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Nitrogen budget - Agriculture Sweden

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Summary

To better understand the sizes of the flows of reactive nitrogen in a country, a national nitrogen budget can be constructed. The Expert Panel on Nitrogen Budgets (EPNB) was established under The Task Force on Reactive Nitrogen (TFRN) and has prepared guidelines for compilations of national N budgets. In this report we present the flows of reactive nitrogen in Sweden in year 2015 in the *Agriculture pool* calculated following the EPNB methodology.

The primary source of data presented in this report are data reported to Eurostat and UNFCCC regarding gross nutrient balance and greenhouse gases. The flows of nitrogen not covered by Eurostat and UNFCCC originates from for example the national compilations of content of feed products and slaughtering weight of animals for consumption.

The major inputs of nitrogen to the agriculture pool are inputs of inorganic fertilizers to soils (190 kT) and of feed to animal husbandry (59 kT). The major outputs of nitrogen from the agriculture pools are found in products to consumers (crops, meat, milk, egg etc.) (171 kT) and emissions to the hydrosphere and atmosphere (93 kT).

In total the inputs in this nitrogen budget for agriculture in Sweden were 15 % larger than the outputs, which is an encouraging result, given heterogeneity of the data sources used to compile the budget. It is also well within differences between inputs and outputs from other countries. The difference could be due to uncertainties in the currently collected data or depend on flows on nitrogen that are not accounted for today that could be investigated in the future. The difference could also indicate that the agricultural pool is actually not in balance, i.e. that there is an ongoing stock change of the amount of nitrogen in soils or in some other compartments.

Introduction

The Task Force on Reactive Nitrogen (TFRN) was established under the Working Group on Strategies and Review (WGSR) by the Executive Body at its twenty-fifth session in December 2007.

The purpose of TFRN has been defined as: *"The Task Force will develop in the long-term technical and scientific information and options which can be used for strategy development across the UNECE to encourage coordination of air pollution policies on nitrogen in the context of the nitrogen cycle and which may be used by other bodies outside the Convention in consideration of other control measures."* For the full terms of reference of the Task Force, see Executive Body decision 2007/1.

At the first meeting (Wageningen, 2008) TFRN agreed to define reactive nitrogen (Nr) as all biologically active, photochemically reactive and radiatively active N compounds in the biosphere and atmosphere. This meant, in practice, all N except N_2 gas; for example, nitric oxides, nitrogen dioxide, nitrate (NO_3^-), organic N compounds, nitrous oxide (N_2O), ammonia (NH_3) and ammonium (NH_4^+). At the same meeting it was proposed that an expert panel could help in preparing for the reporting of national budgets, first exploring methodologies and providing a reference template for the compilation. The Expert Panel on Nitrogen Budgets (EPNB) was established (first as an ad-hoc group) and commenced work to prepare guidelines for compilations of national N budgets of individual countries. EPNB prepared the "Guidance Document on National Nitrogen Budgets". The document was presented and approved at the 31st meeting of the

Executive Body of the Convention on Long-Range Transboundary Air Pollution in December 2012. The document can be downloaded from http://www.clrtap-tfrn.org/sites/clrtap-tfrn.org/files/documents/EPNB_new/ECE_EB.AIR_119_ENG.pdf. After that the work of EPNB continued to provide detailed guidelines for each of the 8 main parts of the National N Budget (NNB) summarised in Annexes to the ECE/EB.AIR/119 – "Guidance document on national nitrogen budgets". Currently the version dated 21. 09. 2016 is available at http://www.clrtap-tfrn.org/sites/clrtap-tfrn.org/files/documents/EPNB_new/EPNB_annex_20160921_public.pdf and it summaries six out of the eight pools. The two Annexes still under development are 1. Energy and Fuels and 5. Waste.

There have been attempts constructing nitrogen budgets in some of the European countries and elsewhere, see for example Switzerland (Heldstab et al., 2010 and 2013), Germany (Geupel et al., 2009), Denmark (Hutchings et al., 2014) or Canada (Clair et al., 2014). These budgets have not followed the same protocol when constructed but provide information on important flows. In Europe Sutton et al. (2011) estimated that 74% of the total input of reactive nitrogen to the environment stems from the Haber-Bosch process, 16% from combustion, and the remaining 10% from biological fixation, import of feed and products. Leip et al. (2011) estimated nitrogen fluxes for EU27 developing and using same protocol for all countries. Among the key findings was that of the large input of reactive nitrogen to agriculture (18 Tg per year) only about 7 Tg per year find a way to the consumer or are further processed by industry (year 2000 values). Leip et al. (2011) recommend development of nitrogen budgets nationwide since the assessment and management of the budgets could become an effective tool to prioritize measures and prevent unwanted effects.

