SNAP CODES :	**100201** **100202** **100203** **100204** **100205** **100206**
SOURCE ACTIVITY TITLE :	**CULTURES WITHOUT FERTILIZERS** **(Unfertilized Agricultural Land)** ***Permanent Crops*** ***Arable Land Crops*** ***Rice Field*** ***Market Gardening*** ***Grassland*** ***Fallows***
NOSE CODES :	**110.02.01** **110.02.02** **110.02.03** **110.02.04** **110.02.05**
NFR CODES :	**4D1** **4C**

1 ACTIVITIES INCLUDED

This chapter considers the emissions of ammonia (NH_3), nitrous oxide (N_2O), other oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). By definition, cultures without fertilizers are soils cultivated for crop production and grasslands, for cutting and grazing, which are not given N-fertilizer (e.g. legumes and grass/clover swards). This includes some grass in hill-land, which is grazed by livestock, as well as lowland grass that only supports small numbers of animals and does not require fertilizer-N. Emissions from the crops and their decomposing residues are also considered. Persistent Organic Pollutants are dealt with separately under SNAP Code 100600, Use of Pesticides.

Emissions following animal manure application are considered in SNAP Code 100900, Manure Management Regarding Nitrogen Compounds.

This chapter is a development of chapter ag100100 (EEA, 1996) which dealt with cultures both with and without fertilizers. Cultures with Fertilizers are now considered in chapter 100100. Reference may be made to that chapter for further discussion of some of the topics covered here.

This chapter is comprised of the following sub-codes.

100201	Permanent Crops
100202	Arable Land Crops
100203	Rice Field
100204	Market Gardening
100205	Grassland
100206	Fallows

In this chapter 100206 includes ‘Set-Aside’ Land.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

The major source of NH_3 emissions in Europe is volatization from livestock excreta. Ammonia may also be emitted from the application of N-fertilizers and from fertilized crops. Emissions from unfertilized crops are usually considered to be negligible, although there may be some emissions from N-rich legumes.

The greatest proportion of N_2O emitted by agriculture is considered to be by soil processes following the application of N fertilizers and animal manures to land. N_2O emissions may also take place during the breakdown of crop residues and mineralisation of excretal N deposited during grazing and soil organic matter. Emission of N_2O may also occur following the deposition of other N compounds (NH_3 and NO_x) to unfertilized soils.

Soils and crops are regarded as a net sink for most NO_x compounds. However NO may be released from soils during the mineralisation of N from incorporated crop residues and soil organic matter followed by nitrification. Only NO emissions are therefore discussed. At present estimates of the proportion of these emissions that arise from cultures without fertilizers are extremely uncertain.

Table 2.1: % Contribution of total emissions of the CORINAIR94 Inventory (28 Countries) from cultures without fertilizers.

SNAP code	SO_2	NO_X	NMVOC	CH_4	CO	CO_2	N_2O	NH_3
100200	-	0.2	0	1.4	-	-	1.5	0.3

0 emissions are reported, but the exact value is below the rounding limit (0.1 %).
- no emissions are reported

As can be seen from Table 2.1, emissions of NH_3, NO and VOCs from cultures without are all < 1 % of current total emission estimates, though agriculture as a whole or global emissions from soils as a whole may play a dominant role even for species which at present receive little attention (NO: Davidson and Kingerlee, 1997). These do not therefore require a methodology for calculation. However given current uncertainties over the magnitude of emissions from unfertilized crops and grass, some information is given in this chapter. This summarises current understanding and uncertainties.

3 GENERAL

3.1 Description

3.1.1 Ammonia

The direct emissions of NH_3 that have been measured from crops have been attributed to enrichment of the apoplast with NH_4^+ following addition of fertilizer-N (Sutton et al., 1995). There is very little information on ammonia emissions from cultures without fertilizers. Significant emissions are not expected from unfertilized crops (with the exception of legumes).

Crops of agricultural legumes, while not given fertilizer-N, have been estimated to fix amounts of N as great, or greater than applied as fertilizer to agricultural crops (Sylvester-Bradley, 1993, Vitousek *et al.*, 2002). Thus emissions of NH_3 may be expected to be similar to those from fertilized agricultural crops (e.g. 0 - 15 kg $ha^{-1}a^{-1}$, Sutton *et al.*, 1995). Data on NH_3 fluxes over legume crops are sparse. Dabney and Bouldin (1985) measured a small net emission of *c.* 2 kg ha^{-1} a^{-1} NH_3-N from an alfalfa crop. Harper *et al.* (1989) found net depositions of 0.4 - 3.1 kg ha^{-1} a^{-1} from soybeans. Lemon and van Houtte (1980) measured both emission and deposition fluxes over soybeans.

