

## 3.D - Agricultural Soils

### Short description

| NFR-Code   | Name of Category  | Method   | AD     | EF  | State of reporting        |
|--|---|--|--------|---|---------------------------|
| <b>3.D</b>   | <b>Agricultural Soils</b>   |  |        |   |                           |
| <b>consisting of / including source categories</b> |   |  |        |   |                           |
| 3.D.a.1  | Inorganic N-fertilizers (includes also urea application)  | T2 (NH <sub>3</sub> ), T1 (for NO <sub>x</sub> )     | NS,RS  | D (NH <sub>3</sub> ), D (NO <sub>x</sub> )  |                           |
| 3.D.a.2.a  | Animal manure applied to soils  | T2, T3 (NH <sub>3</sub> ), T1 (for NO <sub>x</sub> ) | M      | CS (NH <sub>3</sub> ), D (NO <sub>x</sub> ) |                           |
| 3.D.a.2.b  | Sewage sludge applied to soils  | T1 (for NH <sub>3</sub> , NO <sub>x</sub> )          | NS, RS | D (NH <sub>3</sub> ), D (NO <sub>x</sub> )  |                           |
| 3.D.a.2.c  | Other organic fertilisers applied to soils (including compost)  | T2 (for NO <sub>x</sub> , NH <sub>3</sub> )          | M      | CS  |                           |
| 3.D.a.3  | Urine and dung deposited by grazing animals   | T1 (for NH <sub>3</sub> , NO <sub>x</sub> )          | NS,RS  | D   |                           |
| 3.D.c  | Farm-level agricultural operations including storage, handling and transport of agricultural products | T1 (for TSP, PM <sub>10</sub> , PM <sub>2.5</sub> )  | NS, RS | D   |                           |
| 3.D.d  | Off-farm storage, handling and transport of bulk agricultural products                                |  |        |   | NA & for Black Carbon, NR |
| 3.D.e  | Cultivated crops  | T2 (NMVOC)   | NS, RS | D   |                           |
| 3.D.f  | Agriculture other including use of pesticides   | T2 (HCB)   | NS     | D   |                           |

| Key Category | NOx | NMVOC | SO2 | NH3 | PM2_5 | PM10 | TSP | BC | CO | PB | Cd | Hg | Diox | PAH | HCB |
|--------------|-----|-------|-----|-----|-------|------|-----|----|----|----|----|----|------|-----|-----|
| 3.D.a.1      | L/- | -     | -   | L/T | -     | -    | -   | -  | -  | -  | -  | -  | -    | -   | -   |
| 3.D.a.2.a    | L/- | -     | -   | L/T | -     | -    | -   | -  | -  | -  | -  | -  | -    | -   | -   |
| 3.D.a.2.b    | -/- | -     | -   | -/- | -     | -    | -   | -  | -  | -  | -  | -  | -    | -   | -   |
| 3.D.a.2.c    | -/- | -     | -   | L/T | -     | -    | -   | -  | -  | -  | -  | -  | -    | -   | -   |
| 3.D.a.3      | -/- | -     | -   | -/- | -     | -    | -   | -  | -  | -  | -  | -  | -    | -   | -   |
| 3.D.c        | -   | -     | -   | -   | -/-   | L/-  | L/- | -  | -  | -  | -  | -  | -    | -   | -   |
| 3.D.e        | -   | -/-   | -   | -   | -     | -    | -   | -  | -  | -  | -  | -  | -    | -   | -   |
| 3.D.f        | -   | -     | -   | -   | -     | -    | -   | -  | -  | -  | -  | -  | -    | -   | L/- |

**T** = key source by Trend **L** = key source by Level

| Methods   |                                 |
|-----------|---------------------------------|
| <b>D</b>  | Default                         |
| <b>RA</b> | Reference Approach              |
| <b>T1</b> | Tier 1 / Simple Methodology *   |
| <b>T2</b> | Tier 2*                         |
| <b>T3</b> | Tier 3 / Detailed Methodology * |
| <b>C</b>  | CORINAIR                        |
| <b>CS</b> | Country Specific                |
| <b>M</b>  | Model                           |

\* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.

| AD - Data Source for Activity Data |                                      |
|------------------------------------|--------------------------------------|
| <b>NS</b>                          | National Statistics                  |
| <b>RS</b>                          | Regional Statistics                  |
| <b>IS</b>                          | International Statistics             |
| <b>PS</b>                          | Plant Specific data                  |
| <b>AS</b>                          | Associations, business organisations |
| <b>Q</b>                           | specific questionnaires, surveys     |
| EF - Emission Factors              |                                      |
| <b>D</b>                           | Default (EMEP Guidebook)             |
| <b>C</b>                           | Confidential                         |

|                               |  |
|-------------------------------|--|
| <b>EF - Emission Factors</b>  |  |
| <b>CS</b> Country Specific    |  |
| <b>PS</b> Plant Specific data |  |

## Country specifics



### NH<sub>3</sub> and NO<sub>x</sub>

In 2020, agricultural soils emitted 260.0 kt NH<sub>3</sub> or 50.7 % of the total agricultural NH<sub>3</sub> emissions in Germany (512.3 kt NH<sub>3</sub>). The main contributions to the total NH<sub>3</sub> emissions from agricultural soils are the application of manure (3.D.a.2.a), with 158.7 kt (61.0 %) and the application of inorganic N-fertilizers (3.D.a.1) with 50.1 kt (19.3 %).

