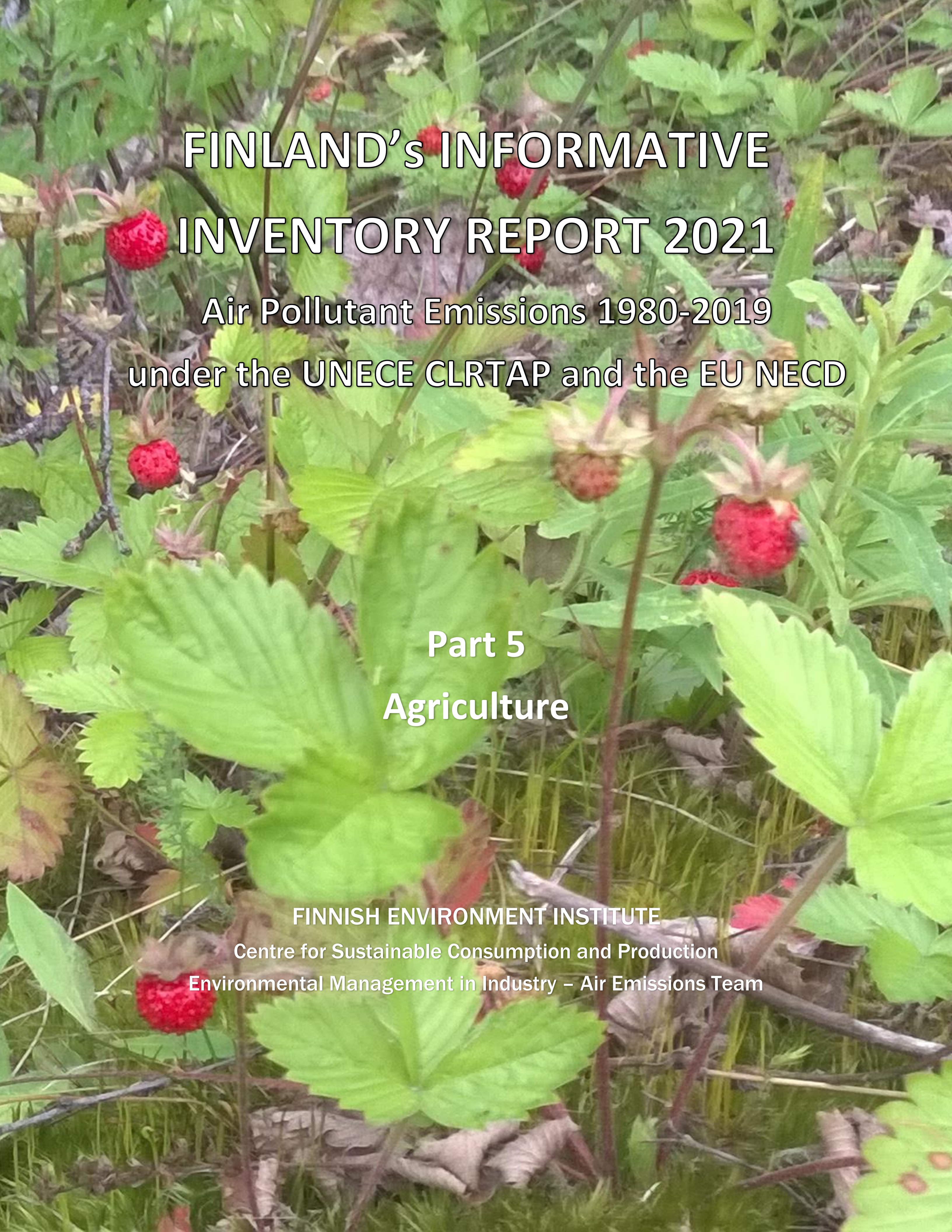

FINLAND's INFORMATIVE INVENTORY REPORT 2021

Air Pollutant Emissions 1980-2019 under the UNECE CLRTAP and the EU NECD

Part 5

Agriculture

FINNISH ENVIRONMENT INSTITUTE
Centre for Sustainable Consumption and Production
Environmental Management in Industry – Air Emissions Team

Finland’s IIR
Part 5
Agriculture

Picture on the cover page: Wild arctic strawberries (Saarinen 2015)

FINLAND'S IIR PART 5 - AGRICULTURE

5 AGRICULTURE (NFR 3)

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5 AGRICULTURE (NFR 3)

5.1 Overview of the sector

Changes in chapter	
March 2020	KS & JM & JMP

Agricultural activities in Finland

Agriculture in Finland is characterized by the northern climate and self-sufficiency in most major agricultural products. Its economic role is declining in terms of GDP and employment in primary production, but together with the food industry and forestry with which it is linked, it forms a significant part of the Finnish economy. The majority of farms and agricultural land in Finland lie between the 60th and 65th parallel, making it the only country in the world with a significant agricultural sector so far in the north. The percentage of farms concentrating on animal production increases towards the north and east.

Since 1990 there have been structural changes in agriculture, which have resulted in an increase in farm size and a decrease in the numbers of domestic livestock. The number of farms has steadily declined for the last decades. Between 2000 and 2019 their number fell from almost 80,000 to about 47,000 while the amount of arable land slightly increased to a total of almost 2.27 million hectares. As another example, the number of cattle was 37 per cent less in 2019 than in 1990. Agriculture employed 84,000 people in 2016 with a drop of 54 percent from 2000.

Although the decrease in the number of livestock cannot be seen in the development of ammonia emissions it is visible in CH_4 emissions from enteric fermentation and N_2O emissions from manure management. For ammonia, the specific ammonia emissions grow simultaneously with the decrease of animal numbers. Specifically, this can be seen in the emissions from dairy cows. However, the emissions have not decreased in proportion to the drop in the number of livestock, because milk and meat output and emissions per animal have increased.

The Finnish inventory of air pollutants from agriculture includes emissions from animal husbandry (including manure management, manure application and grazing), application of mineral fertilizers, harvesting, field preparation, storage and handling of agricultural crops, field burning of agricultural wastes, use of pesticides and sewage sludge application to soils (Table 5.1a).

Key categories and tier levels for the methodologies used are presented in Table 5.1b.

Table 5.1a Activities and emissions reported under NFR 3 Agriculture.

		Pollutants						Activities
NFR	**SNAP**	**NH_3**	**NOx**	**TSP**	**PM10**	**PM2.5**	**NMVOC**	
3B1a	100501	x	x	x	x	x	x	Dairy cattle
3B1b	100502	x	x	x	x	x	x	Non-dairy cattle: including sukcler cows,
3B2	100505	x	x	x	x	x	x	Sheep with lambs
3B3	100503 100504	x	x	x	x	x	x	Swine, incl. fattening pigs, sows with piglets, veaned pigs (20-50 kg)
3B4a	100514	NO	NO	NO	NO	NO	NO	Buffalo
3B4d	100511	x	x	x	x	x	x	Goat
3B4e	100506	x	x	x	x	x	x	Horses and ponies
3B4f	100512	NO	NO	NO	NO	NO	NO	Mules and asses
3B4gi	100507	x	x	x	x	x	x	Laying hens
3B4gii	100508	x	x	x	x	x	x	Broilers, broiler hens
3B4giii	100509a	x	x	x	x	x	x	Turkeys
3B4giv	100509b	x	x	x	x	x	x	Other Poultry, incl. cockerels, broiler hens, chicken and other poultry
3B4h	100515 100516	x	x	x	x	x	x	Fur animals, reindeer

NFR	**SNAP**	**Pollutants**	**Activities**
3Da1	100101 100106	NH_3, NOx	Inorganic N fertilisers (includes urea) ; Application of nitrogen fertilizers (NH_3)
3Da2a	100905	NH_3 (calculated in 3B), NOx,	Animal manure applied to soils
3Da2b	100906	$NH_{3,}$ NOx	Sewage sludge applied to soils
3Da2c	100907	-	Other organic fertilisers applied to soils
3Da3	100517	NH_3 (calculated in 3B),NOx,	Urine and dung deposited by grazing animals
3Da4	100207	-	Crop residues applied to soils
3Db	100208	-	Indirect emissions from managed soils
3Dc	100901,100904, 101000	TSP, PM_{10}, $PM_{2.5}$	Farm-level storage, handling and transport of agricultural products; Storage and handling of agricultural crops and fertilizers
3Dd	101100	-	Off-farm storage, handling and transport of agricultural
3De	100201,100206, 100700	NMVOC	Cultivated crops, crops
3Df	100601,100604	emissions of spesific pestiside	Use of pesticides
3F	100301,100305	NOx, CO, NMVOC, SOx, NH_3, TSP, PM_{10} $PM_{2.5}$, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn , PAH-4	Field burning of agricultural residues

Table 5.1b Key categories and tier level of methods for the Agriculture inventory

NFR	**NH_3**	**Tier**	**NO_x**	**Tier**	**NMVOC**	**Tier**	**TSP**	**Tier**	**PM_{10}**	**Tier**	**Cd**	**Tier**
3B1a	L1, T1	3		2	L1, T1	2		2		2		
3B1b	L1, T1	3		2	L1, T1	2		2		2		
3B3	L1, T1	3		2		2		2		2		
3B4h	L1, T1	3		2		2		2		2		
3B4gii	T1	3		2		2		2		2		
3Da1	L1, T1	2	L1, T1	1								
3Da2a	L1, T1	3		1	L1	2						
3Da3	L1	2		1		2						
3Dc							L1, T1	2	L1, T1	2		
3De						2						
3F		2		2		2		2		2	L1	2

5.2 Emission trends

Changes in chapter	
March 2021	KS & JM & JMP

Ammonia

Ammonia emissions are generated from manure management, application of nitrogen fertilizers, sewage sludge applied to soils and field burning of agricultural wastes. The total agricultural NH_3 emissions in 2018 were 28.8 Gg, out of which 18.3 Gg originated in manure management, 9.1Gg in fertilizer use and manure applied to soils, 1.4 kt in deposits by grazing, and 0.1 in field burning of agricultural wastes. The contribution of NFR sub-sectors to agricultural ammonia emissions is presented in Figure 5.1 and in Table 5.2.

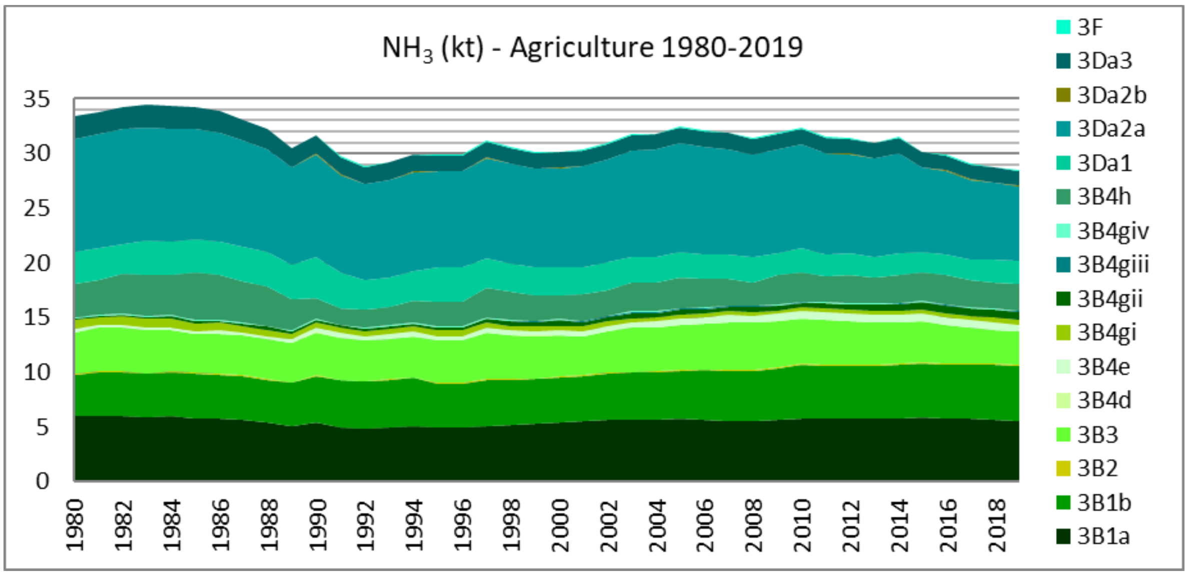

Figure 5.1. Ammonia emissions 1980-2019

Agricultural ammonia emissions have been decreased over the period of 1980-2018 (Figure 5.1 and Table 5.2) partly due to changes in the economic structure in agriculture followed by an increase in the average farm size and the decrease in the number of small farms. Those changes resulted in the decrease of livestock numbers for all other animals than horses. The number of horses increased in the recent years due to the increasing interest in equitation. In addition, the use of nitrogen fertilisers has been reduced, while manure management has been improved due to measures taken by the farmers as part of an agro-environmental programme aiming at minimising nutrient load to surface waters. Since 2014, the Government decree on limiting certain emissions from agriculture and horticulture (1250/2014) has included additional measures for manure storing and application to limit ammonia emissions.

Table 5.2 Ammonia emissions from agricultural sources (Gg) 1980-2018.

Year	NFR 3B	NFR 3D1a	NFR 3Da2a	NFR 3Da2b	NFR 3Da3	NFR 3F	Total
1980	18.09	2.89	10.30	NE	2.10	0.07	33.38
1981	18.40	2.88	10.41	NE	2.09	0.07	33.78
1982	19.01	2.71	10.46	NE	2.07	0.07	34.25
1983	18.86	3.16	10.32	NE	2.05	0.07	34.39
1984	18.86	3.10	10.30	NE	2.05	0.07	34.31
1985	19.15	3.00	10.12	NE	1.98	0.07	34.25
1986	18.92	2.97	10.00	NE	1.96	0.07	33.85
1987	18.29	3.12	9.71	NE	1.89	0.07	33.01
1988	17.84	3.14	9.39	NE	1.83	0.07	32.20
1989	16.62	3.15	8.94	NE	1.79	0.07	30.50
1990	16.76	3.73	9.42	0.04	1.64	0.11	31.70
1991	15.80	3.32	8.95	0.04	1.59	0.10	29.80
1992	15.71	2.71	8.77	0.03	1.53	0.08	28.83
1993	15.93	2.76	8.88	0.03	1.53	0.10	29.23
1994	16.49	2.77	9.03	0.04	1.51	0.10	29.94
1995	16.42	3.16	8.73	0.04	1.43	0.09	29.87
1996	16.96	2.86	8.88	0.04	1.45	0.10	30.29
1997	17.70	2.69	9.20	0.06	1.45	0.10	31.20
1998	17.31	2.66	9.06	0.02	1.42	0.07	30.54
1999	17.05	2.57	9.01	0.02	1.40	0.07	30.12
2000	17.02	2.56	9.07	0.02	1.41	0.10	30.18
2001	17.08	2.57	9.17	0.02	1.39	0.09	30.32
2002	17.53	2.48	9.45	0.02	1.41	0.09	30.98
2003	18.14	2.44	9.68	0.02	1.40	0.08	31.76
2004	18.18	2.36	9.77	0.02	1.40	0.08	31.81
2005	18.70	2.30	9.97	0.02	1.41	0.08	32.48
2006	18.52	2.26	9.79	0.02	1.42	0.07	32.08
2007	18.58	2.20	9.62	0.03	1.42	0.08	31.93
2008	18.15	2.37	9.36	0.03	1.42	0.08	31.41
2009	18.93	1.96	9.42	0.03	1.43	0.07	31.84
2010	19.12	2.22	9.46	0.03	1.45	0.05	32.33
2011	18.72	2.06	9.19	0.04	1.43	0.06	31.50
2012	18.94	1.92	9.06	0.04	1.37	0.06	31.39
2013	18.69	1.87	8.96	0.05	1.36	0.08	31.01
2014	18.94	1.98	9.07	0.05	1.36	0.07	31.47
2015	19.08	1.89	7.71	0.06	1.36	0.07	30.17
2016	18.90	1.86	7.64	0.07	1.35	0.06	29.88
2017	18.40	1.92	7.20	0.07	1.35	0.07	29.01
2018	18.23	2.06	6.98	0.07	1.34	0.05	28.73
2019	18.05	2.10	6.85	0.07	1.34	0.07	28.48

NMVOC

NMVOC emissions are generated in manure management, manure applied to soils, deposits during grazing, cultivated crops and field burning of agricultural waste. A summary of agricultural emissions is presented in Figure 5.2 and in Table 5.3.

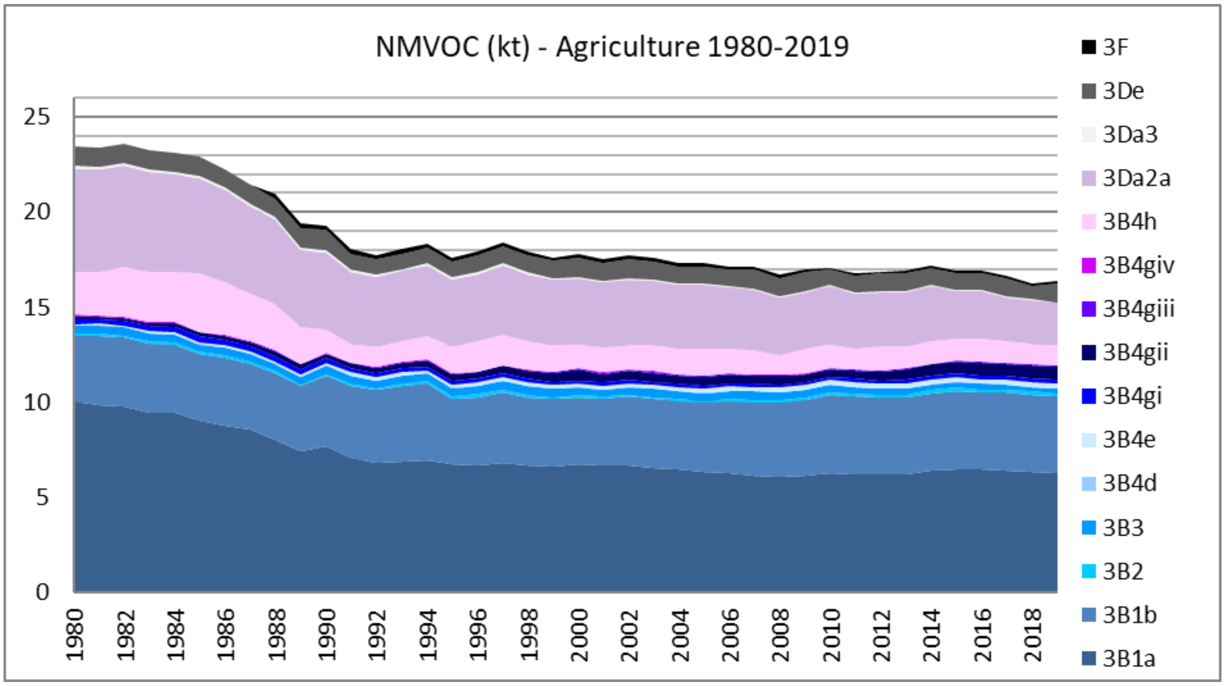

Figure 5.2. NMVOC emissions 1980-2019

Agricultural NMVOC emissions (Figure 5.2 and Table 5.3) have been decreased over the period 1980–2018 partly due to changes in the economic structure followed by an increase in the average farm size and a decrease in the number of small farms. Those changes resulted in the decrease of livestock numbers except for the number of horses that has increased in the recent years due to the increasing interest in equitation.

Table 5.3 NMVOC emissions from agricultural sources (Gg) 1980-2018.

Year	NFR 3B	NFR 3Da2a	NFR 3Da3	NFR 3De	NFR 3F	Total
1980	16.84	5.43	0.16	1.03	NE	23.46
1981	16.86	5.38	0.16	1.03	NE	23.43
1982	17.10	5.33	0.15	1.03	NE	23.61
1983	16.86	5.24	0.15	1.03	NE	23.28
1984	16.82	5.14	0.15	1.01	NE	23.12
1985	16.78	5.01	0.14	0.97	NE	22.9
1986	16.29	4.84	0.14	0.96	NE	22.23
1987	15.67	4.63	0.14	0.98	NE	21.42
1988	15.16	4.43	0.13	0.95	0.30	20.97
1989	13.94	4.07	0.12	1.03	0.27	19.43
1990	13.81	4.08	0.10	1.06	0.25	19.3
1991	13.04	3.83	0.10	0.83	0.23	18.03
1992	12.90	3.70	0.09	0.82	0.19	17.7
1993	13.19	3.71	0.09	0.82	0.24	18.05
1994	13.47	3.73	0.09	0.82	0.23	18.34

1995	12.92	3.54	0.09	0.84	0.21	17.6
1996	13.17	3.56	0.08	0.90	0.22	17.93
1997	13.57	3.63	0.08	0.89	0.22	18.39
1998	13.21	3.53	0.08	0.93	0.15	17.9
1999	12.99	3.45	0.08	0.93	0.17	17.62
2000	13.05	3.44	0.08	1.03	0.21	17.81
2001	12.89	3.41	0.08	0.96	0.18	17.52
2002	12.99	3.43	0.08	1.05	0.17	17.72
2003	12.97	3.41	0.07	0.94	0.16	17.55
2004	12.81	3.35	0.07	0.90	0.16	17.29
2005	12.82	3.34	0.07	0.88	0.18	17.29
2006	12.80	3.25	0.07	0.84	0.16	17.12
2007	12.74	3.16	0.07	1.00	0.16	17.13
2008	12.45	3.02	0.07	0.98	0.17	16.69
2009	12.79	3.01	0.07	0.97	0.16	17
2010	13.09	3.01	0.07	0.79	0.10	17.06
2011	12.81	2.88	0.07	0.89	0.11	16.76
2012	12.94	2.84	0.07	0.91	0.11	16.87
2013	12.92	2.82	0.06	0.94	0.16	16.9
2014	13.22	2.89	0.06	0.89	0.14	17.2
2015	13.35	2.49	0.07	0.87	0.12	16.9
2016	13.33	2.47	0.06	0.89	0.12	16.87
2017	13.18	2.33	0.06	0.96	0.12	16.65
2018	13.07	2.26	0.06	0.73	0.11	16.23
2019	13.00	2.19	0.06	1.00	0.13	16.38

NO_x

NO_x emissions are generated in manure management, use of fertilizers, manure applied to soils, deposits during grazing and field burning of agricultural waste. A summary of agricultural emissions is presented in Table 5.4 and in Figure 5.3.

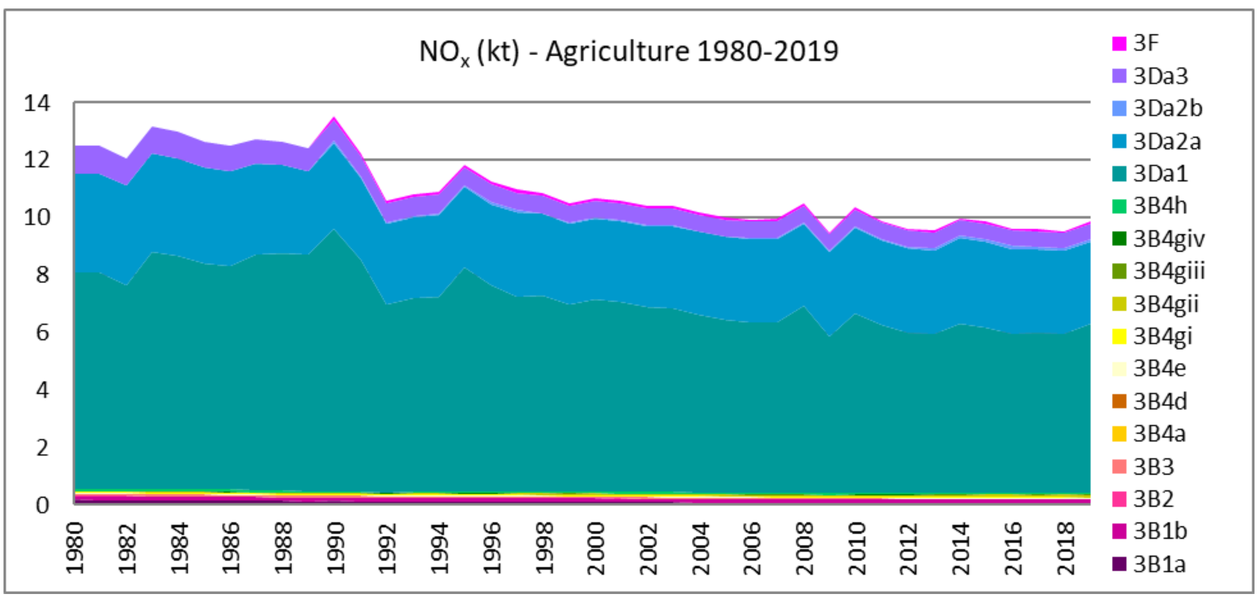

Figure 5.3. NO_x emissions 1980-2019

The decreasing trend in NO_x emissions from agriculture is mainly a result of decreased use of mineral fertilisers (see Table 5.22) and decrease in grazing.

