# Calculation of gaseous emissions from Finnish agriculture – description of the revised model 2016-2017

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Juha Grönroos, Joonas Munther, Sari Luostarinen

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# 1 Introduction

## 1.1 Ammonia and other gaseous N emissions in general: sources, impacts, controlling

Most agricultural gaseous nitrogen emissions are related to manure management and fertilisation (Figure 1). Ammonia ($NH_3$), nitrous oxide ($N_2O$), nitric oxide (NO) and di-nitrogen ($N_2$) are lost during agricultural practices. As most of them have adverse environmental effects, they are inventoried (EMEP/EEA 2016, IPCC 2006) and regulated under the UN Convention on Long-range Transboundary Air Pollution (UNECE 1999), the EU National Emission Ceilings Directive (2001/81/EC) and the UN framework on climate change (UNFCC).

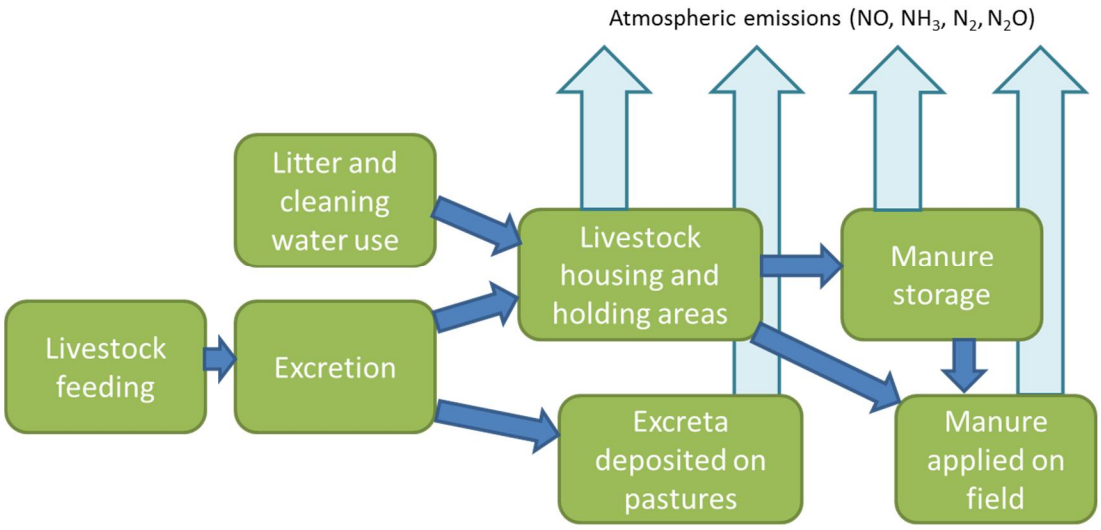


Figure 1. Gaseous nitrogen emissions in manure management of livestock production.

<u>Ammonia</u>
Ammonia ($NH_3$) is a colourless gas known for its foul odour. It forms equilibrium between its ionised form ammonium nitrogen ($NH_4^+$) in solutions depending on temperature and pH. The higher they are, the higher proportion of ammonium nitrogen is converted to ammonia and susceptible to volatilisation into the atmosphere. Volatilisation depends on the solution temperature, surface area exposed and the resistance of ammonia transport into the atmosphere.

Ammonia causes harmful environmental impacts via acidification and eutrophication. It is also a precursor in secondary particle formation (PM2.5 and PM10) causing adverse health effects on humans and an indirect source of greenhouse gas emissions (see below: nitrous oxide).

Ammonia is formed during biological degradation of organic nitrogen compounds e.g. in animal metabolism, soils, manure management and waste treatment and disposal. Approximately 90% of ammonia emissions are released in agriculture, the main source being the nitrogen excreted by livestock into manure. Thus, actions to control ammonia emissions are mainly directed to reducing nitrogen in animal feeding and minimising emissions during manure management (housing, grazing, outdoor yards, storage) and utilisation (fertiliser use). In principle, manure should be collected quickly into covered storages and spread on fields with low-emission application methods.

<u>Nitrous oxide</u>
Nitrous oxide ($N_2O$) is a potent greenhouse gas, being over 300 times stronger than carbon dioxide per mass unit. Its major source is natural and agricultural soil, more precisely denitrification of nitrate during the biological activity of soil microbiota. The main anthropogenic source of nitrous oxide emissions is thus via nitrogen fertilisation, spread either as mineral fertilisers or manure and other organic fertilisers.

Nitrous oxide emissions can best be minimised with precise nitrogen fertilisation. This means using the right dose, depending on the crop produced and the soil characteristics, preferably during vegetative season and with low-emission application methods.

Nitric oxide and di-nitrogen

Nitric oxide (NO) is involved in stratospheric ozone formation with adverse effects on human health and plant growth. Nitric oxide is released during manure management, but the share of agricultural NO emissions in total emissions is modest, approximately 7% (EMEP/EEA 2016a). Specifically nitric oxide is released in nitrification occurring in the surface layer of stored manure and after land application in soils.

Di-nitrogen ($N_2$) is the main result of denitrification in which nitrate is converted into gaseous nitrogen. The atmosphere is largely comprised of di-nitrogen gas (78%), and di-nitrogen formation is not an emission as such. Because emissions of $N_2$ affect the nitrogen content of livestock manure, and consequently the emissions of the other gaseous nitrogen compounds, it is included in the emission calculation system.

## 1.2 Agricultural gaseous nitrogen emission inventory in Finland

Inventories for agricultural gaseous emissions are made to control and report them as part of the emission ceilings set in the UN Convention on Long-range Transboundary Air Pollution (LRTAP, UNECE 1999), EU National Emission Ceilings Directive (2001/81/EC) and the UN framework on climate change (UNFCC). Air pollutant inventory is made according to the EMEP/EEA (2016) joint guidelines, and agricultural GHG-emission inventory according to the IPCC (2006) guidelines. They both provide three-tiered instructions for emission calculations. The guidelines aim to provide procedures to compile emission inventories meeting the quality criteria for Transparency, Consistency, Completeness, Comparability and Accuracy (TCCCA criteria) and estimation methods and emission factors for inventory compilers at various levels of sophistication (tiers 1-3). The tier 1 approach is the simplest method relying on default emission factors and statistics. The tier 2 approach uses country-specific data and emission factors, and thus requires more background data. The tier 3 approach refines the calculations with more detailed descriptions and data and using e.g. sophisticated models. The guidelines are periodically updated and thus the national calculations / models also require updating. The aim and good practice is to use the best available data which then defines which tier to use.

Since 1998, ammonia emissions originating from manure have been calculated by using the national nitrogen model, which is based on the nitrogen flow approach. In this approach, flow of total ammoniacal nitrogen (TAN) and total nitrogen (tot-N) are followed through the manure management system so that the more $NH_3$ and other nitrogen compounds are emitted at the previous stage of the manure management system the less TAN and tot-N remain available for emissions later. The model includes also ammonia emission calculation for mineral N-fertilisers. The documentation of the previous calculation systems were published by Grönroos et al. in 1998 (in Finnish) and in 2009 (in English).

Originally, the model was used only for ammonia emission modelling, but it was supplemented later with $N_2O$ and NO and $N_2$ emission calculation.

## 1.3 Aim of the study

The main aim of the study was to update and expand the model used for calculating the agricultural nitrogen emissions to the atmosphere to meet the most recent requirements of the emission inventory guidelines of UNECE (EMEP/EEA 2016) and UNFCCC (IPCC 2006). The most important task was to change the nitrogen flow approach used to entirely total ammoniacal nitrogen (TAN) based approach. In the previous model version, the approach was mainly based on the total nitrogen.

Nitrogen from bedding materials was also included into the calculation. In addition to the ammonia ($NH_3$) and direct and indirect nitrous oxide ($N_2O$) emissions (originating from manure management and managed soils), emissions of nitric oxide (NO) and di-nitrogen ($N_2$) from manure management are calculated, as well as NO emissions from application of manure and mineral fertilisers.

NMVOC emission calculation for manure management, manure applied to soils, urine and dung deposited by grazing animals and cultivated crops was also added to the calculation system (see Table 1 and chapter 2.2). Further, the changes enabled the establishment of the Finnish normative manure system (see Luostarinen et al. 2017) which was built simultaneously with the revision of this model.

Table 1. Emissions included in the agricultural emission calculation system by emission source category (NFR).

| NFR code | Category name | $NH_3$ | NOx | $N_2O$ direct | $N_2O$ indirect | $N_2$ | NMVOC |
|---|---|---|---|---|---|---|---|
| 3B | Manure management (animal categories: see chapter 2.1.1.1) | x | x | x | x | x | x |
| 3Da1 | Inorganic N-fertilizers (includes also urea application) | x | x | x | x | | x |
| 3Da2a | Animal manure applied to soils | x | | x | x | | x |
| 3Da3 | Urine and dung deposited by grazing animals | x | | x | x | | x |
| 3De | Cultivated crops | | | | | | x |

# 2 Materials and methods

## 2.1 Calculation of nitrogen emissions

### *2.1.1 Emissions from manure management*

#### *2.1.1.1 General system description*

This chapter covers calculation of gaseous nitrogen emission as ammonia ($NH_3$), nitrous oxide ($N_2O$), nitric oxide (NO) and di-nitrogen ($N_2$).

Calculation of the gaseous nitrogen emissions from manure management is based on the mass or nitrogen flow approach, as described in the previous Finnish ammonia and nitrous oxide emission calculation documentations (Grönroos et al. 1998; Grönroos et al. 2009), and in the UNECE and UNFCCC emission inventory guidebooks. In the method used, the pathways of nitrogen are followed starting from the nitrogen excretion of the livestock and ending at the application of manure to the fields (Fig. 1). In each manure management stage, the gaseous losses of nitrogen are calculated. The calculation is made per each animal category (Table 1a and 1b) and for each manure management system.

In general, the agricultural ammonia emission calculation system for Finland follows the principles of Tier 2 method described in the emission inventory guidebook (EMEP/EEA 2016). However, it has some features which move it towards the Tier 3 method. These are the greater number of animal and manure categories than listed under Tier 2, and inclusion of the emission abatement measures.

The manure management systems considered are (manure type acronym in brackets):

- slurry (S)
- deep litter (DL)
- solid manure system (SMS), divided into two separate systems:
    - farm yard manure system (FYM; urine absorbed in bedding material)
    - solid separation system (SS; urine and faeces managed separately, produces two kind of manure: dung with bedding (SSD), and urine (SSU)).

As opposed to the previous calculation systems, nitrogen flow approach is applied to total ammoniacal nitrogen (TAN) of manure in each stage of the manure management system instead of total nitrogen. This means that also the emissions of gaseous nitrogen compounds (except nitrous oxide emissions) are estimated based on the TAN content of manure. Because the effects of dietary changes or nitrogen transformation during the manure management chain affect the TAN content of manure and TAN is the basis of ammonia and other forms of gaseous N emissions, more precise emission estimates are now attained.

Due to the needs of nitrous oxide emission calculation, total nitrogen content of manure was also included in the nitrogen flow approach, as well as nitrogen from bedding materials. Moreover, the revised system considers also the transformation of manure nitrogen during manure storage: immobilisation of solid manure TAN to organic form and mineralisation of slurry organic nitrogen to TAN.

The main manure management phases considered in the calculation system are:

- animal housing,
- manure storing,

- manure spreading (included in the managed soils category in GHG emission inventory),
- outdoor yards.

Moreover, emissions from grazing are estimated. In the GHG emission inventory, emissions from grazing are included in the category of managed soils.

Emission calculation model is one part of the Finnish normative manure system (Luostarinen et al. 2017). Normative manure system is used to calculate normative manure quality and quantity data for various livestock animal categories, to be used e.g. in policymaking, research, technology development and manure fertilisation plans on farms. Major inputs from normative manure system to emission calculation system are nitrogen excretion rates for each animal category (divided between faeces and urine), and effects of nitrogen transformation processes to quantity of TAN in manure management system.

