Protocol
4D: N_2O from agricultural soils: direct emissions and grazing emissions

IPCC Category:	4D1, 4D2, 4D4
NFR Code:	Not applicable
NOSE Code:	Not applicable
NACE Code 2008	011, 012, 014 and 015

Foreword

Under the Kyoto Protocol, the Netherlands is required to set up and maintain a national system to monitor its greenhouse gas emissions. One of the elements of this system is a transparent and verifiable description of the methods and processes used in this monitoring system. These methods must meet international guideline criteria, which have been defined by the United Nations (UN) and the European Union (EU).

The Netherlands meets the aforementioned requirement, for example, by defining a series of Monitoring Protocols, which describe the methods and work processes used to determine greenhouse gas emissions and the amounts of carbon sinks available. Protocols have been written for about 40 greenhouse gas sources or sinks. This document describes the protocol for one of these sources or sinks.

The protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was coordinated by PBL (Planbureau for the Leefomgeving, or the Netherlands Environmental Assessment Agency), but on 1 January 2010 this coordination task was taken over by RIVM (the Netherlands institute for public health and the environment). Other institutions that have contributed to the protocols include NL Agency; Ministry of Agriculture, Nature and Food Quality; and the Ministry of VROM (Housing, Spatial Planning and the Environment).

1 Scope and significance of emission sources/activities

1.1 Scope and definition

This protocol describes the methodology and working processes for determining direct emissions from N_2O (laughing gas) from the soil as a result of agricultural activities in the Netherlands (IPCC categories 4D1, 4D2). This concerns the SBI codes 011 and 012 (agriculture and horticulture), 014 (animal husbandry and breeding) and 015 (agriculture and/or horticulture in combination with animal husbandry and breeding).

Laughing gas is formed in the soil during the microbiological processes of nitrification and denitrification.

Nitrification concerns the process whereby ammonia (NH_4^+) under aerobic (oxygen-rich) conditions is converted into nitrate by bacteria. Laughing gas can thus be formed as a by-product, particularly when the nitrification process is delayed through lack of oxygen. No organic substances are required for nitrification.

Denitrification is the process whereby, under anaerobic (low-oxygen) conditions, bacteria convert nitrates (NO_3^-) into the gaseous nitrogen compound N_2, with N_2O as a by-product. Organic substances are used as energy source. Organic soils have higher emissions of laughing gas than mineral soils.

1.2 Significance and influences

1.2.1 Contribution to total national emissions

The direct N_2O emissions from agricultural soil contribute a few percent to the annual Netherlands greenhouse gas emissions.

1.2.2 Developments that infuence emissions

Direct emissions of laughing gas from agricultural soils started to rise after 1990 and, around 2002, is back at the 1990 level. This increase was caused by the low-ammonia emission manure application techniques that were used after 1990 that, compared to above-ground manure application, result in a higher laughing gas emission (Kroeze, 1994; Kuikman et al., 2006). The consequent drop in laughing gas emission from 1995 was the result of lower nitrogen supply to the soil by (artificial) fertiliser and animal manure application. Both the use of low-ammonia emission manure application techniques and the reduced nitrogen use via fertiliser and animal manure application is the result of the Netherlands manure and ammonia policy (Brandes et al., 2007).

2 Method, emission factors and activity data

2.1 Calculation method

Direct laughing gas emissions from agricultural soils are calculated by multiplying the amount of nitrogen per supply source and soil type by the country-specific emission factor. The total N_2O emissions from all supply sources are then calculated by adding up the N_2O emissions per supply source per soil type. For detailed information, please refer to the Background Document (Van der Hoek et al., 2007).

$$N_2O \text{ emission (in kg } N_2O) = \sum E_{ij} * EF_{ij} * 44/28$$

E_{ij} : amount of N for the defined supply source (i) on soil type (j) (kg N)

EF_{ij} : emission factor for the defined supply source (i) and soil type (j), in kg N_2O-N/kg N in supply source.

44/28 : conversion factor from N_2O-N to N_2O

The aforementioned formula differentiates between the following N supply sources (i).

