

Technical Report No. 3

# NANI/NAPI Calculator Toolbox

## Version 2.0 Documentation:

### Net Anthropogenic Nutrient Inputs in Baltic Sea Catchments

(March, 2011)

Bongghi Hong, Dennis P. Swaney  
Carl-Magnus Mörth, Erik Smedberg  
Hanna Eriksson Hägg, Christoph Humborg



Baltic Nest  
Institute

## The Baltic Nest Institute

The Baltic Nest Institute host the Nest model, a decision support system aimed at facilitating adaptive management of environmental concern in the Baltic Sea.

Nest can be used to calculate required actions needed to attain politically agreed targets for the Baltic Sea ecosystem. By modeling the entire drainage area, Nest is a novel tool for implementing the ecosystem approach in a large marine ecosystem. The main focus of the model is on eutrophication and the flows of nutrients from land to sea.

Reducing the nutrient input to the sea and thus decreasing the negative environmental impacts is a politically prioritized area of international cooperation. Baltic Nest Institute can contribute to this process by formulating policies that are fair, transparent and cost-efficient. The main target group for the Nest Decision Support System is HELCOM and regional water directors in the riparian countries.

Technical Report No. 3

NANI/NAPI Calculator Toolbox - Version 2 Documentation: Net Anthropogenic Nutrient Inputs in Baltic Sea Catchments (March 2011)

Authors: Bongghi Hong, Dennis P. Swaney, Carl-Magnus Mörtö, Erik Smedberg, Hanna Eriksson Hägg and Christoph Humborg

ISBN: 978-91-86655-02-0

Layout: Marmar Nekoro

**Baltic Nest Institute**

Stockholm Resilience Centre, Stockholm University

Address: Baltic Nest Institute, Stockholm University, SE-106 91 Stockholm, Sweden

[www.balticnest.org](http://www.balticnest.org)

# **NANI/NAPI Calculator Toolbox**

Version 2.0 Documentation:  
Net Anthropogenic Nutrient Inputs in  
Baltic Sea Catchments  
(March, 2011)

Bongghi Hong, Dennis P. Swaney,  
Carl-Magnus Mörth, Erik Smedberg,  
Hanna Eriksson Hägg  
and Christoph Humborg

**NANI/NAPI Calculator Toolbox**  
**Version 2.0 Documentation:**  
**Net Anthropogenic Nutrient Inputs in**  
**Baltic Sea Catchments**

Bongghi Hong  
Dennis P. Swaney  
Carl-Magnus Mörth  
Erik Smedberg  
Hanna Eriksson Hägg  
Christoph Humborg

March 2011

## **Table of contents**

List of Tables .....	3
List of Figures .....	4
1. Objectives .....	6
2. Atmospheric N Deposition .....	9
2.1. Overview.....	9
2.2. Data Availability.....	9
2.3. Input Preparation.....	10
2.4. Toolbox Calculation.....	10
2.5. Preliminary Results.....	14
3. Fertilizer N & P Application.....	16
3.1. Overview.....	16
3.2. Data Availability.....	17
3.3. Input Preparation.....	18
3.3.1. ISPRA Data.....	18
3.3.2. Processing Belarusian Data.....	20
3.3.3. Processing Russian Data.....	20
3.3.4. Processing Polish Data.....	23
3.4. Toolbox Calculation.....	24
3.5. Preliminary Results.....	28
4. Agricultural N Fixation.....	29
4.1. Overview.....	29
4.2. Data Availability.....	30
4.3. Input Preparation.....	31
4.4. Toolbox Calculation.....	32
4.5. Preliminary Results.....	38
5. Net Food and Feed Imports.....	42
5.1. Human N Consumption .....	42
5.1.1. Overview.....	42
5.1.2. Data Availability.....	43
5.1.3. Input Preparation.....	43
5.1.4. Toolbox Calculation.....	45
5.1.5. Preliminary Results.....	49
5.2. Animal N Consumption and N Production.....	50
5.2.1. Overview.....	50
5.2.2. Data Availability.....	51
5.2.3. Input Preparation.....	52
5.2.3.1. Animal Numbers.....	52

5.2.3.2. Cattle Parameters .....	52
Dairy Cows .....	56
Bovine Young (Calves 0-2 Years).....	56
Bovine Males .....	57
Heifers.....	57
Other Cows .....	57
5.2.3.3. Pig Parameters .....	57
Piglets (<20 kg).....	58
Pigs (20 - 50 kg).....	58
Fattening Pigs (>50 kg).....	59
Boars (>50 kg) .....	59
Sows (>50 kg).....	59
5.2.3.4. Poultry and Sheep Parameters .....	60
Broilers.....	60
Laying Hens .....	60
Other Poultry (Ducks and Turkey) .....	61
Sheep.....	61
5.2.4. Toolbox Calculation.....	61
5.2.5. Preliminary Results .....	66
5.3. Crop N Production .....	69
5.3.1. Overview .....	69
5.3.2. Data Availability .....	70
5.3.3. Input Preparation.....	70
5.3.4. Crop Distribution to Humans and Animals .....	75
5.3.5. Toolbox Calculation.....	76
5.3.6. Preliminary Results .....	81
5.4. Net Food and Feed Imports.....	83
6. NANI.....	85
7. Acknowledgements.....	87
8. References.....	88
Appendix 1: Details of NAPI Calculations.....	90
A1. Atmospheric Deposition .....	90
A2. Fertilizer Application .....	90
A3. Agricultural Fixation.....	92
A4. Net Food and Feed Imports.....	92
A4.1. Human Consumption .....	92
A4.2. Animal Consumption and Production.....	93
A4.3. Crop Production .....	94

## List of Tables

Table 3.2.A. Comparison of ISPRA and FAO mineral fertilizer data (1000 tonnes N).....	17
Table 3.2.B. Fertilizer data for some Russian Oblasts (data source: International Plant Nutrition Institute).....	17
Table 3.3.2.A. Mineral fertilizer N estimated for watersheds intersecting with areas of Belarus.....	20
Table 3.3.3.A. Mineral fertilizer N estimated for watersheds intersecting with areas of Russia (Oblasts with available data).....	21
Table 3.3.3.B. Mineral fertilizer N estimated for watersheds intersecting with areas of Russia (Oblasts without available data).....	21
Table 3.3.3.C. Mineral fertilizer N estimated for watersheds intersecting with areas of Russia (combined).....	22
Table 3.3.3.D. Mineral fertilizer N for Russian portion estimated from reduced N deposition.....	22
Table 3.3.4.A. Mineral fertilizer N for Poland corrected to actual consumption.....	23
Table 4.3.A. Crop N fixation parameters estimated for European countries (kg-N/km <sup>2</sup> /yr).....	32
Table 5.1.3.A. Human N intake parameters for European countries.....	44
Table 5.2.2.A. Animal classes used in animal N calculation.....	51
Table 5.2.3.1.A. Populations of animals (number of head) used in animal N calculation (cattle).....	53
Table 5.2.3.1.B. Populations of animals (number of head) used in animal N calculation (pigs).....	54
Table 5.2.3.1.C. Populations of animals (number of head) used in animal N calculation (poultry and sheep).....	55
Table 5.2.3.2.A. Animal N parameters for cattle (kg-N/animal/yr).....	56
Table 5.2.3.3.A. Animal N parameters for pigs (kg-N/animal/yr).....	58
Table 5.2.3.4.A. Animal N parameters for poultry and sheep (kg-N/animal/yr).....	60
Table 5.3.3.A. ISPRA code matched with EuroStat code.....	71
Table 5.3.3.B. Crop production table (unit: 1000 tonnes).....	72
Table 5.3.4.A. Estimated distribution of crop yield to humans and animals.....	76
Table A2.A. Mineral fertilizer P estimated for watersheds intersecting with areas of Belarus.....	90
Table A2.B. Mineral fertilizer P estimated for watersheds intersecting with areas of Russia (Oblasts with available data).....	91
Table A2.C. Mineral fertilizer P estimated for watersheds intersecting with areas of Russia (Oblasts without available data).....	91
Table A2.D. Mineral fertilizer P estimated for watersheds intersecting with areas of Russia (combined).....	92
Table A4.1.A. Human P consumption parameters for European countries.....	93
Table A4.2.A. Animal P parameters for cattle (kg-P/animal/yr).....	93
Table A4.2.B. Animal P parameters for pigs (kg-P/animal/yr).....	94
Table A4.2.C. Animal P parameters for poultry and sheep (kg-P/animal/yr).....	94
Table A4.3.A. Percent P content assigned for each crop type.....	95

## List of Figures

Figure 1.A. NANI and their components.....	6
Figure 1.B. Baltic Sea catchments and their surrounding European countries.....	7
Figure 2.1.A. EMEP grid and map of Baltic Sea catchments.....	9
Figure 2.2.A. EMEP website for downloading atmospheric N deposition data.....	10
Figure 2.3.A. EMEP data downloaded for 2000-2006 periods (recalculated in 2009).....	10
Figure 2.4.A. Running NANI-GIS tool to calculate EMEP grid cell proportion.....	11
Figure 2.4.B. Specifying NANI-GIS tool to calculate EMEP grid cell proportion.....	12
Figure 2.4.C. EMEP grid cell proportion table created after running NANI-GIS tool.....	12
Figure 2.4.D. Extracting oxidized N deposition data using NANI-extraction tool.....	13
Figure 2.4.E. Oxidized N deposition data extracted using NANI-extraction tool.....	13
Figure 2.4.F. Calculating atmospheric N deposition using NANI-accounting tool.....	14
Figure 2.5.A. Oxidized N deposition in Baltic Sea catchments.....	14
Figure 2.5.B. Relative frequencies of oxidized N deposition in Baltic Sea catchments.....	15
Figure 2.5.C. Comparison of oxidized N deposition calculated by NANI toolbox and NEST.....	15
Figure 3.1.A. Map of European countries and available ISPRA grid containing fertilizer application rates.....	16
Figure 3.3.1.A. ISPRA grid containing fertilizer application data.....	18
Figure 3.3.1.B. Original fertilizer application data in raster maps.....	18
Figure 3.3.1.C. Point map containing fertilizer application rates.....	19
Figure 3.3.1.D. Text file containing fertilizer application rates.....	19
Figure 3.4.A. Running NANI-GIS tool to calculate ISPRA grid cell proportion.....	24
Figure 3.4.B. Specifying NANI-GIS tool to calculate ISPRA grid cell proportion.....	25
Figure 3.4.C. ISPRA grid cell proportion table created after running NANI-GIS tool.....	25
Figure 3.4.D. Extracting fertilizer data using NANI-extraction tool.....	26
Figure 3.4.E. Fertilizer data extracted using NANI-extraction tool.....	26
Figure 3.4.F. Calculating fertilizer N application using NANI-accounting tool.....	27
Figure 3.4.G. "Post_Calc" worksheet containing fertilizer estimates to be modified.....	27
Figure 3.4.H. Incorporating fertilizer estimates to be modified.....	28
Figure 3.5.A. Fertilizer N application in Baltic Sea catchments.....	28
Figure 3.5.B. Relative frequencies of fertilizer N application in Baltic Sea catchments.....	29
Figure 4.1.A. Map of European countries and extended ISPRA grid containing crop areas.....	30
Figure 4.2.A. Extended ISPRA grid containing crop area data.....	31
Figure 4.3.A. Map of European countries with their NANI parameters.....	32
Figure 4.4.A. Running NANI-GIS tool to calculate extended ISPRA grid cell proportion.....	33
Figure 4.4.B. Specifying NANI-GIS tool to calculate extended ISPRA grid cell proportion.....	34
Figure 4.4.C. Extended ISPRA grid cell proportion table created after running NANI-GIS tool.....	34
Figure 4.4.D. Extracting N fixing crop areas using NANI-extraction tool.....	35
Figure 4.4.E. N fixing crop areas extracted using NANI-extraction tool.....	35
Figure 4.4.F. Running NANI-GIS tool to calculate country proportion.....	36
Figure 4.4.G. Specifying NANI-GIS tool to calculate country proportion.....	36
Figure 4.4.H. Country-level NANI parameters imported into NANI-accounting tool.....	37
Figure 4.4.I. Calculating agricultural N fixation using NANI-accounting tool.....	37
Figure 4.4.J. Watershed-specific agricultural N fixation parameters calculated by NANI toolbox.....	38
Figure 4.5.A. Agricultural N fixation in Baltic Sea catchments.....	39
Figure 4.5.B. Relative frequencies of agricultural N fixation in Baltic Sea catchments.....	39
Figure 4.5.C. Agricultural N fixation by crop type.....	40
Figure 4.5.D. Agricultural N fixation calculated with original (left) and alternative (right) approaches.....	40
Figure 4.5.E. NANI calculated with original (left) and alternative (right) approaches.....	41

Figure 5.1.1.A. Map of European countries and HYDE population grid.....	42
Figure 5.1.3.A. Shapefile containing 2005 HYDE population data.....	43
Figure 5.1.3.B. Population data imported into NANI-extraction tool.....	44
Figure 5.1.4.A. Running NANI-GIS tool to calculate HYDE grid cell proportion.....	45
Figure 5.1.4.B. Specifying NANI-GIS tool to calculate HYDE grid cell proportion.....	46
Figure 5.1.4.C. HYDE grid cell proportion table created after running NANI-GIS tool.....	46
Figure 5.1.4.D. Extracting population data using NANI-extraction tool.....	47
Figure 5.1.4.E. Population data extracted using NANI-extraction tool.....	47
Figure 5.1.4.F. Calculating human N consumption using NANI-accounting tool.....	48
Figure 5.1.4.G. Watershed-specific human N intake parameters calculated by NANI toolbox.....	48
Figure 5.1.5.A. Human N consumption in Baltic Sea catchments.....	49
Figure 5.1.5.B. Relative frequencies of human N consumption in Baltic Sea catchments.....	49
Figure 5.2.1.A. Country map (black) and NUTS 2 level, oblast, and voblast boundaries (red).....	50
Figure 5.2.4.A. Running NANI-GIS tool to calculate animal polygon proportion.....	62
Figure 5.2.4.B. Specifying NANI-GIS tool to calculate animal polygon proportion.....	62
Figure 5.2.4.C. Animal polygon proportion table created after running NANI-GIS tool.....	63
Figure 5.2.4.D. Animal count data imported into NANI-extraction tool.....	63
Figure 5.2.4.E. Extracting animal count data using NANI-extraction tool.....	64
Figure 5.2.4.F. Animal count data extracted using NANI-extraction tool.....	64
Figure 5.2.4.G. Calculating animal N consumption and N production using NANI-accounting tool.....	65
Figure 5.2.4.H. Watershed-specific animal N intake and excretion parameters calculated by NANI toolbox.....	65
Figure 5.2.5.A. Animal N consumption in Baltic Sea catchments.....	66
Figure 5.2.5.B. Animal N production in Baltic Sea catchments.....	66
Figure 5.2.5.C. Relative frequencies of animal N consumption in Baltic Sea catchments.....	67
Figure 5.2.5.D. Relative frequencies of animal N production in Baltic Sea catchments.....	67
Figure 5.2.5.E. Animal N consumption by animal class.....	68
Figure 5.2.5.F. Animal N production by animal class.....	68
Figure 5.3.1.A. Crop production and crop area data available in Baltic Sea catchments.....	69
Figure 5.3.3.A. Crop production table added to ArcGIS.....	73
Figure 5.3.5.A. Running NANI-GIS tool to distribute crop production.....	77
Figure 5.3.5.B. Specifying NANI-GIS tool to distribute crop production.....	77
Figure 5.3.5.C. Running NANI-GIS tool to calculate distributed ISPRA grid cell proportion.....	78
Figure 5.3.5.D. Specifying NANI-GIS tool to calculate distributed ISPRA grid cell proportion.....	78
Figure 5.3.5.E. Distributed ISPRA grid cell proportion table created after running NANI-GIS tool.....	79
Figure 5.3.5.F. Distributed crop production data imported into NANI-extraction tool.....	79
Figure 5.3.5.G. Extracting crop production data using NANI-extraction tool.....	80
Figure 5.3.5.H. Distributed crop production data extracted using NANI-extraction tool.....	80
Figure 5.3.5.I. Calculating crop N production using NANI-accounting tool.....	81
Figure 5.3.6.A. Crop N production in Baltic Sea catchments.....	81
Figure 5.3.6.B. Relative frequencies of crop N production in Baltic Sea catchments.....	82
Figure 5.3.6.C. Crop N production by crop type.....	82
Figure 5.4.A. Calculating net food and feed imports using NANI-accounting tool.....	83
Figure 5.4.B. Net food and feed imports in Baltic Sea catchments.....	83
Figure 5.4.C. Relative frequencies of net food and feed imports in Baltic Sea catchments.....	84
Figure 6.A. Calculating NANI using NANI-accounting tool.....	85
Figure 6.B. NANI in Baltic Sea catchments.....	85
Figure 6.C. Relative frequencies of NANI in Baltic Sea catchments.....	86

## 1. Objectives

The main objective of this work was to develop regional settings of the NANI budgeting tool that will address the significant variation in agricultural practices and resulting nutrient accountings among European countries. NANI (Net Anthropogenic Nitrogen Inputs), first introduced by Howarth et al. (1996), estimate the human-induced nitrogen inputs to a watershed and have been shown to be a good predictor of riverine nitrogen export at a large scale, multi-year average basis. NANI have been calculated as the sum of four major components (Figure 1.A): atmospheric N deposition, fertilizer N application, agricultural N fixation, and net food and feed imports, which in turn are composed of crop and animal N production (negative fluxes removing N from watersheds) and animal and human N consumption (positive fluxes adding N to watersheds). Assuming approximate steady-state behavior, riverine N export is a fixed proportion of net nitrogen inputs.

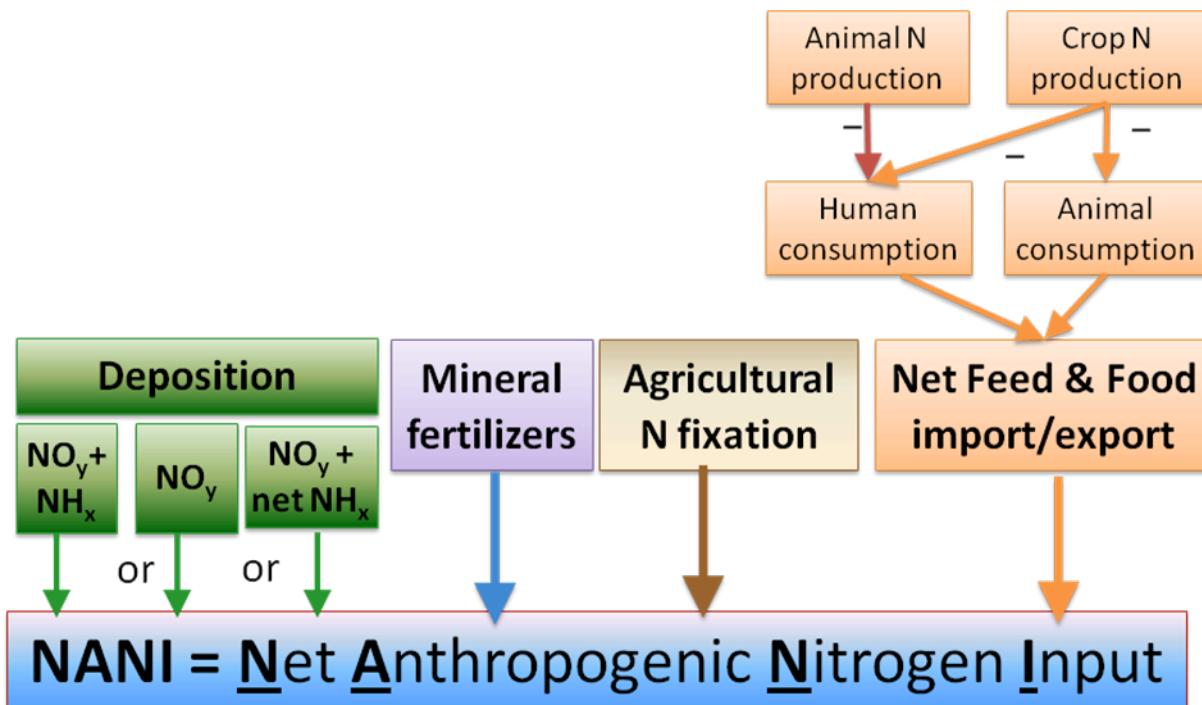


Figure 1.A. NANI and their components.

Similar calculations can be made for phosphorus (P) inputs, though because atmospheric deposition of P is usually considered negligible and there is no analog in P for atmospheric fixation, the calculation of Net Anthropogenic Phosphorus Inputs (NAPI) reduces to accounting for P fertilizer and P in net food/feed terms. While this document is primarily concerned with calculating NANI, we also describe the data sources and assumptions used to make the parallel calculations of NAPI.

Version 2.0 of the Toolbox described in this document is an improvement of version 1.0 developed for US watersheds (<http://www.eeb.cornell.edu/biogeo/nanc/nani/nani.htm>; Hong et al. 2011). Version 1.0 allows the user to calculate NANI in any area within the contiguous United States

(e.g., watershed, county, etc.) from nationally available databases downloadable from the Internet. The toolbox consists of a set of tools that: (1) calculate the proportions of various regions (political or gridded) in which data are collected that fall into areas of interest such as watersheds (“NANI-GIS tools”), (2) extract and organize relevant data downloaded from web-based datasets to be used by the accounting tools (“NANI-extraction tools”), and (3) calculate NANI, their components, and other relevant items such as animal excretion (“NANI-accounting tools”).

While attempting to apply version 1.0 of the toolbox to Baltic Sea catchments (Figure 1.B), we found that the calculation of NANI in Baltic Sea catchments is more challenging than in US watersheds, mainly for two reasons:

- Watersheds span international boundaries. Significant variation in agricultural practices and resulting nutrient accountings among European countries exist. For example, a substantial gradient in agricultural practices is expected among the former EU countries, new EU member states with transitional economies, and Belarus and Russia.
- Gaps and uncertainties in the available data are much greater than those in the US. In general, the problem of missing information is more severe for the transitional countries, Belarus, and Russia, requiring numerous assumptions and guesswork to be made to deal with the insufficient data issue.

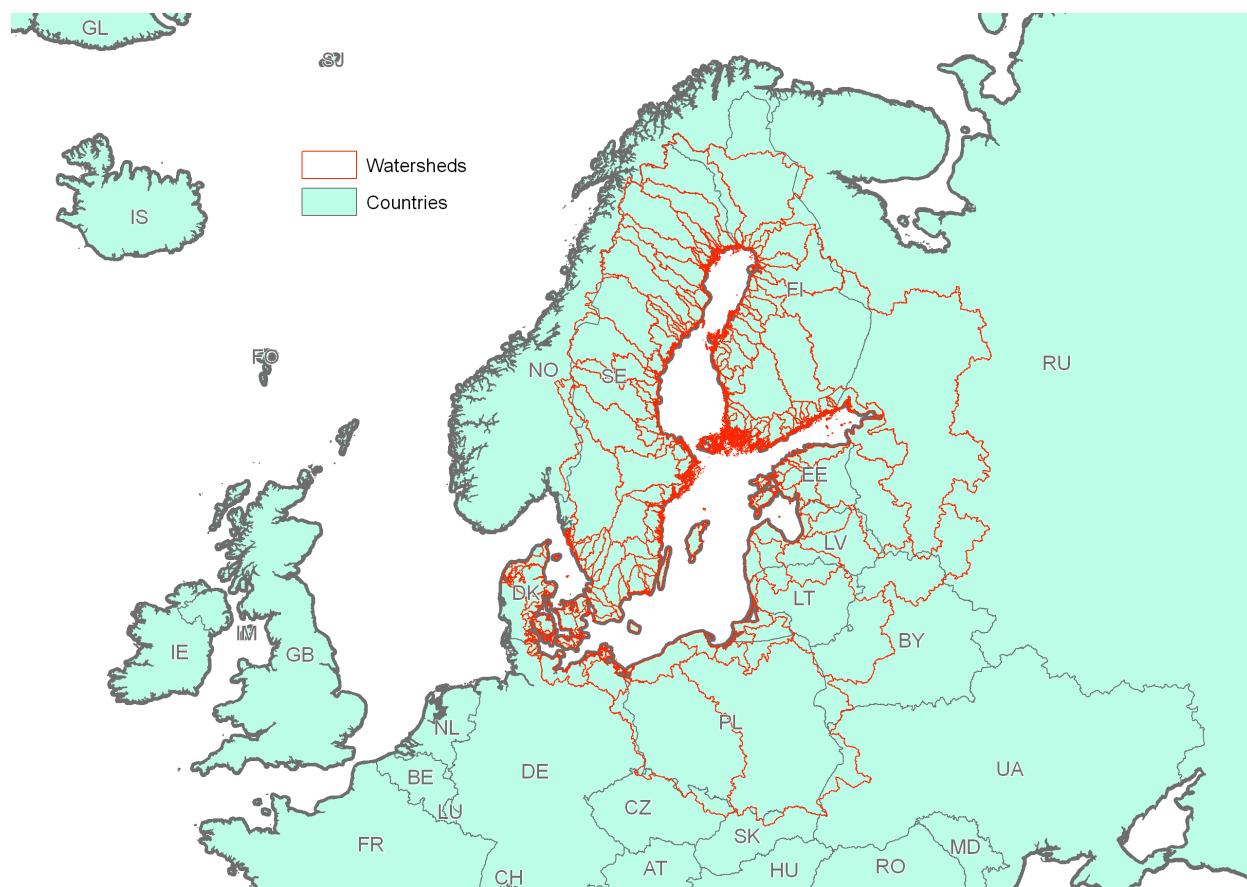


Figure 1.B. Baltic Sea catchments and their surrounding European countries

Version 2.0 of the Toolbox described in this document has several modules and improvements added to version 1.0 (which assumes spatially uniform agricultural practices, i.e., fixed values for all the NANI parameters, supported by the availability of well-established and standardized datasets) to address the above difficulties. These improvements include:

- Allowing spatial variation of NANI parameters (in this example, country-specific NANI parameters) (Sections 4, 5.1, and 5.2)
- Distribution of regional data (e.g., country-level crop production) into smaller spatial units (e.g., grid cells containing crop area information) (Section 5.3)
- Making post-calculation adjustments and refinements by accepting auxiliary datasets and manual calculations from the user (Section 3)

In the following sections we describe the calculation of NANI and their components in the Baltic Sea catchments, with details of data availability, input preparation, and step-by-step procedure of the use of various tools, and provide some preliminary results. In addition, Appendix 1 described parameter values used to create NAPI estimates following an accounting methodology in parallel to that for NANI.

## **2. Atmospheric N Deposition**

### **2.1. Overview**

When a gridded map of atmospheric N deposition for the region of interest is available, watershed N deposition can be calculated by overlaying the deposition map with the watershed map and adding up the deposition values over all of the deposition reporting grid cells (in kg-N deposited per grid cell) falling within each of the watersheds. In this analysis, we used the EMEP deposition data (<http://www.emep.int/>) for the year 2000-2006 (averaged). The EMEP grid covers the entire area of our interest (Figure 2.1.A) at a resolution of 50 km x 50 km. Total or oxidized forms of deposition may be used as the NANI component; in this analysis, atmospheric N deposition included only the oxidized form, assuming that most of the ammonia/ammonium emission from a watershed is redeposited on the same watershed.

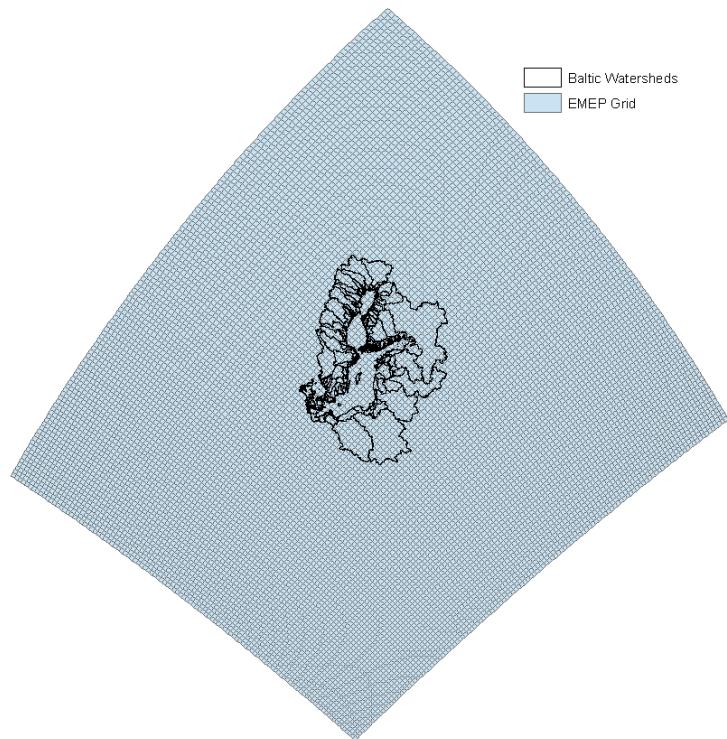


Figure 2.1.A. EMEP grid and map of Baltic Sea catchments.

### **2.2. Data Availability**

The EMEP deposition data (2000-2006 recalculated in 2009) are available at [http://webdab.emep.int/Unified\\_Model\\_Results/AN/](http://webdab.emep.int/Unified_Model_Results/AN/) (Figure 2.2.A):

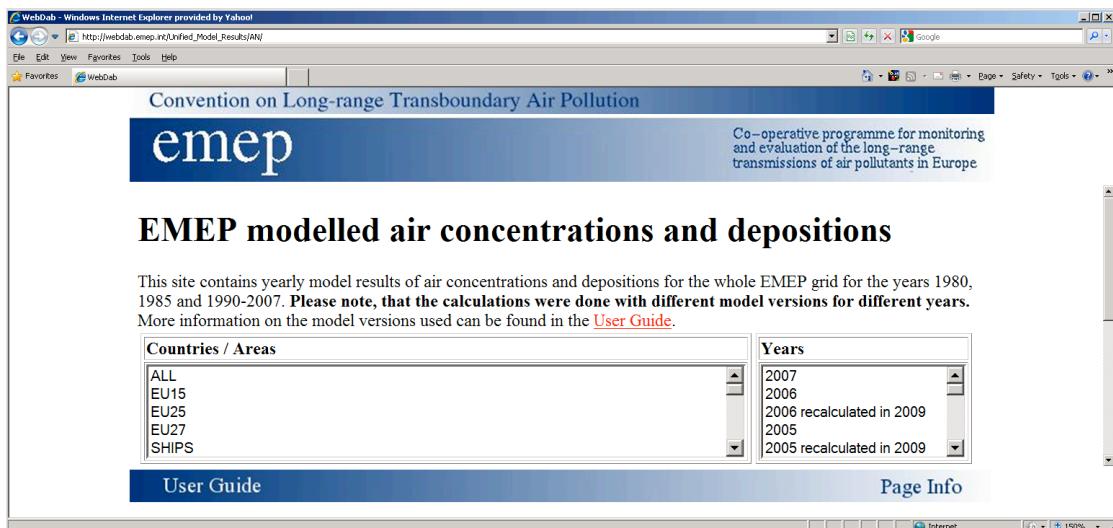


Figure 2.2.A. EMEP website for downloading atmospheric N deposition data.

### 2.3. Input Preparation

The EMEP deposition data downloaded from the EMEP website (Figure 2.2.A) were added to the “Tot\_Ox\_N” (oxidized N deposition) and “Tot\_Red\_N” (reduced N deposition) worksheets of the NANI-extraction tool “NANI\_Extraction\_Tool\_EMEP\_ReCal.xlsxm” (Figure 2.3.A):

NANI_Extraction_Tool_EMEP_ReCal.xlsxm - Microsoft Excel									
	A	B	C	D	E	F	G	H	I
1	# ID	# Format: ISO2	YEAR	SECTOR	COMPONENT	i	j	UNIT	VALUE
3	Cell -17-10	ALL	2006	TOTAL	total ox. nitrogen	-17	-10	mgN/m <sup>2</sup>	0
4	Cell -17-9	ALL	2006	TOTAL	total ox. nitrogen	-17	-9	mgN/m <sup>2</sup>	0
5	Cell -17-8	ALL	2006	TOTAL	total ox. nitrogen	-17	-8	mgN/m <sup>2</sup>	0
6	Cell -17-7	ALL	2006	TOTAL	total ox. nitrogen	-17	-7	mgN/m <sup>2</sup>	0
7	Cell -17-6	ALL	2006	TOTAL	total ox. nitrogen	-17	-6	mgN/m <sup>2</sup>	0
8	Cell -17-5	ALL	2006	TOTAL	total ox. nitrogen	-17	-5	mgN/m <sup>2</sup>	0
9	Cell -17-4	ALL	2006	TOTAL	total ox. nitrogen	-17	-4	mgN/m <sup>2</sup>	0
10	Cell -17-3	ALL	2006	TOTAL	total ox. nitrogen	-17	-3	mgN/m <sup>2</sup>	0
11	Cell -17-2	ALL	2006	TOTAL	total ox. nitrogen	-17	-2	mgN/m <sup>2</sup>	0
12	Cell -17-1	ALL	2006	TOTAL	total ox. nitrogen	-17	-1	mgN/m <sup>2</sup>	0
13	Cell -170	ALL	2006	TOTAL	total ox. nitrogen	-17	0	mgN/m <sup>2</sup>	0
14	Cell -171	ALL	2006	TOTAL	total ox. nitrogen	-17	1	mgN/m <sup>2</sup>	0
15	Cell -172	ALL	2006	TOTAL	total ox. nitrogen	-17	2	mgN/m <sup>2</sup>	0
16	Cell -173	ALL	2006	TOTAL	total ox. nitrogen	-17	3	mgN/m <sup>2</sup>	0
17	Cell -174	ALL	2006	TOTAL	total ox. nitrogen	-17	4	mgN/m <sup>2</sup>	0
18	Cell -175	ALL	2006	TOTAL	total ox. nitrogen	-17	5	mgN/m <sup>2</sup>	0
19	Cell -176	ALL	2006	TOTAL	total ox. nitrogen	-17	6	mgN/m <sup>2</sup>	0
20	Cell -177	ALL	2006	TOTAL	total ox. nitrogen	-17	7	mgN/m <sup>2</sup>	0

Figure 2.3.A. EMEP data downloaded for 2000-2006 periods (recalculated in 2009).

## 2.4. Toolbox Calculation

The following procedure was applied for calculating atmospheric N deposition:

- The proportion of each EMEP grid cell falling onto the watersheds of interest was calculated from the EMEP grid (Figure 2.1.A) and the watershed map.
- EMEP deposition values were extracted from the downloaded EMEP data (Figure 2.3.A) for all the EMEP grid cells that intersect with the watersheds of interest.
- Watershed N deposition was calculated by multiplying the proportion of watershed in each cell and the extracted EMEP deposition value for the corresponding cell, and aggregating them for each watershed.