Application of sewage sludge (3.D.a.2.b) contributes 0.7 % or 1.9 kt NH<sub>3</sub>.

The application of residues from the digestion of energy crops (3.D.a.2.c) leads to 37.0 kt NH<sub>3</sub> or 14.2 %. N excretions on pastures (3.D.a.3) have a share of 12.3 kt NH<sub>3</sub> or 4.7 %.

In 2020, agricultural soils were the source of 98.6 % (107.2 kt) of the total of NO<sub>x</sub> emissions in the agricultural category (108.7 kt). The NO<sub>x</sub> emissions from agricultural soils are primarily due to application of inorganic fertilizer (3.D.a.1) (50.1 %) and manure (3.D.a.2.a) (34.3 %). Application of residues from digested energy crops (3.D.a.2.c) contributes 10.8 % to agricultural soil emissions, 4.3 % are due to excretions on pastures (3.D.a.3). Emissions from application of sewage sludge (3.D.a.2.b) contribute 0.5 %.

### NMVOC

In 2020, the category of agricultural soils contributed 9.2 kt NMVOC or 3.1 % to the total agricultural NMVOC emissions in Germany. The only emission source was cultivated crops (3.D.e).

### TSP, PM<sub>10</sub> & PM<sub>2.5</sub>

In 2020, agricultural soils contributed, respectively, 28.7 % (17.3 kt), 57.2 % (17.3 kt) and 15.1 % (0.7 kt) to the total agricultural TSP, PM<sub>10</sub> and PM<sub>2.5</sub> emissions (60.3 kt, 30.2 kt, 4.4 kt, respectively). The emissions are reported in category 3.D.c (Farm-level agricultural operations including storage, handling and transport of agricultural products).

### 3.D.a.1 - Inorganic N-fertilizers

The calculation of NH<sub>3</sub> and NO<sub>x</sub> (NO) emissions from the application of inorganic fertilizers is described in Vos et al. (2022), Chapter 11.1 <sup>1)</sup>.

#### Activity Data

German statistics report the amounts of fertilizers sold which are assumed to equal the amounts that are applied. Since the 2021 submission, storage effects are approximated by applying a moving average to the sales data (moving centered three-year average, for the last year a weighted two-year average, which assigns 2/3 of the weight to the last year).

Table 1: AD for the estimation of NH<sub>3</sub> and NO<sub>x</sub> emissions from application of inorganic fertilizers

| Application of inorganic fertilizers in Gg N |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|  | 1990  | 1995  | 2000  | 2005  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
| Application of fertilizers (total)           | 2'196 | 1'723 | 1'922 | 1'797 | 1'635 | 1'665 | 1'692 | 1'655 | 1'716 | 1'736 | 1'731 | 1'622 | 1'499 | 1'404 | 1'362 |
| Calcium ammonium nitrate                     | 1'368 | 1'044 | 982   | 824   | 689   | 708   | 680   | 644   | 633   | 618   | 605   | 571   | 543   | 520   | 508   |
| Nitrogen solutions (urea AN)                 | 127   | 223   | 261   | 236   | 180   | 187   | 181   | 173   | 173   | 172   | 171   | 162   | 151   | 137   | 132   |
| Urea   | 243   | 180   | 247   | 290   | 362   | 323   | 348   | 342   | 391   | 417   | 433   | 377   | 310   | 248   | 225   |
| Ammonium phosphates                          | 85    | 55    | 66    | 55    | 64    | 71    | 77    | 78    | 82    | 84    | 82    | 77    | 65    | 64    | 63    |
| Other NK and NPK                             | 246   | 162   | 175   | 126   | 63    | 66    | 73    | 71    | 72    | 67    | 62    | 54    | 52    | 51    | 52    |
| Other straight fertilizers                   | 127   | 60    | 191   | 266   | 277   | 311   | 331   | 348   | 365   | 377   | 377   | 381   | 378   | 383   | 383   |

#### Methodology

NH<sub>3</sub> emissions from the application of inorganic fertilizers are calculated using the Tier 2 approach according to EMEP (2019)-3D-14ff <sup>2)</sup>, distinguishing between various fertilizer types, see Table 2. For NO<sub>x</sub>, the Tier 1 approach described in EMEP (2019) [10]-3D-11 is applied.

#### Emission factors

The emission factors for NH<sub>3</sub> depend on fertilizer type, see EMEP (2019)-3D-15. Table 2 lists the EMEP emission factors for the fertilizers used in the inventory. In order to reflect average German conditions the emission factors for cool climate and a pH value lower than 7 was chosen. For urea fertilizer the German fertilizer ordinance prescribes the use of urease inhibitors or the immediate incorporation into the soil from 2020 onwards. The NH<sub>3</sub> emission factor for urea fertilizers is therefore reduced by 70% from 2020 onwards, according to Bittman et al. (2014, Table 15) <sup>3)</sup>.

