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	SO_2	NO_x	NH_3	NMVOC	CO	BC	Pb	Hg	Cd	Diox	PAH	HCB	TSP	PM_{10}	$PM_{2.5}$
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
RA	Reference Approach
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/CORINAIR Emission Inventory Guidebook - 2007, 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, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential

EF - Emission Factors	
CS	Country Specific
PS	Plant Specific data

Country specifics

NH_3 and NO_x

In 2019, the category of agricultural soils emitted 311.3 kt NH_3 or 55.8 % of the total agricultural NH_3 emissions in Germany (557.8 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 174.1 kt (55.9 %) and the application of inorganic N-fertilizers (3.D.a.1) with 68.1 kt (12,2 %).

Application of sewage sludge (3.D.a.2.b) contributes 0.6 % or 1.7 kt NH_3.

The application of residues from the digestion of energy crops (3.D.a.2.c) leads to 54.6 kt NH_3 or 17.5 %. N excretions on pastures (3.D.a.3) have a share of 12.8 kt NH_3 or 4.1 %.

NH_3 emissions from application of residues from the digestion of energy crops are excluded from emission accounting by adjustment as they are not considered in the NEC and Gothenburg commitments (see Chapter 11 - Adjustments and Emissions Reduction Commitments Adjustment DE - D - Nitrogen oxides (3.D.a.2.c Other organic fertilisers applied to soils (including compost)') & Ammonia from Energy Crops).

In 2019, agricultural soils were the source of 98.6 % (110.7 kt) of the total of NO_x emissions in the agricultural category (112.2 kt). The NO_x emissions from agricultural soils are mostly due to application of inorganic fertilizer (3.D.a.1) (50.6 %) and manure (3.D.a.2.a) (33.9 %). Application of residues from digested energy crops (3.D.a.2.c) contributes 10.4 % to agricultural soil emissions, 4.6 % are due to excretions on pastures (3.D.a.3). Emissions from application of sewage sludge (3.D.a.2.b) contribute 0.5 %.

All NO_x emissions from the agricultural category are excluded from emission accounting by adjustment as they are not considered in the NEC commitments (see Chapter 11 - Adjustments and Emissions Reduction Commitments adjustment_de-c and Adjustment DE - D - Nitrogen oxides (3.D.a.2.c Other organic fertilisers applied to soils (including compost)') & Ammonia from Energy Crops).

NMVOC

In 2019, the category of agricultural soils contributed 8.6 kt NMVOC or 2.8 % to the total agricultural NMVOC emissions in Germany. The only emission source was cultivated crops (3.D.e). All NMVOC emissions from the agricultural category are excluded from emission accounting by adjustment as they are not considered in the NEC commitments (see adjustment_de-c).

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

In 2019, agricultural soils contributed, respectively, 28.9 % (17.4 kt), 57.3 % (17.4 kt) and 15.2 % (0.7 kt) to the total agricultural TSP, PM_{10} and $PM_{2.5}$ emissions (60.3 kt, 30.4 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_3 and NOx (NO) emissions from the application of inorganic fertilizers is described in Rösemann et al. (2021), Chapter 11.1 [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 two-year average).

Table 1: AD for the estimation of NH_3 and NOx 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_3 emissions from the application of inorganic 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.

Table 2: NH_3-EF for inorganic fertilizers

Inorganic 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 (in 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) [3]. 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 five years (and in the last three years in dramatic fashion) fertilizer sales have decreased. Emissions have fallen accordingly. This is even more the case with NH_3 than with NO_x, as total NH_3 from the application of mineral fertilizers is very strongly correlated with the amount of urea applied (R^2 = 0.89), the sales of which have decreased more than for all other mineral fertilizers.

Recalculations

Table REC-1 shows the effects of recalculations on NH_3 and NO_x emissions. The procedure of temporal averaging of activity data has been applied for the first time (**recalculation reason 13**, see main page of the agricultural sector). It results in smoothing of extreme values and redistribution of emissions between neighbouring years. Hence, the emissions from fertilizer application changed markedly in every year compared to last year's submission.

Table REC-1: Comparison of NH_3 and NO_x emissions from fertilizer application of the submissions (SUB) 2020 and 2021

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**
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
NH_3	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_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
NO_x	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_3 and NO_x (NO) emissions from application of manure (including application of anaerobically digested manure). For an overview see Rösemann et al. (2021), 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 Rösemann et al. (2021), Chapter 3.4.3. The frequencies are provided e. g. in the NIR 2021[4], 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**
1'120	972	954	924	928	933	949	961	972	972	966	961	947	940	932

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. (2021), Chapter 4 to 8 and 11.3. For NO_x emissions from manure application the inventory calculates NO-N emissions (see Rösemann et al. (2021), Chapter 11.2, 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 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_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**
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_x the same emission factor as for the application of inorganic 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 remarkably decreased from 1990 to 1991 due to the decline in animal numbers following the German reunification (reduction of livestock numbers in Eastern Germany). Since then the amount of N in manure applied shows no significant trend (950 +/- 40 Gg N), see Table 4 and therefore there is no trend in the NO_x emissions. For total NH_3 emissions even after 1991 there is a slight negative trend. This is due to the increasing use of application practices with lower NH_3 emission factors. For both gases, emissions are slightly decreasing since 2015. This is due to the fact that cattle and swine animal numbers are declining.

