3.D - Agricultural Soils

Short description

NFR-Code	Name of Category	Method	AD	EF	State of reporting
3.D	**Agricultural Soils**				
consisting of / including source categories					
3.D.a.1	Inorganic N-fertilizers (includes also urea application)	T2 (NH_3), T1 (for NO_x)	NS,RS	D (NH_3), D (NO_x)	
3.D.a.2.a	Animal manure applied to soils	T2, T3 (NH_3), T1 (for NO_x)	M	CS (NH_3), D (NO_x)	
3.D.a.2.b	Sewage sludge applied to soils	T1 (for NH_3,NO_x)	NS, RS	D (NH_3), D (NO_x)	
3.D.a.2.c	Other organic fertilisers applied to soils (including compost)	T2 (for NO_x, NH_3)	M	CS	
3.D.a.3	Urine and dung deposited by grazing animals	T1 (for NH_3, NO_x)	NS,RS	D	
3.D.c	Farm-level agricultural operations including storage, handling and transport of agricultural products	T1 (for TSP, PM_{10}, $PM_{2.5}$)	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	NO_x	NMVOC	SO_2	NH_3	$PM_{2.5}$	PM_{10}	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	
D	Default
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/EEA Emission Inventory Guidebook - 2019, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
As	Associations, business organisations
Q	specific Questionnaires (or surveys)
M	Model / Modelled
C	Confidential

EF - Emission Factors	
D	Default (EMEP Guidebook)

C	Confidential
CS	Country Specific
PS	Plant Specific data
M	Model / Modelled

Country specifics

NH_3 and NO_x

In 2021, agricultural soils emitted 270.8 kt NH_3 or 56.1 % of the total agricultural NH_3 emissions in Germany (482.3 kt NH_3). The main contributions to the total NH_3 emissions from agricultural soils are the application of manure (3.D.a.2.a), with 167.4 kt (61.8 %) and the application of other organic N-fertilizers (3.D.a.2.c) with 54.3 kt (20.1 %).

Application of synthetic N-fertilizers (3.D.a.1) contributes 34.9 kt NH_3 (12.9 %). N excretions on pastures (3.D.a.3) have a share of 12.5 kt NH_3 (4.6 %) and the application of sewage sludge (3.D.a.2.b) leads to 1.7 kt NH_3 (0.6 %).

In 2021, agricultural soils were the source of 98.6 % (106.5 kt) of the total of NO_x emissions in the agricultural category (108.0 kt). The NO_x emissions from agricultural soils are primarily due to application of inorganic fertilizer (3.D.a.1) (48.0 %) and manure (3.D.a.2.a) (34 %). Application of other organic N-fertilizers (3.D.a.2.c) contributes 13.1 % 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 2021, the category of agricultural soils contributed 9.4 kt NMVOC or 3.2 % to the total agricultural NMVOC emissions in Germany. The only emission source was cultivated crops (3.D.e).

TSP, PM_{10} & $PM_{2.5}$

In 2021, agricultural soils contributed, respectively, 34.6 % (21.0 kt), 63.0 % (21.0 kt) and 31.1 % (1.6 kt) to the total agricultural TSP, PM_{10} and $PM_{2.5}$ emissions (60.6 kt, 33.3 kt, 5.3 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_3 and NOx (NO) emissions from the application of synthetic fertilizers is described in Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2 [1)].

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_3 and NOx emissions from application of synthetic fertilizers

Application of synthetic fertilizers in Gg N																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
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	1,327	1,301
Calcium ammonium nitrate	1,368	1,044	982	824	689	708	680	644	633	618	605	571	543	520	497	488
Nitrogen solutions (urea AN)	127	223	261	236	180	187	181	173	173	172	171	162	151	137	133	132
Urea	243	180	247	290	362	323	348	342	391	417	433	377	310	248	209	188
Ammonium phosphates	85	55	66	55	64	71	77	78	82	84	82	77	65	64	58	58
Other NK and NPK	246	162	175	126	63	66	73	71	72	67	62	54	52	51	51	50
Other straight fertilizers	127	60	191	266	277	311	331	348	365	377	377	381	378	383	379	384

Methodology

NH_3 emissions from the application of synthetic fertilizers are calculated using the Tier 2 approach according to EMEP (2019)-3D-14ff [2)], distinguishing between various fertilizer types, see Table 2. For NO_x, the Tier 1 approach described in EMEP (2019) [10]-3D-11 is applied.