Table 2: NH<sub>3</sub>-EF for inorganic fertilizers

| Inorganic fertilizers, emission factors in kg NH <sub>3</sub> per kg fertilizer N |                         |
|---|-------------------------|
| Fertilizer type   | EF                      |
| Calcium ammonium nitrate  | 0.008                   |
| Nitrogen solutions (UREA AN)  | 0.098                   |
| Urea  | 0.155 (in 2020: 0.0465) |
| Ammonium phosphates   | 0.050                   |
| Other NK and NPK  | 0.050                   |
| Other straight fertilizers  | 0.010                   |

For NO<sub>x</sub>, the simpler methodology by EMEP (2019)-3D-11 was used. The emission factor 0.040 from EMEP, 2019-3D, Table 3.1 has the units of kg N<sub>2</sub>O per kg fertilizer N and was derived from Stehfest and Bouwman (2006) <sup>4)</sup>. The German inventory uses the emission factor 0.012 kg NO-N per kg N derived from Stehfest and Bouwman (2006). This is equivalent to an emission factor of 0.03943 kg NO<sub>x</sub> per kg fertilizer N (obtained by multiplying 0.012 kg NO-N per kg N with the molar weight ratio 46/14 for NO<sub>2</sub>: NO). The inventory uses the unrounded emission factor.

Table 3: Emission factor for NO<sub>x</sub> emissions from fertilizer application

| Emission factor    | kg NO-N per kg fertilizer N | kg NO <sub>x</sub> per kg fertilizer N |
|--------------------|-----------------------------|--|
| EF <sub>fert</sub> | 0.012                       | 0.039                                  |

### Trend discussion for Key Sources

In the last years (and up to 2019 in dramatic fashion) fertilizer sales have decreased. Emissions have fallen accordingly. This is even more pronounced for NH<sub>3</sub> than for NO<sub>x</sub>, as total NH<sub>3</sub> from the application of mineral fertilizers is, until the year 2019, very strongly correlated with the amount of urea applied (R<sup>2</sup> = 0.89), the sales of which have decreased more than for all other mineral fertilizers. Since 2020 the negative trend is reinforced as urea fertilizer have to be either used with urease inhibitors or have to be incorporated into the soil directly, which causes 70% lower emissions (Bittman et al. 2014).

### Recalculations

Table REC-1 shows the effects of recalculations on NH<sub>3</sub> and NO<sub>x</sub> emissions. The only differences are in 2019 as the year 2020 is now included in the weighted average.

Table REC-1: Comparison of NH<sub>3</sub> and NO<sub>x</sub> emissions from fertilizer application of the submissions (SUB) 2021 and 2022

| NH <sub>3</sub> and NO <sub>x</sub> emissions from fertilizer application, in Gg |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|  | SUB  | 1990  | 1995  | 2000  | 2005  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
| NH <sub>3</sub>  | 2022 | 78.82 | 69.56 | 85.64 | 86.36 | 88.43 | 83.96 | 88.04 | 85.95 | 93.92 | 97.89 | 99.73 | 89.25 | 76.79 | 65.63 | 36.97 |
| NH <sub>3</sub>  | 2021 | 78.82 | 69.56 | 85.64 | 86.36 | 88.43 | 83.96 | 88.04 | 85.95 | 93.92 | 97.89 | 99.73 | 89.25 | 76.79 | 68.09 |       |
| NO <sub>x</sub>  | 2022 | 86.57 | 67.94 | 75.77 | 70.84 | 64.48 | 65.66 | 66.71 | 65.25 | 67.65 | 68.46 | 68.24 | 63.95 | 59.11 | 55.34 | 53.71 |
| NO <sub>x</sub>  | 2021 | 86.57 | 67.94 | 75.77 | 70.84 | 64.48 | 65.66 | 66.71 | 65.25 | 67.65 | 68.46 | 68.24 | 63.95 | 59.11 | 55.97 |       |

### Planned improvements

No improvements are planned at present.

## 3.D.a.2.a - Animal manure applied to soils

In this sub category Germany reports the NH<sub>3</sub> and NO<sub>x</sub> (NO) emissions from application of manure (including application of anaerobically digested manure). For an overview see Vos et al. (2022), Chapter 11.2.

### Activity data

The calculation of the amount of N in manure applied is based on the N mass flow approach (see 3.B). It is the total of N excreted by animals in the housing and the N imported with bedding material minus N losses by emissions of N species from housing and storage. Hence, the amount of total N includes the N contained in anaerobically digested manures to be applied to the field.

The frequencies of application techniques and incorporation times as well as the underlying data sources are described in Vos et al. (2022), Chapter 3.4.3. The frequencies are provided e. g. in the NIR 2022<sup>5)</sup>, Chapter 19.3.2.

Table 4: AD for the estimation of NH<sub>3</sub> and NO<sub>x</sub> emissions from application of manure

| Application of manure in Gg N |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| 1990                          | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |  |
| 1'120                         | 972  | 954  | 924  | 928  | 933  | 949  | 961  | 972  | 972  | 966  | 961  | 947  | 940  | 932  |  |

### Methodology

NH<sub>3</sub> emissions from manure application are calculated separately for each animal species in the mass flow approach by multiplying the respective TAN amount with NH<sub>3</sub> emission factors for the various manure application techniques. For details see [3-b-manure-management 3.B] and Vos et al. (2022), Chapter 4 to 8 and 11.3. For NO<sub>x</sub> emissions from manure

application the inventory calculates NO<sub>x</sub> emissions (see Vos et al. (2022), Chapter 11.2, that are subsequently converted into NO<sub>x</sub> emissions by multiplying with the molar weight ratio 46/14. The Tier 1 approach for the application of inorganic fertilizer as described in EMEP (2019)-3D-11 is used, as no specific methodology is available for manure application.

## Emission factors

Table 5 shows the time series of the overall German NH<sub>3</sub> IEF defined as the ratio of total NH<sub>3</sub>-N emission from manure application to the total amount of N spread with manure.