1. Net application of N from fertiliser, i.e. reduced by the NH_3 emission when applying fertiliser.

2. Net application of N from animal manure, i.e. reduced by the NH_3 emission from stable and storage and when applying animal manure and the net export (so N from animal manure is reduced by export-import)
3. Net N in the soil through grazing domestic agricultural animals, i.e. reduced by the NH_3 emission when grazing.
4. Biological nitrogen fixation by crops
5. Remaining crop residues
6. Agricultural use of histosols.
7. Sewage sludge

The aforementioned formula differentiates between two soil types (j).

1. Mineral soils
2. Organic soils.

For artificial fertiliser, a distinction is made between ammonia-based and other types of artificial fertiliser. With respect to applications, these are also separated into various application techniques and, when referring to grazing, this is split into urine and faeces.

Comparing the IPCC Guidelines and the Good Practice Guidance (GPG)
The methodology described above conforms to the IPCC method, as described in the GPG (IPCC, 2001; pp. 4.40 and 4.53).

Determining the extent of the various supply sources and the ammonia emissions is carried out using country-specific data at tier 2 level. Determining the N2O emissions is carried out using a tier 1b analysis. The use of artificial fertilisers and animal manure is split into two types of artificial fertilisers and two types of manure application techniques. Grazing manure nitrogen is specified into the nitrogen in the urine and faeces. Each specified supply source has its own country-specific emission factor.

2.2 Emission factors

The total direct emissions of laughing gas from agricultural soils are calculated by multiplying the amount of nitrogen per supply source and soil type by a fixed country-specific emission factor, and then to aggregate this over all supply sources and soil types (Van der Hoek et al., 2007). Table 1 provides an overview of the emission factors used.

Table 1. Emission factors for direct laughing gas emission from agricultural soils

Supply source	EF (kg N_2O–N per kg N supply)		Reference
	Mineral soil	Organic soil	
Fertiliser application			
- ammonium fertiliser (no nitrate)	0.005	0.01	2, 4, 5
- other types of fertiliser	0.01	0.02	1, 2, 4, 5
Animal manure application			
- above-ground (surface spreading)	0.01	0.02	1, 5
- low-ammonia emission application	0.02	0.02	1, 5
Meadow manure livestock			
- faeces	0.01	0.01	1
- urine	0.02	0.02	1
Nitrogen fixation	0.01		1, 2
Crop residues	0.01		2
Cultivation of histosols		0.02	2, 3
Sewage sludge	0.01		

references: 1= Kroeze, 1994; 2= Van der Hoek et al., 2007; 3= Kuikman et al, 2005; 4= Velthof et al, 1997; 5= Kuikman et al, 2006

In general, organic soils have an emission factor that is twice that used for mineral soils. However, grazing forms an exception: here there is no differentiation between N_2O emissions for mineral and organic soils. The emission factor for low-emission manure application is also twice that of the emission factor for underground (low-emission) manure application. Research studies (Kroeze, 1994; Velthof et al., 1997; Kuikman et al., 2006) form the basis for these country-specific emission factors. A summary of the results of these research studies can be found in Van der Hoek et al (2007).

The following section provides further information, per supply source, on the emission factors used.

Fertiliser application

For most types of artificial fertilisers, an emission factor of 0.01, or 0.02 kg N_2O-N per kg net added N is calculated for mineral or organic soils respectively. These values are mostly taken from Dutch research studies implemented in the first half of the 1990s (Kroeze, 1994). Later research shows that using ammonia-retaining nitrogen fertiliser (that contains no nitrates) leads to 50% lower laughing gas emissions (Velthof et al., 1997). This type of nitrogen fertiliser is therefore calculated at 50% of the emission factor.

Animal manure application

For above-ground application of animal manure, an emission factor of 0.01 or 0.02 kg N_2O-N per kg net added N is calculated for mineral and organic soils respectively. For low-emission fertiliser use on mineral and organic soils, an emission factor of 0.02 is calculated. An explanation for a higher emission factor may be found in less favourable processing conditions for an optimum nitrification/denitrification process for low-emission manure application. These emission factors are mostly taken from Dutch research studies implemented in the first half of the 1990s (Kroeze, 1994). The first preliminary research results from a study into measurement data from the Dutch practical situation, in combination with measurement data on comparable experiments in other countries, provided (around 2005) insufficient information on new country-specific emission factors (Van der Hoek *et al*., 2007).

Grazing of livestock

For grazing, an emission factor of 0.01 or 0.02 kg N_2O-N per kg net produced N is calculated for faeces and urine respectively. There is no differentiation between mineral and organic soils. These values are mostly taken from Dutch research projects implemented in the first half of the 1990s (Kroeze, 1994).