Emission factors

The emission factors for NH_3 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 NH3 emission factor for urea fertilizers is therefore reduced by 70% from 2020 onwards, according to Bittman et al. (2014, Table 15)[3)].

Table 2: NH_3-EF for synthetic fertilizers

Synthetic fertilizers, emission factors in kg NH_3 per kg fertilizer N	
Fertilizer type	**EF**
Calcium ammonium nitrate	0.008
Nitrogen solutions (UREA AN)	0.098
Urea	0.155 (from 2020: 0.0465)
Ammonium phosphates	0.050
Other NK and NPK	0.050
Other straight fertilizers	0.010

For NO_x, 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_2O per kg fertilizer N and was derived from Stehfest and Bouwman (2006)[4)]. 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_x per kg fertilizer N (obtained by multiplying 0.012 kg NO-N per kg N with the molar weight ratio 46/14 for NO_2: NO). The inventory uses the unrounded emission factor.

Table 3: Emission factor for NO_x emissions from fertilizer application

Emission factor	kg NO-N per kg fertilizer N	kg NO_x per kg fertilizer N
EF_{fert}	0.012	0.039

Trend discussion for Key Sources

In the last years (and ufrom 2016 to 2020 in dramatic fashion) fertilizer sales have decreased. Emissions have fallen accordingly. This is even more pronounced for NH_3 than for NO_x, as total NH_3 from the application of mineral fertilizers is, until the year 2019, very strongly correlated with the amount of urea applied (R2 = 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_3 and NO_x emissions. The only differences are in 200 as the year 2021 is now included in the weighted average.

Table REC-1: Comparison of NH_3 and NO_x emissions from fertilizer application of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from fertilizer application, in Gg																	
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NH_3	2023	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	35.94	34.87
NH_3	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	
NO_x	2023	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	52.31	51.30
NO_x	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	

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_3 and NO_x (NO) emissions from application of manure (including application of anaerobically digested manure). An overview is given in Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2.

Germany uses the Tier 2 methodology for estimating NMVOC emissions for cattle in sector 3.B (manure management). The use of this methodology yields NMVOC emissions which formally could be reported in the sectors 3.D.a.2.a and 3.D.a.3 (grazing emissions). However, to be congruent with the NMVOC emissions for other animal categories, Germany reports these emissions in the NMVOC emissions reported from manure management (3.B). For the NFR codes 3.D.a.2.a and 3.D.a.3 the notation key IE is used for NMVOC emissions.

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 Rösemann et al. (2023), Chapter 2.5. The frequencies are provided e. g. in the NIR 2023[5], Chapter 19.3.2.

Table 4: AD for the estimation of NH_3 and NO_x 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**	**2021**
1,129	983	965	934	938	944	961	973	985	984	978	974	959	951	943	917

Methodology

NH_3 emissions from manure application are calculated separately for each animal species in the mass flow approach by multiplying the respective TAN amount with NH_3 emission factors for the various manure application techniques. For details see [3-b-manure-management 3.B] and Rösemann et al. (2023), Chapter 5.2.1.2. For NO_x emissions from manure application the inventory calculates NO-N emissions (see Rösemann et al. (2023), Chapter 5.2.2.2, that are subsequently converted into NO_x emissions by multiplying with the molar weight ratio 46/14. The Tier 1 approach for the application of synthetic 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_3 IEF defined as the ratio of total NH_3-N emission from manure application to the total amount of N spread with manure.

Table 5: IEF for NH_3–N from application of manure

IEF in kg NH_3-N per kg N in applied manure															
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
0.208	0.194	0.187	0.174	0.168	0.169	0.165	0.164	0.162	0.160	0.158	0.156	0.154	0.152	0.149	0.150

For NO_x the same emission factor as for the application of synthetic fertilizer was used (see Table 3).

Trend discussion for Key Sources

Both NH_3 and NO_x emissions from the application of animal manures are key sources. Total NO_x 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_x emissions follow these trends. For total NH_3 emissions there is a slight negative trend. This is due to the increasing use of application practices with lower NH_3 emission factors.

Recalculations

Table REC-2 shows the effects of recalculations on NH_3 and NO_x. For all years the total emissions of NH_3 and NO_x from application of manure are significantly higher than those of last year's submission.

These differences are predominantly caused by **recalculation No. 2 (deep bedding)**. Most of the other recalculations reasons (except **No. 12-15**) have an effect on emissions from application of manure, some are increasing the emissions (**No.6 air scrubbing**) others are lowering the emissions (**No. 8 protein use in pig fattening**), some lead to changes in both directions (**No. 1 new interpolation of 2020 agricultural census data**), see main page of the agricultural sector, list of recalculation reasons.

Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-2: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from application of manure, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
NH_3	2023	285.58	231.79	218.55	197.69	191.85	193.59	192.17	193.77	193.29	191.19	188.04	184.84	179.85	176.00	170.65	167.43
NH_3	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	
NO_x	2023	44.52	38.77	38.04	36.84	37.00	37.24	37.88	38.36	38.83	38.80	38.56	38.39	37.82	37.51	37.16	36.15
NO_x	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	

Planned improvements

No improvements are planned at present.

3.D.a.2.b – Sewage sludge applied to soils

The calculation of NH_3 and NO_x (NO) emissions from application of sewage sludge is described in Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2.

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 NH_3 and 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**	**2021**
27	35	33	27	26	25	25	22	21	19	19	14	12	14	13	13

Methodology

A tier 1 methodology is used (EMEP, 2019, 3D, Chapter 3.3.1). NH_3 and 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 NH_3 (0.13 kg NH3 per kg N applied) emissions from application of sewage sludge. The German inventory uses the equivalent emission factor in NH_3-N units which is 0.11 kg NH_3-N per kg N applied (cf. the derivation of the emission factor described in the appendix of EMEP (2019)-3D, page 26-27). For NO_x the same emission factor like for the application of synthetic fertilizer was used (see Table 3).

Trend discussion for Key Sources

NH_3 and NO_x emissions from the application of sewage sludge are no key sources.

Recalculations

Table REC-3 shows the effects of recalculations on NH_3 and NO_x emissions. The only change compared to last year's submission occurs for the year 2020 due to the update of the activity data (see main page of the agricultural sector, **recalculation No 13**. Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-3: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from application of sewage sludge, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
NH_3	2023	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	1.67	1.67
NH_3	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	
NO_x	2023	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	0.49	0.49
NO_x	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	

Planned improvements

No improvements are planned at present.

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

This sub category containes the total of Germany's NH_3 and NO_x (NO) emissions from application of

- residues from digested energy crops,

- residues from digested waste,

- compost from biowaste, and

- compost from green waste.

For details see Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2.

Activity data

Activity data is the amount of N in residues from anaerobic digestion of energy crops and waste and of compost from biowaste and green waste when leaving storage. For energy crops this 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 Rösemann et al. (2023), Chapter 5.1). For residues from digested waste, compost from biowaste and compost from green waste the amount of N was derived from the waste statistics of the Federal Statistical Office (see Rösemann et al. (2023), Chapter 2.8.4).

Table 7: AD for the estimation of NH_3 and NO_x emissions emissions from application of other organic fertilizers

Application of other organic fertilizers in Gg N																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Residues, digested energy crops	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	299.41	299.41
Residues, digested waste	0.00	0.00	1.55	4.97	10.46	10.93	11.02	11.83	13.94	15.05	13.97	13.79	14.00	13.75	13.40	13.03
Compost, biowaste	4.51	19.54	31.87	28.82	22.64	23.93	23.94	21.75	23.59	22.59	23.34	21.90	25.14	24.31	25.42	25.52
Compost, greenwaste	1.13	4.90	7.67	9.46	11.27	11.26	12.42	10.82	13.23	13.67	14.29	14.87	14.92	15.89	16.74	16.78
Total	5.68	25.07	46.49	89.01	211.78	255.44	277.91	323.53	343.18	355.13	353.77	347.74	346.91	347.03	354.98	354.74

Methodology

The NH_3 emissions are calculated the same way as the 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 2023, Chapter 19.3.2. It is assumed that residues of digested waste are applied in the same way and have the same emission factors as residues from digested energy crops. For compost from biowaste and green waste it is assumed that they are applied in the same way and have the same emission factors like cattle solid manure. The amounts of TAN in the residues from digested energy crops applied are obtained from the calculations of emissions from the storage of the digested energy crops (3.I). The amounts of TAN in the residues from digested waste, compost from biowaste and compost from green waste are derived from industry data (provided by Bundesgütegemeinschaft Kompost, BGK).

For NO_x emissions the Tier 1 approach for the application of synthetic fertilizer as described in EMEP (2019)-3D-11 is used. The inventory calculates NO emissions that are subsequently converted into NO_x emissions by multiplying with the molar weight ratio 46/30.