A step-by-step procedure for calculating atmospheric N deposition is given below, with the screenshots and file names that can be found in the documentation package:

The NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the EMEP grid “EMEP\_Grid.shp” (Figure 2.1.A) and the watershed map “WSWatershed\_v2008\_4.shp” were added (Figure 2.4.A):

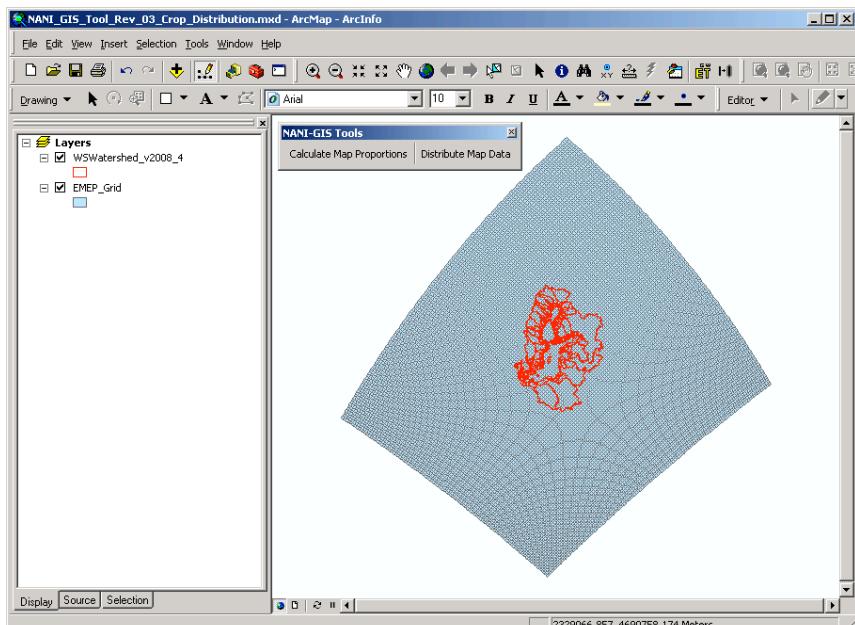


Figure 2.4.A. Running NANI-GIS tool to calculate EMEP grid cell proportion.

The “Calculate Map Proportions” button was clicked, and the tool was specified as shown in Figure 2.4.B:

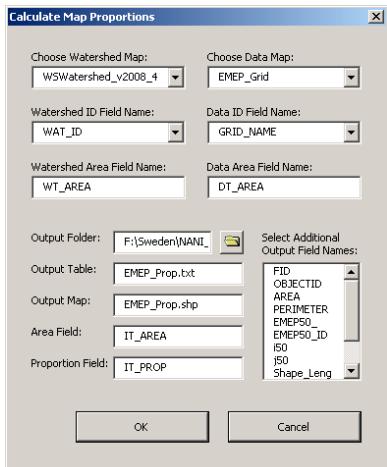


Figure 2.4.B. Specifying NANI-GIS tool to calculate EMEP grid cell proportion.

After running the NANI-GIS tool, a proportion table “EMEP\_Prop.txt” was created, with EMEP grid cells in the rows and watersheds in the columns. This table was imported into the NANI-extraction tool “NANI\_Extraction\_Tool\_EMEP\_ReCal.xlsx” (Figure 2.4.C):

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	GRID_NAME	Area_km2	W9018	W151	W2017	W9019	W149	W2018	W9020	W142	W143	W145	W147
2	-	464.03	51464.56	629.43	745.45	2178.11	12458.89	1877.98	1903.43	6579.13	3152.45	3319.66	
3	Cell 46 84	2688.068723	0	0	0	0	0	0	0	0	0	0	0
4	Cell 43 80	2687.569442	0	0	0	0	0	0	0	0	0	0	0
5	Cell 48 87	2687.215953	0	0	0	0	0	0	0	0	0	0	0
6	Cell 44 81	2686.393926	0	0	0	0	0	0	0	0	0	0	0
7	Cell 58 78	2560.97094	0	0	0	0	0	0	0	0	0	0	0
8	Cell 50 68	2560.565638	0	0	0	0	0	0	0	0	0	0	0
9	Cell 49 67	2560.422494	0	0.557945	0	0	0	0	0	0	0	0	0
10	Cell 51 69	2560.422549	0	0	0	0	0	0	0	0	0	0	0
11	Cell 56 75	2560.493562	0	0	0	0	0	0	0	0	0	0	0
12	Cell 52 70	2559.861292	0	0	0	0	0	0	0	0	0	0	0
13	Cell 61 83	2559.721622	0	0	0	0	0	0	0	0	0	0	0
14	Cell 64 90	2559.922662	0	0	0	0	0	0	0	0	0	0	0
15	Cell 53 71	2559.045681	0	0	0	0	0	0	0	0	0	0	0
16	Cell 62 85	2559.485685	0	0	0	0	0	0	0	0	0	0	0
17	Cell 60 81	2559.11317	0	0	0	0	0	0	0	0	0	0	0
18	Cell 57 76	2558.065183	0	0	0	0	0	0	0	0	0	0	0
19	Cell 63 87	2558.32178	0	0	0	0	0	0	0	0	0	0	0
20	Cell 59 79	2557.630459	0	0	0	0	0	0	0	0	0	0	0
21	Cell 64 89	2556.318201	0	0	0	0	0	0	0	0	0	0	0
22	Cell 58 77	2555.247809	0	0	0	0	0	0	0	0	0	0	0

Figure 2.4.C. EMEP grid cell proportion table created after running NANI-GIS tool.

The “Tot\_Ox\_N” and “Tot\_Red\_N” worksheets (Figure 2.3.A) of the NANI-extraction tool “NANI\_Extraction\_Tool\_EMEP\_ReCal.xlsx” contain the oxidized and reduced N deposition data, respectively, that were downloaded from the EMEP website. The 2000-2006 oxidized N deposition data were extracted by clicking the “Extract” button in the “Extract” worksheet (Figure 2.4.D):

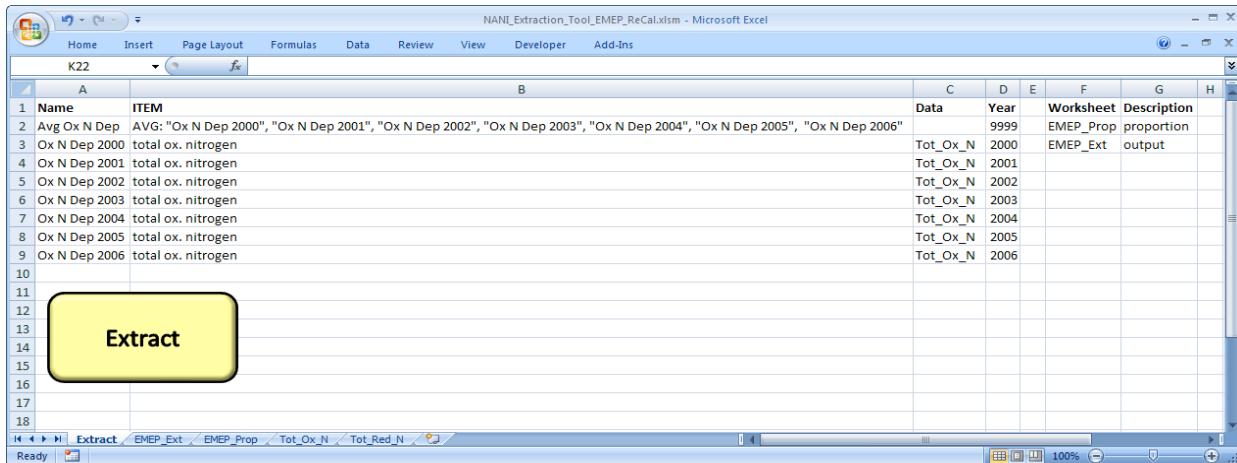


Figure 2.4.D. Extracting oxidized N deposition data using NANI-extraction tool.

As shown in Figure 2.4.D, the 2000-2006 average values were calculated using the “AVG” function of the NANI extraction tool, stored in the “Avg Ox N Dep” variable, and an arbitrary year number “9999” was given. After clicking the “Extract” button, the output worksheet “EMEP\_Ext” was created and the extracted deposition values were reported (Figure 2.4.E):

GRID_NAME	Area_km2	Avg Ox N Dep	Ox N Dep 2000	Ox N Dep 2001	Ox N Dep 2002	Ox N Dep 2003	Ox N Dep 2004	Ox N Dep 2005	Ox N Dep 2006
Cell 46 84	2688.068723	81.59886605	9999	2000	2001	2002	2003	2004	2006
Cell 43 80	2687.569442	81.09722137	67.41091156	73.84780121	65.89893341	110.2994537	67.2852478	93.76663971	89.17156219
Cell 48 87	2687.215953	88.00452641	99.84355164	76.14766993	63.46495056	89.17284393	97.38996887	110.69377114	79.31893150
Cell 44 81	2686.393926	58.52407074	60.70707321	54.79658508	52.80784607	59.08532715	51.2857132	60.94665509	70.03929138
Cell 58 78	2560.97094	242.8339408	278.0358582	257.1302795	186.3877411	250.6339417	219.8277588	262.9746094	244.8473969
Cell 88 68	2560.565638	157.0768062	180.7294922	145.3604736	133.6624908	141.8479309	135.8757018	176.4382629	185.632391
Cell 49 67	2560.422494	130.441306	155.3218994	119.0287323	113.7784119	118.941597	104.8013077	150.1955872	151.0216064
Cell 51 69	2560.422549	167.652335	198.7268372	152.743927	153.4558411	151.863678	145.7998047	182.719635	188.2566223
Cell 56 75	2560.493562	271.1104845	328.660675	281.0102539	217.9480591	290.9571533	242.5385284	283.4665527	253.1921692
Cell 52 70	2559.861292	189.7509809	231.643158	180.9526978	168.0943756	182.3058472	168.2877808	193.9724884	203.0005188
Cell 61 83	2559.721622	228.4398084	243.3280029	217.5667877	179.5032654	263.4154968	229.2157898	241.1516113	224.8977051
Cell 64 90	2559.922662	178.0380031	176.1112671	143.3007507	142.4319611	204.9753418	185.9354553	215.9194641	177.5917816
Cell 53 71	2559.045681	201.5179073	256.2115784	196.5948486	175.4064026	205.4140167	177.9985046	188.9597168	210.0402832
Cell 62 85	2559.485685	212.4495305	224.588623	191.7240601	161.1401215	252.884201	215.056076	240.9614258	200.7922058
Cell 60 81	2559.11317	222.2035348	243.4050293	229.0337372	173.1501312	246.6818848	212.9232178	223.6551208	226.5756226
Cell 57 76	2558.065183	278.4557975	321.788208	299.5151062	214.7536926	295.8543091	249.0738525	292.624176	275.5812378
Cell 63 87	2558.321278	128.5917729	139.4017181	111.073349	100.5597534	148.5175018	138.9537201	142.6403351	118.9960327
Cell 59 79	2557.630459	244.3857618	276.0492859	256.7886963	188.4741203	248.3955383	232.7885132	256.822113	251.3847656
Cell 64 89	2556.318201	197.104841	198.6519012	159.4984283	154.347168	227.7410889	206.2345886	235.6860962	197.5746155
Cell 58 77	2555.247809	271.8836714	305.7702637	294.2689514	209.7370605	287.1307373	242.8006897	295.2263489	268.2516479
Cell 61 82	2554.916457	243.8578578	262.0387878	239.5747681	191.7655792	273.5775146	240.0758362	251.34552	248.6269989
Cell 62 84	2554.995197	242.5463344	258.3493042	215.6895752	190.6884766	280.6799316	247.9502258	266.771637	237.6951904

Figure 2.4.E. Oxidized N deposition data extracted using NANI-extraction tool.

The extraction worksheet “EMEP\_Ext” and the proportion worksheet “EMEP\_Prop” were copied to the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xlsxm”. Atmospheric N deposition was calculated by clicking the “Atmospheric N Deposition” button in the “Atm\_N\_Dep” worksheet (Figure 2.4.F):

**Atmospheric N Deposition**

1	Type	Item Name	Distribute	Reporting	Kilograms Per	Worksheet	Description	Atmospheric N Deposition (kg-N/km <sup>2</sup> /yr)	
				Unit	mg-N/m <sup>2</sup> [AREA]			EMEP_Ext	watershed
				EMEP_Prop	proportion			EMEP_Prop	Oxidized N Deposition
2	Oxidized N Deposition	Avg Ox N Dep						W9018	549.413899
3								W151	345.990393
4								W2017	348.012798
5								W9019	516.465995
6								W149	569.831246
7								W2018	448.734737
8								W9020	552.952542
9								W142	536.442589
10								W143	563.481398
11								W145	561.096222
12								W147	563.895324
13								W2013	464.665696
14								W9021	575.320723
15								W2014	448.220053
16								W1013	556.90868
17								W2015	474.267366
18								W2016	515.732425
19								W9011	489.574343
20								W1011	458.1669
21								W2011	426.659915
22								W9012	423.266918
23									
24									

Figure 2.4.F. Calculating atmospheric N deposition using NANI-accounting tool.

Note that the original EMEP deposition data extracted by the NANI-extraction tool have the unit of “mg-N/m<sup>2</sup>”, which is equivalent to “kg-N/km<sup>2</sup>”. Before the watershed-level aggregation, these values were converted into “kg-N” by setting Cell E2 to “[AREA]” (Figure 2.4.F). (The NANI-accounting tool multiplies the extracted values by their corresponding areas.)

## 2.5. Preliminary Results

Figure 2.5.A below shows the watershed oxidized N deposition in three regions of Baltic Sea catchment areas calculated by NANI toolbox. Relative frequencies of oxidized N deposition are shown in Figure 2.5.B.

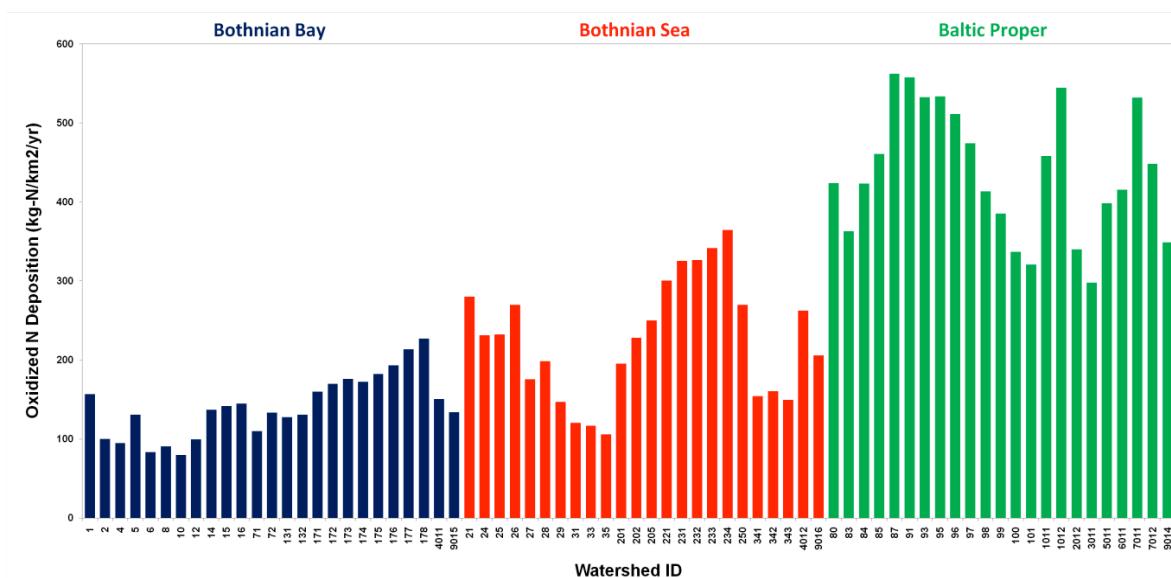


Figure 2.5.A. Oxidized N deposition in Baltic Sea catchments.

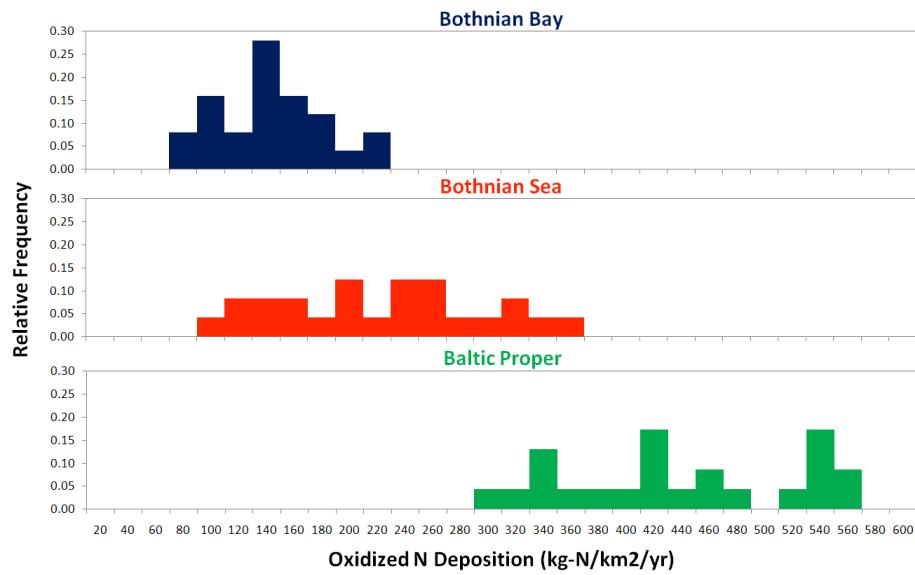


Figure 2.5.B. Relative frequencies of oxidized N deposition in Baltic Sea catchments.

As a check, the watershed oxidized N deposition calculated by NANI toolbox was compared with that by NEST (<http://nest.su.se/nest/>), which also uses EMEP data to estimate atmospheric N deposition. Almost identical results were obtained (Figure 2.5.C):

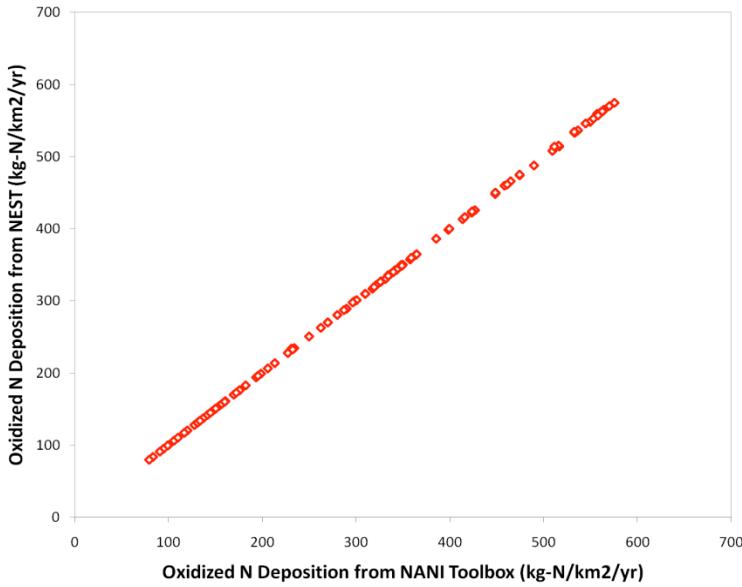


Figure 2.5.C. Comparison of oxidized N deposition calculated by NANI toolbox and NEST.

### 3. Fertilizer N & P Application

#### 3.1. Overview

When a gridded map of fertilizer N application for the region of interest is available, watershed fertilizer N application can be calculated by overlaying the fertilizer map with the watershed map and adding up the fertilizer values over all of the fertilizer reporting grid cells (in kg-N applied per grid cell) falling within each of the watersheds. In practice, however, fertilizer calculation in the Baltic Sea catchments required more effort, because the currently available ISPRA grid containing the fertilizer data (at a resolution of 10 km x 10 km) did not cover the areas of Belarus and Russia (Figure 3.1.A). For these areas, national or regional fertilizer application rates were independently obtained and added as a post-calculation adjustment. In addition, the Poland fertilizer values from ISPRA were compared with data in another independent data source (Section 3.2) and revised again as a post-calculation adjustment. To allow the user to incorporate estimates from supplementary data sources, a general-purpose post-calculation module, “Post\_Calc”, was added to the NANI toolbox (Section 3.4).

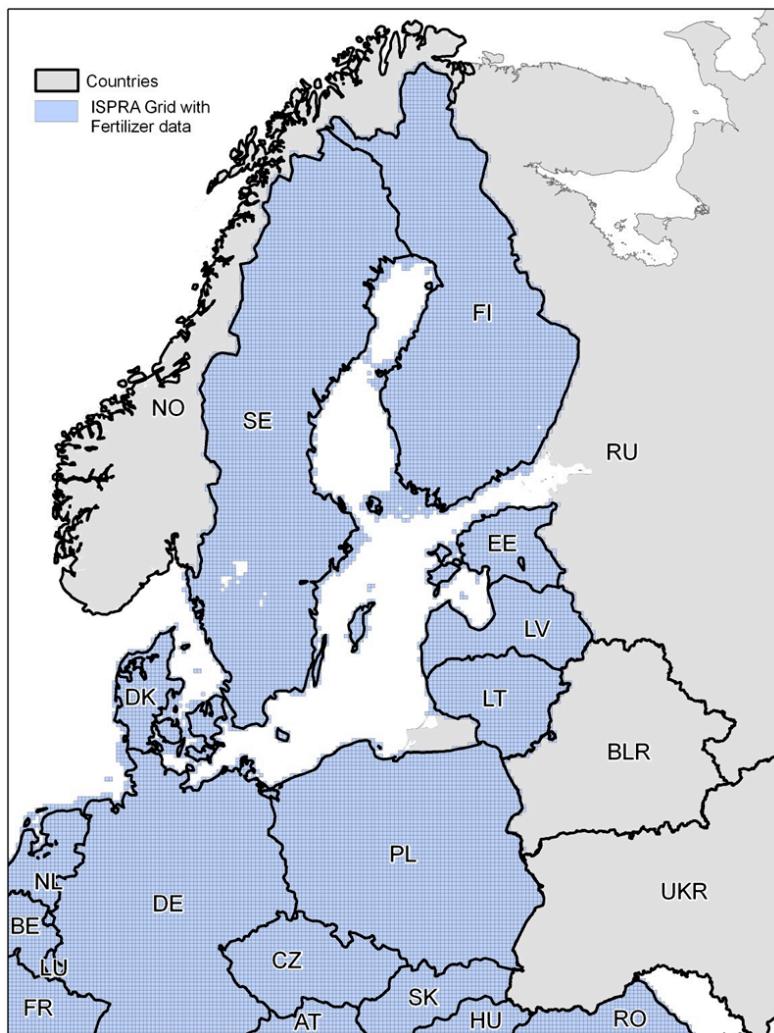


Figure 3.1.A. Map of European countries and available ISPRA grid containing fertilizer application rates.

### 3.2. Data Availability

The fertilizer data were provided as a raster map by ISPRA referring to the same 10 km x 10 km grid cells as the crop types (see Section 5.3). The ISPRA data is published for EU-15 in Grizzetti et al. (2007). The data contained both mineral and manure fertilizer applications for nitrogen and phosphorus in kg for the year 2000. The data referred only to EU25 and not to Belarusian or Russian part of the Baltic Sea drainage area. A comparison between the ISPRA numbers and independent statistics from FAO ([http://www.fao.org/ag/agl/fertistat/fst\\_fubc\\_en.asp](http://www.fao.org/ag/agl/fertistat/fst_fubc_en.asp)) gave reasonable results for the former EU countries (Table 3.2.A). The first data column of Table 3.2.A is the total mineral N from ISPRA (aggregated at the country level) and the second and third data columns are the summed fertilizer consumption values for all crops in each country. The numbers for Denmark, Germany, Sweden, and Finland are fairly similar in magnitude. For Poland, the fertilizer data from ISPRA represent the national production, of which a significant amount is sold to foreign countries, and show a substantial difference from national statistics for fertilizer consumption (fourth data column). The consumption data for the Baltic States vary significantly. This variation can have two possible explanations: either it is actually not consumption but instead production that is in the ISPRA data, or the mineral fertilizer statistics are reported sometimes as the total weight and sometimes as the nutrient weight, i.e., nitrogen.

The average Belarusian national fertilizer N application rate of 1041.24 kg-N/km<sup>2</sup>/yr was reported by FAO ( $216 \times 10^6$  kg-N application divided by Belarusian area of 207,757 km<sup>2</sup>). The mineral fertilizer N and P application data for some Russian Oblasts was made available by IPNI (International Plant Nutrition Institute) (Table 3.2.B).

Table 3.2.A. Comparison of ISPRA and FAO mineral fertilizer data (1000 tonnes N).

Country	ISPRA	FAO (2000)	FAO (2002)	National Statistics	Reference for National Statistics
Denmark	241	252	158	251	Statistics Denmark (2001)
Germany	2043	1996	1788	N/A	
Finland	174	175	179	166	Statistics Finland (2003)
Sweden	164	193	167	174	Statistics Sweden, SCB (2000/01)
Estonia	44.0	20.1	16.7	22.4	Statistics of Estonia (2001)
Lithuania	186	77.4	137	N/A	
Latvia	106	6.4	36.5	37.0	Central Statistical Bureau of Latvia (2000)
Poland	1400	304	832	861	Statistical Yearbook of Agriculture, GUS (2001/02)

Table 3.2.B. Fertilizer data for some Russian Oblasts (data source: International Plant Nutrition Institute).

Oblast	2008		2009		kg per 1 ha of fertilized area	kg per 1 ha of fertilized area
	N (in N)	P (in P2O5)	N (in N)	P (in P2O5)		
	Total, 000' t	Total, 000' t	Total, 000' t	kg per 1 ha of fertilized area	Total, 000' t	kg per 1 ha of fertilized area
Leningradskaya	7.38	1.95	6.67	57.2	1.31	11.2
Kaliningradskaya	8.58	1.59	10.9	121	1.34	14.9
Karelia	0.29	0.07	0.22	36.1	0.06	9.84
Pskovskaya	1.51	0.37	1.85	39.4	0.31	6.60
Novgorodskaya	1.13	0.34	1.32	36.8	0.35	9.75

### 3.3. Input Preparation

#### 3.3.1. ISPRA Data

The mineral fertilizer N application data were available in a 10 km x 10 km ISPRA grid covering Baltic Sea catchments, except for the areas of Belarus and Russia. The ISPRA grid has the column "KeyID" that is used as the unique identifier (Figure 3.3.1.A):

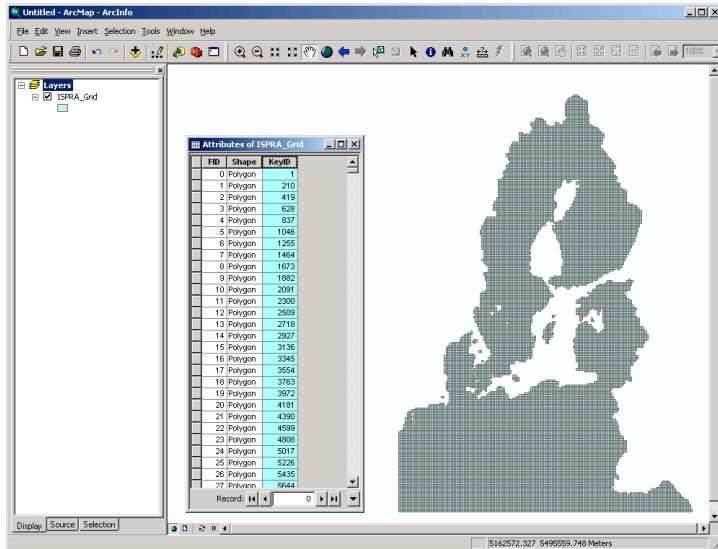


Figure 3.3.1.A. ISPRA grid containing fertilizer application data.

The original fertilizer application data were provided in raster maps containing the mineral and manure fertilizer applications of nitrogen and phosphorus in kg for the year of 2000 (Figure 3.3.1.B):

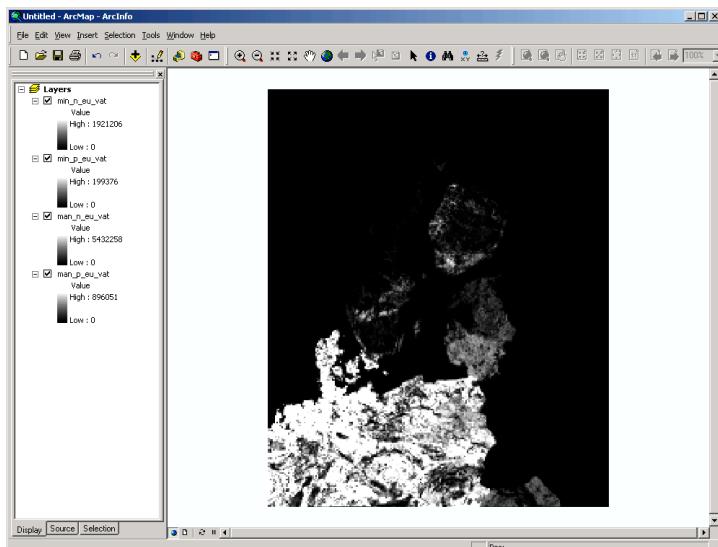


Figure 3.3.1.B. Original fertilizer application data in raster maps.

To convert the raster map values into a table that can be used by the NANI-extraction tool (Section 3.4), the ISPRA grid shapefile (Figure 3.3.1.A) was converted into a point map “ISPRA\_Point.shp”, and then the raster map values were extracted into each column. The columns “MAN\_N”, “MAN\_P”, “MIN\_N”, and “MIN\_P” contain applications of manure N, manure P, mineral N, and mineral P, respectively (Figure 3.3.1.C):

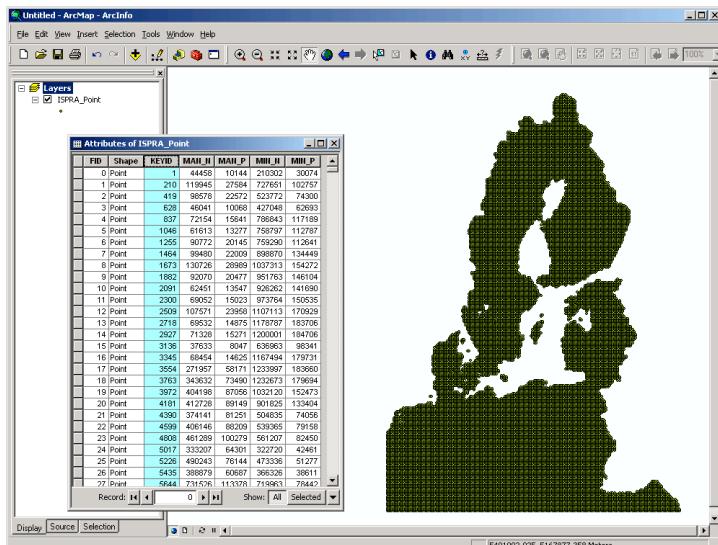


Figure 3.3.1.C. Point map containing fertilizer application rates.

The attribute table of the point map was exported by clicking on “Options > Export” from the attribute table and saving the table as a text file “Fert\_Data.txt” (Figure 3.3.1.D):

FID_	KeyID	MAN_N	MAN_P	MIN_N	MIN_P	DT_AREA
2	1	44458	10144	210302	30074	100
3	210	119945	27584	727651	102757	100
4	419	98578	22572	523772	74300	100
5	628	46041	10068	427048	62693	100
6	837	72154	15641	786843	117189	100
7	1046	61613	13277	758797	112787	100
8	1255	90772	20145	759290	112641	100
9	1464	99480	22009	898870	134449	100
10	1673	130726	28989	1037313	154272	100
11	1882	92070	20477	951763	146104	100
12	2091	62451	13547	926262	141690	100
13	2300	69052	15023	973764	150535	100
14	2509	107571	23958	1107113	170929	100
15	2718	69532	14875	1178787	183706	100
16	2927	71328	15271	1200001	184706	100
17	3136	37633	8047	636963	98341	100
18	3345	68454	14625	1167494	179731	100
19	3554	271957	58171	1233997	183660	100
20	3763	343632	73490	1232673	179694	100

Figure 3.3.1.D. Text file containing fertilizer application rates.

### 3.3.2. Processing Belarusian Data

An average national mineral fertilizer N rate of 1041.24 kg-N/km<sup>2</sup>/yr was reported by FAO (Section 3.2). Five watersheds intersect the areas of Belarus. Fertilizer application was estimated for the missing portions of these watersheds (distributed based on areas) (Table 3.3.2.A):

Table 3.3.2.A. Mineral fertilizer N estimated for watersheds intersecting with areas of Belarus.

Watershed Code	Watershed Name	Watershed Area (km <sup>2</sup> )	Missing Area Intersecting with Belarus (km <sup>2</sup> )	Fertilizer to be Added (kg-N)	Fertilizer to be Added (kg-N/km <sup>2</sup> /yr)
W42	Neva	279,586	812	845,965	3.03
W46	Narva	58,126	179	186,241	3.20
W62	Daugava	84,608	31,119	32,401,883	382.97
W83	Neman	95,925	42,155	43,893,336	457.58
W85	Vistula	193,894	8,549	8,901,301	45.91

### 3.3.3. Processing Russian Data

Eleven watersheds intersect the areas of Russia. For the five Russian Oblasts (Leningradskaya, Kaliningradskaya, Karelia, Pskovskaya, and Novgorodskaya) where the fertilizer N estimates were available (Table 3.2.B), the 2008 and 2009 values were averaged and fertilizer application (in kg-N) for the missing portions of the watersheds was estimated (Table 3.3.3.A). Six Russian Oblasts (Tverskaya, Vologodskaya, Smolenskaya, St. Petersburg, Murmanska, and Arkhangelskaya) did not have fertilizer estimates; for these Oblasts the calculation was made by estimating their fertilizer rates from neighboring Oblasts that had available data (Table 3.3.3.B). These values were combined to calculate the fertilizer to be added, in kg-N/km<sup>2</sup>/yr, for the missing portions of the watersheds (Table 3.3.3.C).

As an alternative estimation, fertilizer application for the Russian portion was calculated from the reduced N deposition using a regression equation (Equation 3.3.3.A) developed from other areas of Baltic Sea catchments ( $N = 72$ , adjusted  $r^2 = 0.739$ ):

$$FT = 10^{-2.846} \times RD^{2.3914} \quad (\text{Equation 3.3.3.A})$$

where FT is fertilizer N application (kg-N/km<sup>2</sup>/yr) and RD is reduced N deposition (kg-N/km<sup>2</sup>/yr).

Fertilizer N application was estimated for the same watersheds by applying this regression equation (Table 3.3.3.D). The fertilizer application estimated from the regression equation was always higher than that from regional statistics. The NANI calculation reported in this document was made with the fertilizer application estimated from regional statistics.

Table 3.3.3.A. Mineral fertilizer N estimated for watersheds intersecting with areas of Russia (Oblasts with available data).

Watershed Code	Watershed Name	Watershed Area (km <sup>2</sup> )	Missing Areas (km <sup>2</sup> )	Leningradskaya	Kaliningradskaya	Karelia	Pskovskaya	Novgorodskaya	Fertilizer to be Added (kg-N)	
				2008 (1000 t)	7.38	8.58	0.29	1.51		
				2009 (1000 t)	6.67	10.9	0.22	1.85		
				Average (1000 t)	7.025	9.74	0.255	1.68		
				Area (km <sup>2</sup> )	84,500	15,100	172,400	55,300		
				Fertilizer (kg-N/km <sup>2</sup> /yr)	83.14	645.03	1.48	30.38	22.15	
W12	Kemijoki	52,513								
W16	Oulujoki	24,242							79	
W42	Neva	279,586		56,747			74,974	16,708	45,204	6,337,583
W46	Narva	58,126			2,124			31,881		1,147,020
W62	Daugava	84,608							4,445	135,023
W83	Neman	95,925				806				520,090
W84	Pregolia	13,419				5,720				3,689,286
W5011	Coast LT & Baltic Proper	1,599				40				25,597
W7012	Coast PL & Baltic Proper	10,778				11				6,910
W8011	Coast RU & Baltic Proper	5,716				4,629				2,985,721
W8012	Coast RU & Gulf of Finland	23,832		18,883				19	1,582	1,605,505

Table 3.3.3.B. Mineral fertilizer N estimated for watersheds intersecting with areas of Russia (Oblasts without available data).