Table 5: IEF for NH<sub>3</sub>-N from application of manure

| IEF in kg NH <sub>3</sub> -N per kg N in applied manure |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1990  | 1995  | 2000  | 2005  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
| 0.202   | 0.187 | 0.180 | 0.168 | 0.162 | 0.162 | 0.157 | 0.155 | 0.152 | 0.150 | 0.148 | 0.147 | 0.145 | 0.143 | 0.140 |

For NO<sub>x</sub> the same emission factor as for the application of inorganic fertilizer was used (see Table 3).

## Trend discussion for Key Sources

Both NH<sub>3</sub> and NO<sub>x</sub> emissions from the application of animal manures are key sources. Total NO<sub>x</sub> is calculated proportionally to the total N in the manures applied which decreased remarkably from 1990 to 1991 due to the decline in animal numbers following the German reunification (reduction of livestock numbers in Eastern Germany). In the 1990s and 2000s this was followed by a weakened decline in animal manure amounts. From 2010 to 2014 there was a slight increase and since then the amount of N in manure applied has been slightly declining again, see Table 4. The NO<sub>x</sub> emissions follow these trends. For total NH<sub>3</sub> emissions there is a slight negative trend. This is due to the increasing use of application practices with lower NH<sub>3</sub> emission factors.

## Recalculations

Table REC-2 shows the effects of recalculations on NH<sub>3</sub> and NO<sub>x</sub>. The total emissions of NH<sub>3</sub> and NO<sub>x</sub> from application of manure are slightly lower than those of last year's submission from the year 2000 onwards for NH<sub>3</sub>, from the year 2010 onwards for NO<sub>x</sub>. In earlier years the emissions are slightly higher than in last year's submission.

These differences are predominantly caused by the update of data from the official agricultural census 2020 as well as the update of the suckler-cow model and the new raw protein contents in feed of fattening pigs and broilers, see [main page of the agricultural sector](#), list of **recalculation reasons, No. 1, 4, 7 and 8**.

Much smaller is the impact of the updates of activity data for male cattle > 2 years, pigs, poultry and sheep (see **recalculation reasons 5, 6 and 9 through 12**) Further details on recalculations are described in Vos et al. (2022), Chapter 3.5.2.

Table REC-2: Comparison of the NH<sub>3</sub> and NO<sub>x</sub> emissions of the submissions (SUB) 2021 and 2022

| NH <sub>3</sub> and NO <sub>x</sub> emissions from application of manure, in Gg |      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
|---|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|   | SUB  | 1990   | 1995   | 2000   | 2005   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   |
| NH <sub>3</sub>   | 2022 | 275.21 | 221.15 | 208.05 | 188.31 | 182.09 | 183.07 | 180.74 | 181.30 | 179.97 | 177.25 | 174.11 | 171.06 | 166.32 | 162.64 | 158.67 |
| NH <sub>3</sub>   | 2021 | 273.67 | 220.82 | 208.69 | 190.07 | 185.28 | 186.32 | 184.07 | 184.62 | 183.26 | 180.08 | 179.11 | 178.15 | 175.65 | 174.11 |        |
| NO <sub>x</sub>   | 2022 | 44.14  | 38.33  | 37.61  | 36.42  | 36.58  | 36.81  | 37.43  | 37.88  | 38.34  | 38.31  | 38.07  | 37.91  | 37.35  | 37.05  | 36.76  |
| NO <sub>x</sub>   | 2021 | 43.46  | 37.99  | 37.41  | 36.35  | 36.71  | 36.99  | 37.67  | 38.18  | 38.70  | 38.58  | 38.39  | 38.27  | 37.80  | 37.54  |        |

## Planned improvements

No improvements are planned at present.

### 3.D.a.2.b - Sewage sludge applied to soils

The calculation of  $\text{NH}_3$  and  $\text{NO}_x$  ( $\text{NO}$ ) emissions from application of sewage sludge is described in Vos et al. (2022), Chapter 11.4.

#### Activity data

N quantities from application of sewage sludge were calculated from data of the German Environment Agency and (since 2009) from data of the Federal Statistical Office (see Table 6).

Table 6: AD for the estimation of  $\text{NH}_3$  and  $\text{NO}_x$  emissions from application of sewage sludge

| Application of sewage sludge in Gg N |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|--------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1990                                 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| 27                                   | 35   | 33   | 27   | 26   | 25   | 25   | 22   | 21   | 19   | 19   | 14   | 12   | 14   | 14   |

#### Methodology

A tier 1 methodology is used (EMEP, 2019, 3D, Chapter 3.3.1).  $\text{NH}_3$  and  $\text{NO}_x$  emissions are calculated by multiplying the amounts of N in sewage sludge applied with the respective emission factors.

#### Emission factors

EMEP (2019)-3.D, Table 3-1 provides a Tier 1 emission factor for  $\text{NH}_3$  (0.13 kg  $\text{NH}_3$  per kg N applied) emissions from application of sewage sludge. The German inventory uses the equivalent emission factor in  $\text{NH}_3\text{-N}$  units which is 0.11 kg  $\text{NH}_3\text{-N}$  per kg N applied (cf. the derivation of the emission factor described in the appendix of EMEP (2019)-3D, page 26-27). For  $\text{NO}_x$  the same emission factor like for the application of inorganic fertilizer was used (see Table 3).