National nitrogen budgets (NNB) following the EPBN methodology are constructed based on eight pools (Figure 1). In this report, data on pool 3 (Agriculture, NNB_Ag) is presented. The Swedish data presented in this report are for year 2015 and consist of data reported to Eurostat as part of the Gross Nutrient Balance, to UNFCCC as part of the greenhouse gas inventory or are calculations based on data from Swedish agencies and reports.

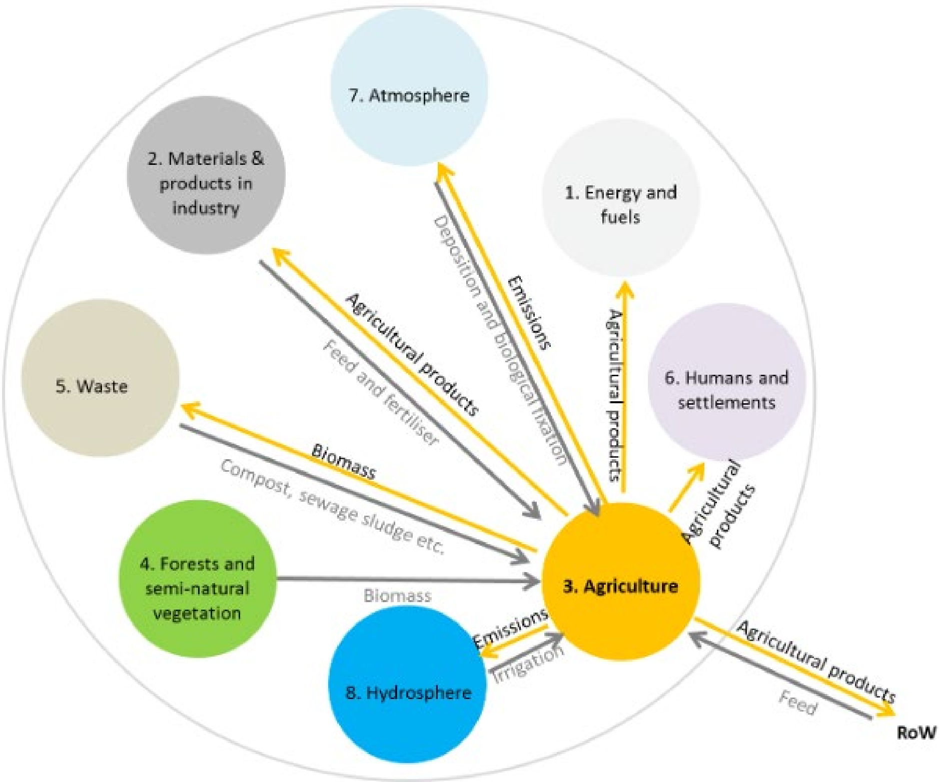

Figure 1. Agriculture pool and links to other pools considered in the National integrated Nitrogen Budget. (Source: http://www.clrtap-tfrn.org/sites/clrtap-tfrn.org/files/documents/EPNB_new/EPNB_annex_20160921_public.pdf)

National nitrogen budget (NNB) for Agriculture (pool 3)

The agriculture pool is divided into three sub-pools:

1. Animal husbandry (including aquaculture)
2. Manure management and manure storage system
3. Soil management

The sub-pools are connected to each other and to other pools in the NNB. The boundary of the agriculture pool is the "extended farm gate", including housing system, manure storage systems, dairies, slaughter houses, bakeries, wineries, breweries etc.

The *basic approach* for constructing a national nitrogen budget for agriculture used in this report has been to use data that are already available by national agencies in the frame of UNFCCC, UN-ECE CLRTAP and OECD/Eurostat Gross Nutrient Balance (GNB). Only for a few remaining flows new estimates need to be calculated using the approaches (Tier 1 or higher) described in Annex 3 (http://www.clrtap-tfrn.org/sites/clrtap-tfrn.org/files/documents/EPNB_new/EPNB_annex_20160921_public.pdf).

The overall summary of the major flows of reactive nitrogen in Swedish agriculture is summarized in Figure 2. In the coming sections the reported or calculated amounts of nitrogen flows are presented with an explanation on how the data was obtained. In Sweden Statistics Sweden is the governmental agency in charge of the reporting to Eurostat. Two major sources of data for this nitrogen budget were the amounts of nitrogen submitted to UNFCCC and Eurostat. Data reported to UNFCCC (in this report referred to as CRF Table 3.B(b) and CRF_Table3.D) were retrieved (25 September 2018) from https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2018 and data reported for the Gross Nutrient Balance (GNB) to Eurostat were retrieved (26 September 2018) from https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB.