Watershed Code	Watershed Name	Watershed Area (km <sup>2</sup> )	Missing Areas (km <sup>2</sup> )	Tverskaya	Vologodskaya	Smolenskaya	St. Petersburg	Murmanskaya	Arkhangelskaya	Fertilizer to be Added (kg-N)
				Fertilizer (kg- N/km <sup>2</sup> /yr)	26.27	42.31	30.38	83.14	1.48	
W12	Kemijoki	52,513							1,050	1,553
W16	Oulujoki	24,242								
W42	Neva	279,586		7,414		8,489				268
W46	Narva	58,126								601,104
W62	Daugava	84,608		13,260				7,717		582,725
W83	Neman	95,925								
W84	Pregolia	13,419								
W5011	Coast LT & Baltic Proper	1,599								
W7012	Coast PL & Baltic Proper	10,778								
W8011	Coast RU & Baltic Proper	5,716								
W8012	Coast RU & Gulf of Finland	23,832						843		70,122

Table 3.3.3.C. Mineral fertilizer N estimated for watersheds intersecting with areas of Russia (combined).

Watershed Code	Watershed Area (km <sup>2</sup> )	Fertilizer to be Added (kg-N)	Fertilizer to be Added (kg-N/km <sup>2</sup> /yr)
W12	52,513	1,553	0.030
W16	24,242	79	0.0032
W42	279,586	6,938,687	24.82
W46	58,126	1,147,020	19.73
W62	84,608	717,748	8.48
W83	95,925	520,090	5.42
W84	13,419	3,689,286	274.93
W5011	1,599	25,597	16.01
W7012	10,778	6,910	0.64
W8011	5,716	2,985,721	522.39
W8012	23,832	1,675,627	70.31

Table 3.3.3.D. Mineral fertilizer N for Russian portion estimated from reduced N deposition.

Watershed Code	Watershed Area (km <sup>2</sup> )	Missing Area (km <sup>2</sup> )	Reduced Deposition (kg-N/km <sup>2</sup> /yr)	Fertilizer Estimated for Missing Area (kg-N/km <sup>2</sup> /yr)	Fertilizer to be Added (kg-N/km <sup>2</sup> /yr)
W12	52,513	1,050	57.37	22.90	0.46
W16	24,242	53	85.60	59.62	0.13
W42	279,586	210,368	166.82	293.96	221.18
W46	58,126	34,092	230.44	636.56	373.36
W62	84,608	25,421	271.65	943.43	283.46
W83	95,925	806	446.35	3,093.32	26.00
W84	13,419	5,720	439.07	2,974.02	1,267.62
W5011	1,599	40	330.40	1,506.68	37.39
W7012	10,778	11	424.13	2,737.76	2.72
W8011	5,716	4,629	407.80	2,492.42	2,018.52
W8012	23,832	21,328	207.51	495.40	443.34

### 3.3.4. Processing Polish Data

As discussed in Section 3.2, for Poland the fertilizer value from ISPRA (1400 thousand tonnes N) was much higher than that from Statistical Yearbook of Agriculture (861 thousand tonnes N) (Table 3.2.A). The ISPRA value is likely to represent the national production of which a significant amount is sold to foreign countries, rather than the actual fertilizer consumption. Thus, the fertilizer application values for the watersheds intersecting the areas of Poland were corrected to the actual consumption given in the national statistics (Table 3.3.4.A). The correction factor (0.62) was calculated as the fertilizer value from Statistical Yearbook of Agriculture (861 thousand tonnes N) divided by that from ISPRA (1400 thousand tonnes N).

Table 3.3.4.A. Mineral fertilizer N for Poland corrected to actual consumption.

Watershed Code	Watershed Area (km <sup>2</sup> )	Watershed Area		Fertilizer Data from ISPRA (kg-N)	Adjusted Fertilizer (Multiplied by 0.62)	Fertilizer to be Subtracted (kg-N)	Fertilizer to be Subtracted (kg-N/km <sup>2</sup> /yr)
		Intersecting with Poland (km <sup>2</sup> )					
W83	95,925	3,875		13,188,228	8,204,717	4,983,511	51.95
W84	13,419	7,564		36,874,841	22,940,735	13,934,106	1038.40
W85	193,894	173,110		746,914,600	464,673,723	282,240,877	1455.64
W87	118,939	109,637		476,744,969	296,594,630	180,150,339	1514.65
W1012	10,585	445		1,978,679	1,230,985	747,695	70.64
W7011	14,333	14,333		58,253,541	36,240,944	22,012,598	1535.80
W7012	10,778	10,753		48,259,677	30,023,518	18,236,159	1691.95
W8011	5,716	687		2,235,484	1,390,749	844,735	147.80
Sum	463,589	320,405		1,384,450,020	861,300,000	523,150,020	

### 3.4. Toolbox Calculation

The following procedure was applied for calculating fertilizer N application:

- The proportion of each ISPRA grid cell falling onto the watersheds of interest was calculated from the ISPRA grid (Figure 3.1.A) and the watershed map.
- Fertilizer application values were extracted from the ISPRA data (Figure 3.3.1.D) for all the ISPRA grid cells that intersect with the watersheds of interest.
- Watershed fertilizer N application was calculated by multiplying the proportion of watershed in each cell by the extracted ISPRA application value for the corresponding cell and aggregating them for each watershed.
- Post-calculation adjustments were made to fertilizer N application for the Belarusian, Russian, and Polish portions of watersheds, as estimated in Sections 3.3.2 (Table 3.3.2.A), 3.3.3 (Table 3.3.3.C), and 3.3.4 (Table 3.3.4.A), respectively.

A step-by-step procedure for calculating fertilizer N application is given below, with the screenshots and file names that can be found in the documentation package:

The NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the ISPRA grid “ISPRA\_Grid.shp” (Figure 3.1.A) and the watershed map “WSWatershed\_v2008\_4.shp” were added (Figure 3.4.A):

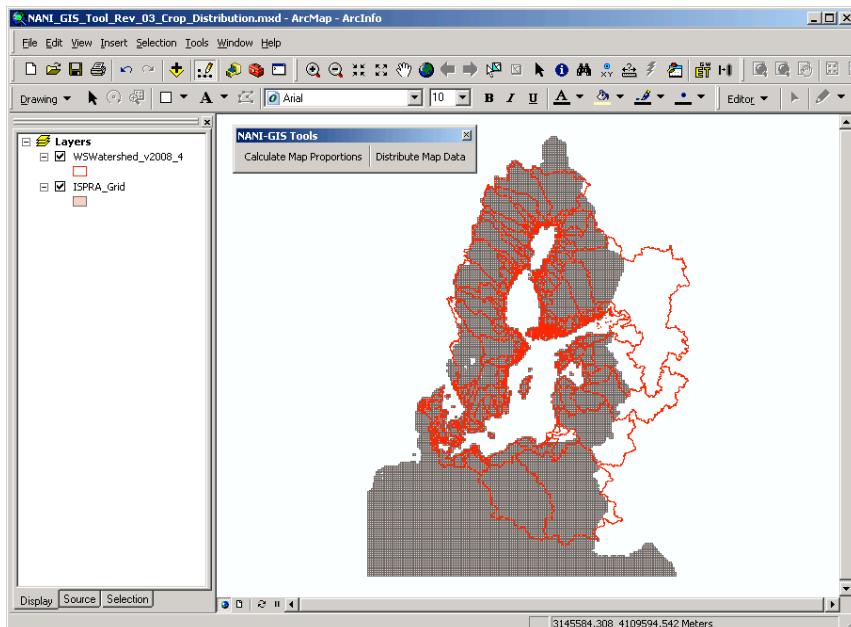


Figure 3.4.A. Running NANI-GIS tool to calculate ISPRA grid cell proportion.

The “Calculate Map Proportions” button was clicked, and the tool was specified as shown in Figure 3.4.B:

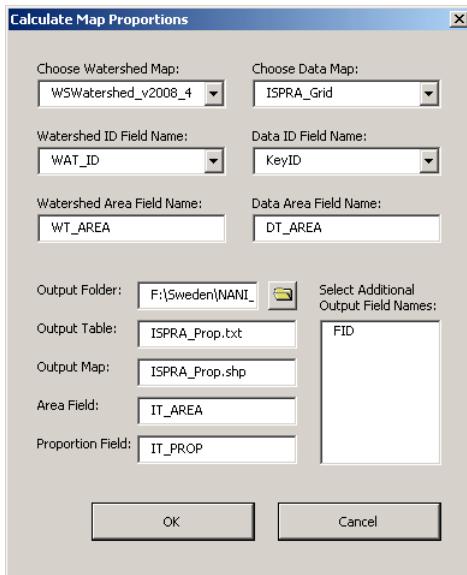


Figure 3.4.B. Specifying NANI-GIS tool to calculate ISPRA grid cell proportion.

After running the NANI-GIS tool, a proportion table “ISPRA\_Prop.txt” was created, with ISPRA grid cells in the rows and watersheds in the columns. This table was imported into the NANI-extraction tool “NANI\_Extraction\_Tool\_Fert.xls” (Figure 3.4.C):

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	KeyID	Area_km2	W9018	W151	W2017	W9019	W149	W2018	W9020	W142	W143	W145	W147	W2013
2	Area_km2 -		464.03	51464.56	629.43	745.45	2178.11	12458.89	1877.98	1903.43	6579.13	3152.45	3319.66	3073.97
3	20094	100	0	0	0	0	0	0.4868	0	0	0	0	0	0
4	20303	100	0	0	0	0	0	0.496	0	0	0	0	0	0
5	20512	100	0	0	0	0	0	0.1504	0	0	0	0	0	0
6	20721	100	0	0	0	0	0	0.131	0	0	0	0	0	0
7	20095	100	0	0	0	0	0	0.482	0	0	0	0	0	0
8	20304	100	0	0	0	0	0	0.0452	0	0	0	0	0	0
9	20513	100	0	0	0	0	0	0.5552	0	0	0	0	0	0
10	20722	100	0	0	0	0	0	0.9409	0	0	0	0	0	0
11	20931	100	0	0	0	0	0	0.5959	0	0	0	0	0	0
12	21140	100	0	0	0	0	0	2.60E-02	0	0	0	0	0	0
13	19887	100	0	0	0	0	0	0.4047	0	0	0	0	0	0
14	20096	100	0	0	0	0	0	0.6246	0	0	0	0	0	0
15	20305	100	0	0	0	0	0	0.509	0	0	0	0	0	0
16	20514	100	0	0	0	0	0	0.5598	0	0	0	0	0	0
17	20723	100	0	0	0	0	0	0.6565	0	0	0	0	0	0
18	20932	100	0	0	0	0	0	1	0	0	0	0	0	0
19	21141	100	0	0	0	0	0	0.5722	0	0	0	0	0	0
20	19679	100	0	0	0	0	0	0.032	0	0	0	0	0	0

Figure 3.4.C. ISPRA grid cell proportion table created after running NANI-GIS tool.

The “Fert\_Data” worksheet of the NANI-extraction tool “NANI\_Extraction\_Tool\_Fert.xls” was imported from the text file “Fert\_Data.txt” (Figure 3.3.1.D) containing the mineral and manure fertilizer data in the ISPRA grid. (As discussed above, the Belarusian and Russian areas are not included.) The fertilizer data were extracted by clicking the “Extract” button in the “Extract” worksheet (Figure 3.4.D):

The screenshot shows a Microsoft Excel spreadsheet titled "NANI\_Extraction\_Tool\_Fert.xlsxm". The "Extract" tab is selected. A yellow rectangular box highlights the "Extract" button located in the center of the worksheet area. The worksheet contains several rows of data with columns labeled "Name", "Item", "Data", "Year", "Worksheet", and "Description". The "Worksheet" column includes entries like "ISPRA\_Prop" and "Fert\_Ext".

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Name	Item	Data	Year	Worksheet	Description								
2	Min N Fert	MIN_N	Fert_Data	2000	ISPRA_Prop	proportion								
3	Min P Fert	MIN_P	Fert_Data		Fert_Ext	output								
4	Man N Fert	MAN_N	Fert_Data											
5	Man P Fert	MAN_P	Fert_Data											
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														
18														

Figure 3.4.D. Extracting fertilizer data using NANI-extraction tool.

After clicking the “Extract” button, the output worksheet “Fert\_Ext” was created and the extracted fertilizer values were reported (Figure 3.4.E):

The screenshot shows the same Microsoft Excel spreadsheet from Figure 3.4.D. The "Fert\_Ext" tab is now selected. The worksheet contains a large dataset with columns labeled "KeyID", "Area\_km2", "Min N Fert", "Min P Fert", "Man N Fert", and "Man P Fert". The data consists of approximately 20 rows of fertilizer application details.

	A	B	C	D	E	F	G	H	I	J	K	L
1	KeyID	Area_km2	Min N Fert	Min P Fert	Man N Fert	Man P Fert						
2			2000	2000	2000	2000						
3	20094	100	719714	60429	1087444	224965						
4	20303	100	286074	24146	435665	90112						
5	20512	100	0	0	0	0						
6	20721	100	1144	74	1548	320						
7	20095	100	579486	48092	869659	179913						
8	20304	100	19986	1662	29398	6083						
9	20513	100	407904	32011	579667	119791						
10	20722	100	604908	47143	862766	178295						
11	20931	100	110468	8509	187170	38698						
12	21140	100	0	0	0	0						
13	19887	100	620558	52124	933960	193208						
14	20096	100	437580	36272	685088	141683						
15	20305	100	360895	29707	536682	111011						
16	20514	100	399862	32170	578146	119512						
17	20723	100	513063	39590	781909	161617						
18	20932	100	724876	56239	1052606	217540						

Figure 3.4.E. Fertilizer data extracted using NANI-extraction tool.

The extraction worksheet “Fert\_Ext” and the proportion worksheet “ISPRA\_Proportion” were copied to the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xlsxm”. Fertilizer N application was calculated by clicking the “Fertilizer N Application” button in the “Fert\_N\_App” worksheet (Figure 3.4.F). Note that the original ISPRA fertilizer data extracted by the NANI-extraction tool have the unit of kilograms and no unit conversion is needed.

NANI\_Accounting\_Tool\_Version\_2.xlsx - Microsoft Excel

R22

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Type	Item Name	Distribute	Unit	Reporting	Kilograms Per		Worksheet	Description	Fertilizer N Application (kg-N/km <sup>2</sup> /yr)			
2	Mineral N Fertilizer	Min N Fert		kg-N		1		Fert_Ext	data	watershed	Mineral N Fertilizer	Mineral P Fertilizer	
3	Mineral P Fertilizer	Min P Fert		kg-N		1		ISPRA_Prop	proportion	2000	2000		
4										W9018	761.897827	88.37048391	
5										W151	489.1010438	59.32244653	
6										W2017	2895.41532	225.9908758	
7										W9019	530.7104765	63.63623424	
8										W149	525.9413414	63.6604427	
9										W2018	5284.398844	396.5363833	
10										W9020	1267.056527	163.8957571	
11										W142	2225.088564	274.4121565	
12										W143	477.3074762	64.56372133	
13										W145	238.4281944	31.83906852	
14										W147	486.0116269	59.83852598	
15										W2013	4293.110762	288.7425906	
16										W9021	2510.867313	315.6135145	
17										W2014	5188.033071	380.8376095	
18										W1013	8108.037299	732.1360743	

Figure 3.4.F. Calculating fertilizer N application using NANI-accounting tool.

The fertilizer calculation so far does not include the missing portions of Belarus (Table 3.3.2.A) and Russia (Table 3.3.3.C), or corrections for Poland (Table 3.3.4.A). To incorporate these additional estimates, a new module, “Post\_Calc”, was added to the NANI toolbox. The user can specify fertilizer values to be modified, estimated from supplementary data sources (e.g., national and regional statistics), in the “Post\_Calc” worksheet as a table with watersheds in the rows and the column heading “Mineral N Fertilizer” (same as specified in Cell A2 of “Fert\_N\_App” worksheet) (Figure 3.4.G):

NANI\_Accounting\_Tool\_Version\_2.xlsx - Microsoft Excel

L721

	A	B	C	D	E	F
1		Fertilizer to be Added (kg-N/km <sup>2</sup> /yr): Belarus	Fertilizer to be Added (kg-N/km <sup>2</sup> /yr): Russia	Fertilizer to be Added (kg-N/km <sup>2</sup> /yr): Poland		
2	watershed	Mineral N Fertilizer	Mineral N Fertilizer	Mineral N Fertilizer		
3		2000	2000	2000		
4	W9018					
5	W151					
6	W2017					
23	W2011					
24	W9012					
25	W87			-1514.65		
26	W91					
27	W93					
28	W95					
29	W1012			-70.64		
30	W2012					
31	W7011			-1535.80		
32	W9013					
33	W47					
34	W80					
35	W83	457.58	5.42	-51.95		
36	W84		274.93	-1038.40		
37	W85	45.91		-1455.64		
38	W96					
39	W97					
40	W98					

Figure 3.4.G. “Post\_Calc” worksheet containing fertilizer estimates to be modified.

These additional estimates were incorporated into the fertilizer calculation by adding the post-calculation worksheet name “Post\_Calc” (Cell G4) to the “Fert\_N\_App” worksheet with the description specified as “post calculation” (Cell H4), and clicking the “Fertilizer N Application” button again (Figure 3.4.H):

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Type	Item Name	Distribute	Reporting Unit	Kilograms Per Reporting Unit	Worksheet	Description	Fertilizer N Application (kg-N/km <sup>2</sup> /yr)					
2	Mineral N Fertilizer	Min N Fert		kg-N		1	Fert_Ext	watershed	Mineral N Fertilizer	Mineral P Fertilizer			
3	Mineral P Fertilizer	Min P Fert		kg-N		1	ISPR_A_Prop	proportion			2000	2000	
4						Post_Calc	post calculation						
5									W9018	761.897827	88.37048391		
6									W151	489.1010438	59.32244653		
7									W2017	2895.41532	225.9908758		
8									W9019	530.7104765	63.63623424		
9									W149	525.9413414	63.6604427		
10									W2018	5284.398844	396.5363833		
11									W9020	1267.056527	163.8957571		
12									W142	2225.088564	274.4121565		
13									W143	477.3074762	64.56372133		
14									W145	238.4281944	31.83906852		
15									W147	486.0116269	59.83852598		
16									W2013	4293.110762	288.7425906		
17									W9021	2510.867313	315.6135145		
18									W2014	5188.033071	380.8376095		
									W1013	8108.037299	732.1360743		

Figure 3.4.H. Incorporating fertilizer estimates to be modified.

### 3.5. Preliminary Results

Figure 3.5.A below shows the watershed fertilizer N application in three regions of Baltic Sea catchment areas calculated by NANI toolbox. Relative frequencies of fertilizer N application are shown in Figure 3.5.B.

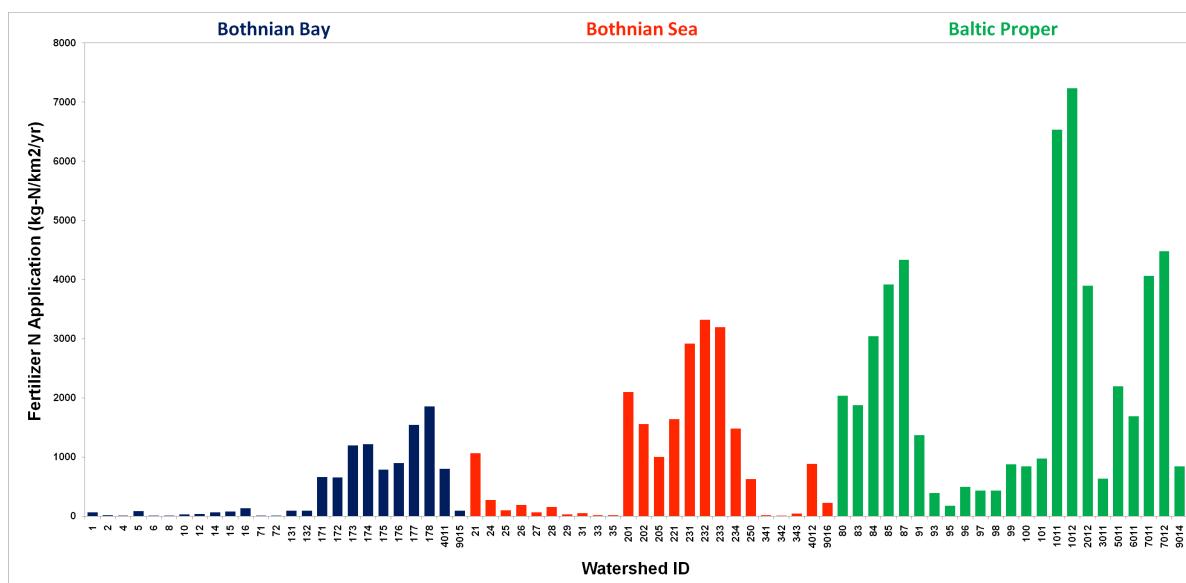


Figure 3.5.A. Fertilizer N application in Baltic Sea catchments.

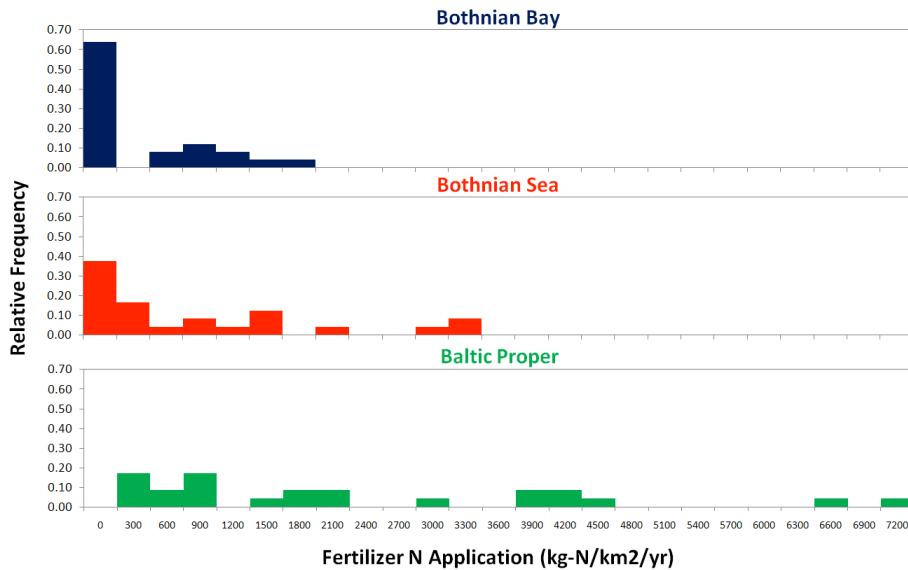


Figure 3.5.B. Relative frequencies of fertilizer N application in Baltic Sea catchments.

#### 4. Agricultural N Fixation

##### 4.1. Overview

When a gridded map of N-fixing crop areas for the region of interest is available, watershed agricultural N fixation can be calculated by overlaying the crop area map with the watershed map, adding up the area values (in hectares or square kilometers for each grid cell or partial grid cell in the watershed) for each crop and for each watershed, and multiplying the crop-specific N fixation rates (in kg-N/ha/yr or kg-N/km<sup>2</sup>/yr) and summing over all crops. In this analysis, we used an extended ISPRA grid that covered the areas of Belarus and Russia (Figure 4.1.A), containing areas of various crops including those fixing nitrogen. Calculating agricultural N fixation in the Baltic Sea catchments was somewhat more challenging than in earlier studies because of significant spatial variation in N fixation rates among European countries. In this analysis, the N fixation parameters were estimated at the country level (Section 4.3) and corresponding modifications were made to the NANI toolbox, allowing the user to incorporate spatial variation in NANI parameters including the N fixation rates (Section 4.4).

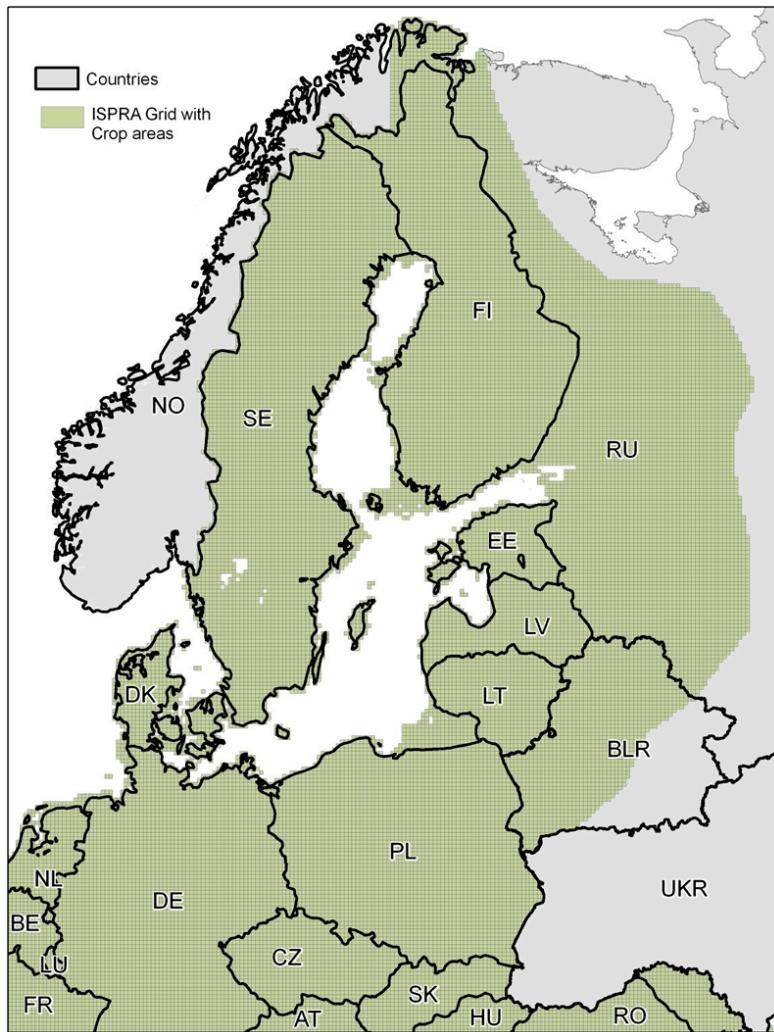


Figure 4.1.A. Map of European countries and extended ISPRA grid containing crop areas.

#### 4.2. Data Availability

A 10 km x 10 km grid, produced by ISPRA, containing harvested areas (in ha) of crop types for the year 2000 was used. This gridded data now covers the entire Baltic drainage area including non-EU countries (Figure 4.1.A). The first version of the dataset from ISPRA covered only the countries in the European Union (Figure 3.1.A) but it has since been extended to also cover the part of Belarus and Russia within the Baltic drainage area. As in the case of fertilizer data (Section 3.3.1), the attribute table of the extended ISPRA grid map has the column “KeyID” that is used as the unique identifier (Figure 4.2.A). The attribute table also contains the crop areas in ha. For example, the column “GRAI” containing areas of pasture and meadow (one of the N fixing areas; see Section 4.3) is shown in Figure 4.2.A.

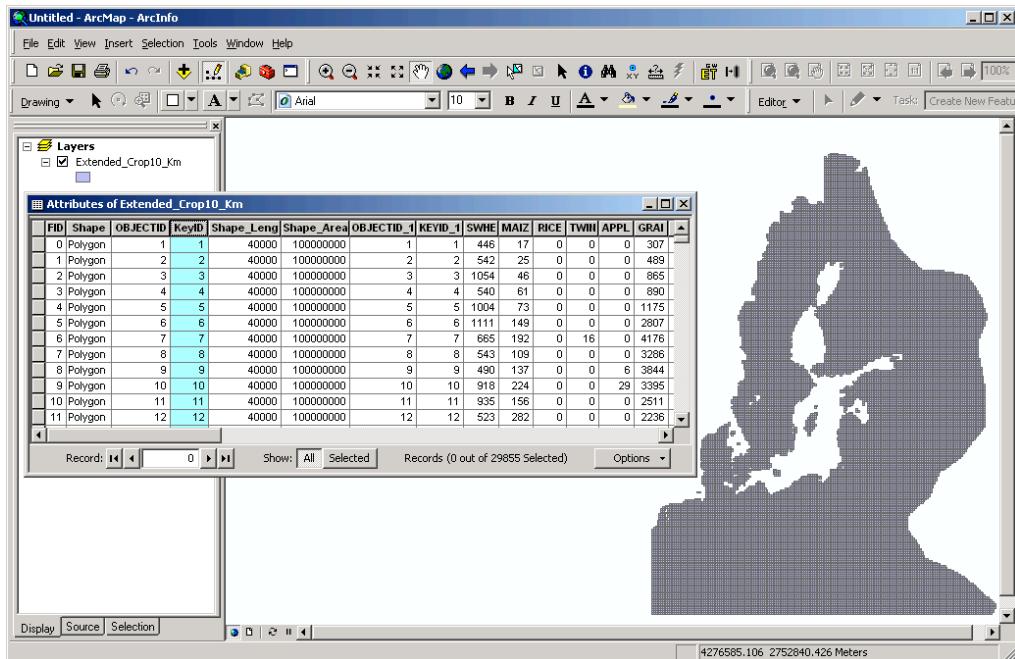


Figure 4.2.A. Extended ISPRA grid containing crop area data.

### 4.3. Input Preparation

The ISPRA grid contains the areas of following crops that potentially fix nitrogen (Table 4.3.A):

- SOYA (Soya Etc): 9600 kg-N/km<sup>2</sup>/yr assumed (Boyer et al. 2002). Not important in Baltic Sea catchments.
- LEFO (Leguminous Plants Etc): We used Lupin and Lucern that have relatively high rates for some countries of 6,000-11,000 kg-N/km<sup>2</sup>/yr.
- GRAI (Pasture and Meadow): We assumed that these are managed grassland or temporary grassland. We grouped them into two classes, the western countries with the N fixation rates of 2,500-3,000 kg-N/km<sup>2</sup>/yr and the transitional countries with 1,100-1,700 kg-N/km<sup>2</sup>/yr.
- GRAE (Rough Grazing): We assumed that this is permanent grassland with a uniform, low fixation rate of 400-500 kg-N/km<sup>2</sup>/yr.
- PULS (Pulses Total): 6,000-17,600 kg-N/km<sup>2</sup>/yr assumed. Country statistics for production and yield available for most countries either from OECD or calculated by Gitte Blicher-Mathiasen. If a value was missing we assumed 6,000 kg-N/km<sup>2</sup>/yr.
- OFAR (Forage Plants Temporary): We assumed rates similar to those of Pasture and Meadow below.
- FALL (Fallow No Subsidies): We assumed uniform and low (400 kg-N/km<sup>2</sup>/yr) rates as indicated by OECD for permanent pasture.
- SETA (Fallow Under Incentive): As with Fallow No Subsidies above, low (400 kg-N/km<sup>2</sup>/yr) rates were assumed.

Table 4.3.A. Crop N fixation parameters estimated for European countries (kg-N/km<sup>2</sup>/yr).

Country Name	Country Code	Soya Etc	Pasture			Pulses Total	Forage Plants Temporary	Fallow No Subsidies	Fallow Under Incentive
			Leguminous Plants Etc	and Meadow	Rough Grazing				
Belarus	BY/BLR	9600	6000	2500	300	6000	2500	400	400
Germany	DE	9600	6560	2560	300	17600	2560	400	400
Denmark	DK	9600	11080	2920	270	13900	2920	400	400
Estonia	EE	9600	6000	2500	290	6910	2500	400	400
Finland	FI	9600	6000	2500	300	8180	2500	400	400
Lithuania	LT	9600	6000	2500	300	6240	1780	400	400
Latvia	LV	9600	6000	2500	150	5990	2500	400	400
Poland	PL	9600	7070	1180	180	7990	1180	400	400
Russian Federation	RU	9600	6000	2500	300	6000	2500	400	400
Sweden	SE	9600	8500	2500	300	9000	2500	400	400
Czech Republic	CZ	9600	6000	2500	300	8000	2500	500	500
Norway	NO	9600	6000	2500	300	9000	2500	400	400
Slovakia	SK	9600	6000	2500	70	7780	650	400	400
Ukraine	UA	9600	6000	2500	300	6000	2500	400	400

This information is included in the attribute table of the shapefile “European\_Countries\_02.shp” (Figure 4.3.A), along with other country-level NANI parameters discussed in Sections 5.1.3 and 5.2.3.

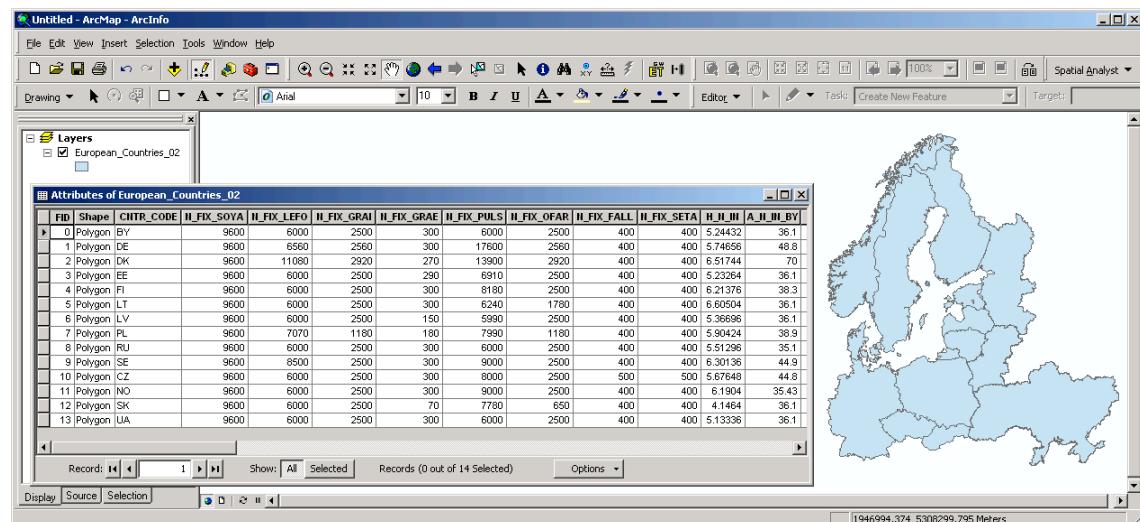


Figure 4.3.A. Map of European countries with their NANI parameters.

#### 4.4. Toolbox Calculation

The following procedure was applied for calculating agricultural N fixation:

- The proportion of each ISPRA grid cell falling onto the watersheds of interest was calculated from the extended ISPRA grid (Figure 4.1.A) and the watershed map.
- Crop area values were extracted from the ISPRA data (Section 4.2) for all the extended ISPRA grid cells that intersect with the watersheds of interest.

- Watershed-specific crop N fixation parameters were estimated from the N fixation parameters provided at the country level (Table 4.3.A).
- Watershed agricultural N fixation was calculated by multiplying the proportion of watershed in each ISPRA cell by the extracted crop area value for the corresponding cell, aggregating the crop areas for each watershed, and multiplying the total by the crop N fixation parameters estimated at the watershed level.

A step-by-step procedure for calculating agricultural N fixation is given below, with the screenshots and file names that can be found in the documentation package:

The NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the extended ISPRA grid “Extended\_Crop10\_Km.shp” (Figure 4.1.A) and the watershed map “WSWatershed\_v2008\_4.shp” were added (Figure 4.4.A):

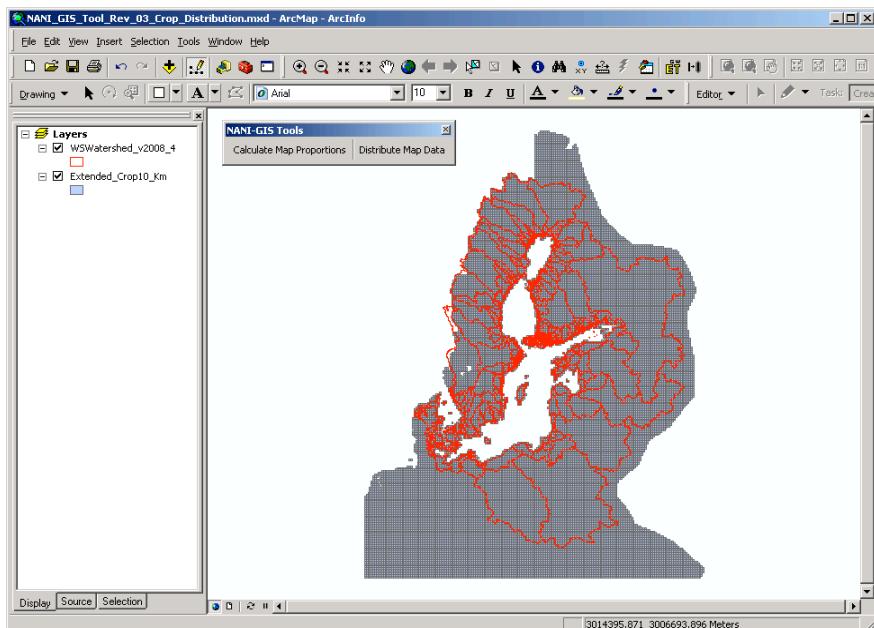


Figure 4.4.A. Running NANI-GIS tool to calculate extended ISPRA grid cell proportion.