Nitrogen fixation

Nitrogen fixation uses an emission factor of 0.01 kg N_2O-N per kg biologically based N for mineral soils. This value is largely taken from Dutch research projects implemented in the first half of the 1990s (Kroeze, 1994). The relevant nitrogen fixation crops in arable farming and outdoor horticulture, are hardly ever found in organic soils.

Remaining crop residues

For crop residues an emission factor of 0.01 kg N_2O-N per kg N is used for the crop residues remaining on mineral soils. This value is largely taken from Dutch research studies carried out in the first half of the 1990s (Kroeze, 1994). Arable farming and outdoor horticulture hardly ever occur in organic soils.

Agricultural use of histosols

A fixed country-specific emission factor of 4.7 kg N_2O-N per hectare is used for this calculation. This value is based on an average mineralisation of around 235 kg N per hectare histosol (Kuikman et al., 2005). Using an emission factor of 0.02 (largely taken from Dutch research projects conducted in the first half of the 1990s and reported in Kroeze, 1994), the laughing gas emission of histosols amounts to 4.7 kg N_2O–N per hectare.

Sewage sludge

The emission factor for sewage sludge is calculated as 0.01 kg N_2O-N per kg N.

2.3 Activity data

The following information is required in order to carry out the calculation using the method described in Section 2.1. Furthermore, the necessary Emission factors are discussed in Section 2.2 of this protocol.

Mineral soils and organic soils

When calculating laughing gas emissions, it was decided (for the period 1990 to today) to use a fixed ratio for the total amount of nitrogen in fertiliser and animal manure applied tot the Netherlands surface areas for both mineral and organic agricultural soils. 90% of fertiliser is allocated to mineral soils and 10% to organic soils, and 87% of animal manure is allocated to mineral soils and 13% to organic soils (Van der Hoek *et al*., 2007).

Net amount of nitrogen in (artificial) fertiliser applied to soil

Figures relating to the gross amounts of nitrogen in ammonia-based fertiliser (that contains no nitrates) and the total gross amount of nitrogen in fertiliser are gathered annually by the LEI (Dutch Agricultural Economic Institute, see also www.lei.wur.nl). The net amount of nitrogen in fertiliser applied to agricultural soils is calculated by taking the total annual amount of nitrogen in fertiliser and deducting the nitrogen in the ammonia emissions released after fertiliser application.
The net amount of nitrogen in artificial fertiliser applied to agricultural soil is yearly calculated for the Emission Registration. The calculation method for ammonia emission from fertiliser is described in Van der Hoek (2002). The results are published annually in the Environmental data compendium; available from www.planbureauvoordeleefomgeving.nl.

Net amount of nitrogen in animal manure applied to soil

The gross amount of nitrogen in the animal manure in stable and storage is published annually by the Environmental data compendium. The calculation is described in Protocol Manure (N_2O). The net amount of nitrogen in animal manure used on agricultural soils is calculated by taking the total annual amount of nitrogen in animal manures and deducting:

1. Ammonia emissions during storage, both in the stables and outside.
2. The amount of nitrogen in animal manure that is exported, reduced by import from foreign countries,
3. Ammonia emissions after animal manure application to agricultural soils.

The remaining amount of nitrogen in animal manure is applied to the Netherlands agricultural soil. All aforementioned manure flows and ammonia fluxes, plus the percentage of the various manure application techniques (above-ground and low-emission) form part of the annual calculations under the framework of the Emission Registration. The calculation method with respect to ammonia emissions from animal manure is described in Van der Hoek (1994, 2002). The amount of nitrogen in animal manure that is exported is published annually in the Environmental Compendium and these are available from www.planbureauvoordeleefomgeving.nl. The ammonia emissions from manure storage (both under the animal houses and in outside storage facilities) and application are available via the Environmental Compendium and the Emission Registration.

Net amount of nitrogen in manure produced in the meadow

Part of the animal manure is produced in the meadow. The amount of nitrogen per animal is calculated by the WUM and is available from the CBS website www.cbs.nl. Statistics concerning the current number of animals are available on CBS/Statline, via http://statline.cbs.nl. The method used to calculate ammonia emissions from meadow manure is described by Van der Hoek (1994, 2002). The results of the ammonia emissions due to grazing are available via the Environmental Compendium (see website: www.planbureauvoordeleefomgeving.nl).