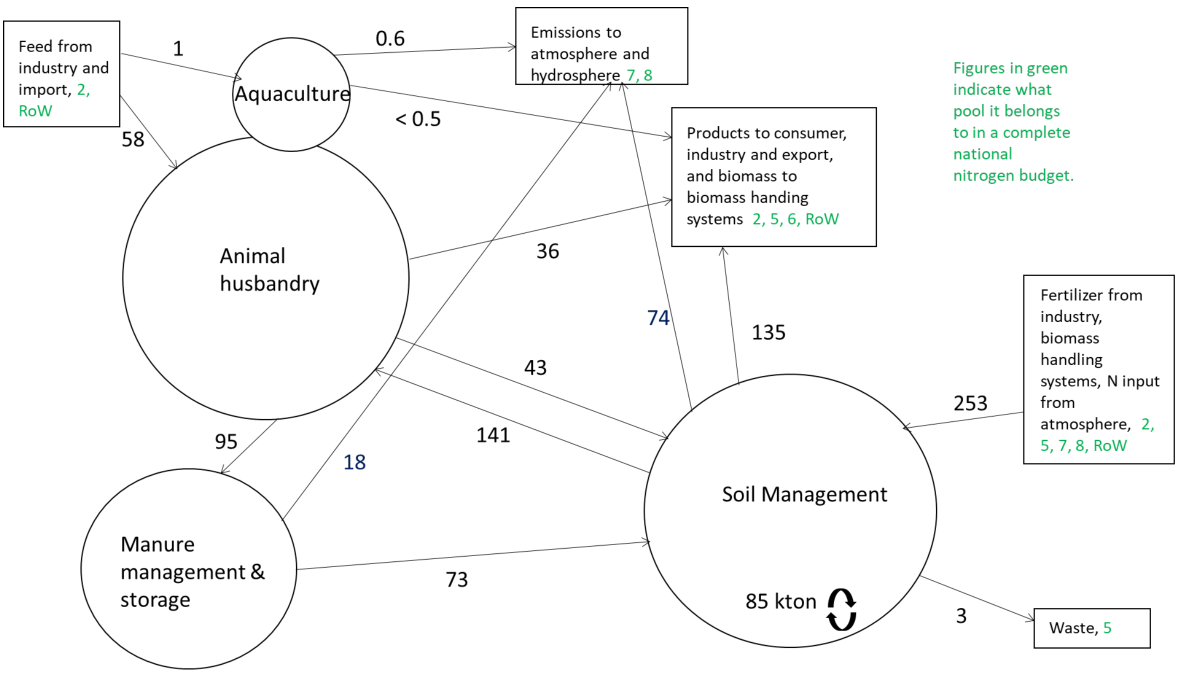

Figure 2. Nitrogen flows into, out of and within the Agricultural pool in Sweden year 2015. Units: ktonnes (kT) of N.

1. Animal husbandry

A good characterization of animal husbandry is essential for the construction of a national nitrogen budget. This sub-pool includes cattle, swine, horses, poultry, sheep, goats, reindeer, other furbearing animals and aquaculture. Reactive nitrogen associated with wild catch and game are considered as flows between other pools and are not included in the national nitrogen budget for agriculture.

Animal Feed intake of nitrogen

There are two main ways to estimate feed intake, a) quantifying the intake of offered feed and b) calculating the feed requirements based on animal productivity and literature data. In this budget mainly alternative a) is used.

The estimated offered feed contains 59 ktonnes (kT) N from feed industry to animal husbandry and aquaculture (of which approximately 1 kT to aquaculture). In addition, 13 kT of N originate from grazing of permanent grasslands and 128 kT of N comes from harvest on arable land.

The nitrogen flow of feed is based on three sources: 1) *Table 1. Feed material in compound feed for all animals (tonnes/year) in Foderstatistik – 2015* published by the Swedish Board of Agriculture, 2) the protein content per compound and 3) the conversion factor from protein to nitrogen. Data on the latter two points were retrieved from the National Food Agency, Sweden (Table 1).

Harvested fodder is presented in section 3 in this report and those data were retrieved from the Swedish gross nitrogen balance reported to Eurostat (https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB).