Some recent results (R. Harrison, ADAS Boxworth, pers. comm.) also suggested no net emission over the growing season. However in that study small (1 - 2 kg ha^{-1} N) emissions early in the season were balanced by deposition (2 - 3 kg ha^{-1} N) later in the season. This deposition may have been a consequence of grazing activity in the locality. The possibility remains that agricultural legume crops, in predominantly arable areas, may emit small amounts of NH_3. Ammonia fluxes are also bi-directional over fertilized arable crops. These few data suggest that, at present, only an approximate, indicative emission factor for cultivated legumes can be made.

Measurements of NH_3 fluxes over unfertilized grassland have usually shown net deposition of NH_3 (Sutton *et al.*, 1993). Whitehead and Lockyer (1989) measured emissions only from grass foliage with a high-N content where large amounts of fertilizer-N had been applied.

Ammonia emissions from unfertilized grass, grazed by livestock, have been made by Jarvis *et al.* (1989, 1991) and Ledgard *et al.* (1996). Jarvis *et al.* (1989) found annual NH_3 emissions of 7 kg ha^{-1} N from a grass/clover pasture grazed by beef cattle. This was *c.* 4 % of the estimated N fixation by the clover (160 kg ha^{-1} a^{-1} N), and *c.* 70 % of NH_3 emissions from grazed grassland given 210 kg ha^{-1} a^{-1} N. Jarvis *et al.* (1991) measured NH_3 emissions from pastures grazed by sheep, including an unfertilized clover monoculture. Emissions of NH_3 from the unfertilized grass/clover pasture (2 kg ha^{-1} a^{-1} N) were less than from an unfertilized grass field (4 kg ha^{-1} a^{-1}), whilst emissions from the pure clover pasture (11 kg ha^{-1} a^{-1} N) were greater than from grassland given 420 kg ha^{-1} a^{-1} N. These losses were smaller (by a factor of 3) than from pastures grazed by cattle (Jarvis *et al.*, 1989). Ledgard *et al.* (1996) measured an annual NH_3 emission of 15 kg ha^{-1} from unfertilized grass/clover grazed by dairy cattle. There are considerable uncertainties in generalizing from these limited data.

Differences in emission are likely to be the result of variation in temperature, soil type and livestock type. In addition, if unfertilized grassland is cut and left in the field for an extended period, decomposition may result in some emission.

3.1.2 Nitrous Oxide

The methodology adopted by the IPCC may be used to calculate emissions of N_2O from cultures without fertilizers as the sum of direct soil emissions and indirect emissions. Direct soil emissions from cultures without fertilizer may be the result of biological N fixation, excreta of grazing animals, crop residue incorporation and soil cultivation. Indirect emissions may arise as a consequence of atmospheric deposition of NH_3 and NO_x to unfertilized soils.

In soil N_2O is produced predominantly by nitrification, *i.e.* the oxidation of ammonium (NH_4^+) to nitrate (NO_3^-), and denitrification, *i.e.* the reduction of NO_3^- to gaseous forms of N: N_2O and N_2. In most soils, these processes are active simultaneously with varying proportions (e.g. Stevens *et al.*, 1997). The rate of N_2O production is to a large extent dependent on the availability of mineral N in the soil (Bouwman 1996), but also on soil pH and management practices (Kaiser *et al.*, 1996, Yamulki *et al.*, 1997, Pathak, 2001, Yamulki and Jarvis, 2002). With respect to the amount of nitrogen added to soils, grassland systems emit more N_2O than arable land systems. Soils are likely to act as a weak sink for N_2O if the nitrogen supply is very low (Conrad and Dentener, 1999, Butterbach-Bahl *et al.*, 2002 a). The cultivation of soils, grazing by livestock and incorporation of crop residues are likely to increase soil mineral N concentrations and hence N_2O emission (e.g. Flessa and Beese, 1995). Moreover large emissions of N_2O may take place following the thawing of frozen soils (Kaiser *et al.*, 1997, Teepe *et al.*, 2001, Butterbach-Bahl *et al.*, 2002 b).

Little information is available on the emission of N_2O from legumes: Wagner-Riddle *et al.* (1997) reported emissions of *c.* 6 kg ha^{-1} a^{-1} N_2O from soybeans and alfalfa, Flessa *et al.* (2002) 9 kg ha^{-1} a^{-1} N_2O from legumes as catch crops.

The magnitude of direct N_2O emissions may be expected to vary with a range of soil and environmental factors. More work is needed on partitioning of N_2O production between nitrification and denitrification. Incorporation of N-rich (*e.g.* leguminous) residues into moisture-retentive soils produces greater N_2O emissions than from free-draining soils (Skiba *et al.*, 1992). Incorporation into warm soils is also likely to lead to greater emissions than from soils which are cold. Rapid crop growth, and demand for NO_3-N, may be expected to reduce N_2O emissions by reducing the pool of mineral N available for denitrification.

The emission of nitrous oxide, which is related to the transformation of nitrogen species which originate from agricultural emissions of NH_3 and NO, but are deposited elsewhere, or are emitted from contaminated ground water after pressure reduction, are called indirect emission. Such soil and environmental factors as mentioned above are also likely to influence the magnitude of indirect N_2O emissions following atmospheric deposition of NH_3 and NO_x or their reaction products.