Table 5.4 NO_x emissions from agricultural sources (Gg) 1980-2018

Year	NFR 3B	NFR 3Da1	NFR 3Da2a	NFR 3Da3	NFR 3F	Total
1980	0.54	7.57	3.42	0.97	0.11	12.50
1981	0.54	7.54	3.45	0.96	0.10	12.50
1982	0.55	7.09	3.47	0.95	0.09	12.06
1983	0.55	8.27	3.42	0.94	0.11	13.18
1984	0.55	8.12	3.39	0.94	0.10	12.99
1985	0.55	7.85	3.34	0.90	0.09	12.64
1986	0.54	7.78	3.29	0.89	0.10	12.49
1987	0.52	8.17	3.18	0.87	0.10	12.74
1988	0.51	8.23	3.07	0.83	0.08	12.64
1989	0.47	8.24	2.90	0.81	0.07	12.41
1990	0.47	9.14	2.99	0.73	0.10	13.45
1991	0.44	8.10	2.84	0.70	0.09	12.19
1992	0.44	6.53	2.79	0.67	0.09	10.52
1993	0.45	6.73	2.82	0.67	0.08	10.77
1994	0.46	6.77	2.87	0.66	0.08	10.85
1995	0.45	7.82	2.79	0.62	0.08	11.77
1996	0.46	7.18	2.83	0.62	0.07	11.19
1997	0.47	6.78	2.92	0.62	0.08	10.89
1998	0.47	6.80	2.86	0.60	0.08	10.80
1999	0.46	6.51	2.82	0.59	0.08	10.45
2000	0.46	6.69	2.81	0.60	0.05	10.66
2001	0.44	6.63	2.80	0.58	0.06	10.54
2002	0.45	6.42	2.84	0.59	0.06	10.39
2003	0.45	6.37	2.88	0.58	0.08	10.38
2004	0.44	6.19	2.87	0.58	0.07	10.17
2005	0.44	5.99	2.90	0.58	0.07	9.99
2006	0.43	5.93	2.89	0.58	0.06	9.90
2007	0.42	5.95	2.89	0.57	0.07	9.92
2008	0.41	6.52	2.86	0.57	0.05	10.44
2009	0.41	5.44	2.93	0.58	0.07	9.44
2010	0.41	6.26	2.98	0.58	0.11	10.29
2011	0.41	5.85	2.94	0.57	0.10	9.83
2012	0.41	5.56	2.96	0.55	0.09	9.54
2013	0.41	5.53	2.93	0.55	0.11	9.49
2014	0.42	5.90	2.96	0.55	0.10	9.90
2015	0.43	5.74	3.00	0.55	0.09	9.79
2016	0.43	5.53	2.96	0.54	0.10	9.52
2017	0.42	5.56	2.89	0.54	0.10	9.48
2018	0.42	5.54	2.87	0.54	0.08	9.41
2019	0.42	5.87	2.87	0.54	0.07	9.78

CO, SO_x

Emissions presented in Table 5.5 and in Figure 5.4 originate from field burning of agricultural waste (see NFR 3F).

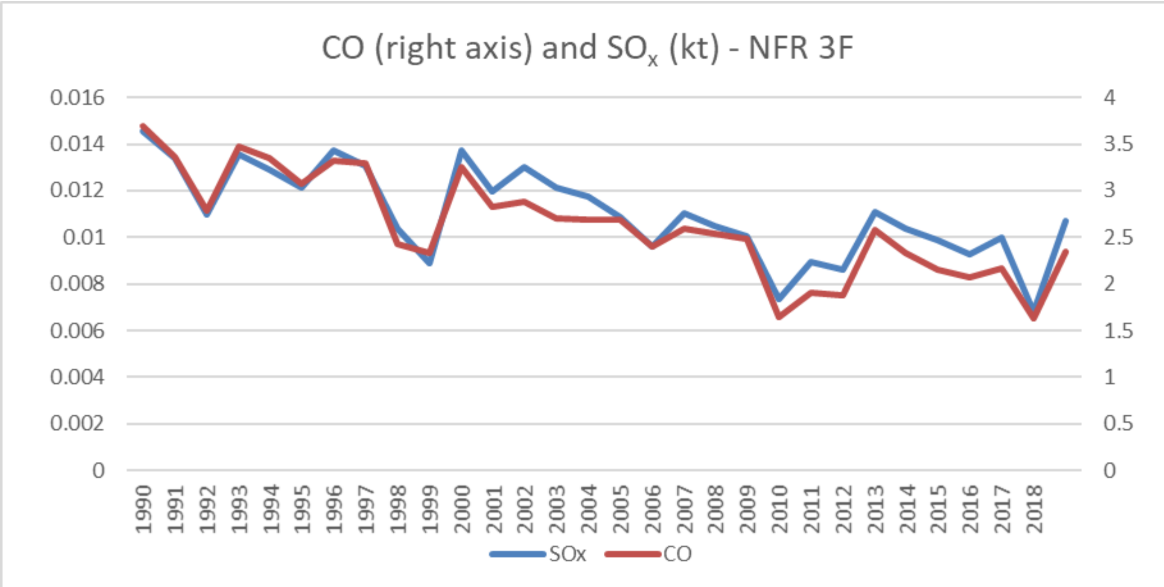

Figure 5.4. CO and SO_x emissions 1980-2019

The CO and SO_x emission trends presented in Figure 5.4 depend on the volume of annually burned biomass, which is calculated using different grain species and specific emission factors.

Table 5.5 CO and SO_x emissions from field burning of agricultural waste (wheat and other grain) in 1990-2018

Year	CO, NFR 3F	SOx, NFR 3F	Year	CO, NFR 3F	SOx, NFR 3F
1990	3.69	0.015	2010	1.65	0.007
1991	3.36	0.013	2011	1.91	0.009
1992	2.78	0.011	2012	1.88	0.009
1993	3.47	0.014	2013	2.58	0.011
1994	3.34	0.013	2014	2.33	0.010
1995	3.08	0.012	2015	2.16	0.010
1996	3.33	0.014	2016	2.08	0.009
1997	3.30	0.013	2017	2.16	0.010
1998	2.43	0.010	2018	1.63	0.007
1999	2.33	0.009	2019	2.34	0.011
2000	3.25	0.014			
2001	2.83	0.012			
2002	2.89	0.013			
2003	2.70	0.012			
2004	2.69	0.012			
2005	2.69	0.011			
2006	2.40	0.010			
2007	2.60	0.011			
2008	2.54	0.010			
2009	2.48	0.010			

Particles

TSP, PM_{10}, $PM_{2.5}$ and BC emissions (Figure 5.5) are generated in animal husbandry, grain fields, storage and handling of agricultural crops and fertilizers as well as from field burning of agricultural waste as presented in Tables 5.6a. The fluctuation in emissions reflects the fluctuations in animal numbers.

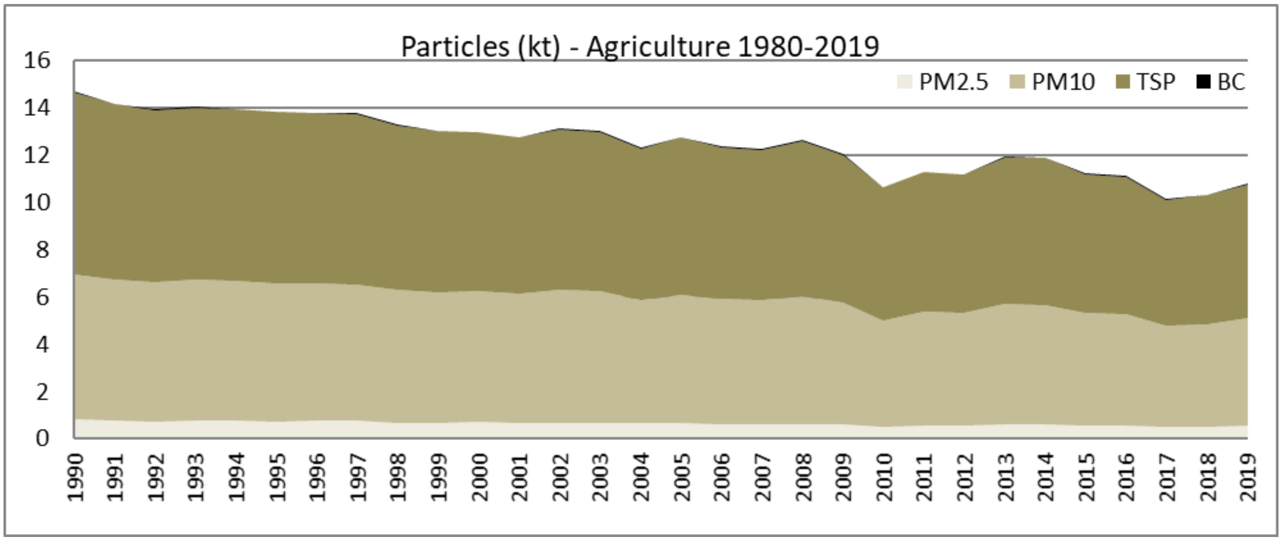

Figure 5.5. Particle emissions 1980-2019

Table 5.6a TSP emissions (kt) by NFR category 1990-2018

TSP (kt)	3B1a	3B1b	3B2	3B3	3B4d	3B4e	3B4gi	3B4gii	3B4gii i	3B4gi v	3B4h	3Dc	3F
1990	0.307	0.203	0.005	0.397	0.000	0.015	0.587	0.116	0.025	0.147	0.064	4.521	0.235
1991	0.295	0.203	0.005	0.408	0.000	0.016	0.589	0.123	0.029	0.111	0.061	4.711	0.241
1992	0.277	0.200	0.005	0.434	0.000	0.017	0.553	0.128	0.033	0.133	0.065	4.677	0.225
1993	0.263	0.193	0.006	0.426	0.000	0.018	0.563	0.117	0.029	0.128	0.064	4.368	0.223
1994	0.253	0.191	0.005	0.438	0.000	0.019	0.573	0.119	0.027	0.135	0.068	4.574	0.222
1995	0.246	0.190	0.006	0.427	0.000	0.020	0.559	0.115	0.027	0.116	0.062	4.462	0.198
1996	0.236	0.185	0.007	0.443	0.000	0.020	0.554	0.109	0.024	0.104	0.063	4.408	0.215
1997	0.231	0.182	0.007	0.431	0.000	0.021	0.554	0.120	0.023	0.114	0.049	4.616	0.211
1998	0.232	0.180	0.007	0.417	0.000	0.021	0.498	0.105	0.017	0.109	0.062	4.384	0.205
1999	0.232	0.181	0.008	0.399	0.000	0.022	0.567	0.101	0.015	0.103	0.063	3.787	0.137
2000	0.229	0.177	0.009	0.386	0.000	0.022	0.541	0.117	0.017	0.091	0.052	4.107	0.160
2001	0.228	0.175	0.009	0.377	0.000	0.022	0.509	0.130	0.016	0.089	0.061	4.073	0.157
2002	0.226	0.174	0.009	0.371	0.000	0.022	0.551	0.148	0.015	0.101	0.055	4.309	0.214
2003	0.227	0.174	0.009	0.353	0.000	0.021	0.585	0.158	0.016	0.085	0.058	4.316	0.194
2004	0.227	0.174	0.011	0.350	0.000	0.021	0.577	0.168	0.014	0.080	0.056	4.013	0.180

2005	0.222	0.171	0.011	0.336	0.000	0.021	0.578	0.176	0.014	0.089	0.058	3.966	0.173
2006	0.215	0.169	0.011	0.309	0.000	0.021	0.601	0.170	0.016	0.065	0.053	3.523	0.181
2007	0.211	0.165	0.011	0.295	0.000	0.021	0.640	0.184	0.016	0.073	0.052	3.658	0.135
2008	0.202	0.161	0.010	0.302	0.000	0.021	0.626	0.190	0.014	0.078	0.051	3.800	0.195
2009	0.307	0.203	0.005	0.397	0.000	0.015	0.587	0.116	0.025	0.147	0.064	4.521	0.235
2010	0.295	0.203	0.005	0.408	0.000	0.016	0.589	0.123	0.029	0.111	0.061	4.711	0.241
2011	0.277	0.200	0.005	0.434	0.000	0.017	0.553	0.128	0.033	0.133	0.065	4.677	0.225
2012	0.263	0.193	0.006	0.426	0.000	0.018	0.563	0.117	0.029	0.128	0.064	4.368	0.223
2013	0.253	0.191	0.005	0.438	0.000	0.019	0.573	0.119	0.027	0.135	0.068	4.574	0.222
2014	0.246	0.190	0.006	0.427	0.000	0.020	0.559	0.115	0.027	0.116	0.062	4.462	0.198
2015	0.236	0.185	0.007	0.443	0.000	0.020	0.554	0.109	0.024	0.104	0.063	4.408	0.215
2016	0.231	0.182	0.007	0.431	0.000	0.021	0.554	0.120	0.023	0.114	0.049	4.616	0.211
2017	0.232	0.180	0.007	0.417	0.000	0.021	0.498	0.105	0.017	0.109	0.062	4.384	0.205
2018	0.232	0.181	0.008	0.399	0.000	0.022	0.567	0.101	0.015	0.103	0.063	3.787	0.137
2019	0.229	0.177	0.009	0.386	0.000	0.022	0.541	0.117	0.017	0.091	0.052	4.107	0.160

Table 5.6b $PM_{2.5}$ emissions (kt) by NFR 1990-2018

$PM_{2.5}$ kt	3B1a	3B1b	3B2	3B3	3B4d	3B4e	3B4gi	3B4gii	3B4giii	3B4giv	3B4h	3Dc	3F
1990	0.132	0.079	0.001	0.004	0.000	0.004	0.014	0.003	0.001	0.032	0.013	0.268	0.287
1991	0.120	0.078	0.001	0.004	0.000	0.004	0.012	0.003	0.001	0.026	0.010	0.267	0.261
1992	0.116	0.077	0.001	0.004	0.000	0.004	0.012	0.004	0.001	0.032	0.011	0.265	0.216
1993	0.116	0.075	0.001	0.004	0.000	0.004	0.012	0.004	0.001	0.030	0.012	0.265	0.270
1994	0.113	0.074	0.001	0.003	0.000	0.004	0.012	0.004	0.001	0.029	0.013	0.264	0.259
1995	0.108	0.066	0.001	0.004	0.000	0.004	0.012	0.005	0.001	0.030	0.015	0.262	0.239
1996	0.106	0.067	0.001	0.004	0.000	0.004	0.012	0.004	0.001	0.025	0.017	0.261	0.259
1997	0.105	0.067	0.001	0.004	0.000	0.004	0.012	0.005	0.001	0.025	0.017	0.259	0.256
1998	0.102	0.065	0.001	0.004	0.000	0.004	0.011	0.006	0.001	0.024	0.016	0.256	0.190
1999	0.098	0.064	0.001	0.004	0.000	0.004	0.010	0.006	0.002	0.020	0.015	0.255	0.181
2000	0.095	0.062	0.001	0.004	0.000	0.004	0.009	0.008	0.002	0.018	0.013	0.249	0.253
2001	0.091	0.061	0.001	0.003	0.000	0.004	0.009	0.006	0.005	0.021	0.014	0.248	0.221
2002	0.088	0.061	0.001	0.003	0.000	0.005	0.009	0.006	0.005	0.016	0.014	0.259	0.226
2003	0.082	0.060	0.001	0.004	0.000	0.005	0.009	0.006	0.006	0.019	0.014	0.257	0.211
2004	0.078	0.058	0.001	0.003	0.000	0.005	0.009	0.006	0.005	0.018	0.014	0.240	0.210
2005	0.075	0.057	0.001	0.004	0.000	0.006	0.009	0.006	0.005	0.019	0.015	0.251	0.209
2006	0.073	0.057	0.001	0.003	0.000	0.006	0.009	0.006	0.005	0.016	0.014	0.245	0.187
2007	0.070	0.056	0.001	0.004	0.000	0.006	0.009	0.005	0.004	0.015	0.014	0.242	0.202
2008	0.069	0.055	0.001	0.003	0.000	0.006	0.009	0.006	0.004	0.016	0.011	0.254	0.198
2009	0.069	0.054	0.001	0.003	0.000	0.006	0.008	0.005	0.003	0.015	0.014	0.241	0.193
2010	0.069	0.055	0.001	0.003	0.000	0.006	0.009	0.005	0.003	0.014	0.014	0.209	0.129
2011	0.068	0.053	0.001	0.003	0.000	0.006	0.009	0.006	0.003	0.013	0.012	0.227	0.150
2012	0.068	0.053	0.001	0.003	0.000	0.006	0.008	0.007	0.003	0.012	0.014	0.225	0.147

2013	0.067	0.053	0.001	0.003	0.000	0.006	0.009	0.007	0.003	0.014	0.012	0.238	0.201
2014	0.067	0.052	0.001	0.003	0.000	0.006	0.009	0.008	0.003	0.012	0.013	0.238	0.182
2015	0.068	0.052	0.002	0.003	0.000	0.006	0.009	0.008	0.002	0.011	0.012	0.222	0.169
2016	0.066	0.052	0.002	0.002	0.000	0.006	0.009	0.009	0.003	0.012	0.013	0.219	0.162
2017	0.064	0.051	0.002	0.002	0.000	0.006	0.009	0.009	0.003	0.009	0.012	0.195	0.169
2018	0.063	0.050	0.002	0.002	0.000	0.006	0.010	0.009	0.003	0.010	0.011	0.202	0.127
2019	0.060	0.048	0.001	0.002	0.000	0.006	0.010	0.010	0.003	0.011	0.011	0.210	0.183

Table 5.6c PM_{10} emissions (kt) by NFR 1990-2019

PM_{10} kt	3B1a	3B1b	3B2	3B3	3B4d	3B4e	3B4gi	3B4gii	3B4giii	3B4giv	3B4h	3Dc	3F
1990	0.203	0.122	0.002	0.086	0.000	0.006	0.189	0.031	0.003	0.227	0.026	4.905	0.301
1991	0.185	0.121	0.002	0.082	0.000	0.006	0.161	0.033	0.004	0.183	0.021	4.883	0.273
1992	0.178	0.118	0.002	0.077	0.000	0.006	0.154	0.036	0.004	0.224	0.023	4.841	0.226
1993	0.178	0.116	0.003	0.073	0.000	0.006	0.156	0.039	0.004	0.214	0.023	4.831	0.282
1994	0.174	0.114	0.003	0.073	0.000	0.006	0.158	0.042	0.004	0.201	0.026	4.819	0.272
1995	0.166	0.103	0.004	0.074	0.000	0.006	0.161	0.045	0.004	0.210	0.030	4.792	0.250
1996	0.163	0.104	0.003	0.076	0.000	0.006	0.161	0.043	0.005	0.175	0.033	4.764	0.271
1997	0.161	0.104	0.003	0.081	0.000	0.006	0.160	0.052	0.006	0.179	0.035	4.720	0.269
1998	0.157	0.101	0.003	0.076	0.000	0.006	0.147	0.059	0.008	0.165	0.032	4.671	0.199
1999	0.151	0.099	0.002	0.074	0.000	0.006	0.130	0.064	0.012	0.144	0.030	4.650	0.190
2000	0.147	0.096	0.002	0.072	0.000	0.006	0.120	0.083	0.012	0.128	0.027	4.552	0.265
2001	0.140	0.094	0.002	0.068	0.000	0.007	0.124	0.058	0.025	0.146	0.028	4.521	0.231
2002	0.135	0.094	0.002	0.070	0.000	0.007	0.124	0.062	0.029	0.110	0.027	4.711	0.237
2003	0.126	0.092	0.002	0.073	0.000	0.008	0.116	0.064	0.033	0.131	0.029	4.677	0.221
2004	0.120	0.089	0.002	0.072	0.000	0.008	0.118	0.059	0.029	0.127	0.028	4.368	0.220
2005	0.116	0.088	0.002	0.074	0.000	0.009	0.121	0.059	0.027	0.133	0.030	4.574	0.219
2006	0.112	0.088	0.003	0.071	0.000	0.009	0.118	0.058	0.027	0.114	0.028	4.462	0.195
2007	0.108	0.086	0.003	0.074	0.000	0.009	0.117	0.054	0.024	0.102	0.028	4.408	0.212
2008	0.105	0.084	0.003	0.071	0.000	0.009	0.117	0.060	0.023	0.112	0.022	4.616	0.208
2009	0.106	0.084	0.003	0.068	0.000	0.010	0.105	0.052	0.017	0.108	0.028	4.384	0.202
2010	0.106	0.084	0.003	0.064	0.000	0.010	0.119	0.050	0.015	0.102	0.028	3.787	0.135
2011	0.105	0.082	0.004	0.061	0.000	0.010	0.114	0.058	0.017	0.088	0.023	4.107	0.157
2012	0.104	0.081	0.004	0.059	0.000	0.010	0.107	0.065	0.016	0.086	0.027	4.073	0.155
2013	0.103	0.081	0.004	0.058	0.000	0.010	0.116	0.074	0.015	0.098	0.024	4.309	0.211
2014	0.104	0.080	0.004	0.055	0.000	0.010	0.123	0.079	0.016	0.082	0.026	4.316	0.191
2015	0.104	0.080	0.005	0.055	0.000	0.010	0.121	0.084	0.014	0.078	0.025	4.013	0.177
2016	0.101	0.079	0.005	0.052	0.000	0.010	0.122	0.088	0.014	0.086	0.026	3.966	0.170
2017	0.098	0.078	0.005	0.048	0.000	0.010	0.127	0.085	0.016	0.063	0.024	3.523	0.178
2018	0.096	0.076	0.005	0.046	0.000	0.010	0.135	0.092	0.016	0.072	0.023	3.658	0.133
2019	0.092	0.074	0.004	0.047	0.000	0.010	0.132	0.095	0.014	0.076	0.023	3.800	0.192

Heavy metals

Emissions are generated in field burning of agricultural waste as described under NFR 3F.

The emission trends presented in Figure 5.6 and Table 5.7 are impacted by the volume of field burning of straw which has a declining trend.

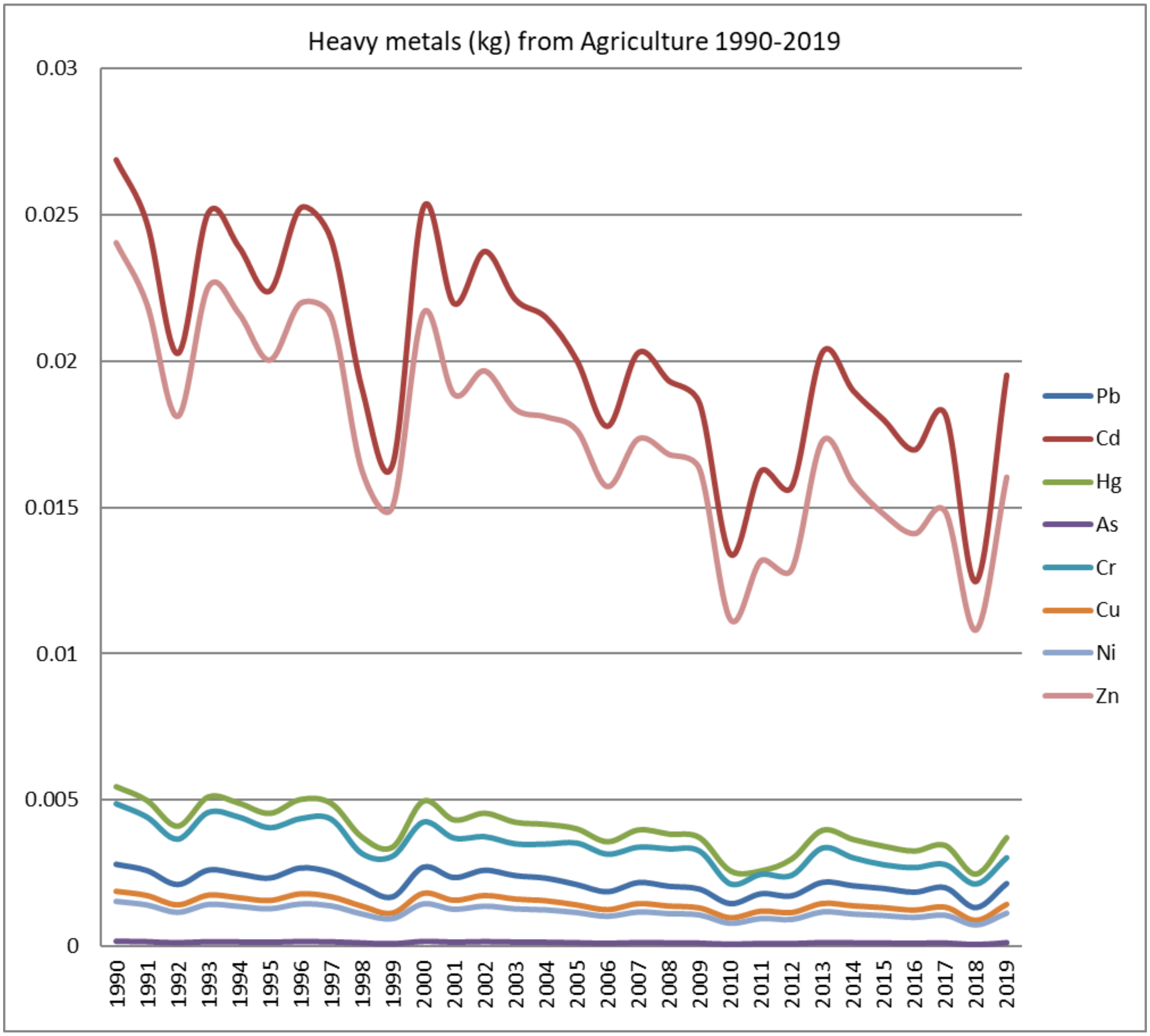

Figure 5.6 Heavy metals from agriculture 1980-2019

Table 5.7 Heavy metal emissions (g) from field burning of agricultural waste NFR 3F 1990-2019

Year	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn
1980	NE	NE	NE	NE	NE	NE	NE	NE	NE
1981	NE	NE	NE	NE	NE	NE	NE	NE	NE
1982	NE	NE	NE	NE	NE	NE	NE	NE	NE
1983	NE	NE	NE	NE	NE	NE	NE	NE	NE
1984	NE	NE	NE	NE	NE	NE	NE	NE	NE
1985	NE	NE	NE	NE	NE	NE	NE	NE	NE
1986	NE	NE	NE	NE	NE	NE	NE	NE	NE
1987	NE	NE	NE	NE	NE	NE	NE	NE	NE
1988	NE	NE	NE	NE	NE	NE	NE	NE	NE
1989	NE	NE	NE	NE	NE	NE	NE	NE	NE
1990	0.003	0.027	0.005	0.000	0.005	0.002	0.002	0.001	0.024
1991	0.003	0.025	0.005	0.000	0.004	0.002	0.001	0.001	0.022
1992	0.002	0.020	0.004	0.000	0.004	0.001	0.001	0.001	0.018
1993	0.003	0.025	0.005	0.000	0.005	0.002	0.001	0.001	0.023
1994	0.002	0.024	0.005	0.000	0.004	0.002	0.001	0.001	0.022
1995	0.002	0.022	0.005	0.000	0.004	0.002	0.001	0.001	0.020
1996	0.003	0.025	0.005	0.000	0.004	0.002	0.001	0.001	0.022
1997	0.003	0.024	0.005	0.000	0.004	0.002	0.001	0.001	0.022
1998	0.002	0.019	0.004	0.000	0.003	0.001	0.001	0.001	0.016
1999	0.002	0.016	0.003	0.000	0.003	0.001	0.001	0.001	0.015
2000	0.003	0.025	0.005	0.000	0.004	0.002	0.001	0.001	0.022
2001	0.002	0.022	0.004	0.000	0.004	0.002	0.001	0.001	0.019
2002	0.003	0.024	0.005	0.000	0.004	0.002	0.001	0.001	0.020
2003	0.002	0.022	0.004	0.000	0.004	0.002	0.001	0.001	0.018
2004	0.002	0.022	0.004	0.000	0.004	0.002	0.001	0.001	0.018
2005	0.002	0.020	0.004	0.000	0.004	0.001	0.001	0.001	0.018
2006	0.002	0.018	0.004	0.000	0.003	0.001	0.001	0.001	0.016
2007	0.002	0.020	0.004	0.000	0.003	0.001	0.001	0.001	0.017
2008	0.002	0.019	0.004	0.000	0.003	0.001	0.001	0.001	0.017
2009	0.002	0.019	0.004	0.000	0.003	0.001	0.001	0.001	0.016
2010	0.001	0.013	0.003	0.000	0.002	0.001	0.001	0.001	0.011
2011	0.002	0.016	0.003	0.000	0.002	0.001	0.001	0.001	0.013
2012	0.002	0.016	0.003	0.000	0.002	0.001	0.001	0.001	0.013
2013	0.002	0.020	0.004	0.000	0.003	0.001	0.001	0.001	0.017
2014	0.002	0.019	0.004	0.000	0.003	0.001	0.001	0.001	0.016
2015	0.002	0.018	0.003	0.000	0.003	0.001	0.001	0.001	0.015
2016	0.002	0.017	0.003	0.000	0.003	0.001	0.001	0.001	0.014
2017	0.002	0.018	0.003	0.000	0.003	0.001	0.001	0.001	0.015
2018	0.001	0.012	0.002	0.000	0.002	0.001	0.001	0.001	0.011
2019	0.002	0.020	0.004	0.000	0.003	0.001	0.001	0.001	0.016

POPs

HCB emissions originate from the use of pesticides while PAH emissions originate from field burning of agricultural waste (NFR 3F) (Figure 5.7).