The part of the total feed that goes to fish (aquaculture) was estimated based on a calculation of the required amount of fodder per amount of harvested fish multiplied by the nitrogen content of the N in the fodder. In year 2015, 10 752 tonnes of fish were harvested (http://www.jordbruksverket.se/webdav/files/SJV/Amnesomraden/Statistik,%20fakta/Vattenbruk/JO60SM1801/JO60SM1801_kommentarer.htm). 1.2 kg of fodder is needed in fish production per kg of produced fish (https://swemarc.gu.se/25svar/18). The nitrogen content of the fodder is allowed to be 7% (http://databas.infosoc.se/rattsfall/27834/fulltext). In total 1 kT of nitrogen was added to aquaculture as fish feed. Approximately 0.4 kT of nitrogen were converted into products to consumers (fish and mussels) and about 0.6 kT were emitted to the hydrosphere (calculated from about 60 kg leaching of N/ton fish, Mietala (2012)).

Table 1. Nitrogen in feed handled by feed suppliers registered at the Swedish Board of Agriculture in 2015. Amounts are calculated from *Table 1. Feed material in compound feed for all animals (tonnes/year) in Foderstatistik – 2015* published by the Swedish Board of Agriculture and the protein content and the protein to nitrogen conversion factors available at the webpage of the National Food Agency, Sweden.

Food species	Manufactured in Sweden (tonnes N)	Imported (tonnes N)
Barley	2965.0	5.1
Wheat	9971.7	65.9
Pollard	3358.4	0.5
Draff	2128.2	0.0
Corn	95.1	55.9
Millet	0.4	562.4
Oats	4110.6	25.3
Oatbran	60.3	0.0
Rye	27.8	0.0
Fishmeal	37.5	139.9
Milk	7.2	0.6
Rape	9850.2	4416.9
Soybean	2419.5	11247.5
Sunflower seed	107.6	5366.6
Linseed	50.1	2.6
Peas	565.4	2.2
Broad bean	510.3	1.0
Beet pulp	435.6	458.7
Potato	9.3	11.1
Lucerne	47.6	12.2
Whey	0.5	0.2
Animal bi-products	223.9	1.9
Total	36982	22376

Nitrogen retention in animals

This pool comprises retention in livestock products that a) are extracted from the system as products (milk, eggs, wool, etc.) or b) retention in animal biomass until death by slaughtering (delivering carcass and non-carcass products) or by other causes (generally waste). In total 35 kT of N were extracted from the animal husbandry sub-pool through slaughtering of livestock or through extraction of livestock products as milk and eggs (Table 2).

Statistics on meat, egg and milk production in Sweden in year 2015 were collected by the Swedish Board of Agriculture, processed by SCB and published (https://www.svensktkott.se/om-kott/statistik/). The content of nitrogen was calculated with data on the amount of protein in the product from https://www.livsmedelsverket.se/livsmedel-och-innehall/naringsamne/protein and the amount of nitrogen per protein. The assumption is therefore that the entire animal has the same protein content per weight.

The amount of nitrogen in carcasses etc. sent to the company Konvex AB (in Karlskoga and Krutmöllan) for destruction, and to some extent production of Biomal (a biofuel) was estimated to be 1 kT, based on 30 000 tons of animals destructed per year by Konvex (pers. comm.) and an average nitrogen content of 3 %. Poultry exported to Denmark to be used as mink fodder was estimated to contain (https://www2.jordbruksverket.se/download/18.68b250de1531241bb31acf45) 27 tonnes of nitrogen, a minor flow in this overall nitrogen budget for agriculture.

The amount of nitrogen in animals not slaughtered for meat production or destructed by the company Konvex are not included in the calculations, and this flow should be further investigated in the future.

Table 2. Extraction of N from the animal husbandry sub-pool in 2015.

Animal	Slaughterweight (incl. bone, fat, head etc) 2015 (tonnes)	N-content (kg N per ton	Swedish production N (tonnes)
Cattle	133 100	33.6	4 472
Swine	233 500	30.4	7 098
Sheep	5 120	28.8	147
Poultry	145 900	32	4 669
Eggs	126 500	19.7	2 492
Milk	2 908 000	5.5	15 994
Total sum			**34 873**

Animal excretion of nitrogen

Excretion factors of N in manure are central for many reporting obligations: N_2O emission from manure management and N_2O emissions from agricultural soils upon application of manure or direct excretion by grazing animals on fields. Manure is also the main cause of NH_3 emissions and manure excretion was almost at the same level as the application of mineral fertilizers for EU28 in 2012 (http://www.clrtap-tfrn.org/sites/clrtap-tfrn.org/files/documents/EPNB_new/EPNB_annex_20160921_public.pdf).

