SNAP CODE: **110117**
110216
110405
111117
111216

SOURCE ACTIVITY TITLE: **OTHER SOURCES AND SINKS**
Non-managed deciduous forests soils (excluding CO_2)
Non-managed coniferous forests soils (excluding CO_2)
Natural grassland and other vegetation soils (excluding CO_2)
Managed deciduous forests soils (excluding CO_2)
Managed coniferous forests soils (excluding CO_2)

NOSE CODE:

NFR CODE: **N/A**

1 ACTIVITIES INCLUDED

This chapter covers emissions from non-agricultural areas that are produced biogenically in soils. Although the magnitude of emissions from soils may be perturbed and controlled by human activities, the actual processes are considered natural. This version of the chapter deals with only NO_x emissions, mainly in the form of nitric oxide (NO), which are produced by micro-organisms in soil. Natural ecosystems tend to have modest fluxes, but soils that are nitrogen-enriched, especially agricultural regions, may have NO_x fluxes approaching those of anthropogenic sources (Williams et al., 1992). Fluxes of CH4 are not dealt with here as fluxes are expected to be to the ground, not to the atmosphere.

This chapter contains the information required to calculate emissions from soils in five SNAP categories (non-managed and managed, deciduous and coniferous, forests, and natural grasslands). Emissions from agricultural soils are covered in 100100 (cultures with fertilisers) and 100200 (cultures without fertilisers), although the methodologies are similar.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

Emissions of NO_x from soils are estimated to be as much as 16% of the global budget of NO_x in the troposphere (Logan, 1983). The contribution of soil NO emissions from agricultural lands has previously been estimated to be 15% of the total European NO_x emissions inventory (Simpson et al., 1995), but emissions from non-agricultural areas are certainly much smaller than this.

These activities are not believed to be a significant source of $PM_{2.5}$ (as of December 2006).

3 GENERAL

3.1 Description

Nitric oxide (as well as N_2 and N_2O) are produced as intermediate steps in microbial nitrification and denitrification processes. As emissions depend on the amounts of nitrogen going through these processes, agricultural soils, subject to direct fertilisation and manure, are responsible for the great majority of emissions, and in some regions may have NO_x fluxes approaching those of anthropogenic sources (Williams et al., 1992).
Soils emit NO_x mainly through biological pathways, and emission rates can be categorised by land use. The quantity of NO_x emissions from agricultural land is dependent on the rate of fertiliser application and the subsequent microbial nitrogen processing in the soil, together with a multitude of other environmental factors. A large number of studies have been discussed in relation to possible controlling factors in Skiba et al. (1997).

Although the magnitude of soil NO_x emissions may be small in overall comparison to anthropogenic NO_x emissions, there is considerable uncertainty in the estimates. Further, soil NO emissions occur in low-NO_x regions where ozone formation is most sensitive to NO_x availability, and the highest fluxes of NO occur in the warmer months of the year--times when photochemical smog is of concern.

3.2 Definitions

Soil NO emissions: nitric oxide produced by micro-organisms in soils, which ultimately "leaks" into the atmosphere.

3.3 Techniques

Current estimation techniques are based on empirical algorithms that account for land use cover and possibly N-inputs and/or soil temperature. These algorithms are based on a limited number of field chamber measurements.

Soil emissions of NO_x are dependent on the crop type and fertilisation rate and on a multitude of other environmental factors. The simple technique is provides an annual estimate based upon N-inputs only, whereas the detailed technique is intended more for modelling purposes and uses the algorithm of Novak and Pierce (1993) that calculates emissions of NO based on land use and temperature.

3.4 Emissions

The current draft of this chapter considers only NO emissions. Other trace gases, such as methane, N_2O, and CO, are known to be emitted from soils but are not yet included in this methodology. For methane, soils, especially within forests, are probably a major sink so it is not clear how emissions should be defined.

3.5 Controls

Nitric oxide emissions from soils are emitted by a natural process, microbial activity in soils. This activity may be influenced by the amount of nitrogen-based fertiliser added to soils, but

this discussion is mainly relevant to agricultural emissions, as discussed in chapter 100100 and Skiba et al. (1997).

4 SIMPLER METHODOLOGY

The simpler methodology is derived from the work of Skiba et al. (1997), who suggested that 0.3% of applied N is returned to the atmosphere as NO. For non-agricultural areas applied N would consist of animal manure and atmospheric deposition. Additionally, a background N-emission rate of 0.1 ng NO-N m^{-2} s^{-1} is assumed. (For agricultural areas the fertiliser application is considered, see 100200 and 100100).

Despite its simplicity, the Skiba et al. approach has the advantage of explicitly relating emissions to applied N amounts.

5 DETAILED METHODOLOGY

Given the lack of evaluation of any paramaterisations in Europe, a detailed methodology is probably not worthwhile for estimates of annual emissions. However, in case hourly changes in emissions are required (e.g. for modelling) the following methodology is proposed. Unfortunately, the simple and detailed methodologies are not consistent - they produce quite different annual estimates. However, until more is known about the merits of either method a consistent description cannot be provided.