#### Trend discussion for Key Sources

$\text{NH}_3$  and  $\text{NO}_x$  emissions from the application of sewage sludge are no key sources.

#### Recalculations

Table REC-3 shows the effects of recalculations on  $\text{NH}_3$  and  $\text{NO}_x$  emissions. The only change compared to last year's submission occurs for the year 2018 and 2019 due to the update of the activity data (see [main page of the agricultural sector](#), **recalculation No 15**). Further details on recalculations are described in Vos et al. (2022), Chapter 3.5.2.

Table REC-3: Comparison of the  $\text{NH}_3$  and  $\text{NO}_x$  emissions of the submissions (SUB) 2021 and 2022

| NH <sub>3</sub> and NO <sub>x</sub> emissions from application of sewage sludge, in Gg |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|--|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|  | SUB  | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| NH <sub>3</sub>  | 2022 | 3.66 | 4.71 | 4.40 | 3.66 | 3.48 | 3.35 | 3.33 | 2.87 | 2.85 | 2.50 | 2.50 | 1.89 | 1.67 | 1.90 | 1.90 |
| NH <sub>3</sub>  | 2021 | 3.66 | 4.71 | 4.40 | 3.66 | 3.48 | 3.35 | 3.33 | 2.87 | 2.85 | 2.50 | 2.50 | 1.89 | 1.73 | 1.73 |      |
| NO <sub>x</sub>  | 2022 | 1.08 | 1.39 | 1.30 | 1.08 | 1.03 | 0.99 | 0.98 | 0.85 | 0.84 | 0.74 | 0.74 | 0.56 | 0.49 | 0.56 | 0.56 |
| NO <sub>x</sub>  | 2021 | 1.08 | 1.39 | 1.30 | 1.08 | 1.03 | 0.99 | 0.98 | 0.85 | 0.84 | 0.74 | 0.74 | 0.56 | 0.51 | 0.51 |      |

#### Planned improvements

No improvements are planned at present.

### 3.D.a.2.c - Other organic fertilizers applied to soils

This sub category describes Germany's  $\text{NH}_3$  and  $\text{NO}_x$  ( $\text{NO}$ ) emissions from application of residues from digested energy crops. For details see Vos et al. (2022), Chapters 10.2 and 11.3.

#### Activity data

Activity data is the amount of N in residues from anaerobic digestion of energy crops when leaving storage. This amount of N is the N contained in the energy crops when being fed into the digestion process minus the N losses by emissions of N species from the storage of the residues (see 3.I). N losses from pre-storage are negligible and there are no N losses from fermenter (see Vos et al. (2022), Chapter 10.2.1).

Table 7: AD for the estimation of  $\text{NH}_3$  and  $\text{NO}_x$  emissions from application of residues from anaerobic digestion of energy crops

| Application of residues from digested energy plants in Gg N |      |      |       |        |        |        |        |        |        |        |        |        |        |        |
|---|------|------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1990  | 1995 | 2000 | 2005  | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   |
| 0.05  | 0.62 | 5.40 | 45.76 | 167.41 | 209.32 | 230.52 | 279.13 | 292.42 | 303.81 | 302.16 | 297.19 | 292.86 | 293.08 | 293.08 |

#### Methodology

The  $\text{NH}_3$  emissions are calculated the same way as the  $\text{NH}_3$  emissions from application of animal manure (3.D.a.2.a). The frequencies of application techniques and incorporation times as well as the underlying data sources are provided e. g. in the NIR 2022, Chapter 19.3.2. The amounts of TAN in the residues applied are obtained from the calculations of emissions from the storage of the digested energy crops (3.I).

For  $\text{NO}_x$  emissions from application of residues the Tier 1 approach for the application of inorganic fertilizer as described in EMEP (2019)-3D-11 is used. The inventory calculates  $\text{NO}$  emissions that are subsequently converted into  $\text{NO}_x$  emissions by multiplying with the molar weight ratio 46/30.

#### Emission factors

For  $\text{NH}_3$  the emission factors for untreated cattle slurry were adopted, see Vos et al. (2022), Chapter 10.2. As the  $\text{NO}_x$  method for fertilizer application is used for the calculation of  $\text{NO}_x$  emissions from the application of residues, the emission factor for fertilizer application was used (see Vos et al. (2022), Chapter 11.1)

Table 8 shows the implied emission factors for  $\text{NH}_3$  emissions from application of residues from digested energy crops.

Table 8: IEF for  $\text{NH}_3$ -N

| IEF in kg $\text{NH}_3$ -N per kg N in digested energy crops |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1990   | 1995  | 2000  | 2005  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
| 0.182  | 0.182 | 0.183 | 0.183 | 0.183 | 0.184 | 0.174 | 0.166 | 0.159 | 0.153 | 0.150 | 0.148 | 0.146 | 0.143 | 0.141 |

#### Trend discussion for Key Sources

The application of residues from anaerobic digestion of energy crops is a key source for  $\text{NH}_3$ . Emissions are dominated by the amounts of N in the substrates fed into the digestion process and to a lesser extent by the increased use of application techniques with lower emission factors. They have become important since about 2005 and have risen sharply until 2013. Since then, they have changed little each year and tend to decrease slightly in the last few years. The latter is mostly due to a small negative trend of the amounts of energy crops digested.

