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National Nutrient Balances in the Baltic Sea Region

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Summary

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The calculation of nutrient balances has been used as an environmental indicator for agriculture for many years. Particularly, nitrogen balances/surpluses have been established as one of the few generally accepted key indicators for the documentation and analysis of the sustainability of agriculture production.

Hence, nutrient balances at national level can be used for communicating changes of agricultural production and related impacts on the environment, showing trends in the effectiveness of nutrient use over time, identifying the factors affecting the nutrient surpluses or deficits and to compare individual countries. The latter one is particularly crucial because water sources and air are not restricted within national boundaries and thus, tackling problems of emissions into waters and air need a transnational approach.

However, different approaches of calculating nutrient balances can lead to different results due to differences in methods and data. This must be considered when comparing countries. Hence, one objective of the Manure Standards project was to calculate nutrient balances for the participating Baltic Sea Countries based on different methods, to compare them, identify the differences and based on that, to give recommendation which method should be used in all Baltic Sea countries. For this, three methods were selected: (1) gross nutrient balance according to OECD/Eurostat (Eurostat, 2013) (2) a nitrogen balance approach currently used in Germany – NBA (Bach et al., 2011; Häußermann https://www.bmel-statistik.de/fileadmin/daten/MBT-0060000-2019.pdf), and (3) the net anthropogenic nitrogen- and phosphorus inputs (NANI and NAPI) approach according to Hong et al. (2017).

Results reveal differences in the level of the nitrogen and phosphorus surpluses (or deficits) for each country depending on the method used. This highlights the importance of considering different material system boundaries when comparing nutrient balances across countries. Only results based on the same method should be compared. However, calculations also show that even the recalculation of different approaches to a comparable material system boundary can lead to different results due to differences in the data and coefficients used.

Currently, the gross nutrient balance according to OECD/Eurostat is the only comparable parameter for the nitrogen and phosphorus balances of BSR countries. However, as only OECD and EU Member States report respective data for the gross nitrogen balance (GNB) and gross phosphorus balance (GPB), not all BSR countries can be compared on this parameter (e.g. Russia is missing). As the majority of BSR countries

already use this approach, adopting it for all BRS countries should be the option with the lowest additional efforts to get a common method for calculating national nutrient balances in the BSR.

However, also the two other approaches used in this project have their justifications in the discussion about a common method for the calculation of national nutrient balances. The nitrogen balance approach currently used in Germany calculates not only a field balance, but also a stable balance (and a biogas balance), which in turn can be summed up to the total national nitrogen balance. Hence, this approach is more sophisticated compared to the approach of OECD/Eurostat and thus, offers the opportunity to analysis nutrient flows between the production sectors within the whole agricultural sector in more detail. However, the close exchange with the work package activity partners revealed some problems of data availability and reliability related to the additionally needed data of fodder production and feed imports. For the net anthropogenic nitrogen and phosphorus inputs approach (NANI and NAPI), data requirements are lower compared to the other ones, because country-specific coefficients can be taken from Hong et al. (2012; 2017) and much information from the Eurostat database can be used. However, compared to the other two approaches, data and coefficients used are often less detailed and thus, balance results could be less precise. Hence, this approach is very useful for calculating nutrient balances when data is rare or when aiming to compare many countries.

Overall, results identified livestock manure production as one of the major sources of nutrient inputs. Thus, improving the precision of manure use offers a high potential for getting to a more effective nutrient management strategy in the BSR and is a key issue to instantly reduce nutrient inflow into the Baltic Sea.

Keywords: Nutrient Balance, Nutrient Use Efficiency, Nitrogen, Phosphorus

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Contents

1. Introduction 6
2. Overview of balance approaches 8
3. Methodology and Data 10
   3.1. System boundaries of used nutrient balance calculation methods 10
   3.2. Database of used nutrient balance calculation methods 13
   3.3. Nutrient excretion values in the Baltic Sea Countries 15
4. Results 20
   4.1. Denmark 20
   4.2. Estonia 25
   4.3. Finland 29
   4.4. Germany 33
   4.5. Latvia 38
   4.6. Lithuania 42
   4.7. Poland 47
   4.8. Russia 52
   4.9. Sweden 55
5. Conclusion 59

References 65

1. Introduction

Calculation of nutrient balances is required from EU countries as part of estimating the total potential threat to the environment of nitrogen and phosphorous surplus or deficit in agricultural soils. According to Eurostat too small nutrient input may reduce soil fertility and increase erosion, while an excess may increase nutrient runoff to surface and groundwater. Nutrients are added to agricultural soils as animal manure and fertilizers while harvested crops, removed residues and runoff remove nutrients from the soil. Nitrogen and phosphorus balance surpluses are monitored for the purposes of the Water Framework Directive and nitrogen for the Nitrates Directive.

HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission) is the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area. All Baltic Sea coastal countries and the European Union are the Contracting Parties to HELCOM and work together towards joint actions to protect the Baltic Sea. HELCOM has a target to reduce nutrient inputs into the Baltic Sea by 41% for phosphorus and 13% for nitrogen. However, these targets have not been met yet and agricultural nutrient input remains high.

Animal manure is one of the nutrient sources in agricultural production. It is simultaneously a valuable source of nutrients for crop growth, but also a risk for emissions to air and waters. Thus, improved precision of manure use is a key to reduce nutrient runoff. Careful fertilization planning and well-balanced nutrient applications are a means to ensure minimization of emissions.

A common method for calculating national nutrient balances is important to compare the nutrient use efficiency of different countries, identifying the major sources for nutrient emission risks and exploring the potential for a more effective nutrient management strategy in the Baltic Sea Region (BSR). Nutrient balances can also be used for communicating aspects of agricultural production and related impacts on the environment, showing trends in the effectiveness of nutrient use over time, identifying the factors determining the nutrient surpluses or deficits and to compare countries. The latter one is particularly crucial because water sources and air are not restricted within national boundaries and thus, tackling problems of emissions into waters and air need a transnational approach.

Furthermore, on farm level, nutrient balances can show weaknesses in fertilization practices and hence, assist in optimizing fertilization management (internal use for the farm). The balances can also be used by farmers for external communication, e.g. evidence for environmentally friendly production towards public, water management and nature conservation authorities as well as agricultural policy (Baumgärtel, 2007).

Figure 1 shows the Gross Nitrogen Balance (GNB) per hectare of utilized agricultural area (UUA) according to the OECD/Eurostat method for the Baltic Sea Countries (Except for Russia) of the Manure Standards project between 2000 and 2015.[1] As can be seen, Denmark and Germany have the highest GNBs, but their nitrogen surpluses significantly decreased during the time considered, resulting in a surplus of approximately 80 kg N per hectare in 2015. All other countries have nitrogen surpluses below 60 kg N per hectare between 2000 and 2015.

[1] As Russia is not in the EU, it does not report the data for balance calculation and thus, Russia as a project partner is not included in the figure.

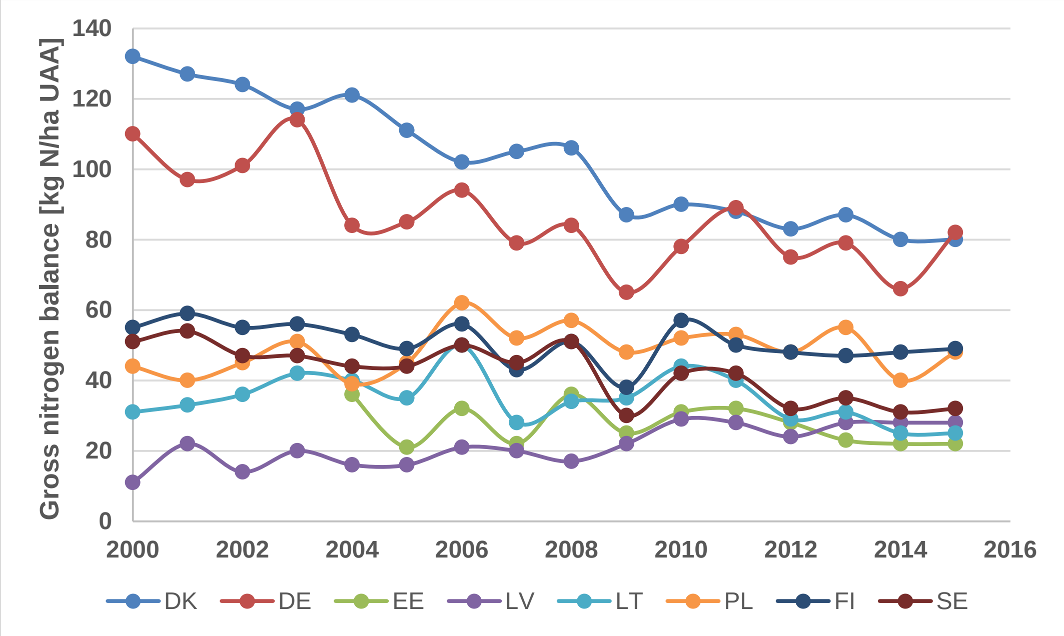

Figure 1: Gross Nitrogen Balances for selected Baltic Sea Countries for 2000-2015

Source: Eurostat (2019a)

However, the GNB according to OECD/Eurostat is just one possible approach to calculate nutrient balances. Different approaches can lead to different results due to differences in methods and data. This must be considered when comparing countries. In current BSR, a harmonized nutrient balance method does not exist leading to the problem that nutrient balance results might be incomparable at BSR level.

Hence, one objective of the Manure Standards project was to calculate nutrient balances for the participating Baltic Sea Countries based on different methods, to compare them, identify the differences and based on that, to give recommendation which method should be used in all Baltic Sea countries. For this, the following three methods were selected:

1) Gross Nutrient Balance according to OECD/Eurostat (consisting of the Gross Nitrogen Balance (GNB) and the Gross Phosphorus Balance (GPB))
2) Nitrogen Balance Approach currently used in Germany (NBA)
3) Net Anthropogenic Nitrogen and Phosphorus Inputs (NANI and NAPI) according to Hong et al. (2017)

2. Overview of balance approaches

A nutrient balance is a comparison of nutrient inputs and nutrient outputs for a well-defined reference level. The choice of the reference level is mainly determined by the objective of balancing (Baumgärtel et al., 2007).

Approaches of balance calculations can be differentiated depending on the material, spatial and temporal system boundary (Bach and Frede, 2005). The spatial system boundary refers to the aggregation level of the balance unit (national, regional, farm etc.) and the temporal system boundary refers to the considered period (year, time series etc.). Regarding the material system boundary, the following balances can be distinguished (cf. Bach und Frede, 2005; Bach et al. 2011):

- Total Balance (synonym: farm gate balance, national balance or sectoral balance)
- Field balance
- Stable balance

For these balances, the surplus (or deficit) of the chosen nutrient is calculated on a respective aggregation level and for a defined period. For reasons of comparability, the resulting surplus (or deficit) is generally related to the utilized agricultural area (UAA) (Baumgärtel et al., 2007). As the activity 2 of work package 4 aims to compare different approaches of national nutrient balance calculation for the Baltic Sea Countries, which can differ regarding their material system boundary, a short description of the total, field and stable nutrient balance is provided below for the national level. Exemplarily, this is done for nitrogen, but the theoretical considerations also apply to phosphorus.

The reference levels of the total balance, the field balance and the stable balance are the agricultural sector, i.e. the plant production and the livestock production of each Baltic Sea Country, respectively. The following applies (Bach et al., 2011):

Total nitrogen balance/surplus = Field nitrogen balance/surplus + Stable nitrogen balance/surplus

The total balance considers as inputs the nitrogen supply in form of mineral fertilizer, externally produced organic fertilizers and imported manure, externally produced and imported feed, seeds and planting materials, biological fixation as well as atmospheric deposition from non-agricultural sources. Animal and plant market products (non-agricultural use like human consumption, industrial raw materials or export) are considered as nitrogen outputs.

The field balance and stable balance are differentiations of the total balance. They specify nutrient flows within the agricultural sector and thus, they quantify the nitrogen flows between the two production sectors „plant production (field)“ and „animal production (stable)“. Nitrogen flows within the agricultural sector are related to domestic feed production, manure and atmospheric deposition from agricultural sources (mainly ammonia emissions from manure management and manure storage) (Bach et al., 2011). Table 1 shows the scheme of the nitrogen balances with related inputs and outputs for the three reference levels. As can be seen, each balance item of the internal flow is simultaneously either an input for the field balance and an output for the stable balance or vice versa. Hence, they cancel each other out when summing up both balances to the total balance.

Table 1: Inputs and Outputs of the total balance, field balance and stable balance for agriculture

Balance item	Total balance[a]	Field balance[a]	Stable balance[a]
Input			
Mineral fertilizer	+	+	
Other organic fertilizer	+	+	
Imported organic fertilizers	+	+	
Biological N Fixation	+	+	
Seeds and Planting materials	+	+	
Non-agricultural atmospheric Deposition	+	+	
Imported Feed	+		+
Output			
Plant based market products (non-agricultural use)	-	-	
Animal based market products (non-agricultural use)	-		-
Internal flows			
Agricultural atmospheric deposition		+	-
Manure		+	-
Plant based market products (agricultural use)		-	+
Animal based market products (agricultural use)			+/-[b]
Balance (N surplus)	∑	∑	∑

[a] '+': Supply, balance item is added; '-': Removal, balance item is subtracted. [b] products like meat and milk are generally outputs but can also be inputs as feed.

Source: Own presentation according to Bach et al. (2011)

Furthermore, nitrogen balances of different studies may differ in terms of considered nitrogen flows or balance items respectively, used databases containing the physical amounts and used coefficients for nitrogen contents of balance items (Bach and Frede, 2005). Hence, differences in nitrogen balances can be a result of different methodological approaches (reference level, considered balance items) and different information used for balance calculations. Both must be taken into account when comparing different methods for national nutrient balances.

3. Methodology and Data

As mentioned in chapter 2, it is very important to be aware of the system boundary and the used database when comparing the three used calculation methods for nutrient balancing. Both issues are dealt with in chapter 3.1 and chapter 3.2, respectively. As improvement of manure use is the overarching goal of the Manure Standards project, the database and calculation of nutrient inputs with manure are described in more detail in chapter 3.3.

3.1. System boundaries of used nutrient balance calculation methods

The Gross Nutrient Balance according to OECD/Eurostat is calculated as the balance between inputs and outputs of nutrients to the agricultural soil. Hence, this method has the material system boundary of a field balance. It consists of the GNB (see figure 1) and the GPB. The surplus of such gross field balances reflects the total amount of the considered nutrient leaving the system boundary, which can potentially harm all three environmental media (soil, water and air). In contrast, the surplus of a net field balance is reduced by gaseous losses (NH_3, N_2O and NO) in housing as well as during storage and application of manure. Hence, the net surplus of the field balance only quantifies the risk potential for soil and water. Accordingly, this differentiation plays only a role for nitrogen balances as for phosphorus gaseous emissions do not exist (or at least, are insignificant small).

The Nitrogen Balance Approach (NBA) currently used in Germany calculates the surpluses of all three balances (total balance, field balance and stable balance). In contrast to the GNB of OECD/Eurostat, the NBA calculates a net surplus for the field balance. For the calculation of the total balance and the stable balance, the quantity structure of the field balance according to OECD/Eurostat was expanded. Hence, the GNB and GPB according to OECD/Eurostat and the calculation of the NBA in Germany are based on the same quantity structure (Bach et al., 2011).

GNB and GPB according to OECD/Eurostat includes:

Inputs:

- Inorganic fertilizers
- Other organic fertilizers (excluding manure): Sewage sludge, urban compost, industrial waste products and other products which are used as fertilizers on agricultural soils
- Gross Input of Manure: sum of manure production by livestock minus manure withdrawals plus manure imports[2]
- Biological fixation of nitrogen by leguminous crops (e.g., pulses, clover, lucerne, soybean) and grass-legume mixtures (permanent grassland with a certain share of leguminous plants)
- Atmospheric deposition on agricultural soils: Total deposition of nitrogen from all sources
- Seeds and planting materials

Outputs:

- Removal of nutrients with the harvest of crops: cereals, pulses, root crops, industrial crops, vegetables, fruit, ornamental plants and other harvested crops

[2] Change in stocks should ideally be considered, but often fail due to lack of data availability.

- Removal of nutrients with the harvest of forage and grazing: green fodder (lucerne, green maize, other plants harvested green), temporary and permanent grassland
- Removal of crop residues from field: straw, head leaves and stems, other crop residuals

A detailed description of the balance calculation according to OECD/Eurostat can be found in the related Nutrient Budgets Handbook (Eurostat, 2013).

The NBA currently used in Germany additionally includes:

- gaseous nitrogen losses in housing, storage and application of manure (nitrogen flow between field balance and stable balance)
- atmospheric deposition differentiated to agricultural and non-agricultural sources (nitrogen flow between field balance and stable balance)
- feed from domestic production: plant-based feed from food processing (coarse meal, molasses etc.), animal-based feed from food processing (fish and bone meal, skimmed milk etc.) and harvested crops and fodder (share of outputs from GNB/GPB which is used as feed; this is considered as an input for the stable balance)
- imported feed (considered as input for total balance and stable balance)
- animal-based market products: meat, milk and eggs (output for total balance and stable balance)

A detailed description of the NBA currently used in Germany can be found in Bach et al. (2011) and Mielenz et al. (2018).

Respective nitrogen and phosphorus amounts are received by multiplying each position of the quantity structure by a corresponding coefficient (e.g. nutrient content of a product or nutrient excretion values of livestock). Afterwards, the surplus (or deficit) of the respective balance (total, field or stable) can be calculated by summing up all inputs and subtracting the sum of all outputs according to the scheme presented in Table 1.

The net anthropogenic nitrogen and phosphorus input approach (NANI and NAPI) according to Hong et al. (2012; 2017) calculates a total balance surplus (or deficit) and generally shows many similarities in the quantity structure with the two methods explained above. However, a few positions of the balance are calculated differently.

According to Hong et al. (2017) NANI can be calculated as the sum of oxidized nitrogen deposition, nitrogen mineral fertilizer application, agricultural nitrogen fixation and, nitrogen in net food and feed imports/exports. Oxidized nitrogen deposition is comparable to the amount of atmospheric deposition from non-agricultural sources as defined in the NBA in Germany. NAPI is calculated in a very similar way, but the position of atmospheric deposition and agricultural fixation is not considered (assumed to be very little or zero). However, NAPI considers the additional term of human non-food use of phosphorus (e.g., detergent). For the phosphorus balance calculations in this project, human non-food use of phosphorus is excluded as this position does not belong to the agricultural sector. Figure 2 exemplarily shows the general structure of NANI.

While atmospheric deposition, mineral fertilizers and agricultural fixation are positions, which can also be found in the other two approaches (NBA and GNB), the term “Net food & feed import/export” indicates a difference in the calculation. The position “Net food & feed imports/exports” is calculated as the sum of human and livestock nitrogen/phosphorus consumption (positive fluxes adding nutrients to the area of interest) minus the sum of livestock and crop nitrogen/phosphorus production (negative fluxes removing nutrients from the area of interest). That means, if the consumption of food and feed is greater than the domestic agricultural production, the deficit of nitrogen/phosphorus is assumed to be met by imported food and feed from outside the area of interest and consumed by the human and livestock. Hence, nutrients enter the area and thus, increase the NANI/NAPI. Accordingly, if domestic agricultural production exceeds demand, the surplus is assumed to be exported. Hence, nutrients leave the area and thus, decrease the NANI/NAPI (Hong et al., 2017).