The distribution of nitrogen over faeces and urine depends on the nitrogen content in the meadow grass, and in turn this depends on the fertilisation level. For the period 1990-1999 a distribution of 30/70 was assumed, and for the period from 2000 onwards, a ratio of 35/65 is used (calculated on the basis of Valk et al., 2002).

Nitrogen fixation for crops

Conform the IPCC calculation rules, only crops from arable farming and outdoor horticulture (e.g. not from greenhouse farming) are included. This concerns the following crops (the figures between brackets show the country-specific value for nitrogen fixation per hectare; Mineralen Boekhouding, 1993).

- Lucerne (422 kg N per hectare)
- Dried peas and green peas, marrowfats, kidney beans, peas (green to harvest) (164 kg N per hectare)
- Broad and field beans (325 kg N per hectare)
- Dwarf beans (green to harvest), (scarlet) runner beans (75 kg N per hectare)
- Broad beans green(164 kg N per hectare).

The areas used for these crops are taken from the annual Agricultural Census (‘Landbouwtellingen’), also known as the May Count (‘Meitelling’), which includes all agricultural companies with their headquarters in the Netherlands and which is greater than, or equal to, three Netherlands size units (nge). These statistics are available from the CBS/Statline website www.cbs.nl, and are also included in the Background Document (Van der Hoek et al., 2007).

Amount of nitrogen in crop residues

Conform the IPCC calculation rules this includes all arable and outdoor horticultural crops (e.g. not from greenhouse farming). All crops that fall under both these two categories are included in the Agricultural Census (‘Landbouwtellingen’), available via www.cbs.nl, are also included in the calculations for laughing gas emissions. In addition, a fixed country-specific value in kg N per hectare is used for the nitrogen content of the above-ground crop residues. Finally, the calculations take account of the fact that sometimes part of the above-ground crop residues are removed from the field and thus do not contribute to laughing gas emissions. Country-specific values are used for this transport. Country-specific values are reported in Van der Hoek et al. (2007).

The areas used for these crops are taken from the annual Agricultural Census (‘Landbouwtellingen’), also known as the May Count (‘Meitelling’), which includes all agricultural companies with their headquarters in the Netherlands and which is greater than, or equal to, three Netherlands size units (nge).

Cultivation of histosols
Laughing gas emissions are determined by multiplying the histosol area by a specific Netherlands emission factor. The extent of the histosol area is estimated (for the base year, 1990) at 223,000 hectare. This is also included in the calculations for the period from 1990 to date (Kuikman et al., 2005 and Van der Hoek et al., 2007). This is in line with the decision to use a fixed area of agricultural soil for calculating the CO_2 emissions/sinks from agricultural soil for this same period.

Sewage sludge
The amount of sewage sludge applied to agricultural soils is calculated by the CBS and published via Statline.

3 Working processes

Process for estimating (t-1)
If preliminary figures are required at any point, the following process is used to estimate the figure for t-1. The preliminary data for the work package leader are calculated by extrapolating them from the previous years’ figures, based on prognoses for the developments in the most important activity data (taken from CBS (Statistics Netherlands) or other statistical sources).
When calculating N_2O emissions from agricultural soil, the data for added nitrogen per manure source is corrected to reflect the changes in animal numbers and in the amount of ground used for arable and horticultural crops in (t-1). See also the process for final determination (t-2).

INPUT	PROCESS	OUTPUT	BY WHOM
Preliminary data work package leader (t-1)	Include t-1 data in ER database	ER-db with (t-1) data	Work package leader non-CO_2 ER working group for agriculture and land use
ER-db with (t-1) data	Check emission figures: compare with previous years (trend), modify if required and document everything	ER-db (t-1) with any modified figures	ER working group for agriculture and land use

Process for final determination of (t-2)
The final emission figures (as described in this protocol) are calculated using the following process.