#### Recalculations

Table REC-4 shows the effects of recalculations on  $\text{NH}_3$  and  $\text{NO}_x$  emissions. The only changes compared to last year's submission occur for the years 2015-2019, due to the use of new data on manure spreading techniques from the official



agricultural census 2020 (see [main page of the agricultural sector](#), list of **recalculation reasons, No 1 and 16**, and Vos et al. (2022), Chapter 3.5.2.)

Table REC-4: Comparison of the  $\text{NH}_3$  and  $\text{NO}_x$  emissions of the submissions (SUB) 2021 and 2022

| <b><math>\text{NH}_3</math> and <math>\text{NO}_x</math> emissions from application of digested energy crops, in Gg</b> |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |
|---|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|   | SUB  | 1990 | 1995 | 2000 | 2005  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
| $\text{NH}_3$   | 2022 | 0.01 | 0.14 | 1.20 | 10.15 | 37.27 | 46.75 | 48.81 | 56.27 | 56.56 | 56.42 | 55.16 | 53.47 | 51.82 | 50.98 | 50.12 |
| $\text{NH}_3$   | 2021 | 0.01 | 0.14 | 1.20 | 10.15 | 37.27 | 46.75 | 48.81 | 56.27 | 56.56 | 56.42 | 56.11 | 55.37 | 54.63 | 54.63 |       |
| $\text{NO}_x$   | 2022 | 0.00 | 0.02 | 0.21 | 1.80  | 6.60  | 8.25  | 9.09  | 11.01 | 11.53 | 11.98 | 11.91 | 11.72 | 11.55 | 11.56 | 11.56 |
| $\text{NO}_x$   | 2021 | 0.00 | 0.02 | 0.21 | 1.80  | 6.60  | 8.25  | 9.09  | 11.01 | 11.53 | 11.98 | 11.91 | 11.72 | 11.55 | 11.55 |       |

### Planned improvements

No improvements are planned at present.

## 3.D.a.3 - Urine and dung deposited by grazing animals

The calculation of  $\text{NH}_3$  and  $\text{NO}_x$  ( $\text{NO}$ ) emissions from N excretions on pasture is described in Vos et al. (2022), Chapter 11.5.

### Activity data

Activity data for  $\text{NH}_3$  emissions during grazing is the amount of TAN excreted on pasture while for  $\text{NO}_x$  emissions it is the amount of N excreted on pasture.

Table 9 shows the N excretions on pasture. The TAN excretions are derived by multiplying the N excretions with the relative TAN contents provided in 3.B, Table 2.

Table 9: N excretions on pasture

| <b>N excretions on pasture in % of total N excreted</b> |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
|   | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |  |
| Dairy cows  | 20.3 | 15.6 | 12.7 | 11.3 | 10.3 | 10.1 | 9.8  | 9.5  | 9.2  | 8.9  | 8.6  | 8.3  | 8.0  | 7.7  | 7.4  |  |
| Other cattle  | 15.1 | 17.3 | 18.9 | 19.0 | 19.4 | 19.5 | 19.6 | 19.7 | 19.9 | 20.3 | 20.5 | 20.7 | 20.9 | 21.2 | 21.5 |  |
| Sheep   | 55.1 | 55.5 | 55.1 | 55.4 | 54.8 | 55.1 | 55.1 | 55.2 | 55.3 | 55.4 | 55.4 | 55.4 | 55.6 | 55.5 | 55.4 |  |
| Goats   | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 | 34.2 |  |
| Horses  | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 |  |

### Methodology

$\text{NH}_3$  emissions from grazing are calculated by multiplying the respective animal population (3.B, Table 1) with corresponding N excretions and relative TAN contents (3.B, Table 2) and the fraction of N excreted on pasture (Table 9). The result is multiplied with the animal specific emission factor (Table 10).  $\text{NO}$  emissions are calculated the same way with the exception that the emission factor is related to N excreted instead of TAN.

### Emission Factors

The emission factors for  $\text{NH}_3$  are taken from EMEP (2019)-3B-31, Table 3.9. They relate to the amount of TAN excreted on pasture. Following the intention of EMEP, 2019-3D, Table 3.1, the inventory uses for  $\text{NO}_x$  the same emission factor as for the application of inorganic fertilizer (see Table 3). In order to obtain  $\text{NO}_x$  emissions (as  $\text{NO}_2$ ) the  $\text{NO-N}$  emission factor of 0.12 kg  $\text{NO-N}$  per kg N excreted is multiplied by 46/14.

Table 10: Emission factors for emissions of  $\text{NH}_3$  and  $\text{NO}$  from grazing



| Emission factors |  |
|------------------|--|
| Dairy cows       | 0.14 kg NH <sub>3</sub> -N per kg TAN excreted |
| Other cattle     | 0.14 kg NH <sub>3</sub> -N per kg TAN excreted |
| Horses           | 0.35 kg NH <sub>3</sub> -N per kg TAN excreted |
| Sheep, goats     | 0.09 kg NH <sub>3</sub> -N per kg TAN excreted |
| All animals      | 0.012 kg NO <sub>x</sub> -N per kg N excreted  |

### Trend discussion for Key Sources

Emissions from urine and dung deposited by grazing animals are no key sources.

### Recalculations

Table REC-5 shows the effects of recalculations on NH<sub>3</sub> and NO<sub>x</sub> emissions.