Table 1a. Animal categories considered in the emission calculation system; the detailed categorisation. The animal categories are the same as those in the Finnish normative manure system (Luostarinen et al. 2017).

| CATTLE | PIGS | POULTRY | OTHER ANIMALS |
|---|---|---|---|
| Dairy cow, big breed | Farrowing sow + piglets (<10-12 kg) | Laying hen breeder | Horse |
| Dairy cow, small breed | Gestating sow | Cockerel (laying hen breeder, male) | |
| | Mating sow | Broiler | Pony (120-140) |
| Suckler cow, big breed | Boar (50- kg) | Broiler breeder hen | Pony, little (<120) |
| Suckler cow, small breed | Fattening pig (50- kg) | Broiler breeder, male | |
| | | Chicken | Ewe |
| Heifer, beef breed (2- yrs) | Veaned pig (<30 kg) | | Ram |
| Heifer, beef breed (1-2 yrs) | Veaned pig (<50 kg) | Groving turkey | Lamb |
| Heifer, dairy breed (2- yrs) | | Turkey breeder hen | |
| Heifer, dairy breed (1-2 yrs) | | Turkey breeder male | Female goat |
| Heifer, small breed (>2 yrs) | | Other poultry | Male goat |
| Heifer, small breed (1-2 yrs) | | | Goatling |
| Bull, beef breed (>2 yrs) | | | Fox breeder, female |
| Bull, beef breed (1-2 yrs) | | | Fox breeder, male |
| Bull, dairy breed (>2 yrs) | | | Fox grover |
| Bull, dairy breed (1-2 yrs) | | | |
| Bull, small breed (1-2 yrs) | | | Mink breeder, female |
| Bull, small breed (>2 yrs) | | | Mink breeder, male |
| | | | Mink grover |
| Calf, female, beef (< 6 m) | | | Reindeer |
| Calf, female, beef (6-12 m) | | | |
| Calf, female, dairy (< 6 m) | | | |
| Calf, female, dairy (6-12 m) | | | |
| Calf, female, small breed (< 6 m) | | | |
| Calf, female, small breed (6-12 m) | | | |
| Calf, male, beef (< 6 m) | | | |
| Calf, male, beef (6-12 m) | | | |
| Calf, male, dairy (< 6 m) | | | |
| Calf, male, dairy (6-12 m) | | | |
| Calf, male, small breed (< 6 m) | | | |
| Calf, male, small breed (6-12 m) | | | |

Table 1b. Animal categories considered in the emission calculation system; the simpler categorisation. The animal categories are the same as those in the Finnish normative manure system (Luostarinen et al. 2017).

| CATTLE | PIGS | POULTRY | OTHER ANIMALS |
|---|---|---|---|
| Dairy cow<br>Suckler cow<br>Heifer >1 yr<br>Bull >1 yr<br>Calf <1 yr | Sow (with piglets)<br>Boar (50- kg)<br>Fattening pig (50- kg)<br>Veaned pig (20-50 kg) | Laying hen breeder (female)<br>Cockerel (laying hen breeder, male)<br>Broiler<br>Broiler breeder hen<br>Broiler breeder, male<br>Chicken<br>Turkey<br>Other poultry | Horse<br>Pony<br>Sheep<br>Goat<br>Fox and racoon<br>Mink and fitch<br>Reindeer |

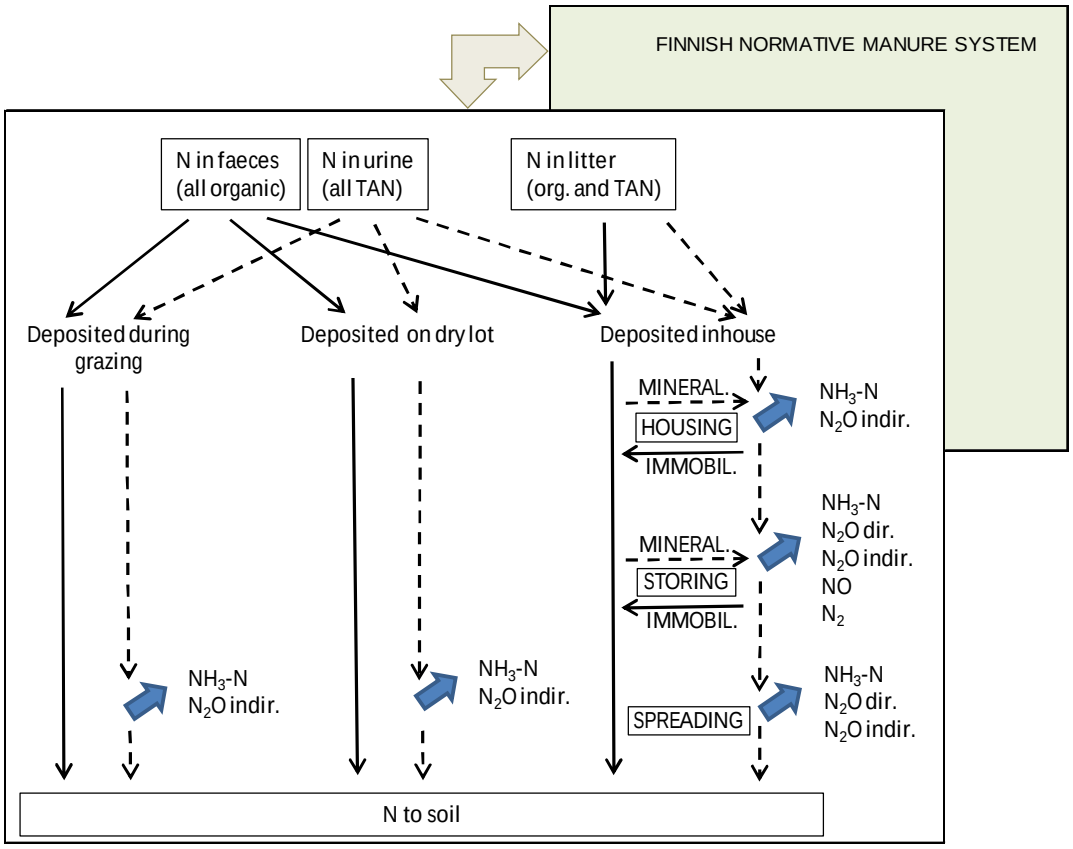


*Fig. 1. Schematic diagram of the N flows in manure management (incl. manure application and grazing) and the related gaseous nitrogen emission calculation system used for calculating the $NH_3$,$N_2O$, NO and $N_2$ emissions from manure management in Finland. Nitrogen transformation processes (immobilisation and mineralisation) are shown, as well as the link between emission calculation system and the Finnish normative manure system (see text for more information). Broad blue arrows: emissions of N-compounds to the atmosphere. Emissions are calculated separately for each animal category and manure management system. For clarity, all manure management systems are not shown in figure. TO BE EDITED*

### *2.1.1.2 Detailed description of emission calculation methods for gaseous N compounds*

#### *2.1.1.2.1 Excreted nitrogen in manure management systems*

The calculation starts from the TAN excretion values of each animal category (as kg TAN per animal place per year; see chapter 2.1.3.1 and Appendix 2). Similar to other agricultural ammonia emission inventories (e.g. Velthof et al. 2012, Haenel et al. 2016), it is assumed that the fraction of TAN in N excretion is equal to the amount of N excreted in urine, being the feed N digested but not converted into animal products. The undigested feed N is supposedly excreted as faecal N. For poultry, the approach of the German emission calculation

documentation (Haenel et al. 2016) was followed. There, uric acid nitrogen (UAN) excreted by poultry is considered completely TAN and the basis for emission calculation. However, as the Finnish normative manure system calculates only total nitrogen excretion for poultry, the proportion of UAN is supposed to be 70% of the total nitrogen, following the default value presented in EMEP/EEA (2016a, table 3.9).

Nitrogen excretion values per animal category and year are based on national data as explained in section 2.1.3.1

TAN excreted is divided between the following locations, where excreta is deposited: a) TAN excreted inhouse ($m_{build_TANex}$), b) TAN excreted during grazing ($m_{graz_TANex}$), and c) TAN excreted on yards ($m_{yards_TANex}$), based on the fraction (x) of the year the animals spend in buildings, on yards and grazing:

$m_{build_TANex} = x_{build} \cdot TAN_{ex}$
$m_{graz_TANex} = x_{graz} \cdot TAN_{ex}$
$m_{yards_TANex} = x_{yards} \cdot TAN_{ex}$

Where:
$x_{build}$, $x_{graz}$ and $x_{yards}$ = fractions of the year (as %; Appendix 1)
$TAN_{ex}$ = annual animal category specific TAN excretion values (as kg TAN per animal place per year; Appendix 2)

Because total nitrogen excretion values are needed for $N_2O$ calculations, respective proportions are calculated also for total N excreted.

TAN (and total N) excreted inhouse are divided between different manure management systems (similar division is made for TAN and tot-N excreted on yards):

$m_{build_S_TANex} = x_S \cdot m_{build_TANex}$
$m_{build_DL_TANex} = x_{DL} \cdot m_{build_TANex}$
$m_{build_SMS_TANex} = x_{SMS} \cdot m_{build_TANex}$

$m_{build_FYM_TANex} = x_{FYM} \cdot m_{build_SMS_TANex}$
$m_{build_SS_TANex} = x_{SS} \cdot m_{build_SMS_TANex}$

$m_{build_SSU_TANex} = x_{SSU} \cdot m_{build_SS_TANex}$
$m_{build_SSD_TANex} = x_{SSD} \cdot m_{build_SS_TANex}$

In solid separation system (SS), faeces and urine are not separated completely. It was assumed that 23% of excreted urine (and urine TAN) is absorbed to bedding material and faeces in animal shelter. This is based on the data on usage and the liquids absorption capacity of different bedding materials. Additionally, 5% of faeces (and faecal nitrogen) was assumed to be mixed with urine before urine is moved to urine storage.

Values for TAN excreted inhouse in each manure management systems (i.e. manure TAN ($m_{build_mms_TAN}$)), are then used as a starting point for emission calculation (see also Figure 1).

In the case of total N, bedding materials' total N is added to the content of manure total N excreted inhouse, based on the information on use of bedding materials in each manure management system (kg per animal place per year; see Luostarinen et al. 2017) and the nitrogen content of bedding materials (Table 7):

$m_{build_mms_N} = m_{build_mms_Nex} + m_{build_mms_Nbed}$

Where:
mms = manure management system (S, DL, FYM, SSD or SSU) (as % of animals; Appendix 1)
$N_{ex}$ = total N excreted (kg)
$N_{bed}$ = total N in bedding material (kg)

#### *2.1.1.2.2 Calculation of inhouse emissions*

In addition to the inhouse manure TAN values ($m_{build_mms_TAN}$), ammonia emissions from housing for each animal category, manure management system and year are based on the following information:
- unabated emission factors for housing (as % of manure TAN; Table 6),
- use of emission abatement measures during housing (as % of manure; Appendix 1),
- emission reduction efficiency of each abatement measure (as %; Table 6), and
- temperature correction factor for housing (as % of abated emission value; Table 5)
- for deep litter: immobilisation rate of manure TAN during housing (as % of manure TAN).

<u>Immobilisation of deep litter TAN during housing</u>

First, influence of nitrogen mineralisation and immobilisation processes for manures stored inhouse are calculated. At the moment, this covers only deep litter because other manure types are stored inhouse only for relatively short time or are removed from building instantly.

It was supposed that 40% of deep litter TAN is immobilised during inhouse storing. This is the same value Haenel et al. (2016) have used for solid manure storing in the German agricultural ammonia emission inventory. See also chapter 2.1.3.2 of this document.

Modified mass (mm) of deep litter TAN ($mm_{build_DL_TAN}$) is calculated based on the changes due to immobilisation as follows:

$$mm_{build_DL_TAN} = m_{build_DL_TAN} - (m_{build_DL_TAN} \cdot f_{imm})$$

$F_{imm}$ = immobilisation factor (40% of manure TAN)

<u>Emissions during housing</u>

For ammonia emission estimates for each animal and manure type, the unabated and non-temperature corrected emission is calculated first. Then, based on the commonness and efficiency of the emission abatement measures in animal buildings, an abated emission level is calculated (abated emissions are subtracted from the unabated emission level). Finally, using temperature correction factor for housing, temperature corrected emission value is calculated.

$$E_{build_mms_NH3\text{-}N} = ((m_{build_mms_TAN} \cdot EF_{build_mms_NH3\text{-}N}) - (\Sigma\, (m_{build_mms_TAN} \cdot EF_{build_mms_NH3\text{-}N} \cdot X_{build_mms_am} \cdot AF_{build_mms_am}))) \cdot TCF$$

Where:
$m_{build_mms_TAN}$ = mass of TAN excreted inhouse in manure management system,
$EF_{build_mms_NH3\text{-}N}$ = unabated emission factor as % of $m_{build_mms_TAN}$ ,
mms = manure management system,
am = abatement measure,
$X_{build_mms_am}$ = share of abatement measure in manure management system (frequency of emission abatement measure, % of manure),
$AF_{build_mms_am}$ = abatement factor (emission reduction efficiency, %) of the abatement measure in manure management system, and
TCF = temperature correction factor.