INPUT	PROCESS	OUTPUT	BY WHOM
Gross extent of nitrogen supply per source: • Fertiliser-N (via LEI/CBS) with N split into 2 types of artificial fertilisers and into mineral and organic soils (Van der Hoek et al., 2007) • N in animal manure, total production stable and storage(calculation: protocol N_2O Manure management; WUM/CBS) • N in animal manure for export (via CBS Statline) • N fertiliser and manure supply to mineral and organic soils (Van der Hoek et al., 2007) and the percentage of N manure applied by low-emission manure application techniques(Van der Hoek, 2002) • N in meadow manure(via WUM/CBS) with N specified into faeces and urine N (Valk et al., 2002) **(A)** ***Extent of NH_3-N per manure and fertiliser source*** (figures of LEI, based on Van der Hoek, 2002; publication in Environmental data compendium; 8% of meadow N) **(B)**	Calculating net extent of nitrogen supply per manure and fertiliser source: **(A) - (B)**	Net extent of nitrogen supply per manure and fertiliser source, in Excel spreadsheet **(C)**	Work package leader non-CO_2 ER working group for agriculture and land use
Areas of arable and horticultural crops, per crop (CBS/Statline) **(D)** ***Percentage crop residues removal*** (Van der Hoek et al., 2007) **(E)**	**(D)** * ((100-**(E)**/100)	Net extent of nitrogen supply crop residues in Excel spreadsheet **(F)**	Work package leader non-CO_2 ER working group for agriculture and land use
Areas N-fixing arable and horticulture crops(CBS/Statline) **(G)** ***Nitrogen fixation per hectare*** Per N-fixing crop (Mineralen Boekhouding, 1993) **(H)**	**(G) x (H)**	Net extent of nitrogen supply N-fixing crops in Excel spreadsheet **(I)**	Work package leader non-CO_2 ER working group for agriculture and land use

Areas of histosols (Kuikman et al., 2005) **(J)** ***Extent of nitrogen mineralisation per hectare*** (Kuikman et al., 2005) **(K)**	**(J) x (K)**	Nitrogen supply from histosols **(L)**	Work package leader non-CO_2 ER working group for agriculture and land use
N_2O emission factors -per nitrogen source -per soil type (Kroeze, 1994 and Van der Hoek et al., 2007) **(M)**	Calculating N_2O emissions **(C+F+I+L) x (M)**	N_2O emissions, per: -nitrogen source -soil type in Excel spreadsheet **(N)**	Work package leader non-CO_2 ER working group for agriculture and land use
N2O emission **(N)**	1st validation emission figures via trend analysis and expert judgement	Validated emission figures in Excel spreadsheet (= Final data Work package leader (t-2)) **(O)**	Work package leader non-CO_2 ER working group for agriculture and land use
Final data Work package leader (t-2) **(O)**	Include (t-2) data in ER database	ER-db with (t-2) data **(P)**	Work package leader non-CO_2 ER working group for agriculture and land use
ER-db with (t-2) data (P)	Check, and trend analysis of air emissions: explain deviations or modify figures	Final defined emission figures (t-2) (Q)	Task forces and PBL experts

4 Uncertainty and quality

4.1 Estimating uncertainties

A Tier-1 uncertainty analysis is implemented every year before the NIR is submitted by the ER, based on the greenhouse gas inventory and in compliance with IPCC guidelines. The assumptions used and the results thereof are described in a background report to the NIR. In addition to this, where included in the QA/QC programme for the relevant period, extra analyses are implemented regularly in specific situations, which include any updating of the Tier-2 uncertainty analyses. The Tier-2 uncertainty assessment was last updated in 2006. This assessment showed that a Tier-1 uncertainty assessment is sufficiently reliable and that Tier-2 uncertainty assessments need only be implemented at periodic intervals of around 5 years, unless a major change in an important source is sufficient to require earlier reassessment.

- Source-specific uncertainty

The uncertainty estimate $_{total}$ concerns the root of the sum of uncertainty in the data sources used (AD_{onz}) in the square and the uncertainty of the emission factor (EF_{onz}) in the square. The extent of the total uncertainty is here primarily determined by the greatest AD or EF uncertainty.

$$\text{Uncertainty estimate}_{\text{total}} = \sqrt{EF_{onz.}^{\;2} + AD_{onz.}^{\;2}}$$

The uncertainty estimates concerning the data sources (AD) and emission factors (EF) used, and the total uncertainty estimate, are listed in the following table.