Because overall N excretions on pasture are lower than in last year's submission for dairy cattle, but higher for other cattle (predominantly due to new cattle grazing data from the official agricultural census 2020 and the update of the suckler-cow models, see [main page of the agricultural sector](#), list of **recalculation reasons, No 1 and 2**), NO<sub>x</sub> emissions are lower than in last year's submission. However, although NH<sub>3</sub> emissions could be expected to show the same pattern, they are slightly higher than in the last submission in 1990-2013 and slightly lower than in last year's submission from 2014 onwards. This is due to a combination of two effects: The TAN content of the suckler cows' N-excretions is higher in the new suckler-cow model, which leads to higher emissions over the whole time series. This is over-compensated by declining dairy cow grazing times from 2014 onwards, which leads to lower emissions (see list of **recalculation reasons, No 1 and 2**). Further details on recalculations are described in Vos et al. (2022), Chapter 3.5.2.

Table REC-5: Comparison of the NH<sub>3</sub> and NO<sub>x</sub> emissions of the submissions (SUB) 2021 and 2022

| NH <sub>3</sub> and NO <sub>x</sub> emissions from grazing, in Gg |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|---|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|   | SUB  | 1990  | 1995  | 2000  | 2005  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
| NH <sub>3</sub>   | 2022 | 22.23 | 18.15 | 16.26 | 14.35 | 13.80 | 13.43 | 13.29 | 13.37 | 13.40 | 13.40 | 13.20 | 13.03 | 12.74 | 12.56 | 12.30 |
| NH <sub>3</sub>   | 2021 | 22.16 | 18.04 | 16.10 | 14.21 | 13.61 | 13.30 | 13.22 | 13.35 | 13.43 | 13.51 | 13.34 | 13.20 | 12.93 | 12.78 |       |
| NO <sub>x</sub>   | 2022 | 8.40  | 6.82  | 6.14  | 5.45  | 5.23  | 5.08  | 5.02  | 5.04  | 5.06  | 5.05  | 4.97  | 4.90  | 4.79  | 4.73  | 4.62  |
| NO <sub>x</sub>   | 2021 | 8.44  | 6.89  | 6.22  | 5.53  | 5.30  | 5.17  | 5.15  | 5.20  | 5.25  | 5.29  | 5.24  | 5.20  | 5.13  | 5.10  |       |

### Planned improvements

No improvements are planned at present.

## 3.D.c - Farm-level agricultural operations including storage, handling and transport of agricultural products

In this category Germany reports TSP, PM<sub>10</sub> and PM<sub>2.5</sub> emissions from crop production according to EMEP (2019)-3D-11. For details see Vos et al. (2022), Chapter 11.14.

### Activity data

The activity data is the total area of arable and horticultural land. This data is provided by official statistics.

Table 11: AD for the estimation of TSP, PM<sub>10</sub> and PM<sub>2.5</sub> emissions from soils

| Arable and horticultural land in 1000*ha |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |
|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|
| 1990                                     | 1995   | 2000   | 2005   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   |  |
| 11'179                                   | 10'257 | 10'683 | 10'902 | 11'411 | 11'431 | 11'421 | 11'478 | 11'475 | 11'346 | 11'281 | 11'273 | 11'181 | 11'163 | 11'071 |  |

## Methodology

As the Tier 2 methodology described in EMEP (2019)-3D-17 cannot be used due to lack of input data, the Tier 1 methodology described in EMEP(2019)-3D-11 is used.

## Emission factors

Emission factors given in EMEP (2019)-3D-12 are used. The Guidebook does not indicate whether EFs have considered the condensable component (with or without).

Table 12: Emission factors for PM emissions from agricultural soils

| Emission factor     | kg ha <sup>-1</sup> |
|---------------------|---------------------|
| EF <sub>TSP</sub>   | 1.56                |
| EF <sub>PM10</sub>  | 1.56                |
| EF <sub>PM2.5</sub> | 0.06                |

## Trend discussion for Key Sources

TSP and PM<sub>10</sub> are key sources. Emissions depend only on the areas covered. These are relatively constant, with a very slight decrease over the past 10 years.

## Recalculations

Table REC-6 shows the effects of recalculations on particulate matter emissions. There are minor changes with respect to last year's submission in several years because of updates of cultivation areas (see [main page of the agricultural sector](#), list of **recalculation reasons, No 17**). However, due to the data format in Table REC-6, these differences are not visible. Further details on recalculations are described in Vos et al. (2022), Chapter 3.5.2.

Table REC-6: Comparison of particle emissions (TSP, PM<sub>10</sub> & PM<sub>2.5</sub>) of the submissions (SUB) 2021 and 2022

| TSP, PM <sub>10</sub> , PM <sub>2.5</sub> emissions from crop production, in Gg |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|---|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|   | SUB  | 1990  | 1995  | 2000  | 2005  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
| TSP   | 2022 | 17.44 | 16.00 | 16.67 | 17.01 | 17.80 | 17.83 | 17.82 | 17.91 | 17.90 | 17.70 | 17.60 | 17.59 | 17.44 | 17.41 | 17.27 |
| TSP   | 2021 | 17.44 | 16.00 | 16.67 | 17.01 | 17.80 | 17.83 | 17.82 | 17.91 | 17.90 | 17.70 | 17.60 | 17.59 | 17.44 | 17.41 |       |
| PM <sub>10</sub>  | 2022 | 17.44 | 16.00 | 16.67 | 17.01 | 17.80 | 17.83 | 17.82 | 17.91 | 17.90 | 17.70 | 17.60 | 17.59 | 17.44 | 17.41 | 17.27 |
| PM <sub>10</sub>  | 2021 | 17.44 | 16.00 | 16.67 | 17.01 | 17.80 | 17.83 | 17.82 | 17.91 | 17.90 | 17.70 | 17.60 | 17.59 | 17.44 | 17.41 |       |
| PM <sub>2.5</sub>   | 2022 | 0.67  | 0.62  | 0.64  | 0.65  | 0.68  | 0.69  | 0.69  | 0.69  | 0.69  | 0.68  | 0.68  | 0.68  | 0.67  | 0.67  | 0.66  |
| PM <sub>2.5</sub>   | 2021 | 0.67  | 0.62  | 0.64  | 0.65  | 0.68  | 0.69  | 0.69  | 0.69  | 0.69  | 0.68  | 0.68  | 0.68  | 0.67  | 0.67  |       |

## Planned improvements

No improvements are planned at present.