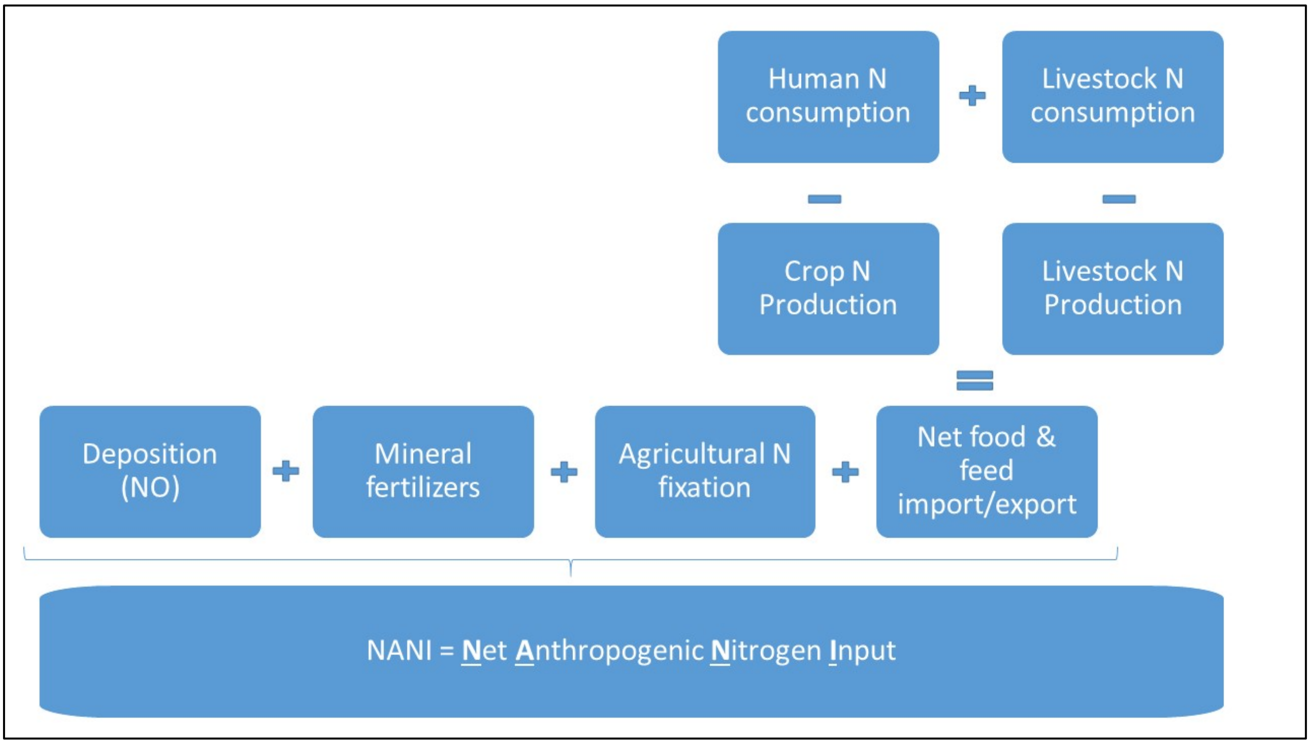

Figure 2: Overview of NANI and its components

Source: Own presentation according to Hong et al. (2012; 2017)

The nitrogen and phosphorus consumption of human and livestock is calculated based on population data and livestock numbers which are multiplied by the country-specific human intake rates and the intake coefficients for the corresponding livestock groups, respectively. Coefficients are given in the supplemental materials of Hong et al. (2017).

For the calculation of livestock nitrogen/phosphorus production, livestock nitrogen/phosphorus excretion must be calculated (product of livestock numbers and the excretion coefficients given in supplemental materials). The difference between nitrogen/phosphorus livestock consumption and excretion gives the nitrogen/phosphorus in livestock products. A processing loss of 10% is considered according to Hong et al. (2017). This is a difference to the NBA currently used in Germany, where nutrient output from livestock production is estimated by multiplying animal product data (meat, milk and eggs) with their nutrient contents.

The nitrogen/phosphorus in crop production is calculated as the product of the mass of harvested crops and their corresponding nutrient contents. This is like the two other approaches (NBA and GNB/GPB). However, NANI and NAPI distinguish between crop production for human and livestock to consider differences in processing losses for food and feed between human and livestock. Respective factors are given in Hong et al. (2012). Distribution of harvested crops to either humans or livestock (Table 7) was estimated based on the Food Balance Sheets calculations from FAO. We used mean values of the distributions of the crops in the major Baltic Sea countries. In some countries, large imports and/or exports may complicate assumptions and add uncertainties, as it is difficult to estimate the degree of utilization of imported crops. Estimated losses of N in seed, processing, other utilization, and export were assumed to be the losses during animal feed processing (Table 7), considering the lack of information on the human- or animal-specific losses.

Non-food use of phosphorus by human is calculated as a product of population data and a constant coefficient of 0.35 kg P/capita and year given in Hong et al. (2017). As NANI and NAPI reflect a total balance, manure is not an explicit term in the calculation (internal nutrient flow). However, Hong et al. (2017) provide the possibility to convert livestock nitrogen/phosphorus excretion to nitrogen/phosphorus manure. Three coefficients are used, which consider the fraction of livestock excretion collected in-house for manure production, the country-specific volatilization and leaching losses during the in-house manure production, and the fraction of manure (produced in-house) applied to agricultural land (see chapter 3.3 for more details). Detailed information of the NANI and NAPI approach can be found in Hong et al. (2012; 2017).

3.2. Database of used nutrient balance calculation methods

The database significantly affects the outcome of the balance calculation. Nutrient flows can only be correctly illustrated when using data with high accuracy (Baumgärtel, 2007). In general, all project partners sent the country-specific data set and coefficients needed for the NBA currently used in Germany to the activity leader of WP4.2 (JKI, Germany). Countries may have used different types of sources for respective data, but the most common sources are listed in Table 2. The calculation of NANI and NAPI is also based on these data, but coefficients are taken from Hong et al. (2012; 2017) (cf. chapter 3.1).

The database was collected on national level (except Russia, where Leningrad region is used) for the period 2000 to 2017. However, not all countries were able to provide data and coefficients for the whole period. Deviations from the general collection scheme are reported in the country-specific subchapters of chapter 4. In cases of missing data, data gaps were tried to be filled by using information available at a higher aggregation level or nearby years. This is exemplarily demonstrated for livestock excretion:

1) Numbers for the main category “Chicken” and one of the two subcategories (e.g. Layers) are available for the whole period, but there are some data gabs for the other subcategory (e.g. Broilers): Missing data are received by subtracting the number of layers from the total number of chickens
2) Numbers for the main category “Chicken” are available for the whole period, but there are some data gabs for the subcategories “Broilers” and “Layers”: Missing data are estimated by assuming the same proportions of the subcategories from other years with full information.
3) Numbers of the subcategories “Broilers” and “Layers” are available, but values for some years are missing where possible, linear interpolation were made to estimate the values in years with missing data. If extrapolation was required, the missing data were set to be the same as those in the closest available years.

In cases of missing coefficients, data gaps were filled by using corresponding German coefficients. If German coefficients were not available, data from other countries were used. Mostly, countries did not report nutrient contents for animal products (meat, milk and eggs) and hence, the calculation of nutrient output from animal products often relies on German coefficients. For some countries data about fodder (domestic production used as feed and feed imports) are estimated because of the uncertainty's available statistics.

Table 2: Sources of data used in this project for the calculation of national nutrient balances

Balance position	Region	Data source	Unit
Inorganic fertilizer	All regions (except RU)	Eurostat (aei_fm_usefert)	Tonnes of nutrient
	RU	National statistics	
Livestock numbers	DK, LV, PL, SE	Eurostat (apro_mt_ls)	Number of animals
	EE, FI, LT, RU	National statistics	
	DE	Emission inventory report (Haenel et al., 2018)	
Manure withdrawal	DE	Nutrient reports from the respective federal states	Tonnes of nutrient
	EE	National statistics	1000 tonnes
Other organic fertilizer	DK, EE, LT, LV	OECD.Stat	Tonnes of nutrient
	DE, FI, PL, SE	National statistics	1000 tonnes
Crops and Forage	DK, DE, EE, FI, LT, LV, PL, RU, SE	Eurostat (apro_cpnh1; apro_acs_a)/ national statistics	1000 tonnes
Seeds	DK, LT, LV	OECD.Stat	Tonnes of nutrient
	DE, EE, FI, PL, RU	National statistics	1000 tonnes
	SE	Eurostat (apro_acs_aa)	1000 hectares
Crop residues	DK, LT, LV	OECD.Stat	Tonnes of nutrient
	DE, EE, FI, PL, SE	National statistics	1000 tonnes
	RU	Calculated according to IPCC	
Biological fixation	DK, DE, EE, FI, LT, LV, PL, RU, SE	Eurostat (apro_cpnh1: apro_acs_a)/ national statistics/ FAO	1000 hectares
Atmospheric deposition	DK, DE, EE, FI, LT, LV, PL, RU	National statistics	1000 hectares (UAA)
	SE	Eurostat (agr_r_acs)	
Emissions	DK, EE, LT, LV, PL	CEIP + UNFCCC	Tonnes of emissions
	DE	Emission inventory report (Haenel et al., 2018)	
	RU	Calculated according to IPCC	Tonnes of Nitrogen
	FI, SE	National statistics + CEIP	
Fodder	DK, DE, EE, FI, LT, LV, PL, RU, SE	Eurostat (apro_cpnh1)/ national statistics	1000 tonnes
Animal products	DK, DE, EE, FI, LT, LV, PL, RU, SE	Eurostat (apro_mt_pann)/ national statistics	1000 tonnes
Biogas	DE	National statistics	1000 tonnes

3.3. Nutrient excretion values in the Baltic Sea Countries

In general, the nitrogen amount in manure is calculated by multiplying the number of animals in the country with the respective nitrogen excretion values (kg N/head and year) for the different animal categories. Nitrogen excretions values used for the NBA in Germany are shown in Table 3. For the calculation of NANI/NAPI, manure nitrogen and phosphorus production from animals and their application to crops are not directly needed because they are considered as internal fluxes in this total balance approach (cf. chapter

3.1). However, they estimated related nutrient fluxes in the study to better understand the potential magnitude of livestock nitrogen and phosphorus excretion that can meet the crop nutrient demands (Hong et al., 2017). Hence, respective nitrogen excretion values given in the related supplemental materials of this study can be used for this project and are given in Table 4.

For example, the nitrogen amount of manure production for dairy cows in Germany for the year 2015 is calculated as:

(1) NBA in Germany: 4.284.390 heads x 120.3 kg N/head and year = 515.412 tonnes of N
(2) NANI 4.284.390 heads x 101.0 kg N/head and year = 432.723 tonnes of N

When comparing the nitrogen excretion values given in Tables 3 and 4, most of the values used in the NBA in Germany (Table 3) are higher compared to the values used for NANI (Table 4). This is particularly true for important animal categories like dairy cows and fattening pigs. Hence, the calculated nitrogen manure production at ex animal level is likely to be higher in the NBA in Germany.

However, both methods calculate the net input of nitrogen manure production by considering nitrogen losses during housing as well as storage and application of manure. In the NBA in Germany, this is achieved by subtracting respective collected emissions (cf. Table 2) from the total amount of nitrogen excreted. In Hong et al. (2017), three coefficients are applied to convert livestock nitrogen excretion to manure application:

(1) Fraction of livestock excretion collected in-house for manure production, estimated from the livestock excretion allocated to non-pasturelands
(2) Fraction of livestock excretion (collected in-house) converted into manure, estimated from the country-specific volatilization and leaching losses during the in-house manure production
(3) Fraction of manure (produced in-house) applied to agricultural land of interest (set to one)

The first parameter reduces the amount of nitrogen excretion calculated in NANI by excluding the amount of nitrogen applied to grassland by grazing. This is different to the NBA in Germany, which includes respective nitrogen manure production and related emissions of grazing. However, this is only relevant for animal categories with significant time on pasture (e.g. dairy cows, heifers, and sheep). As keeping technologies and related time on pasture differ between BSR countries, the resulting differences between the amount of nitrogen excretion calculated in NANI and NBA vary between them. Unfortunately, respective coefficients were not directly available in Hong et al. (2017). For Germany, this parameter (fraction: 0.88) could be taken from Haenel et al. (2018). For all other countries, this parameter was set to 0.90. Hence, related differences between the amount of nitrogen excretion calculated in NANI and NBA should be small. Furthermore, nitrogen manure production is a nutrient flow within the agricultural sector and thus, is only relevant for the field balance and the stable balance. Accordingly, it has no impact on the calculated total balance results.

The second parameter further reduces the nitrogen excretion in NANI by gaseous losses during housing and storage. In contrast, the NBA in Germany also includes the emissions during manure application.

Table 5 compares the resulting net nitrogen manure production of both calculation methods for the years 2010 and 2015. Denmark, Germany and Poland show a higher net nitrogen manure production in NANI compared to the NBA in Germany. For all other countries, the higher nitrogen excretion values used in the NBA in Germany lead to higher net nitrogen manure production compared to NANI.

Table 3: Nitrogen excretion values (kg N/head/year) of the latest available year used in NBA for the Baltic Sea Countries[a] of this project

Country/Animal category[b]	EE	FI	DE	LV	LT	PL	RU	SE
Live bovine animals								
Bovine animals < 1 year		39.5	20.3			19.0		
Bovine animals < 1 year, for slaughter	15.5							30.0
Bovine animals < 1 year, not for slaughter								26.0
Male/female cattle for milk < 1 year	14/17			15.7				
Male/female cattle for meat < 1 year				18.5				
Bovine animals, 1-2 years				20.0		46.0		
Male bovine animals, 1-2 years		66.4	46.2					53.5
Heifers, 1-2 years		54.1	40.2					47.0
Male cattle for milk, 1-2 years / Heifers not for slaughter, 1-2 years	41.3/ 58.1			24.7				
Male cattle for meat, 1-2 years / Heifers for slaughter, 1-2 years				26.4				
Bovine animals, 2 years and over				61.9				
Male bovine animals, 2 years and over	41.3	66.4	84.0	93.9		65.0		57.0
Heifers, 2 years and over	58.1	54.1		49.4		53.0		47.0
Dairy cows	133	129	122	109	107	83.0	131	133
Non dairy cows	72.4	69.3	82.0	65.9	42.8		70.0	63.0
Live swine				10.9	11.8		20.9	
Pigs < 50 kg			3.65	5.1				
Piglets < 20 kg	0.7					2.60		1.20
Pigs 20 - < 50 kg	0.7	9.06				9.00		9.80
Fattening pigs ≥ 50 kg	3.3	17.4	14.3	14.0		15.0		13.4
Breeding boars	25.1	20.4	27.8	27.6		18.0		13.0
Breeding sows (covered/not covered)	25.1	30.7	28.5	27.6		20.0		27/17
Live sheep and goats								
Live sheep	16.9	9.97	10.0	15.3	10.6	9.50		14.0
Lambs		8.89	4.00					
Live goats	17.0	10.7	11.0	15.8	15.8	8.00		11.3
Total poultry							0.79	
Broilers	0.06		0.50	0.35	0.51	0.20		0.28
Broilers < 18 weeks		0.48						
Broilers > 18 weeks		0.99						
Layers	0.69		0.88	0.55	0.47	0.80		0.52
Layers < 18 weeks		0.39						
Layers > 18 weeks		0.59						
Other chickens	0.12	0.89	0.32					0.22
Other poultry	0.78				0.48			
Ducks			0.61	0.58		1.00		
Turkeys		1.65	2.28	1.64	2.09	1.60		0.69
Male			2.53					
Female			1.96					
Other poultry types					0.60			
Geese		0.89	0.55	1.12				
Other livestock								
Horses	50.0	59.36		44.0	51.1	55.0		
Foal < 1 year								
Young horses / light horses / ponies	50.0		33.4					33.0
Old horses / heavy horses			53.6					48.0
Fox		3.00		8.34	12.1			
Mink		1.31		8.34	4.59			
Rabbits				8.10	8.10			

[a] For Denmark, nitrogen excretion values were not available. For the nutrient balance calculations, German values were used.

[b] Countries partly use slightly different categories. For example, in Germany, bovine animals are categorized as calves, heifers, male beef cattle, mature males > 2 years, dairy cows and non-dairy cows.

Table 4: Nutrient excretion values (kg N or P/head/year) used in NANI/NAPI for the nine Baltic Sea Countries of this project

Category	Animal group	N/P	DK	EE	FI	DE	LV	LT	PL	RU	SE
cattle	bovine animals, less than 1 year	N	58.10	30.00	31.80	40.50	30.00	30.00	32.30	30.00	37.30
		P	9.68	5.00	5.30	6.75	5.00	5.00	5.38	5.00	6.22
	bovine animals, 1 year	N	58.10	30.00	31.80	40.50	30.00	30.00	32.30	30.00	37.30
		P	9.68	5.00	5.30	6.75	5.00	5.00	5.38	5.00	6.22
	male bovine animals, 2 years or over	N	54.90	42.00	40.00	59.00	42.00	42.00	42.00	42.00	58.00
		P	9.15	7.00	6.67	9.83	7.00	7.00	7.00	7.00	9.67
	heifers, 2 years or over	N	61.80	40.00	40.00	44.00	40.00	40.00	60.00	40.00	47.00
		P	10.30	6.67	6.67	7.33	6.67	6.67	10.00	6.67	7.83
	dairy cows	N	110.00	93.00	105.00	101.00	86.00	82.00	86.00	76.00	112.00
		P	18.33	15.50	17.50	16.83	14.33	13.67	14.33	12.67	18.67
	non dairy cows	N	73.30	60.00	55.00	84.00	60.00	60.00	60.00	60.00	63.00
		P	12.22	10.00	9.17	14.00	10.00	10.00	10.00	10.00	10.50
pigs	piglets, less than 20 kg	N	2.00	2.00	5.60	3.80	2.00	2.00	2.50	2.00	2.30
		P	0.44	0.44	1.24	0.84	0.44	0.44	0.56	0.44	0.51
	breeding sows	N	25.70	19.00	19.00	26.00	19.00	19.00	16.00	19.00	19.00
		P	5.71	4.22	4.22	5.78	4.22	4.22	3.56	4.22	4.22
	pigs, from 20 kg to less than 50 kg	N	6.20	9.00	9.00	11.00	9.00	9.00	9.00	9.00	9.00
		P	1.38	2.00	2.00	2.44	2.00	2.00	2.00	2.00	2.00
	fattening pigs, 50 kg or over	N	16.30	11.00	11.00	11.00	11.00	11.00	15.00	11.00	9.00
		P	3.62	2.44	2.44	2.44	2.44	2.44	3.33	2.44	2.00
	breeding boars	N	23.00	9.00	9.00	13.00	9.00	9.00	20.00	9.00	9.00
		P	5.11	2.00	2.00	2.89	2.00	2.00	4.44	2.00	2.00
sheep	sheep	N	10.00	10.00	17.00	10.00	10.00	10.00	11.00	10.00	12.00
		P	2.00	2.00	3.40	2.00	2.00	2.00	2.20	2.00	2.40
goats	goats	N	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
		P	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
poultry	broilers	N	2.67	1.56	1.73	1.56	1.56	1.56	2.02	1.56	1.68
		P	0.67	0.39	0.43	0.39	0.39	0.39	0.51	0.39	0.42
	hens	N	0.74	0.60	0.50	0.73	0.60	0.60	0.70	0.60	0.64
		P	0.19	0.15	0.13	0.18	0.15	0.15	0.18	0.15	0.16
	other poultry	N	1.32	1.32	1.32	0.95	1.32	1.32	1.10	1.32	1.32
		P	0.33	0.33	0.33	0.24	0.33	0.33	0.28	0.33	0.33

Source: Hong et al. (2017), Supplemental Materials Table S4

Table 5: Comparison of nitrogen manure production (tonnes of N) between NANI and NBA for 2010 and 2015 for the nine Baltic Sea Countries of the project

	2010			2015		
	NANI	*NBA in Germany*	*Dif. [%]*	*NANI*	*NBA in Germany*	*Dif. [%]*
Denmark	197.235	175.934	-11	190.293	178.801	-6
Estonia	12.713	13.952	10	12.807	14.724	15
Finland	51.569	77.632	51	54.311	76.526	41
Germany	851.049	758.297	-11	883.658	726.418	-18
Latvia	18.028	26.275	46	18.609	29.456	58
Lithuania	38.283	46.443	21	36.061	46.691	29
Poland	407.199	335.704	-18	387.407	292.258	-25
Russia	25.045	29.080	16	28.059	31.556	12
Sweden	80.749	87.195	8	81.026	87.197	8

Digression

For the number of animals, the number of animals counted at a certain reference date is typically used (e.g., in Eurostat, it is a specific day in December of the given year).

In Germany, the nitrogen excretion values calculated for the emission inventory report are used in the NBA to calculate the nitrogen amount in manure. The respective emission inventory model assumes (cf. Haenel et al., 2018):

The numbers of animals counted at a certain reference date represent the animal numbers at any other possible reference date in the same year and can be denoted by n_{op} (n = number, with op = occupied places). Accordingly, the number of animal places not occupied at the reference date is assumed to be constant throughout the year (n_{ep}, with ep = empty places). As animal place number n_{op} is constant for one year, it is equivalent to the annual mean of the animal population and therefore consistent with the definition of the „average annual population" (AAP). The related average animal place is, by definition, occupied on 365 days per year.

Therefore, the inventory uses activity data (e.g. the nitrogen excretions) and calculates emissions for 365 days per year. Empty times on animal places are, on average, represented by the entity n_{ep} as for these n_{ep} animal places the emissions are set to zero. By doing so, it is not necessary to take explicitly into account these n_{ep} animal places in the inventory.

As a further consequence, data about number of animals counted at a certain reference data (as used in the national nutrient balance) indirectly consider days where the barn is empty for cleaning and thus, this must not be considered in the nitrogen excretion values.