The “Calculate Map Proportions” button was clicked, and the tool was specified as shown in Figure 4.4.B:

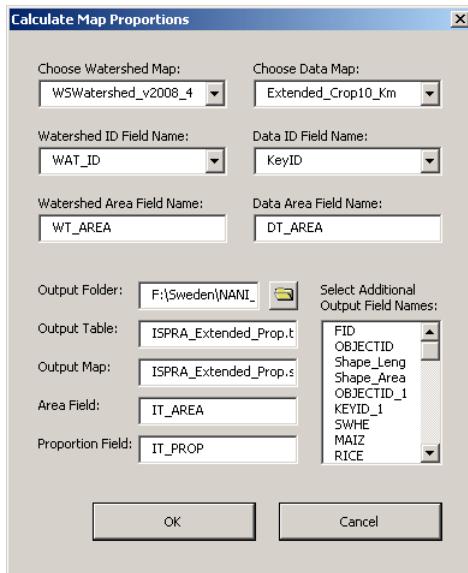
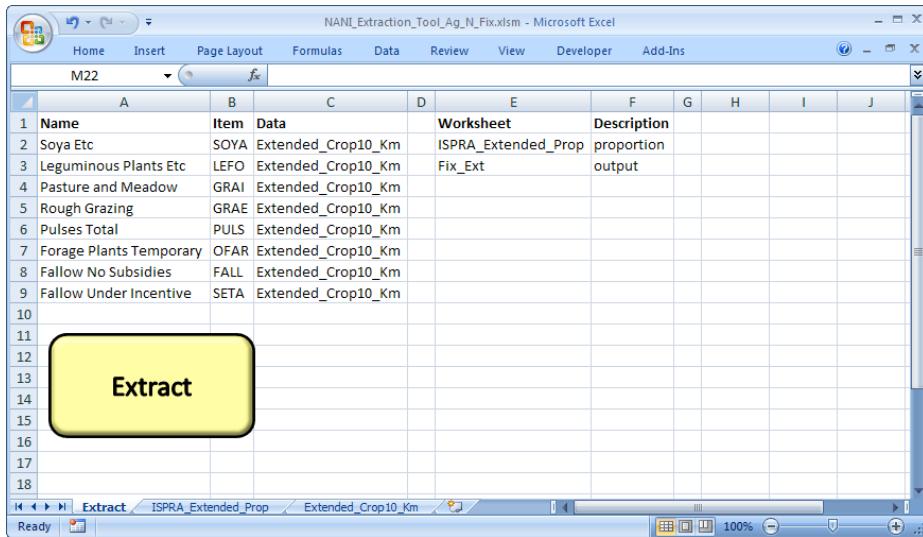


Figure 4.4.B. Specifying NANI-GIS tool to calculate extended ISPRA grid cell proportion.

After running the NANI-GIS tool, a proportion table “ISPRA\_Extended\_Prop.txt” was created, with extended ISPRA grid cells in the rows and watersheds in the columns. This table was imported into the NANI-extraction tool “NANI\_Extraction\_Tool\_Ag\_N\_Fix.xls” (Figure 4.4.C):

Figure 4.4.C. Extended ISPRA grid cell proportion table created after running NANI-GIS tool.

The “Extended\_Crop10\_Km” worksheet, containing the ISPRA crop area data, was imported from the attribute table of the extended ISPRA grid map (Figure 4.2.A). The N fixing crop areas were extracted by clicking “Extract” button in the “Extract” worksheet (Figure 4.4.D):

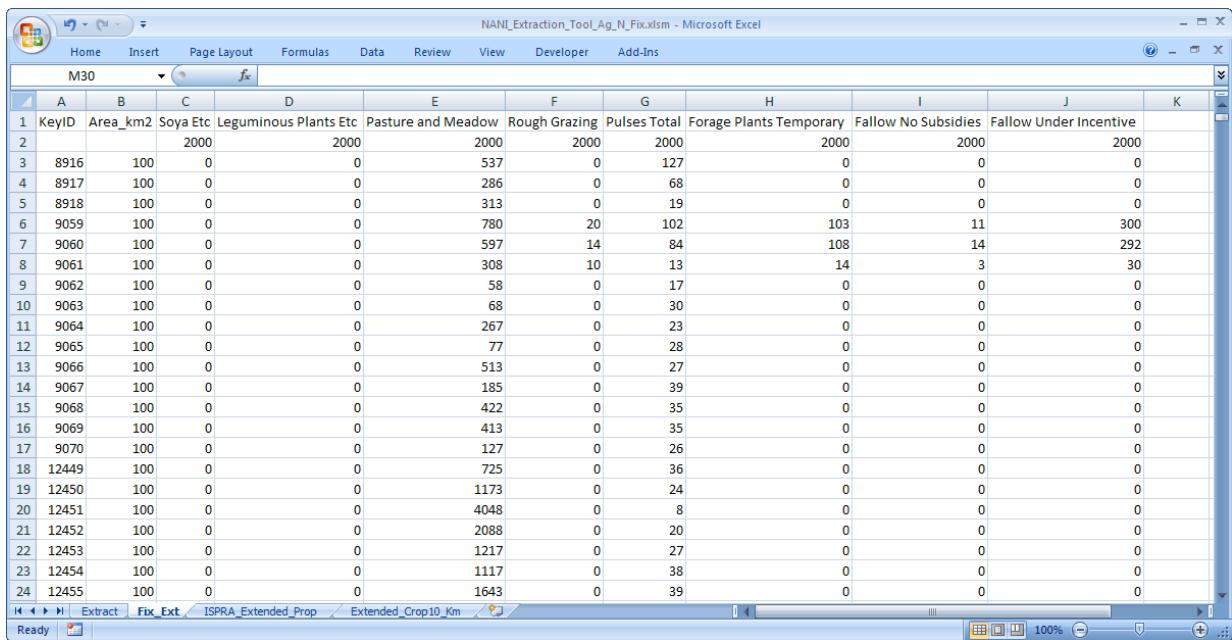


A screenshot of Microsoft Excel showing a table titled "NANI\_Extraction\_Tool\_Ag\_N\_Fix.xlsm - Microsoft Excel". The table has columns A through J. Rows 1 through 9 list various crop types and their corresponding codes and descriptions. Row 10 is blank. Row 11 contains a yellow rectangular button with the word "Extract" in black text. The Excel ribbon at the top shows tabs for Home, Insert, Page Layout, Formulas, Data, Review, View, Developer, and Add-Ins. The status bar at the bottom indicates "Ready".

	A	B	C	D	E	F	G	H	I	J
1	Name	Item	Data		Worksheet	Description				
2	Soya Etc	SOYA	Extended_Crop10_Km		ISPRA_Extended_Proportion	proportion				
3	Leguminous Plants Etc	LEFO	Extended_Crop10_Km		Fix_Ext	output				
4	Pasture and Meadow	GRAI	Extended_Crop10_Km							
5	Rough Grazing	GRAE	Extended_Crop10_Km							
6	Pulses Total	PULS	Extended_Crop10_Km							
7	Forage Plants Temporary	OFAR	Extended_Crop10_Km							
8	Fallow No Subsidies	FALL	Extended_Crop10_Km							
9	Fallow Under Incentive	SETA	Extended_Crop10_Km							
10										
11	Extract									
12										
13										
14										
15										
16										
17										
18										

Figure 4.4.D. Extracting N fixing crop areas using NANI-extraction tool.

After clicking the “Extract” button, the output worksheet “Fix\_Ext” was created and the extracted N fixing crop areas were reported (Figure 4.4.E). The extraction worksheet “Fix\_Ext” and the proportion worksheet “ISPRA\_Extended\_Proportion” were copied to the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xlsm”.



A screenshot of Microsoft Excel showing the "Fix\_Ext" worksheet from the "NANI\_Extraction\_Tool\_Ag\_N\_Fix.xlsm" file. The table has columns A through K. Rows 1 through 24 list various agricultural areas with their respective codes and areas in km². The columns include KeyID, Area\_km2, Soya Etc, Leguminous Plants Etc, Pasture and Meadow, Rough Grazing, Pulses Total, Forage Plants Temporary, Fallow No Subsidies, and Fallow Under Incentive. The Excel ribbon at the top shows tabs for Home, Insert, Page Layout, Formulas, Data, Review, View, Developer, and Add-Ins. The status bar at the bottom indicates "Ready".

	A	B	C	D	E	F	G	H	I	J	K
1	KeyID	Area_km2	Soya Etc	Leguminous Plants Etc	Pasture and Meadow	Rough Grazing	Pulses Total	Forage Plants Temporary	Fallow No Subsidies	Fallow Under Incentive	
2			2000		2000		2000		2000		2000
3	8916	100	0	0	537	0	127	0	0	0	0
4	8917	100	0	0	286	0	68	0	0	0	0
5	8918	100	0	0	313	0	19	0	0	0	0
6	9059	100	0	0	780	20	102	103	11	300	
7	9060	100	0	0	597	14	84	108	14	292	
8	9061	100	0	0	308	10	13	14	3	30	
9	9062	100	0	0	58	0	17	0	0	0	
10	9063	100	0	0	68	0	30	0	0	0	
11	9064	100	0	0	267	0	23	0	0	0	
12	9065	100	0	0	77	0	28	0	0	0	
13	9066	100	0	0	513	0	27	0	0	0	
14	9067	100	0	0	185	0	39	0	0	0	
15	9068	100	0	0	422	0	35	0	0	0	
16	9069	100	0	0	413	0	35	0	0	0	
17	9070	100	0	0	127	0	26	0	0	0	
18	12449	100	0	0	725	0	36	0	0	0	
19	12450	100	0	0	1173	0	24	0	0	0	
20	12451	100	0	0	4048	0	8	0	0	0	
21	12452	100	0	0	2088	0	20	0	0	0	
22	12453	100	0	0	1217	0	27	0	0	0	
23	12454	100	0	0	1117	0	38	0	0	0	
24	12455	100	0	0	1643	0	39	0	0	0	

Figure 4.4.E. N fixing crop areas extracted using NANI-extraction tool.

The calculation of agricultural N fixation uses spatially distributed N fixation parameters estimated at the country level (Table 4.3.A). Watershed-specific crop N fixation parameters were estimated by overlaying the country map that contains NANI parameters (Figure 4.3.A) with the

watershed map. The NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the country map “European\_Countries\_02.shp” and the watershed map “WSWatershed\_v2008\_4.shp” were added (Figure 4.4.F):

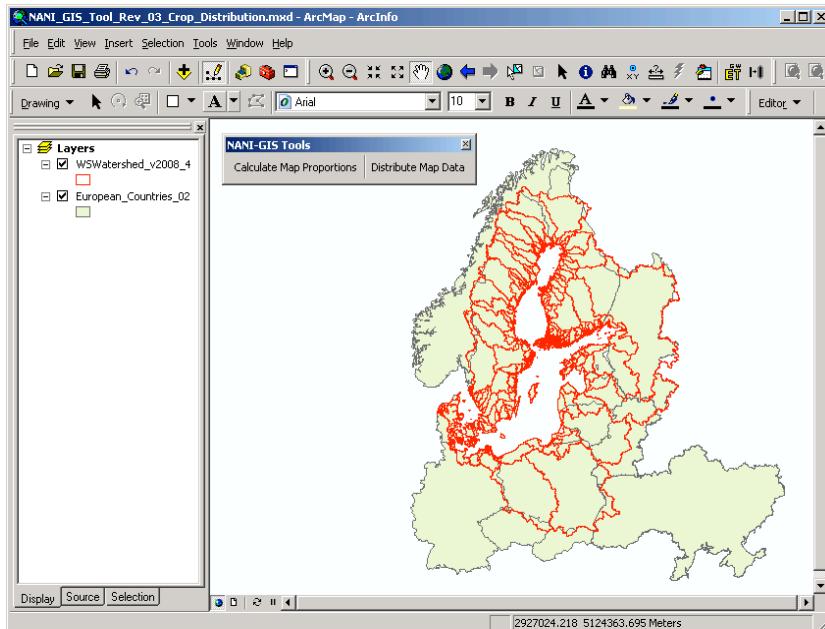


Figure 4.4.F. Running NANI-GIS tool to calculate country proportion.

The “Calculate Map Proportions” button was clicked, and the tool was specified as shown in Figure 4.4.G. (Note that all field names containing country-level NANI parameters were selected as additional output.)

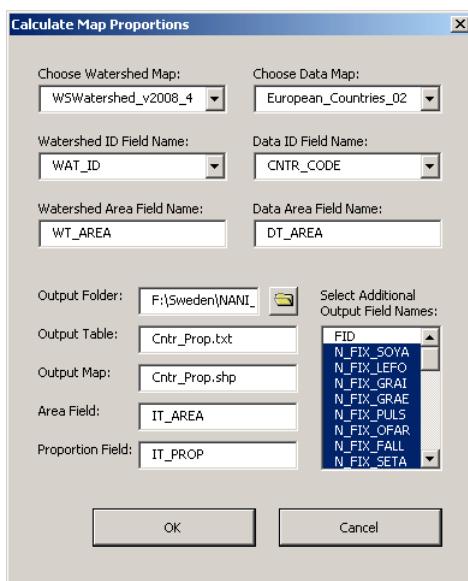


Figure 4.4.G. Specifying NANI-GIS tool to calculate country proportion.

After running the NANI-GIS tool, a proportion table “Cntr\_Prop.txt” was created, with countries in the rows and watersheds in the columns, as well as all the country-level NANI parameters, such as the crop N fixation parameters shown in Table 4.3.A. This table was imported into the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xls” (Figure 4.4.H):

	A	B	C	D	E	F	G	H	I	J	K	AM	AN	AO	AP	AQ
1	CNTR_CODE	N_FIX_SOYA	N_FIX_LEFO	N_FIX_GRAI	N_FIX_GRAE	N_FIX_PULS	N_FIX_OFAR	N_FIX_FALL	N_FIX_SETA	H_N_IN	A_N_IN_BY	Area_km2	W9018	W151	W2017	W9019
2	Area_km2	-	-	-	-	-	-	-	-	-	-	-	464.03	51464.56	629.43	745.45
3	BY	9600	6000	2500	300	6000	2500	400	400	5.24432	36.1	137926.0577	0	0	0	0
4	DE	9600	6560	2560	300	17600	2560	400	400	5.74656	48.8	357353.9731	0	0	0	0
5	DK	9600	11080	2920	270	13900	2920	400	400	6.51744	70	42489.3386	0	0	1.44E-02	0
6	EE	9600	6000	2500	290	6910	2500	400	400	5.23264	36.1	43166.65617	0	0	0	0
7	FI	9600	6000	2500	300	8180	2500	400	400	6.21376	38.3	335047.8523	0	0	0	0
8	LT	9600	6000	2500	300	6240	1780	400	400	6.60504	36.1	64857.91692	0	0	0	0
9	LV	9600	6000	2500	150	5990	2500	400	400	5.36696	36.1	64684.17747	0	0	0	0
10	PL	9600	7070	1180	180	7990	1180	400	400	5.90424	38.9	311282.8098	0	0	0	0
11	RU	9600	6000	2500	300	6000	2500	400	400	5.51296	35.1	326677.7999	0	0	0	0
12	SE	9600	8500	2500	300	9000	2500	400	400	6.30136	44.9	448156.2301	9.22E-04	9.56E-02	0	1.51E-03
13	CZ	9600	6000	2500	300	8000	2500	500	500	5.67648	44.8	79047.50896	0	0	0	0
14	NO	9600	6000	2500	300	9000	2500	400	400	6.1904	35.43	323897.4781	0	2.66E-02	0	0
15	SK	9600	6000	2500	70	7780	650	400	400	4.1464	36.1	49001.63912	0	0	0	0
16	UA	9600	6000	2500	300	6000	2500	400	400	5.13336	36.1	599910.8142	0	0	0	0
17																
18																

Figure 4.4.H. Country-level NANI parameters imported into NANI-accounting tool.

Agricultural N fixation was calculated by clicking the “Agricultural N Fixation” button in the “Ag\_N\_Fix” worksheet (Figure 4.4.I). Note that the country-level NANI parameter worksheet “Cntr\_Prop” is listed in Cell H4, and the column headings containing the spatially varying N fixation parameters are specified in Column F instead of single values.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Type	Item Name	Distribute	Reporting Unit	Square Kilometers Per Reporting Unit (kg-N/km2/yr)	Fixation Rates	Worksheet	Description						
2	Soya Etc	Soya Etc	hectare	0.01 N_FIX_SOYA	Fix_Ext	ISPR_A_Extended_Pro	data proportion							
3	Leguminous Plants Etc	Leguminous Plants Etc	hectare	0.01 N_FIX_LEFO										
4	Pasture and Meadow	Pasture and Meadow	hectare	0.01 N_FIX_GRAI			Cntr_Prop	parameters						
5	Rough Grazing	Rough Grazing	hectare	0.01 N_FIX_GRAE										
6	Pulses Total	Pulses Total	hectare	0.01 N_FIX_PULS										
7	Forage Plants Temporary	Forage Plants Temporary	hectare	0.01 N_FIX_OFAR										
8	Fallow No Subsidies	Fallow No Subsidies	hectare	0.01 N_FIX_FALL										
9	Fallow Under Incentive	Fallow Under Incentive	hectare	0.01 N_FIX_SETA										
10														
11														
12	Agricultural N Fixation													
13														
14														
15														

Figure 4.4.I. Calculating agricultural N fixation using NANI-accounting tool.

The NANI toolbox also reports the watershed-specific agricultural N fixation parameters, calculated as the area-weighted averages of country-level parameters used for calculating watershed agricultural N fixation. The reported values can be found in the “Cntr\_Prop” worksheet below the country proportion table (Figure 4.4.J):

Figure 4.4.J. Watershed-specific agricultural N fixation parameters calculated by NANI toolbox.

## 4.5. Preliminary Results

Figure 4.5.A shows the watershed agricultural N fixation in three Baltic Sea catchment regions calculated with the NANI toolbox. Relative frequencies of agricultural N fixation in Baltic Sea catchments are shown in Figure 4.5.B. Figure 4.5.C shows the watershed agricultural N fixation by crop type (area-weighted averages over all watersheds). Because of limited ISPRA area information in the eastern Baltic Sea catchments, an alternative calculation was made testing its sensitivity:

- Areas of temporary grasslands (OFAR) and fallow lands (FALL and SETA), which were assumed to fix N, may be missing in Russia, Belarus, Estonia, Latvia, Lithuania, and Poland. Unfortunately, it's not entirely clear if the data are really missing, if there are actually no such areas, or if they are classified differently. As a test, it was assumed that these areas were missing and they were added manually based on available data in other countries, and spatially varying parameters as shown in Table 4.3.A were applied.
- Similarly, the pulse (PULS) area is missing in Russia. There are some productions reported (but not many) in the FAO data. This area was estimated from average crop density in other countries and spatially varying parameters (Table 4.3.A) were again applied.

- In some countries GRAE (rough grazing) areas are missing or close to zero, whereas in countries like Russia they are exactly the same as GRAI (pasture and meadow). Since these two classes, when combined, represent “permanent grasslands”, it is possible that it reflects the discrepancy in the classification scheme among different countries. This could be a problem because we assumed about 10 times higher values of N fixation rates for GRAI than for GRAE (Table 4.3.A). To investigate its importance in the overall NANI calculation, these two classes were combined into one and the N fixation parameters for GRAI were applied.

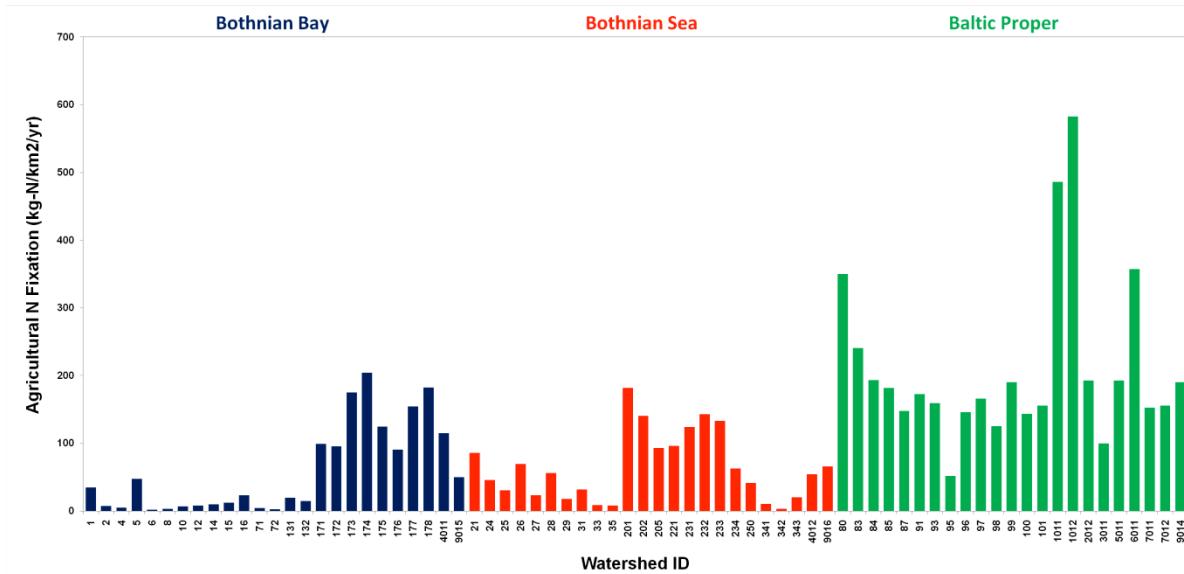


Figure 4.5.A. Agricultural N fixation in Baltic Sea catchments.

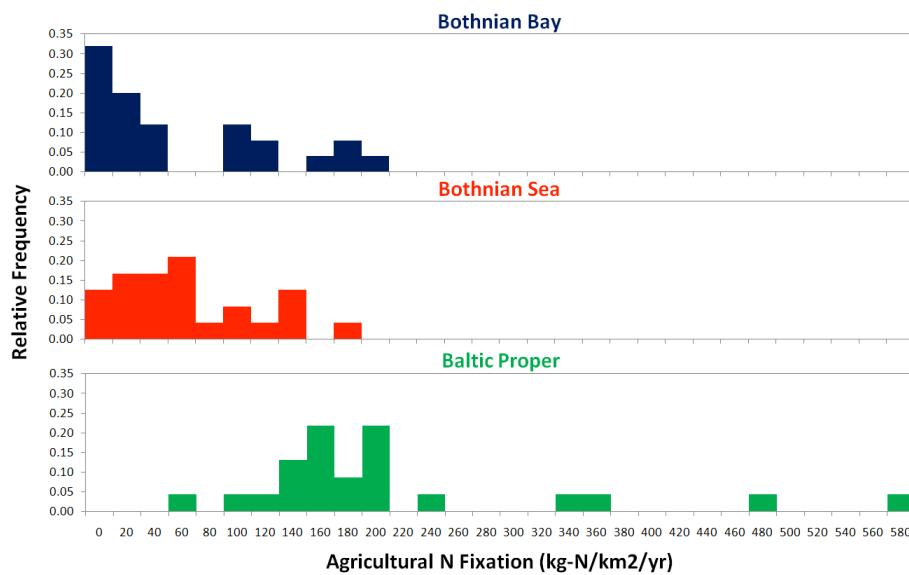


Figure 4.5.B. Relative frequencies of agricultural N fixation in Baltic Sea catchments.

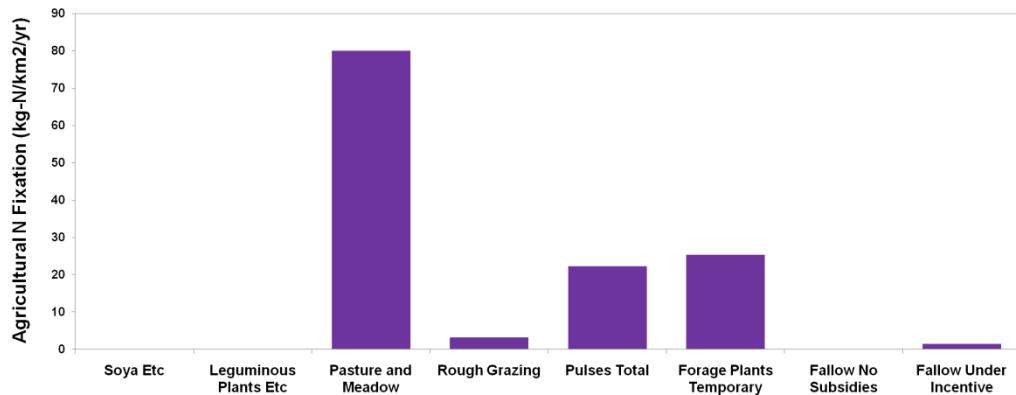


Figure 4.5.C. Agricultural N fixation by crop type.

These changes should increase agricultural N fixation (and, consequently, NANI), particularly for the eastern Baltic Sea catchments, including the Russian watersheds. Figure 4.5.D shows the original (left) and alternative (right) calculations of agricultural N fixation. Figure 4.5.E shows the original (left) and alternative (right) NANI calculated from the corresponding agricultural N fixation. Overall, the alternative approach indeed increased the agricultural N fixation in the eastern Baltic Sea catchments, but its impact on NANI seems to be minimal. It is not clear which version of the N fixation calculation would be better or more accurate. The alternative approach may not necessarily be better as it has more assumptions and also a chance of double counting. (For example, SETA may have been counted as pasturelands in some countries.)

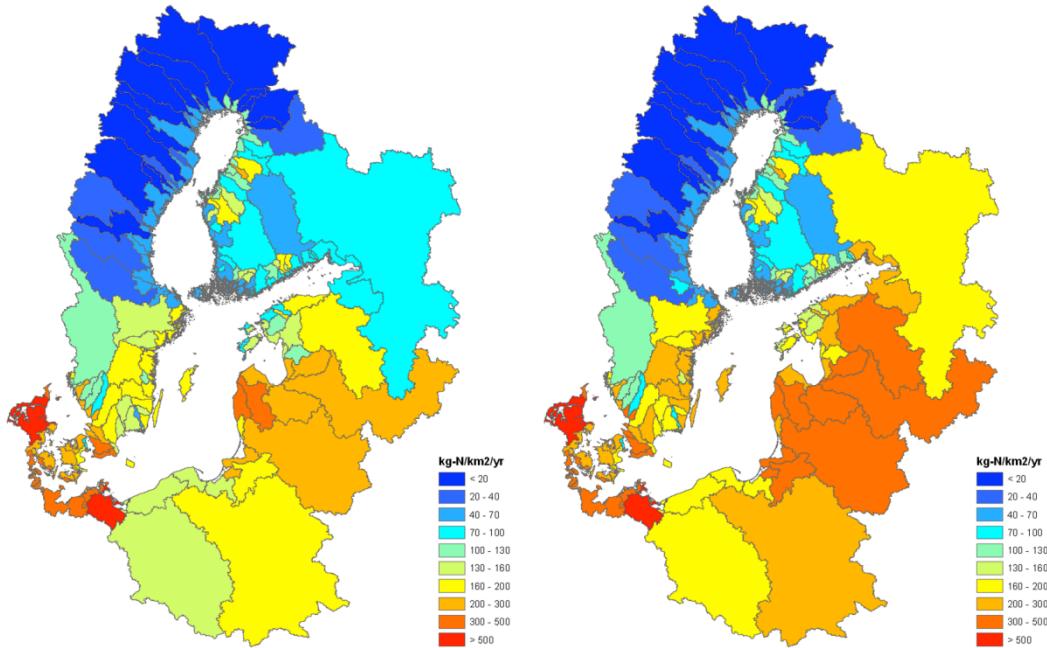


Figure 4.5.D. Agricultural N fixation calculated with original (left) and alternative (right) approaches.

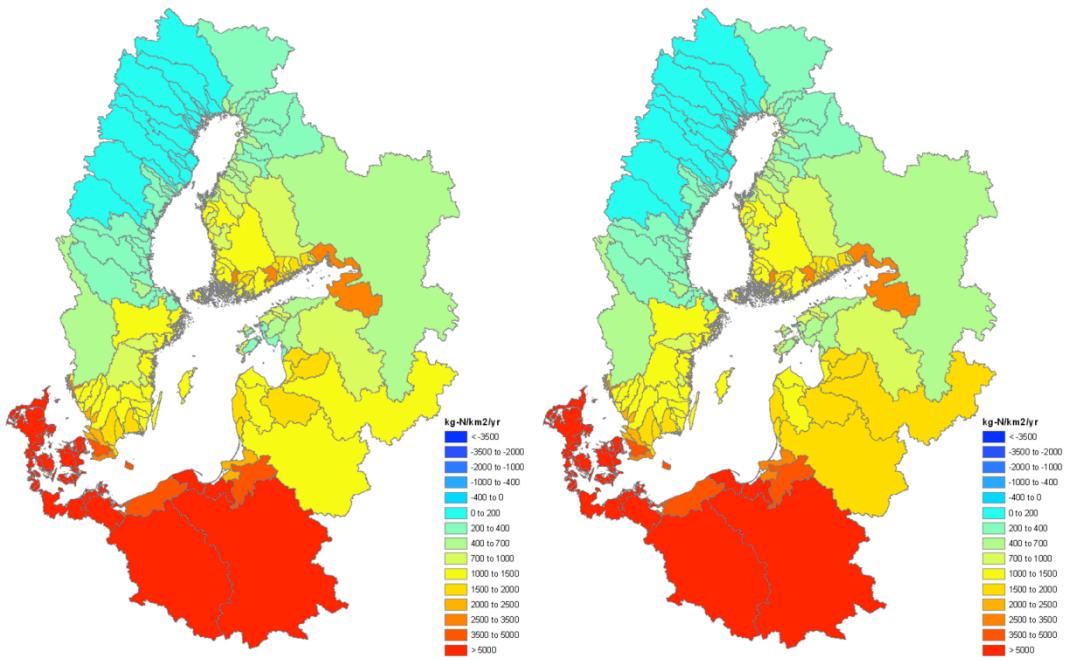


Figure 4.5.E. NANI calculated with original (left) and alternative (right) approaches.

## 5. Net Food and Feed Imports

The net food and feed imports (one of the four major components of NANI) are composed of crop and animal N production (negative fluxes removing N from watersheds) and animal and human N consumption (positive fluxes adding N to watersheds). Calculations of human N consumption (Section 5.1), animal N consumption and N production (Section 5.2), and crop N production (Section 5.3) are performed in the “People”, “Animals”, and “Crops” worksheets, respectively, of the NANI-accounting tool. These results in turn are used for calculating net food and feed imports in the “Food\_Feed\_N” worksheet, as described in Section 5.4.

### 5.1. Human N Consumption

#### 5.1.1. Overview

When a gridded population map for the region of interest is available, watershed human N consumption can be calculated by overlaying the population map with the watershed map, adding up the count values for all grid cells or partial grid cells in each of the watersheds, and multiplying the population density (in individuals/km<sup>2</sup>) by the human N intake parameter (in kg-N/person/year). In this analysis, we used the HYDE population grid (Figure 5.1.1.A) available in 2005:

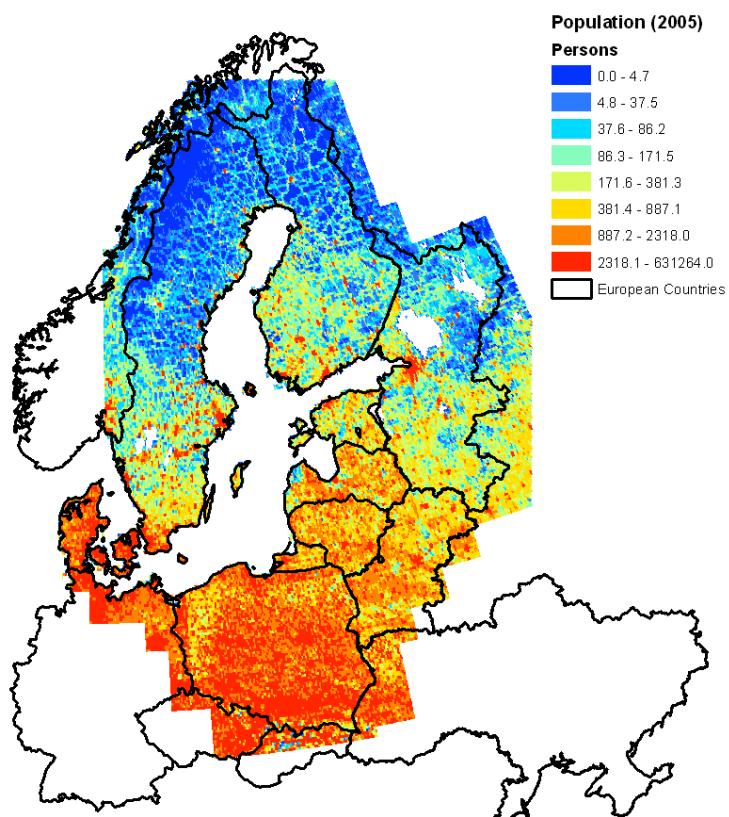


Figure 5.1.1.A. Map of European countries and HYDE population grid.

The calculation of human N consumption in the Baltic Sea catchments was somewhat more challenging than that of earlier studies because of significant spatial variation in human N intake rates among European countries. In this analysis, the human N intake parameters were estimated at the country level (Section 5.1.3), and an updated NANI toolbox which allows the user to incorporate spatial variation in NANI parameters was applied (Section 5.1.4).

### 5.1.2. Data Availability

The HYDE population data is developed under the authority of the Netherlands Environmental Assessment Agency and was downloaded from <http://www.pbl.nl/en/themasites/hyde/index.html>. The data is on a 5' by 5' latitude/longitude grid. The year 2005 was chosen as the most recent year of the years available. (The previous available year was 2000.) The data consisted of rural, urban, and total population.