Note that for deep litter, a modified mass of TAN, i.e. $mm_{build_DL_TAN}$ is used instead of $m_{build_DL_TAN}$

For other gaseous N losses (as well as for indirect $N_2O$ emissions due to volatilisation of $NH_3$ and NO), emission factors presented in tables 4 and 5 are used.

$$E_{build_mms_N2O\text{-}N} = m_{build_mms_N} \cdot EF_{build_mms_N2O}$$
$$E_{build_mms_NO\text{-}N} = m_{build_mms_TAN} \cdot EF_{build_mms_NO}$$
$$E_{build_mms_N2_N} = m_{build_mms_TAN} \cdot EF_{build_mms_N2}$$

Where:
N = total N
TAN = total ammoniacal N
mms = manure management system
EF = emission factor

The remaining TAN (TAN ex housing, i.e. $m_{storage_mms_TAN}$) is used as an input in calculating emissions from manure storing and is calculated as follows:

$$m_{storage_mms_TAN} = m_{build_mms_TAN} - E_{build_mms_NH3\text{-}N} - E_{build_mms_N2O\text{-}N} - E_{build_mms_NO\text{-}N} - E_{build_mms_N2_N}$$

### *2.1.1.2.3 Calculation of emissions from manure storing*

Ammonia emissions from manure storing for each animal category, manure management system and year are based on the following information:
- amount of TAN entering the manure storage (=kg TAN ex housing; $m_{storage_mms_TAN}$)
- mineralisation rate of manure organic nitrogen during slurry storing, and immobilisation rate of manure TAN during solid manure storing
- unabated emission factors for manure storing (as % of TAN; Table 6),
- shares of emission abatement measures during manure storing (as % of manure; Appendix 1),
- emission reduction efficiency of each emission abatement measure (as %; Table 6), and
- temperature correction factor for manure storing (as %, Table 5).

For slurry systems, also following information is needed to calculate emissions from slurry tank filling and slurry aeration:
- share of slurry moved to storage above slurry surface level (Appendix 1),
- share of aerated slurry during slurry storing (Appendix 1),
- share of aerated slurry which is aerated using low-emission aeration practices (Appendix 1),
- unabated emission factor for slurry tank filling (as % of TAN; Table 6),
- unabated emission factor for slurry aeration (as % of TAN; Table 6), and
- emission abatement factor for aerating using low-emission aeration practices (as %; Table 6).

<u>Emissions from slurry storage filling</u>

For slurry system, the $NH_3$-N emission due to slurry storage filling above slurry surface level is calculated as follows. It is assumed that slurry storage filling below slurry surface level does not increase ammonia emissions.

$$E_{fill_s_NH3\text{-}N} = ((m_{storage_s_TAN} \cdot X_{fill_s_above} \cdot EF_{fill_s_NH3\text{-}N}) - (\Sigma_{am}(m_{storage_s_TAN} \cdot X_{fill_s_above} \cdot EF_{fill_s_NH3\text{-}N} \cdot X_{storage_s_am} \cdot AF_{storage_s_am}))) \cdot TCF$$

where:
s = slurry system,
am = abatement measure,
$X_{fill_s_above}$ = share of slurry moved to storage above slurry surface level (as % of slurry),
$EF_{fill_s_NH3\text{-}N}$ = unabated emission factor for slurry filling above slurry surface (as % of $m_{storage_mms_TAN}$),
$X_{storage_s_am}$ = share of slurry storing abatement measure (frequency of emission abatement measure, % of slurry),
$AF_{storage_s_am}$ = abatement factor (emission reduction efficiency, %) of the abatement measure in slurry system, and
TCF = temperature correction factor.

<u>Mineralisation and immobilisation</u>

The influence of nitrogen mineralisation and immobilisation processes during manure storing to manure TAN content is estimated. For slurry, 10% of organic N is supposed to be mineralised during storing (EMEP/EEA 2016, Velthof et al. 2012). For solid manures (except deep litter which is stored outdoor only for relatively short time

and the immobilisation is supposed to take place during inhouse storing), 40% of TAN is immobilised during storing. This is the same approach Haenel et al. (2016) have used in agricultural gaseous emission inventory in Germany. The method described in EMEP/EEA emission inventory guidebook (2016a) was not used (0.0067 kg N $kg^{-1}$ straw) because immobilisation rate depends on the amount of bedding material, and in certain cases, where bedding material use is high, calculated immobilisation rate is higher than the original TAN content of manure resulting negative values for manure TAN content.

Modified mass of TAN ($mm_{storage_mms_TAN}$) is calculated based on the changes due to mineralisation (liquid manure types) or immobilisation (solid manure types):

$$mm_{storage_liquid_TAN} = m_{storage_liquid_TAN} + ((m_{storage_liquid_N} - m_{storage_liquid_TAN}) \cdot f_{min})$$

$$mm_{storage_solid_TAN} = m_{storage_solid_TAN} - (m_{storage_solid_TAN} \cdot f_{imm})$$

Where:
$f_{min}$ = mineralisation factor (10% of liquid manure organic nítrogen)
$F_{imm}$ = immobilisation factor (40% of solid manure TAN)

Note that for slurry, $m_{storage_liquid_TAN}$, $m_{storage_liquid_N}$ and $mm_{storage_liquid_TAN}$ represent the nitrogen in the beginning of the storage period, excluding the nitrogen lost during storage filling as ammonia.

Emissions during manure storing

After calculating the modified mass of TAN, the unabated and non-temperature corrected emission is calculated. Then, based on the frequency and efficiency of the emission abatement measures for manure storing (use of different manure storage coverings), an abated emission level is calculated , i.e. abated emissions are subtracted from the unabated emission level. Finally, using temperature correction factor for storing, temperature corrected emission value is calculated.

$$E_{storage_mms_NH3\text{-}N} = ((mm_{storage_mms_TAN} \cdot EF_{storage_mms_NH3\text{-}N}) - (\Sigma_{am}(mm_{storage_mms_TAN} \cdot EF_{storage_mms_NH3\text{-}N} \cdot X_{storage_mms_am} \cdot AF_{storage_mms_am}))) \cdot TCF$$

Where:
$mm_{storage_mms_TAN}$ = modified mass of TAN,
$EF_{storage_mms_NH3\text{-}N}$ = unabated emission factor (as % of $mm_{storage_mms_TAN}$),
mms = manure management system,
am = abatement measure,
$X_{storage_mms_am_mms}$ = share of abatement measure (frequency of emission abatement measure, % of manure,
$AF_{storage_mms_am_mms}$ = abatement factor (emission reduction efficiency, %) of the abatement measure in manure management system, and
TCF = temperature correction factor.

Emissions from slurry aeration

Additionally, $NH_3$-N emission due to slurry aeration is also considered as an emission source during slurry storing. In addition to the share of aerated slurry and the use of ammonia abatement measures during storing, also information on aeration practices is needed (aeration is/is not done using low-emission practices), and is calculated as follows (unabated emission from aeration minus abated emissions of aeration due to slurry storage covering minus abated emissions due to low-emission aeration practices):

$$E_{aer_s_NH3\text{-}N} = (((mm_{storage_s_TAN} \cdot X_{aer_s} \cdot EF_{aer_s_NH3\text{-}N}) - (\Sigma_{am}(m_{storage_s_TAN} \cdot X_{aer_s} \cdot EF_{aer_s_NH3\text{-}N} \cdot X_{storage_s_am} \cdot AF_{storage_s_am}))) - (((mm_{storage_s_TAN} \cdot X_{aer_s} \cdot EF_{aer_s_NH3\text{-}N}) - (\Sigma_{am}(m_{storage_s_TAN} \cdot X_{aer_s} \cdot EF_{aer_s_NH3\text{-}N} \cdot X_{storage_s_am} \cdot AF_{storage_s_am}))) \cdot (X_{aer_s_red} \cdot AF_{aer_s_red}))) \cdot TCF$$

where:
s = slurry system,

aer = aeration,
am = abatement measure,
$X_{aer_s}$ = share of aerated slurry (as % of stored slurry),
$EF_{aer_s_NH3\text{-}N}$ = unabated emission factor for slurry aeration (as % of $mm_{storage_mms_TAN}$),
$X_{storage_s_am}$ = share of slurry storing abatement measure (frequency of emission abatement measure, % of slurry),
$AF_{storage_s_am}$ = abatement factor (emission reduction efficiency, %) of the abatement measure in slurry system,
$X_{aer_s_red}$ = share of aerated slurry which is aerated using low-emission aeration practices $NH_3$-N losses (as % of aerated slurry),
$AF_{aer_s_red}$ = abatement factor for aerating using low-emission aeration practices, and
TCF = temperature correction factor.

For other gaseous N losses, emission factors presented in tables 3 and 4 are used.

$E_{storage_mms_N2O\text{-}N} = m_{storage_mms_N} \cdot EF_{storage_mms_N2O}$
$E_{storage_mms_NO\text{-}N} = mm_{storage_mms_TAN} \cdot EF_{storage_mms_NO}$
$E_{storage_mms_N2_N} = mm_{storage_mms_TAN} \cdot EF_{storage_mms_N2}$

Where:
N = total N,
TAN = total ammoniacal N, and
mms = manure management system

The remaining TAN (TAN ex storing, i.e. $m_{applic_mms_TAN}$) is used as an input in calculating emissions from manure application, and is calculated as follows:

$m_{applic_mms_TAN} = mm_{storage_mms_TAN} - E_{storage_mms_NH3\text{-}N} - E_{aer_s_NH3\text{-}N} - E_{storage_mms_N2O\text{-}N} - E_{storage_mms_NO\text{-}N} - E_{storage_mms_N2_N}$

Note that for slurry, $mm_{storage_mms_TAN}$ includes the reduction of TAN due to the evaporation of $NH_3$-N during slurry storage filling. Note also that $NH_3$-N emission due to aeration ($E_{aer_s_NH3\text{-}N}$) is only applied for slurry.

#### *2.1.1.2.4 Calculation of emissions from manure application*

Ammonia emissions from manure application for each animal category, manure management system and year are based on the information on:
- amount of TAN in the manure to be applied (=TAN ex storing; $m_{applic_mms_TAN}$),
- shares of the three main manure application sites: arable land, stubble, plant covered land (Appendix 1),
- for liquid manures, shares of the three main manure application methods: injection, trailing hose, broadcast spreading (Appendix 1),
- shares of incorporation methods (ploughing, harrowing) and incorporation time (time between application and incorporation; less than 4 hours, 4-6 hours, 6-12 hours, 12-24 hours, more than 24 hours) for the manure applied on soil surface (Appendix 1),
- unabated emission factors for manure application, separately for each three main application sites, representing emissions from broadcast spreading without incorporation (as % of TAN; Table 6),
- coverage of emission abatement measures of manure application, separately for each three main application sites (as % of manure; Appendix 1),
- emission reduction efficiency of each abatement measure (as %; Table 6), and
- temperature correction factor for manure application (as % of abated emission level, Table 5).

<u>Manure TAN allocation between application sites</u>

Manure TAN is allocated between the three manure application sites (arable land, al; subble, st, plant covered land, pcl) as follows:

$m_{applic_mms_al_TAN} = m_{applic_mms_TAN} \cdot X_{applic_mms_al}$
$m_{applic_mms_st_TAN} = m_{applic_mms_TAN} \cdot X_{applic_mms_st}$
$m_{applic_mms_pcl_TAN} = m_{applic_mms_TAN} \cdot X_{applic_mms_pcl}$

Where:
$x_{applic_mms_al}$, $x_{applic_mms_st}$ and $x_{applic_mms_pcl}$ = shares of the different manure application sites (arable land, al; subble, st, plant covered land, pcl) (as %; Appendix 1)

Emission calculation

The emission calculation is somewhat straightforward for application on plant covered land (pcl) because manure is not incorporated into the soil after application. First, an unabated and non-temperature corrected emission is calculated. Then, based on the frequency and efficiency of the emission abatement measures (only possible for liquid manures: band spreading or injection), an abated emission level is calculated by subtracting the abated emissions from the unabated emission. Finally, the temperature correction factor is used. If abatement measures cannot be used (e.g. in case of solid manure application on plant covered soil), the emission level corresponds with the unabated emission, corrected with the temperature correction factor.

$$E_{applic_mms_pcl_NH3\text{-}N} = ((m_{applic_mms_pcl_TAN} \cdot EF_{applic_mms_pcl_NH3-N}) - (\sum_{am}(m_{applic_mms_pcl_TAN} \cdot EF_{applic_mms_pcl_NH3-N} \cdot X_{applic_mms_pcl_am} \cdot AF_{applic_mms_am})) \cdot TCF)$$

where:
mms = manure management system,
pcl = plant covered land (as manure application site),
am = abatement measure,
$EF_{applic_mms_pcl_NH3\text{-}N}$ = unabated emission factor for plant covered land application in manure management system (as % of $mm_{applic_mms_pcl_TAN}$; Table 6),
$X_{applic_mms_pcl_am}$ = share of abatement measure for plant covered land application in manure management system (frequency of emission abatement measure, % of manure; Appendix 1), and
$AF_{applic_mms_am}$ = abatement factor (emission reduction efficiency, %) of the abatement measure in manure management system (Table 6).

The same principle is used also for solid manure application on arable land (al) and on stubble (st), where different incorporation methods represent the abatement measures, and no injection or band spreading is used.

For liquid manure application on arable land (al) and on stubble/grassland to be terminated (st), the equation shall not only consider the different main application measures (mams; broadcast spreading, band spreading, injection) which may also have emission abatement properties, but also the incorporation methods (the "secondary" abatement measures, i.e. manure incorporation methods) used when manure is applied using broadcast or band spreading. After the abated emission is calculated, the temperature correction factor is used.