The excretion of N in animal husbandry was estimated to be 138 kT (Table 3), where 43 kT are excreted during grazing and 95 kT in other facilities such as indoors.

Total N excretion (by manure management systems) was retrieved from Table 3.B(b) of the CRF for submission of national GHG inventories to the UNFCCC (https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2018).

Figure 3 summarizes and illustrates the above discussed inputs and outputs of reactive nitrogen to the sub-pool Animal husbandry and Aquaculture. The 35 kT of N which ends up in products represent about 18% of the total input of reactive nitrogen to the pool from fodder, grazing and from industrial feed (200 kT).

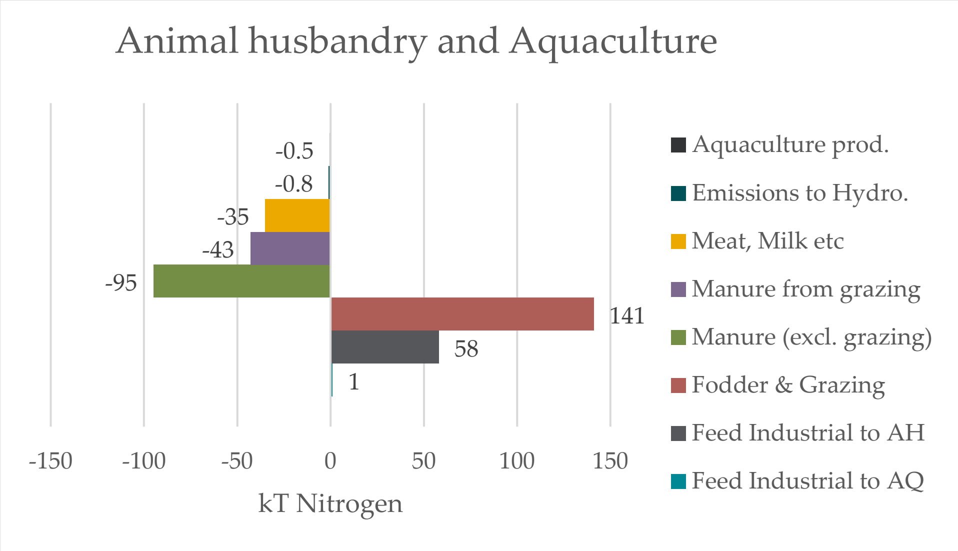

Figure 3. Nitrogen inputs and outputs (in kT) to and from the Animal husbandry and Aquaculture sub-pool of the Swedish national nitrogen budget for Agriculture for year 2015. In total, the inputs to the sub-pool exceed outputs by 26 kT of N corresponding to 13 % of the input.

2. Manure Management and Storage

In this sub-pool emissions from NH_3, N_2O, NO and N_2 and run-off of NO_3^- can occur. The amount of the losses depends on the type of manure management system.

For the basic approach in the construction of a national nitrogen budget, data from UNECE or UNFCCC reporting should be used. The distribution of nitrogen excreted in different manure management and manure storage systems in a country (including the share of manure excreted by grazing animals) is available in CRF Table 3B(b) of the national GHG inventory. A summary table (Table 3) with nitrogen excretion per animal type and manure management system shows that cattle contributed to most of the excreted nitrogen, 92 kT in 2015. Divided into different manure management systems 43 kT were excreted in pasture range and paddock, 49 ktonnes in liquid systems, 30 kT in solid storage and dry lot and 15 kT to the category other (could include pit storage, deep bedding, poultry manure with and without litter, aerobic treatment) (Table 3).

18 kT of nitrogen are volatilized as NH_3 and NO_x and thereby emitted to the atmosphere. This figure does not include N volatilized from manure deposited in pasture, range and paddock systems (CRF_Table3.B(b)).

Table 3. Population size of different species in Sweden and the nitrogen excretion per manure management system (MMS) in tonnes N year 2015 (Source: CRF_Table3.B(b))

Animal	Population size (1000s)	Nitrogen excretion per manure management system (MMS) (tonnes N per year)				Total N excreted (tonnes N per year)
		Liquid system	Solid storage and dry lot	Pasture range and paddock	Other	
Cattle	1 480	38 368	13 165	29 934	10 715	92 183
Sheep	595		2 021	2 021		4 041
Swine	1 356	10 631	1 615		357	12 603
Goats	5.5		24	24		48
Horses	363		8 357	8 705	348	17 410
Poultry	20 613	462	3 863		3 933	8 258
Reindeer	250			2 504		2 504
Fur-bearing animals	210		964			964
Total N handled per MMS		49 461	30 008	43 187	15 354	**138 011**

Similar, but not identical, data have also been reported to Eurostat (https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB) (Table 4). In this report the data in Table 3 are used.