For example for Germany and Finland nitrogen excretion values are first performed for the entire lifetime of the respective animal that is less than one year. The results are then divided by the lifetime (in days) and multiplied by 365 in order to obtain annual data consistent with the AAP definition. However, it is possible that other countries calculate nitrogen excretion values in a different way.

4. Results

4.1. Denmark

Denmark does not participate in this work package activity. However, it was decided to include this country in the best possible way. For this, needed data were collected by the German Julius Kühn-Institute (JKI), who is the work package activity leader. Most data were available in the Eurostat database (Eurostat, 2019b). For missing data, the JKI got help from the Danish project partner Aarhus University and furthermore, from the Ministry of Environment and Food of Denmark. Data sources used for Denmark are shown in Table 2. For coefficients, German values are used. Related uncertainty should be small because agricultural production is more or less comparable between both countries (e.g., animal production and related nutrient excretion values, nutrient contents of animal products, crop production and related crop nutrient contents or nitrogen fixation rates). For the calculation of atmospheric deposition, needed coefficients were calculated based on EMEP data according to the Nutrient Budgets Handbook (Eurostat, 2013).

Based on these collected database and coefficients, Table 6 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for a few selected years between 2000 and 2016. It must be mentioned that the database is not fully complete up to 2005. Some missing values occur in the position’s livestock numbers, amount of crop production and fodder. As of 2006, data from national statistics were available and used to complement data gabs. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods are presented. The last column shows the average difference between the calculated values and those reported to OECD/Eurostat for the period 2000-2014.

As can be seen, there are no differences in nitrogen input by inorganic and organic fertilizer. For livestock manure production, values differ, but the magnitude varies dependent on the specific animal category. The main animal categories (cattle, pigs and poultry) have only small differences, especially when not considering the years 2000 and 2005 (incomplete data set). A certain share of the difference could also be due to the use of German coefficients. The other animal categories are less important for Denmark and thus, the total difference of livestock manure production is only 16% on average. Other nitrogen inputs also differ to a certain amount. Calculated atmospheric deposition and biological fixation are on average 53% and 10% lower compared to the reported values. Seeds and planting materials show the same level of nitrogen input. However, calculated total nutrient inputs are only 14% lower compared to reported total nitrogen inputs.

Nitrogen outputs consist of total harvested crops and forage as well as nitrogen removal by crop residues. Data for crop residues shows a perfect fit and nitrogen output by forage production only slightly differs between both methods. For harvested crops, calculated nitrogen output of cereals, dried pulses and beans and industrial crops is higher, while it is lower for the category of other crops. In total, this results in only a difference of 18% on average for the nitrogen output by harvested crops. Using German crop nutrient contents can be a reason for this difference. In total, nitrogen output calculated on collected data and German coefficients is only 8% higher on average compared to reported values.

Table 6: Nitrogen inputs and outputs (in tonnes of N) of Danish national balance calculation according to NBA and OECD/Eurostat for selected years

	2000			2005			2010			2014			2016	2000-2014
Indicator	**OECD**	**DK**	**Dif.**	**OECD**	**DK**	**Dif.**	**OECD**	**DK**	**Dif.**	**OECD**	**DK**	**Dif.**	**DK**	**Ø Dif.**
Nutrient inputs	632.339	558.596	-12%	586.773	482.654	-18%	551.443	469.323	-15%	537.557	460.316	-14%	471.420	-14%
Total Fertilisers	260.353	260.353	0%	210.920	210.920	0%	196.165	196.165	0%	193.867	193.696	0%	204.096	0%
Total Inorganic Fertilisers	251.581	251.581	0%	206.388	206.388	0%	190.072	190.072	0%	186.971	186.800	0%	197.200	0%
Total Organic Fertilisers[1]	8.772	8.772	0%	4.532	4.532	0%	6.093	6.093	0%	6.896	6.896	0%	6.896	0%
Net input of manure	274.244	233.028	-15%	281.928	216.098	-23%	265.447	229.224	-14%	261.903	224.762	-14%	223.558	-16%
Livestock Manure Production	274.244	233.028	-15%	281.928	216.098	-23%	265.447	229.224	-14%	261.903	224.762	-14%	223.558	-16%
Total Cattle	124.666	116.785	-6%	116.518	100.162	-14%	122.216	103.877	-15%	123.492	99.625	-19%	102.301	-14%
Total Pigs	114.566	112.213	-2%	124.382	112.576	-9%	102.882	109.859	7%	98.777	110.681	12%	106.813	2%
Total Sheep and Goats	6.559	1.160	-82%	7.231	840	-88%	6.655	1.596	-76%	5.580	1.628	-71%	1.615	-80%
Total Poultry	12.007	2.870	-76%	12.872	2.520	-80%	11.239	11.292	0%	9.908	10.710	8%	10.598	-34%
Total Other Livestock	16.446	0	-100%	20.925	0	-100%	22.455	2.599	-88%	24.146	2.118	-91%	2.231	-93%
Manure Imports	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0%
Other Nutrient Inputs	97.742	65.215	-33%	93.925	55.636	-41%	89.831	43.934	-51%	81.787	41.858	-49%	43.766	-43%
Atmospheric deposition	76.866	41.003	-47%	74.056	34.713	-53%	69.535	28.054	-60%	63.390	27.801	-56%	27.518	-53%
Biological Fixation	15.612	18.948	21%	14.442	15.496	7%	14.881	10.465	-30%	13.459	9.119	-32%	11.311	-10%
Seeds + Planting Materials	5.264	5.264	0%	5.427	5.427	0%	5.415	5.415	0%	4.938	4.938	0%	4.938	0%
Nutrient outputs	283.195	309.761	9%	284.832	302.412	6%	310.683	334.231	8%	325.863	353.340	8%	335.224	8%
Total Harvested Crops	172.424	197.918	15%	164.338	194.456	18%	160.705	193.956	21%	172.135	212.540	23%	194.442	18%
Total Cereals	144.715	170.838	18%	140.253	169.949	21%	131.548	163.193	24%	140.577	178.938	27%	162.990	21%
Total Dried Pulses and Beans	4.567	4.993	9%	1.748	1.912	9%	1.113	1.349	21%	1.093	1.276	17%	2.188	13%
Total Industrial Crops	9.285	9.772	5%	9.814	11.464	17%	16.540	19.341	17%	20.265	23.671	17%	16.930	15%
Other crops	13.857	12.315	-11%	12.523	11.132	-11%	11.504	10.073	-12%	10.200	8.655	-15%	12.334	-12%
Total Forage	106.115	107.187	1%	115.913	103.375	-11%	145.755	136.052	-7%	149.164	136.236	-9%	136.219	-4%
Total Harvested Fodder Crops	90.365	89.220	-1%	94.925	85.409	-10%	125.175	119.266	-5%	130.923	120.760	-8%	115.257	-3%
Total Pasture	15.750	17.966	14%	20.988	17.966	-14%	20.580	16.786	-18%	18.241	15.476	-15%	20.961	-11%
Removal by crop residues	4.656	4.656	0%	4.581	4.581	0%	4.223	4.223	0%	4.564	4.564	0%	4.564	0%

[1]excluding livestock manure

Table 7 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2000 and 2016. Oxidized nitrogen deposition and the amount of nitrogen mineral fertiliser are taken from the database used for calculating the net field balance in NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used in NBA, but coefficients are used from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. As the sum of human and livestock nitrogen consumption is higher as the sum of livestock and crop nitrogen production, the nitrogen in net food and feed imports is positive, meaning that the nitrogen deficit of production is assumed to be imported. Accordingly, nitrogen enters the area and increases the NANI.

Table 7: Calculated balance positions (in tonnes of N) for NANI in Denmark

Indicator	2000	2005	2010	2014	2016
Oxidized nitrogen deposition (NO_y)	18.025	15.309	11.641	11.093	10.980
Nitrogen Mineral Fertiliser	251.581	206.388	190.072	186.800	197.200
Biological Nitrogen Fixation	16.576	13.932	8.986	7.965	9.919
Human Nitrogen Consumption	34.814	35.335	36.171	36.795	37.347
Livestock Nitrogen Consumption	497.563	461.196	526.992	514.470	497.701
Livestock Nitrogen Production	200.069	191.027	218.806	214.959	205.217
Net Crop Nitrogen Production for Human	61.495	61.552	68.564	75.144	62.812
Net Crop Nitrogen Production for Livestock	168.186	164.891	182.495	192.828	194.344
Nitrogen in net food and feed imports	102.627	79.060	93.297	68.335	72.675

Table 8 compares the results of the nitrogen balances of the three used methods in this project for the period 2000 to 2016. The first three rows contain the balances calculated according to the NBA in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. As data for fodder are incomplete until 2005, results should only be interpreted as of 2006. All three balances show a nitrogen surplus with a decreasing trend over time. 70-80% of the total balance can be related to the stable balance. Accordingly, the stable balance shows a lower nitrogen use efficiency (NUE)[3] compared to the field balance.

To be able to compare the results of the NBA in Germany and the GNB according to OECD/Eurostat, emissions (row 4) must be added to the net field balance (row 2) calculated with NBA (cf. chapter 3.1). The relative difference between the resulting gross field balance of NBA (row 5) and the GNB (row 6) is shown in row 9. Nitrogen surpluses of GNB are on average 55% higher compared to the calculated nitrogen surpluses according to the NBA in Germany. The differences vary between 43 and 72% (years 2006-2016).

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA in Germany are shown in the rows 10 and 11 of Table 8. For the total balance, both methods show a good fit with an average difference of only 4.5% (2006-2016). With an average difference of 106% (2006-2016), the NBA in Germany and the NANI differ

[3] The nitrogen use efficiency (NUE) is defined as the sum of outputs divided by the sum of inputs.

strongly for the field balance. A certain share of the difference can be related to the higher calculated nitrogen manure production for Denmark in NANI (cf. Table 5).

Table 8: Comparison of Danish nitrogen balance results (kg N/ha) of the three used methods in this project

Balance[1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	10	4	>0	-9	139	135	143	136	127	118	119	113	110	115	104	117	123
Net Field Balance	70	64	60	50	53	44	44	43	41	25	31	32	27	35	22	31	33
Stable Balance	-60	-60	-60	-59	86	91	99	93	85	93	88	81	83	80	83	86	89
Emissions	32	31	30	30	30	28	27	27	27	26	26	26	25	25	25	25	25
Gross Field Balance	102	94	91	80	83	73	71	70	68	51	57	58	52	59	47	56	59
GNB	132	127	124	117	121	111	102	105	106	87	90	88	83	87	80	80	n.a.
NANI Total	147	139	132	124	128	116	126	125	122	115	115	114	107	114	103	111	111
NANI Field	102	94	88	80	83	74	78	76	75	64	65	66	59	65	55	63	63
Relative Difference Eurostat vs. gross field balance	30%	34%	37%	46%	46%	53%	44%	51%	55%	70%	58%	52%	59%	47%	72%	43%	n.a.
Relative Difference NANI vs. total balance	1389%	3227%	n.a.	-1474%	-8%	-14%	-12%	-8%	-4%	-3%	-3%	1%	-2%	-1%	-1%	-5%	-10%
Relative Difference NANI vs. field balance	46%	47%	46%	60%	56%	68%	78%	78%	82%	157%	112%	106%	121%	88%	151%	102%	89%
NUE_{tot}	91%	96%	100%	110%	43%	43%	41%	42%	45%	49%	46%	48%	49%	47%	51%	49%	46%
NUE_{field}	63%	64%	64%	69%	68%	72%	72%	73%	75%	85%	80%	80%	83%	78%	86%	81%	79%
NUE_{stable}	243%	242%	253%	249%	54%	51%	51%	52%	54%	53%	54%	56%	55%	56%	55%	55%	53%

[1]As data for fodder are incomplete until 2005, results should only be interpreted as of 2006. n.a.: not available

Table 9: Comparison of Danish phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	13	14	14	13	13	11	12	12	7	7	8	7	7	8	7	7	n.a.
NAPI	8	8	8	7	8	5	10	9	4	6	6	6	5	7	6	6	7

n.a.: not available

Table 9 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and field balance calculated with NAPI for the period 2000 to 2016. Both methods show comparable phosphorus surpluses between 2006 and 2016 with an average difference of 20%.

4.2. Estonia

Data and coefficients were provided by the Estonian work package activity partner "Estonian University of Life Sciences". Data sources used for Estonia are shown in Table 2. For animal products German values are used. Related uncertainty should be small because nutrient contents of animal products (e.g., meat, milk and eggs) should not strongly vary between countries. For atmospheric deposition, the coefficient was only available as a total nitrogen deposition per hectare. However, for the calculation of the total balance and stable balance, a differentiation between deposition from agricultural and non-agricultural sources is needed. Due to a lack of information, total nitrogen deposition was allocated equally between both sources. For NBA calculations

Based on these database and coefficients, Table 10 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for a few selected years between 2004 and 2016. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods are presented. The last column shows the average difference between the calculated values and those reported to OECD/Eurostat for the period 2004-2014.

As can be seen, there are no or only negligible differences in the positions of nitrogen input, especially in last period Higher difference is for cattle manure input because in NBA calculation dynamic N excretion coefficient related to milk productivity change was used. Average annual milk productivity (kg per dairy cow) has increased from 4544 kg in 2000 to 9176 kg in 2017. N excretion coefficient was differed from 97 to 133 kg N per head. Total nitrogen outputs differences by harvested crops and crop residues are also small. For total forage production, fodder production calculated according to the NBA in Germany is much higher compared to the reported values, while calculated nitrogen output by pasture is lower. However, the differences are a result of a different allocation of crop types to the subcategories and hence, total forage production only slightly differs between the calculated and reported values. In total, nitrogen output calculated is only 6% higher on average compared to reported values.

Table 11 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2004 and 2016. Oxidized nitrogen deposition and the amount of nitrogen mineral fertiliser are taken from the database used for calculating the net field balance in NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. Except for 2004, the sum of human and livestock nitrogen consumption is lower as the sum of livestock and crop nitrogen production. This results in a negative value for the nitrogen in net food and feed imports, meaning that the nitrogen surplus of production is assumed to be exported. Accordingly, nitrogen leaves the area and reduces the NANI.

Table 10: Nitrogen inputs and outputs (in tonnes of N) of Estonian national balance calculation according to NBA and OECD/Eurostat for selected years

	2004			2005			2010			2014			2016	2004-2014
Indicator	**OECD**	**EE**	**Dif.**	**OECD**	**EE**	**Dif.**	**OECD**	**EE**	**Dif.**	**OECD**	**EE**	**Dif.**	**EE**	**Ø Dif.**
Nutrient inputs	60.318	56.786	-6%	56.841	53.205	-6%	65.752	63.696	-3%	72.009	70.966	-1%	71.482	-1%
Total Fertilisers	24.837	24.837	0%	20.110	20.110	0%	28.721	28.721	0%	35.822	35.822	0%	36.390	0%
Total Inorganic Fertilisers	24.833	24.833	0%	20.083	20.083	0%	28.628	28.628	0%	35.806	35.806	0%	36.390	0%
Total Organic Fertilisers[1]	4	4	0%	27	27	2%	93	93	0%	16	16	3%	0	1%
Net input of manure	22.998	19.707	-14%	22.680	19.620	-13%	21.862	20.217	-8%	23.067	22.386	-3%	21.366	0%
Livestock Manure Production	23.384	20.093	-14%	23.212	20.152	-13%	22.052	20.417	-7%	23.463	22.782	-3%	21.366	0%
Total Cattle	20.351	17.058	-16%	20.057	16.995	-15%	18.324	16.675	-9%	19.536	18.852	-4%	17.860	0%
Total Pigs	1.391	1.391	0%	1.398	1.398	0%	1.442	1.442	0%	1.411	1.411	0%	1.064	0%
Total Sheep and Goats	705	707	0%	886	888	0%	1.398	1.402	0%	1.518	1.522	0%	1.536	0%
Total Poultry	682	682	0%	630	630	0%	548	548	0%	682	682	0%	621	0%
Total Other Livestock	255	255	0%	240	240	0%	340	340	0%	315	315	0%	285	0%
Total Manure Withdrawals	-386	-386	0%	-532	-532	0%	-190	-190	0%	-396	-396	0%	0	2%
Manure Imports														
Other Nutrient Inputs	12.483	12.629	1%	14.051	14.007	0%	15.169	14.948	-1%	13.120	13.153	0%	13.726	-3%
Atmospheric deposition	4.887	4.887	0%	5.034	5.034	0%	5.885	5.885	0%	6.441	6.441	0%	6.630	0%
Biological Fixation	7.462	7.606	2%	8.875	8.828	-1%	9.145	8.923	-2%	6.514	6.545	0%	7.096	-5%
Seeds + Planting Materials	134	136	1%	142	144	2%	139	140	1%	165	167	2%	0	1%
Nutrient outputs	31.398	33.539	7%	38.406	40.873	6%	36.511	39.098	7%	50.749	53.704	6%	45.890	6%
Total Harvested Crops	16.545	16.502	0%	20.708	20.650	0%	21.234	21.182	0%	35.531	35.733	1%	29.770	0%
Total Cereals	13.191	13.191	0%	16.559	16.559	0%	15.217	15.217	0%	27.561	27.561	0%	21.004	0%
Total Oil Crops														
Total Dried Pulses and Beans	131	133	1%	228	228	0%	487	502	3%	1.367	1.612	18%	4.595	-1%
Total Industrial Crops	2.473	2.470	0%	2.999	2.992	0%	4.724	4.716	0%	5.983	5.983	0%	3.690	0%
Other crops	750	709	-5%	921	872	-5%	807	747	-7%	620	577	-7%	481	-7%
Total Forage	14.264	16.448	15%	16.975	19.500	15%	14.670	17.310	18%	14.166	16.921	19%	16.120	16%
Total Harvested Fodder Crops	3.381	9.597	184%	4.753	11.760	147%	4.429	11.811	167%	2.995	11.069	270%	11.528	154%
Total Pasture	10.883	6.851	-37%	12.221	7.740	-37%	10.242	5.500	-46%	11.172	5.852	-48%	4.591	-39%
Removal by crop residues	589	589	0%	723	722	0%	606	606	0%	1.051	1.050	0%	0	0%

[1]excluding livestock manure

Table 11: Calculated balance positions (in tonnes of N) for NANI in Estonia

Indicator	2004	2005	2010	2014	2016
Oxidized nitrogen deposition (NO_y)	2.443	2.517	2.943	3.220	3.315
Nitrogen Mineral Fertiliser	24.833	20.083	28.628	35.806	36.390
Biological Nitrogen Fixation	11.891	13.329	12.866	11.145	15.870
Human Nitrogen Consumption	7.126	7.085	6.964	6.875	6.882
Livestock Nitrogen Consumption	31.338	30.625	30.703	32.343	28.619
Livestock Nitrogen Production	9.663	9.367	9.677	9.924	8.378
Net Crop Nitrogen Production for Human	4.607	5.761	7.357	11.464	8.530
Net Crop Nitrogen Production for Livestock	21.681	26.107	22.682	27.061	25.875
Nitrogen in net food and feed imports	2.514	-3.525	-2.050	-9.231	-7.283

Table 12 compares the results of the nitrogen balances of the three used methods in this project for the period 2004 to 2016. The first three rows contain the balances calculated according to NBA used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. All three balances show a small nitrogen surplus (except the stable balance in 2016 and field balance in 2015). Total balance has been in range from 2 to 36 kg N ha^{-1}. The nitrogen use efficiency (NUE) ranges between 66-101% for the field balance and 61-103% for the stable balance.

To be able to compare the results of NBA used in Germany and the GNB according to OECD/Eurostat, emissions (row 4) must be added to the net field balance (row 2) calculated with NBA (cf. chapter 3.1). The relative difference between the resulting gross field balance (row 5) and the GNB (row 6) is shown in row 9. Nitrogen surpluses reported to OECD/Eurostat are on average 3% higher compared to the calculated nitrogen surpluses according to the NBA used in Germany (not considering the year 2015, where high cereal production resulted in an unusual low net field balance and high difference).

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA used in Germany are shown in rows 10 and 11 of Table 12. For both balances, NANI calculates higher nitrogen surpluses resulting in an average difference of 43% and 13% for the total balance and the field balance, respectively.

Table 13 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and the field balance calculated with NAPI for the period 2004 to 2016. While the GPB shows a phosphorus deficit during the whole period, the field balance calculated with NAPI is mostly balanced (-1 to +3 kg P ha^{-1}).