The equation for liquid manure application on arable land (al) is as follows:

$$E_{applic_mms_al_NH3\text{-}N} = (\sum(m_{applic_mms_al_TAN} \cdot EF_{applic_mms_al_NH3-N} \cdot X_{applic_mms_al_mam} \cdot (1 - AF_{applic_mms_mam}) \cdot X_{applic_mms_al_am} \cdot (1 - AF_{applic_mms_am})) \cdot TCF)$$

where:
mms = manure management system (in this case, slurry or urine),
al = arable land (as manure application site),
mam = main application method (injection/band spreading/broadcast spreading),
am = abatement measure (the secondary abatement measures, i.e. manure incorporation methods),
$EF_{applic_mms_al_NH3\text{-}N}$ = unabated emission factor for arable land application (as % of $mm_{applic_mms_al_TAN}$; Table 6),
$X_{applic_mms_al_mam}$ = share of main application method for arable land application (frequency of main manure application method, % of manure; Appendix 1),
$AF_{applic_mms_mam}$ = abatement factor (emission reduction efficiency, %) of the main manure application method (mam) in manure management system (for broadcast spreading this factor is zero) (Table 6),
$X_{applic_mms_al_am}$ = share of secondary abatement measure for arable land application (frequency of emission abatement measure, i.e. incorporation methods, % of manure; Appendix 1), and
$AF_{applic_mms_am}$ = abatement factor (emission reduction efficiency, %) of the secondary abatement measure in manure management system (Table 6).

For injection, no secondary abatement measures are used and are not considered in the calculation.

The same equation is also used for liquid manure application on stubble (st).

For other gaseous N losses (as well as for indirect $N_2O$ emissions due to volatilisation of $NH_3$ and NO), emission factors presented in tables 3 and 4 are used.

$$E_{applic_mms_N2O\text{-}N} = m_{applic_mms_N} \cdot EF_{applic_mms_N2O}$$
$$E_{applic_mms_NO\text{-}N} = m_{applic_mms_TAN} \cdot EF_{applic_mms_NO}$$
$$E_{applic_mms_N2_N} = m_{applic_mms_TAN} \cdot EF_{applic_mms_N2}$$

Where:
N = total N
TAN = total ammoniacal N
mms = manure management system

For manure application, $N_2$ emissions were not calculated.

#### *2.1.1.2.5 Calculation of emissions from grazing and yards*

Ammonia emissions from manure excreted during grazing and on yards for each animal category and year are based on the following information:
- amount of TAN excreted during grazing and on yards ($m_{graz_TANex}$ and $m_{yards_TANex}$)
- unabated emission factors (EF) for ammonia emissions (Table 6),
- temperature correction factor (TCF) for grazing and yards (Table 6).

Ammonia emissions from grazing and from yards are then calculated using temperature correction factors (TCFs; Table 5):

$$E_{graz_NH3\text{-}N} = m_{graz_TANex} \cdot EF_{graz_NH3\text{-}N} \cdot TCF_{graz}$$
$$E_{yard_NH3\text{-}N} = m_{yards_TANex} \cdot EF_{yards_NH3\text{-}N} \cdot TCF_{yards}$$

### *2.1.2 Emissions from mineral N-fertilizers*

Ammonia emissions due to the use of mineral N-fertilizers were calculated separately for different fertilizer types using the emission factors presented in the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA 2016b, Table 3-2). Due to the low soil pH and low average annual temperature in Finland, the 'normal pH' emission factors for cool climate were applied. The total amount of nitrogen sold annually in Finland was divided by fertilizer type using the information obtained from Yara Finland Ltd (Toimela 2016) and Natural Resources Institute Finland (Mattila 2016) (Table 2). EMEP/EEA emission factors presented in Table 2 are based on the emissions from surface applied fertilisers. In Finland, however, placement fertilization is typically used for cereals. According to the EMEP/EEA emission inventory guidebook (2016b, A1.2.2), fertiliser-N that is immediately incorporated into the soil will not be a source of $NH_3$ as the $NH^{4+}$ ions are absorbed onto soil colloids or nitrified. Thus, N-fertilisers used in Finland were divided between fertilisers spread using placement fertilisation and fertilisers applied on soil surface (typically grassland).

For nitric oxide, the emission factor of 0.04 kg $NO_2$ $kg^{-1}$ fertilizer-N applied (EMEP/EEA 2016b) was used. This corresponds to 1.2% of fertilizer-N applied.

Table 2. Distribution of mineral N-fertilizers used in Finland by fertilizer type (%), distribution of each fertilizer type by application method (placement fertilisation or spread on soil surface, %), and $NH_3$-emission factors (EFs for normal pH, cool climate) for different fertilizer types applied.

| Spread as: | % of applied fertiliser-N | Spread using placement | Spread on soil surface (%) | EF for fertilizer-N spread on soil surface |
|---|---|---|---|---|

| | | fertilisation (%) | | (kg $NH_3$ kg $N^{-1}$) |
|---|---|---|---|---|
| Ammonium nitrate | 0.0 % | 65 | 35 | 0.019 |
| Anhydrous ammonia | 0.0 % | 65 | 35 | 0.015 |
| Ammonium phosphates | 0.2 % | 65 | 35 | 0.05 |
| Ammonium sulphate | 0.4 % | 65 | 35 | 0.09 |
| Calcium ammonium nitrate | 30.5 % | 65 | 35 | 0.008 |
| Calcium nitrate | 0.1 % | 65 | 35 | 0.01 |
| Ammonium solutions (AN) | 0.0 % | 65 | 35 | 0.015 |
| Ammonium solutions (Urea AN) | 0.0 % | 65 | 35 | 0.098 |
| Urea ammonium sulphate | 0.0 % | 65 | 35 | 0.098 |
| Urea | 0.6 % | 65 | 35 | 0.155 |
| Other NK and NPK | 68.2 % | 65 | 35 | 0.05 |

### *2.1.3 Basic model parameters*

#### *3.1.1.1 Nitrogen excretion rates*

For the calculation of gaseous N emissions from animal husbandry, nitrogen excretion values (in the form of total nitrogen (tot. N) and total ammoniacal nitrogen, TAN) are needed for each livestock category, as kg tot N or kg TAN per animal place per year. TAN is the part of total nitrogen, and is the origin of gaseous nitrogen emissions. For mammals, it is supposed that all urine nitrogen is TAN, and all faeces nitrogen is organically bound.

Animal type specific nitrogen excretion rates (total nitrogen excretion divided between urine and faeces) are derived from the Finnish normative manure system (Luostarinen et al. 2017). The basis of the nitrogen excretion rates is the nutrient balance calculations carried out by the Natural Resources Institute Finland (Luke). Excretion rate is obtained by subtracting the nitrogen included in animal products and growth from the nitrogen intake through feeding. The most important input data for the calculations are:
- annual feed consumption of the animals
- characteristics of different fodder compounds
- the statistics of milk, meat and egg production, and the slaughter weights.

At the moment, nitrogen excretion values calculated separately for urine and faeces are only available for 2014. However, because the previous version of emission calculation system used total nitrogen excretion values, the time series for 1980 – 2015 and the projections for 2020, 2025 and 2030 are only available for total nitrogen excretion rates (Appendix 2). For emission time series, the proportion of N excreted in urea in the excretion data for 2014 is used when the proportion of TAN for the other years are quantified.

For poultry, the same approach was used as is described in the German emission calculation documentation (Haenel et al. 2016). There, uric acid nitrogen (UAN) excreted by poultry is completely considered to be TAN and is used as a basis for emission calculation. Currently for poultry, only total nitrogen excretion values are produced in the Finnish normative manure system. The proportion of UAN is supposed to be 70% of the total nitrogen, which is the default value presented in EMEP/EEA (2016a, Table 3.9).

#### *2.1.3.2 Nitrogen mineralisation and immobilisation*

For untreated slurry, it was assumed that 10 % of the organic N entering storage is converted to TAN during storing (mineralisation; EMEP/EEA 2016a, Veltohof et al. 2012).

For solid manure (deep litter, FYM, faeces managed separately) the same approach was used as was described in Haenel et al. 2016: 40 % of TAN entering storage is converted to organic N during storing (immobilisation). However, for FYM of laying hens the immobilisation of TAN was not considered because no bedding material is used.

The method described in EMEP/EEA emission inventory guidebook (2016a) was not used (0.0067 kg N $kg^{-1}$ straw) because immobilisation rate depends on the amount of bedding material, and in certain cases, where bedding material use is high, calculated immobilisation rate is higher than the original TAN content of manure resulting negative values for manure TAN content.

### *2.1.3.3 Unabated emission rates (emission factors)*

#### *2.1.3.3.2 Ammonia*

The unabated emission factors (proportion of TAN volatilised in different manure management phases) are based on the EMEP/EEA Guidebook 2016 (EMEP/EEA 2016a), Table 3.9 (see Table 6 of this report).

For reindeer, only emissions from grazing are considered. The same emission factors are applied as those used for cattle.

#### *2.1.3.3.3 Other N emissions*

Emission factors used for calculation of other gaseous N emissions ($N_2O$, NO, $N_2$) were obtained from EMEP/EEA (2016a) and IPCC (2006) guidebooks (see tables 3 and 4).

Table 3. Emission factors used for calculating nitrous oxide ($N_2O$) losses from manure management (including manure application) and grazing (IPCC 2006).

| Emission source category | EF (% of tot-N excreted) |
|---|---|
| Manure management: | |
| - daily spread | 0.0% |
| - solid storage | 0.5% |
| - yards | 2.0% |
| - liquid/slurry - WITH natural crust cover | 0.5% |
| - liquid/slurry - WITHOUT natural crust cover | 0.0% |
| - uncovered anaerobic lagoon | 0.0% |
| - pit storage below animal confinements | 0.2% |
| - anaerobic digester | 0.0% |
| - burned for fuel or as waste | 0.0% |
| - burned for fuel or as waste | 0.0% |
| - cattle and swine deep bedding - NO MIXING | 1.0% |
| - cattle and swine deep bedding - ACTIVE MIXING | 7.0% |
| - composting - In-Vessel | 0.6% |
| - composting - Static Pile | 0.6% |
| - composting - Intensive Windrow | 10.0% |
| - composting - Passive Windrow | 1.0% |
| - poultry manure with litter | 0.1% |
| - poultry manure without litter | 0.1% |
| - aerobic treatment - NATURAL | 1.0% |
| - aerobic treatment - FORCED | 0.5% |
| | |
| Managed soils (N additions) | 1.0% |
| | |
| Grazing of cattle, poultry and pigs | 2.0% |
| Grazing of sheep and other animals | 1.0% |
| | |
| INDIRECT $N_2O$-N (due to volatilization of $NH_3$ and NO) | 1.0% |

Table 4. Emission factors used for calculating of NO and $N_2$ losses from manure management and manure application (EMEP/EEA 2016a).

| Emission source | | EF |
|---|---|---|
| NO-N | Inhouse, slurry | (no EF available) |
| | Inhouse, solid manure | (no EF available) |
| | Storage, slurry | 0.01% of TAN |
| | Storage, solid manure | 1.0% of TAN |
| | Application, solid and liquid manure, and mineral N | 1.2% of tot-N applied |
| $N_2$ | Inhouse, slurry | (no EF available) |
| | Inhouse, solid manure | (no EF available) |
| | Storage, slurry | 0.3% of TAN |
| | Storage, solid manure | 30.0% of TAN |

#### *2.1.3.4 Emission abatement factors for ammonia*

The emission abatement factors of different emission abatement measures were acquired from the studies of Bittman et al. (2014) and Webb et al. (2006) (see Table 6).

#### *2.1.3.5 Temperature correction factors for ammonia*

As mentioned above, the unabated emission factors were acquired from the EMEP/EEA Guidebook 2016 (EME/EEA 2016a, Table 3.9 (see Table 6 of this report). The values (proportion of TAN volatilised in different manure management phases) are based on the studies representing climatic conditions different from those in Finland. The most important distinction can be found in outdoor temperature (Table 5). Cowell and ApSimon (1996) assumed a rise of 3˚C in temperature increases volatilization of ammonia by 10%, based on Oldenburg (1989). The difference of 6˚C in the annual average outdoor temperature between Finland and Central Europe (Table 5) would mean a reduction of 20% in ammonia volatilization giving a correction factor of 0.8 for Finland. However, the temperature difference varies over a year with the largest difference in winter and the smallest in summer.