IPCC	Category	Gas	AD $_{onz.}$	EF $_{onz.}$	Uncertainty estimates $_{tot}$
4D1	Direct N_2O emissions from agricultural soils	N_2O	10	60	61
4D2	Animal production on agricultural soils	N2O	10	100	100

4.2 Quality assurance and quality control (QA/QC)

The ER work package leaders check that:

1. the basic data are well documented and adopted (check for typing errors, use of the correct unit sizes and correct conversion);
2. the calculations have been implemented correctly;
3. assumptions are consistent, also whether specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

Any actions that result from these checks are noted on an ‘action list’. Before defining the data, supervisors check whether the relevant actions on this list, plus the QC checks, have all been completed. Defining the data is carried out by the WEM (working group on emissions monitoring), and confirmed in writing via an e-mail from the institute representatives to the ER project leader at PBL.

The work package leaders fill out a new documentation sheet when adding new data. For reasons of efficiency a minimum level has been set for obligatory documentation, i.e. 5% changes at target group level, and 0.5% at levels concerning the national total. These documentation sheets form part of the trend analysis, as well as the eventual definition of the data set.

The ER work package leaders communicate by e-mail regarding these QC checks, results and actions. They send a printed copy to the ER secretary, who keeps a logbook and compiles these e-mails into an ‘action list’. This shows explicitly that the required checks and corrections have been carried out.

4.3 Verification

In order to check the quality of the emission figures for the sources in this protocol, general QA/QC procedures have been followed that are in line with the IPCC guidelines. These are described further in the QAQC programme used by the National System, and the annual working plans published by the ER.

- Sector-specific QC

No additional specific verification procedures are implemented for the sources defined in this protocol.

4.4 Possibilities for improvement compared to the current calculation method

4.4.1 History

At the beginning of the 1990s laboratory-scale experiments led to country-specific emission factors for laughing gas emissions (Kroeze, 1994) for the various sources. This was later summarised in a methodological description (Spakman *et al*., 1997). Two new sources were added at the beginning of 2005: ‘crop residues’ and ‘agricultural use of histosols’. Another source (background emissions from agricultural soil) was removed. Application of artificial fertiliser includes a separate category for ammonia-based nitrogen fertiliser, because a lower emission factor (50%) is applied here (Velthof *et al*., 1997).

A consistent timeseries is now available. Fur-covered animals have been added for the years 1990 and 1991, and cattle (1990-1994) have now been split into meat calves (rosé veal) and meat calves (white veal), as per following years. The timeseries is also now complete, because horses and ponies are included.

Another change concerns the activity data used for the application of animal manure and the production of meadow manure. This is the result of a change in the activity data used for the N_2O emissions due to manure storage (see protocol 4B N_2O on Manure Management). From 2005 onwards the WUM figures form the basis for the nitrogen excretions per manure management system (see also Section 2.3), although previously the activity data used were taken from those used for ammonia calculations. The modified indoor excretions led to a change in the distribution of the amount of meadow manure and manure used on agricultural soil.

Also beginning in 2005, the data concerning the export of manure was taken from CBS statistics, rather than figures previously taken from the activity data for ammonia calculations. This has also led to a change in the total amount of manure used.

For grazing, the distribution of nitrogen into faeces and urine has been modified, and for nitrogen fixation the activity data have been modified to comply with IPCC Guidelines (Van der Hoek *et al*., 2007).

Around 2005 experts checked to see whether research results released after publication of the Kroeze (2004) report, formed sufficient reason for modifying and/or further refining of emission factors. Research results generally indicated insufficient basis for changing the emission factors. The only exception was the emission factor for using artificial fertiliser: a separate category for artificial fertilisers (ammonia-based fertiliser containing no nitrates) with a 50% lower emission factor is now used for the application of fertilisers.

Finally, two extra sources were added during this period: using horse manure, and using sewage sludge in the agricultural sector.

The N-excretion figures for all animal categories have been recalculated in 2009. The previous method did not take account of feed losses, and the feed intake by dairy cattle was underestimated. The N-excretions are calculated on the basis of feed intake.

Figures for horses and ponies (from 1990 onwards) have also been recalculated in 2009. Before this date the N-excretion factors used did not differentiate between horses and ponies [Van der Hoek *et al.*, 2006]. However, from the NIR 2009 onwards, the N-excretion factors for horses and ponies are calculated via the same method used to calculate all other animal categories. The N-excretion factors are available from 2006 onwards. The figures for 2006 are also used for all preceding years.