Table 12: Comparison of Estonian nitrogen balance results (kg N/ha) of the three used methods in this project

Balance	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	34	23	29	23	36	26	32	29	24	23	20	2	18
Net Field Balance	22	8	20	10	24	14	19	20	15	13	11	-1	19
Stable Balance	12	15	9	13	12	12	13	9	9	10	9	3	-1
Emissions	12	11	11	11	12	11	11	11	12	11	12	12	11
Gross Field Balance	34	18	31	21	36	25	30	30	27	24	23	11	30
GNB	36	21	32	22	36	25	31	32	28	23	22	22	n.a.
NANI Total	53	37	45	38	51	41	45	45	42	42	42	34	48
NANI Field	36	22	31	25	38	27	32	32	30	28	29	22	37
Relative Difference Eurostat vs. gross field balance	6%	14%	3%	5%	0%	0%	3%	6%	4%	-4%	-5%	50%	n.a.
Relative Difference NANI vs. total balance	36%	38%	36%	39%	29%	37%	29%	36%	43%	45%	52%	94%	63%
Relative Difference NANI vs. field balance	6%	18%	0%	16%	5%	7%	6%	6%	10%	14%	21%	50%	19%
NUE_{tot}	44%	56%	47%	59%	47%	56%	46%	51%	60%	62%	68%	96%	66%
NUE_{field}	66%	86%	63%	83%	66%	76%	68%	68%	77%	79%	83%	101%	71%
NUE_{stable}	69%	61%	74%	64%	67%	67%	64%	70%	73%	73%	75%	90%	103%

n.a.: not available

Table 13: Comparison of Estonian phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	-5	-7	-2	-7	-5	-6	-6	-5	-6	-8	-7	-7	n.a.
NAPI	3	1	3	1	3	1	1	1	0	1	1	-1	1

n.a.: not available

4.3. Finland

Data and coefficients were provided by the Finnish work package activity partner “Luke”. Data sources used for Finland are shown in Table 2. For animal products, coefficients were not available and hence, German values are used. Related uncertainty should be small because nutrient contents of animal products (e.g., meat, milk and eggs) should not strongly vary between these countries. For atmospheric deposition, the coefficient was only available as a total nitrogen deposition per hectare. However, for the calculation of the total balance and stable balance, a differentiation between deposition from agricultural and non-agricultural sources is needed. For the allocation, factors were calculated based on EMEP data according to the Nutrient Budgets Handbook (Eurostat, 2013).

Based on these database and coefficients, Table 14 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for a few selected years between 2000 and 2016. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods is presented. The last column shows the average difference between the calculated values if NBA and those reported to OECD/Eurostat for the period 2000-2016.

As can be seen, there are no or only very small differences in all balance positions. The only exceptions are total organic fertilizer and removal by crop residues burned on field. For organic fertilizer, the average difference of 29% is a result of very high differences in the years 2015 and 2016 (until 2014, the difference is 0%). Nitrogen input by organic fertilizer reported to OECD/Eurostat is constant between 2012 and 2016 and hence, the latest values might be rather estimations based on previous years than recent data. Accordingly, this difference can be neglected. Differences of crop residues might be results of data or coefficient updates but can also be neglected as the related nitrogen output is comparatively low.

Table 15 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2000 and 2016. Oxidized nitrogen deposition and the amount nitrogen mineral fertiliser are taken from the database used for calculating the net field balance with NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. The nitrogen in net food and feed imports varies in sign. For 2005 and 2010, the negative value indicates that the sum of human and livestock nitrogen consumption is lower as the sum of livestock and crop nitrogen production, meaning that the nitrogen surplus of production is assumed to be exported. Accordingly, nitrogen leaves the area and reduces the NANI. For 2000, 2015 and 2016, the positive value indicates that the sum of human and livestock nitrogen consumption is higher as the sum of livestock and crop nitrogen production, meaning that the nitrogen deficit of production is assumed to be imported. Accordingly, nitrogen enters the area and increases the NANI.

Table 14: Nitrogen inputs and outputs (in tonnes of N) of Finnish national balance calculation according to NBA and OECD/Eurostat for selected years

	2000			2005			2010			2015			2016			2000-2016
Indicator	OECD	FI	Dif.	OECD	FI	Dif.	OECD	FI	Dif.	OECD	FI	Dif.	OECD	FI	Dif.	Ø Dif.
Nutrient inputs	283.523	283.363	0%	266.972	266.821	0%	277.496	277.284	0%	262.327	263.556	0%	257.955	259.401	1%	0%
Total Fertilisers	168.203	168.203	0%	150.119	150.119	0%	157.275	157.275	0%	144.138	145.670	1%	138.787	140.545	1%	0%
Total Inorganic Fertilisers	167.276	167.276	0%	149.562	149.562	0%	156.523	156.523	0%	143.479	143.479	0%	138.128	138.128	0%	0%
Total Organic Fertilisers[1]	927	927	0%	557	557	0%	752	752	0%	659	2.192	233%	659	2.418	267%	29%
Net input of manure	99.783	99.782	0%	102.228	102.228	0%	105.185	105.186	0%	103.622	103.579	0%	104.337	104.299	0%	0%
Livestock Manure Production	99.783	99.782	0%	102.228	102.228	0%	105.185	105.186	0%	103.622	103.579	0%	104.337	104.299	0%	0%
Total Cattle	67.420	67.420	0%	68.040	68.040	0%	70.279	70.279	0%	68.600	68.600	0%	68.034	68.034	0%	0%
Total Pigs	14.959	14.959	0%	15.989	15.989	0%	15.871	15.871	0%	14.374	14.374	0%	15.422	15.422	0%	0%
Total Sheep and Goats	970	970	0%	892	892	0%	1.240	1.240	0%	1.509	1.509	0%	1.525	1.525	0%	0%
Total Poultry	6.215	6.215	0%	5.796	5.796	0%	5.347	5.347	0%	7.125	7.082	-1%	7.358	7.320	-1%	0%
Total Other Livestock	10.219	10.219	0%	11.511	11.511	0%	12.448	12.448	0%	12.014	12.014	0%	11.998	11.998	0%	0%
Manure Imports	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0%
Other Nutrient Inputs	15.537	15.377	-1%	14.625	14.474	-1%	15.036	14.824	-1%	14.567	14.306	-2%	14.831	14.557	-2%	-1%
Atmospheric deposition	5.589	5.589	0%	4.976	4.976	0%	4.266	4.266	0%	3.865	3.865	0%	3.873	3.873	0%	0%
Biological Fixation	4.859	4.699	-3%	4.319	4.168	-3%	5.602	5.390	-4%	6.076	5.815	-4%	6.495	6.221	-4%	-4%
Seeds + Planting Materials	5.089	5.089	0%	5.330	5.330	0%	5.168	5.168	0%	4.626	4.626	0%	4.463	4.463	0%	0%
Nutrient outputs	161.686	160.994	0%	156.552	155.865	0%	146.493	149.904	2%	149.905	157.253	5%	150.201	155.868	4%	2%
Total Harvested Crops	82.306	82.306	0%	84.214	84.213	0%	66.064	66.064	0%	75.218	75.220	0%	73.744	73.744	0%	0%
Total Cereals	73.545	73.545	0%	73.924	73.924	0%	53.692	53.692	0%	66.866	66.866	0%	64.275	64.275	0%	0%
Total Dried Pulses and Beans	398	398	0%	275	275	0%	1.010	1.010	0%	1.771	1.771	0%	2.210	2.210	0%	0%
Total Industrial Crops	2.641	2.641	0%	4.220	4.220	0%	7.104	7.104	0%	3.262	3.262	0%	3.660	3.660	0%	0%
Other crops	5.722	5.722	0%	5.795	5.794	0%	4.258	4.259	0%	3.319	3.320	0%	3.599	3.599	0%	0%
Total Forage	78.891	78.198	-1%	71.908	71.190	-1%	80.139	83.506	4%	73.990	81.297	10%	75.769	81.399	7%	3%
Total Harvested Fodder Crops	65.054	65.054	0%	60.574	60.574	0%	70.003	73.191	5%	66.249	71.907	9%	68.122	73.657	8%	3%
Total Pasture	13.837	13.144	-5%	11.334	10.616	-6%	10.136	10.315	2%	7.741	9.390	21%	7.647	7.741	1%	4%
Removal by crop residues	303	303	0%	277	277	0%	200	200	0%	568	568	0%	564	564	0%	0%
Removal by crop residues (burned)	186	186	0%	153	184	20%	90	135	50%	129	167	30%	124	161	30%	29%

[1]excluding livestock manure

Table 15: Calculated balance positions (in tonnes of N) for NANI in Finland

Indicator	2000	2005	2010	2015	2016
Oxidized nitrogen deposition (NO_y)	3.756	3.274	2.583	2.385	2.391
Nitrogen Mineral Fertiliser	167.276	149.562	156.523	143.479	138.128
Biological Nitrogen Fixation	17.421	15.722	16.874	17.674	18.729
Human Nitrogen Consumption	32.144	32.578	33.306	34.028	34.126
Livestock Nitrogen Consumption	148.578	134.613	127.459	135.839	137.976
Livestock Nitrogen Production	50.404	46.300	43.583	47.343	48.836
Net Crop Nitrogen Production for Human	13.990	16.348	15.938	16.240	15.347
Net Crop Nitrogen Production for Livestock	115.782	107.131	101.772	103.261	105.092
Nitrogen in net food and feed imports	546	-2.587	-529	3.023	2.827

Table 16 compares the results of the nitrogen balances of the three used methods in this project for the period 2000 to 2016. The first three rows contain the balances calculated according to the NBA used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. All three balances show a nitrogen surplus. Until 2006, 60-70% of the total balance can be related to the field balance. Afterwards, this share decreases to 50-60% and hence, the share of the stable balance increases. Accordingly, the field balance shows a lower nitrogen use efficiency (NUE) compared to the stable balance, but since 2007 both partial balances have converged. However, it must be mentioned that data about fodder (domestic production used as feed and feed imports) are estimated based on unsatisfactory statistics and thus, include some uncertainties. These estimations can affect both partial balances and related shares of the total balance. In Finnish data collection, the available datasets of both domestic feed production and feed import should be developed in order to fit better for balance calculations.

To be able to compare the results of the NBA used in Germany and the GNB according to OECD/Eurostat, emissions (row 4) must be added to the net field balance (row 2) calculated by the NBA used in Germany (cf. chapter 3.1). The relative difference between the resulting gross field balance of NBA (row 5) and the GNB (row 6) is shown in row 9. Nitrogen surpluses reported to OECD/Eurostat are on average 3% lower compared to the calculated nitrogen surpluses according to NBA in Germany.

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA used in Germany are shown in rows of 10 and 11 of Table 16. For both balances, NANI shows a higher nitrogen surplus (on average 18% for total balance and 23% for field balance).

Table 17 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and field balance calculated with NAPI for the period 2000 to 2016. Both methods show comparable phosphorus surpluses during the whole period, whereby the GPB surpluses are a little bit higher.

Table 16: Comparison of Finnish nitrogen balance results (kg N/ha) of the three used methods in this project

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	67	70	65	65	65	60	61	59	65	54	72	63	60	57	64	67	66
Net Field Balance	43	46	43	44	40	37	44	30	37	24	44	37	34	33	34	35	34
Stable Balance	23	24	22	21	24	23	18	29	28	30	29	26	26	24	30	32	32
Emissions	15	15	15	15	15	15	15	15	15	14	15	15	15	15	15	15	15
Gross Field Balance	58	61	58	59	55	52	58	45	52	39	59	51	49	48	49	50	49
GNB	55	59	55	56	53	49	56	43	51	38	57	50	48	47	48	49	47
NANI Total	85	86	81	81	77	73	78	67	75	61	76	72	70	70	73	73	71
NANI Field	55	56	52	52	48	44	50	39	47	33	49	44	41	41	43	44	42
Relative Difference Eurostat vs. gross field balance	-6%	-3%	-5%	-5%	-4%	-5%	-4%	-5%	-2%	-2%	-3%	-3%	-1%	-1%	-2%	-2%	-3%
Relative Difference NANI vs. total balance	28%	22%	25%	25%	19%	23%	27%	13%	14%	14%	6%	14%	17%	23%	13%	10%	8%
Relative Difference NANI vs. field balance	26%	21%	20%	18%	20%	21%	14%	29%	25%	38%	12%	18%	22%	26%	27%	26%	24%
NUE_{tot}	42%	39%	42%	41%	40%	44%	42%	44%	43%	48%	36%	42%	42%	46%	43%	40%	40%
NUE_{field}	63%	59%	62%	60%	63%	65%	58%	71%	66%	75%	60%	65%	66%	68%	67%	66%	67%
NUE_{stable}	66%	65%	67%	68%	65%	66%	71%	60%	63%	60%	62%	64%	64%	66%	60%	59%	59%

Table 17: Comparison of Finnish phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	8	9	8	8	7	6	7	5	5	2	5	4	4	4	4	4	4
NAPI	6	7	6	6	5	5	5	3	3	1	3	2	2	2	2	2	2

4.4. Germany

In Germany, the Julius Kühn-Institute (JKI) calculates the national nutrient balances to fulfil the reporting obligation to the OECD and Eurostat. The surplus is further used as an indicator in the Federal Government's report on sustainable development (Bach et al., 2011). Every year, data and coefficients for the last year are complemented. Simultaneously, data and coefficients for the whole time period are checked and updated if needed (e.g., in cases where improved databases have been found). Data sources used for Germany are shown in Table 2. Last year, the methodology for the calculation of the total national nitrogen balance and its partial balances was updated. According to Mielenz et al. (2018), the most important updates are:

- Introduction of a new partial balance: The biogas balance is a new part of the balance calculation. It is only important for Germany because here, the nitrogen flow into biogas plants has reached a magnitude during the last years, which cannot be neglected anymore. Hence, the energy production by biogas plants was introduced as a third production sector in agriculture (besides plant and livestock production) and consequently, the total balance has been extended by the biogas component.
- New calculation of nitrogen excretion values: The calculation of nitrogen amount in manure was aligned to the emission inventory report (cf. Haenel et al. 2018) to achieve consistency.
- Consideration of manure imports: Manure imports, especially from the Netherlands, are quantitatively important. Since last year, a reliable data source has been available which makes it possible to consider such manure imports.
- Update of forage calculation: Data source changed from fodder balance to harvest statistics. By doing this, fodder production was allocated to the use as feed and for biogas production. Nitrogen coefficients for grassland and corn silage were updated.
- Update of atmospheric deposition data: Data were updated according to a new study.

Based to these updates, Table 18 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for a few selected years between 2000 and 2016. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods is presented. The last column shows the average difference between the calculated values of NBA and those reported to OECD/Eurostat for the period 2000-2015.

As can be seen, there is no differences in nitrogen input by inorganic fertilizer and organic fertilizer differs only by 7% on average. Reasons for this could be data or coefficient updates. For livestock manure production, values differ, but the magnitude varies dependent on the specific animal category. Most animal categories show only small differences, while nitrogen input by manure of sheep, goats and poultry differs to a larger amount. As mentioned above, nitrogen excretion values were updated and thus, related changes can explain the deviation from OECD/Eurostat data without respective updates. Furthermore, updated data also consider nitrogen input by manure imports, which is also not considered in the data reported to OECD/Eurostat so far. Other nitrogen inputs only differ in the level of atmospheric deposition. Again, updates are responsible for this deviation. However, calculated total nutrient inputs are only 1% lower on average compared to reported total nitrogen inputs.

Table 18: Nitrogen inputs and outputs (in tonnes of N) of German national balance calculation according to NBA and OECD/Eurostat for selected years

	2000			2005			2010			2015			2016	2000-2015
Indicator	**OECD**	**German**	**Dif.**	**OECD**	**German**	**Dif.**	**OECD**	**German**	**Dif.**	**OECD**	**German**	**Dif.**	**German**	**Ø Dif.**
Nutrient inputs	4.025.450	3.952.486	-2%	3.658.738	3.652.969	0%	3.420.764	3.398.448	-1%	3.716.493	3.701.612	0%	3.568.769	-1%
Total Fertilisers	2.061.285	2.063.924	0%	1.839.212	1.842.042	0%	1.625.138	1.632.680	0%	1.870.507	1.874.892	0%	1.762.674	0%
Total Inorganic Fertilisers	2.014.357	2.014.357	0%	1.778.400	1.778.400	0%	1.569.045	1.569.045	0%	1.822.791	1.822.791	0%	1.710.616	0%
Total Organic Fertilisers[1]	46.928	49.567	6%	60.812	63.642	5%	56.093	63.635	13%	47.716	52.101	9%	52.058	7%
Net input of manure	1.310.176	1.355.124	3%	1.254.203	1.308.014	4%	1.245.772	1.300.442	4%	1.282.322	1.349.600	5%	1.341.135	5%
Livestock Manure Production	1.310.176	1.347.610	3%	1.254.203	1.297.437	3%	1.245.772	1.286.399	3%	1.282.322	1.334.156	4%	1.326.103	4%
Total Cattle	887.337	940.467	6%	818.422	869.924	6%	824.412	858.984	4%	847.201	870.072	3%	863.689	5%
Total Pigs	276.500	276.660	0%	286.884	290.720	1%	280.664	286.068	2%	279.059	299.631	7%	298.650	3%
Total Sheep and Goats	52.543	22.984	-56%	51.134	22.563	-56%	40.648	19.088	-53%	30.995	15.998	-48%	15.905	-53%
Total Poultry	70.481	83.041	18%	73.243	89.396	22%	77.421	99.733	29%	102.463	126.579	24%	126.292	24%
Total Other Livestock	23.315	24.459	5%	24.520	24.833	1%	22.627	22.525	0%	22.604	21.876	-3%	21.566	0%
Manure Imports	0	7.514		0	10.578		0	14.043		0	15.444		15.033	
Other Nutrient Inputs	653.989	525.925	-20%	565.323	492.336	-13%	549.854	451.285	-18%	563.664	461.676	-18%	449.927	-19%
Atmospheric deposition	409.404	281.465	-31%	327.636	253.747	-23%	334.238	235.150	-30%	334.897	232.283	-31%	215.959	-31%
Biological Fixation	218.456	218.330	0%	212.652	213.552	0%	193.218	193.736	0%	205.794	206.448	0%	211.401	0%
Seeds + Planting Materials	26.129	26.129	0%	25.035	25.036	0%	22.398	22.398	0%	22.973	22.945	0%	22.567	0%
Nutrient outputs	2.149.126	2.270.042	6%	2.208.570	2.281.680	3%	2.125.261	2.063.135	-3%	2.350.145	2.068.021	-12%	2.079.093	-1%
Total Harvested Crops	1.089.681	1.090.874	0%	1.148.079	1.146.801	0%	1.120.415	1.108.384	-1%	1.194.830	1.175.096	-2%	1.102.440	-1%
Total Cereals	838.169	837.545	0%	858.592	853.351	-1%	828.840	812.619	-2%	921.472	894.016	-3%	825.926	-2%
Total Dried Pulses and Beans	17.266	17.266	0%	16.805	16.805	0%	9.607	9.607	0%	17.127	17.142	0%	18.989	0%
Total Industrial Crops	123.168	123.168	0%	172.552	172.552	0%	193.452	193.452	0%	169.940	169.940	0%	155.738	0%
Other crops	111.078	112.896	2%	100.130	104.092	4%	88.516	92.705	5%	86.291	93.997	9%	101.787	4%
Total Forage	1.020.367	1.140.090	12%	1.031.063	1.105.452	7%	994.578	944.483	-5%	1.145.219	883.007	-23%	967.387	0%
Harvested Fodder Crops	212.320	351.607	66%	227.822	361.943	59%	291.808	351.547	20%	354.921	313.118	-12%	342.668	34%
Pasture	808.047	788.483	-2%	803.241	743.509	-7%	702.770	592.936	-16%	790.298	569.888	-28%	624.719	-11%
Removal by crop residues	39.078	39.078	0%	29.428	29.428	0%	10.268	10.268	0%	10.096	9.918	-2%	9.266	0%

[1]excluding livestock manure

Nitrogen outputs consist of total harvested crops and forage as well as nitrogen removal by crop residues. Data for crop residues shows a perfect fit and nitrogen output by harvested crops only slightly differs between both methods. For forage production, calculated nitrogen output of harvested fodder crops shows higher deviations with changing signs (calculated output is partly higher and partly lower compared to reported values). The difference for pasture is much lower, but the resulting difference in calculated nitrogen output increases over time. Overall, forage production was also updated (see above), which can explain the differences. In total, nitrogen output calculated is only 1% lower on average compared to reported values.

Table 19 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2000 and 2016. Oxidized nitrogen deposition and the amount nitrogen mineral fertiliser are taken from the database used for calculating the net field balance in NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. The amount of nitrogen in net food and feed imports changes its sign during the considered period. For 2000 and 2010, the sum of human and livestock nitrogen consumption is higher as the sum of livestock and crop nitrogen production resulting in a positive value for the nitrogen in net food and feed imports. This means that the nitrogen deficit of production is assumed to be imported. Accordingly, nitrogen enters the area and increases the NANI. For 2005, 2015 and 2016, the consumption is lower as the production and thus, the nitrogen surplus of production is assumed to be exported. Hence, nitrogen leaves the area and reduces the NANI in these years.