In Finland, manure is mainly spread in spring (April and May), and summer (June and July). The application of manure in autumn (August - November) has decreased in recent years because of administrative restrictions on the rate and timing of manure application especially in autumn. Winter application of manure is prohibited. The difference in the average temperature was calculated separately for each of the three periods of manure application (Table 5). The calculation was simplified by assuming that in spring all the manure was applied to bare soil, in summer to plant covered soil, and in autumn to stubble, which are the most common surfaces for each application period. The effect of temperature difference on ammonia emissions from manure application was estimated according to the values presented in Table 5I of the EMEP/CORINAIR Emission Inventory Guidebook (EEA 2007). In the table, reduction in temperature from 10˚C to 5˚C lowers ammonia emission 25…50% for cattle slurry and 33…60% for pig slurry. A 30% reduction was estimated for the Finnish spring and autumn periods of manure application, where the difference in the average temperature is about 5˚C compared to Central Europe. This gives a temperature correction factor of 0.7 for spring and autumn. In summer, however, the average temperature in Finland is only 0.8˚C lower. A reduction of 5% in ammonia emission from manure application was estimated and a temperature correction factor of 0.95 was used for summer applications.

The emissions of ammonia from manure storage and other manure management in outdoor conditions are corrected with the factor 0.8, which is based on a difference of 6˚C over the whole-year average temperature between Finland and Central Europe (Table 5). There are no significant differences in the indoor temperatures of animal buildings, but in the Central European conditions higher outdoor temperatures result in a need for greater ventilation, which increasingly affects emissions. In non-isolated animal shelters the indoor temperature closely follows the outdoor temperature. For these reasons, a temperature correction factor of 0.9 was used for animal shelters.

For mineral fertilisers, no temperature factor was used because the emission factors for cool climate include the temperature impact.

Table 5. Average outdoor temperature (°C) in Finland (mean of Jokioinen, Jyväskylä and Oulu) and in Central Europe (mean of Hannover (Germany), De Bilt (the Netherlands) and Birmingham (England) in 1961–1990 (The Weather Network 2008).

| | Whole year | April–May | June–July | August–Nov. |
|---|---|---|---|---|
| Finland | 3.3 | 5.1 | 15.0 | 6.3 |
| Central Europe | 9.2 | 10.0 | 15.8 | 11.5 |
| Difference | 5.9 | 4.9 | 0.8 | 5.2 |

Table 6. Unabated emission factors (Unabated EF; % of TAN), and estimated reduction of losses achieved with abatement measures (am; % of loss without abatement).

| | CATTLE | | | | | PIGS | | | | | POULTRY | | | SHEEP, GOAT | | HORSE, PONY | | FUR ANIMALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slurry | Deep litter | Solid manure with urine | Urine | Dung | Slurry | Deep litter | Solid manure with urine | Urine | Dung | Slurry | Deep litter | Solid manure | Deep litter | Solid manure | Deep litter | Solid manure | Solid manure with urine |
| Housing | | | | | | | | | | | | | | | | | | |
| *Unabated EF* | *20 or 6.6** | *27* | *19 or 6.6** | *20 or 6.6** | *19 or 6.6** | *25* | *45* | *26* | *25* | *26* | *41* | *30* | *41* | *22* | *22* | *22* | *22* | *40* |
| am: rapid urine separation | | | 15 | 20 | | | | 15 | 20 | | *60* | | *85* | | 15 | | 15 | 0 |
| am: flushing | 60 | | | | | 60 | | | | | | | 10 | | | | | |
| am: improved cleaning | 10 | | 10 | 10 | 10 | 10 | | 10 | 10 | 10 | | | 60 | | 10 | | 10 | 0 |
| am: increased manure removal frequency | 10 | | 10 | 10 | 10 | 25 | | 10 | 10 | 10 | 10 | | 10 | | 10 | | 10 | 0 |
| am: biol. or chem. air scrubbers | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | | 85 | 85 | 85 | 85 | 0 |
| am: cooling of slurry channels | 30 | | | | | 30 | | | | | | | | | | | | |
| Filling the manure storage | | | | | | | | | | | | | | | | | | |
| *from the top* | *5* | | | | | *5* | | | | | *5* | | | | | | | |
| *from the bottom* | *0* | | | | | *0* | | | | | *0* | | | | | | | |
| Storing | | | | | | | | | | | | | | | | | | |
| *Unabated EF* | *20* | *27* | *27* | *20* | *27* | *14* | *45* | *45* | *14* | *45* | *14* | *20* | *14* | *28* | *28* | *35* | *35* | *35* |
| am: tight roof (concrete) | 95 | | | 95 | | 95 | | | 95 | | 95 | | | | | | | 0 |
| am: floating cover | 60 | | | 60 | | 60 | | | 60 | | 60 | | | | | | | 0 |
| am: natural crust | 40 | | | | | 40 | | | | | 40 | | | | | | | 0 |
| am: roof of solid manure storage | | 10 | 10 | | 10 | | 10 | 10 | | 10 | | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| am: filling the solid manure storage from the bottom | | | 30 | | 30 | | | 30 | | 30 | | | 30 | | 30 | | 30 | 30 |
| am: tent, roof | 80 | | | | | 80 | | | | | 80 | | | | | | | |

| | CATTLE | | | | | PIGS | | | | | POULTRY | | | SHEEP, GOAT | | HORSE, PONY | | FUR ANIMALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slurry | Deep litter | Solid manure with urine | Urine | Dung | Slurry | Deep litter | Solid manure with urine | Urine | Dung | Slurry | Deep litter | Solid manure | Deep litter | Solid manure with urine | Deep litter | Solid manure | Solid manure with urine |
| Spreading on arable land | | | | | | | | | | | | | | | | | | |
| *Unabated EF (broadcast spr)* | *55* | *79* | *79* | *30* | *79* | *35* | *81* | *81* | *30* | *81* | *69* | *60* | *69* | *90* | *90* | *90* | *90* | *80* |
| am: incorporation with ploughing < 4 hrs | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| am: ncorp. with ploughing < 12 hrs | 45 | 50 | 50 | 45 | 50 | 45 | 50 | 50 | 45 | 50 | 45 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| am: ncorp. with ploughing > 12 hrs | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| am: ncorp. with harrowing < 4 hrs | 60 | 50 | 50 | 60 | 50 | 60 | 50 | 50 | 60 | 50 | 60 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| am: ncorp. with harrowing < 12 hrs | 35 | 25 | 25 | 35 | 25 | 35 | 25 | 25 | 35 | 25 | 35 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| am: ncorp. with harrowing > 12 hrs | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| am: injection | 78 | | | 78 | | 78 | | | 78 | | 78 | | | | | | | |
| am: band spreading | 30 | | | 30 | | 30 | | | 30 | | 30 | | | | | | | |
| Spreading on plant covered land | | | | | | | | | | | | | | | | | | |
| *Unabated EF (broadcast spr)* | *55* | *79* | *79* | *30* | *79* | *35* | *81* | *81* | *30* | *81* | *69* | *60* | *69* | *90* | *90* | *90* | *90* | *80* |
| am: band spreading | 35 | | | 35 | | 35 | | | 35 | | 35 | | | | | | | |
| am: injection | 78 | | | 78 | | 78 | | | 78 | | 78 | | | | | | | |
| am: band spreading + acid | 75 | | | | | 75 | | | | | 75 | | | | | | | |

| | CATTLE | | | | | PIGS | | | | | POULTRY | | | SHEEP, GOAT | | HORSE, PONY | | FUR ANIMALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Slurry | Deep litter | Solid manure with urine | Urine | Dung | Slurry | Deep litter | Solid manure with urine | Urine | Dung | Slurry | Deep litter | Solid manure | Deep litter | Solid manure with urine | Deep litter | Solid manure | Solid manure with urine |
| Spreading on stubble or on grass to be terminated | | | | | | | | | | | | | | | | | | |
| *Unabated EF (broadcast spr)* | *55* | *79* | *79* | *30* | *79* | *35* | *81* | *81* | *30* | *81* | *69* | *60* | *69* | *90* | *90* | *90* | *90* | *85* |
| am: incorp. with ploughing < 4 hrs | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| am: incorp. with ploughing < 12 hrs | 45 | 50 | 50 | 45 | 50 | 45 | 50 | 50 | 45 | 50 | 45 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| am: incorp. with ploughing > 12 hrs | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| am: incorp. with harrowing < 4 hrs | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| am: incorp. with harrowing < 12 hrs | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| am: incorp. with harrowing > 12 hrs | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| am: injection | 78 | | | 78 | | 78 | | | 78 | | 78 | | | | | | | |
| am: band spreading | 30 | | | 30 | | 30 | | | 30 | | 30 | | | | | | | |
| Grazing | | | | | | | | | | | | | | | | | | |
| *evaporate from urine* | *8* | | | | | *25* | | | | | *8* | | | *9* | | *35* | | |
| *evaporate from faeces* | *8* | | | | | *25* | | | | | *8* | | | *9* | | *35* | | |
| Yards | | | | | | | | | | | | | | | | | | |
| *evaporate from urine* | *40* | | | | | *25* | | | | | *40* | | | *75* | | *35* | | |
| *evaporate from faeces* | *40* | | | | | *25* | | | | | *40* | | | *75* | | *35* | | |

*Emission factor for loose housing (former value) and tied housing (latter value).

### 2.1.4 Activity data

#### *2.1.4.2 Animal numbers and use of mineral fertilizers*

Numbers of cattle, pigs, poultry, goats and sheep and the use of mineral N-fertilizers for the years 1990–2015 (Appendix 3, TO BE ADDED) were acquired from the Information Centre of the Ministry of Agriculture and Forestry (Tike). Numbers of horses and ponies were based on the statistics of Suomen Hippos, the Finnish Trotting and Breeding Association, the numbers of fur animals on the statistics of the Finnish Fur Breeders' Association and the numbers of reindeer on the statistics of the Reindeer Herders' Association. Estimated animal numbers and mineral N-fertilizer use for the years 2015–2030 were based on the Dynamic regional sector model of Finnish agriculture, Dremfia (Lehtonen 2001) except for fur animals and reindeer, for which the numbers were estimated based on the numbers of the previous years assuming that there will not be any major changes in coming years.

#### *2.1.4.3 Manure management data*

Manure management data includes following information, on annual basis, for each animal category:
- shares of manure management systems (% of animals):
  - -slurry
  - deep litter
  - farm yard manure FYM (urine absorbed in litter)
  - solid manure (urine separated; produces two kind of manure: faeces and urine),
- detailed management practices of each manure type (including data on emission abatement measures; % of manure in each animal and manure category) and
- time spent at pasture and in yards (per animal category).

Detailed manure management information for the years 2005 and 2015 and estimates for the year 2020 can be found from Appendix 1.

The most recent agricultural ammonia emission estimates (2012-) are based on the manure management data collected from the livestock farms in the end of 2013 (results are partly published in Grönroos 2014). In Finland, there is no systematic collection of information on manure management systems and application methods. Because of this, manure management data for the previous years were based on some scattered data from the Information Centre of the Ministry of Agriculture and Forestry, and expert interviews, collected between the years 1995-2009 for the emission modelling purposes (see also Grönroos et al. 2009). Some changes were made to that old data due to the information acquired from the farm survey in 2013. For example, the survey provided new information on length of cattle grazing period. It proved that the length of the period was overestimated also for previous years, and was corrected respectively.

#### *2.1.4.4 Bedding material use and properties, cleaning water mixed with manure*

Only limited amount of bedding material usage data were available. Data on volume of cleaning water which is mixed with manure were poor as well. For more detailed information on bedding material use, see Luostarinen et al. 2017.

Data on litter properties were acquired from Kapuinen 1992 and Kapuinen 1996 (Table 7).

Table 7. Properties of litter materials.

| Bedding materials | Density (kg/m$^3$) | DM (% of fresh weight) | Ntot (% of fresh weight) | Ptot (% of fresh weight) | Psol (% of fresh weight) | Ktot (% of fresh weight) |
|---|---|---|---|---|---|---|
| Peat | 200 | 43 % | 0,34 % | 0,01 % | 0,01 % | 0,01 % |
| Saw dust | 285 | 50 % | 0,16 % | 0,02 % | 0,01 % | 0,05 % |
| Straw baled | 90 | 95 % | 0,45 % | 0,05 % | 0,03 % | 1,40 % |
| Straw loose | 40 | 95 % | 0,45 % | 0,05 % | 0,03 % | 1,40 % |
| Straw pelleted | 640 | 95 % | 0,45 % | 0,05 % | 0,03 % | 1,40 % |

| | | | | | | |
|---|---|---|---|---|---|---|
| Straw shredded | 75 | 95 % | 0,45 % | 0,05 % | 0,03 % | 1,40 % |
| Wood chips | 81 | 80 % | 0,25 % | 0,03 % | 0,01 % | 0,08 % |

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Appendix 1: Manure management data for 2005 and 2015 and prediction for 2020

All values: % of manure unless otherwise stated.

