling period for the respective study area. Measurements can be made continuously throughout the entire period but resources may make this impossible. Periods of nitrogen management activities (e.g. manure spreading) should be the priority periods in which to measure.

4. Which measurements and where?

The Component 4 workshop in Denmark (Nov-Dec 2006) produced a draft matrix of which measurements were to be done at which study areas and is reproduced below:

	Study area					
	UK	NL	DK	FR	PL	IT
Monthly concentrations						
NH ₃	X	X	X	X	X	X
N ₂ O	X	X	X	X		X
CH ₄	X	X	X	X		X
NO ₂ [†]	X	X	X	X		X
Continuous concentrations						
NH ₃	X	X	(X)	(X)	(X)	(X)
Fluxes						
NH ₃	X	(X)		(X)	?	X
N ₂ O	X	?	?	X	X	X
CH ₄	X	?	?	X		X

[†] NO₂ measurements to be done at small number of locations

In the above table: X = measurement will be made, (X) = measurement probably will be made and ? = not known if measurement will be made

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