This methodology is taken from Novak and Pierce (1993) and is known commonly as the second-version of the Biogenic Emissions Inventory System (BEIS-2). BEIS-2 can estimate NO emissions for forests, agricultural crops, urban trees, and grasslands. BEIS-2 calculates a range of emission flux rates based on land use types and soil temperature. The basis of the BEIS-2 calculation for soil NO emissions originates with the following equation (Williams et al., 1992):

$$F_{NO} = A \times \exp(0.071 \times T_s)$$

where

F_{NO} = NO flux, (ng N m^{-2} s^{-1})
T_s = Soil temperature, degrees Celsius
A = Experimentally derived constant for the land use types of grasslands and pasture, forests and wetlands.

The parameter A is given in Table 8.1. Emissions from soils at sub-zero temperatures can be assumed to be zero for inventory purposes.

6 RELEVANT ACTIVITY STATISTICS

For all approaches land use coverage is required, at least to distinguish agricultural and forest and other soils. For the simple methodology an estimate of N-inputs is required. This can be obtained from national deposition estimates or EMEP modelling. For the detailed approach air temperature statistics are needed.

7 POINT SOURCE CRITERIA

No point sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

A large number of emission factors based on field measurement data are given in the literature. Williams et al. (1992), Yienger and Levy (1995) and Skiba et al. (1997) provide excellent reviews on these data. Emission factors are given as a function of land use and other environmental conditions, such as temperature, soil moisture, and soil nitrate levels. The variation in these measurements is considerable, resulting in a wide range of uncertainty in current emission factors. Williams et al. estimates an annual uncertainty of about a factor of three. The quality code for soil NO emission factors thus should be considered a D.

The factors required for the application of the detailed methodology (recommended for modelling hourly emissions, rather than annual) are given in Table 8.1.

Table 8.1: Empirical coefficients for BEIS-2 system, from Novak and Pierce, 1993

Land use category	A	Function to compute T_s (°C) from ambient temperature (T_a).
Grasslands + pasture	0.9	$T_s = 0.67\ T_a + 8.8$
Forest	0.07	$T_s = 0.84\ T_a + 3.6$
Wetlands	0.004	$T_s = 0.92\ T_a + 4.4$

Valid for $0<T_s<35$ (°C).

9 SPECIES PROFILES

Nitric oxide (NO) is considered to be the predominant NO_x compound emitted from soils.

10 UNCERTAINTY ESTIMATES

The uncertainty of soil NO emission estimates is reported by Williams et al (1992) to be about a factor of three, when averaged over the United States on an annual basis. In view of the poor coverage of data across Europe, especially in Mediterranean areas, a factor of five uncertainty seems reasonable. Additional field studies comparing atmospheric measurements of NO_x fluxes with soil emissions derived from chamber measurements are needed to reduce this uncertainty.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

In developed areas of the world, such as Europe, the greatest uncertainty in total soil NO emissions is the amount of NO emitted from heavily-fertilised farmland. Little information is available on emissions from natural grasslands (see e.g. Skiba et al., 1997). Studies are needed to determine the fraction of nitrogen inputs that are subsequently released into the atmosphere as NO. The role of plant canopies in mitigating the flux of NO into the free atmosphere also needs to be explored.

12 SPATIAL DISSAGGREGATION CRITERIA FOR AREA SOURCES

The spatial disaggregation of soil NO emissions depends on the spatial distribution of land use, with agricultural cropland being the most important.

13 TEMPORAL DISSAGGREGATION CRITERIA

Many meteorological processes affect the temporal distribution of soil NO emissions. These processes and parameters include soil temperature and rainfall (which affects soil moisture).

14 ADDITIONAL COMMENTS

Emissions of NO from soils is both a natural and anthropogenic-influenced source. Although emissions occur as a result of biogenic processes, the magnitude of soil-generated NO is influenced by human cultivation, fertiliser application, animal management and deposition onto the soil.

A more detailed method than those suggested here has been presented in Yienger and Levy (1995) and was initially used for global soil NO_x emissions. In this approach, the variation in soil NO emissions is associated with biomass burning, history of soil moisture (pulsing), temperature, soil moisture, vegetation cover type (biome), canopy reductions, and fertilisation rate. Temperature is calculated from air temperatures using the same empirical relationships used in Novak and Pierce for wet soils, and by adding 5° C to dry soils, based on observations reported in Johansson et al., 1988. In dry soils, rather than an exponential increase, emissions increase with temperature, in a weak linear relationship.

Apart from the differences in methodology, the Yienger-Levy and Skiba approaches differ greatly in their assumption of the fraction of applied N (fertiliser, etc.) which is released as NO. Yienger and Levy assume 2.5%, whereas Skiba et al. assume 0.3% (NO as N). As the Skiba et al. figure is based upon a larger literature than Yienger and Levy and includes many European measurements it is probably a better estimate for European inventories, but the range illustrates well the uncertainties associated with this emission source.

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

Because the emission factors are largely based on soil chambers, independent verification of the fluxes into the free atmosphere is needed. This verification is expensive, but may be accomplished using micrometeorological techniques that examine either the gradient in NO_x concentration differences with height or direct eddy correlation of NO_x fluxes. The rapid conversion of freshly-emitted NO into NO_2 in the presence of O_3 complicates the measurement and interpretation of micrometeorological flux data.

17 REFERENCES

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18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE AND SOURCE

Version: 1.1

Date: 3 February 1999

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December 2006

20 POINT OF ENQUIRY

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