3.1.3 Nitric Oxide

Nitric oxide (NO) may be emitted from unfertilized soils as a consequence of nitrification or denitrification. If soils are maintained at pH > 5.0, NO emission is likely to be mainly from nitrification (Remde and Conrad 1991; Skiba *et al.*, 1997). Increased nitrification is likely to occur following soil cultivation and incorporation of crop residues (Aneja *et al.*, 1997). Activities such as tillage and incorporation were considered to increase NO emissions by a factor of 4 (Skiba *et al.*, 1997, 2002; Civerolo and Dickerson, 1998), for periods of between 1 and 3 weeks.

A major determinant of NO production in agricultural soils is mineral N concentration, which in unfertilized cultures is increased by residue incorporation and cultivation. Soil moisture content, soil temperature and N partitioning into the crop seem to be similarly important (Aneja *et al.*, 1996, Skiba *et al.*, 1997). As a first approximation, 0.7 % of N inputs may be expected to be lost as NO, as per SNAP Code 100100, Cultures with Fertilizers. Thus a knowledge of the available N concentration, and mineralisation rate of crop residues, could provide an estimate of soil NO emissions following cultivation.

However, very little data are available on emissions of NO from unfertilized soils that may be used as a basis for compiling an inventory.

3.1.4 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are defined as all those organic compounds, other than methane, which can produce photochemical oxidants by reaction with nitrogen oxides in the presence of sunlight.

Three categories of sources may be distinguished:

- Activities that emit VOCs by combustion or evaporation;
- Land clearing, including burning;
- Biogenic processes.

The primary sources in the agricultural sector are:

- Burning stubble and other plant wastes;
- The use of organic solvents in pesticide production;
- Anaerobic degradation of livestock feed and animal excreta;
- Emissions from plants.

At present, all these sources are dealt with elsewhere: stubble burning in SNAP Code 100300, emissions from burning other crop residues in SNAP Code 090700 (Open Burning of Agricultural Wastes). Emissions from livestock manures are included in SNAP Code 100500, Manure Management Regarding Carbon Compounds.

The emission of some VOCs may be of benefit to plants to attract pollinating insects. While others may be involved in interactions, be waste products or a means of losing surplus energy (Hewitt and Street, 1992). These emissions have been observed to increase when plants are under stress. Factors that can influence the emission of VOCs include temperature and light intensity, plant growth stage, water stress, air pollution and senescence (Hewitt and Street, 1992). Emissions of VOCs from plants have usually been associated with woodlands (König *et al.*, 1996). Hewitt and Street (1992) took qualitative measurements of the major grass and crop species in the UK (except for barley, *Hordeum vulgare*). None of the grass species were found to emit isoprene or terpenes. The only crop species producing any significant emissions was blackcurrant (*Ribes nigrum*). However, these workers warned against classifying plants as 'non-emitters' on the basis of limited measurements, as plant growth stage had been shown to be an important factor in emission.

Hewitt and Street (1992) concluded that only c. 700 plant species, mainly from North America, had been investigated as isoprene or monoterpene emitters. Few of these were agricultural crops, and quantitative data was available for only a few species. Many measurements had been made at temperatures higher than those prevailing in North and West Europe.

For direct emissions from agricultural plants see 100100, Cultures with Fertilizers.

3.2 Definitions

Animal Manures. Animal excreta deposited in houses and on yards, collected, either with bedding or without, to be applied to land.

Livestock excreta. Animal excreta deposited at any time, including while grazing.

Unfertilized agricultural grassland. Grassland, to be used for either cutting grass for conservation, grazing or both, to which synthetic N-fertilizers have **not** been applied. Phosphorus or potassium fertilizers may be used.

Crop residues. The unharvested parts of crops that are left on the field and ultimately incorporated into the soil.

Hill land. Grassland in the hills or uplands that is used for grazing agricultural livestock.

3.3 Controls

3.3.1 Ammonia

No measures have so far been proposed to reduce NH_3 emissions from cultures without fertilizers. There are some possible suggestions. The area of legumes could be reduced. However, the consequence may be an increase in the area of crops requiring fertilizer-N. Ammonia emissions from these may not be less than from legumes. Pure clover pastures may be replaced by mixed grass/clover. This is unlikely to be of much practical significance, as pure clover pastures are uncommon.

3.3.2 Nitrous Oxide

Nitrous oxide emissions may arise following the incorporation of N-rich crop residues into warm moist soil. A control technique may, therefore, be to avoid incorporating residues in late summer/early autumn and delaying incorporation until late autumn where succeeding crops are to be sown before the onset of winter. This will also have the advantage of reducing the potential for NO_3^- leaching. However leaving N-rich crop residues (e.g. from legumes) on the soil surface will probably give rise to NH_3 emissions as they senesce.

3.3.3 Nitric Oxide

In view of the limited information on the loss of NO from unfertilized soils, no specific control measures are proposed at this stage. However, any measure that reduces mineral N production and input to the soil, as discussed in section 3.3.2, will also reduce loss of NO.