PAH-4 emission trends presented in Figure 5.7 and Table 5.8 are impacted by the volume of field burning of straw and agricultural waste, which both have a declining trend.

The decrease in HCB emissions in early 2000s is due to the strong decrease in the use of Simazine, which was forbidden in 2004 in the EU, and the increase in 2011 is due to the replacement by a new herbicide which came into market (selling permit granted 12.4.2011). The sales of this new herbicide varies quite a lot between years?

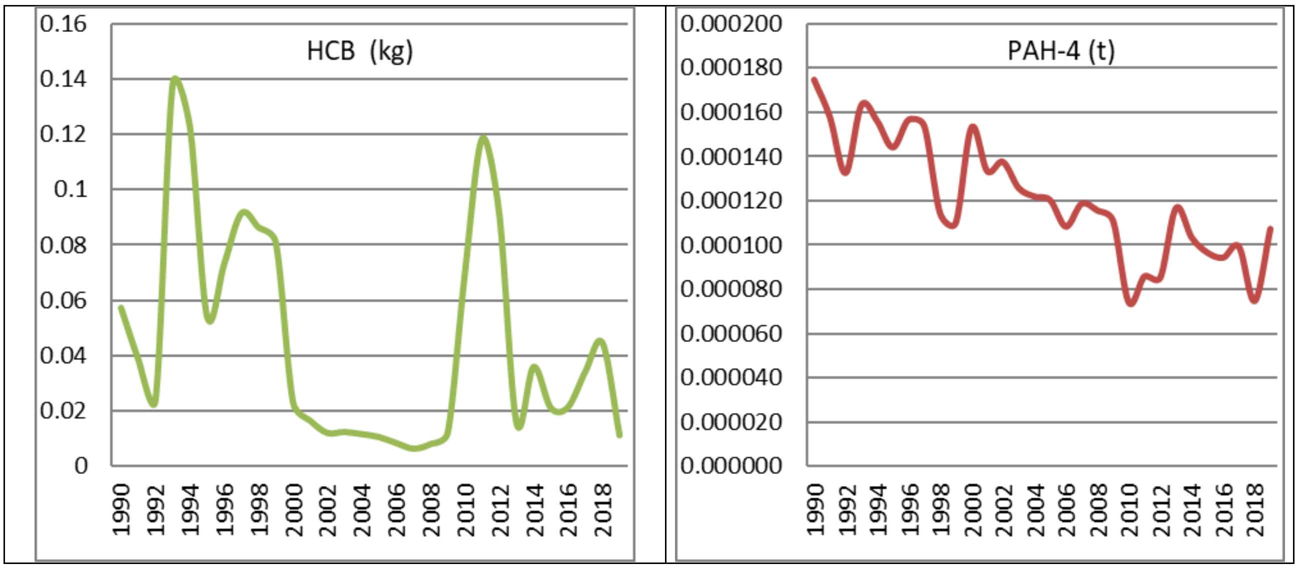

Figure 5.7. POP emissions from agricultural sources 1990-2019

Table 5.8 POP emissions from agriculture 1990-2019

	PCDD/F (3F)	HCB (3Df)	B(a)P (3F)	B(b)F (3F)	B(k)F (3F)	I(1,2,3-cdP) (3F)
	g I-Teq	kg	kg	kg	kg	kg
1990	NA	0.057	0.033	0.101	0.027	0.014
1991	NA	0.039	0.030	0.091	0.024	0.013
1992	NA	0.024	0.025	0.077	0.020	0.010
1993	NA	0.138	0.031	0.095	0.025	0.013
1994	NA	0.123	0.029	0.090	0.024	0.012
1995	NA	0.054	0.027	0.083	0.022	0.012
1996	NA	0.073	0.029	0.091	0.024	0.013
1997	NA	0.091	0.029	0.089	0.024	0.012
1998	NA	0.086	0.021	0.066	0.018	0.009
1999	NA	0.081	0.021	0.064	0.017	0.009
2000	NA	0.023	0.029	0.088	0.024	0.012
2001	NA	0.017	0.025	0.077	0.021	0.011
2002	NA	0.012	0.026	0.079	0.021	0.011
2003	NA	0.012	0.024	0.072	0.020	0.011
2004	NA	0.012	0.023	0.070	0.019	0.010
2005	NA	0.011	0.022	0.069	0.019	0.010
2006	NA	0.008	0.020	0.062	0.017	0.009
2007	NA	0.006	0.022	0.068	0.019	0.010
2008	NA	0.008	0.022	0.066	0.018	0.010
2009	NA	0.012	0.021	0.063	0.017	0.009
2010	NA	0.070	0.014	0.042	0.012	0.006
2011	NA	0.118	0.016	0.049	0.014	0.008
2012	NA	0.091	0.016	0.048	0.014	0.007
2013	NA	0.016	0.022	0.067	0.018	0.010
2014	NA	0.036	0.019	0.059	0.017	0.009
2015	NA	0.021	0.018	0.055	0.015	0.009
2016	NA	0.021	0.018	0.054	0.015	0.008
2017	NA	0.034	0.019	0.057	0.016	0.009
2018	NA	0.045	0.014	0.043	0.012	0.006
2019	NA	0.011	0.020	0.061	0.017	0.009

5.3 Manure Management (NFR 3B)

Changes in chapter	
February 2020	KS, JMP, JG, JM

Source category description

This sector covers management of manure from domestic livestock.

Figure 5.8 K. Inha: Finnish agriculture, series of photographs, 1899, photographed scenes of Finnish agricultural work for the World´s Fair (Exposition Universelle) in Paris in 1900.

Finland reports emissions from manure management of cattle (including dairy cows, suckler cows, heifers, bulls and calves), swine, horses, goats, sheep, poultry, fur animals and reindeer. Mules, asses, camels and buffalos are not farmed in Finland (Table 5.9).

Table 5.9 Animal categories in Finland

NFR	Animal category
3B1a	Cattle, dairy
3B1b	Cattle, non-dairy
3B2	Sheep
3B3	Swine
3B4a	Buffalo - not farmed in Finland
3B4d	Goats
3B4e	Horses

NFR	Animal category
3B4f	Mules and asses - not farmed in Finland
3B4gi	Laying hens
3B4gii	Broilers
3B4giii	Turkeys
3B4giv	Other poultry - cockerels, broiler hens, chicken and other poultry
3B4h	Other - reindeer and fur animals

Methodological issues

Documentation of the revised method is presented below and in a separate document Grönroos et al 2017 (saved in the submission folder).

Calculation model for agricultural emissions

Since 1998, ammonia emissions originating from manure have been calculated by using the national nitrogen model, which is based on the nitrogen flow approach. In this approach, flow of total ammoniacal nitrogen (TAN) and total nitrogen (tot-N) are followed through the manure management system so that the more NH_3 and other nitrogen compounds are emitted at the previous stage of the manure management system the less TAN and tot-N remain available for emissions later. The model includes also ammonia emission calculation for mineral N-fertilisers. The documentation of the previous calculation systems was published by Grönroos et al. in 1998 (in Finnish) and in 2009 (in English). Originally, the model was used only for ammonia emission modelling, but it was supplemented later with N_2O and NO and N_2 emission calculation.

The model was revised in 2016-2017 (Figure 5.9) and includes currently gaseous nitrogen emissions (N_2, NH_3, N_2O and NO) thus integrating the calculation of nitrogen emissions between the greenhouse gas and air pollutant emission inventories. It also enables reporting of emissions at the level of detail in the reporting guidelines of the UNECE CLRTAP and the UNFCCC.

The revision of the model included updating and expanding the model to meet the most recent requirements of the emission inventory guidelines of UNECE (EMEP/EEA 2019) and UNFCCC (IPCC 2006). The revision included change of the nitrogen flow approach to a entirely total ammoniacal nitrogen (TAN) based approach. In the previous model version, the approach was mainly based on the total nitrogen.

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

NMVOC emission calculation for manure management, manure applied to soils, urine and dung deposited by grazing animals and cultivated crops was added to the calculation system (see Table 5.6 and Chapter 2.2 in Grönroos et al., 2017). Further, the changes enabled the establishment of the Finnish normative manure system (see Luostarinen et al. 2017), which was built simultaneously with the revision of this model. Particle emissions from animal husbandry and field operations (cultivation, harvesting, cleaning and drying) were added to the model in 2019.

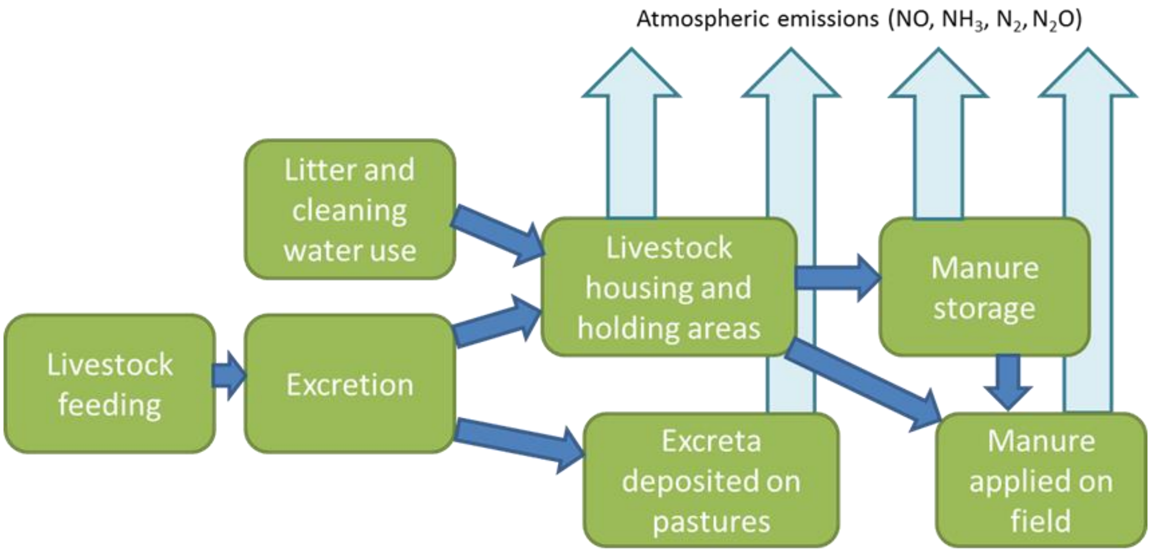

Figure 5.9 Revised calculation model for agriculture (Grönroos et al., 2017)

Table 5.10 Source categories and emissions included in the Finnish Agricultural Emissions Calculation System in 2019.

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

The model is updated yearly, a new reporting year is added every year and the previous years are updated when new information is available.

Basis of calculation

Calculation of the gaseous nitrogen emissions from manure management is based on the mass or nitrogen flow approach, as described in the model documentation (Grönroos et al. 2017), and in the UNECE and UNFCCC emission inventory guidebooks. In the method used, the pathways of nitrogen are followed starting from the nitrogen excretion of the livestock and ending at the application of manure to the fields (Figure 5.10). In each manure management stage, the gaseous losses of nitrogen are calculated. The calculation is carried out per each animal category (Table 5.11.a and 5.11.b) and for each manure management system.

In general, the Finnish agricultural ammonia emission calculation system follows the principles of the Tier 2 method described in the EMEP/EEA Guidebook 2019. However, it has some features, which move it towards the Tier 3 method, such as the greater number of animal and manure categories than listed under Tier 2, and the inclusion of the emission abatement measures.

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

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

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

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

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

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

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

Unabated ammonia emission factors for each animal category (unabated EF; % of TAN) and estimated reduction of ammonia emission losses achieved with abatement measures (% of loss without abatement) for manure management, manure application and grazing are presented in Table 5.11. Emission factors used for calculating nitrous oxide (N_2O) losses from manure management (including manure application) and grazing (Table 5.12), and emission factors used for calculating of nitric oxide (NO) and di-nitrogen (N_2) losses from manure management and manure application are presented in Table 5.13.

Currently, Finland uses an average ammonia-EF for housing for all pig categories (per manure type) instead of more specific swine category specific EFs provided by the 2019 Guidebook, because of the structure of the calculation system. During the updating process of the calculation system in 2021, it will be modified so that it will be possible to use more detailed animal specific emission/volatilisation factors for all animal groups.

Table 5.11. Unabated emission factors (unabated EF; % of TAN) and estimated reduction of losses achieved with abatement measures (am, % of loss without abatement) for ammonia.

	CATTLE					PIGS					POULTRY			SHEEP, GOAT		HORSE, PONY		FUR ANIMALS
	Slurry	Deep litter	FYM	Urine	Dung	Slurry	Deep litter	FYM	Urine	Dung	Slurry	Deep litter	Solid manure	Deep litter	FYM	Deep litter	FYM	FYM
Housing																		
Unabated EF	*24 or 9**	*32*	*8 or 9**	*8 or 9**	*8 or 9**	*31*	*29*	*24*	*24*	*24*	*41*	*25*	*20*	*32*	*22*	*35*	*22*	*40*
am: rapid urine separation			15	20				15	20		*60*		*85*		15		15	0
am: flushing	60					60							10					
am: improved cleaning	10		10	10	10	10		10	10	10			60		10		10	0
am: increased manure removal frequency	10		10	10	10	25		10	10	10	10		10		10		10	0
am: biol. or chem. air scrubbers	85	85	85	85	85	85	85	85	85	85	85	85		85	85	85	85	0
am: cooling of slurry channels	30					30												
Filling the manure storage																		
from the top	*5*					*5*					*5*							
from the bottom	*0*					*0*					*0*							
Storing																		
Unabated EF	*25*	*32*	*32*	*25*	*32*	*11*	*29*	*29*	*11*	*29*	*14*	*30*	*8*	*32*	*32*	*35*	*35*	*35*
am: tight roof (concrete)	95			95		95			95		95							
am: floating cover	60			60		60			60		60							
am: natural crust	40					40					40							
am: roof of solid manure storage		10	10		10		10	10		10		10	10	10	10	10	10	10
am: filling the solid manure storage from the bottom			30		30			30		30			30		30		30	30
am: tent, roof	80					80					80							

*Emission factor for loose housing (first value) and tied housing (second value).
FYM = solid manure with urine

	CATTLE					PIGS					POULTRY			SHEEP, GOAT		HORSE, PONY		FUR ANIMALS
	Slurry	Deep litter	FYM	Urine	Dung	Slurry	Deep litter	FYM	Urine	Dung	Slurry	Deep litter	Solid manure	Deep litter	FYM	Deep litter	FYM	FYM
Spreading on arable land																		
Unabated EF (broadcast spr)	*55*	*68*	*68*	*50*	*68*	*35*	*45*	*45*	*30*	*45*	*69*	*38*	*45*	*90*	*90*	*90*	*90*	*80*
am: incorporation with ploughing < 4 hrs	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
am: incorp. with ploughing < 12 hrs	45	50	50	45	50	45	50	50	45	50	45	50	50	50	50	50	50	50
am: incorp. with ploughing > 12 hrs	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
am: incorp. with harrowing < 4 hrs	60	50	50	60	50	60	50	50	60	50	60	50	50	50	50	50	50	50
am: incorp. with harrowing < 12 hrs	35	25	25	35	25	35	25	25	35	25	35	25	25	25	25	25	25	25
am: incorp. with harrowing > 12 hrs	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
am: injection	78			78		78			78		78							
am: band spreading	30			30		30			30		30							
Spreading on plant covered land																		
Unabated EF (broadcast spr)	*55*	*68*	*68*	*50*	*68*	*35*	*45*	*45*	*30*	*45*	*69*	*38*	*45*	*90*	*90*	*90*	*90*	*80*
am: band spreading	35			35		35			35		35							
am: injection	78			78		78			78		78							
am: band spreading + acid	75					75					75							

FYM = solid manure with urine

	CATTLE					PIGS					POULTRY			SHEEP, GOAT		HORSE, PONY		FUR ANIMA LS
	Slurry	Deep litter	FYM	Urine	Dung	Slurry	Deep litter	FYM	Urine	Dung	Slurry	Deep litter	Solid manure	Deep litter	FYM	Deep litter	FYM	FYM
Spreading on stubble or on grass to be terminated																		
Unabated EF (broadcast spr)	*55*	*68*	*68*	*50*	*68*	*35*	*45*	*45*	*30*	*45*	*69*	*38*	*45*	*90*	*90*	*90*	*90*	*80*
am: incorp. with ploughing < 4 hrs	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
am: incorp. with ploughing < 12 hrs	45	50	50	45	50	45	50	50	45	50	45	50	50	50	50	50	50	50
am: incorp. with ploughing > 12 hrs	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

am: incorp. with harrowing < 4 hrs	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
am: incorp. with harrowing < 12 hrs	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
am: incorp. with harrowing > 12 hrs	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
am: injection	78			78		78			78		78							
am: band spreading	30			30		30			30		30							
Grazing																		
evaporate from urine	*14*					*10*					*10*			*9*		*35*		
evaporate from faeces	*14*					*10*					*10*			*9*		*35*		
Yards																		
evaporate from urine	*40*					*53*					*40*			*75*		*35*		
evaporate from faeces	*40*					*53*					*40*			*75*		*35*		

FYM = solid manure with urine

Table 5.12 Emission factors used for calculating nitrous oxide (N_2O) losses from manure management (including manure application) and grazing (IPCC 2006).

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

Table 5.13. Emission factors used for calculating of nitric oxide (NO) and di-nitrogen (N_2) losses from manure management and manure application (EMEP/EEA 2019).

Parameter	Emission source	Emission factor
NO-N	Inhouse, slurry	NA
	Inhouse, solid manure	NA
	Storage, slurry	0.01% of TAN
	Storage, solid manure	1.0% of TAN
	Application, solid and liquid manure, and mineral N	1.22% of tot-N applied
N_2	Inhouse, slurry	NA
	Inhouse, solid manure	NA
	Storage, slurry	0.3% of TAN
	Storage, solid manure	30.0% of TAN

Currently, anaerobic digestion is not considered in the agricultural emission calculation system. According to the Natural Resources Institute Finland (Luke), quantity of anaerobically digested livestock manure is currently around 160 000 tons/year, which represents about 1% of the total amount of livestock manure (excluding manure excreted on pasture). The amount of anaerobically digested manure is so small that it has not been seen essential to make major changes to the agricultural emission calculation system. However, the calculation system will be supplemented in this respect during 2021.

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

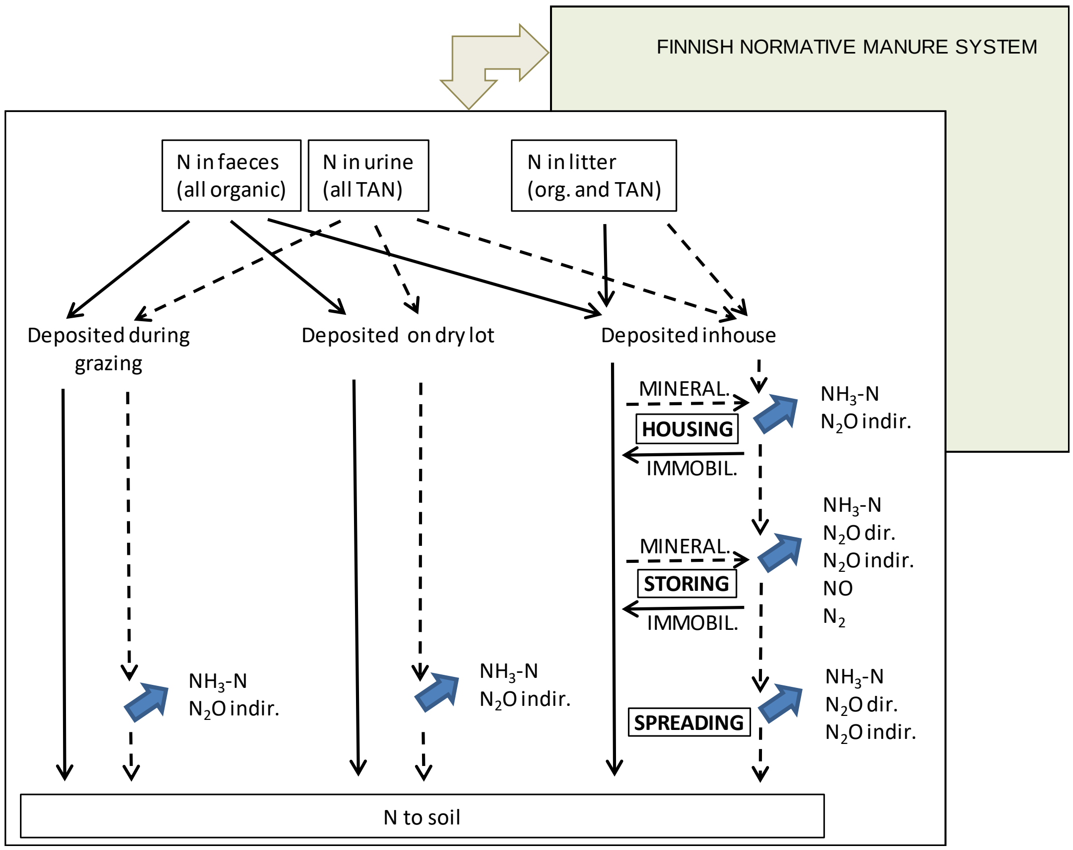

Figure 5.10. Schematic diagram of the N flows in manure management (incl. manure application, grazing and dry lots) and the related gaseous nitrogen emission calculation system used for calculating the NH_3, N_2O, NO and N_2 emissions from manure management in Finland. Nitrogen transformation processes (immobilisation and mineralisation) are shown, as well as the link between emission calculation system and the Finnish normative manure system (see text for more information). Broad blue arrows: emissions of N-compounds to the atmosphere. Emissions are calculated separately for each animal category and manure management system. For clarity, all manure management systems are not shown in the figure.

Table 5.14.a. Animal categories considered in the emission calculation system; the detailed categorisation. The animal categories are the same as those in the Finnish normative manure system (Luostarinen et al. 2017).