Table 4. Data on Swedish manure production in 2015 reported to Eurostat (https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB). These data were not used in this report.

Manure production from livestock	N (tonnes)
Cattle	90 249
Pigs	14 405
Sheep and goats	4 108
Poultry	6 762
Other livestock	4 584
Total	**120 106**

Figure 4 summarizes and illustrates the above discussed inputs and outputs of reactive nitrogen to the sub-pool Manure Management and Storage. The 73 kT of reactive nitrogen which ends up in manure used as a fertilizer on fields represent about 77 % of the total Nr input to the pool (95 kT). Losses associated with distribution of manure onto the fields are the major contributor to losses to the atmosphere from the sub-pool Soil Management and not accounted for here.

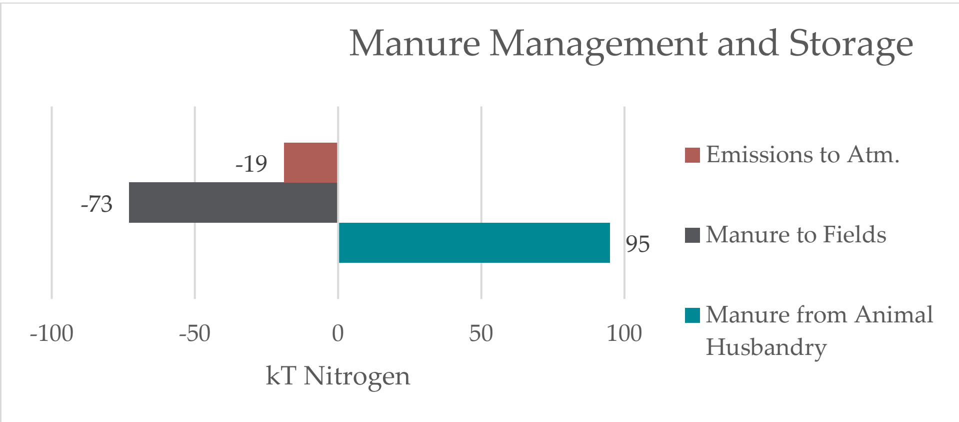

Figure 4. Nitrogen inputs and outputs (in kT) to and from the Manure Management & Storage sub-pool of the Swedish national nitrogen budget for Agriculture for year 2015. In total, the inputs to the sub-pool exceed the outputs by 4 kT N corresponding to 4 % of the input.

3. Soil management

N-releases that occur during or after the application to arable land are included in this sub-pool (i.e. not the N-releases connected to manure management or storage).

Mineral fertilizer, manure and organic waste application

Data on fertilizer application was derived from CRF_Table 3.D from the reported national GHG inventories. In 2015, 190 kT of inorganic nitrogen fertilizers and 81 kT of organic nitrogen fertilizers were applied to cropland and grassland in Sweden. The organic fraction consisted of 73 kT of animal manure, 3 kT of sewage sludge, and 4 kT of other organic fertilizers. In addition, 43 kT of nitrogen in urine and dung were excreted by grazing animals. 85 kT of nitrogen in crops were returned to soils.

Table 5. Nitrogen input from fertilizers and crop residues (Source: CRF_Table3.D) in 2015.

N input from	N (tonnes)
Inorganic N fertilizers	**190 200**
Organic fertilizers	**80 569**
Animal manure applied to soils	*73 381*
Sewage sludge applied to soils	*2 802*
Other organic fertilizers applied to soils	*4 386*
Urine and dung deposited by grazing animals	**43 187**
Crop residues	**85 433**
Cultivation of organic soils (i.e. histosols)	139

Other nitrogen inputs

Seeds and planting material

Seeds and planting material contributed with 4 kT of nitrogen input in 2015 (Eurostat, https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB).

Biological N fixation

Biological nitrogen fixation contributed with 34 kT of nitrogen input in 2015 (Eurostat, https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB).

Atmospheric deposition

Atmospheric deposition contributed with 18 kT of nitrogen input in 2015 (Eurostat, https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB).

Crop removal

Nitrogen export in harvested crops was 135 kT of nitrogen in 2015 (Eurostat, https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB) (Table 6).

Table 6. Nitrogen in harvested crops in 2015 divided by crop type.