3.3.4 Volatile Organic Compounds

To reduce emissions of VOCs, crop residues should be removed from the field (to be used for animal feed and bedding) rather than be disposed of by burning.

4 SIMPLER METHODOLOGY

4.1 Ammonia

4.4.1 Legumes

Since legumes are the only arable crops regarded as sources of NH_3 in cultures without fertilizers, a simple estimate of NH_3 emissions may be made by multiplying the known area of legumes with an estimated emission factor of 1 kg ha^{-1} a^{-1} NH_3-N.

4.4.2 Animal grazing

If the amount of nitrogen excreted cannot be obtained from SNAP 100900, Manure Management Regarding Nitrogen Compounds, the following emission factors (kg ha^{-1} a^{-1} NH_3-N) are proposed for all unfertilized pastures grazed by cattle, and for lowland pastures grazed by sheep :

Grass/clover:	cattle 7, sheep 2;
Unfertilized grass:	cattle 4, sheep 4.

These emission factors are taken from studies of grazing emissions by Jarvis *et al.* (1989, 1991). Greater emission factors from unfertilized grass than from grass/clover swards, may appear contrary to expectations. Jarvis *et al.* (1991) were unable to fully explain this observation, but suggested the different crop canopy structure of grass/clover pastures might reduce NH_3 losses. The use of the above factors also gives greater apparent NH_3 emissions than are estimated by additions of fertilizer-N of up to c. 200 kg ha^{-1} N in Chapter 100100, Cultures with fertilizers. These anomalies emphasise the lack of data available on NH_3 emissions from unfertilized, grazed grass, and hence the uncertainty of this component of the Emission Inventory.

If nitrogen excretion by grazing animals can be assessed by SNAP 100900, the methodology given in SNAP 100100 should be applied to achieve emissions from grazing:

To estimate NH_3 emissions from grazed grassland, Pain *et al.* (1997) proposed a function of the form

$$E_{NH3} = c + d\,N \quad \textbf{(1)}$$

which subsequently was applied to a variety of experimental data sets in Misselbrook *et al.* (2001)

with		
	E_{NH3}	NH_3 emitted (kg a^{-1} NH_3)
	c	-0.51 kg a^{-1} NH_3
	d	0.0742 kg (kg N)$^{-1}$ NH_3
	N	N excreted (kg a^{-1} N)

to estimate NH_3 emissions from grassland grazed by cattle. Thus, a mean emission factor of 7.5 % of the N excreted is recommended.

For further details see SNAP 100100, paragraph 4.1.2.

Hill-land grass grazed by sheep, is not regarded as a net source of NH_3 emission over the year (*e.g.* Sutton *et al.*, 1993).

Care is to be taken that double counting of emissions from grazed grassland in SNAPs 100100 and 100200 is avoided.

4.2 Nitrous Oxide

Following the IPCC methodology (IPCC/OECD, 1997), N_2O emissions from unfertilized agricultural soils may be calculated as the sum of:

i. direct soil emissions (1.25 % of N inputs are emitted as N_2O-N); (where N inputs are from biological N fixation and crop residues). See IPCC Worksheet 4-5, sheet 1;

ii. direct N_2O emissions from cultivation of histosols (IPCC Worksheet 4-5, sheet 2);

iii. direct soil emissions (2 % of N inputs) from grazing animals (IPCC Worksheet 4-5, sheet 3);

iv. indirect emissions following deposition of NH_3 and NO_x (1% of N is subsequently re-emitted as N_2O), or leaching and run-off (2.5% of N leached or run-off, IPCC Worksheet 4-5, sheets 4 and 5).

The respective input data can be estimated from FAO data (see IPCC/OECD 1997) (Table 4.1) (http://apps.fao.org/default.htm)

The default emission factors for the above are given in Table 4.2. More detail may be obtained from IPCC Worksheet 4-5, sheets 1-5.

Total N_2O emission are subdivided in direct and indirect emissons:

$$E_{\mathrm{N2O\text{-}N}} = E_{\mathrm{N2O,\,direct}} + E_{\mathrm{N2O,\,indirect}}$$

4.2.1 Direct emissions

Within SNAP 100200, direct emissions comprise the emissions from grazing animals and from crop residues:

$$E_{\mathrm{N2O\text{-}N,\,direct}} = EF_{\mathrm{crop}} \cdot m_{\mathrm{crop}} + EF_{\mathrm{graz}} \cdot m_{\mathrm{graz}} \qquad \mathbf{(2)}$$

where	$E_{\mathrm{N2O\text{-}N,\,direct}}$	emission flux of N_2O directly emitted from soils ($\mathrm{Mg\ a^{-1}\ N_2O}$)
	EF_{crop}	emission factor for emissions from crop residues ($EF_{\mathrm{crop}} = 0.0125\ \mathrm{kg\ kg^{-1}\ N}$)
	m_{crop}	amount of N in crop residues ($\mathrm{Mg\ a^{-1}\ N}$)
	EF_{graz}	emission factor for emissions from grazing ($EF_{\mathrm{graz}} = 0.02\ \mathrm{kg\ kg^{-1}\ N}$)
	m_{graz}	amount of N in excreta dropped during grazing ($\mathrm{Mg\ a^{-1}\ N}$)