CATTLE	PIGS	POULTRY	OTHER ANIMALS
Dairy cow, high yielding	Farrowing sow + piglets (<10-12 kg)	Laying hen breeder	Horse
Dairy cow, indigenous	Gestating sow	Cockerel (laying hen breeder, male)	
	Mating sow	Broiler	Pony (120-140)
Suckler cow, high yielding	Boar (50- kg)	Broiler breeder hen	Pony, little (<120)
Suckler cow, indigenous	Fattening pig (50- kg)	Broiler breeder, male	
		Chicken	Ewe
Heifer, beef (2- yrs)	Weaned pig (<30 kg)		Ram
Heifer, beef (1-2 yrs)	Weaned pig (<50 kg)	Groving turkey	Lamb
Heifer, dairy (2- yrs)		Turkey breeder hen	
Heifer, dairy (1-2 yrs)		Turkey breeder male	Female goat
Heifer, small (>2 yrs)		Other poultry	Male goat
Heifer, small (1-2 yrs)			Goatling

Bull, beef (>2 yrs)			Fox breeder, female
Bull, beef (1-2 yrs)			Fox breeder, male
Bull, dairy (>2 yrs)			Fox grover
Bull, dairy (1-2 yrs)			
Bull, indigenous (1-2 yrs)			Mink breeder, female
Bull, indigenous (>2 yrs)			Mink breeder, male
			Mink grover
Calf, female, beef (< 6 m)			Reindeer
Calf, female, beef (6-12 m)			
Calf, female, dairy (< 6 m)			
Calf, female, dairy (6-12 m)			
Calf, female, indigenous (< 6 m)			
Calf, female, indigenous (6-12 m)			
Calf, male, beef (< 6 m)			
Calf, male, beef (6-12 m)			
Calf, male, dairy (< 6 m)			
Calf, male, dairy (6-12 m)			
Calf, male, indigenous (< 6 m)			
Calf, male, indigenous (6-12 m)			

Table 5.14.b. Animal categories in the calculation system; the simpler categorisation. The animal categories are the same as those in the Finnish normative manure system (Luostarinen et al. 2017).

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

A detailed description of the calculation of emissions is provided in the document Grönroos et al., 2017, Chapter 2.1.1.2 (available in the 2018 EIONET CDR submission folder).

Activity data

Animal numbers are received from Statistical services of the Natural resources institute Finland (Luke), the Finnish Trotting and Breeding Association of horses (Suomen Hippos) and from the statistics of the Finnish Fur Breeders' Association, as presented in Tables 5.20a-c.

The number of reindeer is taken from the Yearbook of Farm Statistics or the E-Yearbook of Food and Natural Resource Statistics (https://stat.luke.fi/en/e-yearbook-food-and-natural-resource-statistics-2017-2017_en), or, for the years 2018 and 2019, obtained directly from Luke Statistical Services. The number of reindeer corresponds to the number of reindeers left alive during the reindeer herding year.

Animal-specific nitrogen excretion rates are based on the nutrient balance calculations carried out by Natural Resources Institute Finland (Luke; Table 5.15).

Manure management data

Before 2013, data on manure management and emission abatement techniques based mainly on expert opinions and on some statistical data. In 2013, a questionnaire on manure management was sent to ca 10 000 livestock farms to collect more recent and detailed data. The results from the survey were used in updating the emission calculation system.

Changes in legislation and Agri-environmental support system in 2014-2015 caused changes in manure management practices and have been taken into account in emission calculation too. Some new statistical data and data from Ministry of Agriculture and Forestry about the implemention of the new agri-environmental measures related to slurry injection have been taken into account as well. New data on manure management practices have been collected in a survey in early 2021 and will be available for emission calculation purposes later this year.

Table 5.15. Time series for animal-specific nitrogen excretion rates used in the 2021 submission.

Year	Dairy cow	Calve <1 yr	Bull >1 yr	Heifer >1 yr	Suckler cow	Veaned pig	Fattening pig	Sow	Boar	Horse	Pony	Goat	Sheep
1980	78.95	24.25	40.80	36.59	61.20	9.66	19.58	27.76	19.34	61.80	43.67	10.70	7.28
1981	79.88	24.47	41.31	36.68	61.20	9.58	19.45	27.76	19.26	61.49	43.57	10.70	7.28
1982	80.82	24.70	41.82	36.78	61.20	9.51	19.32	27.75	19.17	61.17	43.47	10.70	7.28
1983	81.75	24.92	42.34	36.87	61.20	9.43	19.18	27.75	19.09	60.86	43.38	10.70	7.28
1984	82.68	25.15	42.85	36.96	61.20	9.36	19.05	27.74	19.00	60.54	43.28	10.70	7.28
1985	83.62	25.37	43.36	37.05	61.20	9.28	18.92	27.74	18.92	60.23	43.18	10.70	7.28
1986	84.50	25.63	43.60	37.13	61.43	9.22	18.83	27.87	18.90	60.20	42.92	10.70	7.28
1987	85.21	26.09	43.77	37.33	61.69	8.92	18.32	28.13	19.37	59.54	43.48	10.70	7.28
1988	85.96	25.95	43.77	37.44	61.96	8.88	18.34	28.15	19.48	59.57	43.36	10.70	7.28
1989	88.03	26.64	45.35	38.36	62.22	8.85	18.30	28.00	19.31	59.59	43.49	10.70	7.28
1990	89.96	27.23	47.07	39.52	62.48	8.81	18.30	27.77	19.56	59.37	43.39	10.70	7.28
1991	90.10	27.43	47.79	39.99	63.09	8.77	17.99	27.33	19.68	59.22	43.15	10.70	7.28
1992	90.55	27.50	47.70	39.94	63.70	8.74	17.80	27.49	19.39	59.12	43.23	10.70	7.28
1993	92.31	28.47	48.95	41.63	64.31	8.75	17.58	27.39	19.27	59.59	43.43	10.70	7.28
1994	94.70	28.89	49.91	42.22	64.91	8.76	17.50	27.08	19.09	60.06	43.92	10.70	7.28
1995	95.24	29.06	49.95	42.25	65.51	8.54	17.39	26.46	19.14	60.51	44.41	10.70	7.28
1996	95.43	29.28	50.57	42.59	66.11	8.42	17.30	26.46	19.06	60.51	44.24	10.70	7.46
1997	98.05	29.73	51.08	43.26	66.71	8.47	17.31	26.46	19.80	60.27	44.40	10.70	7.34
1998	99.32	30.14	51.70	43.65	67.31	8.50	17.44	26.62	19.90	59.98	44.30	10.70	7.15
1999	102.52	30.88	52.40	44.08	67.90	8.56	17.47	26.68	17.93	60.03	44.24	10.70	7.43
2000	106.52	31.96	54.05	45.47	68.49	8.61	17.47	26.80	17.81	60.10	44.14	10.70	7.39
2001	109.33	32.87	55.95	46.58	69.08	8.65	17.50	26.60	18.87	60.29	44.11	10.70	6.91
2002	111.84	33.93	58.90	47.81	69.67	8.71	17.58	27.29	19.22	60.54	44.22	10.70	7.38
2003	114.32	35.08	61.46	48.82	69.96	8.78	17.48	27.76	19.37	60.76	44.24	10.70	7.43
2004	117.31	36.16	63.29	50.11	71.76	8.80	17.45	28.20	19.65	60.99	43.97	10.70	7.36
2005	119.06	36.60	63.80	50.41	71.48	8.87	17.47	28.38	20.06	60.96	43.62	10.70	7.20
2006	120.71	37.14	64.91	51.17	72.04	8.94	17.60	28.73	20.49	60.93	43.46	10.70	7.26
2007	122.58	37.98	66.73	52.17	72.28	8.97	17.57	29.08	20.54	61.00	43.29	10.70	7.14
2008	123.84	38.35	66.95	52.83	73.15	9.00	17.60	29.49	20.32	60.94	43.21	10.70	7.26
2009	126.13	39.05	67.06	53.60	73.52	9.03	17.53	29.49	20.28	61.19	43.36	10.70	7.27
2010	128.53	40.07	68.72	54.93	75.28	9.01	17.55	29.90	20.53	61.09	43.46	10.70	7.12
2011	128.94	40.18	68.15	55.08	75.72	9.04	17.46	30.90	20.69	61.32	43.48	10.70	7.28
2012	129.50	39.69	66.76	54.61	74.11	9.07	17.45	30.24	20.41	61.29	43.50	10.70	7.12
2013	128.31	39.50	66.39	54.10	74.10	9.06	17.40	30.73	20.38	61.59	43.65	10.70	7.19
2014	130.24	39.94	67.30	54.60	74.96	9.09	17.34	31.19	20.69	61.71	44.02	10.70	7.19
2015	131.91	40.44	68.67	54.99	75.67	9.12	17.38	31.37	20.56	61.91	44.33	10.70	7.26
2016	130.42	40.28	68.71	54.59	75.03	9.12	17.27	32.06	20.56	61.99	44.52	10.70	7.31
2017	132.83	40.91	69.63	55.51	74.88	9.13	17.22	31.95	20.81	61.97	44.48	10.70	7.43
2018	133.37	41.14	70.65	55.66	75.30	9.16	17.21	32.88	21.03	61.90	44.59	10.70	7.60
2019	136.71	42.81	73.01	57.80	77.28	9.16	17.17	32.27	20.94	61.77	44.68	10.70	7.60

Year	Broiler hen	Broiler	Laying hen	Laying hen pullet	Cockerel	Turkey	Other poultry	Fox and racoon	Mink and fitch	Reindeer
1980	0.992	0.441	0.631	0.353	0.969	1.07	0.62	2.13	1.24	10.70
1981	0.992	0.438	0.631	0.353	0.969	1.07	0.62	2.13	1.24	10.70
1982	0.992	0.436	0.631	0.353	0.969	1.07	0.62	2.13	1.24	10.70
1983	0.992	0.433	0.631	0.353	0.969	1.07	0.62	2.13	1.24	10.70
1984	0.992	0.431	0.631	0.353	0.969	1.07	0.62	2.13	1.24	10.70
1985	0.992	0.428	0.572	0.353	0.969	1.07	0.62	2.13	1.24	10.70
1986	0.992	0.426	0.585	0.353	0.969	1.08	0.62	2.13	1.24	10.70
1987	0.992	0.457	0.555	0.353	0.969	1.08	0.62	2.13	1.24	10.70
1988	0.992	0.454	0.556	0.353	0.969	1.08	0.62	2.13	1.24	10.70
1989	0.992	0.452	0.546	0.353	0.969	1.08	0.62	2.13	1.24	10.70
1990	0.992	0.449	0.567	0.353	0.969	1.08	0.62	2.13	1.24	10.70
1991	0.992	0.425	0.585	0.356	0.969	1.20	0.64	2.15	1.25	10.70
1992	0.992	0.376	0.578	0.359	0.969	1.21	0.63	2.17	1.26	10.70
1993	0.992	0.401	0.605	0.362	0.969	1.32	0.66	2.19	1.26	10.70
1994	0.992	0.399	0.599	0.366	0.969	1.24	0.66	2.21	1.27	10.70
1995	0.992	0.396	0.588	0.369	0.969	1.30	0.65	2.24	1.27	10.70
1996	0.992	0.366	0.607	0.372	0.969	1.29	0.67	2.26	1.28	10.70
1997	0.992	0.363	0.605	0.376	0.969	1.31	0.66	2.28	1.29	10.70
1998	0.992	0.416	0.615	0.379	0.969	1.34	0.67	2.30	1.29	10.70
1999	0.992	0.414	0.612	0.382	0.969	1.36	0.67	2.32	1.30	10.70
2000	0.992	0.411	0.616	0.385	0.969	1.42	0.68	2.34	1.31	10.70
2001	0.992	0.409	0.601	0.389	0.969	1.42	0.66	2.42	1.31	10.70
2002	0.992	0.406	0.585	0.389	0.969	1.48	0.64	2.51	1.31	10.70
2003	0.992	0.430	0.607	0.389	0.969	1.48	0.67	2.59	1.31	10.70
2004	0.992	0.428	0.615	0.389	0.969	1.53	0.68	2.67	1.31	10.70
2005	0.992	0.425	0.598	0.389	0.969	1.54	0.66	2.75	1.31	10.70
2006	0.992	0.422	0.583	0.389	0.969	1.48	0.65	2.84	1.31	10.70
2007	0.992	0.446	0.575	0.388	0.969	1.50	0.64	2.92	1.31	10.70
2008	0.992	0.479	0.573	0.388	0.969	1.50	0.64	3.00	1.31	10.70
2009	0.992	0.483	0.576	0.388	0.969	1.60	0.64	3.00	1.31	10.70
2010	0.992	0.476	0.574	0.388	0.969	1.61	0.64	3.00	1.31	10.70
2011	0.992	0.477	0.579	0.388	0.969	1.58	0.64	3.00	1.31	10.70
2012	0.992	0.477	0.598	0.388	0.969	1.61	0.64	3.00	1.31	10.70
2013	0.992	0.477	0.595	0.388	0.969	1.65	0.64	3.00	1.31	10.70
2014	0.992	0.477	0.574	0.388	0.969	1.59	0.64	3.00	1.31	10.70
2015	0.992	0.478	0.623	0.388	0.969	1.63	0.64	3.00	1.31	10.70
2016	0.992	0.479	0.615	0.388	0.969	1.63	0.64	3.00	1.31	10.70
2017	0.992	0.478	0.601	0.389	0.969	1.66	0.64	3.00	1.31	10.70
2018	0.992	0.478	0.601	0.389	0.969	1.64	0.64	3.00	1.31	10.70
2019	0.992	0.478	0.583	0.388	0.969	1.70	0.64	3.00	1.31	10.70

Emission factors

<u>Ammonia</u>

The domestic emission factors calculated on basis of national studies (Grönroos et al 2017) are presented in Table 5.16 and the tables are updated for the Informative Inventory Report of 2019. The emission factors include emissions from animal shelter, manure storing and application, grazing and dry lot.

Due to the cold climate, grazing period is relatively short in Finland. For example, for sheep the grazing period is averagely 153 days (2016) whereas in the EMEP/EEA (2016) guidebook, the housing period for sheep is 30 days thus implicating a grazing period of 335 days. In Finland, the short grazing period might lead to the higher manure management IEFs of some animal categories.

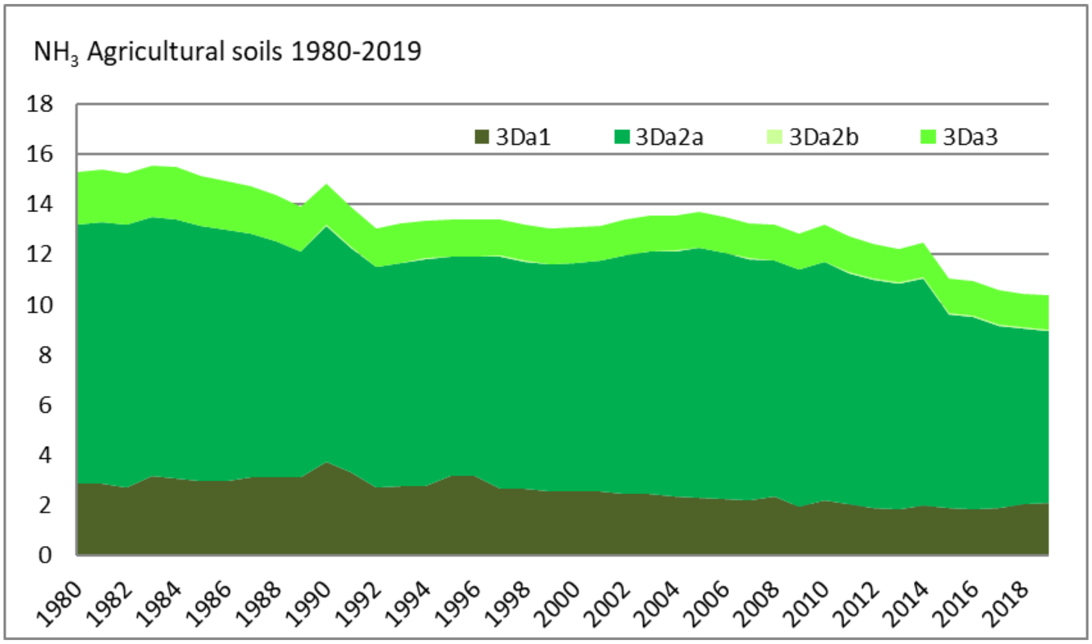

Figure 5.11 Ammonia emissions from NFR 3B categories 1980-2019

Table 5.16a NH_3 emissions factors for Cattle and swine (kg NH_3 / animal) (Grönroos et al., 2017).

Year	Dairy cow	Suckler cow	Heifer >1 yr	Bull >1 yr	Calf <1 yr	Sow (with	Boar (50-	Fattening	Veaned
1980	16.95	11.18	7.91	11.65	6.01	8.30	6.61	6.17	2.62
1981	17.23	11.15	7.95	11.82	6.14	8.43	6.58	6.16	2.60
1982	17.51	11.12	7.98	11.99	6.27	8.56	6.55	6.15	2.58
1983	17.71	11.12	7.99	12.14	6.35	8.63	6.52	6.10	2.56
1984	18.08	11.06	8.06	12.34	6.53	8.83	6.49	6.12	2.54
1985	18.37	11.03	8.09	12.51	6.66	8.96	6.45	6.11	2.52
1986	18.64	11.04	8.13	12.61	6.81	9.13	6.44	6.11	2.51
1987	18.89	11.06	8.19	12.68	7.01	9.35	6.60	5.97	2.42
1988	19.14	11.08	8.23	12.71	7.05	9.49	6.63	6.01	2.41
1989	19.70	11.10	8.45	13.20	7.32	9.57	6.56	6.02	2.40
1990	21.10	11.12	8.73	13.73	7.57	9.61	6.64	6.05	2.39
1991	21.22	11.17	8.87	14.00	7.68	9.49	6.69	6.02	2.41
1992	21.43	11.21	8.90	14.03	7.77	9.56	6.61	6.02	2.44
1993	21.95	11.25	9.32	14.47	8.11	9.55	6.59	6.00	2.47
1994	22.63	11.29	9.50	14.82	8.29	9.47	6.55	6.04	2.50
1995	22.87	11.33	9.55	14.91	8.42	9.28	6.58	6.06	2.47
1996	23.18	11.63	9.63	15.10	8.48	9.27	6.55	6.03	2.43
1997	24.10	11.93	9.78	15.25	8.61	9.27	6.80	6.03	2.44
1998	24.71	12.23	9.87	15.44	8.73	9.32	6.83	6.07	2.45
1999	25.81	12.54	9.97	15.66	8.95	9.33	6.15	6.07	2.47
2000	27.14	12.86	10.29	16.16	9.26	9.37	6.11	6.07	2.48
2001	28.35	13.03	10.55	16.74	9.54	9.32	6.48	6.10	2.50
2002	29.52	13.20	10.84	17.65	9.86	9.58	6.62	6.15	2.53
2003	30.72	13.32	11.08	18.44	10.21	9.77	6.69	6.14	2.56
2004	32.09	13.73	11.39	19.01	10.53	9.95	6.80	6.15	2.57
2005	33.16	13.74	11.46	19.19	10.67	10.04	6.96	6.18	2.60
2006	33.55	13.46	11.77	19.43	10.64	10.26	7.17	6.19	2.60
2007	33.99	13.14	12.14	19.88	10.70	10.47	7.25	6.14	2.58
2008	34.27	12.97	12.44	19.86	10.63	10.69	7.22	6.11	2.56
2009	34.82	12.73	12.77	19.81	10.65	10.75	7.25	6.05	2.55
2010	35.39	12.74	13.24	20.22	10.77	10.95	7.37	6.01	2.52
2011	35.41	12.56	13.43	19.97	10.65	11.36	7.46	5.94	2.50
2012	35.46	12.07	13.46	19.49	10.39	11.07	7.33	5.85	2.46
2013	35.16	12.09	13.39	19.38	10.36	11.30	7.35	5.85	2.46
2014	35.47	12.22	13.53	20.00	10.58	11.44	7.44	5.79	2.46
2015	33.19	12.23	12.87	19.29	10.17	10.89	7.00	5.44	2.31
2016	32.89	12.16	12.86	19.35	10.18	11.04	6.95	5.35	2.28
2017	32.95	12.10	12.92	19.32	10.25	10.88	6.95	5.25	2.26
2018	32.75	12.12	12.87	19.54	10.24	11.18	7.01	5.23	2.25
2019	33.36	12.37	13.35	20.06	10.64	10.59	6.74	5.02	2.17

Table 5.16b NH_3 emissions factors for Poultry (kg NH_3 / animal) (Grönroos et al., 2017).

Year	Laying hen breeder (female)	Cockerel (laying hen breeder, male)	Broilers	Broiler hens	Chicken	Turkey	Other poultry
1980	0.20	0.23	0.07	0.00	0.00	0.07	0.17
1981	0.20	0.23	0.07	0.00	0.00	0.07	0.17
1982	0.20	0.23	0.07	0.00	0.00	0.07	0.17
1983	0.20	0.23	0.07	0.00	0.00	0.07	0.17
1984	0.20	0.23	0.07	0.00	0.00	0.07	0.17
1985	0.18	0.23	0.07	0.00	0.00	0.07	0.17
1986	0.18	0.23	0.07	0.00	0.00	0.08	0.18
1987	0.17	0.23	0.07	0.00	0.00	0.08	0.18
1988	0.17	0.23	0.07	0.00	0.00	0.08	0.18
1989	0.16	0.23	0.07	0.00	0.00	0.08	0.18
1990	0.16	0.23	0.07	0.16	0.00	0.08	0.18
1991	0.17	0.23	0.07	0.16	0.00	0.08	0.20
1992	0.17	0.23	0.06	0.16	0.00	0.09	0.20
1993	0.18	0.23	0.07	0.16	0.00	0.09	0.22
1994	0.18	0.23	0.07	0.16	0.00	0.09	0.21
1995	0.17	0.23	0.07	0.17	0.00	0.09	0.22
1996	0.18	0.23	0.06	0.17	0.00	0.09	0.21
1997	0.18	0.23	0.06	0.17	0.00	0.09	0.22
1998	0.18	0.23	0.07	0.17	0.00	0.09	0.22
1999	0.18	0.23	0.07	0.17	0.00	0.09	0.23
2000	0.18	0.23	0.07	0.17	0.00	0.09	0.24
2001	0.18	0.23	0.07	0.16	0.00	0.09	0.24
2002	0.17	0.23	0.07	0.16	0.00	0.09	0.24
2003	0.18	0.23	0.07	0.16	0.00	0.09	0.24
2004	0.18	0.23	0.07	0.16	0.00	0.09	0.25
2005	0.17	0.23	0.07	0.16	0.00	0.09	0.25
2006	0.17	0.22	0.07	0.16	0.00	0.09	0.24
2007	0.17	0.22	0.07	0.16	0.00	0.09	0.24
2008	0.17	0.21	0.08	0.16	0.00	0.09	0.24
2009	0.17	0.21	0.08	0.16	0.00	0.08	0.26
2010	0.16	0.20	0.08	0.16	0.00	0.08	0.26
2011	0.16	0.20	0.08	0.16	0.00	0.08	0.26
2012	0.17	0.19	0.08	0.16	0.00	0.08	0.26
2013	0.17	0.19	0.08	0.16	0.00	0.08	0.27
2014	0.16	0.19	0.08	0.16	0.00	0.08	0.26
2015	0.17	0.19	0.08	0.16	0.00	0.08	0.26
2016	0.17	0.19	0.08	0.16	0.00	0.08	0.26
2017	0.17	0.19	0.08	0.16	0.00	0.08	0.27
2018	0.17	0.19	0.08	0.16	0.00	0.08	0.27
2019	0.16	0.19	0.08	0.16	0.00	0.08	0.27

Table 5.16c NH_3 emissions factors for other animals (kg NH_3 / animal) (Grönroos et al., 2017).

Year	Horse	Pony	Sheep	Goat	Fox and racoon	Mink and fitch	Reindeer
1980	16.06	11.28	1.29	1.89	0.84	0.49	0.87
1981	16.07	11.31	1.27	1.87	0.84	0.49	0.87
1982	16.07	11.35	1.26	1.86	0.84	0.49	0.87
1983	15.99	11.32	1.26	1.85	0.84	0.49	0.87
1984	16.07	11.41	1.24	1.82	0.84	0.49	0.87
1985	16.07	11.45	1.23	1.81	0.84	0.49	0.87
1986	16.14	11.43	1.22	1.79	0.84	0.49	0.87
1987	16.05	11.64	1.21	1.78	0.84	0.49	0.87
1988	16.14	11.67	1.20	1.76	0.84	0.49	0.87
1989	16.22	11.76	1.19	1.75	0.84	0.49	0.87
1990	16.25	11.79	1.18	1.73	0.84	0.49	0.87
1991	16.27	11.78	1.19	1.75	0.85	0.49	0.87
1992	16.27	11.82	1.21	1.77	0.86	0.50	0.87
1993	16.39	11.87	1.22	1.79	0.87	0.50	0.87
1994	16.47	11.97	1.23	1.81	0.87	0.50	0.87
1995	16.50	12.04	1.25	1.84	0.88	0.50	0.87
1996	16.50	11.99	1.28	1.84	0.89	0.51	0.87
1997	16.43	12.03	1.26	1.84	0.90	0.51	0.87
1998	16.35	12.01	1.23	1.84	0.91	0.51	0.87
1999	16.37	11.99	1.27	1.84	0.92	0.51	0.87
2000	16.39	11.96	1.27	1.84	0.92	0.52	0.87
2001	16.69	12.14	1.18	1.83	0.96	0.52	0.87
2002	17.01	12.35	1.26	1.83	0.99	0.52	0.87
2003	17.32	12.53	1.27	1.83	1.02	0.52	0.87
2004	17.63	12.63	1.26	1.83	1.05	0.52	0.87
2005	17.87	12.70	1.23	1.83	1.09	0.52	0.87
2006	17.75	12.57	1.26	1.86	1.12	0.52	0.87
2007	17.69	12.47	1.26	1.89	1.15	0.52	0.87
2008	17.62	12.41	1.31	1.93	1.18	0.52	0.87
2009	17.68	12.45	1.33	1.97	1.18	0.52	0.87
2010	17.67	12.49	1.33	2.01	1.18	0.52	0.87
2011	17.80	12.54	1.39	2.05	1.18	0.52	0.87
2012	17.90	12.62	1.40	2.10	1.18	0.52	0.87
2013	17.98	12.66	1.41	2.10	1.18	0.52	0.87
2014	18.01	12.76	1.41	2.10	1.18	0.52	0.87
2015	18.06	12.85	1.42	2.10	1.18	0.52	0.87
2016	18.17	12.96	1.43	2.10	1.18	0.52	0.87
2017	18.16	12.95	1.45	2.10	1.18	0.52	0.87
2018	18.14	12.99	1.49	2.10	1.18	0.52	0.87
2019	18.07	12.99	1.49	2.09	1.15	0.50	0.87

Particle emissions

Particle emissions are generated in manure management, harvesting and field preparation, storage and handling of agricultural crops and fertilizers and field burning of agricultural wastes and have been included in the inventory since the submission in 2004. Figure 5.12 below presents the $PM_{2.5}$ emissions from manure management.