### 5.1.3. Input Preparation

The HYDE population grid in 2005, described in Section 5.1.2, was clipped for the area of interest. The original data were in a raster format, with separate maps for the total, urban, and rural populations. These data were combined into different columns of the shapefile “Population\_2005.shp” representing the population grid. The population map “Population\_2005.shp” has the column “ID” that is used as a unique identifier (Figure 5.1.3.A):

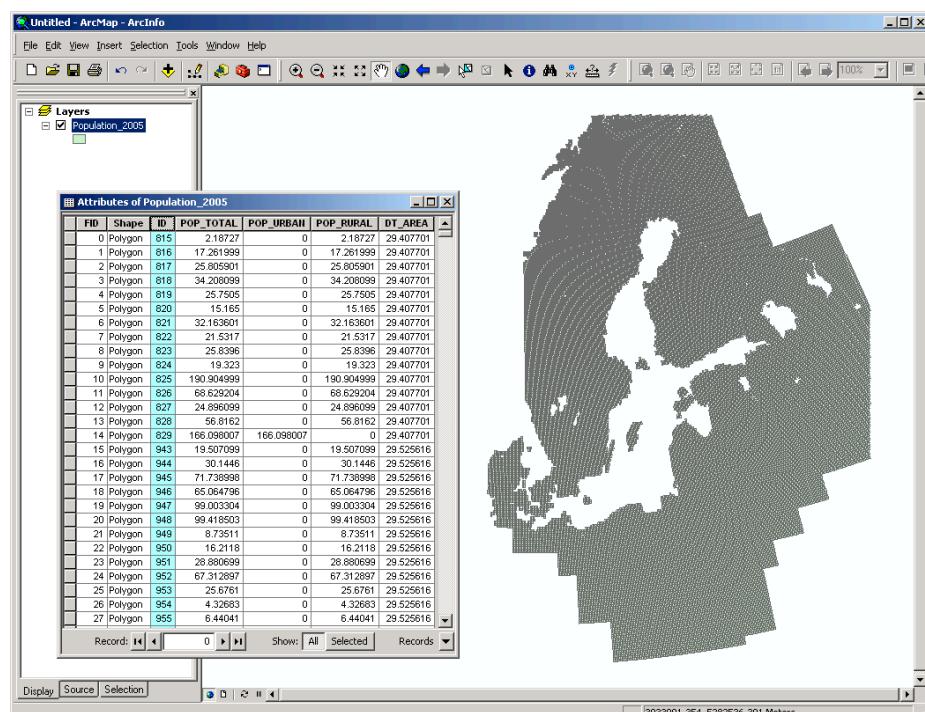


Figure 5.1.3.A. Shapefile containing 2005 HYDE population data.

The attribute table of “Population\_2005.shp” was exported as a text file “Pop\_Data.txt” to be used as a data worksheet of the NANI-extraction tool “NANI\_Extraction\_Tool\_People.xlsm” described in Section 5.1.4 (Figure 5.1.3.B). (Alternatively, the dbf file “Population\_2005.dbf” may be imported directly into the NANI-extraction tool.)

	B1	f(x)	ID	C	D	E	F	G	H	I
1	FID_	ID		POP_TOTAL	POP_URBAN	POP_RURAL	DT_AREA			
2		815	2.187269	0	2.187269	29.4077				
3		816	17.261999	0	17.261999	29.4077				
4		817	25.8059	0	25.8059	29.4077				
5		818	34.208099	0	34.208099	29.4077				
6		819	25.750499	0	25.750499	29.4077				
7		820	15.164999	0	15.164999	29.4077				
8		821	32.1636	0	32.1636	29.4077				
9		822	21.5317	0	21.5317	29.4077				
10		823	25.839599	0	25.839599	29.4077				
11		824	19.322999	0	19.322999	29.4077				
12		825	190.904998	0	190.904998	29.4077				
13		826	68.629203	0	68.629203	29.4077				
14		827	24.896099	0	24.896099	29.4077				
15		828	56.8162	0	56.8162	29.4077				
16		829	166.098007	166.098007	0	29.4077				
17		943	19.507099	0	19.507099	29.525615				
18		944	30.144599	0	30.144599	29.525615				
19		945	71.738998	0	71.738998	29.525615				
20		946	65.064796	0	65.064796	29.525615				

Figure 5.1.3.B. Population data imported into NANI-extraction tool.

Table 5.1.3.A below summarizes the estimation of human N intake parameters (in kg-N/capita/year) for the European countries. This information is included in the attribute table of the shapefile “European\_Countries\_02.shp” (Figure 4.3.A), along with other country-level NANI parameters discussed in Sections 4.3 and 5.2.3.

Table 5.1.3.A. Human N intake parameters for European countries.

Country Name	Country Code	Protein Consumption (g/capita/day)	Human N Consumption (kg-N/capita/year)
Belarus	BY/BLR	89.8	5.24
Germany	DE	98.4	5.75
Denmark	DK	111.6	6.52
Estonia	EE	89.6	5.23
Finland	FI	106.4	6.21
Lithuania	LT	113.1	6.61
Latvia	LV	91.9	5.37
Poland	PL	101.1	5.90
Russian Federation	RU	94.4	5.51
Sweden	SE	107.9	6.30
Czech Republic	CZ	97.2	5.68
Norway	NO	106	6.19
Slovakia	SK	71	4.15
Ukraine	UA	87.9	5.13

The average protein consumption (PROT, grams raw protein per capita and year) has been estimated country wise by FAOSTAT Food Balance Sheets in 2005 available at: <http://faostat.fao.org/site/368/default.aspx#ancor>. We then recalculated the protein consumption (g/capita/day) to nitrogen consumption (NT, kg-N/capita/year), using the nitrogen conversion factor (NCF) of 6.25 (Jones 1941). See Equation 5.1.3.A:

$$NT = ((PROT/1000)/NCF) \times 365 \quad (\text{Equation 5.1.3.A})$$

#### 5.1.4. Toolbox Calculation

The following procedure was applied for calculating human N consumption:

- The proportion of each HYDE population grid cell falling onto the watersheds of interest was calculated from the HYDE grid map (Figure 5.1.3.A) and the watershed map.
- Population count values were extracted from the HYDE data for all the HYDE grid cells that intersect with the watersheds of interest.
- Watershed-specific human N intake parameters were estimated from the N intake parameters provided at the country level (Table 5.1.3.A).
- Watershed human N consumption was calculated by multiplying the proportion of watershed in each HYDE cell by the extracted population count value for the corresponding cell, aggregating the population for each watershed, and multiplying the total by the human N intake parameters estimated at the watershed level.

A step-by-step procedure for calculating human N consumption is given below, with the screenshots and file names that can be found in the documentation package:

The NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the HYDE grid “Population\_2005.shp” (Figure 5.1.3.A) and the watershed map “WSWatershed\_v2008\_4.shp” were added (Figure 5.1.4.A):

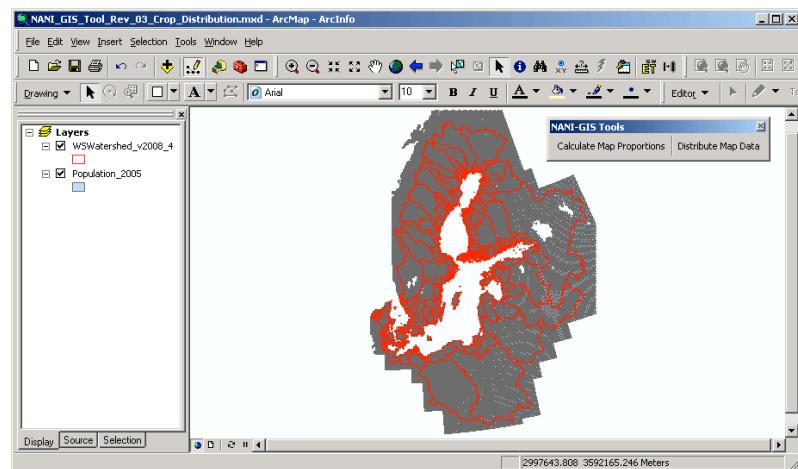


Figure 5.1.4.A. Running NANI-GIS tool to calculate HYDE grid cell proportion.

The “Calculate Map Proportions” button was clicked, and the tool was specified as shown in Figure 5.1.4.B:

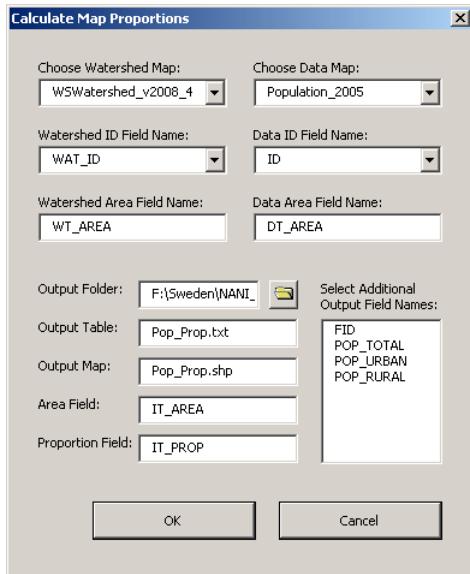


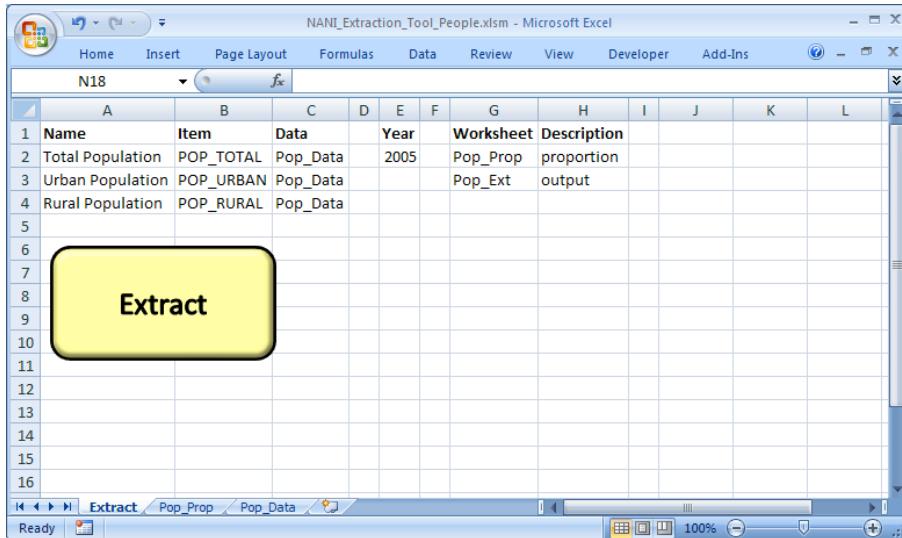
Figure 5.1.4.B. Specifying NANI-GIS tool to calculate HYDE grid cell proportion.

After running the NANI-GIS tool, a proportion table “Pop\_Prop.txt” was created, with HYDE grid cells in the rows and watersheds in the columns. This table was imported into the NANI-extraction tool “NANI\_Extraction\_Tool\_People.xls” (Figure 5.1.4.C):

	A	B	C	D	E	F	G	H	I	J	K
1	ID	Area_km2	W9018	W151	W2017	W9019	W149	W2018	W9020	W142	W143
2	Area_km2 -		464.03	51464.56	629.43	745.45	2178.11	12458.89	1877.98	1903.43	6579.13
3	2249	30.46651151	0	0	0	0	0	0	0	0	0
4	2445	30.58381666	0	0	0	0	0	0	0	0	0
5	2446	30.58381666	0	0	0	0	0	0	0	0	0
6	2447	30.58381666	0	0	0	0	0	0	0	0	0
7	2448	30.58381666	0	0	0	0	0	0	0	0	0
8	2449	30.58381666	0	0	0	0	0	0	0	0	0
9	2450	30.58381666	0	0	0	0	0	0	0	0	0
10	2451	30.58381666	0	0	0	0	0	0	0	0	0
11	2452	30.58381666	0	0	0	0	0	0	0	0	0
12	2453	30.58381666	0	0	0	0	0	0	0	0	0
13	2649	30.70105277	0	0	0	0	0	0	0	0	0
14	2650	30.70105277	0	0	0	0	0	0	0	0	0
15	2651	30.70105277	0	0	0	0	0	0	0	0	0
16	2652	30.70105277	0	0	0	0	0	0	0	0	0
17	2653	30.70105277	0	0	0	0	0	0	0	0	0
18	2654	30.70105277	0	0	0	0	0	0	0	0	0

Figure 5.1.4.C. HYDE grid cell proportion table created after running NANI-GIS tool.

The “Pop\_Data” worksheet of the NANI-extraction tool “NANI\_Extraction\_Tool\_People.xlsxm” was imported from the text file “Pop\_Data.txt” (Figure 5.1.3.B) containing the total, urban, and rural population data in 2005 in the HYDE grid cells. The population count values were extracted by clicking the “Extract” button in the “Extract” worksheet (Figure 5.1.4.D):

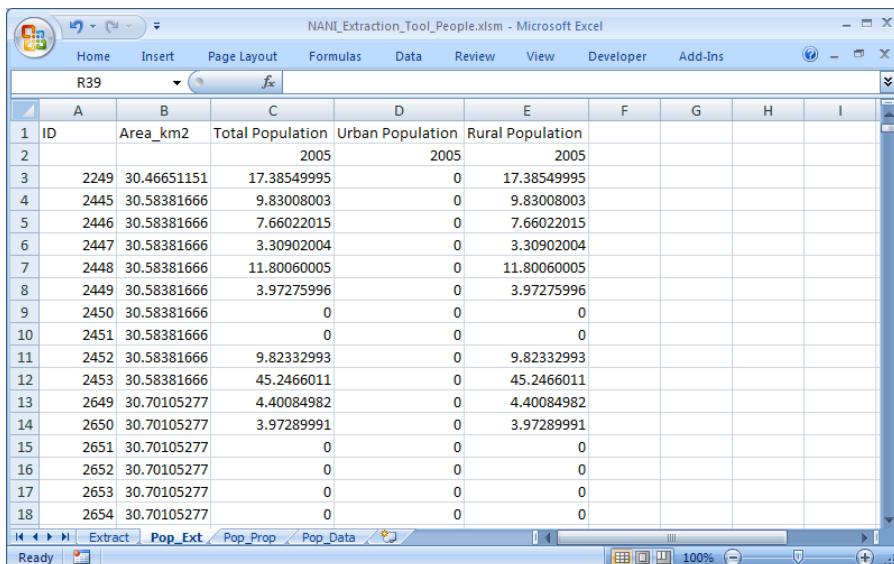


A screenshot of Microsoft Excel showing the 'Extract' worksheet. The window title is 'NANI\_Extraction\_Tool\_People.xlsxm - Microsoft Excel'. The 'Extract' tab is selected in the ribbon. The data starts at row 1 with columns A through L. Row 1 contains headers: Name, Item, Data, Year, Worksheet, and Description. Rows 2, 3, and 4 contain data for Total Population, Urban Population, and Rural Population respectively, all pointing to the 'Pop\_Data' worksheet. Row 10 contains a yellow rectangular button labeled 'Extract'.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Name	Item	Data	Year	Worksheet	Description						
2	Total Population	POP_TOTAL	Pop_Data	2005	Pop_Prop	proportion						
3	Urban Population	POP_URBAN	Pop_Data		Pop_Ext	output						
4	Rural Population	POP_RURAL	Pop_Data									
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												

Figure 5.1.4.D. Extracting population data using NANI-extraction tool.

After clicking the “Extract” button, the output worksheet “Pop\_Ext” was created and the extracted population count values were reported (Figure 5.1.4.E). The extraction worksheet “Pop\_Ext” and the proportion worksheet “Pop\_Prop” were copied to the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xlsxm”.



A screenshot of Microsoft Excel showing the 'Pop\_Ext' worksheet. The window title is 'NANI\_Extraction\_Tool\_People.xlsxm - Microsoft Excel'. The 'Pop\_Ext' tab is selected in the ribbon. The data starts at row 1 with columns A through I. Row 1 contains headers: ID, Area\_km2, Total Population, Urban Population, and Rural Population. Rows 2 through 18 contain data for various grid cells, mostly showing 0 or specific values like 17.38549995 or 45.2466011.

	A	B	C	D	E	F	G	H	I
1	ID	Area_km2	Total Population	Urban Population	Rural Population				
2			2005	2005	2005				
3	2249	30.46651151	17.38549995	0	17.38549995				
4	2445	30.58381666	9.83008003	0	9.83008003				
5	2446	30.58381666	7.66022015	0	7.66022015				
6	2447	30.58381666	3.30902004	0	3.30902004				
7	2448	30.58381666	11.80060005	0	11.80060005				
8	2449	30.58381666	3.97275996	0	3.97275996				
9	2450	30.58381666	0	0	0				
10	2451	30.58381666	0	0	0				
11	2452	30.58381666	9.82332993	0	9.82332993				
12	2453	30.58381666	45.2466011	0	45.2466011				
13	2649	30.70105277	4.40084982	0	4.40084982				
14	2650	30.70105277	3.97289991	0	3.97289991				
15	2651	30.70105277	0	0	0				
16	2652	30.70105277	0	0	0				
17	2653	30.70105277	0	0	0				
18	2654	30.70105277	0	0	0				

Figure 5.1.4.E. Population data extracted using NANI-extraction tool.

The calculation of human N consumption uses spatially distributed N intake parameters estimated at the country level (Table 5.1.3.A). Watershed-specific human N intake parameters were estimated by overlaying the country map that contains NANI parameters (Figure 4.3.A) with the watershed map. A detailed procedure for calculating watershed-specific NANI parameters including human N intake is given in Section 4.4 (Figures 4.4.F, 4.4.G, and 4.4.H). Human N consumption was calculated by clicking the “People” button in the “People” worksheet (Figure 5.1.4.F). Note that the country-level NANI parameter worksheet “Cntr\_Prop” is listed in Cell F5, and the column heading containing the spatially varying human N intake parameters (“H\_N\_IN” shown in Figure 4.4.H) is specified in Cell D2 instead of a single number for all watersheds.

1	Type	Item Name	Distribute N/person/yr	Human N Intake (kg- N/person/yr)	Worksheet	Description	Population (persons or housing units/km2)			Interpolated Population (persons/km2) and Human Requirements of N		
							watershed	Total Popul	Urban Popu	Rural Population	watershed	2000
2	Total Population	Total Population			Pop_Ext	data		2005	2005	2005	W9018	29.1493202
3	Urban Population	Urban Population			Pop_Prop	proportion					W151	17.7530817
4	Rural Population	Rural Population			Fix_Ext	years	W9018	29.1493202	23.2530411	5.89627912	W9018	29.1493202
5					Cntr_Prop	parameters	W151	17.7530817	14.4321427	3.32093911	W151	17.7530817
6							W2017	53.602617	40.589868	13.012749	W2017	53.602617
7							W9019	256.977486	253.294547	3.68293907	W9019	256.977486
8							W149	27.2320551	23.2699855	3.96306954	W149	27.2320551
9							W2018	71.8633091	60.3747528	11.4885563	W2018	71.8633091
10							W9020	50.0459814	44.6755166	5.3704648	W9020	50.0459814
11							W142	48.6896673	25.9904462	22.6992211	W142	48.6896673
12							W143	22.5111285	16.7610765	5.75005203	W143	22.5111285
13							W145	20.6363089	14.8189219	5.81738699	W145	20.6363089
14							W147	9.98466536	5.18567973	4.79898563	W147	9.98466536
15							W2013	169.665908	127.800394	41.8555145	W2013	169.665908
16							W9021	89.3522739	78.5327118	10.8195621	W9021	89.3522739
17							W2014	132.092322	120.235783	11.8565393	W2014	132.092322
18							W1013	149.966344	115.356942	34.6094014	W1013	149.966344

Figure 5.1.4.F. Calculating human N consumption using NANI-accounting tool.

The NANI toolbox also reports the watershed-specific human N intake parameters, calculated as the area-weighted averages of country-level parameters used for calculating of watershed human N consumption. The reported values can be found in the “Cntr\_Prop” worksheet below the country proportion table (Figure 5.1.4.G):

AN26	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	
1	CNTR_CODE	Area_km2	W9018	W151	W2017	W9019	W149	W2018	W9020	W142	W143	W145	W147	W2013	W9021
2	Area_km2	-	464.03	51464.56	629.43	745.45	2178.11	12458.89	1877.98	1903.43	5759.13	3152.45	3319.66	3073.97	2233.67
3	BY	137926.0577	0	0	0	0	0	0	0	0	0	0	0	0	0
4	DE	357353.9731	0	0	0	0	0	0	0	0	0	0	0	0	0
5	DK	42489.3386	0	0	1.44E-02	0	0	0.28601	0	0	0	0	0	6.89E-02	0
17	N_FIX_SOYA	9600	9600	9600	9600	9600	9600	9600	9600	9600	9600	9600	9600	9600	
18	N_FIX_LEFO	8500	7955.346	11080	8500	8500	11080	8500	8500	8500	8500	8500	8500	11080	
19	N_FIX_GRAI	2500	2500	2920	2500	2920	2500	2500	2500	2500	2500	2500	2500	2500	
20	N_FIX_GRAE	300	300	270	300	300	270	300	300	300	300	300	270	300	
21	N_FIX_PULS	9000	9000	13900	9000	13900	9000	9000	9000	9000	9000	9000	13900	9000	
22	N_FIX_OFAR	2500	2500	2920	2500	2920	2500	2500	2500	2500	2500	2500	2920	2500	
23	N_FIX_FALL	400	400	400	400	400	400	400	400	400	400	400	400	400	
24	N_FIX_SETA	400	400	400	400	400	400	400	400	400	400	400	400	400	
25	H_N_IN	6.30136	6.277186	6.51744	6.30136	6.30136	6.51744	6.30136	6.30136	6.30136	6.30136	6.51744	6.30136	6.30136	

Figure 5.1.4.G. Watershed-specific human N intake parameters calculated by NANI toolbox.

### 5.1.5. Preliminary Results

Figure 5.1.5.A below shows the watershed human N consumption in three regions of Baltic Sea catchment areas calculated by NANI toolbox. Relative frequencies of human N consumption are shown in Figure 5.1.5.B.

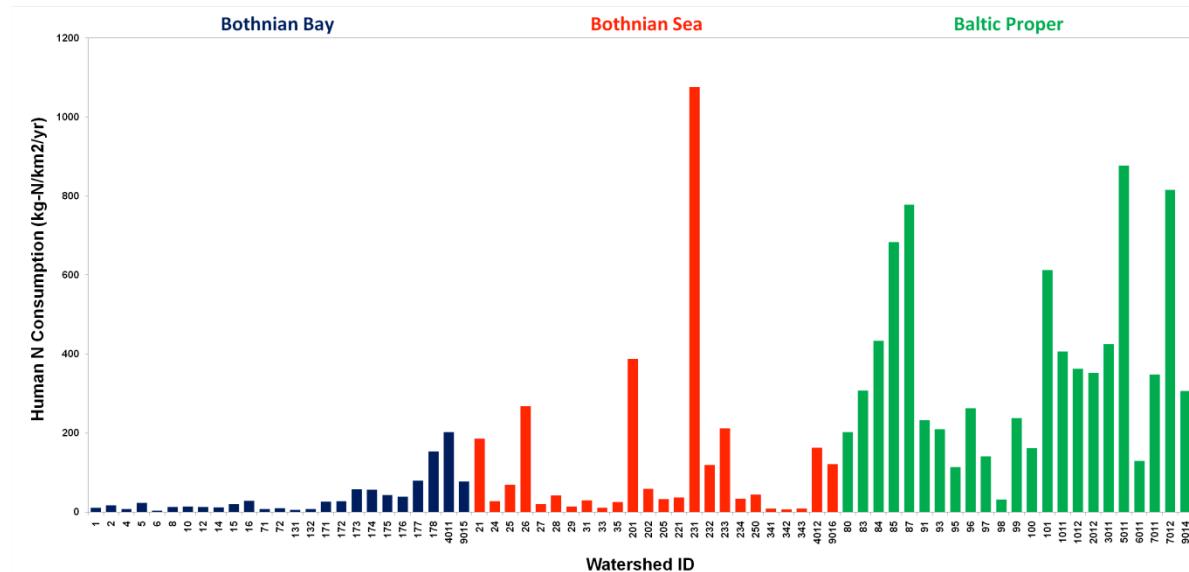


Figure 5.1.5.A. Human N consumption in Baltic Sea catchments.

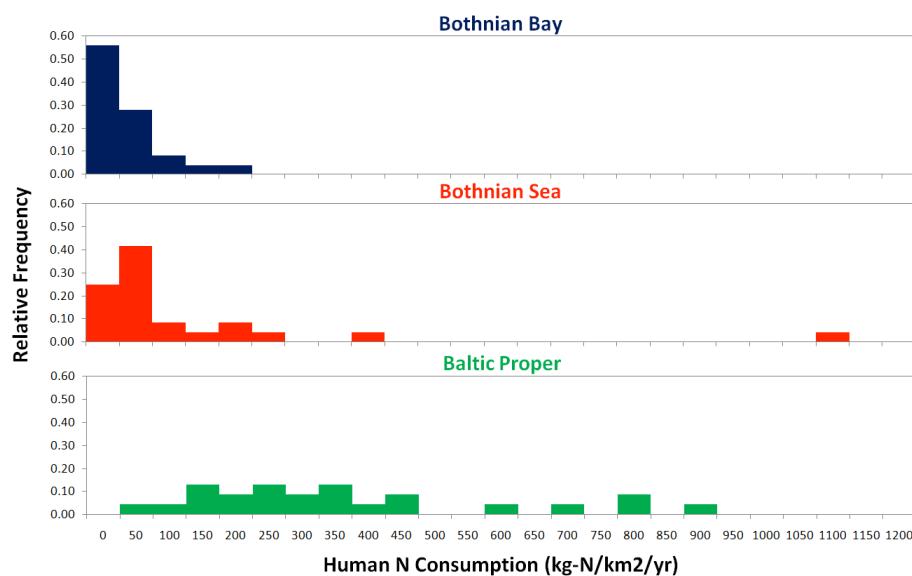


Figure 5.1.5.B. Relative frequencies of human N consumption in Baltic Sea catchments.

## 5.2. Animal N Consumption and N Production

### 5.2.1. Overview

When a map of animal counts for the region of interest is available, watershed animal N consumption can be calculated by overlaying the animal count map on the watershed map, summing the animal numbers for each animal group in each accounting region for each watershed, and multiplying by the associated animal N intake rates (in kg-N/animal/yr) and then summing over all animal groups. Watershed animal N excretion can be calculated by multiplying the animal numbers by the N excretion rates (in kg-N/animal/yr). Finally, watershed animal N production can be calculated by subtracting animal N excretion from animal N consumption and applying the percent loss of N which occurs during food processing. In this analysis, animal N calculations in the Baltic Sea catchments were performed using the animal numbers prepared at the NUTS 2 level (Figure 5.2.1.A). (Note that Russia and Belarus were divided into oblasts and voblasts, respectively.)

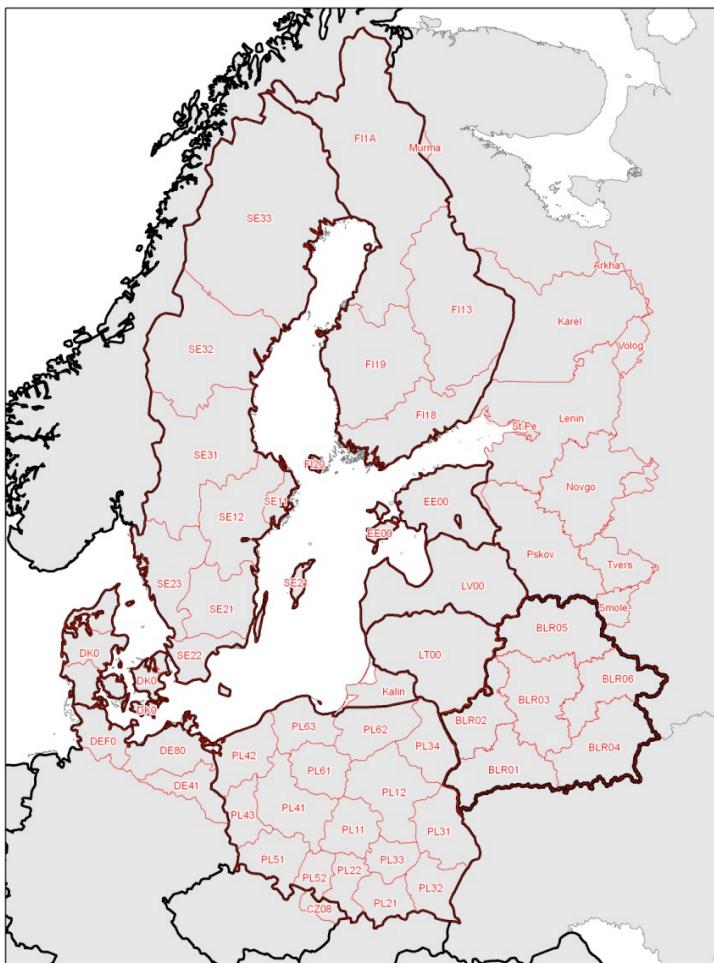


Figure 5.2.1.A. Country map (black) and NUTS 2 level, oblast, and voblast boundaries (red).

The animal N calculation in the Baltic Sea catchments was somewhat more difficult than that in earlier studies because of significant spatial variation in animal intake and excretion rates among European countries. In this analysis, the animal parameters were estimated at the country level (Section 5.2.3), and updated NANI toolbox allowing the user to incorporate spatial variation in NANI parameters was applied (Section 5.2.4).

### **5.2.2. Data Availability**

For the EU countries data on NUTS level 2 on animal numbers (originally reported in units of 1000 heads) for various classes was derived from  
<http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/> (Table 5.2.2.A):

Table 5.2.2.A. Animal classes used in animal N calculation.

EuroStat Code	Animal Class
PC1	Bovine animals less than 1 year old
PC2	Bovine animals aged between 1 and 2 years
PC3100	Bovine animals of 2 years and over: Male
PC3210	Heifers
PC3221	Dairy cows
PC3222	Other cows
PP1000	Piglets with a live weight of less than 20 kg
PP2000	Pigs with a live weight of 20 kg and less than 50 kg
PP3000	Fattening pigs (including rejected boars and sows) of at least 50 kg
PP4100	Boars
PP4200	Sows - total
J14	Poultry - broilers
J15	Poultry - laying hens
J16	Poultry - others
PS0000	Sheep - total

For the three Belarus voblasts situated mostly within the Baltic drainage area, Brest (BLR01 in Figure 5.2.1.A), Grodno (BLR02), and Vitebsk (BLR05), regional data was found in the statistical yearbook “Regions of the Republic of Belarus, 2008”, with the animal classes of total cattle, cows, pigs, sheep and goats, and poultry (<http://belstat.gov.by/homep/ru/publications/regions/tables.php>).

National data for Belarus for the years 2001, 2006, 2009, and estimated data for 2010 was found in [http://belstat.gov.by/homep/ru/publications/belarus\\_in%20figures/belarus\\_in\\_figures.pdf](http://belstat.gov.by/homep/ru/publications/belarus_in%20figures/belarus_in_figures.pdf). The animal classes were the same as for the regional data (total cattle, cows, pigs, sheep and goats, and poultry).

For Russia, regional data for 2009 for the following oblasts were available for the animal classes of total cattle, cows, pigs, sheep and goats (poultry numbers were also available for Kaliningrad and Leningrad):

- Kaliningrad  
(<http://kaliningrad.gks.ru/digital/region4/DocLib/%D0%96%D0%B8%D0%B2%D0%BE%D1%82%D0%BD%D0%BE%D0%B2%D0%BE%D0%B4%D1%81%D1%82%D0%B2%D0%BE.htm>)
- Leningrad ([http://petrostat.gks.ru/lenobl/sh/2009/03zivl\\_o.htm](http://petrostat.gks.ru/lenobl/sh/2009/03zivl_o.htm))
- Pskov ([http://pskovstat.gks.ru/digital/region4/DocLib/ibd100602\\_9.HTM](http://pskovstat.gks.ru/digital/region4/DocLib/ibd100602_9.HTM))
- Novgorod  
(<http://novgorodstat.natm.ru/digital/operinf/%D0%A1%D0%B5%D0%BB%D1%8C%D1%81%D0%BA%D0%BE%D0%B5%D0%A5%D0%BE%D0%B7%D1%8F%D0%B9%D1%81%D1%82%D0%B2%D0%BE/%D0%9F%D0%BE%D0%B3%D0%BE%D0%BB%D0%BE%D0%B2%D1%8C%D0%B5%D0%A1%D0%BA%D0%BE%D1%82%D0%B0.htm>)

### **5.2.3. Input Preparation**

#### **5.2.3.1. Animal Numbers**

A table of animal numbers for the NUTS 2 level areas for the EU countries and for the Russian and Belarusian oblasts and voblasts, respectively, were calculated (Tables 5.2.3.1.A, 5.2.3.1.B, and 5.2.3.1.C). For the EU countries the median value for the years 2000-2005 was calculated, except for NUTS areas in Denmark where the 2009 values were used since it was the only year with data.

For the three Belarus voblasts (Brest, Grodno, and Vitebsk), regional data from 2008 was used. Data for the three remaining voblasts (Minsk, Gomel, and Mogilev) were calculated by using the median value of the national data and subtracting the regional animal numbers from the three voblasts (Brest, Grodno, and Vitebsk). The remaining animal numbers were distributed over the three remaining voblasts Minsk, Gomel, and Mogilev based on area.

For the Russian oblasts Kaliningradskaya, Leningradskaya, Pskovskaya, and Novgorodskaya, regional data from 2009 on cattle, cows, pigs, and sheep were used. For Kaliningradskaya and Leningradskaya regional data on poultry from 2009 was used. For the oblasts Karelia, Arkhangelskaya, Vologodskaya, Smolenskaya, Tveskaya, and St. Petersburg, cattle, cows, pigs, sheep and poultry were calculated. For Pskovskaya and Novgorodskaya poultry was calculated. The calculations were made based on animal number correlations with rural population. Using population data for 2005 from the HYDE database (Section 5.1.2), rural population estimates were correlated to animal number estimates for the oblasts that had data. These correlations were then used to calculate animal number in the neighboring oblasts lacking data on animal number.

When animal numbers for only aggregated classes were available (e.g., total poultry instead of broilers, laying hens, and other poultry as listed in Table 5.2.2.A), they were distributed into sub-classes according to their proportions observed over the Baltic Sea catchments. When only spatially aggregated animal numbers were available (e.g., country level statistics in EU countries instead of the NUTS 2 level), they were disaggregated into finer scales, as shown in Figure 5.2.1.A, according to their areas.

Table 5.2.3.1.A. Populations of animals (number of head) used in animal N calculation (cattle).