The IPCC default value is likely to underestimate N_2O emissions (e.g. Flessa *et al.*, 2002)

The amount of N left with residues will have to be calculated for each crop as the product of area covered by the crop, the total dry matter left unharvested for later incorporation, and the N content according to

$$m_{\mathrm{crop}} = \sum A_{\mathrm{i}} \cdot m_{\mathrm{i}} \cdot N_{\mathrm{i}} \qquad \mathbf{(3)}$$

where	A_{i}	area covered by crop i (ha)
	m_{i}	dry matter of crop i ($\mathrm{Gg\ a^{-1}}$)
	N_{i}	concentration of N in dry matter of crop i ($\mathrm{kg\ kg^{-1}\ N}$)

Emissions from grazing should be calculated under SNAP 100900, Manure Management Regarding Nitrogen Compounds. If SNAP 100900 cannot be used, default excretion factors are to be used. Prior to estimation of direct N_2O emissions, excretal N returns are reduced by 20 % to allow for N lost as NH_3. However those values are likely to be an overestimate for unfertilized grass as they are averages across a range of production systems and both fertilized and unfertilized grassland.

The amount of N dropped during grazing of an animal category j is a function of the amount of N excreted and the duration of the grazing period; it also depends on animal behaviour:

$$m_{\mathrm{graz}} = \sum \left(n_{\mathrm{j}} \cdot m_{\mathrm{excr,\,j}} \cdot t_{\mathrm{graz,\,j}} \cdot f_{\mathrm{beh,\,j}} \right) \qquad \mathbf{(4)}$$

where	m_{graz}	amount of N dropped during grazing (kg animal^{-1} a^{-1} N)
	n_{j}	number of animals in category j (animals)
	m_{excr}	mean rate of N excreted (kg animal^{-1} a^{-1} N)
	t_{graz}	share of grazing period (d d^{-1})
	f_{beh}	factor reflecting animal behaviour which leads to an uneven distribution of droppings between animal house and pasture/paddock (dimensionless)

4.2.2 Indirect emissions

Indirect emissions comprise emissions resulting from atmospheric deposition of reactive nitrogen species and from leached and/or run-off nitrogen:

$$E_{\mathrm{N2O\text{-}N,\ indirect}} = EF_{\mathrm{dep}} \cdot m_{\mathrm{dep}} + EF_{\mathrm{leach}} \cdot m_{\mathrm{leach}} \qquad \textbf{(5)}$$

where	$E_{\mathrm{N2O\text{-}N,\ indirect}}$	emission flux of N_2O indirectly emitted from soils (Mg a^{-1} N_2O)
	EF_{dep}	emission factor for emissions reulting from atmospheric deposition (EF_{dep} = 0.01 kg kg^{-1} N)
	m_{dep}	amount of N deposited (Mg a^{-1} N)
	EF_{leach}	emission factor for emissions from leaching or run-off (EF_{leach} = 0.025 kg kg^{-1} N)
	m_{leach}	amount of N in leachate or run off (Mg a^{-1} N)

Countries may use their own estimates for any step in the IPCC method if this will increase precision. In particular countries are encouraged to estimate N_2O losses as a result of NH_3 and NO deposition using the methods described in this section (chapters 100100, this chapter, and 100900), rather than the IPCC default values for reactive nitrogen species emitted from arable or animal agriculture.

It is assumed that the amount of nitrogen deposited equals the amount of reactive nitrogen released. Irrespective of the location of emissions, depositions are calculated as the sum of the NH_3-N and NO-N (E_{NH3}, E_{NO}) released in agriculture.

$$m_{\mathrm{dep}} = \sum (E_{\mathrm{NH3\text{-}N,i}} + E_{\mathrm{NO-N,\,i}}) \qquad \textbf{(6)}$$

For indirect emissions from deposition, observed emission factors sometimes fit the default value (Oura *et al.*, 2001), in many cases this factor leads to an underestimation of N_2O emissions (e.g. Butterbach-Bahl *et al.*, 2002 a, b) and may range from 0.2 to 15 % of the atmospheric N deposited (Skiba *et al.*, 1999).

The amount of nitrogen lost from agricultural fields due to leaching or run-off is estimated to be c. 30 % of the total nitrogen input into soils, *i.e.*:

$$m_{leach} = f_{leach} \cdot (m_{fert} + m_{man} + m_{graz}) \qquad \textbf{(6)}$$

where

m_{leach}	amount of nitrogen leached (Mg a^{-1} N)
f_{leach}	fraction of N in leachate or run off (kg kg^{-1} N)
m_{fert}	N input into soil with mineral fertilizers (Mg a^{-1} N)
m_{man}	N input into soil with manure applied (Mg a^{-1} N)
m_{graz}	N input into soil during grazing (Mg a^{-1} N)

Table 4.1: Summary of IPCC source categories (IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Workbook, 1997) to be reported as CORINAIR sub-sectors for agriculture.