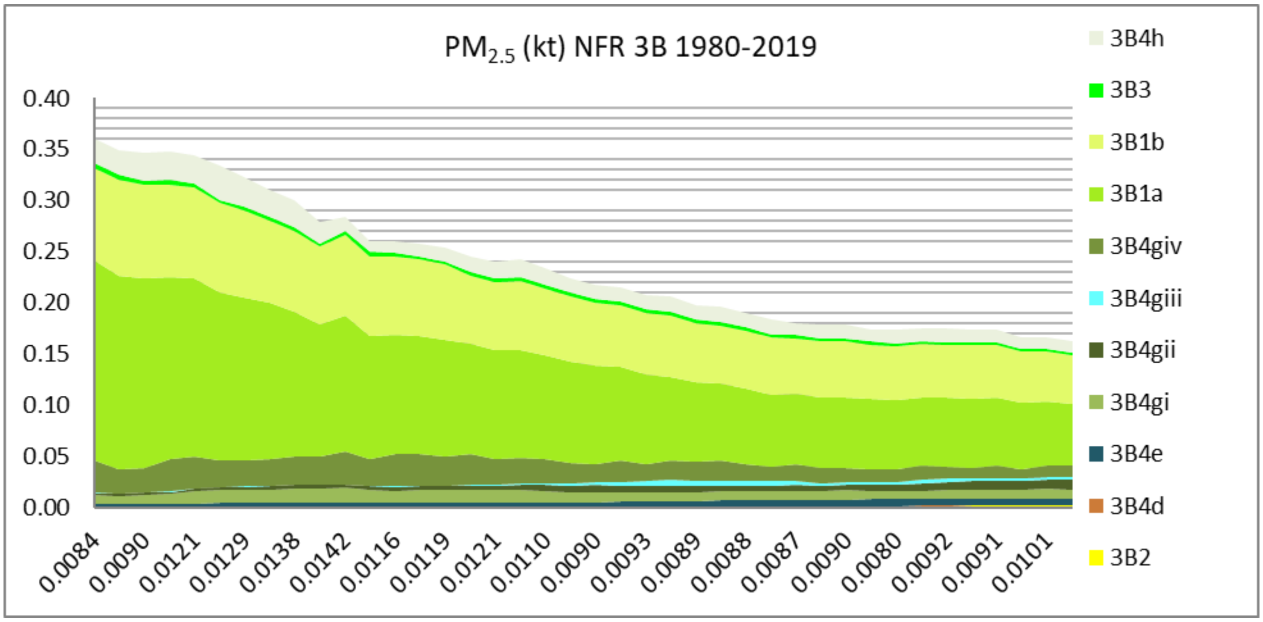

Figure 5.12 $PM_{2.5}$ emissions from NFR 3B categories 1990-2019

According to the Guidebook, particle emissions occur from both housed and free-range animals while the emission factors presented are for housed animals only. The most important parameters impacting particle emissions are feeding conditions, animal activity and bedding material.

In the 2019 submission the calculation of particulate matter emissions for manure management was revised to the Tier 2 method presented in Guidebook 2016 and implemented as Equation 1 below describes.

Equation 1. Particle emissions from animal husbandry for a single animal category

$$E_{PM\,i,j} = AAP_{i,j} * x_{i,j,house} * \sum \left(x_{mms,i,j} * EF_{mms,j} \right)$$

where

i	= Inventory year
j	= Animal category
E_{PM}	= PM emissions (TSP, PM_{10}, $PM_{2.5}$) for an animal category (in kg/a)
AAP	= Annual average population
x_{house}	= Share of time the animals spend in the animal house (in a/a)
x_{mms}	= Portion of manure that is handled as slurry, deep litter or solid manure.
EF	= Emission factor (kg AAP–1 a–1)

The methodology remains by principle the same as in previous submissions, but the revised calculation introduces deep litter and previously absent animal categories into calculation. Emission factors are updated to correspond to the Guidebook of 2016 and presented in Table 5.17. Livestock numbers for 1990-2018 are presented in Tables 5.20a-c.

Table 5.17a Tier 1 particle emission factors for animal husbandry (Guidebook 2016, Table 3.5) and portions of manure handled as slurry, deep litter and solid manure per animal category for 2018.

Animal Category	Tier 1 Emission factor (kg AAP^{-1} a^{-1})			Portion of manure handled as:		
	TSP	PM10	$PM_{2.5}$	Slurry	Deep litter	Solid manure
Dairy cow	1.38	0.63	0.41	0.73	0.00	0.27
Suckler cow	0.59	0.27	0.18	0.06	0.32	0.62
Heifer >1 yr	0.59	0.27	0.18	0.57	0.08	0.35
Bull >1 yr	0.59	0.27	0.18	0.59	0.11	0.30
Calf <1 yr	0.34	0.16	0.1	0.43	0.16	0.41
Sow (with piglets)	0.62	0.17	0.01	0.87	0.00	0.13
Boar (50- kg)	0.62	0.17	0.01	0.87	0.00	0.13
Fattening pig (50- kg)	1.05	0.14	0.006	0.98	0.01	0.01
Veaned pig (20-50 kg)	0.27	0.05	0.002	0.90	0.04	0.06
Laying hen breeder (female)	0.19	0.04	0.003	0.09	0.22	0.69
Cockerel (laying hen breeder, male)	0.19	0.04	0.003	0.00	0.50	0.50
Broiler	0.04	0.02	0.002	0.00	1.00	0.00
Broiler breeder hen	0.04	0.02	0.002	0.00	1.00	0.00
Broiler breeder, male	0.04	0.02	0.002	0.00	1.00	0.00
Chicken	0.14	0.14	0.02	0.00	0.40	0.60
Turkey	0.11	0.11	0.02	0.00	1.00	0.00
Other poultry	0.14	0.14	0.02	0.00	0.40	0.60
Horse	0.48	0.22	0.14	0.00	0.13	0.87
Pony	0.48	0.22	0.14	0.00	0.13	0.87
Sheep	0.14	0.06	0.02	0.00	0.50	0.50
Goat	0.14	0.06	0.02	0.00	0.50	0.50
Fox and racoon	0.018	0.008	0.004	0.00	0.00	1.00
Mink and fitch	0.018	0.008	0.004	0.00	0.00	1.00
Reindeer	0.018	0.008	0.004	0.00	0.00	1.00

The parameter EF_{mms} of Equation 1 for technology specific emission factors are derived by applying the Tier 1 emission factor to the share of manure management systems present for each animal category with the assumption of slurry and deep litter systems having PM emission rates half of those in solid manure systems. This assumption is based on notes in the Guidebook 2016 section A1.2.1 for particulate matter. The relative difference between slurry and solid manure hereby differs from the corresponding figures presented in Guidebook 2013, for which some animal categories suggested higher emission rates for slurry-based systems.

Data on grazing times (grazing period in days), manure handling systems (deep litter, slurry or solid manure) and indoor/outdoor times (% of pastured animals, animals inside in nights during grazing period, house inside in nights) presented in Table 5.18 were updated 2014 according to domestic studies (Grönroos et al., 2009/2014) for the years 2006-2012 . Detailed information on these are available in Grönroos al., 2009/2015 for years the 1990, 1995, 2000 and 2005. The values for the year 1990 are used over the period of 1990-1994 and the year 1995 values over the period of 1996-1999 etc.

Table 5.18a Parameters by animal category in five-year intervals: grazing times, manure handling and outdoor/ indoors times

	Grazing times, grazing period (days)				
	1990	**1995**	**2000**	**2005**	**2015**
Dairy cows	125	125	125	125	112
Suckler cows	140	140	140	140	171
Bulls	0	0	0	0	161
Calves < 1 yr	100	100	100	100	127
Heifers >1 yr	140	140	140	140	134
Horses	140	140	140	140	180
Ponies	140	140	140	140	180
Sheep with lambs	140	130	130	130	153
Goat with gilts	140	130	130	130	153
Fattening pigs	0	0	0	0	0
Sows (with piglets)	90	0	0	0	0
Boars	90	0	0	0	0
Weaned pigs (20-50kg)	0	0	0	0	0
Reindeer	365	365	365	365	365

	Percentage of pastured animals (%)				
	1990	**1995**	**2000**	**2005**	**2015**
Dairy cows	90	90	90	90	69
Suckler cows	90	95	95	95	92
Bulls	0	0	0	0	9
Calves < 1 yr	30	25	25	25	31
Heifers >1 yr	95	90	90	90	69
Horses	95	95	95	95	97
Ponies	95	95	95	95	97
Sheep with lambs	95	90	90	90	90
Goat with gilts	95	90	90	90	90
Reindeer	100	100	100	100	100
	Animals inside in nights during pasturing period (%)				
	1990	**1995**	**2000**	**2005**	**2015**
Dairy cows	60	75	90	100	100
	Hours inside in nights (hours)				
	1990	**1995**	**2000**	**2005**	**2015**
Dairy cows	12	12	12	12	11

The parameters of Table 5.19a contribute to the formation of the parameter x_{house} of equation 1. The complete series of the share of time the animals spend in housing is presented in Table 5.14b below.

Table 5.19b Share of time the animals spend in the animal house (in a/a) for animal categories with annual variation.

Year	Dairy cow	Suckler cow	Heifer >1 yr	Bull >1 yr	Calf <1 yr	Sow (with piglets)	Horse	Pony	Sheep	Goat
1980	0.74	0.65	0.65	0.96	0.86	0.90	0.64	0.64	0.68	0.68
1981	0.74	0.65	0.65	0.96	0.87	0.91	0.64	0.64	0.68	0.68
1982	0.74	0.65	0.65	0.96	0.87	0.92	0.64	0.64	0.67	0.67
1983	0.74	0.65	0.65	0.96	0.88	0.93	0.64	0.64	0.67	0.67
1984	0.74	0.65	0.65	0.96	0.88	0.94	0.64	0.64	0.66	0.66
1985	0.74	0.65	0.65	0.96	0.89	0.95	0.64	0.64	0.66	0.66
1986	0.74	0.65	0.64	0.96	0.90	0.96	0.64	0.64	0.65	0.65
1987	0.74	0.65	0.64	0.96	0.90	0.97	0.64	0.64	0.65	0.65
1988	0.74	0.65	0.64	0.96	0.91	0.98	0.64	0.64	0.64	0.64
1989	0.74	0.65	0.64	0.96	0.91	0.99	0.64	0.64	0.64	0.64
1990	0.78	0.65	0.64	0.96	0.92	0.99	0.64	0.64	0.64	0.64
1991	0.79	0.65	0.64	0.96	0.92	0.99	0.64	0.64	0.64	0.64
1992	0.79	0.65	0.64	0.96	0.92	1.00	0.64	0.64	0.65	0.65
1993	0.80	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.66	0.66
1994	0.80	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.67	0.67
1995	0.81	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
1996	0.81	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
1997	0.82	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
1998	0.82	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
1999	0.83	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2000	0.83	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2001	0.83	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2002	0.84	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2003	0.84	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2004	0.84	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2005	0.85	0.64	0.65	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2006	0.85	0.63	0.67	0.96	0.93	1.00	0.64	0.64	0.68	0.68
2007	0.86	0.62	0.68	0.96	0.92	1.00	0.64	0.64	0.67	0.67
2008	0.86l	0.61	0.70	0.96	0.92	1.00	0.64	0.64	0.67	0.67
2009	0.87	0.61	0.71	0.96	0.91	1.00	0.64	0.64	0.67	0.67
2010	0.87	0.60	0.73	0.96	0.91	1.00	0.64	0.64	0.66	0.66
2011	0.88	0.59	0.74	0.96	0.90	1.00	0.64	0.64	0.66	0.66
2012	0.88	0.58	0.76	0.96	0.90	1.00	0.64	0.64	0.65	0.65
2013	0.88	0.58	0.76	0.96	0.90	1.00	0.64	0.64	0.65	0.65
2014	0.88	0.59	0.76	0.96	0.90	1.00	0.64	0.64	0.65	0.65
2015	0.88	0.59	0.76	0.96	0.90	1.00	0.64	0.64	0.65	0.65
2016	0.89	0.59	0.77	0.96	0.90	1.00	0.64	0.64	0.65	0.65
2017	0.89	0.59	0.77	0.96	0.90	1.00	0.64	0.64	0.65	0.65
2018	0.89	0.59	0.77	0.96	0.90	1.00	0.64	0.64	0.65	0.65
2019	0.89	0.59	0.77	0.96	0.90	1.00	0.64	0.64	0.65	0.65

Fur animals and poultry are considered to stay always indoors (x_{house} = 1) and reindeer always outdoors (x_{house} = 0).

NMVOC emissions

Emissions of NMVOC in manure management originate from silage store and feed, manure in the barns, outdoor manure stores, field application of manure and grazing of animals. In-house emissions are reported under NFR 3B (Figure 5.13) and emissions of field application of manure and grazing under NFRs 3Da2a and 3Da3, respectively.

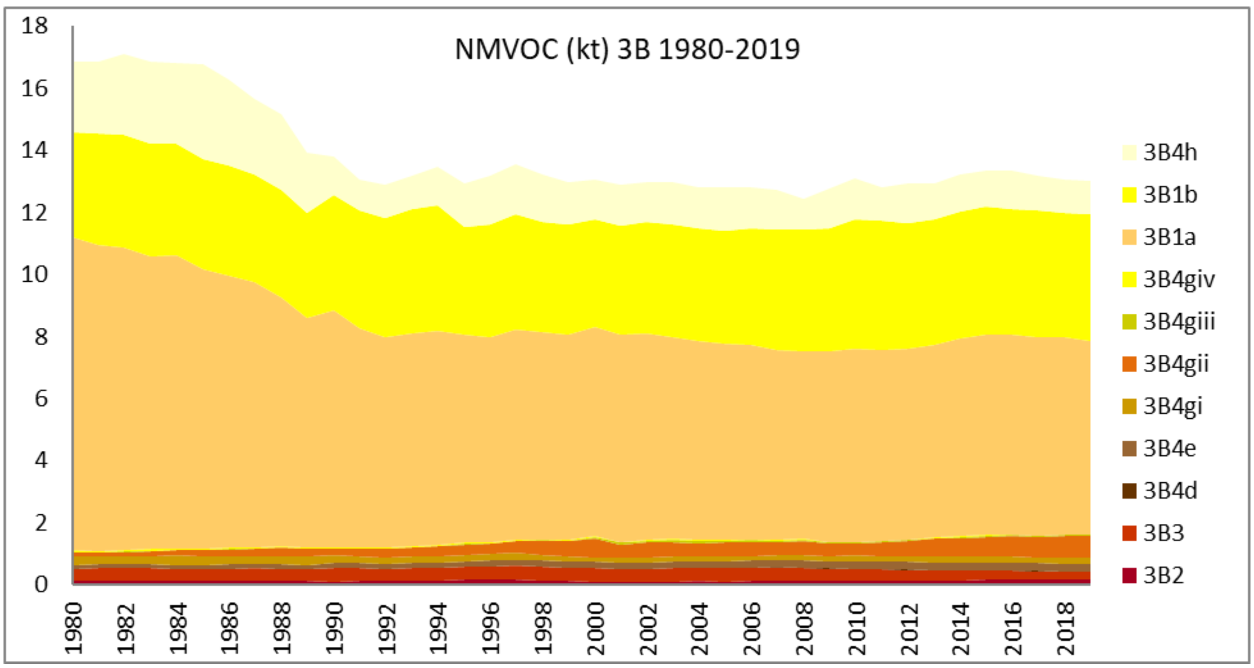

Figure 5.13 NMVOC emissions from NFR 3B categories 1980-2019

The calculation method for NMVOC emissions is presented in detail in Grönroos et al., 2017 (in the reporting folder).

The main parameters for calculation are gross energy intake (GEI as megajoules MJ/a), volatile solids excreted (VS), annual average population (AAP) which are provided by Natural Resources Institute Finland (Luke). Detail increasing parameters such as the share of time the animals spend in housing, fractions of silage store and feed (Table 5.20) are national values. Data is available for GEI and VS for the years 1990-2018 and for AAP for the years 1980-2018. The livestock classification varies between the data sources. Gross energy intake (Table 5.21) is available for dairy cows, non-dairy cattle, suckler cows, bulls (age over 1 year), heifers, calves (under 1 year) and non-dairy gross energy. Data of gross energy intakes as required by the EF of cattle are presented in Table 5.21. For VS (Table 5.22), primary data is available for dairy cows, non-dairy cattle, suckler cows, bulls (age over 1 year), heifers, calves (under 1 year), swine, sow, piglets, fattening pigs, boars, weaned pigs, sheep, goats, horses, poultry, laying hens, chickens, cockerels, broiler hens, broilers, turkeys, other poultry (ducks), other animals, reindeer, fur animals, mink and fitch, fox and raccoon.

Emission factors from EMEP/EAA Guidebook 2019 are presented in Table 5.20.

Table 5.20 Default NMVOC Tier 2 emission factors for livestock (EMEP/EAA Guidebook 2019)

NFR	Animal category	$EF_{silage\_feeding}$	EF_{house}	$EF_{grazing}$	Unit
3B1a	Dairy cattle	2,00E-04	3,53E-05	6,90E-06	kg NMVOC kg/MJ feed
3B1b	Non-dairy cattle	2,00E-04	3,53E-05	6,90E-06	kg NMVOC kg/MJ feed
3B2	Sheep	1,08E-02	1,61E-03	2,35E-05	kg NMVOC/kg VS excreted
3B3	Swine (fattening pigs	1,70E-03			kg NMVOC/kg VS excreted
3B3	Swine (sows)		7,04E-03		kg NMVOC/kg VS excreted
3B4a	Buffalo	1,08E-02	1,61E-03	2,35E-05	kg NMVOC/kg VS excreted
3B4d	Goats	1,08E-02	1,61E-03	2,35E-05	kg NMVOC/kg VS excreted
3B4e	Horses	1,08E-02	1,61E-03	2,35E-05	kg NMVOC/kg VS excreted
3B4f	Mules and Asses	1,08E-02	1,61E-03	2,35E-05	kg NMVOC/kg VS excreted
3B4gi	Laying hens	5,68E-03			kg NMVOC/kg VS excreted
3B4gii		9,15E-03			kg NMVOC/kg VS excreted
3B4giii	Turkeys		5,68E-03		kg NMVOC/kg VS excreted
3B4giv	Other poultry (ducks, geese)	5,68E-03			kg NMVOC/kg VS excreted
3B4h	Other animals (fur animals	5,68E-03			kg NMVOC/kg VS excreted
3B4h	Other animals (rabbits)	1,61E-03			kg NMVOC/kg VS excreted
3B4h	Other animals (reindeer)	1,61E-03	2,35E-05		kg NMVOC/kg VS excreted

To accommodate the emission factors to the categorization of livestock in the Finnish Normative Manure system, the following applications are made:

- Heifers: emission factor of dairy cattle applied
- Bulls: emission factor of dairy cattle applied
- Calves: emission factor of dairy cattle applied
- Weaned pig (20-50kg): emission factor of swine (fattening pigs)

Table 5.21 Gross energy intake (MJ/day) in five-year intervals and the inventory year 2019

Livestock	1980	1985	1990	1995	2000	2005	2010	2015	2019
Dairy cows	248.77	256.81	262.80	276.24	298.62	320.84	339.05	352.52	371.95
Suckler cows	234.99	234.63	235.03	232.37	229.32	227.07	230.63	231.23	235.90.
Bulls (age over 1 year)	123.38	127.03	129.66	135.49	141.14	157.83	167.91	168.26	176.23
Heifers	98.47	100.95	102.62	106.54	112.44	121.55	129.01	128.87	134.33
Calves (under 1 year)	67.57	69.35	70.70	73.46	76.99	82.90	88.76	89.57	93.94
Non-dairy GE	86.44	89.53	91.51	97.04	103.23	113.50	125.66	126.10	132.44

Table 5.22 Volatile solids (VS) excreted in five-year intervals and the inventory year 2019 (kg/head/day)

Animal category	1980	1985	1990	1995	2000	2005	2010	2015	2019
Dairy cows	4.20	4.34	4.44	4.67	5.02	5.39	5.71	5.96	6.31
Non-dairy cattle	1.45	1.51	1.55	1.65	1.76	1.94	2.17	2.19	2.30
Suckler cows	5.25	5.18	5.17	4.92	4.68	4.47	4.38	4.39	4.48
Bulls (age over 1 year)	2.03	2.10	2.15	2.28	2.40	2.71	2.90	2.91	3.05
Heifers	1.67	1.72	1.76	1.83	1.94	2.13	2.29	2.29	2.38
Calves (under 1 year)	1.10	1.13	1.15	1.20	1.25	1.35	1.45	1.46	1.54
Swine	0.22	0.22	0.22	0.21	0.22	0.22	0.22	0.21	0.22
Sow	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Piglets	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Fattening pigs	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Boars	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Weaned pigs	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

Sheep	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Goats	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Horses	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13
Poultry	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Laying hens	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Chicken	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cockerels	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Broiler hens	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Broilers	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Turkeys	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Other poultry (ducks)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Other animals									
Reindeer	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Fur animals	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Mink and fitch	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Fox and racoon	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14

Emissions are calculated separately for silage store and feeding, housing, manure storage and field application of manure. The emissions are calculated for every animal category with annually calculated parameters (where available). In each activity, emissions are calculated for the count of one animal. The animal and year specific emissions are then multiplied by the average annual population. The corresponding equation is presented below.

$$\boldsymbol{E_{NMVOC\,i,j} = AAP_{i,j} * \left(E_{silage_{store}} + E_{silage_{feed}} + E_{house} + E_{manure_{storage}} + E_{manure_{application}} + E_{grazing}\right)_{i,j}}$$

Where,

i	= Livestock category
j	= Inventory year
$AAP_{i,j}$	= Annual average population within the animal category in the given year
$E_{silage_{store}}$	= Emissions from silage store
$E_{silage_{feed}}$	= Emissions from silage feeding
E_{house}	= Emissions from housing
$E_{manure_{storage}}$	= Emissions from manure in barns and outside stores
$E_{manure_{application}}$	= Emissions from field application of manure (reported under 3Da2a)
$E_{grazing}$	= Emissions from grazing (reported under 3Da3)

Emissions from housing are estimated based on the time that the livestock spends in buildings, which is estimated annually. The estimates are retrieved from the Finnish Normative Manure System. The emission values are calculated with equations presented below.

Cattle:

$$\boldsymbol{E_{house} = MJ_i * X_{house_i} * EF_{house_i}}$$

Other livestock:

$$\boldsymbol{E_{house} = VS_i * X_{house_i} * EF_{house_i}}$$

Where,

i	= Livestock category
MJ_i	= Gross feed intake as (MJ/a)
VS_i	= Volatile solids excreted (kg/a)
X_{house_i}	= Annual proportion of time the livestock spends inside buildings (%)
$EF_{house\,i}$	= Emission factor for emissions from housing

Emissions from silage store are estimated based on the time that the livestock spends in buildings (see Table 5.14b for the applied rates) and by estimating the fraction of silage feeding in the given livestock category. In order to apply the formula, it is to be assumed that silage feeding always occurs inside livestock buildings.

Cattle:

$$\boldsymbol{E_{silage_{store}} = MJ_i * X_{house_i} * \left(EF_{silage_{feed}} * Frac_{silage}\right)_i}$$

Other livestock:

$$\boldsymbol{E_{silage_{store}} = VS_i * X_{house_i} * \left(EF_{silage_{feed}} * Frac_{silage}\right)_i}$$

Where,

i	= Animal category
$EF_{silage_{feed}}$	= Emission factor for silage feed
$Frac_{silage}$	= Proportion of silage as feed (%)

Table 5.23 Fraction of feed as silage for all animal categories

Animal category	Fracsilage	Animal category	Fracsilage
Dairy cow	0.56	Chicken	0
Suckler cow	1	Turkey	0
Heifer >1 yr	0.7	Other poultry	0
Bull >1 yr	0.61	Horse	0.375
Calf <1 yr	0	Pony	0.375
Sow (with piglets)	0	Sheep	0.68
Boar (50- kg)	0	Goat	0.67
Fattening pig (50- kg)	0	Fox and racoon	0
Weaned pig (20-50 kg)	0	Mink and fitch	0
Laying hen breeder (female)	0	Reindeer	0
Cockerel (laying hen breeder, male)	0	Broiler breeder hen	0
Broiler	0	Broiler breeder. male	0

Emissions from silage store are estimated as the share of stored silage in relation to silage in the feeding table by introducing an estimate of the fraction of the stored silage to equations *4* and *5*.