Table 1. General information on cattle manure management and grazing in Finland in 2005 and 2015 and as a prediction for 2020.

| | Dairy cows | | | Suckler cows | | | Heifers | | | Bulls | | | Calves <1 yr | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Manure management | | | | | | | | | | | | | | | |
| Treated as slurry (%) | 63 | 70 | 75 | 30 | 6 | 7 | 36 | 54 | 60 | 40 | 57 | 60 | 38 | 40 | 45 |
| Treated as deep litter (%) | 1 | 0 | 0 | 39 | 29 | 27 | 3 | 9 | 7 | 6 | 11 | 10 | 3 | 16 | 15 |
| Treated as solid manure (%), of which | 36 | 30 | 25 | 31 | 65 | 66 | 61 | 37 | 33 | 54 | 32 | 30 | 59 | 44 | 40 |
| urine not separated (%) | 50 | 23 | 23 | 50 | 91 | 91 | 50 | 58 | 58 | 50 | 88 | 88 | 50 | 63 | 63 |
| urine separated (%) | 50 | 77 | 77 | 50 | 9 | 9 | 50 | 42 | 42 | 50 | 12 | 12 | 50 | 37 | 37 |
| Grazing | | | | | | | | | | | | | | | |
| Grazing period (days) | 125 | 112 | 112 | 140 | 171 | 171 | 140 | 134 | 134 | 0 | 161 | 161 | 100 | 127 | 127 |
| Grazed animals (%) | 90 | 69 | 65 | 95 | 92 | 90 | 90 | 69 | 65 | 0 | 9 | 9 | 25 | 31 | 30 |
| Animals inside in nights (%) | 100 | 100 | 100 | 0 | 100 | 100 | 0 | 100 | 100 | 0 | 100 | 100 | 0 | 100 | 100 |
| Time inside at night (h) | 12 | 11 | 11 | 0 | 1 | 1 | 0 | 1,5 | 1,5 | 0 | 1 | 1 | 0 | 2 | 2 |
| Manure excreted on pasture (%) | 15 | 12 | 11 | 36 | 41 | 40 | 35 | 24 | 22 | 0 | 4 | 4 | 7 | 10 | 10 |

Table 2. General information on manure management and grazing of sheep, goats, horses, ponies, fur animals and reindeer in Finland in 2005 and 2015 and as a prediction for 2020.

| | Sheep & Goat | | | Horses & Ponies | | | Fur animals | Reindeer |
|---|---|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005-2020 | 2005-2020 |
| Manure management | | | | | | | | |
| Treated as slurry (%) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| Treated as deep litter (%) | 90 | 50 | 50 | 0 | 13 | 13 | 0 | - |
| Treated as solid manure (%), of which | 10 | 50 | 50 | 100 | 87 | 87 | 100 | - |
| urine not separated (%) | 100 | 100 | 100 | 100 | 99 | 99 | 100 | - |
| urine separated (%) | 0 | 0 | 0 | 0 | 1 | 1 | 0 | - |
| Grazing | | | | | | | | |
| Grazing period (days) | 130 | 153 | 153 | 140 | 180 | 180 | - | 365 |
| Grazed animals (%) | 90 | 90 | 90 | 95 | 97 | 97 | - | 100 |
| Animals inside in nights (%) | 0 | 100 | 100 | 0 | 100 | 100 | - | 0 |
| Time inside at night (h) | 0 | 2 | 2 | 0 | 6 | 6 | - | 0 |
| Manure excreted on pasture (%) | 32 | 35 | 35 | 36 | 36 | 36 | - | 100 |

Table 3. Percentages (%) of management methods for pig manure in Finland in 2005 and 2015 and as a prediction for 2020.

| | Sows | | | Fattening pigs | | | Boars | | | Weaned pigs | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Treated as slurry (%) | 30 | 82 | 90 | 80 | 98 | 100 | 30 | 82 | 90 | 80 | 90 | 90 |
| Treated as deep litter (%) | 5 | 0 | 0 | 5 | 1 | 0 | 5 | 0 | 0 | 5 | 4 | 4 |
| Treated as solid manure (%), of which | 65 | 18 | 10 | 15 | 1 | 0 | 65 | 18 | 10 | 15 | 6 | 6 |
| urine not separated (%) | 50 | 30 | 30 | 50 | 18 | 18 | 50 | 30 | 30 | 50 | 11 | 11 |
| urine separated (%) | 50 | 70 | 70 | 50 | 82 | 82 | 50 | 70 | 70 | 50 | 89 | 89 |

Table 4. Percentages (%) of management methods for poultry manure in Finland in 2005 and 2015 and as a prediction for 2020.

| | Laying hens | | | Broilers | Chickens | | | Cockerels | | | Broiler hens | Turkeys | Other poultry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2020 | 2005 – 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 - 2020 | 2005 - 2020 | 2005- 2020 |
| Slurry | 2 | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Deep litter | 5 | 22 | 22 | 100 | 5 | 40 | 40 | 5 | 50 | 50 | 100 | 100 | 40 |
| Solid manure | 93 | 69 | 69 | 0 | 95 | 60 | 60 | 95 | 50 | 50 | 0 | 0 | 60 |

Table 5. Detailed information on slurry management in animal shelters and manure storages in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total slurry per animal species.

| Abatement measures | Slurry | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cattle | | | Pigs | | | Poultry | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Animal shelter (% of manure) | | | | | | | | | |
| Improved cleaning of surfaces | 5 | 13 | 14 | 5 | 14 | 20 | 0 | 0 | 0 |
| Flushing | 0 | 1 | 2 | 0 | 2 | 4 | 0 | 0 | 0 |
| Manure removed more frequently | 5 | 3 | 4 | 5 | 3 | 4 | 0 | - | - |
| Rapid urine separation | - | - | - | - | - | - | - | - | - |
| Biological or chemical air scrubbers | 0 | 0 | 0 | 0 | 1 | 2 | 0 | - | - |
| Cooling of manure channels | - | 0 | 0 | - | 6 | 12 | - | - | - |
| Drying of manure on manure belt | - | - | - | - | - | - | - | - | - |
| Non-leaking drinking system | - | - | - | - | - | - | - | - | - |
| Manure storage (% of manure) | | | | | | | | | |
| No measures | 30 | 0 | 0 | 60 | 38 | 27 | 60 | 38 | 27 |
| Tight roof (concrete) | 20 | 2 | 2 | 20 | 3 | 3 | 20 | 3 | 3 |
| Semi-tight roof (floating covers) | 10 | 5 | 5 | 10 | 27 | 33 | 10 | 27 | 33 |
| Natural crust | 30 | 73 | 73 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tent, roof | 10 | 20 | 20 | 10 | 32 | 37 | 10 | 32 | 37 |
| Filling of storage from the bottom | 70 | 92 | 95 | 70 | 78 | 90 | 70 | 78 | 75 |

Table 6. Detailed information on deep litter management in animal shelters and manure storages in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total deep litter per animal species.

| Abatement measures | Deep litter | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle | | | Pigs | | | Poultry | | | Sheep + Goat | | | Horses | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Animal shelter (% of manure) | | | | | | | | | | | | | | | |
| Improved cleaning of surfaces | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Flushing | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Manure removed more frequently | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Rapid urine separation | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Biological or chemical air scrubbers | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cooling of manure channels | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Drying of manure on manure belt | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-leaking drinking system | - | - | - | - | - | - | - | 37 | 42 | - | - | - | - | - | - |
| Manure storage (% of manure) | | | | | | | | | | | | | | | |
| No measures | 65 | 62 | 60 | 65 | 62 | 60 | 65 | 62 | 60 | 65 | 62 | 60 | 45 | 45 | 39 |
| Tight roof (concrete) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Semi-tight roof (floating covers) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Natural crust | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tent, roof | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Solid manure covering | 35 | 38 | 40 | 35 | 38 | 40 | 35 | 38 | 40 | 35 | 38 | 40 | 55 | 55 | 61 |
| Filling of storage from the bottom | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Additional information | | | | | | | | | | | | | | | |
| Percentage of deep litter stored after removal from animal shelter | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |

Table 7. Detailed information on solid manure management in animal shelters and manure storages in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total solid manure per animal species.

| Abatement measures | Solid manure (urine + dung) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle | | | Pigs | | | Poultry | | | Sheep + Goat | | | Horses | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Animal shelter (% of manure) | | | | | | | | | | | | | | | |
| Improved cleaning of surfaces | - | 13 | 14 | - | 11 | 12 | - | 5 | 5 | - | 1 | 1 | - | 15 | 15 |
| Flushing | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Manure removed more frequently | - | 3 | 4 | - | 2 | 2 | - | 27 | 28 | - | 0 | 0 | - | 0 | 0 |
| Rapid urine separation | - | 1 | 2 | - | 5 | 5 | - | 0 | 0 | - | 0 | 0 | - | 0 | 0 |
| Biological or chemical air scrubbers | - | 0 | 0 | - | 1 | 1 | - | 4 | 5 | - | 0 | 0 | - | 0 | 0 |
| Cooling of manure channels | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Drying of manure on manure belt | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-leaking drinking system | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Manure storage (% of manure) | | | | | | | | | | | | | | | |
| Solid manure covering | 35 | 44 | 55 | 35 | 44 | 55 | 35 | 44 | 55 | 35 | 44 | 55 | 60 | 61 | 61 |
| Filling of storage from the bottom | 25 | 33 | 35 | 25 | 49 | 50 | 25 | 0 | 0 | 25 | 0 | 0 | 25 | 0 | 0 |

Table 8. Detailed information on urine and dung management in animal shelters and manure storages in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total urine and dung per animal species.

| Abatement measures | Urine | | | | | | Dung | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle | | | Pigs | | | Cattle | | | Pigs | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Animal shelter (% of manure) | | | | | | | | | | | | |
| Improved cleaning of surfaces | 0 | 13 | 14 | 0 | 11 | 12 | 5 | 13 | 14 | 5 | 11 | 12 |
| Flushing | - | - | - | - | - | - | - | - | - | - | - | - |
| Manure removed more frequently | - | - | - | - | - | - | 0 | 3 | 4 | 0 | 2 | 2 |
| Rapid urine separation | 5 | 1 | 2 | 5 | 1 | 2 | - | - | - | - | - | - |
| Biological or chemical air scrubbers | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| Cooling of manure channels | - | - | - | - | - | - | - | - | - | - | - | - |
| Drying of manure on manure belt | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-leaking drinking system | - | - | - | - | - | - | - | - | - | - | - | - |
| Manure storage (% of manure) | | | | | | | | | | | | |
| Tight roof (concrete) | 75 | 7 | 8 | 75 | 8 | 8 | - | - | - | - | - | - |
| Natural crust | - | - | - | - | - | - | - | - | - | - | - | - |
| Tent, roof, floating cover | - | 65 | 72 | - | 71 | 72 | - | - | - | - | - | - |
| Solid manure covering | - | - | - | - | - | - | 35 | 44 | 55 | 35 | 44 | 55 |
| Filling of storage from the bottom | - | - | - | - | - | - | 25 | 38 | 35 | 25 | 49 | 50 |

Table 9. Detailed information on slurry application in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total slurry per animal species.

| | Slurry | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Abatement measures | Cattle | | | Pigs | | | Poultry | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Type of surface for application | | | | | | | | | |
| Arable land | 65 | 31 | 31 | 65 | 44 | 44 | 65 | 44 | 44 |
| Plant covered land | 20 | 44 | 44 | 10 | 31 | 31 | 10 | 31 | 31 |
| Stubble | 15 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| | | | | | | | | | |
| Application on arable land | | | | | | | | | |
| Injection | 0 | 55 | 70 | 0 | 55 | 70 | 0 | 55 | 70 |
| Band spreading | 10 | 25 | 30 | 10 | 25 | 30 | 10 | 25 | 30 |
| Broadcast spreading | 90 | 20 | 0 | 90 | 20 | 0 | 90 | 20 | 0 |
| Of manure spread on soil surface: | | | | | | | | | |
| No incorporation | 10 | 9 | 0 | 10 | 7 | 0 | 10 | 7 | 11 |
| Incorp. with ploughing < 4 h | 0 | 9 | 10 | 0 | 14 | 15 | 0 | 14 | 15 |
| Incorp. with ploughing < 12 h | 0 | 12 | 14 | 0 | 10 | 11 | 0 | 10 | 11 |
| Incorp. with ploughing > 12 h | 0 | 20 | 22 | 0 | 19 | 20 | 0 | 19 | 20 |
| Incorp. with harrowing < 4 h | 5 | 15 | 16 | 5 | 23 | 24 | 5 | 23 | 24 |
| Incorp. with harrowing < 12 h | 45 | 14 | 16 | 45 | 12 | 13 | 45 | 12 | 13 |
| Incorp. with harrowing > 12 h | 40 | 20 | 22 | 40 | 16 | 17 | 40 | 16 | 17 |
| | | | | | | | | | |
| Application on plant covered land | | | | | | | | | |
| Broadcast spreading | 65 | 20 | 0 | 65 | 20 | 0 | 65 | 20 | 0 |
| Band spreading | 15 | 25 | 30 | 20 | 25 | 30 | 20 | 25 | 30 |
| Injection | 20 | 55 | 70 | 15 | 55 | 70 | 15 | 55 | 70 |
| | | | | | | | | | |
| Application on stubble | | | | | | | | | |
| Injection | 5 | 55 | 70 | 5 | 55 | 70 | 5 | 55 | 70 |
| Band spreading | 10 | 25 | 30 | 10 | 25 | 30 | 10 | 25 | 30 |
| Broadcast spreading | 85 | 55 | 0 | 85 | 55 | 0 | 85 | 55 | 0 |
| Of manure spread on soil surface: | | | | | | | | | |
| No incorporation | 10 | 8 | 0 | 10 | 7 | 0 | 10 | 7 | 0 |
| Incorp. with ploughing < 4 h | 5 | 13 | 14 | 5 | 11 | 12 | 5 | 11 | 12 |
| Incorp. with ploughing < 12 h | 40 | 14 | 15 | 40 | 20 | 21 | 40 | 20 | 21 |
| Incorp. with ploughing > 12 h | 45 | 26 | 27 | 45 | 21 | 22 | 45 | 21 | 22 |
| Incorp. with harrowing < 4 h | 0 | 14 | 15 | 0 | 14 | 15 | 0 | 14 | 15 |
| Incorp. with harrowing < 12 h | 0 | 12 | 13 | 0 | 13 | 14 | 0 | 13 | 14 |
| Incorp. with harrowing > 12 h | 0 | 14 | 16 | 0 | 14 | 16 | 0 | 14 | 16 |