Emission factors

For NH_3 the emission factors for untreated cattle slurry were adopted for residues from digested energy crops and residues from waste. The emission factors for cattle solid manure were adopted for compost from biowaste and compost from green waste, see Rösemann et al. (2023), Chapters 5.2.1.2 and 5.2.2.2 As the NO_x method for fertilizer application is used for the calculation of NO_x emissions from the application of residues, the emission factor for fertilizer application was used (see Table 3).

Table 8 shows the implied emission factors for NH_3 emissions from application of other organic fertilizers.

Table 8: IEF for NH_3-N emissions from application of other organic fertilizers

IEF in kg NH3-N per kg N of other organic fertilizers																
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Residues, digested energy crops	0.182	0.182	0.183	0.183	0.183	0.184	0.174	0.166	0.159	0.153	0.150	0.147	0.144	0.141	0.139	0.139
Residues, digested waste	0.000	0.000	0.192	0.193	0.193	0.189	0.195	0.196	0.183	0.171	0.164	0.156	0.163	0.162	0.163	0.162
Compost, biowaste	0.038	0.038	0.038	0.036	0.034	0.035	0.033	0.033	0.033	0.032	0.032	0.032	0.029	0.033	0.034	0.036
Compost, greenwaste	0.014	0.014	0.014	0.014	0.013	0.014	0.013	0.014	0.014	0.015	0.015	0.020	0.013	0.012	0.012	0.012
Total	0.034	0.037	0.056	0.118	0.159	0.163	0.156	0.153	0.146	0.141	0.137	0.135	0.131	0.128	0.126	0.126

Trend discussion for Key Sources

The application of other organic fertilizers is a key source for NH_3. Emissions are dominated by the emissions from digested energy crops. 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 the increasing use of application practices with lower NH_3 emission factors.

Recalculations

Table REC-4 shows the effects of recalculations on NH_3 and NO_x emissions. For all years the total emissions of NH_3 and NO_x from application of other organic fertilizers are significantly higher than those of last year's submission. The main reason for that is, that the emissions from application of residues from digested waste, compost of biowaste and compost of green waste are reported for the first time in the agriculture sector (see main page of the agricultural sector, list of recalculation **reasons, No 14**, and Rösemann et al. (2023), Chapter 1.3)

Table REC-4: Comparison of the NH3 and NOx emissions from application of other organic fertilizers of the submissions (SUB) 2022 and 2023

NH_3 and NO_x emissions from application of digested energy crops, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
NH_3	2023	0.24	1.12	3.15	12.72	40.83	50.45	52.59	60.14	60.84	60.66	58.87	56.82	55.02	53.96	54.33	54.31
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	
NO_x	2023	0.22	0.99	1.83	3.51	8.35	10.07	10.96	12.76	13.53	14.00	13.95	13.71	13.68	13.68	14.00	13.99
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	

Planned improvements

No improvements are planned at present.

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

The calculation of NH_3 and NO_x (NO) emissions from N excretions on pasture is described in Rösemann et al. (2023), Chapters 5.2.1.1 and 5.2.2.1.

Activity data

Activity data for NH_3 emissions during grazing is the amount of TAN excreted on pasture while for NO_x emissions it is the amount of N excreted on pasture.

Table 9 shows the share of N excretions on pasture. The TAN excretions are derived by multiplying the share of N excretion on pastures with the N excretions and TAN contents provided in 3.B, Table 2.

Table 9: Share of N excretions on pasture

	N excretions on pasture in % of total N excreted															
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Dairy cows	20.3	15.6	12.7	11.4	10.0	9.7	9.4	9.2	8.9	8.6	8.3	8.0	7.6	7.4	7.4	7.4
Other cattle	15.1	17.3	18.9	19.0	19.6	19.7	19.8	19.9	20.1	20.5	20.7	20.9	21.2	21.4	21.5	21.4
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	55.5
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	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	20.5
Laying hens	0.1	0.1	0.5	1.1	1.7	1.9	2.0	2.1	2.3	2.3	2.4	2.3	2.5	2.6	2.8	2.8

Methodology

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). 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 NH_3 are taken from EMEP (2019)-3B-31, Table 3.9. They relate to the amount of TAN excreted on pasture. For laying hens there is no emission factor given in this table. Germany uses an emission factor of 0.35 kg NH3-N per kg TAN excreted, based on an expert judgement from KTBL (see Rösemann et al. 2023, Chapter 5.2.1.1). The same EF is used by UK. Following the intention of EMEP, 2019-3D, Table 3.1, the inventory uses for NO_x the same emission factor as for the application of synthetic fertilizer (see Table 3). In order to obtain NO_x emissions (as NO_2) the NO-N emission factor of 0.12 kg NO-N per kg N excreted is multiplied by 46/14.