Table 19: Calculated balance positions (in tonnes of N) for NANI in Germany

Indicator	2000	2005	2010	2015	2016
Oxidized nitrogen deposition (NO_y)	110.880	95.368	81.719	68.515	63.290
Nitrogen Mineral Fertiliser	2.014.357	1.778.400	1.569.045	1.822.791	1.710.616
Biological Nitrogen Fixation	175.673	170.714	152.424	164.440	171.359
Human Nitrogen Consumption	472.716	474.199	470.217	469.698	473.505
Livestock Nitrogen Consumption	2.186.806	2.108.690	2.105.964	2.228.747	2.204.417
Livestock Nitrogen Production	718.743	720.805	728.452	794.244	787.042
Net Crop Nitrogen Production for Human	390.234	435.302	441.421	455.267	423.753
Net Crop Nitrogen Production for Livestock	1.484.950	1.465.103	1.378.837	1.457.453	1.521.610
Nitrogen in net food and feed imports	65.596	-38.321	27.472	-8.519	-54.482

Table 20 compares the results of the nitrogen balances of the three used methods in this project for the period 2000 to 2016. The first four rows contain the balances calculated according to the NBA used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance, stable balance, and - for Germany as a special case - the biogas balance. All four balances show a nitrogen surplus. The biogas balance surplus increases over time reflecting the increasing role of this production sector in agriculture and the importance of considering related nitrogen flows. Depending on the year, 50-70% of the total balance can be related to the field balance and 30-50% to the stable balance. As of

2004, the share of the biogas balance surplus increases from 1% to 5-6%. The nitrogen use efficiency (NUE) is comparable for the field balance and stable balance. The biogas balance shows a higher NUE compared to the other two partial balances.

To be able to compare the results of the NBA in Germany and the GNB according to OECD/Eurostat, emissions (row 5) must be added to the net field balance (row 2) calculated by the NBA in Germany (cf. chapter 3.1). The relative difference between the resulting gross field balance of NBA (row 6) and the GNB (row 7) is shown in row 10. For the first years, the difference is slightly positive (nitrogen surpluses reported to OECD/Eurostat are slightly higher compared to the calculated nitrogen surpluses according to the NBA in Germany), but then, becomes negative and increases over time. This might reflect the changes related to the introduction of the biogas balance.

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA in Germany are shown in rows 11 and 12 of Table 20. For both balances, NANI shows a higher nitrogen surplus. However, with an average of 16% for the total balance and 14% for the net field balance, the difference is quite small.

Table 21 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and field balance calculated with NAPI for the period 2000 to 2016. Both methods show comparable results during the whole period, whereby the NAPI surpluses are a little bit higher.

Table 20: Comparison of German nitrogen balance results (kg N/ha) of the three used methods in this project

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	118	103	108	108	98	105	109	103	104	85	95	111	96	97	87	105	102
Net Field Balance	73	60	64	81	52	55	65	52	57	40	54	65	54	58	42	71	62
Stable Balance	45	43	44	27	46	49	41	48	44	42	37	41	37	33	39	29	34
Biogas Balance	0	0	0	0	1	1	2	3	3	3	4	4	5	5	5	5	5
Emissions	34	35	34	34	34	34	34	35	36	36	36	38	37	38	38	39	39
Gross Field Balance	107	95	98	114	86	89	100	87	93	76	89	103	91	96	80	109	101
GNB	110	97	101	114	84	85	94	79	84	65	78	89	75	79	66	82	n.a.
NANI Total	139	127	128	143	118	118	124	108	116	98	110	120	108	113	99	123	114
NANI Field	88	76	77	92	68	68	74	59	66	48	59	70	56	61	47	71	62
Relative Difference Eurostat vs. gross field balance	3%	2%	3%	0%	-2%	-4%	-6%	-9%	-10%	-15%	-13%	-13%	-18%	-18%	-18%	-25%	n.a.
Relative Difference NANI vs. total balance	18%	23%	19%	32%	20%	12%	14%	5%	12%	16%	16%	9%	12%	18%	15%	17%	12%
Relative Difference NANI vs. field balance	22%	26%	21%	14%	30%	23%	14%	14%	16%	20%	10%	7%	5%	5%	11%	1%	-1%
NUE_{tot}	42%	47%	43%	42%	49%	46%	44%	45%	47%	53%	49%	44%	48%	50%	54%	48%	47%
NUE_{field}	65%	70%	67%	58%	73%	71%	66%	72%	71%	78%	71%	68%	73%	71%	79%	67%	70%
NUE_{stable}	65%	66%	66%	75%	64%	63%	67%	64%	66%	67%	70%	68%	70%	73%	70%	76%	73%
NUE_{biogas}	77%	76%	76%	77%	77%	77%	78%	80%	81%	81%	82%	83%	84%	84%	84%	85%	85%

n.a.: not available

Table 21: Comparison of German phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	4	1	2	5	-1	0	1	0	-1	-5	-1	0	-3	-1	-4	-2	n.a.
NAPI	6	3	3	6	1	2	2	1	2	-2	1	2	0	2	0	2	2

n.a.: not available

4.5. Latvia

The Latvian work package activity partner “State Plant Protection Service” provided data and coefficients. Data sources used for Latvia are shown in Table 2. Nitrogen fixation rates were not available and hence, German coefficients are used. For crop production, missing country-specific coefficients were also replaced by German values. For the calculation of atmospheric deposition, needed coefficients were calculated based on EMEP data according to the Nutrient Budgets Handbook (Eurostat, 2013).

Based on these database and coefficients, Table 22 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for a few selected years between 2000 and 2016. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods is presented. The last column shows the average difference between the calculated values of NBA and those reported to OECD/Eurostat for the period 2000-2014.

As can be seen, there are no differences in nitrogen input by inorganic and organic fertilizer, despite one missing reported value for organic fertilizer in 2000. For livestock manure production, values differ, but the magnitude varies dependent on the specific animal category. The main animal categories (cattle, pigs and poultry) have only small differences. The other animal categories are less important for Latvia and thus, the total difference of livestock manure production is only 4% on average. Other nitrogen inputs also differ to a small amount. Calculated atmospheric deposition and biological fixation are on average 4% and 24% lower compared to the reported values. For biological fixation, the use of German coefficients could be the reason for the difference. Seeds and planting materials show the same level of nitrogen input. In total, calculated total nutrient inputs are only 7% lower compared to reported total nitrogen inputs.

Nitrogen outputs consist of total harvested crops and forage as well as nitrogen removal by crop residues. Data for crop residues shows a perfect fit. For crop production, values differ, but the magnitude varies dependent on the specific crop type. While cereal and forage production show only minor differences, dried pulses and beans as well as the category “other crops” differ to a larger amount and furthermore, showing varying signs of deviations. Extremely large differences are related to industrial crops. However, data and coefficients were checked in close exchange with the Latvian partner and concluded that the calculated values should be correct. Hence, this indicates a data problem of reported values. However, this crop category plays a quantitatively low role for the total nitrogen output with crop production.

Table 23 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2000 and 2016. Oxidized nitrogen deposition and the amount nitrogen mineral fertiliser are taken from the database used for calculating the net field balance in NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. As the sum of human and livestock nitrogen consumption is lower as the sum of livestock and crop nitrogen production, the nitrogen in net food and feed imports is negative, meaning that the nitrogen surplus of production is assumed to be exported. Accordingly, nitrogen leaves the area and reduces the NANI.

Table 22: Nitrogen inputs and outputs (in tonnes of N) of Latvian national balance calculation according to NBA and OECD/Eurostat for selected years

	2000			2005			2010			2014			2016	2000-2014
Indicator	**OECD**	**LV**	**Dif.**	**OECD**	**LV**	**Dif.**	**OECD**	**LV**	**Dif.**	**OECD**	**LV**	**Dif.**	**LV**	**Ø Dif.**
Nutrient inputs	95.781	89.384	-7%	116.395	107.220	-8%	141.237	127.817	-10%	159.152	153.066	-4%	185.044	-7%
Total Fertilisers	23.000	24.547	7%	41.227	41.227	0%	60.448	60.448	0%	73.962	73.962	0%	79.347	0%
Total Inorganic Fertilisers	23.000	23.000	0%	40.900	40.900	0%	59.500	59.500	0%	72.900	72.900	0%	78.285	0%
Total Organic Fertilisers[1]		1.547		327	327	0%	948	948	0%	1.062	1.062	0%	1.062	0%
Net input of manure	33.032	31.216	-5%	34.072	31.994	-6%	34.081	32.225	-5%	37.415	35.016	-6%	34.128	-4%
Livestock Manure Production	33.032	31.216	-5%	34.072	31.994	-6%	34.081	32.225	-5%	37.415	35.016	-6%	34.128	-4%
Total Cattle	23.984	23.606	-2%	23.990	23.016	-4%	23.956	22.646	-5%	26.585	25.106	-6%	24.093	-4%
Total Pigs	4.545	4.586	1%	4.673	4.805	3%	4.279	4.427	3%	3.784	3.926	4%	3.739	3%
Total Sheep and Goats	234	602	157%	735	872	19%	1.174	1.388	18%	1.362	1.610	18%	1.839	65%
Total Poultry	1.645	1.542	-6%	2.046	1.927	-6%	2.375	2.270	-4%	2.163	2.061	-5%	2.197	-6%
Total Other Livestock	2.624	880	-66%	2.628	1.373	-48%	2.297	1.494	-35%	3.521	2.313	-34%	2.259	-22%
Manure Imports	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0%
Other Nutrient Inputs	39.749	33.621	-15%	41.096	34.000	-17%	46.708	35.144	-25%	47.775	44.088	-8%	71.569	-17%
Atmospheric deposition	11.702	11.290	-4%	11.857	11.440	-4%	12.931	12.467	-4%	12.634	11.774	-7%	12.139	-4%
Biological Fixation	26.218	20.501	-22%	27.284	20.604	-24%	31.778	20.678	-35%	32.743	29.916	-9%	57.032	-24%
Seeds + Planting Materials	1.829	1.829	0%	1.955	1.955	0%	1.999	1.999	0%	2.398	2.398	0%	2.398	0%
Nutrient outputs	79.106	82.294	4%	88.450	96.112	9%	88.453	102.966	16%	107.056	113.114	6%	120.816	9%
Total Harvested Crops	21.285	19.944	-6%	28.596	31.563	10%	28.261	34.488	22%	43.528	50.989	17%	64.613	11%
Total Cereals	16.603	16.672	0%	23.998	24.127	1%	27.718	26.751	-3%	41.741	43.306	4%	51.006	0%
Total Dried Pulses and Beans	132	155	17%	108	138	28%	216	213	-1%	1.308	1.315	1%	4.933	27%
Total Industrial Crops	22	366	1.565%	47	4.666	9.828%	28	6.602	23.479%	22	5.703	25.822%	8.003	28.558%
Other crops	4.528	2.751	-39%	4.443	2.632	-41%	299	922	208%	457	665	46%	671	4%
Total Forage	57.199	61.728	8%	58.967	63.662	8%	59.227	67.513	14%	62.059	60.656	-2%	54.734	7%
Total Harvested Fodder Crops	26.672	29.959	12%	27.270	30.667	12%	27.717	32.075	16%	28.941	32.071	11%	27.403	13%
Total Pasture	30.527	31.769	4%	31.697	32.995	4%	31.510	35.438	12%	33.118	28.585	-14%	27.331	3%
Removal by crop residues	622	622	0%	887	887	0%	965	965	0%	1.469	1.469	0%	1.469	0%

[1] excluding livestock manure

Table 23: Calculated balance positions (in tonnes of N) for NANI in Latvia

Indicator	2000	2005	2010	2014	2016
Oxidized nitrogen deposition (NO_y)	6.587	6.583	6.637	6.300	6.495
Nitrogen Mineral Fertiliser	23.000	40.900	59.500	72.900	78.285
Biological Nitrogen Fixation	15.636	16.079	15.889	17.204	18.493
Human Nitrogen Consumption	12.714	12.022	11.264	10.707	10.523
Livestock Nitrogen Consumption	43.355	46.147	46.258	46.390	46.532
Livestock Nitrogen Production	12.375	13.538	13.595	12.916	13.081
Net Crop Nitrogen Production for Human	6.271	12.416	16.005	19.469	27.716
Net Crop Nitrogen Production for Livestock	54.504	58.594	60.050	61.178	60.637
Nitrogen in net food and feed imports	-17.080	-26.379	-32.127	-36.466	-44.380

Table 24 compares the results of the nitrogen balances of the three used methods in this project for the period 2000 to 2016. The first three rows contain the balances calculated according to the method used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. The total balance and stable balance show a nitrogen surplus over the whole period, while the field balance shows some years with nitrogen deficits. The overwhelming share of total balance can be related to the stable balance. Accordingly, the stable balance shows a lower nitrogen use efficiency (NUE) compared to the field balance. In years with field balance deficits, the stable balance surplus must be higher as the total balance, so that the sum of both partial balances results in the total balance surplus.

To be able to compare the results of the NBA in Germany and the GNB according to OECD/Eurostat, emissions (row 4) must be added to the net field balance (row 2) calculated by the NBA used in Germany (cf. chapter 3.1). The relative difference between the resulting gross field balance of NBA (row 5) and the GNB (row 6) is shown in row 9. Nitrogen surpluses reported to OECD/Eurostat and calculated nitrogen surpluses according to the NBA used in Germany differ in sign, especially by large amount for years with calculated nitrogen deficits. So far, these extremely high differences cannot be explained.

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA used in Germany are shown in the rows 10 and 11 of Table 24. While the total balance shows a comparatively good fit for both approaches (average difference is 20%), the results of the field balances substantially differ.

Table 25 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and field balance calculated with NAPI for the period 2000 to 2016. Both methods show comparable results between 2006 and 2016.

Table 24: Comparison of Latvian nitrogen balance results (kg N/ha) of the three used methods in this project

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	20	26	21	29	25	24	27	25	26	28	36	36	34	39	40	41	47
Net Field Balance	0	15	3	15	9	3	4	-1	-1	6	10	12	10	14	18	23	30
Stable Balance	20	11	18	14	16	21	22	26	26	22	25	24	24	25	22	17	17
Emissions	8	8	8	8	8	7	7	7	7	7	8	8	8	8	8	8	8
Gross Field Balance	8	23	11	23	17	10	11	6	6	13	18	20	18	22	26	31	38
GNB	11	22	14	20	16	16	21	20	17	22	29	28	24	28	28	28	n.a.
NANI Total	18	31	22	32	26	21	21	18	18	23	28	29	26	29	32	27	31
NANI Field	4	17	7	18	13	9	10	6	6	11	17	18	16	19	21	17	20
Relative Difference Eurostat vs. gross field balance	30%	-5%	25%	-11%	-4%	63%	84%	216%	163%	68%	57%	38%	35%	26%	7%	-11%	n.a.
Relative Difference NANI vs. total balance	-10%	20%	3%	12%	6%	-11%	-21%	-29%	-30%	-19%	-22%	-20%	-23%	-26%	-20%	-34%	-35%
Relative Difference NANI vs. field balance	735%	13%	119%	23%	50%	219%	126%	-985%	-1215%	79%	62%	46%	64%	33%	16%	-27%	-34%
NUE_{tot}	46%	40%	47%	39%	45%	49%	42%	49%	50%	48%	40%	40%	49%	43%	45%	51%	45%
NUE_{field}	99%	74%	94%	76%	85%	95%	92%	101%	101%	90%	84%	82%	86%	81%	77%	74%	67%
NUE_{stable}	55%	69%	57%	63%	60%	52%	50%	48%	47%	51%	47%	49%	49%	49%	52%	58%	57%

n.a.: not available

Table 25: Comparison of Latvian phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	0	1	1	1	1	2	2	2	1	1	2	2	1	3	2	2	n.a.
NAPI	-2	0	-1	0	0	0	0	-1	-1	-1	0	0	0	1	1	0	1

n.a.: not available

4.6. Lithuania

The Lithuanian work package activity partner “Lithuanian University of Health Sciences” provided data and coefficients. Data sources used for Lithuania are shown in Table 2. Country-specific coefficients could not be provided and thus, German values are used. The level of related uncertainty may vary dependent on the respective balance position. For example, while it should be small for the nitrogen output with animal products (nutrient contents of meat, milk and eggs should not strongly vary between countries), differences in nitrogen excretion values and related nitrogen manure production could be high. However, to be able to calculate the balances for Lithuania, using German coefficients is the best available approximation. For the calculation of atmospheric deposition, needed coefficients were calculated based on EMEP data according to the Nutrient Budgets Handbook (Eurostat, 2013).

Based on these database and German coefficients, Table 26 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with the NBA for a few selected years between 2000 and 2016. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods is presented. The last column shows the average difference between the calculated values and those reported to OECD/Eurostat for the period 2000-2014.

As can be seen, there are no or only minor differences in nitrogen input by inorganic and organic fertilizer. For livestock manure production, values differ, but the magnitude varies dependent on the specific animal category. The calculated nitrogen production by cattle and pig manure is lower compared to reported values. A reason could be the use of German nitrogen excretion values (see above), which are possibly lower due to a higher production efficiency. The category “Other livestock” shows higher calculated nitrogen manure production compared to reported values. These differences may occur due to data and/or coefficient uncertainties related to these less important animal types. Other nitrogen inputs also differ to a certain amount. Calculated atmospheric deposition and biological fixation differ on average by -7% and 4% compared to the reported values. However, it has to be mentioned that the yearly deviations are much higher as indicated by the presented years. Seeds and planting materials show the same level of nitrogen input. Overall, calculated total nutrient inputs are on average only 6% lower compared to reported total nitrogen inputs.

Nitrogen outputs consist of total harvested crops and forage as well as nitrogen removal by crop residues. Data for crop residues shows a perfect fit and nitrogen output by forage production only slightly differ between both methods. For harvested crops, values differ, but the magnitude varies dependent on the specific crop type. While cereal production shows lower calculated nitrogen output compared to reported values, the other crop categories show higher results. Using German crop nutrient contents can be a reason for these deviations. Extremely large differences are found for industrial crops. There was no possibility to check data and hence, it was decided to keep data as they are. However, compared to other crops, this crop category plays a quantitatively minor role for the total nitrogen output with crop production.

Table 26: Nitrogen inputs and outputs (in tonnes of N) of Lithuanian national balance calculation according to NBA and OECD/Eurostat for selected years

	2000			2005			2010			2014			2016	2000-2014
Indicator	**OECD**	**LT**	**Dif.**	**OECD**	**LT**	**Dif.**	**OECD**	**LT**	**Dif.**	**OECD**	**LT**	**Dif.**	**LT**	**Ø Dif.**
Nutrient inputs	209.546	180.033	-14%	237.997	210.010	-12%	258.622	256.316	-1%	265.892	290.538	9%	319.675	-6%
Total Fertilisers	98.361	98.361	0%	119.470	119.470	0%	143.536	143.566	0%	154.084	162.084	5%	160.321	0%
Total Inorganic Fertilisers	98.000	98.000	0%	119.000	119.000	0%	143.200	143.200	0%	154.000	162.000	5%	160.237	0%
Total Organic Fertilisers[1]	361	361	0%	470	470	0%	336	366	9%	84	84	0%	84	1%
Net input of manure	64.113	48.532	-24%	73.551	54.392	-26%	69.976	67.438	-4%	67.213	66.090	-2%	62.231	-19%
Livestock Manure Production	64.113	48.532	-24%	73.551	54.392	-26%	69.976	67.438	-4%	67.213	66.090	-2%	62.231	-19%
Total Cattle	46.453	30.500	-34%	50.956	31.241	-39%	50.206	47.400	-6%	49.441	47.644	-4%	43.816	-27%
Total Pigs	10.342	8.801	-15%	13.220	11.465	-13%	11.013	9.670	-12%	8.320	7.561	-9%	7.014	-12%
Total Sheep and Goats	484	486	0%	655	657	0%	869	872	0%	1.498	1.519	1%	1.949	1%
Total Poultry	2.454	2.543	4%	4.041	4.345	8%	4.260	4.636	9%	4.190	4.944	18%	5.181	10%
Total Other Livestock	4.380	6.203	42%	4.679	6.683	43%	3.628	4.860	34%	3.764	4.422	17%	4.272	39%
Manure Imports	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0%
Other Nutrient Inputs	47.072	33.140	-30%	44.976	36.148	-20%	45.110	45.312	0%	44.595	62.364	40%	97.122	-3%
Atmospheric deposition	30.934	23.031	-26%	24.302	23.326	-4%	26.318	25.260	-4%	24.618	23.869	-3%	23.883	-7%
Biological Fixation	11.982	5.953	-50%	16.922	9.070	-46%	14.949	16.209	8%	15.221	33.739	122%	68.483	4%
Seeds + Planting Materials	4.156	4.156	0%	3.752	3.752	0%	3.843	3.843	0%	4.756	4.756	0%	4.756	0%
Nutrient outputs	99.982	93.232	-7%	139.101	135.083	-3%	137.287	143.031	4%	192.611	193.317	0%	221.280	-3%
Total Harvested Crops	67.524	64.547	-4%	67.464	68.008	1%	67.223	74.439	11%	124.215	126.975	2%	141.066	3%
Total Cereals	55.903	47.007	-16%	59.556	50.223	-16%	60.909	51.628	-15%	111.510	92.813	-17%	98.506	-16%
Total Dried Pulses and Beans	3.139	2.654	-15%	2.533	3.127	23%	3.014	4.595	52%	8.639	11.832	37%	24.312	24%
Total Industrial Crops	136	3.208	2259%	91	7.070	7670%	7	14.056	200701%	11	17.138	155700%	13.922	100747%
Other crops	8.346	11.679	40%	5.284	7.588	44%	3.293	4.160	26%	4.055	5.192	28%	4.326	37%
Total Forage	31.047	27.274	-12%	70.220	65.658	-6%	68.723	67.251	-2%	65.958	63.904	-3%	77.776	-9%
Total Harvested Fodder Crops	11.449	10.766	-6%	35.105	37.260	6%	44.509	44.162	-1%	43.601	43.854	1%	32.696	-5%
Total Pasture	19.598	16.508	-16%	35.115	28.398	-19%	24.214	23.089	-5%	22.357	20.050	-10%	45.080	-11%
Removal by crop residues	1.411	1.411	0%	1.417	1.417	0%	1.341	1.341	0%	2.438	2.438	0%	2.438	0%

[1]excluding livestock manure

Table 27 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2000 and 2016. Oxidized nitrogen deposition and the amount nitrogen mineral fertiliser are taken from the database used for calculating the net field balance in NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. For 2000 and 2005, the sum of human and livestock nitrogen consumption is higher as the sum of livestock and crop nitrogen production resulting in a positive value for the nitrogen in net food and feed imports. This means that the nitrogen deficit of production is assumed to be imported. Accordingly, nitrogen enters the area and increases the NANI. For 2010, 2014 and 2016, the consumption is lower as the production and thus, the nitrogen surplus of production is assumed to be exported. Hence, nitrogen leaves the area and reduces the NANI in these years.