Nitrogen in harvested crops	N (tonnes)
Cereal	108 378
Industrial crops	14 175
Dried pulses	6 416
Root crops	5 326
Vegetables	1 073
Fruits	34
Total	**135 4012**

Fodder removal

Nitrogen export in harvested fodder was 141 kT of nitrogen in 2015 (Eurostat, https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB) (Table 7).

Table 7. Nitrogen in harvested fodder or grazed in 2015.

Nitrogen in fodder harvested or grazed	N (tonnes)
Harvest and grazing of permanent grasslands	12 955
Harvest of plants harvested green from arable land	128 270
Total	**141 225**

Crop residues outputs

In addition to the nitrogen removed from the fields according to the tables above (Tables 6 and 7) 3 kT of nitrogen was exported in crop residues removed from the fields in 2015 (Eurostat, https://ec.europa.eu/eurostat/en/web/products-datasets/-/AEI_PR_GNB).

Emissions to atmosphere and hydrosphere

21 kT of nitrogen was emitted to the atmosphere and 53 kT leached to the hydrosphere in 2015 (CRF_Table 3.D, https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2018) (Table 8)

Table 8. Nitrogen emissions to the atmosphere and the hydrosphere from the Soil Management pool (tonnes of N in 2015).

Emissions to atmosphere and hydrosphere	N (tonnes)
Emissions to atmosphere	**20 537**
Nitrogen leaching and run-off	**53 395**

Soil nitrogen stock changes

In this report we assume no net change of soil nitrogen stock in 2015. Data could be obtained from long term monitoring programs, through process-based modelling or on a basis of regression assumptions. To address stock changes over time could provide further improvement to our understanding of the NNB but is beyond the scope of this report.

Figure 5 summarizes and illustrates the above discussed inputs and outputs of reactive nitrogen to the sub-pool Soil Management. The 276 kT of reactive nitrogen that end up in crops, fodder and grazing represent about 75 % of the total input of reactive nitrogen to the pool (369 kT).

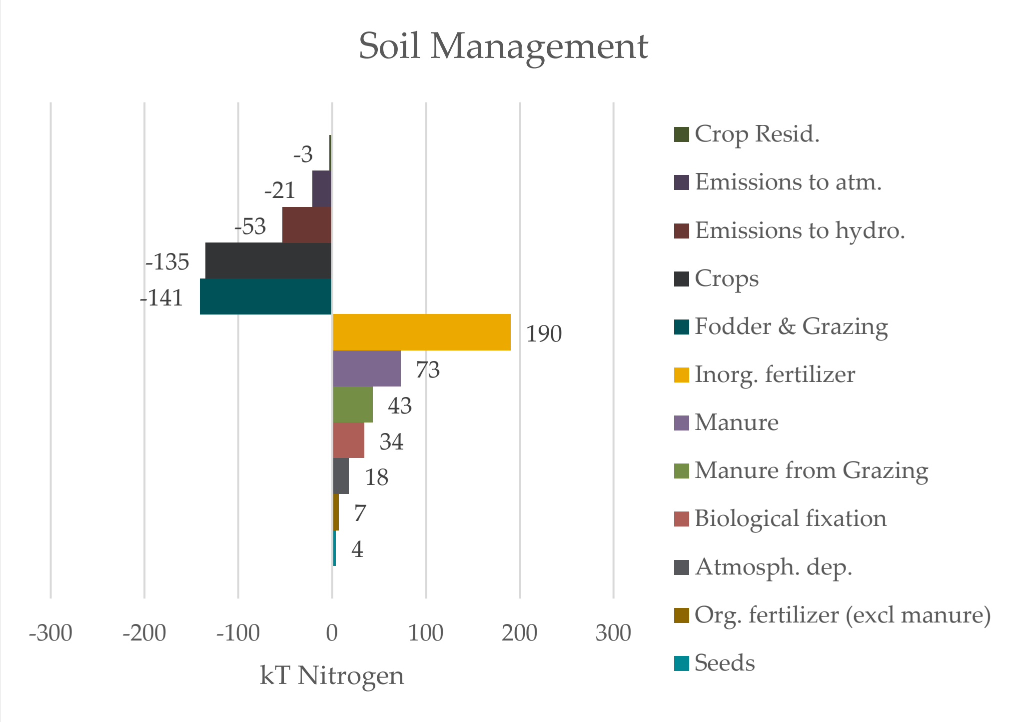

Figure 5. Nitrogen inputs and outputs (in kT) to and from the Soil Management sub-pool of the Swedish national nitrogen budget for Agriculture year 2015. In total the inputs to the sub-pool exceed outputs by 16.5 kT N corresponding to 4% of the input.