CORINAIR SUB-SECTOR (SNAP code)	**IPCC N_2O SOURCE (IPCC WORKBOOK WORKSHEET**
Cultures with/without Fertilizers (100100, 100200)	- Direct soil emission due to N-inputs including manure (4-5, sheet 1) - Direct soil emissions due to histosol cultivation (4-5, sheet 2) - Direct soil emissions from grazing animals; pasture, range & paddock (4-5, sheet 3) - Indirect emissions due NH_3 and NO_x emissions/deposition from synthetic fertilizer use and grazing animals (4-5, sheet 4, excluding animal waste used as fertilizer) - Indirect emissions due N leaching/runoff from synthetic fertilizer use and grazing animals (4-5, sheet 5, excluding animal waste used as fertilizer)

The default values used by IPCC (IPCC/OECD 1997) for the above are given in Table 4.2.

Table 4.2: Default emission factors for N_2O emissions from cultures without fertilizer

SOURCE OF N_2O	**EMISSION FACTOR**
<u>Direct soil emissions</u>	
N inputs (crop residues and biological N fixation).	0.0125 kg N_2O-N per kg N input
†Excretal N deposited during grazing.	0.02 kg N_2O-N per kg 'net' N $input^{-1}$
Cultivation of histosols.	5 kg ha^{-1} N_2O-N
<u>Indirect emissions</u>	
Emission of NH_3 and NO_x	0.010 kg N_2O-N per kg NH_3-N and NO_x-N deposited
N leaching and runoff.	0.025 kg N_2O-N per kg N leached or lost by runoff.

† Manure N inputs, other than from animals during grazing. are dealt with in SNAP Code 100900, Manure Management Regarding Nitrogen Compounds.

4.3 Nitric Oxide

An estimate of the amount of crop residues, together with their N concentrations, returned to unfertilized soils, together with an estimate of excretal N deposited during grazing would provide estimate of NO emissions.

Indirect emissions of NO are in the same order of magnitude as N_2O emissions (*e.g.* Butterbach-Bahl *et al.*, 2002 a, Jensen *et al.*, 2002, Yamulki and Jarvis, 2002) or may exceed them (Butterbach-Bahl *et al.*, 1997). Therefore, it seems justified to treat them in the same way as other NO emissions from soils and assuming 0.7 % of the N returned to the soil is emitted as NO.

5 DETAILED METHODOLOGY

5.1 Ammonia

To provide a more detailed methodology it would be necessary to distinguish between different legume species.

Where data are available on the areas of legumes under cultivation and the extent of typical N fixation by each crop type, national NH_3 emission from this source may be approximately estimated as:

$$E_{\mathrm{NH3}} = \sum \left(A_{\mathrm{leg,i}} \cdot NF_{\mathrm{i}} \cdot EF_{\mathrm{NH3}} \right) \qquad \textbf{(7)}$$

where		
	E_{NH3}	NH3 emitted (kg a^{-1})
	$A_{\mathrm{leg,\,i}}$	area covered by legume i (ha)
	NF_{i}	nitrogen fixation (kg ha^{-1} N)
	EF_{NH3}	emission factor (0.01 kg kg^{-1} N)

Where information on average N fixation rates for different legume species is unavailable for a country, 100 kg N ha^{-1} a^{-1} may be used as a first estimate.

Further detail may be provided if estimates are available of NH_3 emissions from crops (*e.g.* hay), or unfertilized crop residues left on the surface. The effects of different climates on NH_3 emissions both from unfertilized crops, and from their residues, needs to be known. However emissions from unfertilized cultures are likely to be small in relation to emissions from livestock husbandry.

5.2 Nitrous Oxide

More detailed methodologies for calculating N_2O emissions need to include soil moisture and soil temperature in addition to N input. Multiple linear regression models and process based models (DNDC) have been developed and are outlined in ag 100100, section 5.2 (Butterbach-Bahl *et al.*, 2001, Skiba *et al.*, 2001). Improving the estimate of N deposition will also lead to significant improvements in the N_2O flux estimate. In particular, countries are encouraged to estimate NH_3 losses using the methods described in this Guidebook, rather than the IPCC default values.

5.3 Nitric Oxide

Consideration of the data available suggest that NO emissions may vary substantially according to the prevailing soil moisture regime and soil temperature. Simple models including the control by temperature (Williams *et al.*, 1992) or soil moisture (Skiba *et al.*, 2001) in addition to N input are outlined in chapter 100100, Section 5.3, of this Guidebook.

However, as there is so little information on soil NO emissions from cultures without fertilizers, it is not appropriate to provide a detailed methodology. Improving the estimate of N deposition rates, and using the detailed methods to calculate N inputs from animal manures (chapter 100900 of this Guidebook) is likely to improve the quality of the emission calculations.