## 3.D.e - Cultivated crops

In this category Germany reports NMVOC emissions from crop production according to EMEP (2019)-3D-16. For details see Vos et al. (2022), Chapter 11.12.

## Activity data

The activity data is the total area of arable land and grassland. This data is provided by official statistics.

Table 13: AD for the estimation of NMVOC emissions from crop production

| Arable land and grassland in 1000*ha |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|
| 1990                                 | 1995   | 2000   | 2005   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | 2020   |  |
| 16'506                               | 15'312 | 15'498 | 15'561 | 15'734 | 15'752 | 15'729 | 15'769 | 15'802 | 15'719 | 15'662 | 15'647 | 15'570 | 15'563 | 15'447 |  |

## Methodology

The Tier 2 methodology described in EMEP (2019)-3D-16ff is used.

## Emission Factors

The emission factors for wheat, rye, rape and grass (15°C) given in EMEP (2019)-3D-16, Table 3.3 were used. For all grassland areas the grass (15°C) EF is used, for all other crops except rye and rape the EF of wheat is used. Table 14 shows the implied emission factors for NMVOC emissions from crop production. The implied emission factor is defined as ratio of the total NMVOC emissions from cultivated crops to the total area given by activity data.

Table 14: IEF for NMVOC emissions from crop production

| IEF for NMVOC emissions from crop production in kg ha <sub>-1</sub> |      |      |      |      |      |      |      |      |      |      |      |      |      |      |  |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|--|
| 1990  | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |  |
| 0.47  | 0.53 | 0.57 | 0.59 | 0.61 | 0.57 | 0.64 | 0.66 | 0.72 | 0.63 | 0.62 | 0.62 | 0.50 | 0.55 | 0.59 |  |

## Trend discussion for Key Sources

NMVOC emissions from crop production are no key sources.

## Recalculations

Table REC-7 shows the effects of recalculations on NMVOC emissions. There are minor changes with respect to last year's submission in several years because of updates of yields (see [main page of the agricultural sector](#), list of **recalculation reasons, No 17**). However, due to the data format in Table REC-6, these differences are not visible. Further details on recalculations are described in Vos et al. (2022), Chapter 3.5.2.

Table REC-7: Comparison of NMVOC emissions of the submissions (SUB) 2021 and 2022

| NMVOC emissions from crop production, in Gg |      |      |      |      |      |      |       |       |       |      |      |      |      |      |      |
|---|------|------|------|------|------|------|-------|-------|-------|------|------|------|------|------|------|
| SUB   | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012  | 2013  | 2014  | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| 2022  | 7.69 | 8.19 | 8.79 | 9.17 | 9.53 | 9.03 | 10.05 | 10.36 | 11.40 | 9.91 | 9.69 | 9.74 | 7.82 | 8.56 | 9.16 |
| 2021  | 7.69 | 8.19 | 8.79 | 9.17 | 9.53 | 9.03 | 10.05 | 10.36 | 11.40 | 9.91 | 9.69 | 9.74 | 7.82 | 8.56 |      |

## Planned improvements

No improvements are planned at present.

## Uncertainty

Details are described in [chapter 1.7](#).

<sup>1)</sup>

Vos et al. (2022): Vos C., Rösemann C., Haenel H-D., Dämmgen U., Döring U., Wulf S., Eurich-Menden B., Freibauer A., Döhler H., Schreiner C., Osterburg B. & Fuß, R. (2022): Calculations of gaseous and particulate emissions from German Agriculture 1990 –2020. Report on methods and data (RMD), Submission 2022. Thünen Report (in preparation).

<https://www.thuenen.de/de/ak/arbeitsbereiche/emissionsinventare/>

<sup>2)</sup>

EMEP (2019): EMEP/EEA air pollutant emission inventory guidebook – 2019, EEA Report No 13/2019,

<https://www.eea.europa.eu/publications/emep-eea-guidebook-2019>.

<sup>3)</sup>

Bittman, S., Dedina, M., Howard C.M., Oenema, O., Sutton, M.A., (eds) (2014): Options for Ammonia Mitigation. Guidance from the UNECE task Force on Reactive Nitrogen. Centre for Ecology and Hydrology, Edinburgh, UK.

<sup>4)</sup>

Stehfest E., Bouwman L. (2006): N<sub>2</sub>O and NO emission from agricultural fields and soils under natural vegetation: summarizing available measurement data and modelling of global emissions. Nutr. Cycl. Agroecosyst. 74, 207 – 228.

<sup>5)</sup>

NIR (2022): National Inventory Report 2022 for the German Greenhouse Gas Inventory 1990-2019. Available in April 2022.