Table 27: Calculated balance positions (in tonnes of M) for NANI in Lithuania

Indicator	2000	2005	2010	2014	2016
Oxidized nitrogen deposition (NO_y)	11.782	11.425	11.469	10.930	10.936
Nitrogen Mineral Fertiliser	98.000	119.000	143.200	162.000	160.237
Biological Nitrogen Fixation	2.646	3.523	6.344	12.956	24.999
Human Nitrogen Consumption	23.132	21.962	20.473	19.383	18.959
Livestock Nitrogen Consumption	88.148	105.089	96.020	93.614	88.973
Livestock Nitrogen Production	25.894	33.734	30.449	29.582	27.988
Net Crop Nitrogen Production for Human	20.815	24.223	32.173	51.186	53.587
Net Crop Nitrogen Production for Livestock	43.805	65.799	60.197	79.815	107.582
Nitrogen in net food and feed imports	20.766	3.294	-6.325	-47.585	-81.225

Table 28 compares the results of the nitrogen balances of the three used methods in this project for the period 2000 to 2016. The first three rows contain the balances calculated according to the NBA used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. As data for fodder are incomplete until 2010, results of the total balance and stable balance should only be interpreted as of 2011. The field balances show a nitrogen surplus over the whole period. Between 2011 and 2014, the stable balance is negative. For the latest two years, the stable balance also shows a nitrogen surplus. For most of the years, the nitrogen use efficiency (NUE) of the stable balance is higher as for the field balance. In years with calculated nitrogen deficits in the stable balance, the NUE exceeds 100% because nitrogen output is higher as nitrogen input.

To be able to compare the results of the NBA used in Germany and the GNB according to OECD/Eurostat, emissions (row 4) must be added to the net field balance (row 2) calculated by the NBA used in Germany (cf. chapter 3.1). The relative difference between the resulting gross field balance of NBA (row 5) and the GNB (row 6) is shown in row 9. The yearly differences vary in sign, showing lower calculated NBA surpluses up to 35% and higher calculated NBA surpluses up to 27%.

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA used in Germany are shown in rows

10 and 11 of Table 28. Considering the period 2011-2016, the average difference amounts to 89% and 32% for the total balance and field balance, respectively.

Table 29 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and the field balance calculated with NAPI for the period 2000 to 2016. Both methods show comparable results for 2000-2003 and 2013-2015. Between 2004 and 2012, the GPB mostly shows higher phosphorus balances.

Table 28: Comparison of Lithuanian nitrogen balance results (kg N/ha) of the three used methods in this project

Balance[1]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	18	24	26	28	24	22	33	26	19	20	30	28	20	24	23	20	32
Net Field Balance	26	32	37	21	23	18	32	16	14	15	33	30	24	28	27	19	27
Stable Balance	-7	-8	-11	7	1	3	0	10	5	5	-3	-3	-4	-4	-4	1	5
Emissions	13	13	14	14	14	13	13	13	13	13	13	13	12	12	12	12	11
Gross Field Balance	39	45	50	35	37	31	45	30	27	28	46	43	36	39	38	31	39
GNB	31	33	36	42	40	35	50	28	34	35	44	40	29	31	25	25	n.a.
NANI Total	53	58	63	47	51	48	58	46	43	46	56	53	47	50	47	35	39
NANI Field	38	43	47	30	36	34	44	32	29	32	44	41	36	38	36	25	28
Relative Difference Eurostat vs. gross field balance	-20%	-26%	-29%	21%	8%	13%	10%	-5%	27%	25%	-5%	-6%	-20%	-21%	-35%	-19%	n.a.
Relative Difference NANI vs. total balance	186%	143%	145%	68%	116%	124%	76%	79%	123%	129%	84%	92%	135%	108%	103%	76%	21%
Relative Difference NANI vs. field balance	47%	34%	29%	46%	56%	87%	36%	101%	111%	118%	31%	36%	50%	38%	33%	28%	4%
NUE_{tot}	61%	52%	53%	52%	58%	57%	39%	55%	65%	67%	52%	57%	70%	65%	68%	75%	62%
NUE_{field}	59%	51%	48%	72%	68%	72%	54%	78%	81%	81%	61%	64%	73%	69%	71%	81%	73%
NUE_{stable}	165%	169%	218%	75%	98%	86%	98%	68%	80%	80%	112%	111%	117%	117%	116%	97%	84%

[1]As data for fodder are incomplete until 2010, results of the total balance and stable balance should only be interpreted as of 2011. n.a.: not available

Table 29: Comparison of Lithuanian phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	6	5	5	6	10	13	9	4	6	-1	6	5	7	2	1	1	n.a.
NAPI	6	6	6	4	5	4	6	3	1	2	3	3	2	3	2	0	2

n.a.: not available

4.7. Poland

The Polish work package activity partner "Institute of Soil Science and Plant Cultivation" provided data and coefficients. Data sources used for Poland are shown in Table 2. For animal products, coefficients were not available and hence, German values are used. Related uncertainty should be small because nutrient contents of animal products (e.g., meat, milk and eggs) should not strongly vary between countries. For Poland, data about biogas production is available. However, this production sector has not been included in the calculations so far for two reasons. First, related emissions (e.g., emission due to the storage and application of digestates) are missing, which have a high impact on the results. Second, related nutrient flow is comparatively low. However, the nutrient flow increased over time (significant values exist since 2011) and thus, it could be reasonable to introduce the biogas balance also for Poland in future.

Based on these database and coefficients, Table 30 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for a few selected years between 2000 and 2016. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods is presented. The last column shows the average difference between the calculated values and those reported to OECD/Eurostat for the period 2000-2014.

As can be seen, there are no differences in nitrogen input by inorganic fertilizer. Organic fertilizer showed some deviation in the beginning of the considered period, but the differences decreased and even became 0% in 2014. For livestock manure production, only the nitrogen input by manure of sheep and goats differs to a higher amount. However, this animal category plays a quantitative minor role compared to other animal types and hence, it does not strongly affect the total livestock manure production. Regarding other nitrogen inputs, only biological fixation shows a difference between both methods. Data were checked and some differences in the amount of nitrogen fixing area were found. As the impact on total nitrogen input is quite low, it was decided to keep data as they are.

Nitrogen outputs consist of total harvested crops and forage as well as nitrogen removal by crop residues. Data for crop residues shows a perfect fit and nitrogen output by most of the harvested crops and pasture differs only to a small amount. The category of other crops shows a lower calculated nitrogen output and calculated values for fodder crops are higher compared to reported values. These differences cannot be explained so far. In total, calculated nitrogen output is only 1% lower on average compared to reported values.

Table 30: Nitrogen inputs and outputs (in tonnes of N) of Polish national balance calculation according to NBA and OECD/Eurostat for selected years

	2000			2005			2010			2014			2016	2000-2014
Indicator	**OECD**	**PL**	**Dif.**	**OECD**	**PL**	**Dif.**	**OECD**	**PL**	**Dif.**	**OECD**	**PL**	**Dif.**	**PL**	**Ø Dif.**
Nutrient inputs	1.803.928	1.828.658	1%	1.743.737	1.738.269	0%	1.857.414	1.852.546	0%	1.860.955	1.846.192	-1%	1.848.277	0%
Total Fertilisers	863.614	863.095	0%	898.630	897.617	0%	1.031.820	1.032.249	0%	1.102.968	1.102.968	0%	1.047.716	0%
Total Inorganic Fertilisers	861.300	861.300	0%	895.294	895.294	0%	1.027.430	1.027.430	0%	1.098.455	1.098.455	0%	1.043.003	0%
Total Organic Fertilisers	2.314	1.795	-22%	3.336	2.323	-30%	4.390	4.819	10%	4.513	4.513	0%	4.713	-11%
Net input of manure	556.312	556.312	0%	578.949	564.530	-2%	559.549	537.325	-4%	514.462	484.839	-6%	489.849	-4%
Livestock Manure Production	556.312	556.312	0%	578.949	564.530	-2%	559.549	537.325	-4%	514.462	484.839	-6%	489.849	-4%
Total Cattle	314.253	314.253	0%	296.379	282.621	-5%	319.748	293.174	-8%	311.544	282.322	-9%	285.768	-7%
Total Pigs	167.321	167.321	0%	178.624	178.624	0%	153.691	153.691	0%	119.783	119.783	0%	117.334	0%
Total Sheep and Goats	4.847	4.847	0%	3.750	3.090	-18%	3.137	2.546	-19%	2.332	1.930	-17%	1.696	-14%
Total Poultry	39.642	39.642	0%	83.028	83.028	0%	73.386	73.386	0%	69.415	69.415	0%	74.849	0%
Total Other Livestock	30.250	30.250	0%	17.168	17.168	0%	9.587	14.528	52%	11.389	11.389	0%	10.202	9%
Manure Imports	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0%
Other Nutrient Inputs	384.001	409.250	7%	266.159	276.121	4%	266.045	282.972	6%	243.525	258.385	6%	310.712	5%
Atmospheric deposition	252.789	252.789	0%	185.268	185.268	0%	174.918	174.918	0%	157.005	157.005	0%	154.891	0%
Biological Fixation	86.017	111.266	29%	45.164	55.126	22%	57.030	73.957	30%	52.977	67.837	28%	120.368	26%
Seeds + Planting Materials	45.195	45.195	0%	35.728	35.728	0%	34.098	34.098	0%	33.544	33.544	0%	35.453	0%
Nutrient outputs	1.016.147	993.941	-2%	1.029.898	1.006.293	-2%	1.100.546	1107.900	1%	1287.667	1.297.729	1%	1.264.771	-1%
Total Harvested Crops	565.066	540.891	-4%	606.063	584.597	-4%	631.889	614.139	-3%	762.624	738.119	-3%	690.471	-3%
Total Cereals	392.565	392.565	0%	469.512	469.512	0%	476.712	476.712	0%	558.263	558.263	0%	522.736	0%
Total Dried Pulses and Beans	10.880	10.880	0%	10.120	10.120	0%	14.386	14.386	0%	19.921	19.921	0%	33.763	0%
Total Industrial Crops	34.019	35.028	3%	51.063	51.939	2%	78.212	79.379	1%	113.975	114.763	1%	78.235	2%
Other crops	127.602	102.418	-20%	75.368	53.027	-30%	62.578	43.662	-30%	70.466	45.173	-36%	55.736	-29%
Total Forage	380.420	382.389	1%	366.265	364.126	-1%	412.056	437.160	6%	454.968	489.535	8%	518.724	3%
Total Harvested Fodder Crops	81.398	98.935	22%	62.374	89.100	43%	89.741	126.799	41%	117.316	173.633	48%	202.853	41%
Total Pasture	299.022	283.454	-5%	303.891	275.026	-9%	322.315	310.361	-4%	337.652	315.902	-6%	315.871	-7%
Removal by crop residues	70.661	70.661	0%	57.570	57.570	0%	56.601	56.601	0%	70.075	70.075	0%	55.576	0%

[1]excluding livestock manure

Table 31 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2000 and 2016. Oxidized nitrogen deposition and the amount nitrogen mineral fertiliser are taken from the database used for calculating the net field balance in NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. For 2000, 2005 and 2010, the sum of human and livestock nitrogen consumption is higher as the sum of livestock and crop nitrogen production resulting in a positive value for the nitrogen in net food and feed imports. This means that the nitrogen deficit of production is assumed to be imported. Accordingly, nitrogen enters the area and increases the NANI. For 2014 and 2016, the consumption is lower as the production and thus, the nitrogen surplus of production is assumed to be exported. Hence, nitrogen leaves the area and reduces the NANI in these years.

Table 31: Calculated balance positions (in tonnes of N) for NANI in Poland

Indicator	2000	2005	2010	2014	2016
Oxidized nitrogen deposition (NO_y)	169.984	127.673	122.389	106.013	104.951
Nitrogen Mineral Fertiliser	861.300	895.294	1.027.430	1.098.455	1.043.003
Biological Nitrogen Fixation	92.120	59.043	66.422	63.652	89.784
Human Nitrogen Consumption	225.726	225.176	224.452	224.269	224.024
Livestock Nitrogen Consumption	958.694	1.292.295	1.212.172	1.081.237	1.135.880
Livestock Nitrogen Production	339.254	504.232	461.590	403.575	427.430
Net Crop Nitrogen Production for Human	188.545	211.282	239.794	297.702	259.280
Net Crop Nitrogen Production for Livestock	614.384	610.816	670.309	737.269	755.390
Nitrogen in net food and feed imports	42.237	191.141	64.932	-133.039	-82.196

Table 32 compares the results of the nitrogen balances of the three used methods in this project for the period 2000 to 2016. The first three rows contain the balances calculated according to the NBA used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. All three balances show a nitrogen surplus over the whole period with an increasing trend for the stable balance. Accordingly, the total balance also increases. More than half of the total balance can be related to the field balance, but for more recent years, this share seems to get below 50%. Accordingly, the nitrogen use efficiency (NUE) of the field balance has been improved.

To be able to compare the results of the NBA used in Germany and the GNB according to OECD/Eurostat, emissions (row 4) have to be added to the net field balance (row 2) calculated by the NBA used in Germany (cf. chapter 3.1). The relative difference between the resulting gross field balance of NBA (row 5) and the GNB (row 6) is shown in row 9. Nitrogen surpluses reported to OECD/Eurostat are on average 9% lower compared to the calculated nitrogen surpluses according to the NBA used in Germany. The differences vary between 7 and 13% (years 2006-2016).

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the method used in Germany are shown in rows 10 and 11 of Table 32. NANI estimates higher nitrogen surpluses for both balances compared to the field balance of NBA, leading to an average difference of 26% and 45% for the total balance and the field balance, respectively.

Table 33 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and the field balance calculated with NAPI for the period 2000 to 2016. The field balance calculated with NAPI shows higher phosphorus surpluses compared to GPB.

Table 32: Comparison of Polish nitrogen balance results of the three used methods in this project

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	51	53	50	51	54	56	64	69	74	72	75	78	79	86	77	73	75
Net Field Balance	34	28	32	38	28	32	48	37	43	34	37	38	33	40	25	34	28
Stable Balance	17	25	19	13	26	24	16	32	31	38	38	40	46	46	52	39	47
Emissions	17	17	18	18	17	18	19	20	19	18	19	19	19	19	19	18	19
Gross Field Balance	51	45	50	56	45	50	67	57	62	52	56	57	52	59	44	52	46
GNB	44	40	45	51	39	45	62	52	57	48	52	53	48	55	40	48	n.a.
NANI Total	65	60	81	86	76	80	94	87	92	82	88	91	84	92	79	86	81
NANI Field	42	37	48	52	43	47	61	53	59	50	53	55	51	58	45	51	46
Relative Difference Eurostat vs. gross field balance	-13%	-11%	-9%	-8%	-13%	-10%	-8%	-9%	-8%	-8%	-8%	-7%	-8%	-8%	-9%	-8%	n.a.
Relative Difference NANI vs. total balance	29%	14%	60%	71%	41%	42%	46%	26%	23%	14%	18%	16%	6%	7%	2%	18%	8%
Relative Difference NANI vs. field balance	24%	33%	52%	37%	57%	45%	27%	43%	36%	48%	41%	45%	52%	45%	81%	50%	67%
NUE_{tot}	44%	45%	47%	47%	49%	47%	41%	44%	42%	44%	44%	42%	43%	42%	47%	47%	48%
NUE_{field}	62%	69%	65%	59%	71%	66%	53%	66%	62%	69%	67%	67%	71%	67%	78%	70%	76%
NUE_{stable}	66%	56%	66%	75%	59%	62%	71%	56%	56%	50%	53%	50%	47%	47%	44%	52%	48%

n.a.: not available

Table 33: Comparison of Polish phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	4	3	5	6	3	5	10	7	8	4	5	6	3	3	0	2	n.a.
NAPI	5	4	9	9	7	8	12	10	11	8	8	10	8	8	6	7	6

n.a.: not available

4.8. Russia

The Russian work package activity partner "Institute for Engineering and Environmental Problems in Agricultural Production" provided data and coefficients. The Russian partners decided to collect data for Leningrad region and not for the whole country due to better data availability. Data sources used for Leningrad region are shown in Table 2. For animal products, coefficients were not available and hence, German values are used. Related uncertainty should be small because nutrient contents of animal products (e.g., meat, milk and eggs) should not strongly vary between countries. For atmospheric deposition, the coefficient was only available as a total nitrogen deposition per hectare. However, for the calculation of the total balance and stable balance, a differentiation between deposition from agricultural and non-agricultural sources is needed. Total nitrogen deposition was allocated based on EMEP data according to the Nutrient Budgets Handbook (Eurostat, 2013).

Based on these collected database and coefficients, Table 34 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for the period 2012-2016. For previous years, data were not fully available. As Russia does not report nitrogen balance calculation results to OECD/Eurostat, a comparison could not be prepared.

Table 34: Nitrogen inputs and outputs (in tonnes of N) for balance calculation of Leningrad region according to NBA in the period 2012-2016

			Leningrad region		
Indicator	**2012**	**2013**	**2014**	**2015**	**2016**
Nutrient inputs	47.815	51.862	51.462	51.563	50.467
Total Fertilisers	1.491	5.450	5.525	5.233	4.844
Total Inorganic Fertilisers	1.491	5.450	5.525	5.233	4.844
Total Organic Fertilisers[1]	0	0	0	0	0
Net input of manure	43.726	43.887	43.492	43.848	43.019
Livestock Manure Production	43.726	43.887	43.492	43.848	43.019
Total Cattle	17.464	17.081	17.133	17.476	17.741
Total Pigs	4.126	3.990	3.975	4.113	3.902
Total Sheep and Goats	288	293	312	412	431
Total Poultry	21.847	22.523	22.072	21.847	20.946
Total Other Livestock	0	0	0	0	0
Manure Imports	0	0	0	0	0
Other Nutrient Inputs	2.598	2.525	2.445	2.482	2.604
Atmospheric deposition	1.189	1.157	1.134	1.150	1.202
Biological Fixation	877	856	820	816	851
Seeds + Planting Materials	532	512	491	516	551
Nutrient outputs	11.885	12.122	13.076	13.012	11.374
Total Harvested Crops	3.913	3.952	4.320	4.788	3.534
Total Cereals	2.002	2.172	2.548	2.916	2.348
Total Dried Pulses and Beans	0	0	0	0	0
Total Industrial Crops	0	0	0	0	0
Other crops	1.911	1.780	1.772	1.872	1.186
Total Forage	7.841	8.042	8.640	8.108	7.717
Total Harvested Fodder Crops	1.193	932	1.306	1.430	1.170
Total Pasture	6.648	7.110	7.333	6.678	6.546
Removal by crop residues[2]	131	128	116	116	123

[1]excluding livestock manure

[2]It has to be mentioned that the values presented here do not correctly reflect the nitrogen removal by crop residues removed from field. The values reflect the total amount of nitrogen in crop residues. Hence, the correct values must be smaller as not all crop residues are removed from field. As no information about the share of crop residues removed from field is available and the related nitrogen output plays a quantitatively small role compared to other nitrogen outputs, it was decided to use these data for crop residues.