Table 10. Detailed information on deep litter application in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total deep litter per animal species.

| | Deep litter | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abatement measures | Cattle | | | Pigs | | | Poultry | | | Sheep + Goat | | | Horses | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Type of surface for application | | | | | | | | | | | | | | | |
| Arable land | 100 | 68 | 68 | 100 | 88 | 88 | 100 | 88 | 88 | 100 | 68 | 68 | 100 | 76 | 76 |
| Plant covered land | 0 | 32 | 32 | 0 | 12 | 12 | 0 | 12 | 12 | 0 | 32 | 32 | 0 | 24 | 24 |
| Stubble | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Application on arable land | | | | | | | | | | | | | | | |
| No incorporation | 10 | 1 | 0 | 10 | 4 | 0 | 10 | 4 | 0 | 10 | 1 | 0 | 10 | 4 | 0 |
| Incorp. with ploughing < 4 h | 0 | 14 | 15 | 0 | 13 | 14 | 0 | 13 | 14 | 0 | 14 | 15 | 0 | 13 | 14 |
| Incorp. with ploughing < 12 h | 20 | 16 | 16 | 20 | 12 | 13 | 20 | 12 | 13 | 20 | 16 | 16 | 20 | 16 | 17 |
| Incorp. with ploughing > 12 h | 20 | 28 | 28 | 20 | 29 | 30 | 20 | 29 | 30 | 20 | 28 | 28 | 20 | 28 | 27 |
| Incorp. with harrowing < 4 h | 10 | 15 | 15 | 10 | 13 | 14 | 10 | 13 | 14 | 10 | 15 | 15 | 10 | 10 | 11 |
| Incorp. with harrowing < 12 h | 20 | 3 | 3 | 20 | 13 | 14 | 20 | 13 | 14 | 20 | 3 | 3 | 20 | 13 | 14 |
| Incorp. with harrowing > 12 h | 20 | 23 | 23 | 20 | 14 | 15 | 20 | 14 | 15 | 20 | 23 | 23 | 20 | 16 | 17 |
| Application on plant covered land | | | | | | | | | | | | | | | |
| Broadcast spreading | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Table 11. Detailed information on solid manure (urine + dung) application in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total solid manure per animal species.

| | Solid manure (urine + dung) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abatement measures | Cattle | | | Pigs | | | Poultry | | | Sheep + Goat | | | Horses | | | Fur animals | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Type of surface for application | | | | | | | | | | | | | | | | | | |
| Arable land | 96 | 68 | 68 | 100 | 88 | 88 | 100 | 88 | 88 | 98 | 68 | 68 | 98 | 76 | 76 | 95 | 95 | 95 |
| Plant covered land | 4 | 32 | 32 | 0 | 12 | 12 | 0 | 12 | 12 | 2 | 32 | 32 | 2 | 24 | 24 | 5 | 5 | 5 |
| Stubble | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Application on arable land | | | | | | | | | | | | | | | | | | |
| No incorporation | 10 | 1 | 0 | 10 | 4 | 0 | 10 | 4 | 0 | 10 | 1 | 0 | 10 | 4 | 0 | 30 | 30 | 0 |
| Incorp. with ploughing < 4 h | 0 | 14 | 15 | 0 | 13 | 14 | 0 | 13 | 14 | 0 | 14 | 15 | 0 | 13 | 14 | 0 | 0 | 14 |
| Incorp. with ploughing < 12 h | 20 | 16 | 16 | 20 | 12 | 13 | 20 | 12 | 13 | 20 | 16 | 16 | 20 | 16 | 17 | 0 | 0 | 13 |
| Incorp. with ploughing > 12 h | 20 | 28 | 28 | 20 | 29 | 30 | 20 | 29 | 30 | 20 | 28 | 28 | 20 | 26 | 27 | 60 | 60 | 30 |
| Incorp. with harrowing < 4 h | 10 | 15 | 15 | 10 | 13 | 14 | 10 | 13 | 14 | 10 | 15 | 15 | 10 | 10 | 11 | 0 | 0 | 14 |
| Incorp. with harrowing < 12 h | 20 | 3 | 3 | 20 | 13 | 14 | 20 | 13 | 14 | 20 | 3 | 3 | 20 | 13 | 14 | 0 | 0 | 14 |
| Incorp. with harrowing > 12 h | 20 | 23 | 23 | 20 | 14 | 15 | 20 | 14 | 15 | 20 | 23 | 23 | 20 | 16 | 17 | 10 | 10 | 15 |
| Application on plant covered land | | | | | | | | | | | | | | | | | | |
| Broadcast spreading | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Table 12. Detailed information on urine and dung application in Finland in 2005 and 2015 and as a prediction for 2020. Unit: percentage of total solid manure per animal species.

| | Urine | | | | | | Dung | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abatement measures | Cattle | | | Pigs | | | Cattle | | | Pigs | | |
| | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 | 2005 | 2015 | 2020 |
| Type of surface for application | | | | | | | | | | | | |
| Arable land | 50 | 17 | 17 | 50 | 23 | 23 | 96 | 68 | 68 | 100 | 88 | 88 |
| Plant covered land | 25 | 63 | 63 | 25 | 26 | 26 | 4 | 32 | 32 | 0 | 12 | 12 |
| Stubble | 25 | 20 | 20 | 25 | 51 | 51 | - | - | - | - | - | - |
| Application on arable land | | | | | | | | | | | | |
| Injection | 0 | 55 | 70 | 0 | 55 | 70 | - | - | - | - | - | - |
| Band spreading | 10 | 25 | 30 | 10 | 25 | 30 | - | - | - | - | - | - |
| Broadcast spreading | 90 | 20 | 0 | 90 | 20 | 0 | - | - | - | - | - | - |
| Of manure spread on soil surface: | | | | | | | | | | | | |
| No incorporation | 10 | 11 | 0 | 10 | 0 | 0 | 10 | 1 | 0 | 10 | 4 | 0 |
| Incorp. with ploughing < 4 h | 0 | 10 | 10 | 0 | 9 | 15 | 0 | 14 | 15 | 0 | 13 | 14 |
| Incorp. with ploughing < 12 h | 0 | 11 | 14 | 0 | 14 | 11 | 20 | 16 | 16 | 20 | 12 | 13 |
| Incorp. with ploughing > 12 h | 0 | 22 | 22 | 0 | 18 | 20 | 20 | 28 | 28 | 20 | 29 | 30 |
| Incorp. with harrowing < 4 h | 5 | 12 | 16 | 5 | 25 | 24 | 10 | 15 | 15 | 10 | 13 | 14 |
| Incorp. with harrowing < 12 h | 45 | 12 | 16 | 45 | 13 | 13 | 20 | 3 | 3 | 20 | 13 | 14 |
| Incorp. with harrowing > 12 h | 40 | 21 | 22 | 40 | 22 | 17 | 20 | 23 | 23 | 20 | 14 | 15 |
| Application on plant covered land | | | | | | | | | | | | |
| Broadcast spreading | 65 | 20 | 0 | 65 | 20 | 0 | 100 | 100 | 100 | 100 | 100 | 100 |
| Band spreading | 15 | 25 | 30 | 15 | 25 | 30 | - | - | - | - | - | - |
| Injection | 20 | 55 | 70 | 20 | 55 | 70 | - | - | - | - | - | - |
| Application on stubble | | | | | | | | | | | | |
| Injection | 5 | 55 | 70 | 5 | 55 | 70 | - | - | - | - | - | - |
| Band spreading | 10 | 25 | 30 | 10 | 25 | 30 | - | - | - | - | - | - |
| Broadcast spreading | 85 | 20 | 0 | 85 | 20 | 0 | - | - | - | - | - | - |
| Of manure spread on soil surface: | | | | | | | | | | | | |
| No incorporation | 10 | 13 | 0 | 10 | 3 | 0 | | | | | | |
| Incorp. with ploughing < 4 hrs | 5 | 14 | 14 | 5 | 12 | 12 | - | - | - | - | - | - |
| Incorp. with ploughing < 12 h | 40 | 13 | 15 | 40 | 14 | 21 | - | - | - | - | - | - |
| Incorp. with ploughing > 12 h | 45 | 27 | 27 | 45 | 26 | 22 | - | - | - | - | - | - |
| Incorp. with harrowing < 4 h | 0 | 10 | 15 | 0 | 18 | 15 | - | - | - | - | - | - |
| Incorp. with harrowing < 12 h | 0 | 6 | 13 | 0 | 14 | 14 | - | - | - | - | - | - |
| Incorp. with harrowing > 12 h | 0 | 17 | 16 | 0 | 15 | 16 | - | - | - | - | - | - |

Table 13. Shares of animal housing on Finnish cattle farms.

| Manure type | Housing type | Dairy cow | Suckler cow | Heifer >1 yr | Bulls >1 yr | Calf <1 yr |
|---|---|---|---|---|---|---|
| Slurry | Tied stall | 31 % | 38 % | 28 % | 10 % | 15 % |
| | Loose warm | 45 % | 24 % | 48 % | 30 % | 60 % |
| | Loose semiwarm | 23 % | 8 % | 12 % | 30 % | 20 % |
| | Loose cold | 1 % | 30 % | 12 % | 30 % | 5 % |
| Deep litter | Tied stall | 23 % | 0 % | 1 % | 0 % | 6 % |
| | Loose warm | 0 % | 2 % | 5 % | 5 % | 30 % |
| | Loose semiwarm | 24 % | 3 % | 19 % | 5 % | 25 % |
| | Loose cold | 53 % | 95 % | 75 % | 90 % | 39 % |
| Farmyard manure | Tied stall | 62 % | 4 % | 20 % | 7 % | 14 % |
| | Loose warm | 9 % | 1 % | 8 % | 3 % | 35 % |
| | Loose semiwarm | 2 % | 6 % | 8 % | 4 % | 20 % |
| | Loose cold | 27 % | 89 % | 64 % | 86 % | 31 % |
| Urine | Tied stall | 88 % | 30 % | 75 % | 80 % | 40 % |
| | Loose warm | 8 % | 0 % | 11 % | 8 % | 37 % |
| | Loose semiwarm | 1 % | 1 % | 4 % | 4 % | 10 % |
| | Loose cold | 3 % | 69 % | 10 % | 8 % | 13 % |
| Dung | Tied stall | 88 % | 30 % | 75 % | 80 % | 40 % |
| | Loose warm | 8 % | 0 % | 11 % | 8 % | 37 % |
| | Loose semiwarm | 1 % | 1 % | 4 % | 4 % | 10 % |
| | Loose cold | 3 % | 69 % | 10 % | 8 % | 13 % |

Appendix 2. Nitrogen excretion rates, as kg total N/animal place/yr (1980 – 2015).