Cattle:

$$\boldsymbol{E_{silage_{store}} = MJ_i * X_{house_i} * \left(EF_{silage_{feed}} * Frac_{silage} * Frac_{silage_{store}}\right)_i}$$

Other livestock:

$$E_{silage_{store}} = VS_i * X_{house_i} * \left(EF_{silage_{feed}} * Frac_{silage} * Frac_{silage_{store}}\right)_i$$

Where,
i = Animal category
$Frac_{silage_{store}}$ = The relative share of stored silage in relation to silage in feeding table (%)

The guidebook default for $Frac_{silage_{store}}$ of 0.25 is used for all species and all years. Emission factors of silage feeding, however, are not cross-applied between the species except for categories with close resemblance to each other. The model suggests emissions from silage store to occur on all cattle, horses, sheep and goats.

Manure storage

The proportion of emissions from storage is assumed to possess the same ratio as with ammonia. The equation only factorizes NMVOC emissions from housing with the storage/building-ratio of ammonia emissions. Ammonia emissions are calculated in the Finnish Normative Manure System.

$$E_{manure_{storage}} = E_{NMVOC_{house}} * \left(\frac{E_{NH3_{storage}}}{E_{NH3_{building}}}\right)_i$$

Where,
i = Livestock category
$E_{NMVOC_{house}}$ = NMVOC emissions from housing
$E_{NH3_{storage}}$ = Ammonia emissions from storage
$E_{NH3_{building}}$ = Ammonia emissions from housing

Table 5.24a Animal numbers in Finland for cattle and swine (x 1 000 heads).

Year	Dairy cow	Suckler cow	Bull >1 yr	Calf <1 yr	Heifer >1 yr	Boar (50- kg)	Fattening pig (50- kg)	Sow (with piglets)	Veaned pig (20-50 kg)
1980	720	8	109	676	233	6	447	182	320
1981	701	9	114	690	253	6	465	190	333
1982	689	8	125	652	244	6	467	191	335
1983	663	9	120	640	250	6	457	186	327
1984	660	8	126	631	234	6	430	176	308
1985	628	9	125	631	215	5	404	165	289
1986	607	9	131	602	218	6	413	169	296
1987	589	9	125	558	217	6	420	172	301
1988	551	10	130	538	215	6	409	167	293
1989	507	9	134	490	206	5	405	165	290
1990	490	14	149	488	219	6	476	179	283
1991	446	21	144	486	214	6	464	174	276
1992	428	28	143	463	211	6	448	168	266
1993	426	33	139	437	217	5	439	165	261
1994	417	33	144	425	215	6	448	168	266
1995	399	29	109	422	189	7	491	161	277
1996	392	31	115	407	201	7	484	180	279
1997	391	32	121	402	197	7	512	185	332
1998	383	31	115	398	190	8	458	187	323
1999	372	30	118	379	188	6	469	180	269
2000	364	28	115	365	185	6	441	184	262
2001	355	27	111	362	182	5	426	164	264
2002	348	28	115	354	180	5	441	172	268
2003	334	28	115	344	179	5	483	178	269
2004	324	31	110	330	173	5	480	175	264
2005	319	35	108	329	169	4	500	177	280
2006	309	39	112	318	171	4	498	171	296
2007	296	43	110	311	166	4	525	177	329
2008	289	48	109	305	165	4	533	167	312
2009	290	52	110	304	163	4	535	156	303
2010	289	55	114	303	164	3	526	146	304
2011	286	57	111	299	162	3	531	134	288
2012	284	58	109	303	160	2	534	130	277
2013	283	57	110	300	162	2	534	122	273
2014	285	58	110	303	158	2	507	118	269
2015	285	59	109	307	155	2	501	116	275
2016	282	59	108	310	150	2	489	108	256
2017	275	60	111	297	150	1	447	99	249
2018	271	60	106	299	146	1	425	95	246
2019	262	60	105	288	142	1	439	92	258

Table 5.24b Animal numbers in Finland for poultry, sheep and goat (x 1 000 heads).

Year	Broiler breeder hen	Broiler	Chicken	Cockerel (laying hen breeder, male)	Laying hen breeder (female)	Other poultry	Turkey	Goat	Sheep
1980		1867	2435	50	6041	20	60	6	106
1981		1918	1707	50	5200	20	60	6	103
1982		1970	1622	50	5292	20	60	6	104
1983		2197	2169	50	5440	20	60	6	104
1984		2423	1932	50	6025	20	60	6	110
1985		2654	1547	50	5922	20	60	6	112
1986		2884	1505	50	5532	20	60	6	116
1987		3319	1449	50	5342	20	60	6	126
1988		3754	1441	50	5238	20	60	6	119
1989		3374	1415	50	4923	20	60	6	108
1990	62	2993	1633	50	4845	21	60	6	103
1991	97	3250	1304	45	4138	32	64	5	107
1992	133	3506	1598	40	3969	43	68	5	108
1993	168	3763	1522	35	4025	54	72	5	120
1994	203	4020	1422	30	4090	65	76	6	121
1995	240	4276	1482	25	4179	75	80	6	159
1996	279	4052	1246	25	4184	54	96	7	150
1997	299	4911	1288	32	4152	33	112	8	150
1998	347	5507	1185	30	3802	35	145	8	128
1999	382	5998	1025	17	3361	39	210	8	107
2000	364	7918	914	18	3110	32	215	9	100
2001	394	5412	1043	12	3202	35	455	7	96
2002	402	5766	772	9	3213	41	531	7	96
2003	346	6050	931	10	3016	40	603	7	98
2004	287	5573	912	10	3069	18	535	7	109
2005	457	5472	954	12	3128	20	495	7	90
2006	405	5366	844	13	3103	15	493	7	117
2007	351	5074	764	13	3134	24	431	6	119
2008	339	5675	865	19	3190	19	415	6	122
2009	329	4918	859	15	2926	16	306	6	118
2010	433	4616	838	14	3394	12	280	5	126
2011	421	5421	745	22	3304	14	308	5	129
2012	471	6038	743	27	3173	14	295	5	130
2013	520	6861	858	22	3432	13	274	5	136
2014	544	7341	714	25	3645	15	292	4	138
2015	548	6840	662	26	3501	23	247	5	155
2016	523	8175	748	26	3662	17	260	5	157
2017	473	8047	509	22	3746	47	292	5	156
2018	424	8781	608	17	3985	26	299	5	155
2019	395	9112	647	16	3900	27	263	6	145

Table 5.24c Animal numbers in Finland for other animals (x 1 000 heads).

Year	Fox and racoon	Mink and fitch	Reindeer	Horse	Pony
1980	1751	4207	186	30	1
1981	1894	4200	178	31	2
1982	2532	4379	185	31	2
1983	2546	4448	204	32	2
1984	2289	4686	223	33	3
1985	3117	5036	221	34	3
1986	3380	3982	230	35	4
1987	3175	3368	229	31	4
1988	2917	3520	227	34	5
1989	1995	3162	256	36	5
1990	1478	1805	239	39	6
1991	1092	1505	260	42	6
1992	1272	1576	232	43	6
1993	1221	1659	215	43	6
1994	1645	1639	214	42	6
1995	1804	1945	208	44	6
1996	2344	1801	213	46	6
1997	2493	1828	203	48	7
1998	2322	1646	196	49	7
1999	1972	1733	195	50	7
2000	1863	1498	203	51	7
2001	2044	1399	186	52	7
2002	2003	1408	200	52	7
2003	2205	1379	197	53	7
2004	2175	1355	201	54	7
2005	2320	1466	207	56	8
2006	2025	1422	198	58	8
2007	1713	1768	193	60	9
2008	1440	1259	195	61	9
2009	2116	1327	193	63	9
2010	1898	1576	194	65	10
2011	1784	1115	196	65	10
2012	1974	1402	192	65	10
2013	1816	1218	192	65	10
2014	2028	1170	187	64	10
2015	2084	1027	191	64	10
2016	2202	1027	191	64	10
2017	2028	934	193	64	10
2018	2017	843	185	64	10
2019	2017	843	188	64	10

Uncertainty and time series' consistency

The time series is consistent. The results of the uncertainty analysis are provided in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checks related to the assessment of magnitude and trends have been carried out. At present, no verification has been carried out for the specific source-sector emissions. Cross-checking of data and functions of the model are carried out as the same model is used both by SYKE for air pollutant emissions inventories and by Luke for greenhouse gas emissions inventories.

Source-specific recalculations including changes made in response to the review Process

2009

- The agriculture emissions calculation model was used for the first time in the ammonia emissions inventory in the submission in 2009.

2011

- The allocation of boars was changed from NFR 4B13 to 4B8.
- NH_3 and particle emissions were recalculated and reported in NFR format.

2013

- The time series 1990-2013 was recalculated and reported in NFR14 format.

2014

- Revision of ammonia emission factors and disaggregation of activity data in cooperation with the Natural Resources Institute Finland.

2015

- Particulate matter emission factors for manure management revised according to Guidebook 2013 for the whole time series. Also data on grazing times, manure handling systems and indoor/outdoor times were updated according to domestic studies.

2017

- Particle emissions from heifers were inserted in the time series as they were missing due to an error from inventory submissions in 2010-2014.

2016-2017

- The Finnish Agriculture Emissions Calculation Model was completed with NMVOC emissions according to the method presented in the 2016 Guidebook. (Munther et al., 2017)
- The calculation of NH_3 and NOx emissions was revised (Grönroos et al, 2017)

2019

- Particulate matter emissions were included for goats, sheep, fur animals and reindeer based on Guidebook 2016
- The implied emission factors for NH_3 have changed from the previous reporting because of the correction of the error in emission calculation of deep litter manure system. The emissions (NH_3, NO, N_2O) from spreading of 80% of the manure managed as deep litter were missing because of an error in the calculation sheets.of all other animals than broilers.

2020

- New Tier 2 ammonia emission factors of the EMEP/EEA air pollutant emission inventory guidebook 2019 were introduced for manure management, manure spreading and grazing, replacing the Tier 2 emission factors of EMEP/EEA 2016 guidebook.
- Nitrogen excretion factors time series (1990-2018) of suckler cows and dairy cows were updated due to the changes in excretion calculation methods. Nitrogen excretion of suckler cows was recalculated to better reflect the change in their diet that has taken place along

the time series. A double counting error in dairy cow N excretion was corrected: the increased energy demand during the first pregnancy was removed from dairy cows, since it is already included in the heifer stage.

- Nitrogen excretion factor of horses was corrected for 2017.
- Numbers of fur animals were updated for the years 2016 and 2017. A technical error in the calculation of particle emissions for manure management for the early years of the time series corrected.
- A technical error in the calculation of particle emissions for manure management for the early years of the time series corrected.

2021

- Nitrogen excretion factor time series (1990-2019) for sheep was corrected based on the new data provided by the Natural Resources Institute Finland (Luke).
- Nitrogen excretion factor of Turkey for 2018 was corrected.
- Minor changes to the numbers of calves (year 2015) and foxes (year 2011) were done.
- The number of Reindeer for 2015 was corrected.

Source-specific planned improvements

Currently, anaerobic digestion is not considered in the agricultural emission calculation system. The calculation system will be supplemented in this respect during 2021.

New activity data on manure management will be collected from farms during early 2021, and that data will be utilised when the emission calculation system is updated in 2021.

Additionally, the calculation system will be modified during 2021 so that there will be possible to use more detailed animal specific emission/volatilisation factors (e.g. separate factors for housing of sows and fattening pigs instead of one average factor for all pigs per manure type).

5.4 Agricultural Soils (NFR 3D)

Figure 5.14 K. Inha (1899)

Source category description

Changes in chapter	
March 2021	KS, JMP, JG, JM

The category covers emission sources presented in Table 5.25

Table 5.25 Emission sources and emissions reported under NFR 3D

NFR		Emissions
3Da1	Inorganic N-fertilizers	NOx, , NH_3
3Da2a	Animal manure applied to soils	NOx, NMVOC, NH_3 (calculated in 3B)
3Da2b	Sewage sludge applied to soils	NH_3, NOx
3Da2c	Other organic fertilisers applied to soils	NO
3Da3	Urine and dung deposited by grazing animals	NOx, NMVOC, NH3(calculated in 3B)
3Da4	Crop residues applied to soils	NA
3Db	Indirect emissions from managed soils	
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	TSP, PM10, PM2.5
3Dd	Off-farm storage, handling and transport of bulk	NA
3De	Cultivated crops	NMVOC
3Df	Use of pesticides	HCB
3F	Field burning of agricultural residues	NOx, NMVOC, SOx, CO, NH_3, particles heavy metals, PCDD/F, PAH-4
3I	Agriculture other	NO

5.4.1 Synthetic N-fertilizers (NFR 3D1a)

Changes in chapter	
March 2021	KS & JM JMP JG

Source category description

Nitrogen oxides and ammonia emissions from the use of synthetic nitrogen fertilizers are included under this category.

Emission trend

The emission trend fluctuates according to the use of fertilizers (Figure 5.15).

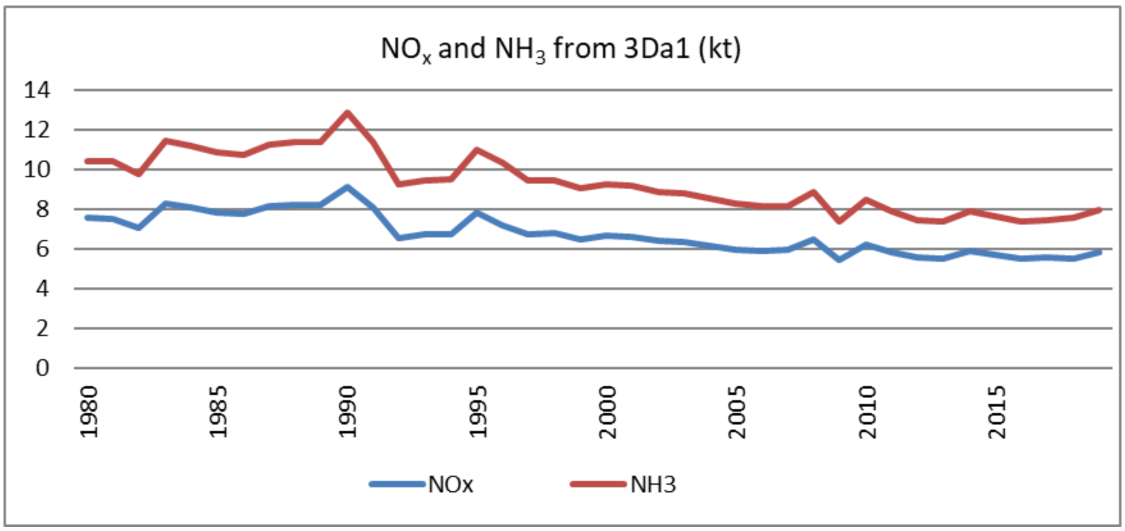

Figure 5.15 NO_x and NH_3 emissions 1980-2019 from the use of synthetic N-fertilizers

Methodological issues

Ammonia emissions

Calculation of NH_3 emissions from application of nitrogen fertilizers is carried out in the agriculture emissions calculation model (Grönroos et al. 2017). The calculation is consistent with the EMEP/EEA Guidebook 2019.

Ammonia emissions from the use of mineral N-fertilisers were calculated separately for different fertiliser types using the emission factors presented in the EMEP/EEA Emission Inventory Guidebook (EMEP/EEA 2019b, Table 3-2). Due to the low soil pH and low average annual temperature in Finland, the 'normal pH' emission factors for cool climate were applied. The total amount of nitrogen sold annually in Finland (Table 5.26) was divided over fertiliser types using the information obtained from Yara Finland Ltd (Toimela 2016) and Natural Resources Institute Finland (Mattila 2016; Tables 5.27 and 5.28). EMEP/EEA emission factors presented in Table 5.27 are based on the emissions from surface applied fertilisers. In Finland, however, placement fertilisation is typically used for cereals. According to the EMEP/EEA (2019b, A1.2.2), fertiliser-N that is immediately incorporated into the soil will not be a source of ammonia as the NH_4^+ ions are absorbed onto soil colloids or nitrified. Thus, N-fertilisers used in Finland were divided between fertilisers spread using placement fertilisation and fertilisers applied on soil surface (typically grassland).

The proportion of placement fertilisation (65%) is based on the ratio between non-grasses and the total actively cultivated argicultural land. For grasses, mineral fertilisers are typically applied by proadcast spreading technique, and for other crops the placement fertilisation technique is used. Between the years 1980 and 2018, the proportion of other than grasses has varied between 58 and 69 percent, being averagely 65% (See Table 5.29).

Table 5.26. Use of mineral N-fertilizers as N (tonnes) 1980-2019

Year	Use of N-fertlizers (t)	Year	Use of N-fertlizers (t)	Year	Use of N-fertlizers (t)
1980	189 098	2000	167 276		
1981	188 457	2001	165 621		
1982	177 234	2002	160 403		
1983	206 665	2003	159 288		
1984	202 814	2004	154 708		
1985	196 242	2005	149 562		
1986	194 304	2006	148 161		
1987	204 140	2007	148 784		
1988	205 674	2008	162 905		
1989	205 862	2009	136 009		
1990	228 470	2010	156 523		
1991	202 462	2011	146 189		
1992	163 229	2012	138 900		
1993	168 199	2013	138 136		
1994	169 138	2014	147 373		
1995	195 460	2015	143 479		
1996	179 529	2016	138 128		
1997	169 345	2017	138 948		
1998	169 928	2018	138 385		
1999	162 700	2019	146 798		

Table 5.27. Distribution of mineral N-fertilisers used in Finland by fertiliser type (%) in 2019, distribution of each fertiliser type by application method (placement fertilisation or spread on soil surface, %), and ammonia emission factors (EFs for normal pH, cool climate) for different fertiliser types applied.

Spread as:	% of applied fertiliser-N	Spread using placement fertilisation (%)	Spread on soil surface (%)	EF for fertiliser-N spread on soil surface (kg NH_3 kg^{-1} N)
Ammonium nitrate	0.0 %	65	35	0.015
Anhydrous ammonia	0.0 %	65	35	0.019
Ammonium phosphates	0.0 %	65	35	0.05
Ammonium sulphate	0.53 %	65	35	0.09
Calcium ammonium nitrate	24.4 %	65	35	0.008
Calcium nitrate	0.0 %	65	35	0.01
Ammonium solutions (AN)	0.07 %	65	35	0.015
Ammonium solutions (Urea AN)	0.0 %	65	35	0.098
Urea ammonium sulphate	0.0 %	65	35	0.098
Urea	0.88 %	65	35	0.155
Other NK and NPK	74.08 %	65	35	0.05

Table 5.28 Distribution of mineral N-fertilisers used in Finland by fertiliser type. The share of each fertiliser depends on the year (Sources: Kemira / Yara Finland and Finnish Food Safety Authority Evira / Finnish Food Authority) (Finland's NIR 15.1.2021)

	% of applied N									
Fertiliser type	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Ammonium sulphate	0.004	0	0	0	0.2	0.4	0	0.7	0.4	0.5
Ammonium nitrate	0	0	0	0	0	0	0	0	0	0.0
Calcium ammonium nitrate	10.8	9.3	15.3	15.2	23.8	30.9	30.5	27.1	19.9	24.4
Anhydrous ammonia	0	0	0	0	0	0	0	0	0	0
Urea	1.3	0.1	0.2	0.4	0.5	0.8	1.2	0.7	0.7	0.9
Nitrogen solutions	0.003	0	0	0.02	0.02	0	0	0.09	0.06	0.07
Ammonium phosphates	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.4	0.0	0.0
Other NK and NPK	87.5	90.3	84.3	84.2	75.3	67.6	68.1	70.7	79.0	74.1
Nitrate only	0.3	0.09	0.08	0.06	0.06	0.07	0.10	0.29	0	0

Table 5.29. The proportion of other crops than grasses of the total cultivated area, excluding fallows, between the years 1980 and 2019.

Year	All crops, 1000 ha (without fallow)	Other than grasses (1000 ha)	Proportion of other than grassess (= placement fertilisation-%)
1980	2269.7	1318.3	58 %
1981	2288.2	1362.6	60 %
1982	2253.5	1327.3	59 %
1983	2262	1381.6	61 %
1984	2229.8	1386.1	62 %
1985	2206.7	1402.6	64 %

1986	2157.7	1374.7	64 %
1987	2162.9	1436.8	66 %
1988	2094.3	1402	67 %
1989	2051.5	1366.6	67 %
1990	2088.2	1406.3	67 %
1991	1808	1184.9	66 %
1992	1758	1096.8	62 %
1993	1784	1097.4	62 %
1994	1796.8	1112.5	62 %
1995	1918.1	1163.5	61 %
1996	1942.9	1240.7	64 %
1997	1963.6	1277.1	65 %
1998	1999.8	1318.2	66 %
1999	1965.2	1293.8	66 %
2000	2005.7	1318.7	66 %
2001	1990	1325.3	67 %
2002	1992.9	1355.2	68 %
2003	1991.7	1362.3	68 %
2004	2022.9	1402.9	69 %
2005	1993.4	1373.2	69 %
2006	2005.4	1380.7	69 %
2007	2023.8	1370	68 %
2008	2068.9	1413.6	68 %
2009	2026.8	1386.3	68 %
2010	1946.3	1287.2	66 %
2011	1973.3	1306.5	66 %
2012	1980.5	1320.6	67 %
2013	1969.1	1319.6	67 %
2014	1982.8	1330.7	67 %
2015	1969.6	1317.1	67 %
2016	1983	1295.4	65 %
2017	1988.3	1271.4	64 %
2018	1996.4	1235.5	62 %
2019	2022.7	1236.6	61 %

Nitrogen dioxide emissions

Nitric oxide emissions expressed as nitrogen dioxide (NO_2) were included to the inventory for first time in the 2017 submission for the whole time series (1990-2016). The calculation is carried out in the Agriculture Emissions Calculation Model (Grönroos et al., 2017). The model is described in more detail above (ammonia emissions), nitric oxide emissions are calculated in the model as part of other nitrogen emissions. For nitrogen dioxide, the emission factor of 0.04 kg NO_2 kg^{-1} fertiliser-N applied (EMEP/EEA 2019b) was used.

The emission factor for NO_2 emissions from NFR 3Da1 was updated to the 2018 submission. In the previous submission (2017), the emission factor of 0.04 was assumed to mean NO emissions, and the result was further multiplied by 46/30 to convert NO emissions to NO_2 emissions, resulting too high emission values for NO_2.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied since the 2012 submission. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2018
- The emission factor for NO_x emissions from NFR 3Da1 was updated to the 2018 submission

2020
- Distribution of mineral N-fertilisers used in Finland by fertiliser type for the years 2015-2017 was corrected to the 2020 submission.

Source-specific planned improvements

The proportion of placement fertilisation will be checked and the year-specific value will be used in the future submissions instead of the average value (65%).

5.4.2 Animal manure applied to soils (NFR 3Da2a)

Changes in chapter	
March 2021	KS JM

Source category description

Nitrogen oxides, NMVOC and ammonia emissions due to application of manure to soils are included under this category.

Emission trend

The emissions fluctuate according to the amount of manure applied annually (Figure 5.16)

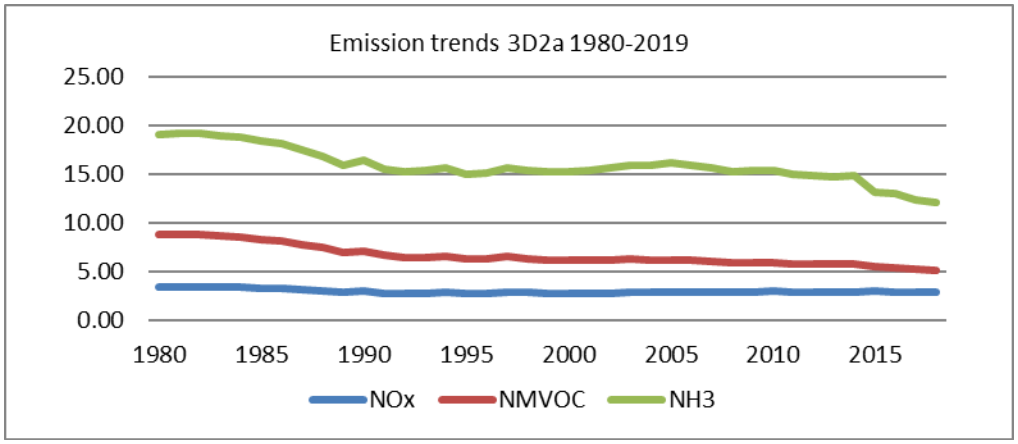

Figure 5.16 NOx, NMVOC and NH_3 emissions 1980-2019 from manure application to soils

Methodological issues

Ammonia emissions
For the detailed description see Grönroos et al 2017 (in the CDR folder).

Nitrogen dioxide emissions

The calculation is carried out in the Agriculture Emissions Calculation Model (Grönroos et al., 2017). For nitrogen dioxide, the emission factor of 0.04 kg NO_2 kg^{-1} manure-N applied (EMEP/EEA 2019b) was used.

NMVOC
Calculation of NMVOC emissions from field application of manure follows the same principle than emissions from manure storage reported under NFR 3 B. The method is based on EMEP/EEA Emission Inventory Guidebook 2019.

$$E_{manure_{application}} = E_{NMVOC_{house}} * \left(\frac{E_{NH3_{application}}}{E_{NH3_{building}}}\right)_i$$

Where,
i = Animal category
$E_{NMVOC_{house}}$ = NMVOC emissions from housing
$E_{NH3_{application}}$ = Ammonia emissions from application
$E_{NH3_{building}}$ = Ammonia emissions from housing

Activity data

Amount of manure total nitrogen applied to the fields totalled to 72 kilotonnes in 2019 and was divided per animal category as presented in Table 5.30.