Recalculations

Table REC-2 shows the effects of recalculations on NH_3 and NO_x .The total emissions of NH_3 and NO_x from application of manure are significantly lower than those of last year's submission. These differences are predominantly caused by the update of the models of dairy cows, calves, heifers and male beef cattle, see main page of the agricultural sector, list of **recalculation reasons, No. 1 through 3**. Much smaller is the impact of the updates of activity data for male cattle > 2 years, pigs, poultry and sheep (see **recalculation reasons 4, 6, 7, and 9 through 12**) as well as the update of activity data for air scrubbing systems in pig and broiler houses (see **recalculation reasons 8 and 10**). Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-2: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2020 and 2021

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**
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
NH_3	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_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
NO_x	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 NH_3 and NO_x (NO) emissions from application of sewage sludge is described in Rösemann et al. (2021), 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 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**
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). 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 inorganic 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 2018, due to the update of the activity data (see main page of the agricultural sector, **recalculation No 14**. Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-3: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2020 and 2021

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**
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
NH_3	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_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
NO_x	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 NH_3 and NO_x (NO) emissions from application of residues from digested energy crops. For details see Rösemann et al. (2021), 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 Rösemann et al. (2021), Chapter 10.2.1).

Table 7: AD for the estimation of NH_3 and 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**
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	292.86

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 2021, 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 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 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, see Rösemann et al. (2021), Chapter 10.2. 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 Rösemann et al. (2021), Chapter 11.1)

Table 8 shows the implied emission factors for NH_3 emissions from application of residues from digested energy crops.

Table 8: IEF for NH_3-N

IEF in kg NH_3-N per kg N in digested energy crops													
1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
0.182	0.182	0.183	0.183	0.183	0.184	0.174	0.166	0.159	0.153	0.153	0.153	0.154	0.154

Trend discussion for Key Sources

The application of residues from anaerobic digestion of energy crops is a key source for 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 NH_3 and NO_x emissions. The only change compared to last year's submission occurs for 2018, due to the update of the activity data (see main page of the agricultural sector, list of

recalculation reasons, No 15, and Rösemann et al. (2021), Chapter 3.5.2.)

Table REC-4: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2020 and 2021

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**
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
NH_3	2020	0.01	0.14	1.20	10.15	37.27	46.75	48.81	56.27	56.56	56.42	56.11	55.37	55.66	
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
NO_x	2020	0.00	0.02	0.21	1.80	6.60	8.25	9.09	11.01	11.53	11.98	11.91	11.72	11.77	

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. (2021), Chapter 11.5.

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 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

N excretions on pasture in % of total N excreted														
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Dairy cows	20.3	15.6	12.7	11.3	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.7
Other cattle	15.2	17.5	19.2	19.2	19.6	19.6	19.4	19.3	19.4	19.6	19.5	19.6	19.6	19.6
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
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
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

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. 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 inorganic 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
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 NOx emissions. Because overall N excretions on pasture are lower than in last year's submission (predominantly due to the update of cattle models, see main page of the agricultural sector, list of **recalculation reasons, No 1 through 3**), NO_x emissions are lower as well. However, although NH_3 emissions could be expected to show the same pattern, this is more than compensated by increased emission factors for cattle grazing (see list of **recalculation reasons, No 5**). Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-5: Comparison of the NH_3 and NO_x emissions of the submissions (SUB) 2020 and 2021

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**
NH_3	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
NH_3	2020	14.45	11.59	10.74	9.53	8.93	8.79	8.77	8.87	8.95	9.02	8.94	8.85	8.71	
NO_x	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
NO_x	2020	8.65	7.03	6.84	6.06	5.80	5.67	5.65	5.73	5.80	5.85	5.80	5.75	5.66	

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-11. For details see Rösemann et al. (2021), 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_{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**
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

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^{-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 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. The only changes with respect to last year's submission occur in the years 2010 through 2012 because of updates of cultivation areas (see main page of the agricultural sector, list of **recalculation reasons, No 16**). However, due to the data format in Table REC-6, these differences are not visible. Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-6: Comparison of particle emissions (TSP, PM_{10} & $PM_{2.5}$) of the submissions (SUB) 2020 and 2021

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**
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
TSP	2020	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	
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_{10}	2020	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	
$PM_{2.5}$	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
$PM_{2.5}$	2020	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	

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. (2021), 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**
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

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**
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

Trend discussion for Key Sources

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

Recalculations

Table REC-7 shows the effects of recalculations on NMVOC emissions. The only changes with respect to last year's submission occur in the years 1999 (not shown in Table REC-7) and 2010 through 2012 because of updates of yields in 1999 and 2010 and of cultivation areas 2010 through 2012 (see main page of the agricultural sector, list of **recalculation reasons, No 16**). However, due to the data format in Table Table REC-6, these differences are not visible. Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-7: Comparison of NMVOC emissions of the submissions (SUB) 2020 and 2021

NMVOC emissions from crop production, in Gg														
SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
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
2020	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	

Planned improvements

No improvements are planned at present.

Uncertainty

Details will be described in chapter 1.7.

[1]
Rösemann et al. (2021): Rösemann C., Haenel H-D., Vos C., Dämmgen U., Döring U., Wulf S., Eurich-Menden B., Freibauer A., Döhler H., Schreiner C., Osterburg B. & Fuß, R. (2021): Calculations of gaseous and particulate emissions from German Agriculture 1990 –2019. Report on methods and data (RMD), Submission 2021. Thünen Report (in preparation). https://www.thuenen.de/de/ak/arbeitsbereiche/emissionsinventare/
[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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Stehfest E., Bouwman L. (2006): N2O 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.
[4]
NIR (2021): National Inventory Report 2021 for the German Greenhouse Gas Inventory 1990-2019. Available in April 2021.