4.4.2 Future

Preliminary results from research implemented around 2005 provided insufficient basis for revising the emission factors for above-ground and low emission manure application, and for further refining emission factors according to soil type and/or land use. Comparable field research into taking N_2O emission factors for above-ground and low emission manure application (possibly as correction factor) is desired, so that the influence of soil type and land use can be included.

With respect to grazing of domestic agricultural animals, a differentiation is now only made between emission factors for faeces and urine, where urine has an emission factor that is twice as high as the emission factor of faeces. There is no differentiation between mineral and organic soils. Further study is required to determine whether or not this is correct, considering the initial results of research into measurement data in the Netherlands.

Current calculations, to determine the net amount of nitrogen in the animal manure applied, only takes account of gaseous nitrogen losses in the form of NH_3-N from stables and storage. Other gaseous losses are not included. Further study is required to determine whether this needs to be revised. This could occur together with the activity data used for manure application: adding nitrogen to the soil. The current calculation method complies with the IPCC Guidelines, by deducting the NH_3-N losses during application from the (net) nitrogen in manure used on agricultural soils. The new IPCC Guidelines state that this is no longer allowed, at least for the default method. This is because the new (lower) default N_2O emission factors are also based on the amount of nitrogen in the manure used.

In the future, when animal manure is transported to an individual corporate or central facility for (co)-digestion or processing manure, this means a reduction in the amount of animal manure used directly on agricultural soil. If information is available on the associated amount, this can be factored into the calculations described in Section 2.3. However, if animal manure (after fermentation or processing) is used on Dutch agricultural soil, this must be included as a supply source to the soil. An accurate calculation cannot be made until further information is available concerning the extent of this new subcategory and the associated emission factor.

5 Remaining aspects

5.1 Point source criteria

Not applicable

5.2 Substance profiles

Not applicable

5.3 Regionalisation
Not applicable

5.4 Time-based variations in source strength
Not applicable

6 References and additional information

6.1 References

- Brandes L.J., P.G. Ruyssenaars, H.H.J. Vreuls, P.W.H.G. Coenen, K. Baas, G. van den Berghe, G.J. van den Born, B. Guis, A. Hoen, R. te Molder, D.S. Nijdam, J.G.J. Olivier, C.J. Peek, M.W. van Schijndel, Greenhouse Gas Emissions in the Netherlands 1990-2005, National Inventory Report 2007, MNP report 500080006 / 2007 Bilthoven, the Netherlands.
- CBS, www.cbs.nl - Statline, Landbouwtellingen. CBS, Voorburg / Heerlen
- IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories, Three volumes: Reference Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK
- IPCC, 2001: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan
- Kroeze, C., 1994: *Nitrous oxide. Emission inventory and options for control in the Netherlands*. RIVM report 773001004. Bilthoven, the Netherlands.
- Kuikman, P.J., J.J.H. van den Akker, F. de Vries, 2005*: Lachgasemissie uit organische landbouwbodems.* Alterra report 1035-2, Alterra, Wageningen (in preparation).
- Kuikman, P.J., K.W. van der Hoek, A. Smit, K. Zwart, 2006. Update of emission factors for direct emissions of nitrous oxide from agricultural soils on the basis of measurements in the Netherlands. Alterra report 1217. Alterra, Wageningen.
- LEI, Land- en Tuinbouwcijfers, also available via www.lei.wur.nl, yearly
- Mineralen Boekhouding, 1993: *Kiezen uit gehalten. Forfaitaire gehalten voor de Mineralen Boekhouding*.
- Olivier J.G.J., L.J. Brandes and R.A.B. te Molder, 2009 (in print) Uncertainty in the Netherlands’ greenhouse gas emissions inventory: Estimate of annual and trend uncertainty for Dutch sources of greenhouse gas emissions using the IPCC Tier 1 approach, PBL-Report 500080013, Bilthoven
- PlanBureau voor de Leefomgeving (PBL), Milieucompendium: www.planbureauvoordeleefomgeving.nl, yearly
- Spakman, J., M.M.J. van Loon, R.J.K. van der Auweraert, D.J. Gielen, J.G.J. Olivier, E.A. Zonneveld, 1997: *Methode voor de berekening van broeikasgasemissies.* Publicatiereeks Emissieregistratie 37. Ministry of VROM, The Hague.
- Valk, H., A.M. van Vuuren, A.C. Beynen, 2002: *Effect of grassland fertilizer on urinary and fecal concentrations of nitrogen and phosphorus in grass-fed dairy cows.* In: H. Valk, 2002: *Nitrogen and phosphorus supply of dairy cows*. Dissertatie RU Utrecht.
- Van der Hoek, K.W., 1994: *Berekeningsmethodiek ammoniakemissie in Nederland voor de jaren 1990, 1991 en 1992*. RIVM report 773004003. Bilthoven.