Table 5.30. Amount of manure total nitrogen applied to the fields in 2019.

Animal type	Tonnes of tot-N
Bulls >1 yr	5806
Calves <1 yr	9674
Dairy cows	26064
Heifers >1 yr	5573
Suckler cows	2539
Boars	23
Fattening pigs	5832
Sows	2411
Weaned pigs	1884
Broiler hens	171
Broilers	1729
Pullets	145
Cockerels	10
Laying hen breeders	1468
Other poultry	10
Turkeys	206
horses	2516
Ponies	268
Goats	30
Sheep	808
Foxes and racoons	3940
Minks and fitches	787
Reindeer	0
TOTAL	**71894**

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied since the 2012 submission. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2017

- Nitric oxide emissions expressed as nitrogen dioxide (NO_2) were included to the inventory for first time for the whole time series

2018

The emission factor for NO_x emissions from NFR 3Da2a was updated to the 2018 submission. In the previous submission (2017), the emission factor of 0.04 was assumed to mean NO emissions, and the result was further multiplied by 46/30 to convert NO emissions to NO_2 emissions, resulting too high emission values for NO_2.

Source-specific planned improvements

None.

5.4.3 Sewage sludge applied to soils (NFR 3Da2b)

Changes in chapter	
March 2021	KS, JM, JG

Source category description

The category includes nitrogen oxides and ammonia emissions to soils from the application of sewage sludge.

Emission trend

The emission trend is impacted by the amount of sludge which started to decrease since 1998 due to Finland's joining the EU earlier in 1995. As late as in the beginning of the 1990's sludge storages were too small and sludge spreading was common even in the wintertime. After Finland joined the EU, the amounts of sludge spread have decreased significantly. (Figure 5.17)

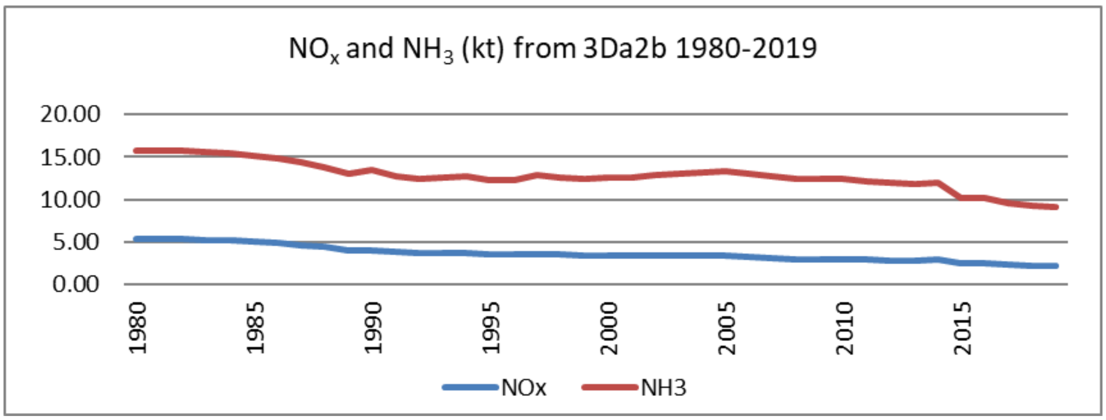

Figure 5.17. Sewage sludge applied to soils 1980-2019

Methodology

Ammonia

Ammonia emissions are calculated using emissions factor from the Guidebook 2019. N input from sewage sludge used in agriculture (Finland's NIR 2020) is used as activity data. It is assumed that 15 % of total nitrogen is in the form of ammonium nitrogen and that 15 % of that ammonium nitrogen evaporates during the spreading on the fields.

NO_x emissions

NO_x emissions from 3Da2b Sewage Sludge Applied to Soils were included in the 2018 submission using emission factors from the 2019 EMEP/EEA Guidebook and amounts of N inputs from sewage sludge to soils from 1990-2018 (Table 5.26). It is assumed that 15 % of total nitrogen is in the form of ammonium nitrogen and that 15 % of that ammonium nitrogen evaporates during the spreading on the fields.

Annual nitrogen input from sewage sludge is presented in Table 5.31 (Finland's NIR 2021)

Table 5.31 N input from sewage sludge 1990-2019 (Mg N/year)

Year	N input from sewage sludge (Mg N/year)	Year	N input from sewage sludge (Mg N/year)	Year	N input from sewage sludge (Mg N/year)
1990	1 586	2000	741	2010	1 260
1991	1 384	2001	718	2011	1 400
1992	1 181	2002	748	2012	1 444
1993	1 199	2003	679	2013	1 826
1994	1 396	2004	664	2014	1 978
1995	1 345	2005	695	2015	2 066
1996	1 566	2006	828	2016	2 547
1997	2 058	2007	917	2017	2 731
1998	837	2008	976	2018	2 420
1999	831	2009	1 203	2019	2 420

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied since the 2012 submission. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2013
- Ammonia emissions from sewage sludge application were included in the inventory

2018
- NO_x emissions were included in the inventory due to the recommendation of the NECD 2017 review.

2020
- N input from sewage sludge for whole timeseries was updated.

Source-specific planned improvements

None.

5.4.4. Other organic fertilizers applied to soils (NFR 3Da2c)

Changes in chapter	
March 2021	JG

Source category description

Other organic fertilisers applied to fields, such as composted household waste and industrial waste, are not considered in the emission inventory as the amounts applied to fields are considered small because they are mainly used in landscaping.

Source-specific recalculations including changes made in response to the review process

2018
- The notation key was changed to NO

5.4.5 Urine and dung deposited by grazing animals (NFR 3Da3)

Changes in chapter	
February 2021	JG, JM, KS

Source category description

This source category includes emissions originating from urine and dung deposited by grazing livestock to fields during grazing.

Emission trend

Emission trend is affected by changes in animal numbers, N-excretion rates, percentage of grazing animals and length of the grazing period. Since the beginning of 1980's, numbers and grazing of other cattle than suckler cows have decreased, resulting decrease in total emissions. However, increase in numbers of horses, ponies and suckler cows has smoothened the decreasing trend in emissions.

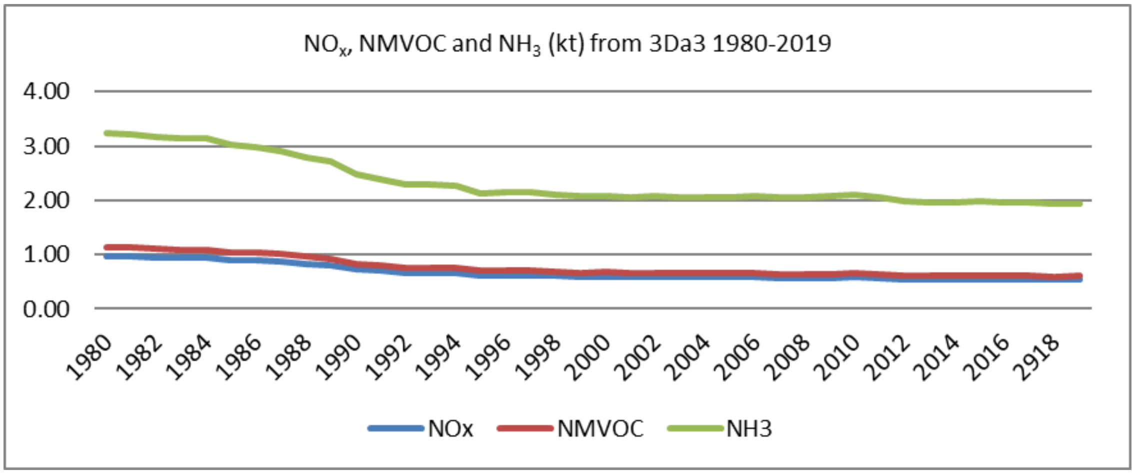

Figure 5.18 NO_x, NMVOC and NH_3 emissions from 3Da3 in 1980-2019

Methodology

Ammonia emissions
For the detailed description, see Grönroos et al 2017 (in the CDR folder)

Nitrogen dioxide emissions

The calculation is carried out in the Agriculture Emissions Calculation Model (Grönroos et al., 2017). For nitrogen dioxide, the emission factor of 0.04 kg NO_2 kg^{-1} manure N excreted (EMEP/EEA 2016b) was used.

The emission factor for NO_2 emissions from NFR 3Da1 was updated to the 2018 submission. In the previous submission (2017), the emission factor of 0.04 was assumed to mean NO emissions, and the result was further multiplied by 46/30 to convert NO emissions to NO_2 emissions, resulting too high emission values for NO_2.

NMVOC
Emissions from outdoors grazing of animals are calculated by gross feed intake (cattle) and volatile solids (other livestock) with an estimate of the time spent outdoors. The time animals spend indoors is estimated annually. The estimates are retrieved from the Finnish Normative Manure System. The emission factors in Table 5.32 are from Guidebook 2019.

Cattle:
$$\boldsymbol{E_{graz} = MJ_i * (1 - X_{house_i}) \; * EF_{graz_i}}$$

Other livestock:
$$\boldsymbol{E_{graz} = VS_i * (1 - X_{house_i}) \; * EF_{graz_i}}$$

where,

i = Animal category
MJ_i = Gross feed intake as (MJ/a)
VS_i = Volatile solids excreted (kg/a)
EF_{graz_i} = Emission factor for grazing presented in Table 5.27.
X_{house_i} = annual proportion of time the animal spends inside a livestock building (%)

Table 5.32 NMVOC emission factors for grazing animals (Source Guidebook 2019)

NFR	Livestock	$EF_{grazing}$	Unit
3B1a	Dairy cattle	6,90E-06	kg NMVOC kg/MJ feed intake
3B1b	Non-dairy cattle	6,90E-06	kg NMVOC kg/MJ feed intake
3B2	Sheep	2,35E-05	kg NMVOC/kg VS excreted
3B4a	Buffalo	2,35E-05	kg NMVOC/kg VS excreted
3B4d	Goats	2,35E-05	kg NMVOC/kg VS excreted
3B4e	Horses	2,35E-05	kg NMVOC/kg VS excreted
3B4f	Mules and Asses	2,35E-05	kg NMVOC/kg VS excreted
3B4h	Other animals (reindeer)	2,35E-05	kg NMVOC/kg VS excreted

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied since the 2012 submission. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2017

- Nitric oxide emissions expressed as nitrogen dioxide (NO_2) were included to the inventory for first time in the 2017 submission for the whole time series (1990-2016).

2018

- NFR 3Da3: The emission factor for NOx was changed due to the change in the 2016 Guidebook. The emissions decreased by 40%.

Source-specific planned improvements

None.

5.4.6 Crop residues applied to soils (NFR 3Da4)

Changes in chapter	
March 2020	JG

Emissions from crop residues applied to soils are reported as NA, because no methodology is presented in Guidebook 2019.

Indirect emissions from managed soils (NFR 3Db)

Changes in chapter	
January 2020	JG

Indirect emissions from managed soils are reported as NA, because no methodology is presented in Guidebook 2019.

5.4.7 Farm-level agricultural operations including storage, handling and transport of agricultural products (NFR 3Dc)

Changes in chapter	
February 2021	JG, KS

Source category description

Particle emissions from cultivation, harvesting, cleaning and drying of crops are included under this category.

Emission trend

The activity data figures fluctuate annually mostly due to market demands. The count of producers has been steadily declining since the 1990’s and simultaneously the land area per producer has been increasing. Farming subsidy policies, which in the early 1990s were reshaped upon joining the European Union, is also a notable factor influencing the composition of Finnish agriculture in general. However, these factors do not present notable trends in emissions throughout the time series. A minor decline can be observed in total TSP emissions, despite the total land area for cultivated crops remaining constant (Figure 5.19) This is due to a slight shift from most common crops towards more specialized crops for which there is no emission factor for harvesting, cleaning or drying.

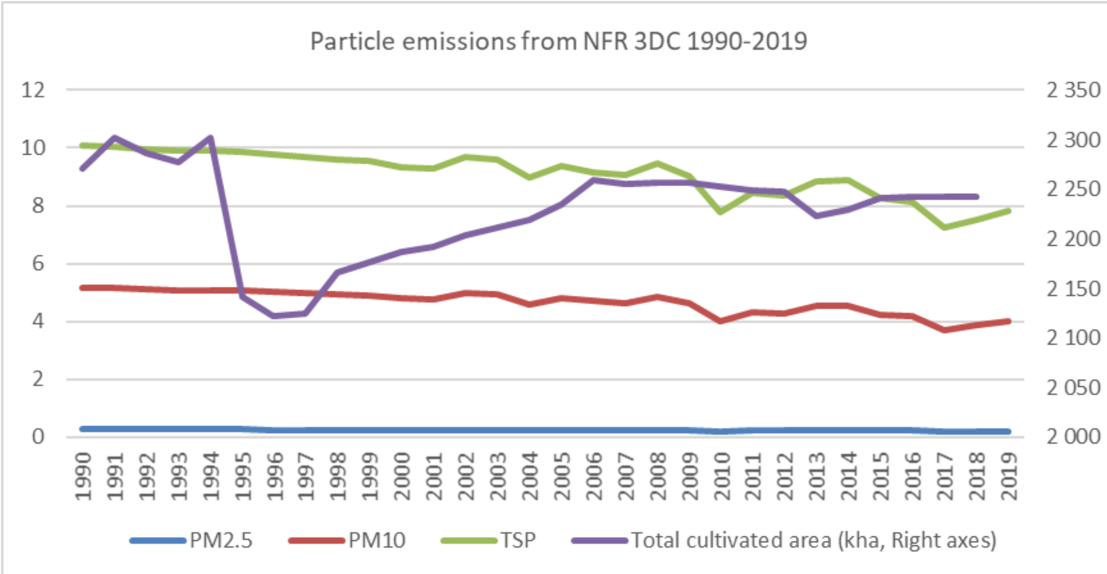

Figure 5.19 Particle emissions from NFR 3DC 1990-2019

Methodological issues

Activity data

Information on the use of arable land and harvested areas are provided by Natural Institute Resources Finland. For harvesting, data is available only from the year 2000 onwards. The figures used in calculation for 1990's are trend-projected values. Reliable statistics of cleaning and drying of crops does not exist and harvested areas are applied instead. This leads to a possible over-estimate on emission values for cleaning and drying, as it can be safely assumed that not all of the harvested crops go through these processes. The activity data used in calculation is presented in Tables 5.33a and b (Natural Resources Institute Finland)

Table 5.33a Use of arable land area as thousands of hectares (Natural Resources Institute Finland)

Year	Wheat	Rye	Barley	Oats	Mixed grain	Other grains	Peas	Potatoes	Sugar beet	Turnip rape and rape	Hay	Silage	Pasture	Other grassland	Other crops	Fallow
1990	191	83	503	461	14	0	3	37	31	66	291	224	129	39	19	183
1991	118	10	541	343	12	0	11	36	32	61	232	234	120	37	21	494
1992	88	11	473	335	13	0	16	35	32	73	243	247	130	42	21	529
1993	99	23	459	332	13	0	13	36	33	69	255	261	125	46	20	494
1994	89	9	506	334	10	0	6	37	34	67	258	268	123	36	21	505
1995	101	21	516	329	11	1	5	36	35	85	287	301	127	40	25	223
1996	113	35	543	374	14	1	6	35	35	62	244	302	118	38	24	179
1997	125	23	583	369	16	2	6	33	35	61	220	314	114	39	25	162

1998	137	36	578	387	16	3	5	33	33	65	198	339	112	34	26	167
1999	118	12	581	404	18	1	5	32	35	63	175	350	114	33	25	211
2000	150	45	559	400	17	3	5	32	32	53	160	376	118	33	24	181
2001	145	29	547	423	16	1	5	30	31	73	158	381	94	32	25	202
2002	175	31	523	451	16	1	5	30	31	68	118	397	95	28	27	211
2003	192	31	531	426	16	1	4	29	29	75	101	399	102	27	30	220
2004	236	31	565	372	17	1	4	29	31	83	93	415	87	26	35	196
2005	215	14	595	346	16	1	4	29	31	77	107	398	92	24	45	241
2006	192	22	564	354	19	1	4	28	24	108	126	386	88	26	64	253
2007	204	32	550	362	20	1	4	28	16	90	103	438	90	23	64	232
2008	220	24	613	373	21	1	3	27	14	65	103	452	81	21	55	189
2009	218	16	601	343	23	2	4	26	15	81	86	450	79	25	57	230
2010	214	25	448	296	26	3	6	25	15	158	106	452	77	24	71	307
2011	257	27	465	324	28	3	5	25	14	92	103	472	75	17	67	276
2012	242	21	503	353	32	2	5	23	12	69	95	471	73	20	59	267
2013	231	12	533	367	33	2	4	22	12	53	93	466	72	19	50	254
2014	272	24	532	326	37	2	6	22	14	44	94	472	71	16	53	247
2015	249	32	513	307	36	3	12	22	13	57	86	492	58	16	75	271
2016	223	27	486	332	40	3	12	22	12	62	94	512	58	24	79	261
2017	219	32	437	337	43	3	11	22	12	65	87	552	57	21	90	254
2018	190	17	463	324	42	4	10	22	10	58	110	572	56	25	96	246
2019	206	38	455	319	41	6	14	22	11	37	118	593	54	22	88	222

Table 5.33b Harvested area as thousands of hectares (Natural Resources Institute Finland)

Year	Wheat	Rye	Barley	Oats	Mixed grain	Peas	Potatoes	Sugar beet	Turnip rape and rape	Hay	Silage
1990	*119*	*42*	*589*	*480*	*14*	*5*	*35*	*44*	*55*	*162*	*331*
1991	*124*	*40*	*588*	*474*	*14*	*4*	*35*	*44*	*56*	*160*	*333*
1992	*128*	*39*	*581*	*467*	*15*	*5*	*34*	*43*	*59*	*157*	*335*
1993	*133*	*39*	*578*	*461*	*15*	*4*	*34*	*42*	*61*	*155*	*339*
1994	*139*	*38*	*587*	*458*	*15*	*4*	*34*	*41*	*56*	*150*	*344*
1995	*142*	*36*	*590*	*450*	*15*	*4*	*33*	*39*	*59*	*146*	*348*
1996	*148*	*35*	*588*	*441*	*15*	*4*	*33*	*38*	*66*	*143*	*354*
1997	*154*	*35*	*581*	*428*	*15*	*4*	*33*	*36*	*71*	*139*	*361*
1998	*157*	*33*	*573*	*420*	*14*	*4*	*32*	*35*	*75*	*136*	*368*
1999	*163*	*31*	*569*	*414*	*16*	*4*	*31*	*33*	*77*	*133*	*373*
2000	149	45	559	400	17	5	32	32	53	158	372
2001	143	29	543	416	16	5	30	31	72	158	381
2002	174	30	522	451	16	5	30	31	66	118	397
2003	191	31	530	425	16	4	29	29	75	101	399
2004	225	27	532	326	16	3	27	30	68	91	412
2005	215	14	594	345	16	4	29	31	77	107	398
2006	192	22	564	353	19	4	28	24	107	125	384

2007	203	32	533	347	15	4	27	16	90	102	438
2008	216	24	586	355	13	3	26	14	64	102	451
2009	216	16	562	322	15	4	26	15	81	86	450
2010	211	25	417	278	19	6	25	15	158	106	452
2011	253	27	432	308	19	5	24	14	91	103	472
2012	227	21	451	314	21	4	21	12	57	95	471
2013	228	12	494	344	21	4	22	12	53	93	465
2014	267	24	497	305	24	6	22	14	43	94	472
2015	242	31	452	281	11	12	22	12	55	86	492
2016	215	26	436	305	14	10	22	12	60	94	511
2017	194	29	358	270	10	4	21	12	55	87	552
2018	178	16	405	289	15	9	21	10	53	110	570
2019	198	38	398	298	16	12	21	11	32	117	591

** Figures in grey represents projected data.*

Particles

The emission factors are from EMEP/EEA Emission Inventory Guidebook 2019. For TSP emissions same emission factor as for PM10 emissions is used. The emission factor of cultivation of “other arable” is applied to all cultivated species with available statistics. This leads to a minor increase in total particle emissions as opposed to the previous submissions. The wet climate emission factors of the Guidebook 2019 are applied to local crops as presented in Tables 5.34 a-c.

Table 5.34a TSP emission factor for farm-level agricultural operations: cultivation, harvesting, cleaning and drying of crops (Applied to Finnish conditions from Guidebook 2019)

Species	**TSP ***			
	Cultivation	Harvesting	Cleaning	Drying
Wheat	0.250	2.7	0.190	0.560
Rye	0.250	.2.0	0.160	0.370
Barley	0.250	.2.3	0.160	0.430
Oats	0.250	.3.4	0.250	0.660
Mixed grain	0.250	NC	NC	NC
Other grains	0.250	NC	NC	NC
Peas	0.250	NC	NC	NC
Potatoes	0.250	NC	NC	NC
Sugar beet	0.250	NC	NC	NC
Turnip rape and rape	0.250	NC	NC	NC
Hay	0.250	0.250	0.000	0.000
Silage	0.250	NC	NC	NC
Pasture	0.250	NC	NC	NC
Other grassland	0.250	NC	NC	NC
Other crops	0.250	NC	NC	NC
Fallow	0.250	NC	NC	NC

* PM10 EF's in use

Table 5.34b PM_{10} emission factor for farm-level agricultural operations: cultivation, harvesting, cleaning and drying of crops (Applied to Finnish conditions from Guidebook 2019)

Species	PM10			
	Cultivation	Harvesting	Cleaning	Drying
Wheat	0.250	.2.7	0.190	0.560
Rye	0.250	.2.0	0.160	0.370
Barley	0.250	.2.3	0.160	0.430
Oats	0.250	.3.4	0.250	0.660
Mixed grain	0.250	NC	NC	NC
Other grains	0.250	NC	NC	NC
Peas	0.250	NC	NC	NC
Potatoes	0.250	NC	NC	NC
Sugar beet	0.250	NC	NC	NC
Turnip rape and rape	0.250	NC	NC	NC
Hay	0.250	0.250	0.000	0.000
Silage	0.250	NC	NC	NC
Pasture	0.250	NC	NC	NC
Other grassland	0.250	NC	NC	NC
Other crops	0.250	NC	NC	NC
Fallow	0.250	NC	NC	NC

Table 5.34c $PM_{2.5}$ emission factor for farm-level agricultural operations: cultivation, harvesting, cleaning and drying of crops (Applied to Finnish conditions from Guidebook 2019)

Species	PM2.5			
	Cultivation	Harvesting	Cleaning	Drying
Wheat	0.015	0.020	0.009	0.168
Rye	0.015	0.015	0.008	0.111
Barley	0.015	0.016	0.008	0.129
Oats	0.015	0.025	0.013	0.198
Mixed grain	0.015	NC	NC	NC
Other grains	0.015	NC	NC	NC
Peas	0.015	NC	NC	NC
Potatoes	0.015	NC	NC	NC
Sugar beet	0.015	NC	NC	NC
Turnip rape and rape	0.015	NC	NC	NC
Hay	0.015	0.010	0.000	0.000
Silage	0.015	NC	NC	NC
Pasture	0.015	NC	NC	NC
Other grassland	0.015	NC	NC	NC
Other crops	0.015	NC	NC	NC
Fallow	0.015	NC	NC	NC

$$E_i = \sum\left(\left(\mathbf{EF_{j,cultivation}} * \mathbf{A_{j,cultivation}}\right) + \mathbf{A_{j,harvesting}}\left(\mathbf{EF_{j,harvesting}} + \mathbf{EF_{j,cleaning}} + \mathbf{EF_{j,drying}}\right)\right)$$

Where,

i	= Inventory year
j	= Crops species
EF	= Emission factor (cultivation, harvesting, cleaning or drying) as kg/ha
A	= Land area as hectares (cultivation or harvesting)

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied since the 2012 submission. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2018
- Particle emission factors (as well as activity data) were revised from the TNO emission factors used earlier to those presented in the EMEP/EEA Emission Inventory Guidebook 2016 due to the recommendation of the 2017 NECD review. The revision increased the emissions to be 10-fold compared to the earlier estimates.

2019
- Calculation of new species for which statistical data is available. Considered as "other arable" and the emissions were recalculated with Tier 2 methodology of EMEP/EEA Guidebook 2016.

2020
- Emission factors for harvesting updated according to the EMEP/EEA 2019 guidebook.

Source-specific planned improvements

None.

5.4.8 Off farm storage, handling and transport of bulk agricultural products (NFR 3Dd)

Changes in chapter	
February 2021	JG

Emissions from off-farm storage, handling and transport of bulk agricultural products are reported as NA, because no methodology is presented in Guidebook 2019.

5.4.9 Cultivated crops (NFR 3De)

Changes in chapter	
February 2021	JG, KS

Source category description

This chapter describes the calculation of NMVOC from cultivated crops, grasslands and fallows that serve agricultural purposes. Activity data is provided by Natural Resources Institute Finland (LUKE).

Emission trend

The activity data figures fluctuate annually mostly due to market demands and production rates of specific crops. NMVOC emissions follow this trend (Figure 5.20).