Name	Country (Oblasts/Voblast)	Area (km <sup>2</sup> )	Bovine Young (PC1 & PC2)	Bovine Male (PC3100)	Heifers (PC3210)	Dairy Cows (PC3221)	Other Cows (PC3222)
BLR01	Belarus (Brest)	32,759	377,321	13,036	51,512	277,400	49,931
BLR02	Belarus (Grodno)	24,916	343,333	11,861	46,872	203,800	45,433
BLR03	Belarus (Minsk)	40,234	386,527	13,354	52,769	265,598	51,149
BLR04	Belarus (Gomel)	40,558	389,636	13,461	53,193	267,735	51,561
BLR05	Belarus (Vitebsk)	40,017	300,215	10,372	40,985	238,700	39,728
BLR06	Belarus (Mogilev)	29,050	279,079	9,642	38,100	191,766	36,931
DE	Germany	303,030	-	-	-	-	-
DE41	Germany	15,644	95,750	3,300	-	102,200	54,300
DE80	Germany	23,062	165,400	4,700	29,400	183,900	72,800
DEF0	Germany	15,548	418,300	12,800	94,300	354,500	63,900
DK01	Denmark	2,609	15,000	-	2,000	9,000	4,000
DK02	Denmark	6,958	47,000	1,000	4,000	21,000	13,000
DK03	Denmark	11,937	317,000	5,000	26,000	237,000	29,000
DK04	Denmark	12,813	276,000	3,000	22,000	173,000	35,000
DK05	Denmark	8,071	199,000	2,000	18,000	133,000	27,000
EE00	Estonia	43,164	69,900	1,200	14,500	116,800	1,600
FI13	Finland	85,266	93,900	1,900	7,900	93,700	4,800
FI18	Finland	43,305	55,300	1,950	5,700	56,750	7,750
FI19	Finland	64,204	103,300	2,700	9,700	97,550	12,050
FI1A	Finland	141,326	80,750	1,400	6,500	78,550	3,850
FI20	Finland	911	2,350	100	300	1,950	600
LT00	Lithuania	64,858	169,300	8,700	37,500	442,550	4,250
LV00	Latvia	64,683	110,550	1,550	13,100	195,400	3,250
PL11	Poland	18,259	98,150	6,200	5,700	255,600	4,600
PL12	Poland	35,583	175,450	11,450	34,000	541,650	4,300
PL21	Poland	15,012	50,950	2,150	5,300	184,500	600
PL22	Poland	12,367	33,700	2,050	4,800	66,100	1,800
PL31	Poland	24,927	82,500	4,450	13,300	259,300	3,550
PL32	Poland	17,881	28,350	700	4,000	141,900	450
PL33	Poland	11,715	44,100	3,200	4,700	122,300	-
PL34	Poland	20,316	141,550	7,550	38,100	380,200	3,400
PL41	Poland	29,790	210,650	13,000	37,600	300,550	6,600
PL42	Poland	22,392	28,650	1,650	5,500	46,150	3,250
PL43	Poland	13,757	17,900	1,100	4,300	26,700	2,900
PL51	Poland	19,870	32,900	1,650	5,900	55,250	2,100
PL52	Poland	9,266	37,350	1,250	5,200	55,100	700
PL61	Poland	17,959	115,350	6,250	9,600	168,800	1,900
PL62	Poland	23,895	97,400	3,450	20,500	177,150	6,200
PL63	Poland	18,170	49,500	2,700	8,000	81,050	1,900
Arkha	Russian Federation (Arkhangelskaya)	4,912	184	6	25	479	24
Kalin	Russian Federation (Kalininogradskaya)	13,322	22,326	771	3,048	31,700	2,954
Karel	Russian Federation (Karelia)	85,419	7,813	270	1,067	20,368	1,034
Lenin	Russian Federation (Leningradskaya)	79,378	75,725	2,616	10,338	84,600	10,021
Murma	Russian Federation (Murmanskaya)	1,749	-	-	-	-	-
Novgo	Russian Federation (Novgorodskaya)	47,092	17,723	612	2,420	24,600	2,345
Pskov	Russian Federation (Pskovskaya)	55,237	43,041	1,487	5,876	57,800	5,696
Smole	Russian Federation (Smolenskaya)	7,827	8,635	298	1,179	11,256	1,143
St Pe	Russian Federation (St. Petersburg)	1,501	145,580	5,029	19,875	94,874	19,265
Tvers	Russian Federation (Tverskaya)	21,534	20,285	701	2,769	26,439	2,684
Volog	Russian Federation (Vologodskaya)	8,708	884	31	121	2,304	117
SE11	Sweden	6,438	12,100	600	1,400	4,500	3,600
SE12	Sweden	43,302	156,600	5,300	16,500	61,900	33,300
SE21	Sweden	35,855	224,000	7,400	25,100	100,700	40,300
SE22	Sweden	14,205	139,000	4,300	14,800	47,400	41,600
SE23	Sweden	34,279	202,000	6,600	21,400	90,100	37,400
SE31	Sweden	72,043	74,800	2,900	7,700	26,400	18,600
SE32	Sweden	77,129	35,200	1,700	4,500	17,000	8,400
SE33	Sweden	164,815	35,900	1,000	3,600	21,600	2,400
CZ	Czech Republic	73,504	-	-	-	-	-
CZ08	Czech Republic	5,559	25,000	1,000	3,900	25,000	11,000

Table 5.2.3.1.B. Populations of animals (number of head) used in animal N calculation (pigs).

Name	Country (Oblasts/Voblast)	Area (km <sup>2</sup> )	Piglets (PP1000)	Pigs (PP2000)	Fattening Pigs (PP3000)	Boars (PP4100)	Sows (PP4200)
BLR01	Belarus (Brest)	32,759	181,994	149,888	183,440	1,128	57,049
BLR02	Belarus (Grodno)	24,916	241,781	199,127	243,702	1,499	75,791
BLR03	Belarus (Minsk)	40,234	218,076	179,604	219,809	1,352	68,360
BLR04	Belarus (Gomel)	40,558	219,830	181,049	221,577	1,363	68,910
BLR05	Belarus (Vitebsk)	40,017	171,585	141,315	172,949	1,064	53,787
BLR06	Belarus (Mogilev)	29,050	157,454	129,677	158,705	976	49,357
DE	Germany	303,030	-	-	-	-	-
DE41	Germany	15,644	102,900	85,200	103,150	1,350	46,200
DE80	Germany	23,062	155,500	183,900	239,700	700	75,800
DEF0	Germany	15,548	383,500	331,400	573,800	3,800	120,800
DK01	Denmark	2,609	72,000	69,000	87,000	-	21,000
DK02	Denmark	6,958	455,000	398,000	341,000	1,000	142,000
DK03	Denmark	11,937	1,258,000	1,041,000	1,036,000	3,000	396,000
DK04	Denmark	12,813	1,602,000	1,426,000	1,255,000	4,000	490,000
DK05	Denmark	8,071	947,000	787,000	739,000	2,000	299,000
EE00	Estonia	43,164	104,100	83,900	106,600	1,500	37,700
FI13	Finland	85,266	27,900	16,200	31,100	600	12,800
FI18	Finland	43,305	160,400	128,450	227,850	1,850	73,900
FI19	Finland	64,204	183,050	142,200	238,200	2,650	90,600
FI1A	Finland	141,326	22,550	16,950	30,150	250	10,150
FI20	Finland	911	-	-	50	-	150
LT00	Lithuania	64,858	184,850	253,850	485,600	3,350	94,850
LV00	Latvia	64,683	96,600	100,900	187,900	2,050	48,300
PL11	Poland	18,259	451,650	311,650	481,300	2,700	125,350
PL12	Poland	35,583	618,800	452,800	644,500	4,750	178,100
PL21	Poland	15,012	185,800	111,050	162,450	950	57,650
PL22	Poland	12,367	126,600	85,850	135,700	1,150	32,800
PL31	Poland	24,927	426,000	288,400	478,550	3,150	119,950
PL32	Poland	17,881	89,300	81,450	129,450	800	33,900
PL33	Poland	11,715	158,250	86,950	117,650	850	50,000
PL34	Poland	20,316	276,950	219,700	320,550	2,150	83,450
PL41	Poland	29,790	1,418,250	1,230,100	1,499,950	9,850	405,550
PL42	Poland	22,392	214,250	162,000	197,550	2,150	71,200
PL43	Poland	13,757	77,200	68,000	89,100	1,000	26,550
PL51	Poland	19,870	165,450	117,950	176,050	1,550	50,400
PL52	Poland	9,266	242,650	185,550	244,550	1,550	65,750
PL61	Poland	17,959	710,700	561,750	687,400	5,800	210,150
PL62	Poland	23,895	263,000	228,150	290,600	3,050	81,750
PL63	Poland	18,170	361,550	264,250	312,350	2,600	99,550
Arkha	Russian Federation (Arkhangelskaya)	4,912	304	250	306	2	95
Kalin	Russian Federation (Kalininogradskaya)	13,322	15,772	12,989	15,897	98	4,944
Karel	Russian Federation (Karelia)	85,419	12,927	10,647	13,030	80	4,052
Lenin	Russian Federation (Leningradskaya)	79,378	52,742	43,437	53,161	327	16,533
Murma	Russian Federation (Murmanskaya)	1,749	-	-	-	-	-
Novgo	Russian Federation (Novgorodskaya)	47,092	26,466	21,797	26,676	164	8,296
Pskov	Russian Federation (Pskovskaya)	55,237	21,928	18,060	22,102	136	6,874
Smole	Russian Federation (Smolenskaya)	7,827	7,144	5,883	7,200	44	2,239
St Pe	Russian Federation (St. Petersburg)	1,501	54,193	44,633	54,624	336	16,988
Tvers	Russian Federation (Tverskaya)	21,534	16,781	13,820	16,914	104	5,260
Volog	Russian Federation (Vologodskaya)	8,708	1,462	1,204	1,474	9	458
SE11	Sweden	6,438	2,700	3,400	5,200	-	600
SE12	Sweden	43,302	96,100	71,200	93,900	300	22,500
SE21	Sweden	35,855	61,300	39,200	42,600	200	11,200
SE22	Sweden	14,205	146,700	121,400	137,900	1,200	35,200
SE23	Sweden	34,279	143,300	112,500	138,200	600	34,600
SE31	Sweden	72,043	20,300	17,700	19,600	100	4,700
SE32	Sweden	77,129	2,400	1,800	2,700	-	500
SE33	Sweden	164,815	6,800	7,400	10,200	100	2,200
CZ	Czech Republic	73,504	-	-	-	-	-
CZ08	Czech Republic	5,559	42,550	41,500	59,650	150	18,800

Table 5.2.3.1.C. Populations of animals (number of head) used in animal N calculation (poultry and sheep).

Name	Country (Oblasts/Voblast)	Area (km <sup>2</sup> )	Broilers (J14)	Hens (J15)	Other Poultry (J16)	Sheep (PS0000)
BLR01	Belarus (Brest)	32,759	2,783,365	1,888,639	527,996	10,022
BLR02	Belarus (Grodno)	24,916	1,873,419	1,271,200	355,382	7,661
BLR03	Belarus (Minsk)	40,234	4,136,918	2,807,087	784,761	12,298
BLR04	Belarus (Gomel)	40,558	4,170,198	2,829,669	791,074	12,397
BLR05	Belarus (Vitebsk)	40,017	2,248,102	1,525,440	426,458	12,246
BLR06	Belarus (Mogilev)	29,050	2,986,922	2,026,762	566,610	8,879
DE	Germany	303,030	47,827,120	47,233,416	10,907,196	-
DE41	Germany	15,644	2,469,021	2,438,372	563,072	101,500
DE80	Germany	23,062	3,639,945	3,594,761	830,106	112,000
DEF0	Germany	15,548	2,453,913	2,423,452	559,626	359,100
DK01	Denmark	2,609	751,535	308,369	42,470	6,463
DK02	Denmark	6,958	2,004,221	822,371	113,261	17,235
DK03	Denmark	11,937	3,438,566	1,410,911	194,317	29,570
DK04	Denmark	12,813	3,690,889	1,514,444	208,576	31,740
DK05	Denmark	8,071	2,324,789	953,906	131,376	19,992
EE00	Estonia	43,164	1,005,000	1,175,000	25,000	29,900
FI13	Finland	85,266	1,539,830	1,122,421	129,804	12,300
FI18	Finland	43,305	782,045	570,053	65,924	19,000
FI19	Finland	64,204	1,159,466	845,164	97,740	25,500
FI1A	Finland	141,326	2,552,215	1,860,375	215,145	23,500
FI20	Finland	911	16,445	11,987	1,386	7,100
LT00	Lithuania	64,858	3,260,000	4,185,000	1,810,000	12,950
LV00	Latvia	64,683	930,000	2,750,000	110,000	35,050
PL11	Poland	18,259	6,061,817	2,944,060	1,269,872	20,350
PL12	Poland	35,583	11,812,932	5,737,220	2,474,655	12,050
PL21	Poland	15,012	4,983,878	2,420,534	1,044,057	79,700
PL22	Poland	12,367	4,105,739	1,994,046	860,099	20,750
PL31	Poland	24,927	8,275,330	4,019,103	1,733,574	26,700
PL32	Poland	17,881	5,936,332	2,883,115	1,243,584	12,750
PL33	Poland	11,715	3,889,289	1,888,922	814,755	4,050
PL34	Poland	20,316	6,744,455	3,275,598	1,412,875	21,250
PL41	Poland	29,790	9,889,728	4,803,172	2,071,769	46,450
PL42	Poland	22,392	7,433,842	3,610,415	1,557,293	8,050
PL43	Poland	13,757	4,567,194	2,218,162	956,767	4,800
PL51	Poland	19,870	6,596,384	3,203,684	1,381,856	11,950
PL52	Poland	9,266	3,076,208	1,494,031	644,425	3,350
PL61	Poland	17,959	5,962,081	2,895,621	1,248,978	30,800
PL62	Poland	23,895	7,932,706	3,852,699	1,661,798	8,550
PL63	Poland	18,170	6,032,086	2,929,620	1,263,643	14,050
Arkha	Russian Federation (Arkhangelskaya)	4,912	12,313	8,355	2,336	240
Kalin	Russian Federation (Kalininogradskaya)	13,322	757,450	513,964	143,686	30,500
Karel	Russian Federation (Karelia)	85,419	523,305	355,086	99,269	10,184
Lenin	Russian Federation (Leningradskaya)	79,378	11,079,933	7,518,238	2,101,830	10,450
Murma	Russian Federation (Murmansкая)	1,749	-	-	-	-
Novgo	Russian Federation (Novgorodskaya)	47,092	881,529	598,158	167,223	10,600
Pskov	Russian Federation (Pskovskaya)	55,237	1,203,417	816,573	228,285	20,050
Smole	Russian Federation (Smolenskaya)	7,827	240,987	163,521	45,715	4,502
St Pe	Russian Federation (St. Petersburg)	1,501	13,711,305	9,303,744	2,600,993	-
Tvers	Russian Federation (Tverskaya)	21,534	566,078	384,110	107,383	10,576
Volog	Russian Federation (Vologodskaya)	8,708	59,191	40,164	11,228	1,152
SE11	Sweden	6,438	84,921	97,135	1,724	18,300
SE12	Sweden	43,302	571,158	653,304	11,597	113,500
SE21	Sweden	35,855	472,926	540,945	9,603	136,000
SE22	Sweden	14,205	187,366	214,313	3,804	63,500
SE23	Sweden	34,279	452,139	517,168	9,180	93,000
SE31	Sweden	72,043	950,242	1,086,909	19,294	47,800
SE32	Sweden	77,129	1,017,334	1,163,651	20,657	18,500
SE33	Sweden	164,815	2,173,914	2,486,575	44,140	18,300
CZ	Czech Republic	73,504	15,986,073	9,110,992	1,264,383	-
CZ08	Czech Republic	5,559	1,208,927	689,008	95,617	9,150

### 5.2.3.2. Cattle Parameters

Table 5.2.3.2.A below summarizes the N intake and N excretion parameters for cattle:

Table 5.2.3.2.A. Animal N parameters for cattle (kg-N/animal/yr).

Country Code	Bovine Young (PC1 & PC2)		Bovine Male (PC3100)		Heifers (PC3210)		Dairy Cows (PC3221)		Other Cows (PC3222)	
	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion
BY	36.1	30	49.41	42	50.7	40	93.92	75	67.42	60
DE	48.8	40.5	69.41	59	55.8	44	137.82	101	94.38	84
DK	70.0	58.1	64.59	54.9	78.3	61.8	154.57	110	82.36	73.3
EE	36.1	30	49.41	42	50.7	40	124.14	93	67.42	60
FI	38.3	31.8	47.06	40	50.7	40	146.88	105	61.80	55
LT	36.1	30	49.41	42	50.7	40	104.60	82	67.42	60
LV	36.1	30	49.41	42	50.7	40	108.91	86	67.42	60
PL	38.9	32.3	49.41	42	76.0	60	109.13	86	67.42	60
RU	35.1	30	49.41	42	50.7	40	92.00	76	67.42	60
SE	44.9	37.3	68.24	58	59.6	47	156.75	112	70.79	63
CZ	44.8	37.2	92.47	78.6	74.1	58.5	133.07	98	88.31	78.6
NO	35.43	29.3	47.06	40	50.7	40	121.13	93	74.6	66.6
SK	36.1	30	49.41	42	50.7	40	83.39	70	67.42	60
UA	36.1	30	49.41	42	50.7	40	89.50	74	67.42	60

#### Dairy Cows

Intake for dairy cows was calculated using the relationship between milk production and milk N content and nitrogen intake. Milk yield (kg milk per cow) was derived from FAO (2005) and all milk was assumed to have an average protein content of 3.5%. Using average milk yield, milk protein content and a nitrogen conversion factor of 6.38 from milk protein to nitrogen the average nitrogen content in milk per cow and year was calculated. The nitrogen intake was estimated based on the milk N content using the relationship between milk N and N intake in feed (NRC 2001).

Excretion was estimated based on the relationship between milk yield and excretion (OECD 2004, Fig page 67).

#### Bovine Young (Calves 0-2 Years)

Excretion for young cattle in Denmark, Czech Republic, Germany, Finland, Poland, and Sweden was calculated as a weighted average of the OECD coefficients for “bovine animals <1 years”, “Male cattle 1-2 years” and “female cattle 1-2 years” (OECD 2001), i.e.:

$$E_{\text{cattle 0-2 years}} = (E_{\text{Bovine animals <1year}} + ((E_{\text{Male cattle 1-2 years}} + E_{\text{Female cattle 1-2 years}})/2)/2 \quad (\text{Equation 5.2.3.2.A})$$

For Norway, excretion is an average of the categories Heifers 0-1 y, Heifers 1-2 y, Ox 0-1 y and Ox 12-16.5 months in Bleken and Bakken (1997). For the remaining countries we assume an excretion rate of 30 kg-N/animal/year.

Intake for young bovine cattle in Norway was calculated as average of the categories Heifers 0-1 y, Heifers 1-2 y, Ox 0-1 y, and Ox 12-16, 5 months in Bleken and Bakken (1997). For the other countries, intake was calculated as excretion/0.83 based on the relationship between intake and excretion for Norwegian young cattle.

### **Bovine Males**

For bovine males (male cattle, including bulls and steers) in Denmark, Czech Republic, Germany, Finland, Poland, Norway, and Sweden we use the OECD excretion coefficients for "Male cattle >2 years" (OECD 2001). Bovine males >2 years in other countries are assumed to have an excretion of 42 kg-N/animal/year.

The intake for N for bovine males >2 years was calculated as excretion/0.85 assuming that 25% of the intake is used for maintenance and growth.

### **Heifers**

For heifers in Denmark, Czech Republic, Germany, Finland, Norway, Poland, and Sweden we use the OECD excretion coefficients for "Heifers >2 years" (OECD 2001). Heifers >2 years in other countries are assumed to have an excretion of 40 kg-N/animal/year.

In the NRC (2001) Nutrient Requirements of Dairy Cattle, guidelines for average daily intake of crude protein (CP) for a heifer might be around 0.868 g CP/day for maintenance and average growth. This gives a yearly nitrogen intake of 50.7 kg-N per animal and year. We then assume that this intake gives the lowest OECD excretion of 40 kg-N per animal and year which give us a nitrogen efficiency of 78.9%. We then calculated the intake as excretion/0.789 assuming that this relationship will be valid for all countries.

### **Other Cows**

For "other cows" in Denmark, Czech Republic, Germany, Finland, Poland, and Sweden we use the OECD excretion coefficients for "Other cows" (OECD 2001). For Norway, excretion for "other cows" originates from Bleken and Bakken (1997). For the other countries we assume an excretion of 60 kg-N per animal and year.

Nitrogen intake for "Other cows" in Norway is, according to Bleken and Bakken (1997), 74.6 kg-N per animal and year. This gives a nitrogen efficiency for "Other cows" of 89.3%. This nitrogen efficiency is used to calculate the nitrogen intake for "Other cows" in the remaining countries, i.e., intake = excretion/0.893.

### 5.2.3.3. Pig Parameters

Table 5.2.3.3.A below summarizes the N intake and N excretion parameters for pigs:

Table 5.2.3.3.A. Animal N parameters for pigs (kg-N/animal/yr).

Country Code	Piglets (PP1000)		Pigs (PP2000)		Fattening Pigs (PP3000)		Boars (PP4100)		Sows (PP4200)	
	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion
BY	7.31	2	21.43	9	31.60	11	10.81	9	25.49	19
DE	13.89	3.8	26.19	11	31.60	11	15.62	13	34.88	26
DK	7.31	2	14.76	6.2	46.83	16.3	27.63	23	34.48	25.7
EE	7.31	2	21.43	9	31.60	11	10.81	9	25.49	19
FI	20.46	5.6	21.43	9	31.60	11	10.81	9	25.49	19
LT	7.31	2	21.43	9	31.60	11	10.81	9	25.49	19
LV	7.31	2	21.43	9	31.60	11	10.81	9	25.49	19
PL	9.14	2.5	21.43	9	43.10	15	24.03	20	21.47	16
RU	7.31	2	21.43	9	31.60	11	10.81	9	25.49	19
SE	8.40	2.3	21.43	9	25.86	9	10.81	9	25.49	19
CZ	12.79	3.5	22.14	9.3	43.10	15	25.11	20.9	28.04	20.9
NO	7.31	2	21.43	9	31.60	11	16.70	13.9	29.65	22.1
SK	7.31	2	21.43	9	31.60	11	10.81	9	25.49	19
UA	7.31	2	21.45	9	31.60	11	10.81	9	25.49	19

#### Piglets (<20 kg)

The excretion coefficients for Finland, Denmark, Czech Republic, Germany, Poland, and Sweden originate from the OECD (2001) Nitrogen Balance Database. For the remaining countries we assume the lowest excretion coefficient, i.e., 2.0 kg-N per animal and year.

An average intake of nitrogen for piglets of 8.4 kg-N per animal per year was calculated using CP intake rates and feed intake volumes given in Table 10-1 of NRC (2001) Nutrient Requirements of Swine. This intake rate was then assumed to be correlated with the excretion rate for Sweden 2.3 kg-N per animal per year, giving a nitrogen loss of 30%. Hence we calculate the intake for "Piglets" in the other countries as  $\text{intake}_{\text{Piglets}} = \text{excretion}_{\text{Piglets}} / 0.3$ .

#### Pigs (20 - 50 kg)

The excretion coefficients for Finland, Denmark, Czech Republic, Germany, Poland, and Sweden originate from the OECD (2001) Nitrogen Balance Database. For the remaining countries we assume the lowest excretion coefficient, i.e., 9.0 kg-N per animal and year.

An average intake of nitrogen for "Pigs (20-50 kg)" of 21.4 kg-N per animal per year was calculated using CP intake rates and feed intake volumes given in Table 10-1 of NRC (2001) Nutrient Requirements of Swine. This intake rate was then assumed to be correlated with the lowest excretion, i.e., 9.0 kg-N per animal and year giving a nitrogen loss of 42%. Hence we calculate the intake for "Pigs" in the other countries as  $\text{intake}_{\text{Pigs}} = \text{excretion}_{\text{Pigs}} / 0.42$ .

### **Fattening Pigs (>50 kg)**

The excretion coefficients for Finland, Denmark, Czech Republic, Germany, Poland, and Sweden originate from the OECD (2001) Nitrogen Balance Database. For the remaining countries we assume the lowest excretion coefficient, i.e., 11.0 kg-N per fattening pig.

An average intake of nitrogen for fattening pigs (>50 kg) of 25.9 kg-N per animal per year was calculated using CP intake rates and feed intake volumes given in Table 10-2 of NRC (2001) Nutrient Requirements of Swine. This Intake rate was then assumed to be correlated with the lowest excretion, i.e., 11.0 kg-N per animal and year giving a nitrogen loss of 34.8%. Hence we calculate the intake for "Fattening Pigs" in the other countries as  $\text{intake}_{\text{Fattening pigs}} = \text{excretion}_{\text{Fattening pigs}} / 0.348$ .

### **Boars (>50 kg)**

The excretion coefficients for Finland, Denmark, Czech Republic, Germany, Poland, and Sweden originate from the OECD (2001) Nitrogen Balance Database. The rate from Norway is estimated to 13.9 kg-N per animal and year by Bleken and Bakken (1997). For the remaining countries we assume the lowest excretion coefficient, i.e., 9.0 kg-N per animal and year.

In Norway, boars have an intake of nitrogen of 16.7 kg-N per animal per year (Bleken and Bakken 1997). This gives a relationship between intake and excretion in Norwegian boars of 83.2%. This nitrogen loss efficiency was then used to calculate the nitrogen Intake for boars in the other countries as  $\text{intake}_{\text{Boars}} = \text{excretion}_{\text{Boars}} / 0.832$ .

### **Sows (>50 kg)**

The excretion coefficients for Finland, Denmark, Czech Republic, Germany, Poland, and Sweden originate from the OECD (2001) Nitrogen Balance Database. For the remaining countries we assume the lowest excretion coefficient, i.e., 19.0 kg-N per animal.

An average intake of nitrogen for sows (>50 kg) of 34.9 kg-N per animal per year was calculated using CP intake rates and feed intake volumes given in Tables 10-7 and 10-8 of NRC (2001) Nutrient Requirements of Swine. We assumed that half of the sows were gestating sows with 12 pigs in the litter and that the other half were lactating sows with a medium gain in the piglets. This Intake rate was then assumed to be correlated with the highest excretion rate, i.e., 26.0 kg-N per animal and year giving a nitrogen loss of 74.5%. Hence we calculate the intake for "Sows" in the other countries as  $\text{intake}_{\text{Sows}} = \text{excretion}_{\text{Sows}} / 0.745$ .

#### 5.2.3.4. Poultry and Sheep Parameters

Table 5.2.3.4.A below summarizes the N intake and N excretion parameters for poultry and sheep:

Table 5.2.3.4.A. Animal N parameters for poultry and sheep (kg-N/animal/yr).

Country Code	Broilers (J14)		Hens (J15)		Other Poultry (J16)		Sheep (PS0000)	
	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion
BY	3.23	1.56	0.92	0.60	1.94	1.32	11.22	10
DE	3.23	1.56	1.12	0.73	1.40	0.95	11.22	10
DK	5.53	2.67	1.14	0.74	1.94	1.32	11.22	10
EE	3.23	1.56	0.92	0.60	1.94	1.32	11.22	10
FI	3.59	1.73	0.77	0.50	1.94	1.32	19.07	17
LT	3.23	1.56	0.92	0.60	1.94	1.32	11.22	10
LV	3.23	1.56	0.92	0.60	1.94	1.32	11.22	10
PL	4.19	2.02	1.08	0.70	1.62	1.10	12.34	11
RU	3.23	1.56	0.92	0.60	1.94	1.32	11.22	10
SE	3.47	1.68	0.99	0.64	1.94	1.32	13.46	12
CZ	4.19	2.02	0.92	0.60	2.50	1.70	10.99	9.8
NO	4.12	1.99	0.94	0.61	1.94	1.32	9.76	8.7
SK	3.23	1.56	0.92	0.60	1.94	1.32	11.22	10
UA	3.23	1.56	0.92	0.60	1.94	1.32	11.22	10

#### Broilers

The excretion coefficients for Finland, Denmark, Czech Republic, Germany, Poland, and Sweden originate from the OECD (2001) Nitrogen Balance Database and were recalculated to a yearly emission assuming a 9 week lifecycle of the broilers. Broilers in the remaining countries were assigned the lowest excretion rate, i.e., 1.6 kg-N per animal per year.

The average nitrogen intake for male and female broilers was calculated using Tables 2-5 and 2-6 in the NRC (2001) Nutrient Requirements of Poultry. The nitrogen intake for the 9 weeks lifecycle was then recalculated to a yearly nitrogen intake of 5.53 kg-N per year. This intake was then assumed to give the highest of the OECD excretions, i.e., 2.7 giving a factor of 0.483 between intake and excretion. Thus, the intake for "Broilers" in the countries was calculated as  $\text{intake}_{\text{Broilers}} = \text{excretion}_{\text{Broilers}} / 0.483$ .

#### Laying Hens

The excretion coefficients for Finland, Denmark, Czech Republic, Germany, Poland, and Sweden originate from the OECD (2001) Nitrogen Balance Database. In Norway, laying hens were estimated to excrete 0.61 kg-N per animal (Bleken and Bakken 1997). Lifespan of laying hens is expected to be between 20 and 72 weeks so we assume an average lifespan of 52 weeks, equal to one year, thus there is no correction for life length. Laying hens in the remaining countries were assigned the lowest excretion rate, i.e., 0.60 kg-N per laying hen per year.

For Norwegian laying hens we use the estimation by Bleken and Bakken (1997). The intake for laying hens in the remaining countries was calculated using the relationship between intake and excretion for Norwegian laying hens, i.e.,  $\text{Intake}_{\text{Laying hens}} = \text{Excretion}_{\text{Laying hens}} / 0.65$ .

### **Other Poultry (Ducks and Turkey)**

The excretion coefficients for Denmark, Czech Republic, Germany, and Poland originate from the OECD (2001) Nitrogen Balance Database. The “Other Poultry” in the remaining countries was assigned the medium excretion rate, i.e., 1.32 kg-N per animal and year.

An average nitrogen intake for “Other Poultry” of 2.5 kg-N per year was calculated using intake data for ducks and turkey in the NRC (2001) Nutrient Requirements of Poultry. This intake was then assumed to give the highest of the OECD excretions, i.e., 1.70 kg-N per year. Hence the intake for “Other Poultry” in the remaining countries was calculated as  $\text{intake}_{\text{Other Poultry}} = \text{excretion}_{\text{Other Poultry}} / 0.68$ .

### **Sheep**

The excretion coefficients for Czech Republic, Sweden, and Poland originate from the OECD (2001) Nitrogen Balance Database. Norwegian sheep were assumed to excrete 8.7 kg-N per year (Bleken and Bakken 1997). “Sheep” in the remaining countries was assigned the medium excretion rate, i.e., 10 kg-N per animal and year.

For Norwegian sheep we use the estimation by Bleken and Bakken (1997). The intake for sheep in the remaining countries was calculated using the relationship between intake and excretion for Norwegian sheep, i.e.,  $\text{intake}_{\text{Sheep}} = \text{excretion}_{\text{Sheep}} / 0.89$ .

#### **5.2.4. Toolbox Calculation**

The following procedure was applied for calculating animal N consumption and N production:

- The proportion of each animal reporting unit polygon falling onto the watersheds of interest was calculated from the animal map (Figure 5.2.1.A) and the watershed map.
- Animal numbers were extracted from the animal count data (Tables 5.2.3.1.A, 5.2.3.1.B, and 5.2.3.1.C) for all the polygons that intersect with the watersheds of interest.
- Watershed-specific animal N intake and N excretion parameters were estimated from the animal N parameters provided at the country level (Tables 5.2.3.2.A, 5.2.3.3.A, and 5.2.3.4.A).
- Watershed animal N consumption and N excretion were calculated by multiplying the proportion of watershed in each animal reporting unit polygon and the extracted animal count value for the corresponding polygon, aggregating the animal numbers for each watershed, and multiplying the animal N intake and N excretion parameters, respectively, estimated at the watershed level.
- Watershed animal N production was calculated by subtracting watershed animal N excretion from N consumption, and applying the percent loss of N during the food processing.

A step-by-step procedure for calculating animal N consumption and N production is given below, with the screenshots and file names that can be found in the documentation package:

The NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the animal map “09\_Merged\_Final.shp” and the watershed map “WSWatershed\_v2008\_4.shp” were added (Figure 5.2.4.A):

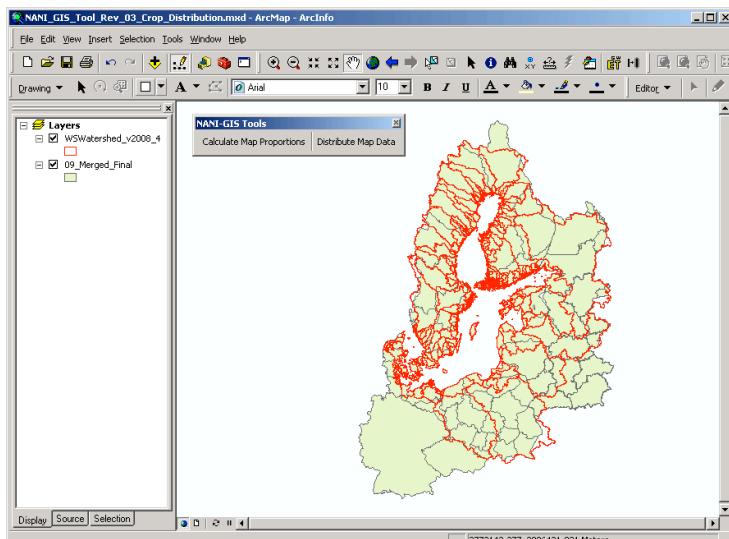


Figure 5.2.4.A. Running NANI-GIS tool to calculate animal polygon proportion.

The “Calculate Map Proportions” button was clicked, and the tool was specified as shown in Figure 5.2.4.B:

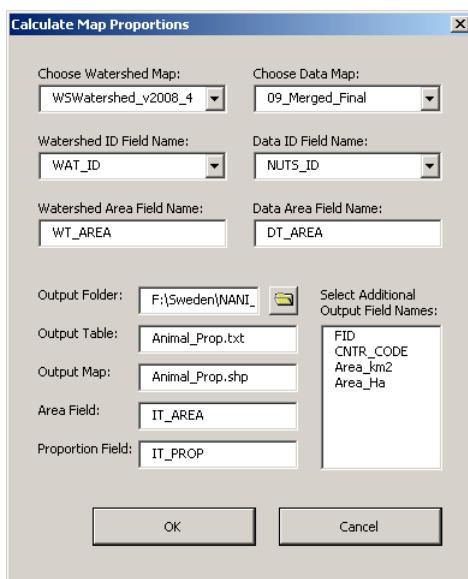


Figure 5.2.4.B. Specifying NANI-GIS tool to calculate animal polygon proportion.

After running the NANI-GIS tool, a proportion table “Animal\_Prop.txt” was created, with animal polygons in the rows and watersheds in the columns. This table was imported into the NANI-extraction tool “NANI\_Extraction\_Tool\_Animals.xlsxm” (Figure 5.2.4.C):

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	NUTS_ID	Area_km2	W9018	W151	W2017	W9019	W149	W2018	W9020	W142	W143	W145	W147
2	Area_km2 -	464.03	51464.56	629.43	745.45	2178.11	12458.89	1877.98	1903.43	6579.13	3152.45	3319.66	
3	CZ08	5558.670701	0	0	0	0	0	0	0	0	0	0	0
4	DE41	15643.56308	0	0	0	0	0	0	0	0	0	0	0
5	DE80	23062.46798	0	0	0	0	0	0	0	0	0	0	0
6	DEF0	15547.84207	0	0	0	0	0	0	0	0	0	0	0
7	EE00	43163.59409	0	0	0	0	0	0	0	0	0	0	0
8	FI13	85266.13802	0	0	0	0	0	0	0	0	0	0	0
9	FI18	43304.77152	0	0	0	0	0	0	0	0	0	0	0
10	FI19	64203.97341	0	0	0	0	0	0	0	0	0	0	0
11	FI1A	141325.6995	0	0	0	0	0	0	0	0	0	0	0
12	FI20	910.6145906	0	0	0	0	0	0	0	0	0	0	0
13	LT00	64857.91692	0	0	0	0	0	0	0	0	0	0	0
14	LV00	64682.91261	0	0	0	0	0	0	0	0	0	0	0
15	PL11	18259.41981	0	0	0	0	0	0	0	0	0	0	0
16	PL12	35582.93897	0	0	0	0	0	0	0	0	0	0	0
17	PL21	15012.44749	0	0	0	0	0	0	0	0	0	0	0
18	PL22	12367.31569	0	0	0	0	0	0	0	0	0	0	0

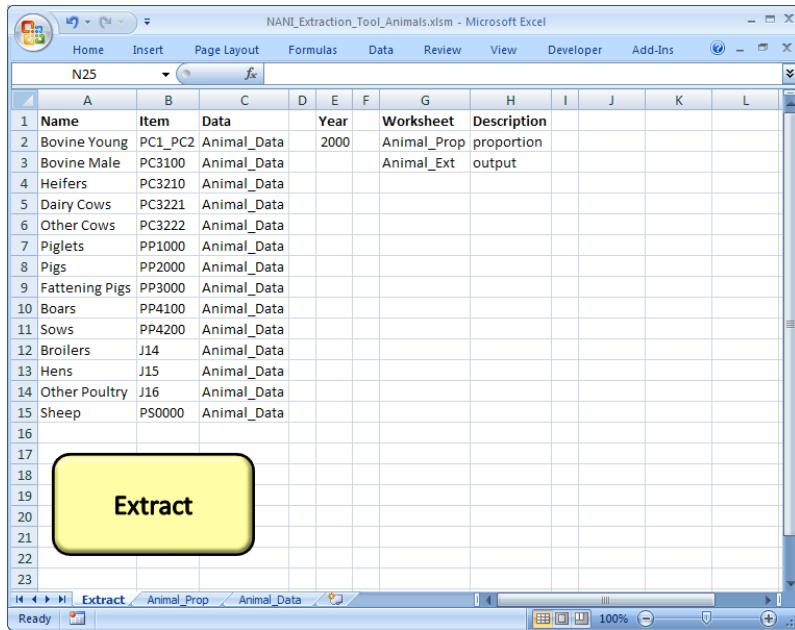
Figure 5.2.4.C. Animal polygon proportion table created after running NANI-GIS tool.