Conclusions

The largest input of reactive nitrogen to agriculture is from inorganic fertilizer. The total input of reactive nitrogen to agriculture was 312 kT (Table 9) of which 171 kT (or 55%) ended up in products (Table 10).

Table 9. Inputs to the Agriculture pool for year 2015.

Inputs	N (ktonnes)
Inorganic N	190
Feed from industry and import	58 (AH) + 1 (AQ)
Biological fixation	34
Atmospheric deposition	18
Organic fertilizer (excl. manure)	7
Seeds and planting material	4

Table 10. Outputs of nitrogen from the Agriculture pool for year 2015.

Outputs	N (ktonnes)
Products to consumer, industry and export (crops from sub-pool Soil Management)	135
Emission to hydrosphere (N leaching and run-off)	53
Emission to atmosphere	40
Products to consumer, industry and export and biomass to biomass handling systems (milk, meat, bone etc. from sub-pool Animal Husbandry)	36
Crop residues (to waste)	3

In total, the input of reactive nitrogen to agriculture was 312 kT and output to products and to losses was 266 kT, thus leaving an input of 46 kT (or 15% of the input) unaccounted for. There are uncertainties associated with each of the posts which could lead to imbalance even if the system as a whole is balanced. Alternatively, the Swedish agricultural system is not in balance and could be accumulating reactive nitrogen, for instance in soils. There could also be other flows which were not accounted for, or there is a risk of misinterpretation of the data leading to double-counting. However, the situation that national nitrogen budgets do not exactly add up is more a rule than an exception. Leip et al. (2011) constructed budgets of reactive nitrogen for EU27 and in a greater detail for 6 countries: Switzerland, the Netherlands, Germany, France, the UK and Czech Republic. The methodology of the EPNB was not developed at the time and the results are therefore not fully compatible with this report which makes comparison of individual flows in Sweden to flows in other countries difficult. But the differences between total inputs and outputs could be compared. For the agricultural part of the national budgets of reactive nitrogen of these 6 countries the difference between inputs and outputs ranged between outputs exceeding inputs by 25% in the UK to inputs exceeding outputs by 78% in France. On average the inputs exceeded outputs by 20%. In that perspective the imbalance of 15% is within what could be expected provided the heterogeneity of the data on which the budget has been constructed and the independence of many of the major posts in the budget.

The nitrogen budget for agriculture in Sweden for year 2015 (Figure 2) has been constructed from publicly available data and using the methodology developed by the Expert Panel on Nitrogen Budget within UN ECE CLRTAP WGSR, Task force for Reactive Nitrogen. Two primary sources of data were the amounts of nitrogen submitted to UNFCCC and Eurostat, which included information needed to calculate most of the posts needed. Other flows we had to be calculated by combining the best data available. For example, the nitrogen content in feed had to be estimated from data on the amounts of feed handled by feed suppliers registered at the Swedish Board of Agriculture. The nitrogen flows on products to consumers from animal husbandry were calculated on statistics on the Swedish meat production and nitrogen content in different types of products (different kinds of meat, milk, egg) and on data obtained from the company extracting energy from animals that are sent to destruction. The amount of N in animals not slaughtered for meat production or destructed by the company Konvex are not included in the calculations, and this flow, although assumed to be small, should be further investigated in the future.

The results reported here represent a step towards constructing a Swedish N budget covering all major flows for all 8 major parts defined by EPNB, of which here we report pool 3 – Agriculture. Work is in progress with respect to Pools 7 Atmosphere and 8 Hydrosphere. Future work should focus on the remaining 5 pools. This however does not mean that there is no room for further improvements in the Agriculture pool. The nitrogen content of feed to animal husbandry and aquaculture could potentially be further constrained and the amount of N in animals not slaughtered for meat production or destructed should be further investigated. Another interesting potential for future assessments is to look at how the national flows of N develop over time, for example by constructing an NNB for multiple years to reveal the current and potential future development of nitrogen flows.

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We thank Gunnel Wahlstedt at Statistics Sweden, for data and explanations on the reporting to Eurostat, Leo Virta at Konvex AB for figures on the amount of agricultural animals that are destructed, Kersti Andersson at the Swedish Board of Agriculture for figures on feed. We also thank Wilfried Winiwarter at IIASA for providing us with the latest updates on the methodology to calculate a national N budget. The work presented in this report has been financed by the Swedish EPA within the project "Deltagande i ICP M&M, JEG DM och TFRN" NV-02448-18.

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