Table 35 shows the calculated balance positions for the third balance approach used in this project between 2012 and 2016. Oxidized nitrogen deposition and the amount nitrogen mineral fertiliser are taken from the database used for calculating the net field balance with NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data for Leningrad region and country-specific intake rates from Hong et al. (2017) are used. As the sum of human and livestock nitrogen consumption is higher as the sum of livestock and crop nitrogen production, the nitrogen in net food and feed imports is positive, meaning that the nitrogen deficit of production is assumed to be imported. Accordingly, nitrogen enters the area and increases the NANI.

Table 35: Calculated balance positions for the Net Anthropogenic Nitrogen Input approach in Leningrad region

Indicator	2012	2013	2014	2015	2016
Oxidized nitrogen deposition (NO_y)	638	608	596	604	631
Nitrogen Mineral Fertiliser	1.491	5.450	5.525	5.233	4.844
Biological Nitrogen Fixation	4.387	4.281	4.099	4.081	4.253
Human Nitrogen Consumption	9.460	9.460	9.460	9.460	9.460
Livestock Nitrogen Consumption	62.290	63.278	62.399	62.446	60.611
Livestock Nitrogen Production	16.456	16.759	16.494	16.458	15.870
Net Crop Nitrogen Production for Human	1.003	1.027	1.134	1.281	958
Net Crop Nitrogen Production for Livestock	7.368	7.831	8.180	7.777	7.248
Nitrogen in net food and feed imports	46.923	47.121	46.051	46.390	45.995

Table 36 compares the results of the nitrogen balances calculated with the NBA used in Germany and NANI for the period 2012 to 2016. The first three rows contain the balances calculated according to the NBA used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. The field balance shows a nitrogen surplus with a comparatively low nitrogen use efficiency (NUE) of 32% on average, while the stable balance has a nitrogen deficit. Accordingly, the NUE of the stable balance exceeds 100% because nitrogen output is higher as nitrogen input. However, it must be mentioned that the calculation of manure production and feed import, which strongly affects the stable balance, is subject to uncertainty. Hence, the negative result of the stable balance should be interpreted with caution.

The gross nitrogen field balance according to NBA is also presented (adding emissions in row 4 to the net field balance in row 2). However, as nutrient balance results are not reported to OECD/ Eurostat, a comparison of both methods is not possible.

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA used in Germany are shown in rows 10 and 11 of Table 36. While the average difference between both methods for the total balance is very high (157%), the nitrogen surplus of the field balance calculated with both approaches is on a similar level with an average difference of only 11%.

As Russia does not report phosphorus balance calculation results to OECD/Eurostat and for NAPI the amount of phosphorus applied by mineral fertilizer is not available, both phosphorus balances cannot be calculated.

Table 36: Comparison of Leningrad region nitrogen balance results (kg N/ha) of the three used methods in this project

Balance	2012	2013	2014	2015	2016
Total Balance	77	104	100	92	96
Net Field Balance	99	118	115	114	113
Stable Balance	-22	-14	-16	-22	-17
Emissions	52	54	54	54	50
Gross Field Balance	151	172	170	168	163
Gross Field Balance Eurostat	n.a.	n.a.	n.a.	n.a.	n.a.
NANI Total	225	248	248	245	232
NANI Field	112	131	130	128	122
Relative Difference Eurostat vs. gross field balance	n.a.	n.a.	n.a.	n.a.	n.a.
Relative Difference NANI vs. total balance	192%	139%	149%	166%	141%
Relative Difference NANI vs. field balance	13%	11%	13%	12%	8%
NUE_{tot}	48%	42%	45%	47%	43%
NUE_{field}	33%	31%	33%	33%	30%
NUE_{stable}	113%	108%	108%	112%	110%

n.a.: not available

4.9. Sweden

The Swedish work package activity partner “Swedish Board of Agriculture” provided data and coefficients. Data sources used for Sweden are shown in Table 2. For atmospheric deposition, the coefficient was only available as a total nitrogen deposition per hectare. However, for the calculation of the total balance and stable balance, a differentiation between deposition from agricultural and non-agricultural sources is needed. Total nitrogen deposition was allocated based on EMEP data according to the Nutrient Budgets Handbook (Eurostat, 2013). For Sweden, data about biogas production is available. However, no biogas balance has been calculated since biogas substrates are dominated by sewage sludge and other external substrates while agricultural products like energy crops and manure play only a marginal role. Hence, nutrient flows between field production, barn and biogas plants related to these agricultural products are negligible. Sewage sludge and other external substrates are considered in the category of "other organic fertilizer" and thus, related nutrients enter the balance as nutrient input in the total balance and the field balance. However, if the role of energy crops and manure for biogas production will increase, it could be reasonable to introduce the biogas balance also for Sweden in future.

Based on these database and coefficients, Table 37 shows the nitrogen inputs and outputs broken down by the individual balance positions calculated with NBA for a few selected years between 2000 and 2016. For comparison, the results reported to OECD/Eurostat are also shown (OECD.Stat, 2019). For each year, the relative difference between both methods is presented. The last column shows the average difference between the calculated values and those reported to OECD/Eurostat for the period 2000-2016.

As can be seen, there are no or only very small differences in all balance positions. Sweden have delivered the same data as delivered to Eurostat, which may be one of the reasons for this smaller difference compared to other countries.

Table 38 shows the calculated balance positions for the third balance approach used in this project for the same selected years between 2000 and 2016. Oxidized nitrogen deposition and the amount nitrogen mineral fertiliser are taken from the database used for calculating the net field balance in NBA. Biological fixation, livestock consumption and production as well as crop production for human and livestock are also based on the same database used for NBA, but coefficients are taken from Hong et al. (2017) (see chapter 3.1). For human nitrogen consumption, population data from Eurostat (2019b) and country-specific intake rates from Hong et al. (2017) are used. As the sum of human and livestock nitrogen consumption is lower than the sum of livestock and crop nitrogen production the value for the nitrogen in net food and feed imports is negative. This means that the nitrogen surplus of production is assumed to be exported. Accordingly, nitrogen leaves the area and reduces the NANI.

Table 37: Nitrogen inputs and outputs (in tonnes of N) of Swedish national balance calculation according to NBA and OECD/Eurostat for selected years

	2000			2005			2010			2015			2016			2000-2016
Indicator	**OECD**	**SE**	**Dif.**	**OECD**	**SE**	**Dif.**	**OECD**	**SE**	**Dif.**	**OECD**	**SE**	**Dif.**	**OECD**	**SE**	**Dif.**	**Ø Dif.**
Nutrient inputs	379.812	379.727	0%	352.929	352.629	0%	352.442	352.123	0%	375.934	375.610	0%	371.889	371.572	0%	0%
Total Fertilisers	192.761	192.761	0%	165.322	165.322	0%	174.136	174.136	0%	199.259	199.259	0%	195.059	195.059	0%	0%
Total Inorganic Fertilisers	189.400	189.400	0%	161.500	161.500	0%	168.000	168.000	0%	190.200	190.200	0%	186.000	186.000	0%	0%
Total Organic Fertilisers[1]	3.361	3.361	0%	3.822	3.822	0%	6.136	6.136	0%	9.059	9.059	0%	9.059	9.059	0%	0%
Net input of manure	132.211	132.212	0%	130.335	130.335	0%	119.696	119.697	0%	120.108	120.106	0%	120.304	120.304	0%	0%
Livestock Manure Production	132.211	132.212	0%	130.335	130.335	0%	119.696	119.697	0%	120.108	120.106	0%	120.304	120.304	0%	0%
Total Cattle	99.360	99.360	0%	97.559	97.559	0%	87.768	87.768	0%	90.249	90.249	0%	89.914	89.914	0%	0%
Total Pigs	19.717	19.717	0%	18.521	18.521	0%	16.566	16.566	0%	14.405	14.405	0%	14.849	14.849	0%	0%
Total Sheep and Goats	2.630	2.630	0%	2.948	2.948	0%	3.611	3.611	0%	4.108	4.108	0%	3.996	3.996	0%	0%
Total Poultry	6.073	6.073	0%	6.273	6.273	0%	6.697	6.697	0%	6.762	6.762	0%	7.173	7.173	0%	0%
Total Other Livestock	4.431	4.431	0%	5.034	5.034	0%	5.054	5.054	0%	4.584	4.584	0%	4.372	4.372	0%	0%
Manure Imports	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0%
Other Nutrient Inputs	54.840	54.754	0%	57.272	56.973	-1%	58.610	58.290	-1%	56.567	56.244	-1%	56.526	56.210	-1%	0%
Atmospheric deposition	22.092	22.092	0%	22.407	22.407	0%	21.516	21.516	0%	18.170	18.170	0%	18.126	18.126	0%	0%
Biological Fixation	27.946	27.860	0%	30.722	30.423	-1%	33.103	32.783	-1%	34.334	34.011	-1%	34.284	33.968	-1%	-1%
Seeds + Planting Materials	4.802	4.802	0%	4.143	4.143	0%	3.991	3.991	0%	4.063	4.063	0%	4.116	4.116	0%	0%
Nutrient outputs	218.007	229.132	5%	211.687	221.912	5%	221.880	235.241	6%	279.676	276.472	-1%	260.011	256.849	-1%	4%
Total Harvested Crops	114.441	114.620	0%	106.950	106.975	0%	96.145	96.166	0%	135.402	135.432	0%	122.538	122.564	0%	0%
Total Cereals	97.912	97.912	0%	87.497	87.497	0%	74.533	74.533	0%	108.378	108.378	0%	96.535	96.535	0%	0%
Total Dried Pulses and Beans	2.509	2.663	6%	2.988	2.988	0%	3.150	3.150	0%	6.416	6.416	0%	6.923	6.923	0%	2%
Total Industrial Crops	4.529	4.529	0%	7.487	7.487	0%	10.612	10.612	0%	14.175	14.175	0%	10.850	10.850	0%	0%
Other crops	9.491	9.516	0%	8.978	9.004	0%	7.850	7.872	0%	6.433	6.464	0%	8.230	8.257	0%	0%
Total Forage	99.551	110.497	11%	100.722	110.921	10%	121.720	135.059	11%	141.225	138.271	-2%	134.772	131.786	-2%	7%
Total Harvested Fodder Crops	88.840	99.786	12%	86.006	96.205	12%	108.712	122.051	12%	128.270	125.316	-2%	121.756	118.770	-2%	9%
Total Pasture	10.711	10.711	0%	14.716	14.716	0%	13.008	13.008	0%	12.955	12.955	0%	13.016	13.016	0%	0%
Removal by crop residues	4.015	4.015	0%	4.015	4.015	0%	4.015	4.015	0%	3.049	2.769	-9%	2.701	2.499	-7%	-2%

[1]excluding livestock manure

Table 38: Calculated balance positions (in tonnes of N) for NANI in Sweden

Indicator	2000	2005	2010	2015	2016
Oxidized nitrogen deposition (NO_y)	14.093	14.238	12.722	10.693	10.667
Nitrogen Mineral Fertiliser	189.400	161.500	168.000	190.200	186.000
Biological Nitrogen Fixation	26.180	28.593	30.833	32.092	32.123
Human Nitrogen Consumption	55.894	56.886	59.082	61.735	62.515
Livestock Nitrogen Consumption	196.448	198.532	181.531	183.162	185.485
Livestock Nitrogen Production	57.567	58.575	52.763	53.851	54.910
Net Crop Nitrogen Production for Human	33.620	34.442	33.785	47.238	40.404
Net Crop Nitrogen Production for Livestock	167.544	165.131	178.001	199.863	190.308
Nitrogen in net food and feed imports	-6.388	-2.729	-23.936	-56.055	-37.621

Table 40 compares the results of the nitrogen balances of the three used methods in this project for the period 2000 to 2016. The first three rows contain the balances calculated according to the NBA used in Germany. As explained in chapter 2, the total balance can also be calculated by summing up the field balance and stable balance. As of 2004, all three balances show a nitrogen surplus. 70-80% of the total balance can be related to the field balance. Accordingly, the field balance shows a lower nitrogen use efficiency (NUE) compared to the stable balance. However, for more recent years, this share seems to decrease 50-60%. Accordingly, the NUE of the field balance has been improved. However, it must be mentioned that data about fodder (domestic production used as feed and feed imports) are estimated due to uncertainties of available statistics, which show strong differences dependent on the source of data. Thus, results of respective partial balances are subject to not negligible uncertainties.

To be able to compare the results of the NBA used in Germany and the GNB according to OECD/Eurostat, emissions (row 4) must be added to the net field balance (row 2) calculated by the NBA used in Germany (cf. chapter 3.1). The relative difference between the resulting gross field balance of NBA (row 5) and the GNB (row 6) is shown in row 9. Nitrogen surpluses reported to OECD/Eurostat are on average 7% lower compared to the calculated nitrogen surpluses according to the NBA used in Germany. The differences vary between 3 and 17%.

With the NANI approach, a total balance and a net field balance can be calculated. The relative differences to the total balance (row 1) and the net field balance (row 2) of the NBA used in Germany are shown in rows 10 and 11 of Table 39. While the average difference between both methods for the total balance is very high (81%), the field balance results calculated with the NBA and NANI are on a comparable level and differ only by 6% on average.

Table 40 compares the results of the phosphorus balances of the GPB according to OECD/Eurostat and the field balance calculated with NAPI for the period 2000 to 2016. Both methods show comparable results during the considered period.

Table 39: Comparison of Swedish nitrogen balance results (kg N/ha) of the three used methods in this project

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total Balance	29	33	28	28	40	36	45	40	47	23	45	29	26	39	36	44	45
Net Field Balance	37	40	32	33	30	30	36	31	37	16	27	28	18	25	21	22	27
Stable Balance	-8	-7	-4	-5	11	6	9	9	10	7	17	0	8	14	15	22	18
Emissions	17	17	16	16	16	16	16	16	17	15	16	16	16	16	16	17	16
Gross Field Balance	54	56	49	49	46	46	52	47	53	31	43	45	34	41	37	38	44
Gross Field Balance Eurostat	51	54	47	47	44	44	50	45	51	30	42	42	32	35	31	32	37
NANI Total	71	74	66	66	63	63	68	64	70	50	61	62	52	59	57	58	63
NANI Field	39	42	35	34	31	31	36	32	38	18	29	30	19	26	24	25	29
Relative Difference Eurostat vs. gross field balance	-5%	-4%	-3%	-5%	-4%	-4%	-4%	-4%	-4%	-3%	-3%	-6%	-5%	-15%	-17%	-17%	-15%
Relative Difference NANI vs. total balance	144%	123%	137%	133%	56%	74%	52%	61%	51%	115%	36%	115%	101%	54%	60%	32%	41%
Relative Difference NANI vs. field balance	7%	6%	8%	4%	6%	4%	1%	4%	4%	12%	6%	4%	6%	5%	13%	12%	5%
NUE_{tot}	62%	58%	62%	62%	54%	55%	46%	52%	49%	67%	48%	61%	65%	55%	60%	56%	53%
NUE_{field}	66%	64%	70%	69%	72%	70%	64%	70%	67%	84%	74%	73%	81%	76%	81%	81%	76%
NUE_{stable}	121%	118%	111%	113%	80%	88%	83%	83%	81%	85%	71%	99%	84%	75%	74%	65%	71%

Table 39: Comparison of Swedish phosphorus balance results (kg P/ha) of GPB and NAPI

Balance	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
GPB	2	2	1	1	1	2	2	1	2	-2	0	0	0	1	0	0	1
NAPI	2	2	2	2	2	2	3	1	1	-2	-1	0	-1	0	-2	-2	0

5. Conclusion

In the current EU, EUROSTAT is established as a harmonized method of calculating nutrient balances. But Russia as a member of the BSR is outside of the EU and non-responsible for OECD. Hence, a common method for calculating national nutrient balances is needed to compare the countries, identifying the major sources of nutrient inputs and exploring the potential for a more effective nutrient management strategy in the Baltic Sea Region. Accordingly, one objective of the Manure Standards project was to calculate nutrient balances for the participating Baltic Sea countries based on different methods, to compare them and to identify the differences. Based on that, a recommendation should be given which method should be used in all Baltic Sea countries. Three different nutrient balance approaches were used to calculate the nitrogen and phosphorus surpluses or deficits for the BSR countries participating in this project. The three approaches are:

1) Gross Nutrient Balance according to OECD/Eurostat (consisting of the Gross Nitrogen Balance (GNB) and the Gross Phosphorus Balance (GPB))
2) Nitrogen Balance Approach currently used in Germany (NBA)
3) Net Anthropogenic Nitrogen and Phosphorus Inputs (NANI and NAPI) according to Hong et al. (2017)

The GNB and GPB as well as the individual balance positions (nutrient inputs and outputs) are published by the OECD/Eurostat (OECD.Stat, 2019) and were used for comparison with the other two approaches. For the NBA used in Germany, needed data and coefficients were provided by the work package activity partners of all countries in the project. As the GNB/GPB and the NBA are based on the same quantity structure, reported values of OECD/Eurostat and calculated values of the NBA were compared in a first step. For some countries larger differences exist for specific balance positions like nitrogen manure production of specific animal categories (e.g., Denmark, Germany, Latvia and Lithuania), nitrogen output with industrial crops (e.g., Latvia and Lithuania) or harvested fodder crops (e.g., Estonia, Germany and Poland). However, in most of the cases, the differences were related to positions playing a quantitative minor role for the total nutrient inputs and outputs (e.g., less important animal categories or cultivated crops). Overall, the comparison showed that data fit quite well for the BSR countries. Existing differences might be explained by data and coefficient updates. For GNB and GPB, data collection takes places every second year and the next collection year is 2019. Accordingly, last collection took place in 2017. However, it is also possible that reported data are even older than 2017, e.g. if countries did not report updates to OECD/Eurostat soon. Data and coefficients for the NBA in Germany were collected in 2018/2019. Hence, differences between both methods might be related to more actual data and/or coefficients used for NBA in Germany. For some countries, country-specific coefficients were not available and thus, German coefficients were used (e.g., Denmark and Lithuania). This can also partly explain existing differences (for more details, see country-specific chapters). Furthermore, transmission errors when reporting national statistical data to OECD/Eurostat cannot totally be excluded. Based on the close exchange with the work package activity partners, it seems that most of them were more confident about the accuracy and reliability of the data and coefficients they sent to the JKI compared to the reported values to OECD/Eurostat. Some of the partners also mentioned that they found discrepancies between national statistics and OECD/Eurostat data. This is however not surprising as definitions may vary between national and EU statistics. It is therefore recommended to use EU statistics/databases to maximize comparability between countries. However, it is always advisable to check reported values to OECD/Eurostat for all countries to ensure the accuracy and reliability of published nutrient balances.

The three approaches differ according to the material system boundary (total, field or stable balance), leading to different results for nitrogen and phosphorus surpluses (or deficits) depending on the used approach. This must be considered when comparing them.

The NBA in Germany calculates the total balances as well as the field balance and the stable balance, which are the respective partial balances. The GNB and GPB according to OECD/Eurostat are gross field balances while NANI and NAPI are total balance approaches. However, NANI and NAPI can be recalculated into field balances. Hence, the nitrogen balances calculated with the NBA can be compared to both other approaches and the GPB and NAPI can be compared. For the comparison of the NBA and GNB, the net field balance of the NBA needs to be recalculated into a gross field balance by adding the nitrogen emissions.

Figures 3-6 as well as table 41 and 42 show the nitrogen and phosphorus balance results as a five-year average of 2012-2016 for all countries participating in the project for the three methods used. Comparing all results reveals differences in the level of the nitrogen and phosphorus surpluses (or deficits) for each country depending on the method used.