Table 10: Emission factors for emissions of NH_3 and NO from grazing

Emission factors	
Dairy cows	0.14 kg NH3-N per kg TAN excreted
Other cattle	0.14 kg NH3-N per kg TAN excreted
Horses	0.35 kg NH3-N per kg TAN excreted
Sheep, goats	0.09 kg NH3-N per kg TAN excreted
Laying hens	0.35 kg NH3-N per kg TAN excreted
All animals	0.012 kg NO-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_3 and NO_x emissions.

For all years the total emissions of NH_3 and NO_x from grazing are slightly higher than those of last year's submission. The main reason for that is the introduction of pasture emissions from free-range laying hens see (see main page of the agricultural sector, list of **recalculations, No 10**). Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-5: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2022 and 2023

NH$_3$ and NO$_x$ emissions from grazing, in Gg																	
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
NH_3	2023	22.24	18.17	16.32	14.48	13.91	13.58	13.49	13.61	13.66	13.67	13.48	13.29	13.05	12.89	12.68	12.47
NH_3	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	
NO_x	2023	8.40	6.82	6.15	5.48	5.22	5.07	5.02	5.05	5.07	5.06	4.98	4.91	4.81	4.74	4.67	4.59
NO_x	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	

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_{10} and $PM_{2.5}$ emissions from crop production according to EMEP (2019)-3D-17. For details see Rösemann et al. (2023), Chapter 5.2.4.

Activity data

The activity data is the total area of agricultural land (arable land, grassland and horticultural land). This data is provided by official statistics.

Table 11: AD for the estimation of TSP, PM_{10} and $PM_{2.5}$ 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

The Tier 2 methodology used is described in EMEP (2019)-3D-17.

Emission factors

Emission factors given in EMEP (2019)-3D-18, Tables 3.5 and 3.7 are used with the exception of „Harvesting“ PM_{10}-factors for Wheat, Rye, Barley and Oat which were taken from the Danish IIR. These Guidebook-EFs are obviously too high by a factor of 10 and were corrected in the Danish IIR. The missing default-EFs for „other arable“ in the 2019 EMEP/EEA Guidebook were replaced with the average of the EFs of wheat, rye, barley and oat, as it was done in the Danish IIR. The PM_{10} EFs were also used as TSP EFs. The Guidebook does not indicate whether EFs have considered the condensable component (with or without). For details on country specific numbers of agricultural crop operations see Rösemann et al. (2023), Chapter 5.2.4. Table 12 shows the implied emission factors for PM emissions from soils.

Table 12: Emission factors for PM emissions from agricultural soils

Emission factor	**kg ha^{-1}**
EF_{TSP}	1.56
EF_{PM10}	1.56
$EF_{PM2.5}$	0.06

Trend discussion for Key Sources

TSP and PM_{10} are key sources. Emissions depend on the areas covered, crop types and number of crop operations. With the exception of the numbers of soil cultivations, which is slightly decreasing, these data are relatively constant. Overall this is reflected in a slight decline of emissions in the last 12 years.

Recalculations

Table REC-6 shows the effects of recalculations on particulate matter emissions. The emissions are considerably higher than those of submission 2022. In particular the $PM_{2.5}$ emissions are now more than twice as high. This is a consequence of changing the methodology to Tier 2 (see main page of the agricultural sector, list of **recalculation reasons, No 12**). Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-6: Comparison of particle emissions (TSP, PM_{10} & $PM_{2.5}$) of the submissions (SUB) 2022 and 2023

TSP, PM_{10}, $PM_{2.5}$ 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_{10}	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_{10}	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	
$PM_{2.5}$	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
$PM_{2.5}$	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 Rösemann et al. (2023), Chapter 5.2.3.

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_{-1}

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 no changes with respect to last year's submission. Further details on recalculations are described in Rösemann et al. (2023), Chapter 1.3.

Table REC-7: Comparison of NMVOC emissions of the submissions (SUB) 2022 and 2023

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	

For **pollutant-specific information on recalculated emission estimates for Base Year and 2020**, please see the pollutant specific recalculation tables following chapter 8.1 - Recalculations.

Planned improvements

No improvements are planned at present.

Uncertainty

Details are described in chapter 1.7.

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2)
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.
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5)
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