- Van der Hoek, K.W., 2002: *Uitgangspunten voor de mest- en ammoniakberekeningen 1999 tot en met 2001 zoals gebruikt in de Milieubalans 2001 en 2002, inclusief dataset landbouwemissies 1980-2001*. RIVM report 773004013. Bilthoven.
- Van der Hoek, K.W., M.W. van Schijndel and P.J. Kuikman, 2007. Direct and indirect nitrous oxide emissions from agricultural soils, 1990-2003, Background document on the calculation method for the Dutch National Inventory Report; RIVM report 680125003/2007; MNP report 500080003/2007, Bilthoven, the Netherlands.
- Van der Hoek, K.W., and M.W. van Schijndel, 2006. Methane and nitrous oxide emissions from animal manure management, 1990 - 2003. Background document on the calculation method for the Dutch National Inventory Report. RIVM report 680125002, MNP report 500080002. Bilthoven.
- Velthof, G.L., O. Oenema, R. Postma and M.L. van Beusichem, 1997: *Effects of type and amount of applied nitrogen fertilizer on nitrous fluxes from intensively managed grassland.* Nutrient Cycling in Agroecosystems 46, 257-267.
- Velthof, G.L. en P.J. Kuikman, 2000: *Beperking van lachgasemissie uit gewasresten*. Een systeemanalyse. Alterra report 114.3. Alterra, Wageningen.

6.2 Additional information

Appendix 1: Statistics concerning crop residues

Appendix 1: Statistics concerning crop residues

Table 1 Crop residues from arable farming and outdoor horticulture: nitrogen content of above-ground crop residues, per hectare and fraction of the crop residues remaining in the field

		Crop residue	Remaining in the field
		kg N/ha	fraction
Arable crops			
Grains	Winter wheat	28	0.1
	Summer wheat	28	0.1
	Winter barley	19	0.1
	Summer barley	19	0.1
	Rye	16	0.1
	Oats	19	0.1
	Triticale	24	0.1
Peas and beans	Dried peas and green peas	74	1
	Peas (harvested green)	194	1
	Marrowfats	74	1
	Kidney beans	74	1
	Broad and field beans	16	1
Grass seed		28	1
Commercial crops	Rapeseed	42	1
	Caraway seed (actual year)	37	1
	Blue poppy seed	20	1
	Flax	23	1
	Evening Primrose	40	1
Tuber and root crops	Seed potatoes in sand or peat	26	1
	Seed potatoes in clay	26	1
	Consumer potatoes in sand or peat	26	1
	Consumer potatoes in clay	26	1
	Starchy potatoes	26	1
	Sugar beet	174	1
	Fodder beets	92	1
Green fodder crops	Lucerne	23	1
	Cut corn	22	0.1
Green fertilisation crops		80	1
Course corn		70	1
Corn-cob-mix		70	1
Chicory		40	1
Hemp		40	1
Onions		4	1
Other arable crops		40	1
Horticultural (open ground) crops	Strawberries	23	1
	Endive	78	1
	Asparagus	24	1
	Gerkins	78	1
	Preserving cabbage	206	1
	Cauliflower	89	1
	Broccoli	89	1
	Headed cabbage	206	1
	Celery	78	1
	Beetroots	78	1

4D: N_2O from Agricultural soils: direct emissions and grazing emissions (NIR 2010)

	Crop residue	Remaining in the field
	kg N/ha	fraction
Salad	25	1
Leeks	62	1
Black salsify	78	1
Spinace	62	1
Sprouts	206	1
French beans	61	1
Runner beans	61	1
Broad beans green	13	1
Carrots	99	1
Winter carrots	99	1
Chicory root	78	1
Other vegetables	78	1

Sources: nitrogen-retaining above-ground crop residues per hectare: Velthof and Kuikman, 2000; fractions that remain behind in the field: Van der Hoek et al., 2007