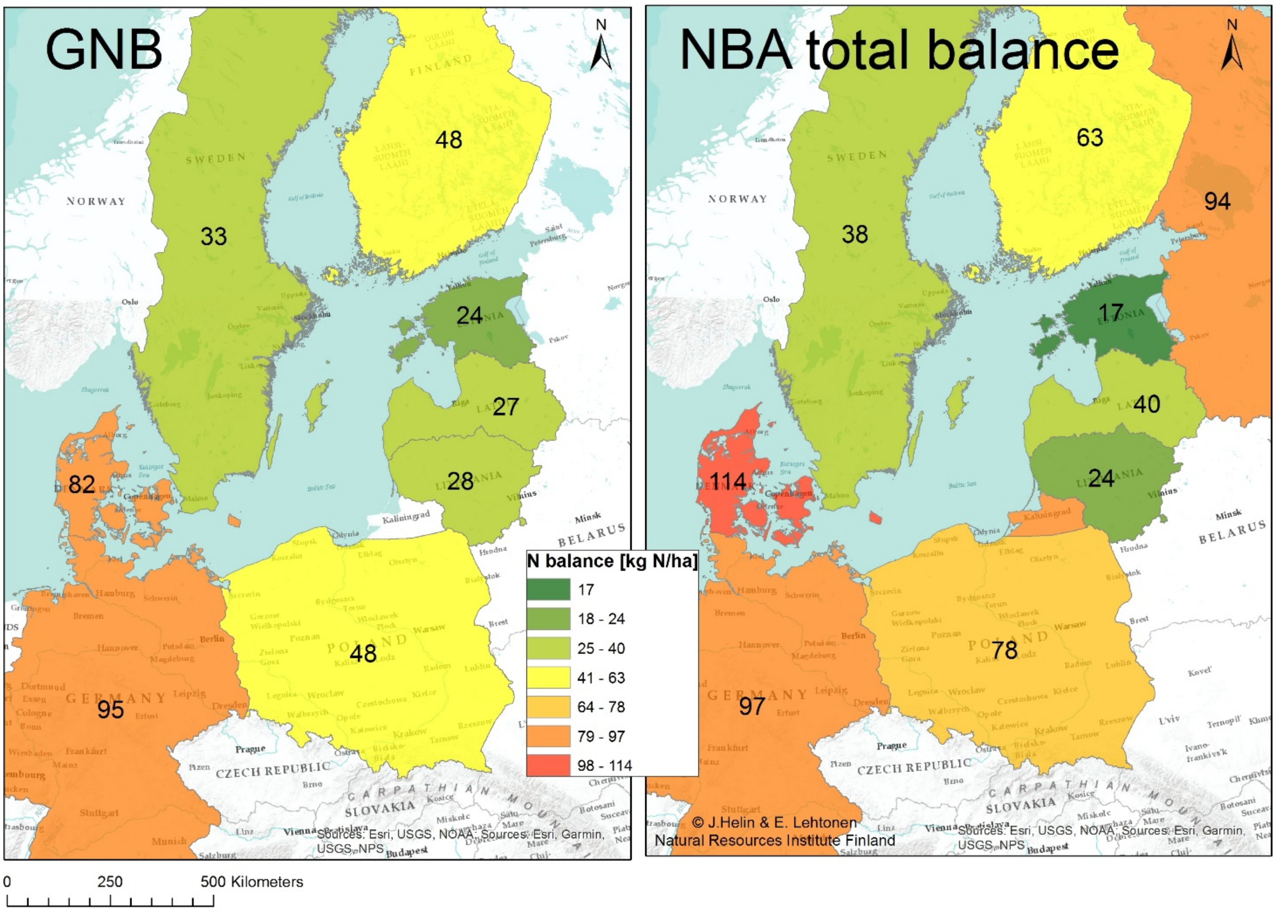

Figure 3: Gross Nitrogen Balance (GNB) according to OECD/Eurostat and total balance according to the NBA currently used in Germany as a five-year average of 2012-2016 (RU only Leningrad region)

This highlights the importance of considering different material system boundaries when comparing nutrient balances across countries. Only results based on the same method should be compared. However, even if approaches with different material system boundaries are recalculated to a comparable unit, results can differ due to differences in the data and coefficients used. This is shown in Table 41, where the results of the gross field balance for all three approaches used in the project are presented. The table shows the 5-year average. Comparing the GNB and the gross field balance calculated with the NBA currently used in Germany shows different results depending on the countries (Figure 3). For Denmark, Finland, Latvia and Poland, the NBA shows higher nitrogen surpluses as the GNB and related differences are large. For all other countries GNB is higher for some years and lower for other years compared to the NBA but the differences are quite small.

Table 41: 5-year average of gross field balances (kg N/ha) calculated with the three balance approaches used in this project for the Baltic Sea Region countries centred on 2014

	DK	EE	FI	DE	LV	LT	PL	RU*	SE
GNB according to OECD/Eurostat	82	24	48	95	27	28	48	n.a.	33
NBA total balance	114	17	63	97	40	24	78	94	38
NANI total balance	109	42	71	76	29	44	84	240	58

n.a.: not available; RU* only Leningrad region

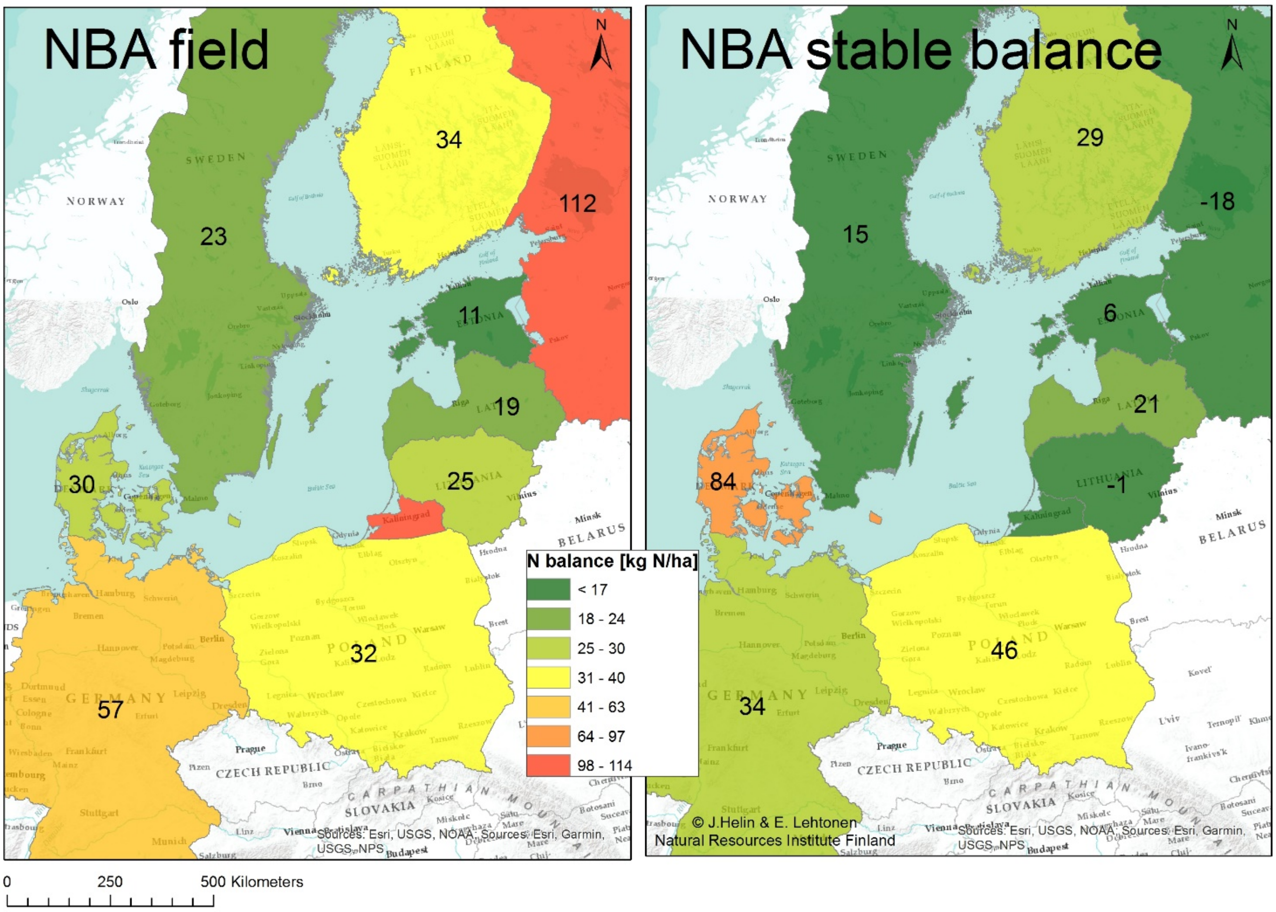

Figure 4: field balance and stable balance according to the NBA currently used in Germany as a five-year average of 2012-2016 (RU only Leningrad region)

Comparing the results of NBA and NANI total balance shows higher nitrogen surpluses calculated with NANI compared to the NBA for most of the countries while the respective differences show a large range depending on the country. Exceptions are Denmark, Latvia and Germany. For the total balance in this countries, the nitrogen surplus calculated with the NBA is higher compared to NANI.
Comparing the GPB and NAPI shows different results depending on the countries (Table 42 & Figure 6). For Germany, Poland and Estonia, the NAPI shows higher phosphorus surpluses and amounts respectively as the GPB. For all other countries, the balance results are on a comparable level.

Table 42: 5-year average of gross field balances (kg P/ha) calculated with the two balance approaches used in this project for the Baltic Sea Region countries centred on 2014

	DK	EE	FI	DE	LV	LT	PL	RU*	SE
GPB according to OECD/Eurostat	7	-7	4	-3	2	3	2	n.a.	0
NAPI total balance	6	0	2	1	1	2	7	n.a.	-1

n.a.: not available

Currently, the GNB and GPB, which are reported to OECD/Eurostat, is the only comparable parameter for the nitrogen and phosphorus balances of Baltic Sea Region countries. However, as only OECD and EU Member States report respective data for the GNB and GPB, not all BSR countries can be compared on this parameter (e.g. Russia is missing). As the majority of BSR countries already use the GNB and GPB according to OECD/Eurostat, adopting this method for all BRS countries should be the option with the lowest additional efforts to get a common method for calculating national nutrient balances in the Baltic Sea Region.

However, also the two other approaches used in this project have their justifications in the discussion about a common method for the calculation of national nutrient balances. The NBA currently used Germany calculates not only a field balance, but also a stable balance (and a biogas balance), which in turn, can be summed up to the total national nutrient balance. Hence, this approach is more differentiated compared to the approach of OECD/Eurostat and thus, offers the opportunity to analysis nutrient flows between the production sectors within the whole agricultural sector in more detail. Additional information needed for this more differentiated approach is not that much: Animal products are already available in the Eurostat database. The only new data is related to fodder production and feed imports. However, the close exchange with the work activity partners revealed some problems of data availability and reliability related to fodder production and feed imports.

These problems must be overcome when the NBA should be used as a common method for calculating national nutrient balances in the Baltic Sea Region. However, expanding the GNB and GPB according to OECD/Eurostat to the more holistic approach of calculating the total balance with all related partial balances (field balance, stable balance and biogas balance) would give a deeper insight into the nutrient flows of the BSR countries. In this project, a first attempt was made to calculate the NBA for all participating countries showing promising results.

For NANI and NAPI, data requirements are lower compared to the NBA in Germany because country-specific coefficients can be taken from Hong et al. (2012; 2017) and much information from the Eurostat database can be used. However, compared to the other two approaches, data and coefficients used are often less detailed and thus, balance results could be less precise. Hence, this approach is a good alternative method for calculating nutrient balances when data is rare. As showed by Hong et al. (2017), such an approach is also very useful when aiming to compare many countries.

Table 43 shows the average shares of nitrogen inputs on total nitrogen input calculated based on the net field balance according to the NBA currently used in Germany between 2000 and 2016 for the nine BSR countries in the project. Inorganic fertilizer and manure are by far the most important nitrogen inputs. The share of nitrogen inorganic fertilizer varies between 12 and 62% of total nitrogen input, while for most of the countries this share is approximately 50% or more. Leningrad region in Russia shows a comparatively low share of inorganic fertilizer (12%). In this region, manure contributes the overwhelming share to the total nitrogen input of the net field balance (82%). For the other countries, the share of manure varies between 17 and 40%. Hence, livestock manure production as one of the major sources of nutrient inputs offers a high potential for getting to a more effective nutrient management strategy in the BSR and improving the precision of manure use is a key to instantly reduce nutrient inflow into the Baltic Sea.

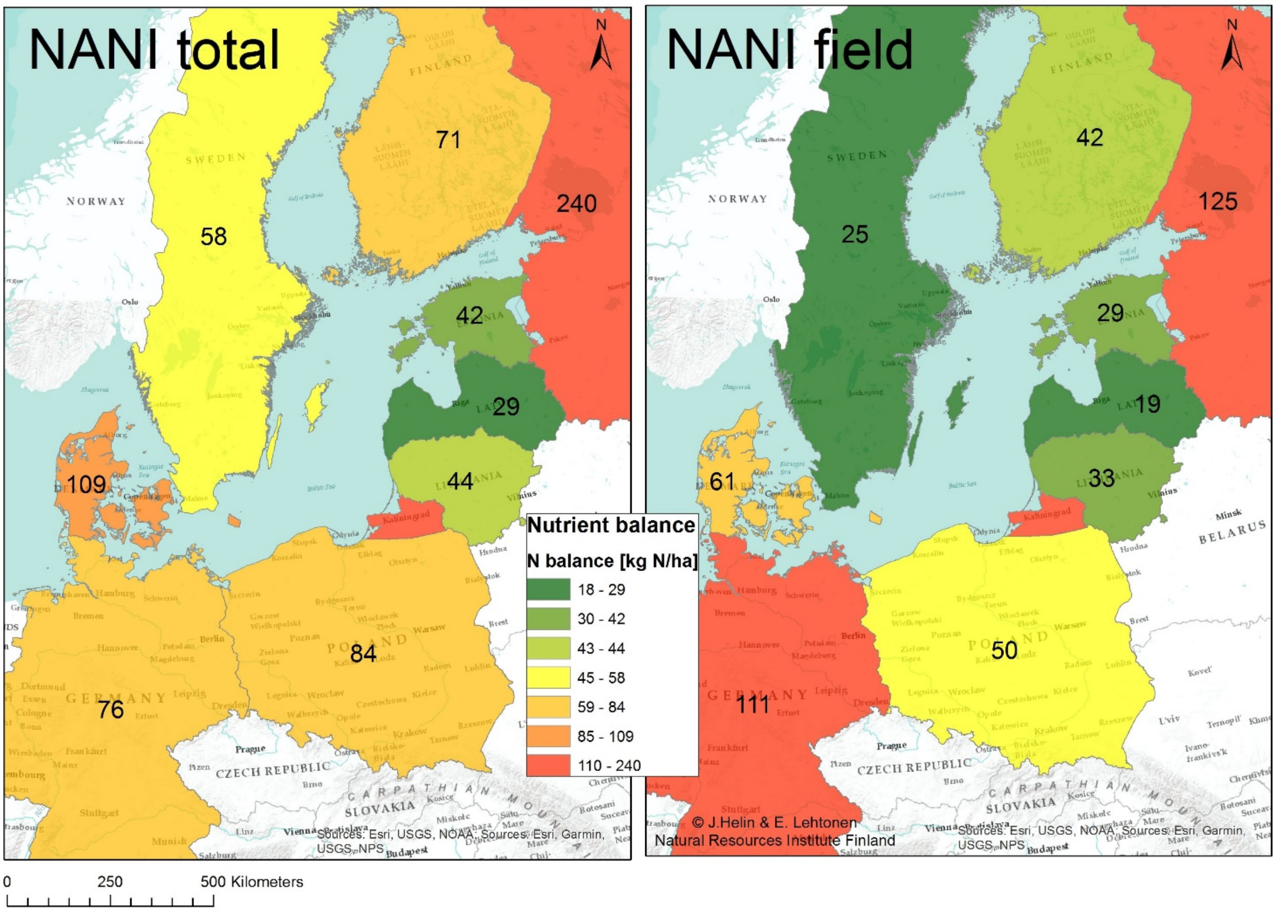

Figure 5: NANI total balance and NANI field balance according to Hong et al. (2012; 2017) as a five-year average of 2012-2016 (RU only Leningrad region*)*

Table 43: Average shares (in %) of nitrogen inputs on total nitrogen input for the net field balance according to the NBA between 2000 and 2016 for the nine Baltic Sea Countries

Nitrogen Inputs [Shares in %]	DK	EE	FI	DE	LV	LT	PL	RU*	SE
Inorganic Fertilizer	47	50	62	53	42	61	61	12	53
Organic Fertilizer (excluding manure)	2	0	0	2	1	0	0	0	2
Manure production (less gaseous emissions)	40	26	31	31	24	17	20	82	28
Atmospheric deposition	8	10	2	7	11	11	12	3	6
Biological Fixation	3	14	2	6	21	9	5	2	9
Seeds + Planting materials	1	0	2	1	2	2	2	1	1

*average of 2012-2016; only Leningrad region

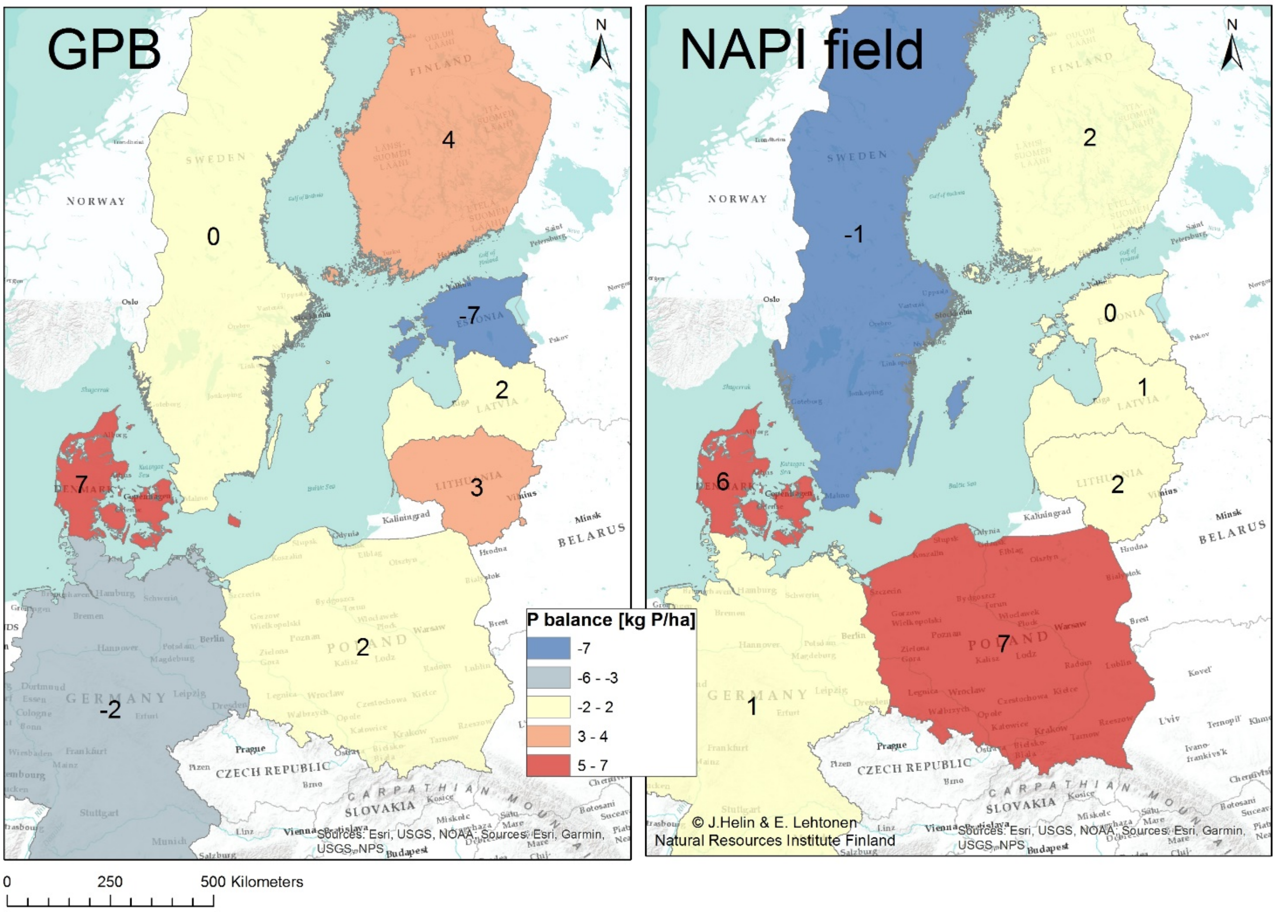

Figure 6: Gross Phosphorus Balance (GPB) according to OECD/Eurostat and field balance calculated with NAPI according to Hong et al. (2012; 2017) as a five-year average of 2012-2016 (RU only Leningrad region)

Accordingly, this work package activity also reveals a further research need. As now all information for all countries is collected, it could be of interest to analyse the impact of different measures related to manure use on the nitrogen and phosphorus balances in the Baltic Sea Region. For example, this could include the impact of using updated manure nutrient contents as a result of improved measurements or calculation, the impact of new technologies reducing emissions during housing, storage and application of manure as well as the impact of new manure processing technologies.

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Manure Standards

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