6 RELEVANT ACTIVITY STATISTICS

Information is required on the areas of legumes cultivated and by crop type for the more detailed approach, as well as the area of unfertilized grassland grazed by livestock, and an estimate of N deposited in excreta during grazing.

Information may also be required on the amounts and N concentrations of crop residues returned to the soil. This information may be obtained from national statistics on crop production. The area of organic soils (histosols) under cultivation is also useful. Finally, information is needed on deposition of NH_3 and NO_x to soils.

Where spatially disaggregated inventories of unfertilized culture emissions are required (section 12), information on the spatial distribution of different legume and other unfertilized crops are required. The distribution of cultivated, but unfertilized organic soils (histosols) will also be needed).

Table 6.1: Summary of activity statistics which may be required for the simple and detailed methodologies.

Activity Statistic		Source
Amount and N concentration of crop residues	By crop type	FAO, See IPCC/OECD (1997)
Amount and N concentration of animal excreta deposited during grazing	By livestock type	SNAP Code 100900, Manure Management Regarding N Compounds
Area of cultivated histosols		FAO, see IPCC/OECD (1997)
Atmospheric emissions of NH_3 and NO_x		ETCAE (1997), SNAP Codes 100100 and 100900
N lost from soils by leaching and runoff		FAO, See IPCC/OECD, (1997)

7 POINT SOURCE CRITERIA

NH_3, N_2O, NO and VOC emissions from cultures without fertilizers should be treated as area sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

The emission factors for NH_3 losses from cultures without fertilizers are treated as kg ha^{-1} N of leguminous crops and grazed, unfertilized grassland. However, emissions from animal grazing are calculated as kg NH_3. For N_2O, losses are kg N_2O-N per kg N returned to the soil in crop residues and excreta deposited during grazing, or N deposited from the atmosphere, or lost by leaching or runoff. Losses of N_2O from cultivated organic soils (histosols) are expressed as kg ha^{-1}N.

Table 8.1: Spreadsheet for calculating nitrous oxide emissions from cultures without fertilizers according to the simpler methodology.

	A	B	
	Emission factor kg kg^{-1} N_2O-N	N input kg a^{-1} N	N_2O emission, kg a^{-1} N_2O (A * B * 44/28)
Crop residues			
N with crop residues	0.0125		
Excretal-N deposited during grazing	0.020		
Indirect emissions			
Emission of NH_3 Emission of NO_x N lost by leaching or runoff	0.010 0.010 0.025		
	Emission factor kg ha^{-1}	area ha	
Cultivation of histosols	5		

9 SPECIES PROFILES

As with forest NMVOC emissions, biogenic emissions from grasslands consist of a wide variety of species, including isoprene, monoterpenes (alpha-pinene, beta-pinene, limonene, etc), and ‘other’ VOC. The ‘other’ VOC (OVOC) species consist of a large number of oxygenated compounds (alcohols, aldehydes, etc.), and have proven difficult to quantify in atmospheric samples. Progress in quantification of OVOC from European vegetation has been made (König *et al.*, 1996), although many more measurement data will be required before reliable attempts to inventory specific OVOC can be made.

10 UNCERTAINTY ESTIMATES

10.1 Ammonia

The main uncertainty lies in the magnitude of emission factors for unfertilized grassland and leguminous crops, rather than the areas of unfertilized crops under cultivation, which is probably accurate in most countries to better than ± 10 %. The overall uncertainty is at least a factor of 5.

10.2 Nitrous Oxide

The processes controlling the emission of N_2O from soils are reasonably well understood but their interactions and hence estimates of emission have not yet been accurately modelled.

The magnitude of crop residues and their N contents are only likely to be accurate to within ± 25 %. Wet deposition of N may be estimated to ± 20 % , but dry deposition of NH_3 to no more than ± 50% (UKRGIAN 1994). As for NH_3 the main uncertainty lies on the generalisation of emission factors, which are perhaps greater than a factor of 5.

10.3 Nitric Oxide

Much less information is available on factors determining losses of NO from soils (available N, temperature and soil moisture are likely to be the main factors). In view of the paucity of data, the overall uncertainty is likely to be greater than a factor of 5.

10.4 Volatile Organic Compounds

Estimates of biogenic VOC emissions for the UK range from 38 - 211 Gg a^{-1} total VOCs. Between *c.* 10 and 59 Gg a^{-1} appear to be of agricultural origin. This compares with the CORINAIR94 estimate of only 2 Gg a^{-1} for SNAP Code 100100 or <2 % of emission from agriculture and forestry. Thus the emission estimates appear to be uncertain by a factor of 30.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

11.1 Ammonia

Little data is available on NH_3 emissions from leguminous crops, and it does not allow to differentiate between species. Measurements of emissions from crop residues after harvest is also lacking. The majority of data on NH_3 emissions from grazed grassland have been made on North West Europe. Emissions may be greater in drier and warmer areas, *e.g.* Southern Europe. While more work on the development of mechanistic models, which take into account both physicochemical and biological processes is desirable, the primary interest is in understanding atmospheric budgets rather than in the definition of net emissions. It should also be recognised that there is a very large uncertainty in NH_3 emissions in relation to climate and more work is necessary, in particular in Southern and Eastern European conditions.