| | Dairy cows | Suckler cows | Heifers >1 yr | Bulls >1 yr | Calves <1 yr | Sows (with piglets) | Fattening pigs (50- kg) | Boars | Veaned pigs (20-50 kg) | Laying hens | Broilers | Chickens | Cocerels | Broiler hens |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 78,9 | 61,2 | 36,6 | 40,8 | 24,3 | 27,8 | 19,6 | 19,3 | 9,7 | 0,63 | 0,4 | 0,353 | 0,969 | 0,99 |
| 1981 | 79,9 | 61,2 | 36,7 | 41,3 | 24,5 | 27,8 | 19,4 | 19,3 | 9,6 | 0,63 | 0,4 | 0,353 | 0,969 | 0,99 |
| 1982 | 80,8 | 61,2 | 36,8 | 41,8 | 24,7 | 27,8 | 19,3 | 19,2 | 9,5 | 0,63 | 0,4 | 0,353 | 0,969 | 0,99 |
| 1983 | 81,7 | 61,2 | 36,9 | 42,3 | 24,9 | 27,7 | 19,2 | 19,1 | 9,4 | 0,63 | 0,4 | 0,353 | 0,969 | 0,99 |
| 1984 | 82,7 | 61,2 | 37,0 | 42,8 | 25,1 | 27,7 | 19,1 | 19,0 | 9,4 | 0,63 | 0,4 | 0,353 | 0,969 | 0,99 |
| 1985 | 83,6 | 61,2 | 37,1 | 43,4 | 25,4 | 27,7 | 18,92 | 18,9 | 9,28 | 0,57 | 0,428 | 0,353 | 0,969 | 0,99 |
| 1986 | 84,5 | 61,4 | 37,1 | 43,6 | 25,6 | 27,9 | 18,83 | 18,9 | 9,22 | 0,59 | 0,426 | 0,353 | 0,969 | 0,99 |
| 1987 | 85,2 | 61,7 | 37,3 | 43,8 | 26,1 | 28,1 | 18,32 | 19,4 | 8,92 | 0,56 | 0,457 | 0,353 | 0,969 | 0,99 |
| 1988 | 86,0 | 62,0 | 37,4 | 43,8 | 26,0 | 28,2 | 18,34 | 19,5 | 8,88 | 0,56 | 0,454 | 0,353 | 0,969 | 0,99 |
| 1989 | 88,0 | 62,2 | 38,4 | 45,4 | 26,6 | 28,0 | 18,30 | 19,3 | 8,85 | 0,55 | 0,452 | 0,353 | 0,969 | 0,99 |
| 1990 | 91,3 | 62,5 | 39,5 | 47,1 | 27,2 | 28,4 | 18,30 | 19,6 | 8,81 | 0,57 | 0,449 | 0,3526 | 0,969 | 0,99 |
| 1991 | 91,5 | 62,8 | 40,0 | 47,8 | 27,4 | 28,4 | 17,99 | 19,7 | 8,77 | 0,58 | 0,425 | 0,3559 | 0,969 | 0,99 |
| 1992 | 92,0 | 63,2 | 39,9 | 47,7 | 27,5 | 28,1 | 17,80 | 19,4 | 8,74 | 0,58 | 0,376 | 0,3592 | 0,969 | 0,99 |
| 1993 | 93,7 | 63,5 | 41,6 | 49,0 | 28,5 | 28,1 | 17,58 | 19,3 | 8,75 | 0,61 | 0,401 | 0,3624 | 0,969 | 0,99 |
| 1994 | 96,1 | 63,9 | 42,2 | 49,9 | 28,9 | 28,0 | 17,50 | 19,1 | 8,76 | 0,60 | 0,399 | 0,3657 | 0,969 | 0,99 |
| 1995 | 96,6 | 64,2 | 42,3 | 50,0 | 29,1 | 27,5 | 17,39 | 19,1 | 8,54 | 0,59 | 0,396 | 0,369 | 0,969 | 0,99 |
| 1996 | 96,8 | 64,6 | 42,6 | 50,6 | 29,3 | 27,9 | 17,30 | 19,1 | 8,42 | 0,61 | 0,366 | 0,3723 | 0,969 | 0,99 |
| 1997 | 99,4 | 65,0 | 43,3 | 51,1 | 29,7 | 27,7 | 17,31 | 19,8 | 8,47 | 0,60 | 0,363 | 0,3755 | 0,969 | 0,99 |
| 1998 | 100,6 | 65,3 | 43,6 | 51,7 | 30,1 | 28,1 | 17,44 | 19,9 | 8,50 | 0,61 | 0,416 | 0,3788 | 0,969 | 0,99 |
| 1999 | 103,8 | 65,6 | 44,1 | 52,4 | 30,9 | 28,5 | 17,47 | 17,9 | 8,56 | 0,61 | 0,414 | 0,3821 | 0,969 | 0,99 |
| 2000 | 107,7 | 66,0 | 45,5 | 54,1 | 32,0 | 28,8 | 17,47 | 17,8 | 8,61 | 0,62 | 0,411 | 0,3854 | 0,969 | 0,99 |
| 2001 | 110,5 | 66,3 | 46,6 | 56,0 | 32,9 | 28,4 | 17,50 | 18,9 | 8,65 | 0,60 | 0,409 | 0,3886 | 0,969 | 0,99 |
| 2002 | 112,9 | 66,7 | 47,8 | 58,9 | 33,9 | 28,5 | 17,58 | 19,2 | 8,71 | 0,59 | 0,406 | 0,3886 | 0,969 | 0,99 |
| 2003 | 115,4 | 66,8 | 48,8 | 61,5 | 35,1 | 28,5 | 17,48 | 19,4 | 8,78 | 0,61 | 0,430 | 0,3886 | 0,969 | 0,99 |
| 2004 | 118,3 | 68,3 | 50,1 | 63,3 | 36,2 | 28,9 | 17,45 | 19,6 | 8,80 | 0,62 | 0,428 | 0,3886 | 0,969 | 0,99 |
| 2005 | 120,0 | 67,8 | 50,4 | 63,8 | 36,6 | 29,1 | 17,47 | 20,1 | 8,87 | 0,60 | 0,425 | 0,3885 | 0,969 | 0,99 |
| 2006 | 121,7 | 68,1 | 51,2 | 64,9 | 37,1 | 29,3 | 17,60 | 20,5 | 8,94 | 0,58 | 0,422 | 0,3885 | 0,969 | 0,99 |
| 2007 | 123,5 | 68,1 | 52,2 | 66,7 | 38,0 | 29,2 | 17,57 | 20,5 | 8,97 | 0,57 | 0,446 | 0,3885 | 0,969 | 0,99 |
| 2008 | 124,7 | 68,7 | 52,8 | 66,9 | 38,3 | 29,4 | 17,60 | 20,3 | 9,00 | 0,57 | 0,479 | 0,3885 | 0,969 | 0,99 |
| 2009 | 126,9 | 68,9 | 53,6 | 67,1 | 39,1 | 29,0 | 17,53 | 20,3 | 9,03 | 0,58 | 0,483 | 0,3885 | 0,969 | 0,99 |
| 2010 | 129,2 | 70,3 | 54,9 | 68,7 | 40,1 | 29,1 | 17,55 | 20,5 | 9,01 | 0,57 | 0,476 | 0,3885 | 0,969 | 0,99 |
| 2011 | 129,6 | 70,7 | 55,1 | 68,1 | 40,2 | 29,4 | 17,46 | 20,7 | 9,04 | 0,58 | 0,477 | 0,3885 | 0,969 | 0,99 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | 130,2 | 69,263 | 54,609 | 66,759 | 39,694 | 30,241 | 17,45 | 20,414 | 9,0714 | 0,598 | 0,477 | 0,388 | 0,891 | 0,99 |
| 2013 | 130,6 | 69,7 | 54,6 | 67,0 | 39,8 | 30,7 | 17,4 | 20,6 | 9,1 | 0,6 | 0,5 | 0,4 | 0,9 | 1,0 |
| 2014 | 130,92 | 70,048 | 54,601 | 67,298 | 39,942 | 31,192 | 17,34 | 20,689 | 9,0861 | 0,5736 | 0,4774 | 0,3885 | 0,969 | 0,992 |
| 2015 | 132,6 | 70,7 | 55,0 | 68,7 | 40,4 | 31,4 | 17,38 | 20,6 | 9,12 | 0,62 | 0,478 | 0,3885 | 0,97 | 0,99 |

| Year | Turkeys | Other poultry | Sheep with lambs | Goats with goatlings | Horses | Ponies | Minks and fitches | Foxes and racoons | Reindeer |
|---|---|---|---|---|---|---|---|---|---|
| 1980 | 1,074 | 0,62 | 8,5 | 10,7 | 61,8 | 43,7 | 1,244 | 2,13 | 10,70 |
| 1981 | 1,074 | 0,62 | 8,5 | 10,7 | 61,5 | 43,6 | 1,244 | 2,13 | 10,70 |
| 1982 | 1,074 | 0,62 | 8,5 | 10,7 | 61,2 | 43,5 | 1,244 | 2,13 | 10,70 |
| 1983 | 1,074 | 0,62 | 8,5 | 10,7 | 60,9 | 43,4 | 1,244 | 2,13 | 10,70 |
| 1984 | 1,074 | 0,62 | 8,5 | 10,7 | 60,5 | 43,3 | 1,244 | 2,13 | 10,70 |
| 1985 | 1,074 | 0,62 | 8,5 | 10,70 | 60,2 | 43,2 | 1,244 | 2,13 | 10,70 |
| 1986 | 1,076 | 0,62 | 8,5 | 10,70 | 60,2 | 42,9 | 1,244 | 2,13 | 10,70 |
| 1987 | 1,078 | 0,62 | 8,5 | 10,70 | 59,5 | 43,5 | 1,244 | 2,13 | 10,70 |
| 1988 | 1,078 | 0,62 | 8,5 | 10,70 | 59,6 | 43,4 | 1,244 | 2,13 | 10,70 |
| 1989 | 1,080 | 0,62 | 8,5 | 10,70 | 59,6 | 43,5 | 1,244 | 2,13 | 10,70 |
| 1990 | 1,080 | 0,62 | 8,46 | 10,70 | 59,4 | 43,4 | 1,244 | 2,13 | 10,70 |
| 1991 | 1,195 | 0,64 | 8,51 | 10,70 | 59,2 | 43,2 | 1,25 | 2,151 | 10,70 |
| 1992 | 1,206 | 0,63 | 8,58 | 10,70 | 59,1 | 43,2 | 1,256 | 2,172 | 10,70 |
| 1993 | 1,315 | 0,66 | 8,66 | 10,70 | 59,6 | 43,4 | 1,262 | 2,193 | 10,70 |
| 1994 | 1,240 | 0,66 | 8,73 | 10,70 | 60,1 | 43,9 | 1,268 | 2,214 | 10,70 |
| 1995 | 1,300 | 0,65 | 8,69 | 10,70 | 60,5 | 44,4 | 1,274 | 2,235 | 10,70 |
| 1996 | 1,285 | 0,67 | 8,85 | 10,70 | 60,5 | 44,2 | 1,28 | 2,256 | 10,70 |
| 1997 | 1,307 | 0,66 | 8,86 | 10,70 | 60,3 | 44,4 | 1,286 | 2,277 | 10,70 |
| 1998 | 1,336 | 0,67 | 8,97 | 10,70 | 60,0 | 44,3 | 1,292 | 2,298 | 10,70 |
| 1999 | 1,363 | 0,67 | 9,15 | 10,70 | 60,0 | 44,2 | 1,298 | 2,319 | 10,70 |
| 2000 | 1,423 | 0,68 | 9,32 | 10,70 | 60,1 | 44,1 | 1,305 | 2,34 | 10,70 |
| 2001 | 1,422 | 0,66 | 9,46 | 10,70 | 60,3 | 44,1 | 1,305 | 2,4225 | 10,70 |
| 2002 | 1,479 | 0,64 | 9,57 | 10,70 | 60,5 | 44,2 | 1,305 | 2,505 | 10,70 |
| 2003 | 1,483 | 0,67 | 9,60 | 10,70 | 60,8 | 44,2 | 1,305 | 2,5875 | 10,70 |
| 2004 | 1,532 | 0,68 | 9,64 | 10,70 | 61,0 | 44,0 | 1,305 | 2,67 | 10,70 |
| 2005 | 1,536 | 0,66 | 9,88 | 10,70 | 61,0 | 43,6 | 1,305 | 2,7525 | 10,70 |
| 2006 | 1,482 | 0,65 | 9,97 | 10,70 | 60,9 | 43,5 | 1,305 | 2,835 | 10,70 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | 1,497 | 0,64 | 9,97 | 10,70 | 61,0 | 43,3 | 1,305 | 2,9175 | 10,70 |
| 2008 | 1,499 | 0,64 | 9,97 | 10,70 | 60,9 | 43,2 | 1,305 | 3 | 10,70 |
| 2009 | 1,595 | 0,64 | 9,97 | 10,70 | 61,2 | 43,4 | 1,305 | 3 | 10,70 |
| 2010 | 1,606 | 0,64 | 9,97 | 10,70 | 61,1 | 43,5 | 1,305 | 3 | 10,70 |
| 2011 | 1,583 | 0,64 | 9,97 | 10,70 | 61,3 | 43,5 | 1,305 | 3 | 10,70 |
| 2012 | 1,6062 | 0,64 | 9,97 | 10,7 | 61,288 | 43,501 | 1,305 | 3 | 10,70 |
| 2013 | 1,6 | 0,6 | 10,0 | 10,7 | 61,5 | 43,8 | 1,3 | 3,0 | 10,7 |
| 2014 | 1,5946 | 0,6358 | 9,9744 | 10,7 | 61,715 | 44,022 | 1,305 | 3 | 10,7 |
| 2015 | 1,629 | 0,64 | 9,97 | 10,70 | 61,9 | 44,3 | 1,305 | 3 | 10,70 |

Appendix 3. Animal numbers (1980 – 2015 + projections)
>>TO BE ADDED<<