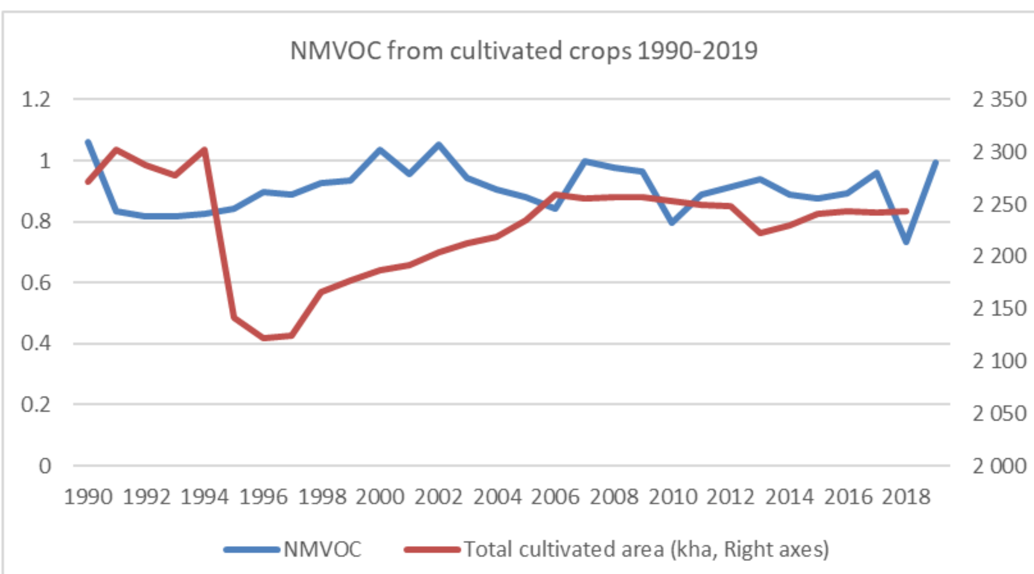

Figure 5.20 NMVOC emissions from cultivated crops 1990-2019

Methodological issues

The emissions of cultivated crops are calculated according to the guidance of EMEP/EAA Guidebook 2019. The model is constructed to calculate by Tier 1 and Tier 2 methods with a possibility to extend calculation into Tier 3.

NMVOC

NMVOC emissions from cultivated crops such as cereals, grasslands and silage are included in the inventory. Table 5.35 presents total cultivated land area for the years 1990-2019. Table 5.36 presents cultivated land areas by species included in the inventory.

Table 5.35 Total cultivated land area per species (thousands of hectares)

Year	Total Cultivated Area (kha)	Year	Total Cultivated Area (kha)
1 990	2 271	2 005	2 235
1 991	2 302	2 006	2 259
1 992	2 287	2 007	2 255
1 993	2 278	2 008	2 257
1 994	2 302	2 009	2 257
1 995	2 141	2 010	2 253
1 996	2 122	2 011	2 249
1 997	2 125	2 012	2 248
1 998	2 166	2 013	2 223
1 999	2 177	2 014	2 230
2 000	2 187	2 015	2 241
2 001	2 192	2 016	2 243
2 002	2 204	2 017	2 242
2003	2 212	2018	2 243
2 004	2 219	2019	2 245

Table 5.36 Total cultivated land area per species in 2019 (thousands of hectares)

Species	Cultivated area	SNAP
Wheat	206	100102
Rye	38	100102
Barley	455	100102
Oats	319	100102
Mixed grain	41	100102
Other grains	6	100102
Peas	14	100102
Potatoes	22	100102
Sugar beet	11	100102
Turnip rape and rape	38	100102
Hay	118	100105
Silage	593	100105
Pasture	54	100105
Other grassland	22	100105
Other crops	88	100104
Fallow	222	100101
Total	**2 245**	

The methodology for the calculation is based on EMEP/EEA Guidebook 2019 Tier 2 method, which reproduces the calculation of Tier 1 emission factor of by substituting the estimation of NMVOC Tier1 emission factor in kg ha-1 a-1 with national data. The recalculation is done for each year independently taking into account the annual relative changes within crop distribution and mean dry matter.

Default emission factor for Tier 1 calculation is 0.86 kg of NMVOC per hectare. The Tier 2 emission factor is calculated annually with the equation presented below.

$$\boldsymbol{EF_i = \sum \left(E_{j,NMVOC} * 24 * 365 * Frac_{emit,j}\right) * m_{dm_j} * Frac_{i,j}}$$

Where,

i	= Inventory year
j	= Crops species
$E_{j,NMVOC}$	= Hourly emission flux of NMVOC per species (kg/dm^3/h)
$Frac_{emit}$	= Fraction of the year during which the species is emitting
m_{dm}	= Mean dry matter of crop (kg/ha/a)
$Frac_{i,j}$	= Fraction of species j in relation to the total of cultivated areas and fallows for the year i

The Guidebook presents default values for calculation of the EF (Table 5.37). These defaults are used whenever national data is not available and replaced if more detailed information is available.

Table 5.37 Default values for emission factor calculation

Species (i)	Ej,NMVOC	Fracemit	mdm,	Fracij
Wheat	2.60E-8	0,3	4700	0.35
Rye	1.41E-7	0.3	2800	0.05
Rape	2.02E-7	0.3	2500	0.1
Grass (15 C)	1.03E-8	0.5	9000	0.25
Grass (25 C)	4.67E-8	0.5	9000	0.25

Mean dry matter is derived from national statistics of species-specific yields per hectare by estimating their share of dry matter. Yield mean dry matter content remains constant throughout all years. Statistical data for yield per hectare is available for 2000-2018. The values for the year 2018 are presented in Table 5.38.

Table 5.38 Yields per hectare and dry matter of 2019 in Finland

Species	Yield per hectare (kg/ha)	Yield mean dry matter content (kg/kg)	Mean dry matter mdm (kg/ha)
Wheat	4560	0.86	3921,6
Rye	4820	0.86	4145,2
Barley	4230	0.86	3637,8
Oats	3930	0.86	3379,8
Mixed grain	2960	0.86	2545,6
Other grains	2960	0.86	2545,6
Peas	2860	0.86	2459,6
Potatoes	28930	0.22	6364,6
Sugar beet	47640	0.23	10957,2
Turnip rape	1330	0.92	1223,6
Hay	3520	0.86	3027,2
Silage	15720	0.25	3930,0
Pasture	15720	0.2	3144,0

Other	15720	0.2	3144,0
Other crops	9000	0.22	1980,0
Fallows	7860	0.21	1650,6

The total cultivated area as thousands of hectares for all species accompanied with the calculated crop distribution (from the total of 2 245 000 hectares including fallows and other grasslands) are presented in Table 5.39. Emission factors are presented in Table 5.40.

Table 5.39 Weighed emission factor and crop distribution of the year 2019, and NMVOC flux per for the main cultivated species.

Species	Cultivated area (1 000 ha)	Crop distribution (%)	NMVOC (kg/dm/a)	Weighted EF (kg NMVOC / ha / a)
Wheat	206	9,2 %	6.82E-05	2,46E-02
Rye	38	1,7 %	3.70E-04	2,62E-02
Barley	455	20,3 %	6.82E-05	5,03E-02
Oats	319	14,2 %	5.30E-04	2,55E-01
Mixed grain	41	1,8 %	6.82E-05	3,19E-03
Other grains	6	0,2 %	6.82E-05	4,25E-04
Peas	14	0,6 %	6.82E-05	1,04E-03
Potatoes	22	1,0 %	6.82E-05	4,20E-03
Sugar beet	11	0,5 %	6.82E-05	3,53E-03
Turnip rape and	37	1,6 %	5.30E-04	1,06E-02
Hay	118	5,2 %	4.51E-05	7,15E-03
Silage	593	26,4 %	4.51E-05	4,68E-02
Pasture	54	2,4 %	4.51E-05	3,42E-03
Other grassland	22	1,0 %	4.51E-05	1,36E-03
Other crops	88	3,9 %	4.51E-05	3,49E-03
Fallows	222	9,9 %	4.51E-05	7,36E-03

Table 5.40 Finnish NMVOC emission factors of cultivated crops in 5-year intervals and in 2019

Year	1980	1985	1990	1995	2000	2005	2010	2015	2019
Total Cultivated Area	2372	2276	2271	2141	2186	2234	2253	2240	2245
Emission Factor	0.482	0.470	0.513	0.431	0.477	0.399	0.358	0.396	0.448

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied since the 2012 submission. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2018
Open and stubble fallows were removed from the total cultivated area as these are not expected to be sources of NMVOC emissions.

Source-specific planned improvements

None.

5.4.10 Use of pesticides (NFR 3Df)

Changes in chapter	
March 2021	KS, JG & JMP

Source category description

HCB emissions from the use of pesticides resulting from HCB residues in chlorine containing pesticides are included under this category.

Emission trend

The emission trend (Figure 5.21) is sharply declining in the early 2000s due to decreased in the use of Simazine, which was forbidden in 2004 in the EU. A new herbicide containing clopyralid was put on the market in Finland in 2010. The use of this new herbicide varies quite a lot between years.

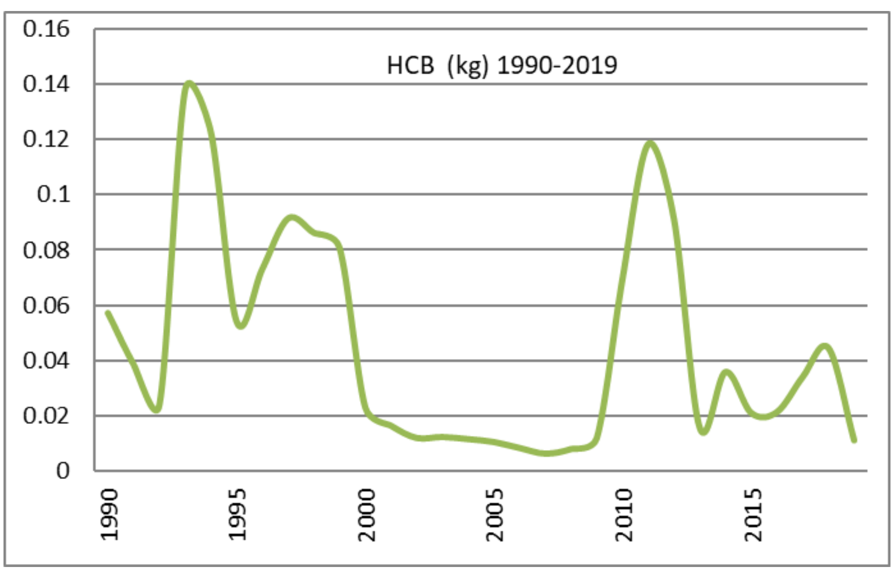

Figure 5.21 HCB from the use of pesticides

Methodological issues

NH_3

In the Guidebook 2019 version calculation of ammonia emissions from ammonia treated straw is presented. In Finland straw is neither treated with ammonia nor urea, therefore NH_3 emissions from this category are reported as NA.

HCB emissions

In the 2020 submission, the calculation of HCB emissions from chlorine containing pesticides has been changed. New information of the use of chlorothalonil has been received and also Guidebook 2019 emission factors have been applied in the calculation. As result from review during summer 2020 the impurity factor for chlorothalonil has been changed so the same impurity factor (10 mg/kg) is used to calculate HCB emissions since the year 2005.

According Finnish Safety and Chemicals Agency (Tukes) chlorothalonil has been sold in Finland by the trade name BRAVO 500 for years 1993-2001. The use of Bravo 500 has been approved for certain forestry purposes. Since 2009 chlorothalonil has been by the trade name Bravo Premium. The use of Bravo Premium has been approved for certain agricultural purposes.

During the manufacture of chlorine containing pesticides HCB may be formed as a by-product and part of this may be left in the product as an impurity (Jones. 2005). Pesticides where HCB can exist as impurity include Lindane, Dacthal (DCPA), Pentachlorophenol, Atrazine, Simazine. Picloram, Pentachloronitrobenzene (PCNB, quintozene), Chlorothalonil, Endosulfan and Clopyralid (Jones, 2005; Environment Canada. 2006/Guidebook 2019).

It is assumed that all HCB residues in the pesticides are emitted to the air, which might be considered as an overestimation.

The HCB impurity concentrations in certain pesticides have been used as emission factors as described in Guidebook 2019 in Table 3 and the sales of the effective substance (Finnish Safety and Chemicals Agency Tukes, 2020) in pesticides as activity data. Sales information provided by Tukes has been claimed confidential since the year 2009 and cannot therefore be published.

Lindane, Dacthal, PCNB and Picloram have not been used or been included in pestisides used in Finland during the period 1990-2018. A new herbicide containing clopyralid was put on the market in Finland in 2010.

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied in the calculation of 2010 emissions. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2020

- The calculation of HCB emissions from chlorine containing pesticides was changed due to new information on the use of chlorothalonil and adoption of Guidebook 2019 emission factors.

2021

- As result from review during summer 2020 the impurity factor for chlorothalonil has been changed so the same impurity factor (10 mg/ kg) is used to calculate HCB emissions since year 2005.
- The activity data for 2018 was updated.

Source-specific planned improvements

2022

Activity data to be obtained from TUKES for the recent years.

5.5 Field burning of agricultural wastes (NFR 3F)

Changes in chapter	
February 2021	JG, JMP, KS, JM

Source category description

Field burning of crop residues is a source of NH_3, NO_x, CO, SO_x, NMVOC, particle (TSP, PM_{10}, $PM_{2.5}$, BC) and heavy metal emissions. Also PCDD/F and PAH emissions are included in the inventory.

Burning of straw is forbidden in Finland from 1.1.2021.

Emission trend

The emission trends follow the trends in the activity data for all pollutants (Figure 5.22).

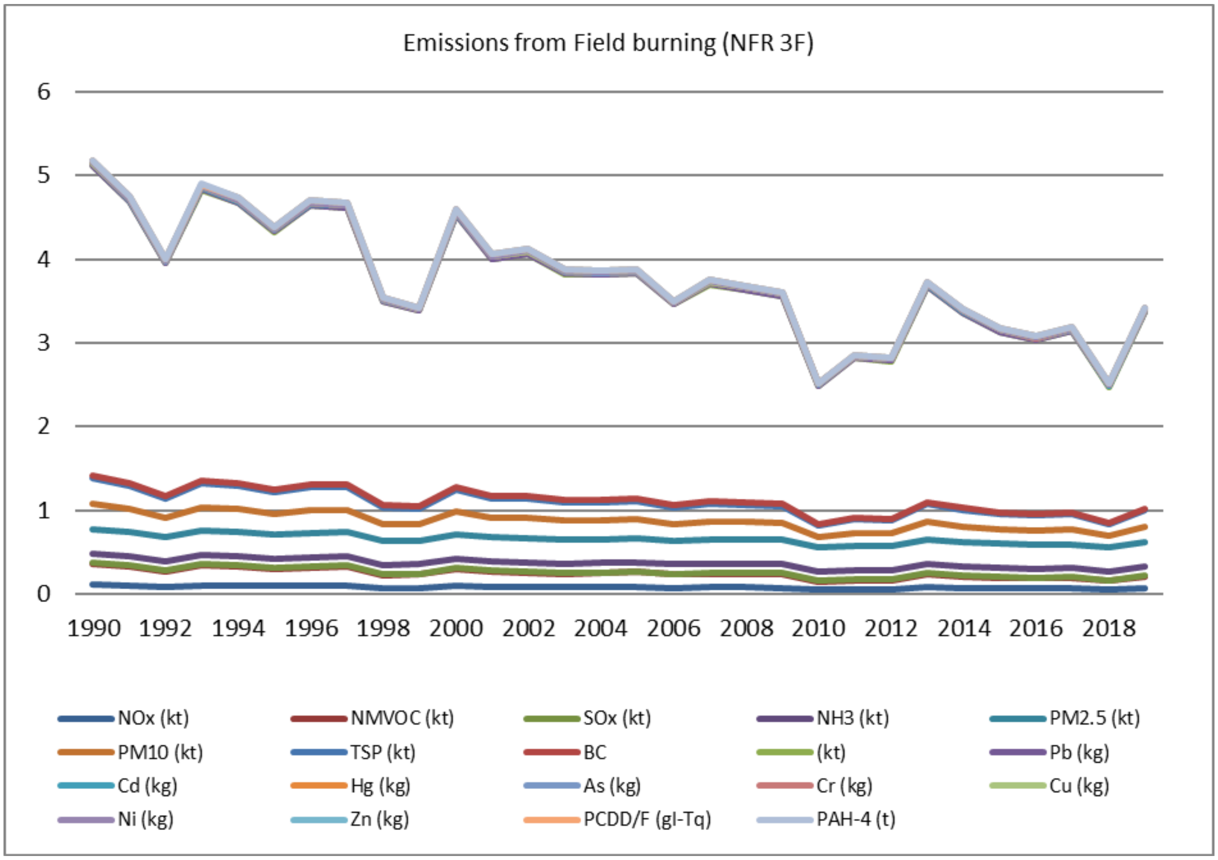

Figure 5.22 Emissions from field burning 1990-2019

Methodological issues

The calculation follows the methodology presented in EMEP/EEA Guidebook 2019.

Activity data

In Finland, burning of agricultural residues occurs only at small scale and it is becoming increasingly rare. Straw is assumed to be the most important agricultural residue burned.

According to the Decree 189/2009 of the Ministry of Agriculture and Forestry field burning of crop residues has to be avoided and is allowed only if it is necessary in order to succeed in sowing or to prevent weeds or pests. According to several agricultural experts, residue burning on fields occurs only in small scale in Finland and is becoming increasingly rare. The machinery is usually able to manage the excess straw left on fields after harvesting. Cereal (especially rye) straw is the most important crop residue that may be burned on fields. Straw is mainly left on field, but a minor part is used for feed or as litter in animal shelters or burning in boilers.

The annual crop yields for cereals and other crops are based on data from the Yearbook of Agricultural Statistics and the areas for cultivated cereals were also obtained from TIKE (the Information Centre of the Ministry of Agriculture and Forestry). The share of burned residue from total cereal residue on the fields for the years 1990-2013 was re-evaluated and simplified. The situation of residue burning for years 2013 (0.9%) and 2012 (0.7%) is rather accurately known as

TIKE made an inquiry to the farmers. From the year 2014 onwards the estimate for burning is an average of years 2012 and 2013 (0.008)

The situation in the beginning of the 1990's is, however, still highly uncertain. Most likely, burning has been more common than nowadays and an expert opinion (Ansalehto, 2007) supports this. Therefore, field burning in the year 1990 was estimated to be twice as much as the average of years 2012 and 2013 and was assumed to rise linearly from year 2012 backwards.

Estimates for the burned fraction of cereal are presented in Table 5.42 and emission factors from Guidebook 2019. Emission factors for wheat are used also for rye and oats.

Table 5.42a Estimates of the burned fraction. Fraction of total residue burned is calculated by dividing the burned straw with total residue of all crops (as dry matter) (Finland's NIR 2021 Table 5.5-2)

Year	Frac of residue burned, cereals	Frac of residue burned, total residue
1990	0.016	0.008
1995	0.014	0.007
2000	0.012	0.007
2005	0.010	0.005
2009	0.008	0.005
2010	0.008	0.004
2011	0.007	0.004
2012*	0.007*	0.004
2013*	0.009*	0.005
2014	0.008	0.005
2015	0.008	0.005
2016	0.008	0.005
2017	0.008	0.005
2018	0.008	0.005
2019	0.008	0.005

*an estimate based on TIKE inquiry

Table 5.42b Activity data for total burned biomass (kt dm)

Year	Wheat	Barley	Oats	Rye	Total	Year	Wheat	Barley	Oats	Rye	Total
1990	5.97	20.57	17.82	1.16	45.52	**2010**	6.25	7.85	6.22	0.63	20.95
1991	6.26	18.42	15.79	1.04	41.51	**2011**	7.97	8.44	7.51	0.69	24.61
1992	3.90	15.47	14.01	0.91	34.29	**2012**	7.19	8.58	7.79	0.55	24.10
1993	5.93	19.51	16.29	0.97	42.69	**2013**	8.66	12.90	10.63	0.28	32.47
1994	6.05	19.02	15.02	0.91	41.00	**2014**	9.66	11.07	8.22	0.68	29.64
1995	5.77	17.14	14.08	0.94	37.93	**2015**	8.87	9.85	7.87	1.03	27.61
1996	6.79	17.55	15.73	1.39	41.45	**2016**	7.42	9.82	8.36	0.84	26.43
1997	6.72	18.24	15.04	0.73	40.73	**2017**	7.70	9.76	9.13	1.19	27.77
1998	5.69	12.26	11.80	0.86	30.60	**2018**	4.63	8.55	6.79	0.42	20.40
1999	3.43	13.49	11.26	0.34	28.53	**2019**	8.25	10.71	9.28	1.75	29.99
2000	7.10	16.54	15.57	1.52	40.73						

2001	6.22	14.48	13.93	0.87	35.50						
2002	6.89	13.50	15.47	0.96	36.82						
2003	7.93	12.70	12.82	0.92	34.37						
2004	9.14	13.11	10.84	0.87	33.97						
2005	8.62	14.52	9.81	0.38	33.33						
2006	7.05	13.06	9.03	0.57	29.71						
2007	7.91	13.14	10.64	0.94	32.62						
2008	7.52	13.39	10.17	0.63	31.71						
2009	8.03	13.34	9.02	0.41	30.79						

Emission factors

The emission factors used are from the EMEP/EEA Guidebook 2019 (Table 5.43). For wheat and barley Tier 2 EF is used. For oats and rye the emission factor of wheat is used.

Table 5.43 Emission factors used for field burning of agricultural residues.

Pollutant	Wheat	Barley	Oats	Rye	Unit
NOx	0.0023	0.0027	0.0023	0.0023	kg kg-1 dm
CO	0.0667	0.0987	0.0667	0.0667	kg kg-1 dm
NMVOC	0.0005	0.0117	0.0005	0.0005	kg kg-1 dm
SOx	0.0005	0.0001	0.0005	0.0005	kg kg-1 dm
NH_3	0.0024	0.0024	0.0024	0.0024	kg kg-1 dm
TSP	0.0058	0.0078	0.0058	0.0058	kg kg-1 dm
PM10	0.0057	0.0077	0.0057	0.0057	kg kg-1 dm
PM2.5	0.0054	0.0074	0.0054	0.0054	kg kg-1 dm
BC	500	1200	500	500	mg kg-1 dm
Pb	0.11	0.0036	0.11	0.11	mg kg-1 dm
Cd	0.88	0.24	0.88	0.88	mg kg-1 dm
Hg	0.14	0.096	0.14	0.14	mg kg-1 dm
As	0.0064	NA	0.0064	0.0064	mg kg-1 dm
Cr	0.08	0.14	0.08	0.08	mg kg-1 dm
Cu	0.073	0.0036	0.073	0.073	mg kg-1 dm
Ni	0.052	0.011	0.052	0.052	mg kg-1 dm
Se	0.02	0.039	0.02	0.02	mg kg-1 dm
Zn	0.56	0.49	0.56	0.56	mg kg-1 dm
Benzo(a)pyrene	67.7	98.8	67.7	67.7	mg kg-1 dm
Benzo(b)fluoranthene	189.1	307.4	189.1	189.1	mg kg-1 dm
Benzo(k)fluoranthene	80.7	77	80.7	80.7	mg kg-1 dm
Indeno(1.2.3-cd)pyrene	57.9	38.2	57.9	57.9	mg kg-1 dm

* For wheat and barley. Tier 2 EF is used. (EMEP/EEA Guidebook 2019)

* For PCDD/F Tier 1 EF is used for all species

$$E_i = \sum (\mathbf{EF_{pollutant.}} * \mathbf{AR})_j$$

Where.

i	= Inventory year
j	= Crops species
EF	= Emission factor for pollutant (kg/kg dm)
AR	= Activity rate (AR). mass of residue burnt (kg dry matter)

Uncertainty and time series' consistency

The results of the uncertainty analysis are presented in Annex 7 of the IIR.

Source-specific QA/QC and verification

Normal statistical quality checking related to the assessment of the magnitude and trends has been carried out. The quality system is implied in the calculation of 2010 emissions. At present, no verification has been carried out for the specific source-sector emissions.

Source-specific recalculations including changes made in response to the review process

2009
- Emissions from cereal straw (wheat. barley. oats. rye) burning were included

2014
- The activity data for field burning was revised due to new information from inquiries in 2012 and 2013 for the whole time series and thus NH_3 emissions have also changed.

2015
- Calculation of emissions from field burning of agricultural waste was revised according to new emission factors presented in Guidebook 2013

2016
- Calculation of emissions from field burning of agricultural waste was revised for the 2016 submission due to update of emission factors according to Guidebook 2016 and new studies that improved the activity data.

2017
- Calculation of heavy metal and PCDD/F emissions from field burning of agricultural waste was revised for the 2017 submission due to inclusion of emission factors from Guidebook 2016.

2019
- In response to a question raised during the review, activity data (kg dm burning for specific crop types) has been included in the IIR.

2021
- Activity data for total burned biomass (kt dm) for the whole time series was updated based on the data provided by the Natural Resources Institute Finland (Luke).
- In submissions prior to 2021 the emissions of PCDD/F were calculated with the Tier 1 methodology of the 2019 Guidebook, whereas all other pollutants are estimated with Tier 2 methodology. Closer inspection of the EF of PCDD/F in the Tier 1 methodology lead to the conclusion that the emission factor is not applicable to the Finnish conditions, as the crop

distribution does not correlate to the distribution within the European region. Furthermore, the confidence interval for the EF is not presented, which supports the decision to perform the calculation with the Tier 2 methodology only. Therefore PCDD/F emissions from NFR 3F were removed from the 2019 inventory. Possibilities to include the Tier 2 calculation are studied to the future submissions.

Source-specific planned improvements

None.

5.6 Agriculture other (NFR 3 I)

Not occurring in Finland.