11.2 Nitrous Oxide

Current estimates of N_2O emissions are also limited by the use of fixed emission factors. More work needs to be done in the development of process-based models that will allow greater discrimination to be made between soils with different moisture regimes, and between areas of different climate. The localised very high inputs of N and C, from animal excreta, are likely to stimulate N_2O emissions.

Estimates of indirect emissions of N_2O are dependent on accurate estimates of N deposition and N leaching and runoff as long as the uncertainties in these estimates are large, then so too will be estimates of indirect N_2O emissions.

11.3 Nitric Oxide

Very little information is available on NO emissions from any of the aspects discussed in this section. More work on NO emissions from unfertilized grassland, land cultivated with legumes and as a result of crop incorporation is particularly desirable. Localised, very high inputs of N and C from animal excreta, are likely to stimulate NO emissions.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

12.1 Ammonia

Census data on the location of unfertilized crops and grassland, and particularly the distribution of legume crops may be used.

12.2 Nitrous Oxide

Direct emissions may be spatially disaggregated using census data on the distribution of different unfertilized crops and grassland, together with estimates of the N returned in their residues. Data on the distribution of cultivated, unfertilized organic soils (histosols) may also be included to improve spatial disaggregation. Indirect emissions may also be spatially disaggregated if spatial data is available for N deposition and also for N leaching and run off.

12.3 Nitric Oxide

Emissions may be spatially disaggregated using census data on the distribution of different unfertilized crops and grassland, together with estimates of N returned in their residues.

12.4 Volatile Organic Compounds

In the absence of specific data for VOC emissions from different agricultural crops, there appears to be little scope at present for spatially disaggregating VOC emissions.

13 TEMPORAL DISAGGREGATION CRITERIA

13.1 Ammonia

Almost no information is available to generalise on temporal disaggregation of NH_3 from unfertilized crops. Crop emissions are likely to be greatest during crop senescence and from residues left on the soil surface. Dabney and Bouldin (1985) observed a marked seasonal variation in NH_3 fluxes. Emissions were approximately in balance for most of the year, but emissions were greater in the 10 days after the crop was cut for hay. Harper *et al.* (1989) noted that absorption of NH_3 took place while the soybean crop was well-supplied with water, while emission of NH_3 tool place during drought. Such losses are likely to vary greatly from year to year depending upon environmental conditions. Emissions of NH_3 from grazed grassland will largely take place while animals are grazing, although some emission is likely for a period after the animals have left the field.

13.2 Nitrous Oxide

Some data may also be available on the timing of incorporating crop residues. However, until process-based models have been developed and validated it will not be possible to take account of fluxes of N_2O emission that take place when soil mineral N concentrations, soil water regimes and soil temperature combine to produce favourable conditions for denitrification and N_2O emission by nitrification.

Data will be available, for some countries at least, on the temporal variation in N deposition and N leaching and run off.

As for NH_3, losses may vary greatly from year to year, depending upon weather conditions.

13.3 Nitric Oxide

Losses of NO take place mainly as a consequence of nitrification. Peaks in NO emission are, therefore, likely in the first 1 to 3 weeks following incorporation of crop residues and tillage of soils. Data on all these should be available, for some countries at least. At present, however, there is insufficient data on NO emissions to quantify these effects. Ultimately, as the mechanisms of NO production become better understood, climatic data may also be utilised to assess when soil and weather conditions are favourable for nitrification and hence NO production. In common with NH_3 and N_2O, emissions may vary greatly from year to year, depending upon weather conditions.

13.4 Volatile Organic Compounds

Emissions of VOCs are likely to differ according to crop growth stage and weather conditions. Some temporal disaggregation may be possible, if seasonal variations in emissions by non-agricultural plants can be assumed to be valid for unfertilized crops.

14 ADDITIONAL COMMENTS

Where more detailed methodologies than those described here are used by countries, a detailed description should be given of the methodology used, and comparison made to the results of the methodology described here.

15 SUPPLEMENTARY DOCUMENTS

The main supplementary documentation required for applying the estimates in this chapter are details of spatially disaggregated legume crop and unfertilized grass distributions.

16 VERIFICATION PROCEDURES

There are no direct methods to evaluate total inventory estimates of NH_3 emissions from unfertilized croplands, and verification is dependent on laboratory and micrometeorological field studies of emissions from example situations. In particular, many studies have focused on laboratory measurements and there is a need to provide long-term field measurements using micrometeorological techniques to estimates fluxes over a range of crop types in different climates.

Emissions of N_2O, NO and VOCs cannot be verified except by field studies of emissions from example situations. There is a need to long-term field measurements to estimate fluxes over a range of crop types and climates.

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