The animal numbers reported in Tables 5.2.3.1.A, 5.2.3.1.B, and 5.2.3.1.C are in the “Animal\_Data” worksheet of the NANI-extraction tool “NANI\_Extraction\_Tool\_Animals.xlsxm” (Figure 5.2.4.D):

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	NUTS_ID	Country_Oblast	Area_km2	PC1	PC2	PC3100	PC3210	PC3221	PP1000	PP2000	PP3000	PP4100	PP4200	J14	J15	J16	PS0000
2	BLR01	Belarus (Brest)	32,759	377,321	13,036	51,512	277,400	49,931	181,994	149,888	183,440	1,128	57,049	2,783,365	1,888,639	527,996	10,022
3	BLR02	Belarus (Grodno)	24,916	343,333	11,861	46,872	203,800	45,433	241,781	199,127	243,702	1,499	75,791	1,873,419	1,271,200	355,382	7,661
4	BLR03	Belarus (Minsk)	40,234	386,527	13,354	52,769	265,598	51,149	218,076	179,604	219,809	1,352	68,360	4,136,918	2,807,087	784,761	12,298
5	BLR04	Belarus (Gomel)	40,558	389,636	13,461	53,193	267,735	51,561	219,830	181,049	221,577	1,363	68,910	4,170,198	2,829,669	791,074	12,397
6	BLR05	Belarus (Vitebsk)	40,017	300,215	10,372	40,985	238,700	39,728	171,585	141,315	172,949	1,064	53,787	2,248,102	1,525,440	426,458	12,246
7	BLR06	Belarus (Mogilev)	29,050	279,079	9,642	38,100	191,766	36,931	157,454	129,677	158,705	976	49,357	2,986,922	2,026,762	566,610	8,879
8	DE	Germany	303,030	-	-	-	-	-	-	-	-	-	-	47,827,120	47,233,416	10,907,196	-
9	DE41	Germany	15,644	95,750	3,300	-	102,200	54,300	102,900	85,200	103,150	1,350	46,200	2,469,021	2,438,372	563,072	101,500
10	DE80	Germany	23,062	165,400	4,700	29,400	183,900	72,800	155,500	183,900	239,700	700	75,800	3,639,945	3,594,761	830,106	112,000
11	DEF0	Germany	15,548	418,300	12,800	94,300	354,500	63,900	383,500	331,400	573,800	3,800	120,800	2,453,913	2,423,452	559,626	359,100
12	DK01	Denmark	2,609	15,000	-	2,000	9,000	4,000	72,000	69,000	87,000	-	21,000	751,535	308,369	42,470	6,463
13	DK02	Denmark	6,958	47,000	1,000	4,000	21,000	13,000	455,000	398,000	341,000	1,000	142,000	2,004,221	822,371	113,261	17,235
14	DK03	Denmark	11,937	317,000	5,000	26,000	237,000	29,000	1,258,000	1,041,000	1,036,000	3,000	396,000	3,438,566	1,410,911	194,317	29,570
15	DK04	Denmark	12,813	276,000	3,000	22,000	173,000	35,000	1,602,000	1,426,000	1,255,000	4,000	490,000	3,690,889	1,514,444	208,576	31,740
16	DK05	Denmark	8,071	199,000	2,000	18,000	133,000	27,000	947,000	787,000	739,000	2,000	299,000	2,324,789	953,906	131,376	19,992
17	EE00	Estonia	43,164	69,900	1,200	14,500	116,800	1,600	104,100	83,900	106,600	1,500	37,700	1,005,000	1,175,000	25,000	29,900
18	FI13	Finland	85,266	93,900	1,900	7,900	93,700	4,800	27,900	16,200	31,100	600	12,800	1,539,830	1,122,421	129,804	12,300
19	FI18	Finland	43,305	55,300	1,950	5,700	56,750	7,750	160,400	128,450	227,850	1,850	73,900	782,045	570,053	65,924	19,000
20	FI19	Finland	64,204	103,300	2,700	9,700	97,550	12,050	183,050	142,200	238,200	2,650	90,600	1,159,466	845,164	97,740	25,500

Figure 5.2.4.D. Animal count data imported into NANI-extraction tool.

The animal count values were extracted by clicking the “Extract” button in the “Extract” worksheet (Figure 5.2.4.E):

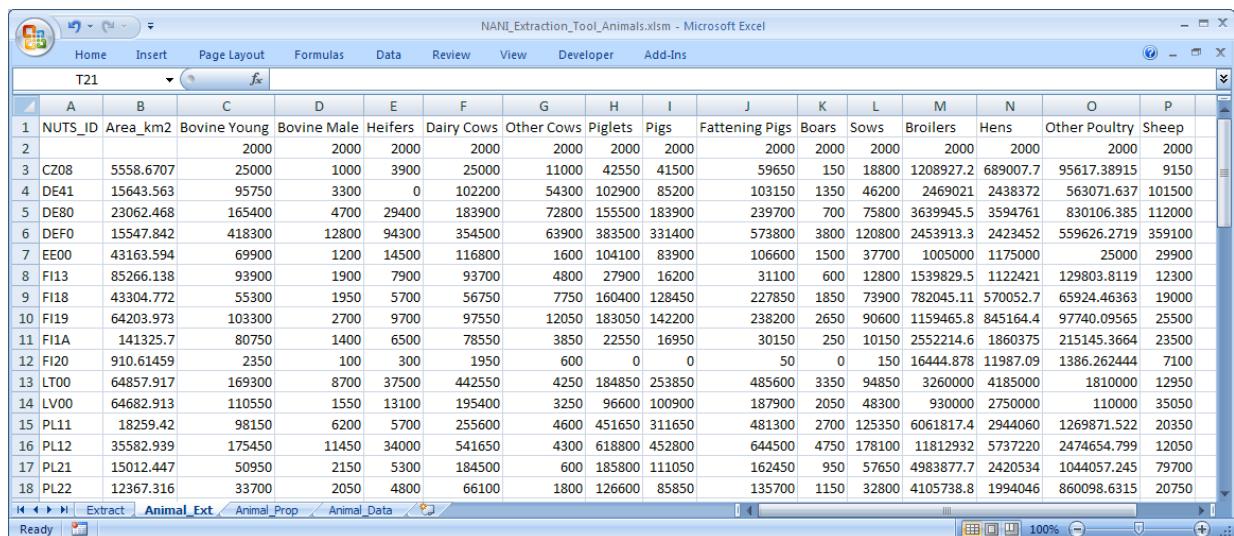


A screenshot of Microsoft Excel showing a table of animal count data. The table has columns for Name, Item, Data, Year, Worksheet, and Description. A yellow callout box highlights the 'Extract' button in the toolbar.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Name	Item	Data	Year	Worksheet	Description						
2	Bovine Young	PC1_PC2	Animal_Data	2000	Animal_Prop	proportion						
3	Bovine Male	PC3100	Animal_Data		Animal_Ext	output						
4	Heifers	PC3210	Animal_Data									
5	Dairy Cows	PC3221	Animal_Data									
6	Other Cows	PC3222	Animal_Data									
7	Piglets	PP1000	Animal_Data									
8	Pigs	PP2000	Animal_Data									
9	Fattening Pigs	PP3000	Animal_Data									
10	Boars	PP4100	Animal_Data									
11	Sows	PP4200	Animal_Data									
12	Broilers	J14	Animal_Data									
13	Hens	J15	Animal_Data									
14	Other Poultry	J16	Animal_Data									
15	Sheep	PS0000	Animal_Data									
16												
17												
18												
19												
20												
21												
22												
23												

Figure 5.2.4.E. Extracting animal count data using NANI-extraction tool.

After clicking the “Extract” button, the output worksheet “Animal\_Ext” was created and the extracted animal count values were reported (Figure 5.2.4.F). The extraction worksheet “Animal\_Ext” and the proportion worksheet “Animal\_Prop” were copied to the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xlsx”.



A screenshot of Microsoft Excel showing the 'Animal\_Ext' worksheet. The table contains data for various animal categories across different locations (NUTS\_ID) and years. The columns include Area\_km2, Bovine Young, Bovine Male, Heifers, Dairy Cows, Other Cows, Piglets, Pigs, Fattening Pigs, Boars, Sows, Broilers, Hens, Other Poultry, and Sheep.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	NUTS_ID	Area_km2	Bovine Young	Bovine Male	Heifers	Dairy Cows	Other Cows	Piglets	Pigs	Fattening Pigs	Boars	Sows	Broilers	Hens	Other Poultry	Sheep
2		2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	
3	CZ08	5558.6707	25000	1000	3900	25000	11000	42550	41500	59650	150	18800	1208927.2	689007.7	95617.38915	9150
4	DE41	15643.563	95750	3300	0	102200	54300	102900	85200	103150	1350	46200	2469021	2438372	563071.637	101500
5	DE80	23062.468	165400	4700	29400	183900	72800	155500	183900	239700	700	75800	363945.5	3594761	830106.385	112000
6	DEF0	15547.842	418300	12800	94300	354500	63900	383500	331400	573800	3800	120800	2453913.3	2423452	559626.2719	359100
7	EE00	43163.594	69900	1200	14500	116800	1600	104100	83900	106600	1500	37700	100500	1175000	25000	29900
8	FI13	85266.138	93900	1900	7900	93700	4800	27900	16200	31100	600	12800	1539829.5	1122421	129803.8119	12300
9	FI18	43004.772	55300	1950	5700	56750	7750	160400	128450	227850	1850	73900	782045.11	570052.7	65924.46363	19000
10	FI19	64203.973	103300	2700	9700	97550	12050	183050	142200	238200	2650	90600	1159465.8	845164.4	97740.09565	25500
11	FI1A	141325.7	80750	1400	6500	78550	3850	22550	16950	30150	250	10150	2552214.6	1860375	215145.3664	23500
12	FI20	910.61459	2350	100	300	1950	600	0	0	50	0	150	16444.878	11987.09	1386.262444	7100
13	LT00	64857.917	169300	8700	37500	442550	4250	184850	253850	485600	3350	94850	3260000	4185000	1810000	12950
14	LV00	64682.913	110550	1550	13100	195400	3250	96600	100900	187900	2050	48300	93000	2750000	110000	35050
15	PL11	18259.42	98150	6200	5700	255600	4600	451650	311650	481300	2700	125350	6061817.4	2944060	1269871.522	20350
16	PL12	35582.939	175450	11450	34000	541650	4300	618800	452800	644500	4750	178100	11812932	5737220	2474654.799	12050
17	PL21	15012.447	50950	2150	5300	184500	600	185800	111050	162450	950	57650	4983877.7	2420534	1044057.245	79700
18	PL22	12367.316	33700	2050	4800	66100	1800	126600	85850	135700	1150	32800	4105738.8	1994046	860098.6315	20750

Figure 5.2.4.F. Animal count data extracted using NANI-extraction tool.

The calculation of animal N consumption and N production uses spatially distributed animal N parameters estimated at the country level (Tables 5.2.3.2.A, 5.2.3.3.A, and 5.2.3.4.A). Watershed-specific animal N parameters were estimated by overlaying the country map that contains NANI parameters (Figure 4.3.A) with the watershed map. The detailed procedure for calculating watershed-

specific NANI parameters including animal N intake and N excretion is given in Section 4.4 (Figures 4.4.F, 4.4.G, and 4.4.H). Animal N consumption and N production were calculated by clicking the “Animals” button in the “Animals” worksheet (Figure 5.2.4.G). Note that the country-level NANI parameter worksheet “Cntr\_Prop” is listed in Cell L4, and the column headings containing the spatially varying animal N intake and N excretion parameters are specified in Columns G and H, respectively, instead of single numbers for all watersheds. (For example, the country-level N intake parameters for the “Bovine Young” can be found in the “A\_N\_IN\_BY” column of the “Cntr\_Prop” worksheet, as shown in Figure 4.4.H.)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Type	Inventory Item Name	Sales Item Name	Cycles per Year	Days on the Farm	Animal N Intake (kg./N/animal/yr)	N in Animal (kg./N/animal/yr)	Ammonia Emission (kg./Human N/animal/yr)	% Loss in Consumption										
2	Bovine Young	Bovine Young				365 A_N_IN_BY	A_N_EX_BY		10										
3	Bovine Male	Bovine Male				365 A_N_IN_BM	A_N_EX_BM		10										
4	Heifers	Heifers				365 A_N_IN_HF	A_N_EX_HF		10										
5	Dairy Cows	Dairy Cows				365 A_N_IN_DC	A_N_EX_DC		10										
6	Other Cows	Other Cows				365 A_N_IN_OC	A_N_EX_OC		10										
7	Piglets	Piglets				365 A_N_IN_PL	A_N_EX_PL		10										
8	Pigs	Pigs				365 A_N_IN_PG	A_N_EX_PG		10										
9	Fattening Pigs	Fattening Pigs				365 A_N_IN_FP	A_N_EX_FP		10										
10	Boars	Boars				365 A_N_IN_BR	A_N_EX_BR		10										
11	Sows	Sows				365 A_N_IN_SW	A_N_EX_SW		10										
12	Broilers	Broilers				365 A_N_IN_BL	A_N_EX_BL		10										
13	Hens	Hens				365 A_N_IN_HN	A_N_EX_HN		10										
14	Other Poultry	Other Poultry				365 A_N_IN_OP	A_N_EX_OP		10										
15	Sheep	Sheep				365 A_N_IN_SP	A_N_EX_SP		10										
16																			
17																			
18																			
19																			
20																			
21																			
22																			
23																			

Figure 5.2.4.G. Calculating animal N consumption and N production using NANI-accounting tool.

The NANI toolbox also reports the watershed-specific animal N intake and excretion parameters, calculated as the area-weighted averages of country-level parameters, that were used for calculating watershed animal N consumption and N production. The reported values can be found in the “Cntr\_Prop” worksheet below the country proportion table (Figure 5.2.4.H):

	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	
1	CNTR_CODE	W9018	W151	W2017	W9019	W149	W2178.11	12458.89	1877.98	1903.43	6579.13	3152.45	3319.66	3073.97	2233.67
2	Area_km2	464.03	51464.56	629.43	745.45										
3	BY	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	DE	357353.9731	0	0	0	0	0	0	0	0	0	0	0	0	0
5	DK	42489.3386	0	0	1.44E-02	0	0	0.28601	0	0	0	0	0	6.89E-02	0
23	N_FIX_OFAR	2500	2500	2920	2500	2500	2500	2500	2500	2500	2500	2500	2920	2500	
24	N_FIX_FALL	400	400	400	400	400	400	400	400	400	400	400	400	400	
25	N_FIX_SETA	400	400	400	400	400	400	400	400	400	400	400	400	400	
26	H_N_IN	6.30136	6.277186	6.51744	6.30136	6.30136	6.51744	6.30136	6.30136	6.30136	6.30136	6.30136	6.51744	6.30136	
27	A_N_IN_BY	44.9	42.83685	70	44.9	44.9	70	44.9	44.9	44.9	44.9	44.9	44.9	70	44.9
28	A_N_IN_BM	68.23529	63.62175	64.58824	68.23529	64.58824	68.23529	68.23529	68.23529	68.23529	68.23529	68.23529	64.58824	68.23529	
29	A_N_IN_HF	59.6	57.66103	78.3	59.6	59.6	78.3	59.6	59.6	59.6	59.6	59.6	59.6	78.3	59.6
30	A_N_IN_DC	156.7501	148.99	154.5663	156.7501	156.7501	154.5663	156.7501	156.7501	156.7501	156.7501	156.7501	156.7501	156.7501	
31	A_N_IN_OC	70.78652	71.61733	82.35955	70.78652	82.35955	70.78652	70.78652	70.78652	70.78652	70.78652	70.78652	82.35955	70.78652	
32	A_N_IN_PL	8.404733	8.165898	7.308464	8.404733	7.308464	8.404733	8.404733	8.404733	8.404733	7.308464	8.404733	7.308464	8.404733	
33	A_N_IN_PG	21.42857	21.42857	14.7619	21.42857	21.42857	14.7619	21.42857	21.42857	21.42857	21.42857	21.42857	14.7619	21.42857	
34	A_N_IN_FP	25.8574	27.10926	46.83063	25.8574	46.83063	25.8574	25.8574	25.8574	25.8574	25.8574	25.8574	46.82063	25.8574	
35	A_N_IN_BR	10.81295	12.09603	27.63309	10.81295	10.81295	27.63309	10.81295	10.81295	10.81295	10.81295	10.81295	27.63309	10.81295	

Figure 5.2.4.H. Watershed-specific animal N intake and excretion parameters calculated by NANI toolbox.

### 5.2.5. Preliminary Results

Figures 5.2.5.A and 5.2.5.B below show the watershed animal N consumption and N production, respectively, in three regions of Baltic Sea catchment areas calculated by NANI toolbox.

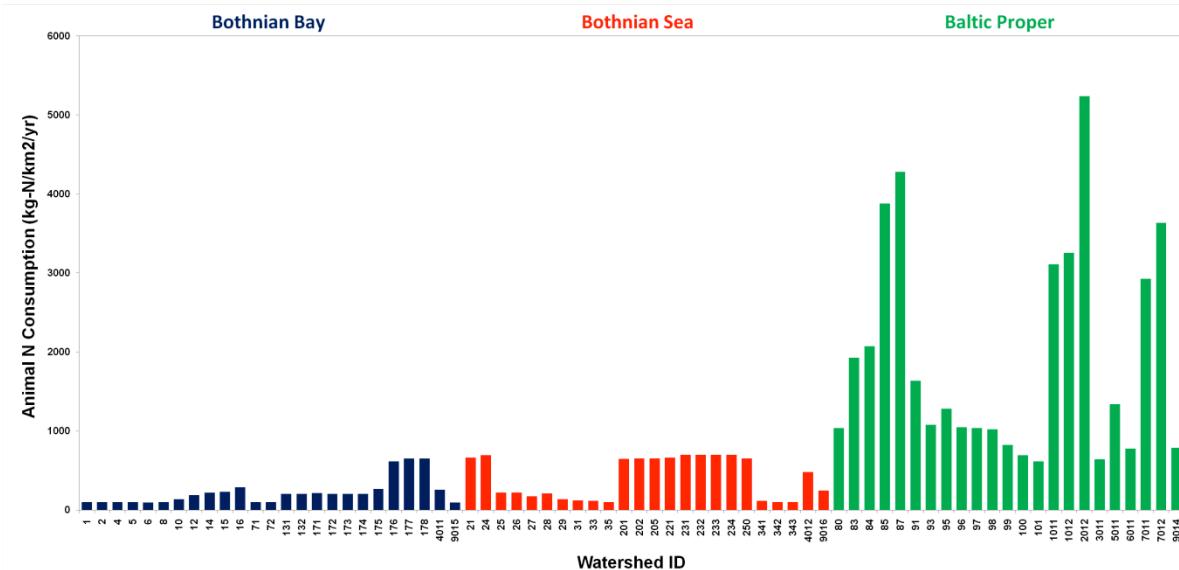


Figure 5.2.5.A. Animal N consumption in Baltic Sea catchments.

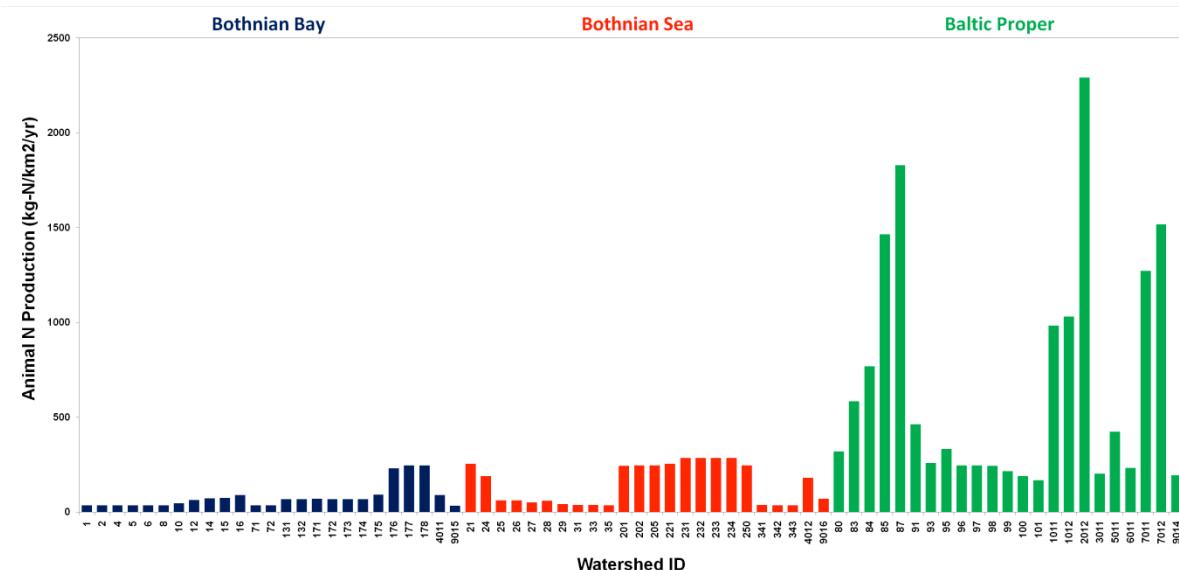


Figure 5.2.5.B. Animal N production in Baltic Sea catchments.

Relative frequencies of animal N consumption and N production are shown in Figures 5.2.5.C and 5.2.5.D, respectively.

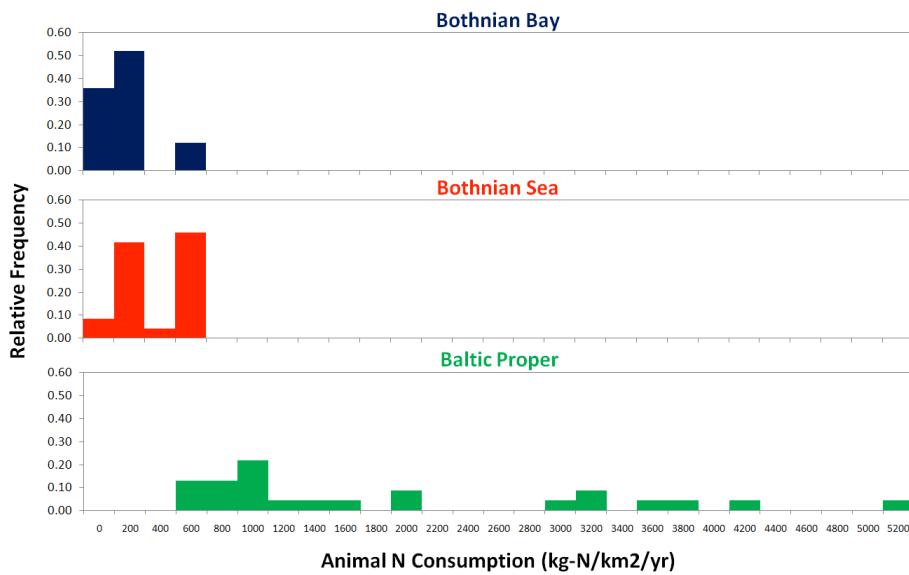


Figure 5.2.5.C. Relative frequencies of animal N consumption in Baltic Sea catchments.

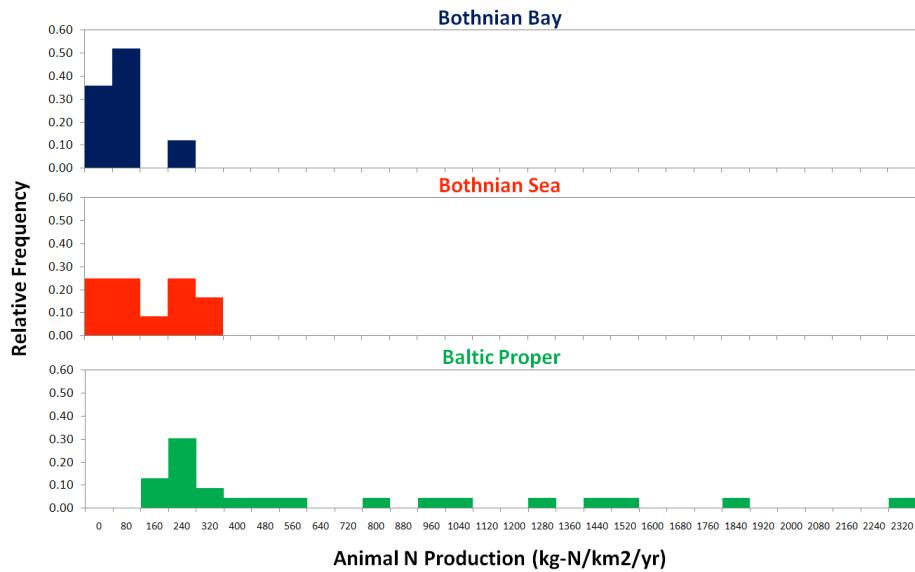


Figure 5.2.5.D. Relative frequencies of animal N production in Baltic Sea catchments.

Figures 5.2.5.E and 5.2.5.F below show the watershed animal N consumption and N production, respectively, by animal class (area-weighted averages over all watersheds).

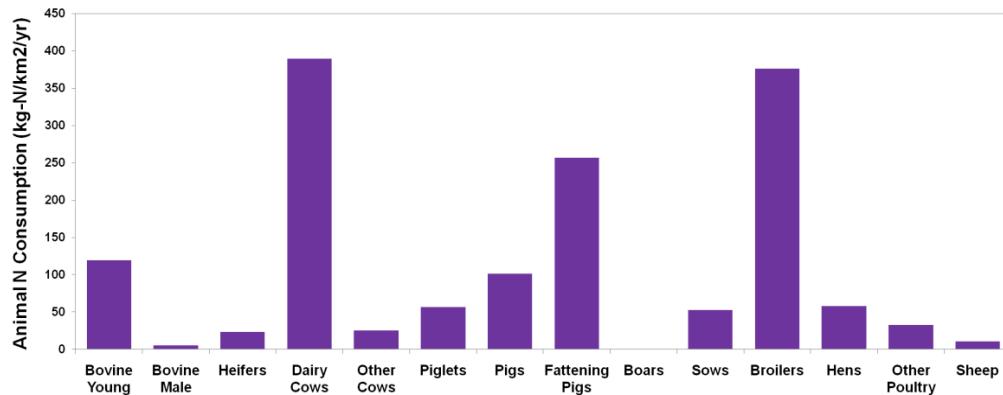


Figure 5.2.5.E. Animal N consumption by animal class.

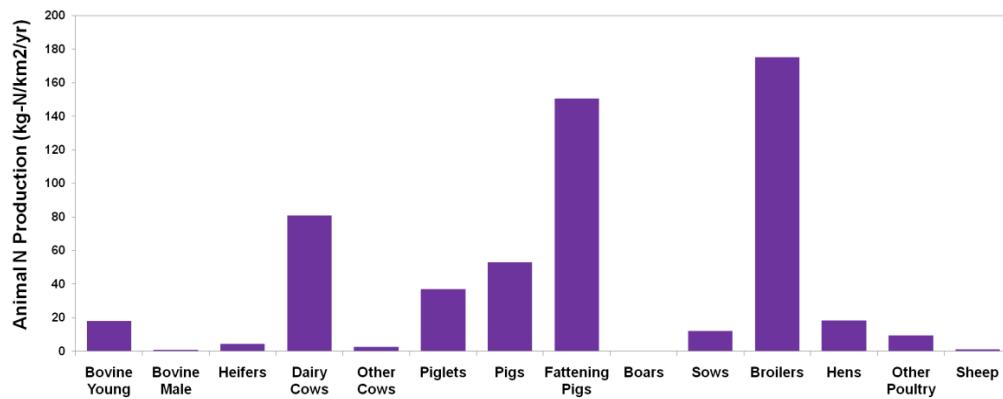


Figure 5.2.5.F. Animal N production by animal class.

## 5.3. Crop N Production

### 5.3.1. Overview

When a map of harvested crop production (in kilograms harvested in the mapped reporting units) for the region of interest is available, watershed crop N production can be calculated by overlaying the crop map with the watershed map, summing the production values for each crop type over all production reporting unit regions for each watershed, and applying the crop N parameters (e.g., percent N content) and summing over all crop types. Harvested crops may be reported on a wet or dry matter basis, and the percent N content must be provided accordingly. Harvested crops may also be reported as harvested areas (in square kilometers or hectares), and conversion factors to kilograms of weight per area may be specified. Additional parameters such as percent distribution to humans and animals and percent loss of N during food processing can be used for calculating N in crop products for humans and animals.

The calculation of crop N production in the Baltic Sea catchments was more challenging than that in earlier studies, because the harvested crop production data were available only at the country level, somewhat coarser resolution than desired. Relevant finer scale data available were the harvested crop areas (in hectares harvested) in the extended ISPRA grid covering the areas of Belarus and Russia. The resolutions of these data are compared in Figure 5.3.1.A below.

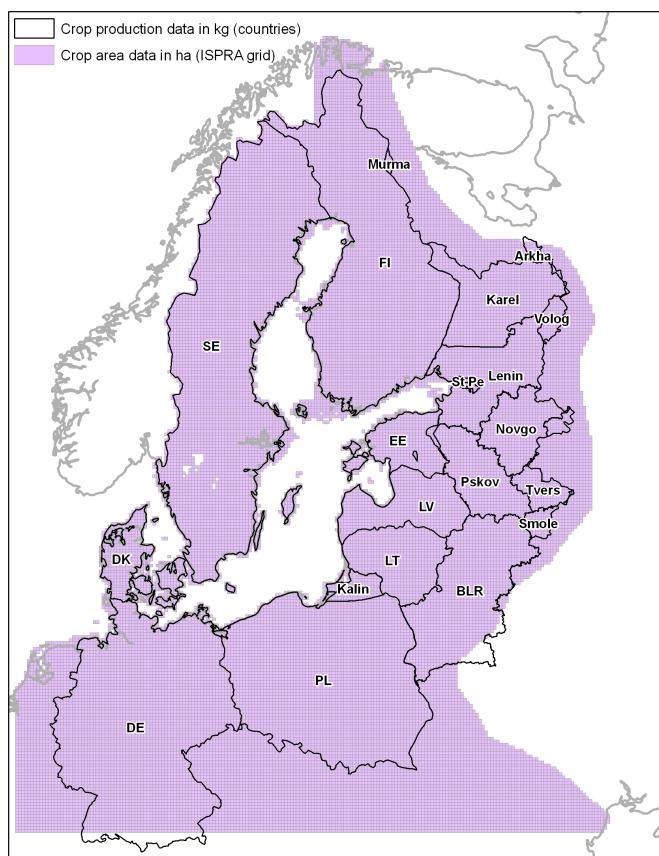


Figure 5.3.1.A. Crop production and crop area data available in Baltic Sea catchments.

Note that, out of six administrative regions of Belarus (BLR), only the four shared by the extended ISPRA grid were included (i.e., Brest, Grodno, Minsk, and Vitebsk Voblasts were included; Gomel and Mogilev Voblasts were excluded). Also note that Russia is further divided into eleven oblasts (Karelia, Arkhangelskaya, Vologodskaya, Kaliningradskaya, Leningradskaya, Murmanska, Novgorodskaya, Pskovskaya, Smolenskaya, Tverskaya, and St. Petersburg) according to data availability.

Given these considerations, the strategy taken in this analysis was to distribute the country-based harvested crop values into the ISPRA cells of the corresponding countries in proportion to the areas of an “equivalent” crop. The implicit assumption in this approach is that crop production (in kilograms) is proportional to crop area (ha) for a given country. The country-based harvested crop data (original values obtained from the EuroStat website; Section 5.3.2) and the ISPRA crop area data do not have the same classification system for crops (e.g., ISPRA data include the variable “OCER” representing “Other Cereals” that is not defined in the EuroStat data). Matching the crop types between the two datasets is described in Section 5.3.3. A new GIS tool was added to the NANI toolbox to allow the user to distribute regional data (in this example, country-level crop production) into finer spatial units (grid cells containing crop area information) (Section 5.3.5).

### **5.3.2. Data Availability**

For the EU countries, country-level EuroStat data on annual crop production (in 1000 tonnes) was derived from <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/>. For Belarus, country level production numbers were derived from FAOSTAT available at (<http://faostat.fao.org/site/567/default.aspx#ancor>). For Russia, country level yield (Hg/Ha) was derived from FAOSTAT (<http://faostat.fao.org/site/567/default.aspx#ancor>).

A 10 km x 10 km grid, produced by ISPRA, containing crop areas in ha for crop types for the year 2000 was used. This gridded data covers the entire Baltic drainage area including non-EU countries (Figure 5.3.1.A).

### **5.3.3. Input Preparation**

The ISPRA crop area data do not have the same classification system for harvested crops as the data from EuroStat. The EuroStat code closest to each ISPRA crop code was found, as summarized in Table 5.3.3.A. The table also contains the percent N content of the crop as described in detail below. For the class “OCER”, production data from FAOSTAT on cereal types that did not have a specific class in ISPRA data was aggregated. Following this classification scheme, the original harvested crop data (in 1000 tonnes) described in Section 5.3.2 were used to create a country-by-crop production table (Table 5.3.3.B). This table was saved as a comma-delimited text file “CNTR\_SUM\_BL\_RU\_Added\_Rev\_05.csv” (Figure 5.3.3.A) and used as input to the NANI-GIS tool described in Section 5.3.5. The EuroStat crop production data for the EU countries was averaged over the years 1998-2009 and distributed over the harvested areas from the ISPRA data (Section 5.3.5). For Belarus, the production numbers from FAO was distributed over the harvested areas from the ISPRA data. For Russia, yield data was used with the ISPRA harvested area data to calculate production numbers. Median values of the years 2000-2008 was used for both Belarus and Russia.

Table 5.3.3.A. ISPRA code matched with EuroStat code.

ISPRA Crop Code	ISPRA Crop Description	EuroStat Code	EuroStat Description	Parameter Used (% N in Crop)	Notes and References
BARL	Barley	C1160	Barley	1.877	Derived from US values
SWHE	Common Wheat and Spelt	C1120	Common Wheat and Spelt	1.64	Eriksson-Hägg
DWHE	Durum Wheat	C1130	Durum Wheat	2.144	Derived from US values
MAIF	Green Maize: Other Green Fodder: Forage Plant	C2625	Green maize	0.354	Derived from US values
HOPS	Hops	C1560	Hops	2.2	Derived from US values
OATS	Oats	C1180	Oats	1.65	Eriksson-Hägg
POTA	Potatoes	C1360	Potatoes	0.3	Johnes
PULS	Pulses - Total	C1885	Pulses	4.05	Eriksson-Hägg average
RAPE	Rape and Turnip: Other Oil-Seed or Fiber Plants	C1420	Rape - Turnip rape	3.542	Derived from US values
RYEM	Rye	C1150	Rye	1.51	Eriksson-Hägg
SOYA	Soya: Other Oil-Seed or Fiber Plants	C1470	Soya bean	5.92	Derived from US values
SUGB	Sugar Beet	C1370	Sugar Beet	0.225	Johnes average
SUNF	Sunflower: Other Oil-Seed or Fiber Plants	C1450	Sunflower seed	2.86	Derived from US values
APPL	Fruit and Berry Plantations - Total	C2009	Total Fruit (including all olives, all grapes, wild products and fruits from kitchen gardens)	0.04	Sosulksi and Imafidon (1990)
LEFO	Leguminous Plants: Other Green Fodder: Forage Plants	C2671, C2672, C2673	Clover and mixtures, Lucerne, Other legumes (sainfoin, sweet clover)	2.52	Derived from US values
ROOF	Fodder Roots and Brassicas	C1381, C1383	Fodder Beet, Fodder Kale	0.225	Johnes average
MAIZ	Maize	C1200	Grain Maize	1.425	Derived from US values
OCER	Other Cereals			1.9	Johnes
GRAI	Pasture and Meadow: Permanent Grassland and Meadow			2.5	Derived from US values
OFAR	Forage Plants - Temporary Grass			2.5	Derived from US values
GRAE	Rough Grazing: Permanent Grassland and Meadow			2	Derived from US values
FALL	Fallow Land without Subsidies			2	Derived from US values
SETA	Fallow Land with No Economic Use: Set-Aside Areas Under Incentive Schemes				No grazing or harvest assumed

Table 5.3.3.B. Crop production table (unit: 1000 tonnes).

Country Code	BARL	SWHE	DWHE	MAIF	HOPS	OATS	POTA	PULS	RAPE	RYEM	SOYA	SUGB	SUNF	APPL	LEFO	ROOF	MAIZ	OCER
Karel	1.41	0.036	0	10.1	0	1.09	0.139	0.018	0.044	0.099	0	0.386	0	0.033	0	0	0	0.002
Arkha	0	0	0	1.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volog	0	0	0	3.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalin	127	99.1	0	684	0	44.3	616	16.0	2.35	38.3	0	15.7	0	43.6	0	0	0.188	14.4
Lenin	54.6	30.3	0	355	0	12.7	260	0.031	0.091	1.42	0	0.422	0.0006	0.017	0	0	0	0.093
Murma	0.014	0	0	0	0	0.0022	0.020	0.0011	0.0009	0	0	0	0	0	0	0	0	0
Novgo	31.9	17.6	0	231	0	8.58	161	0	0	1.86	0	0	0	0	0	0	0	0
Pskov	103	67.5	0	590	0	33.4	502	0.898	0.420	15.3	0	4.75	0	9.63	0	0	0	1.22
Smole	11.7	7.80	0	72.6	0	4.35	59.5	0.033	0	1.32	0	0	0	0	0	0	0	0.048
Tvers	10.7	4.28	0	78.3	0	0.873	43.3	0	0	0	0	0	0	0	0	0	0	0
St Pe	2.89	1.84	0	17.7	0	0.807	16.5	0	0	0.424	0	0	0	0	0	0	0	0
DE	12012	22270	46.2	55449	30.0	1052	11486	72.5	4605	3683	0	25322	64.7	2641	1930	883	3727	2834
DK	3655	4683	0	3753	0	260	1514	15.4	393	225	0	2904	0	51.1	66.9	842	0	156
EE	296	195	0	18.0	0	80.6	258	0.027	67.3	40.4	0	0	0	13.5	726	0	0	24.4
FI	1846	637	0	0	0	1184	690	5.93	98.2	60.7	0	924	0.1	16.1	145	0	0	47.4
LT	888	1281	0	329	0.6	99.9	1130	0.95	184	199	0	817	0	105	2051	883	14.7	256
LV	282	600	0	50.4	0	98.3	682	0.273	92.1	121	0	419	0	44.2	0	153	0	56.3
PL	3435	8867	0	10591	2.85	1315	15850	98.9	1426	3944	0.233	12265	3.06	3104	1876	2618	1503	6924
SE	1612	2207	0	0	0	963	928	0	186	148	0	2430	0	33.0	0	0	0	311
BLR	1223	718	0	0	0	387	5778	123	84.3	872	0	2047	13.4	255	93.0	577	33.5	668

The screenshot shows the ArcMap application interface with a CSV file open. The file name is 'CNTR\_SUM\_BL\_RU\_Added\_Rev\_05.csv'. The table has 20 rows and 17 columns. The columns are labeled: CHTR\_CODE, BARL, SWHE, DWHE, MAIF, HOPS, OATS, POTA, PULS, RAPE, RYEM, SOYA, SUGB, SUNF, APPL, LEFO, ROOF, MAIZ, OCER. The data includes regional names like Karel, Arkha, Volog, Kalin, Lenin, Murma, Novgoro, Pskov, Smole, Tvers, St.Pe, DE, DK, EE, FI, LT, LV, PL, SE, and BLR, along with their corresponding crop production values.

CHTR_CODE	BARL	SWHE	DWHE	MAIF	HOPS	OATS	POTA	PULS	RAPE	RYEM	SOYA	SUGB	SUNF	APPL	LEFO	ROOF	MAIZ	OCER	
Karel	1.41340	0.03587	0	10.1087	0	1.06854	0.13850	0.01791	0.04445	0.09856	0	0.38629	0	0.03331	0	0	0	0.00228	
Arkha	0	0	0	1.46674	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Volog	0	0	0	3.33039	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Kalin	126.542	99.0795	0	684.442	0	44.3075	615.852	15.9776	2.34603	38.3014	0	15.6950	0	43.5551	0	0	0.16807	14.4201	
Lenin	54.6434	30.2740	0	354.987	0	12.7340	260.177	0.03073	0.09099	1.42382	0	0.42223	0.00062	0.01655	0	0	0	0.09260	
Murma	0.01416	0	0	0	0	0.00216	0.02015	0.00105	0.00088	0	0	0	0	0	0	0	0	0	
Novgoro	31.8859	17.6293	0	231.050	0	8.57590	160.774	0	0	1.8605	0	0	0	0	0	0	0	0	
Pskov	102.922	67.5354	0	590.325	0	33.4241	502.485	0.89832	0.42019	15.3107	0	4.75481	0	9.63006	0	0	0	1.21815	
Smole	11.7421	7.79985	0	72.6014	0	4.35357	59.4805	0.03342	0	1.32332	0	0	0	0	0	0	0	0.04621	
Tvers	10.7441	4.28266	0	78.2692	0	0.87311	43.3024	0	0	0	0	0	0	0	0	0	0	0	
St.Pe	2.88890	1.8417	0	17.7227	0	0.06061	16.5086	0	0	0.42411	0	0	0	0	0	0	0	0	
DE	12012.3	22270.1	46.1583	55448.5	29.95	1052.24	11485.7	72.4636	4605.4	3682.86	0	25321.9	64.6636	2640.8	1929.54	883.1	3727.18	2833.9	
DK	3654.94	4682.50	0	3752.93	0	259.654	1514.04	15.4444	393.054	224.509	0	2903.50	0	51.1	66.89	842.1	0	156.3	
EE	295.890	191.945	0	18.0166	0	80.6363	257.872	0.02727	67.3	40.4454	0	0	0	13.525	725.525	0	0	24.446	
FI	1845.65	636.758	0	0	0	116.88	689.916	5.92727	98.1686	60.6833	0	923.625	0.1	16.0727	144.7	0	0	47.4	
LT	888.341	1280.60	0	328.916	0	0.99.8636	1130.25	0.95	183.841	199.341	0	817.4	0	104.911	2051.33	883.445	14.7	256.1	
LV	282.441	599.766	0	50.3727	0	0.98.3454	681.845	0.27272	92.0666	121.2	0	419.327	0	44.2222	0	153.4	0	56.3	
PL	3434.93	8867.24	0	10590.5	2.8454	1314.93	15849.5	98.8714	1426.1	3944.38	0	23333.1	12265.4	3.05833	3104.38	1875.98	2618.04	1503.08	6923.88
SE	1611.71	2207.02	0	0	0	0.963.481	927.863	0	166.075	147.933	0	2429.94	0	33.04	0	0	0	310.6	
BLR	1222.64	716.242	0	0	0	0.387.424	5777.79	122.739	84.2602	671.686	0	2047.49	13.3596	254.979	92.9707	577.178	33.5034	667.594	

Figure 5.3.3.A. Crop production table added to ArcGIS.

Crop production is converted into crop N production by applying the percent N content of the harvested crop. The percent N content assigned for each crop type is summarized in Table 5.3.3.A above. Detailed consideration on crop parameter estimation for each crop type is given below:

- BARL (Barley) – EuroStat code: C1160 (Barley)  
Penny Johnes' value for UK: 1.9 (Cereals)  
US value (Lander et al. 1998): 1.877 (= % dry matter 88.85 x % N in dry matter 2.112; Barley)  
Value used: 1.877
- SWHE (Common Wheat and Spelt) – EuroStat code: C1120 (Common Wheat and Spelt)  
Hanna Eriksson-Hägg's value for Sweden: 1.64 (Wheat)  
Penny Johnes' value for UK: 1.9 (Cereals)  
US value: 1.9 (= % dry matter 88.542 x % N in dry matter 2.15; wheat varieties averaged)  
Value used: 1.64
- DWHE (Durum Wheat) – EuroStat code: C1130 (Durum Wheat)  
Hanna Eriksson-Hägg's value for Sweden: 1.64 (Wheat)  
Penny Johnes' value for UK: 1.9 (Cereals)  
US value: 2.144 (= % dry matter 88.167 x % N in dry matter 2.432; Durum Wheat Harvested)  
Value used: 2.144
- MAIF (Green Maize: Other Green Fodder: Forage Plant) – EuroStat code: C2625 (Green maize)  
US value: 0.354 (= % dry matter 28.4 x % N in dry matter 1.248; Field Corn for Silage)  
Value used: 0.354
- HOPS (Hops) – EuroStat code: C1560 (Hops)  
US value: 2.2 (= % dry matter 70 x % N in dry matter 3.15; Hops)  
Value used: 2.2

- OATS (Oats) – EuroStat code: C1180 (Oats)  
 Hanna Eriksson-Hägg's value for Sweden: 1.65 (Rye)  
 Penny Johnes' value for UK: 1.9 (Cereals)  
 US value: 1.83 (= % dry matter 89.43 x % N in dry matter 2.048; Oats)  
 Value used: 1.65
- POTA (Potatoes) – EuroStat code: C1360 (Potatoes)  
 Hanna Eriksson-Hägg's value for Sweden: 0.25 (Fresh potatoes) - 0.35 (Other potatoes)  
 Penny Johnes' value for UK: 0.3 - 0.35 (Potatoes)  
 US value: 0.357 (= % dry matter 22.275 x % N in dry matter 1.601; Irish Potatoes)  
 Value used: 0.3
- PULS (Pulses – Total) – EuroStat code: C1885 (Pulses)  
 Hanna Eriksson-Hägg's value for Sweden: 3.5 (Peas) - 4.6 (Beans)  
 Penny Johnes' value for UK: 1.1 - 3.6 (Peas & Beans)  
 Value used: 4.05
- RAPE (Rape & Turnip: Other Oil-Seed or Fiber Plants) – EuroStat code: C1420 (Rape - turnip rape)  
 US value: 3.542 (= % dry matter 91.067 x % N in dry matter 3.889; Canola)  
 Value used: 3.542
- RYEM (Rye) – EuroStat code: C1150 (Rye)  
 Hanna Eriksson-Hägg's value for Sweden: 1.51 (Reye)  
 Penny Johnes' value for UK: 1.9 (Cereals)  
 US value: 1.91 (= % dry matter 88.05 x % N in dry matter 2.168; Rye for Grain)  
 Value used: 1.51
- SOYA (Soya: Other Oil-Seed or Fiber Plants) – EuroStat code: C1470 (Soya bean)  
 US value: 5.92 (= % dry matter 90.575 x % N in dry matter 6.535; Soybeans)  
 Value used: 5.92
- SUGB (Sugar Beet) – EuroStat code: C1370 (Sugar Beet)  
 Penny Johnes' value for UK: 0.15 - 0.3 (Sugar Beet)  
 US value: 0.238 (= % dry matter 19.075 x % N in dry matter 1.248; Sugar Beets, Root)  
 Value used: 0.225
- SUNF (Sunflower: Other Oil-Seed or Fiber Plants) – EuroStat code: C1450 (Sunflower seed)  
 US value: 2.86 (= % dry matter 93.3 x % N in dry matter 3.066; Sunflower Seed)  
 Value used: 2.86
- APPL (Fruit and Berry Plantations – Total) – EuroStat code: C2009 (Total fruit (including all olives, all grapes, wild products and fruits from kitchen gardens))  
 Value used: 0.04 (= % dry matter 19.075 (same as "Sugar Beet") x % N in dry matter 0.21 (Sosulksi and Imafidon 1990, "apple"))
- LEFO (Leguminous Plants: Other Green Fodder: Forage Plants) – EuroStat code: C2671, C2672, C2673 (Clover and mixtures, Lucerne, Other legumes (sainfoin, sweet clover))  
 Value used: 2.52 (= % dry matter 90.35 (same as US "Alfalfa Hay") x % N in dry matter 2.789 (same as US "Alfalfa Hay"; alternative values from Hanna are 3.2 (Clover Silage), 2.72 (Clover Grass Silage), 1.92 (Clover hay silage)))
- ROOF (Fodder Roots and Brassicas) – EuroStat code: C1381, C1383 (Fodder Beet, Fodder Kale)  
 Value used: 0.225 (same as "Sugar Beet")
- MAIZ (Maize) – EuroStat code: C1200 (Grain Maize)  
 US value: 1.425 (= % dry matter 86.7 x % N in dry matter 1.643; Field Corn for Grain)  
 Value used: 1.425

- OCER (Other Cereals)  
Penny Johnes' value for UK: 1.9 (Cereals)  
Value used: 1.9
- GRAI (Pasture and Meadow: Permanent Grassland and Meadow)  
US value: 2.5 (Cropland Pasture)  
Value used: 2.5
- OFAR (Forage Plants - Temporary Grass)  
US value: 2.5 (Cropland Pasture)  
Value used: 2.5
- GRAE (Rough Grazing: Permanent Grassland and Meadow)  
US value: 2 (Noncropland Pasture)  
Value used: 2
- FALL (Fallow Land without Subsidies)  
US value: 2 (Noncropland Pasture)  
Value used: 2
- SETA (Fallow Land with No Economic Use: Set-Aside Areas Under Incentive Schemes)  
Value used: 0 (No grazing or harvest assumed)

Area-based production estimates were made for GRAI and OFAR (2200 kg/ha; from US value for Cropland Pasture) and GRAE and FALL (1100 kg/ha; from US value for Noncropland Pasture), instead of using the FAO data for the permanent and temporary grasslands, respectively. The production values in the FAO data associated with hay, grazing, fresh cut grass, silage, etc. showed large gaps, possibly representing one of the biggest uncertainties in NANI calculation.

#### **5.3.4. Crop Distribution to Humans and Animals**

The distributions of crop yield to either humans or animals in the Baltic Sea catchment are based on the Food Balance Sheets (FBS) calculations from FAO (<http://faostat.fao.org>). In this version of the NANI calculation, we have used a mean of the different distributions of the crops in the major Baltic Sea countries. In some countries, there are large imports and/or exports that may complicate the assumptions and add uncertainty since we do not know the degree of utilization of the imported crops. The general losses (seed, processing, other utilization, and export) are set as "Losses in animal food" since there is no general loss before the distribution to humans or animals. The estimated distribution of crop yield to humans and animals in the Baltic Sea countries is summarized in Table 5.3.4.A, with the columns "OLD" and "NEW" indicating the values used in the US (see NANI Calculator Toolbox version 1.0 documentation at <http://www.eeb.cornell.edu/biogeo/nanc/nani/nani.htm>) and Baltic applications, respectively.

Table 5.3.4.A. Estimated distribution of crop yield to humans and animals.

Type	Changed	% Dist to	% Dist to	% Loss in	% Loss in	% Loss in
		humans (OLD)	humans (NEW)	human food (OLD)	in human food (NEW)	animal food (OLD)
Barley	yes	3	10	10	10	10
Common wheat & spelt	yes	61	54	10	10	10
Durum wheat	no	61	61	10	10	10
Green maize	no	0	0	0	0	0
Hops	yes	100	100	10	20	10
Oats	yes	6	10	10	10	10
Potatoes	yes	100	36	10	10	10
Pulses total	yes	2	20	10	15	10
Rape & tunip	yes	100	100	10	20	10
Rye	yes	17	43	10	10	10
Soya	no	2	2	10	10	10
Sugar beet	yes	10	30	10	10	10
Sunflower	no	100	100	10	10	10
Fruits & berries	yes	100	76	10	10	10
Leguminous	no	0	0	0	0	0
Fodder root & Brassicas	no	10	10	10	10	10
Maiz	yes	4	6	10	10	10
Other cereal	yes	61	61	10	10	10
Pasture & Meadow	no	0	0	10	10	10
Temp grassland	no	0	0	10	10	10
Rough grazing	no	0	0	10	10	10
Fallow	no	0	0	10	10	10

### 5.3.5. Toolbox Calculation

The following procedure was applied to calculate crop N production:

- Country-based crop production values (Table 5.3.3.B), in 1000 tonnes, were distributed into the extended ISPRA grid cells of corresponding countries (Figure 5.3.1.A) for each crop type listed in Table 5.3.3.A in proportion to the crop areas.
- The proportion of each ISPRA grid cell falling onto the watersheds of interest was calculated from the extended ISPRA grid and the watershed map.
- Distributed crop production values were extracted from the ISPRA grid cells that intersect with the watersheds of interest.
- Watershed crop N production was calculated by multiplying the proportion of watershed in each ISPRA cell by the extracted crop production value for the corresponding cell, aggregating the crop production for each watershed, and applying the crop N parameters (e.g., percent N content).

A step-by-step procedure for calculating crop N production is given below, with the screenshots and file names that can be found in the documentation package:

The NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the extended ISPRA grid “Extended\_Crop\_Rev\_02.shp” (originally “Extended\_Crop10\_Km.shp”, revised to be used as distribution map), the country map “11\_For\_Crop\_Distribution\_Final\_02.shp” (Figure 5.3.1.A), and the crop production table “CNTR\_SUM\_BL\_RU\_Added\_Rev\_05.csv” (Figure 5.3.3.A) were added (Figure 5.3.5.A):

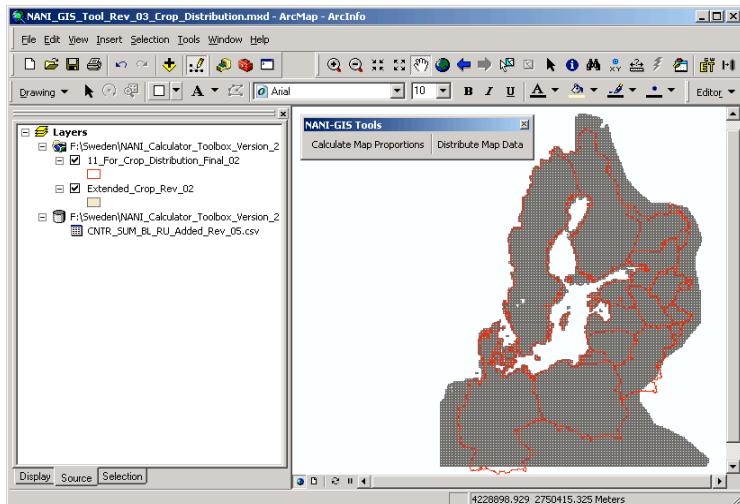


Figure 5.3.5.A. Running NANI-GIS tool to distribute crop production.

The “Distribute Map Data” button was clicked, and the tool was specified as shown in Figure 5.3.5.B:

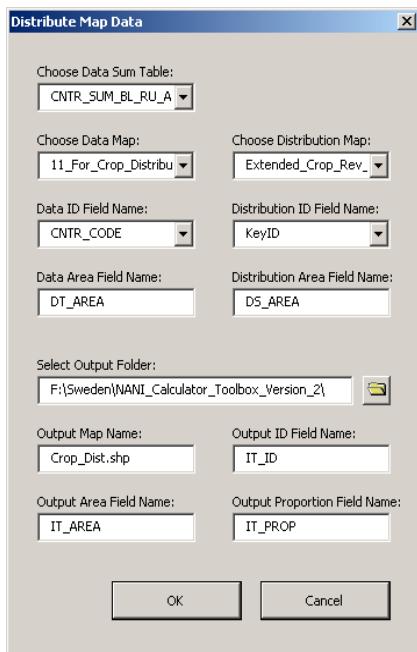


Figure 5.3.5.B. Specifying NANI-GIS tool to distribute crop production.

Clicking the “OK” button created the “Crop\_Dist.shp” shapefile containing crop productions. To create proportion table, the NANI-GIS tool “NANI\_GIS\_Tool\_Rev\_03\_Crop\_Distribution.mxd” was opened, and the distributed ISPRA grid “Crop\_Dist.shp” (output from above) and the watershed map “WSWatershed\_v2008\_4.shp” were added (Figure 5.3.5.C):

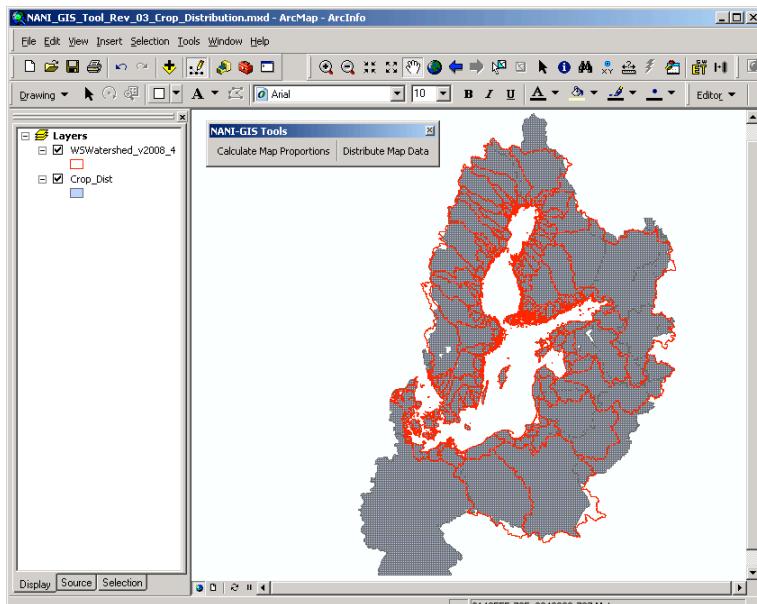


Figure 5.3.5.C. Running NANI-GIS tool to calculate distributed ISPRA grid cell proportion.

The “Calculate Map Proportions” button was clicked, and the tool was specified as shown in Figure 5.3.5.D. (Note that “IT\_ID” was selected as the data ID, not “Key\_ID”).

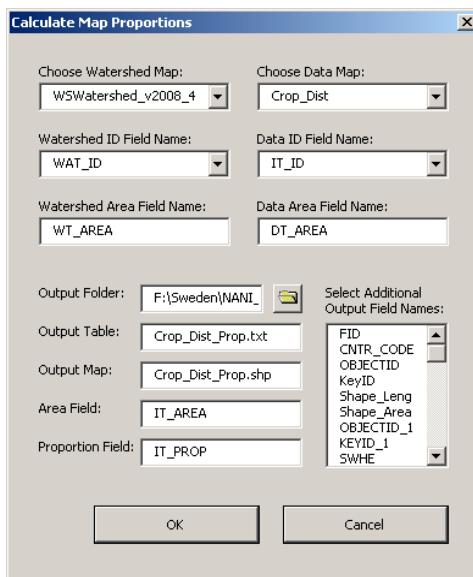


Figure 5.3.5.D. Specifying NANI-GIS tool to calculate distributed ISPRA grid cell proportion.

After running the NANI-GIS tool, a proportion table “Crop\_Dist\_Prop.txt” was created, with distributed ISPRA grid cells in the rows and watersheds in the columns. This table was imported into the NANI-extraction tool “NANI\_Extraction\_Tool\_Crops\_Dist.xls” (Figure 5.3.5.E):

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	IT_ID	Area_km2	W9018	W151	W2017	W9019	W149	W2018	W9020	W142	W143	W145	W147
2	Area_km2 -		464.03	51464.56	629.43	745.45	2178.11	12458.89	1877.98	1903.43	6579.13	3152.45	3319.66
3	884	18.4122744	0	0	0	0	0	0	0	0	0	0	0
4	885	15.806874	0	0	0	0	0	0	0	0	0	0	0
5	931	35.80889945	0	0	0	0	0	0	0	0	0	0	0
6	932	95.11760845	0	0	0	0	0	0	0	0	0	0	0
7	933	67.41325657	0	0	0	0	0	0	0	0	0	0	0
8	934	0.323467209	0	0	0	0	0	0	0	0	0	0	0
9	936	2.252685854	0	0	0	0	0	0	0	0	0	0	0
10	938	18.40737417	0	0	0	0	0	0	0	0	0	0	0
11	983	46.72971018	0	0	0	0	0	0	0	0	0	0	0
12	984	82.64958535	0	0	0	0	0	0	0	0	0	0	0
13	985	7.895472766	0	0	0	0	0	0	0	0	0	0	0
14	987	56.98925766	0	0	0	0	0	0	0	0	0	0	0
15	988	100.0000094	0	0	0	0	0	0	0	0	0	0	0
16	989	99.9999534	0	0	0	0	0	0	0	0	0	0	0
17	990	40.35357606	0	0	0	0	0	0	0	0	0	0	0
18	991	6.971771576	0	0	0	0	0	0	0	0	0	0	0

Figure 5.3.5.E. Distributed ISPRA grid cell proportion table created after running NANI-GIS tool.

The “Crop\_Dist” worksheet of the NANI-extraction tool (Figure 5.3.5.F) was imported from the dbf file “Crop\_Dist.dbf” created after running the “Distribute Map Data” tool (Figure 5.3.5.B).

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	CNTR_CODE	DT_AREA	OBJECTID	KeyID	Shape_Leng	Shape_Area	OBJECTID_1	KEYID_1	SWHE	MAIZ	RICE	TWIN	APPL
2	DE	1.284828817	1	64	513.9315269	1284828.817	1	1	0.0009	0.00124	0	0	0.00054
3	DE	62.75446784	14	23	25101.78714	62754467.84	14	14	6.02647	14.6133	0	64.6371	0.68014
4	DE	99.9999534	24	24	39999.99814	9999995.34	24	24	7.98816	9.21555	0	626	7.50333
5	DE	100.0000094	25	25	40000.00374	100000009.4	25	25	0.09603	2.43308	0	0	0
6	DE	100.0000094	26	26	40000.00374	100000009.4	26	26	0	0.12919	0	0	0
7	DE	99.9999534	27	27	39999.99814	9999995.34	27	27	0	0.4737	0	0	0
8	DE	100.0000094	28	28	40000.00374	100000009.4	28	28	0.06111	0.23685	0	0	0
9	DE	100.0000094	29	29	40000.00374	100000009.4	29	29	3.85876	5.69512	0	0	0
10	DE	99.9999534	30	30	39999.99814	9999995.34	30	30	6.22465	6.63175	0	0	0
11	DE	100.0000094	31	31	40000.00374	100000009.4	31	31	3.07304	3.97259	0	0	0
12	DE	100.0000094	32	32	40000.00374	100000009.4	32	32	3.31749	3.35894	0	0	0
13	DE	99.9999534	33	33	39999.99814	9999995.34	33	33	4.08575	4.71543	0	0	0
14	DE	100.0000094	34	34	40000.00374	100000009.4	34	34	5.33417	4.83386	0	0	0
15	DE	100.0000094	35	35	40000.00374	100000009.4	35	35	8.27626	0.27991	0	0	0
16	DE	99.9999534	36	36	39999.99814	9999995.34	36	36	7.05402	0.65672	0	0	0
17	DE	100.0000094	37	37	40000.00374	100000009.4	37	37	7.76117	1.04429	0	0	0
18	DE	100.0000094	38	38	40000.00374	100000009.4	38	38	6.13735	0.02153	0	0	0

Figure 5.3.5.F. Distributed crop production data imported into NANI-extraction tool.

The crop production values were extracted by clicking the “Extract” button in the “Extract” worksheet (Figure 5.3.5.G):

	A	B	C	D	E	F	G	H	I	J	K
1	Name	Item	Data	Year	Worksheet	Description					
2	Barley	BARL	Crop_Dist	2000	Crop_Dist_Prop	proportion					
3	Common Wheat and Spelt	SWHE	Crop_Dist		Crop_Dist_Ext	output					
4	Durum Wheat	DWHE	Crop_Dist								
5	Green Maize	MAIF	Crop_Dist								
6	Hops	HOPS	Crop_Dist								
7	Oats	OATS	Crop_Dist								
8	Potatoes	POTA	Crop_Dist								
9	Pulses Total	PULS	Crop_Dist								
10	Rape and Turnip	RAPE	Crop_Dist								
11	Rye	RYEM	Crop_Dist								
12	Soya	SOYA	Crop_Dist								
13	Sugar Beet	SUGB	Crop_Dist								
14	Sunflower	SUNF	Crop_Dist								
15	Fruit and Berry Plantations	APPL	Crop_Dist								
16	Leguminous Plants	LEFA	Crop_Dist								
17	Fodder Roots and Brassicas	ROOF	Crop_Dist								
18	Maiz	MAIZ	Crop_Dist								
19	Other Cereal	OCER	Crop_Dist								
20	Pasture and Meadow	GRAI	Crop_Dist								
21	Temporary Grasslands	OFAR	Crop_Dist								
22	Rough Grazing	GRAE	Crop_Dist								
23	Fallow No Subsidies	FALL	Crop_Dist								
24	Fallow Under Incentive	SETA	Crop_Dist								
25											
26											

Figure 5.3.5.G. Extracting crop production data using NANI-extraction tool.

After clicking the “Extract” button, the output worksheet “Crop\_Dist\_Ext” was created and the extracted crop production values were reported (Figure 5.3.5.H). The extraction worksheet “Crop\_Dist\_Ext” and the proportion worksheet “Crop\_Dist\_Prop” were copied to the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xls”.

	A	B	C	D	E	F	G	H	I	J	K	L	M		
1	IT_ID	Area_km2	Barley	Common Wheat	Durum Wheat	WI	Green Maize	Hops	Oats	Potatoes	Pulses	Total	Rape	Rye	Soya
2			2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	
3	884	18.4122744	0	0	0	0	0.000168	0.077778	0	0	0	0	0	1.38E-05	
4	885	15.806874	0	0	0	0	0.000144	0.066772	0	0	0	0	0	1.18E-05	
5	931	35.80889945	0.002386	0.01523	0	0	0.000327	0.151266	0.041689	0.000238	0	0.000974	2.68E-05		
6	932	95.11760845	0.088718	0.285427	0	0	0.266106	0.00869	0.401801	0.698493	0.001266	0	0.021985	7.13E-05	
7	933	67.41325657	0.065872	0.21185	0	0	0.157165	0.000616	0.28477	0.652013	0.000998	0.004631	0.028413	5.05E-05	
8	934	0.323467209	0.000496	0.000665	0	0	0.003469	2.96E-06	0.001366	0.000435	4.31E-06	0.000244	2.2E-05	2.42E-07	
9	936	2.252685854	0	0	0	0	2.06E-05	0.009516	0	0	0	0	0	1.69E-06	
10	938	18.40737417	0	0	0	0	0.000168	0.077757	0	0	0	0	0	1.38E-05	
11	983	46.72971018	0.069529	0.120351	0	0	0.305044	0.000427	0.197398	0.2762	0.000622	0.029958	0.03812	3.5E-05	
12	984	82.64958535	0.227595	0.476499	0	0	0.847923	0.000756	0.349132	1.095443	0.00055	0.045416	0.159565	6.2E-05	
13	985	7.895472766	0.060843	0.139917	0	0	1.030808	7.22E-05	0.033352	0.077071	0.001472	0.030913	0.14921	5.92E-06	
14	987	56.98925766	0.346772	0.851023	0	0	5.719117	0.000521	0.240737	0.88293	0.004173	0.174848	0.079032	4.27E-05	
15	988	100.0000094	0.20431	0.583617	0	0	0.559529	0.000914	0.422425	1.674669	0.003994	0.006669	0.076137	7.5E-05	
16	989	99.99999534	0.273153	0.78682	0	0	0.839294	0.000914	0.422425	2.40006	0.00466	0.020606	0.076137	7.5E-05	
17	990	40.35357606	0.176542	0.438602	0	0	1.279477	0.000369	0.170464	0.726383	0.003224	0.081307	0.023592	3.02E-05	
18	991	6.97171576	0.092431	0.168519	0	0	0.997983	6.37E-05	0.029451	0.076795	0.002321	0.062095	0.007962	5.23E-06	

Figure 5.3.5.H. Distributed crop production data extracted using NANI-extraction tool.

Crop N production was calculated by clicking the “Crops” button in the “Crops” worksheet (Figure 5.3.5.I). Note that area-based production estimates were made for Pasture and Meadow (GRAI), Temporary Grasslands (OFAR), Rough Grazing (GRAE), and Fallow No Subsidies (FALL). The harvested crop area information, originally stored in the extended ISPRA grid “Extended\_Crop\_Rev\_02.shp”, was not converted into production estimates (because these items were not included in the production table “CNTR\_SUM\_BL\_RU\_Added\_Rev\_05.csv” shown in Figure 5.3.3.A), but appropriately adjusted by the NANI-GIS tool. Also note that Fallow Land with No Economic Use (SETA) is not included in the crop list, as no grazing or harvest was assumed there.

1	Type	Item Name	Distribute	Reporting Unit	Kilograms Per Reporting Unit	% N in Dry Matter					Worksheet	Description	Crop Production (kg/km <sup>2</sup> /yr)			
						G	H	I	J	K			M	N	O	
2	Barley	Barley		100 tonnes	1000000	1.8765	10	10	30				watershed	total	Barley	Common W
3	Common Wheat and Spelt	Common Wheat and Spelt		1000 tonnes	1000000	3.64	54	10	30		Crop_Dist_Ext			2000	2000	2000
4	Durum Wheat	Durum Wheat		1000 tonnes	1000000	2.1442	61	10	10		Crop_Dist_Prop					
5	Green Maize	Green Maize		1000 tonnes	1000000	0.3544	0	0	0							
6	Hops	Hops		1000 tonnes	1000000	2.205	100	20	10							
7	Oats	Oats		1000 tonnes	1000000	1.65	10	10	20							
8	Potatoes	Potatoes		1000 tonnes	1000000	0.3	36	10	34							
9	Pulses Total	Pulses Total		1000 tonnes	1000000	4.05	20	15	16							
10	Rape and Turnip	Rape and Turnip		1000 tonnes	1000000	3.5416	100	20	10							
11	Rye	Rye		1000 tonnes	1000000	1.51	43	10	22							
12	Soya	Soya		1000 tonnes	1000000	5.9191	2	10	10							
13	Sugar Beet	Sugar Beet		1000 tonnes	1000000	0.225	30	10	69							
14	Sunflower	Sunflower		1000 tonnes	1000000	2.8606	100	10	10							
15	Fruit and Berry Plantations	Fruit and Berry Plantations		100 tonnes	1000000	0.0401	76	10	23							
16	Leguminous Plants	Leguminous Plants		1000 tonnes	1000000	2.5199	0	0	0							
17	Fodder Roots and Brassicas	Fodder Roots and Brassicas		1000 tonnes	1000000	0.225	10	10	10							
18	Maiz	Maiz		1000 tonnes	1000000	1.4245	6	10	17							
19	Other Cereal	Other Cereal		1000 tonnes	1000000	1.9	61	10	20							
20	Pasture and Meadow	Pasture and Meadow		hectare	2241.740022	2.5	0	10	10							
21	Temporary Grasslands	Temporary Grasslands		hectare	2241.740022	2.5	0	10	10							
22	Rough Grazing	Rough Grazing		hectare	1120.870011	2	0	10	10							
23	Fallow No Subsidies	Fallow No Subsidies		hectare	1120.870011	2	0	10	10							
24																
25																
26																
27																
28																
29																
30																
31																
32																

Figure 5.3.5.I. Calculating crop N production using NANI-accounting tool.

### 5.3.6. Preliminary Results

Figure 5.3.6.A below shows the watershed crop N production in three regions of Baltic Sea catchment areas calculated by NANI toolbox. Relative frequencies of crop N production are shown in Figure 5.3.6.B.

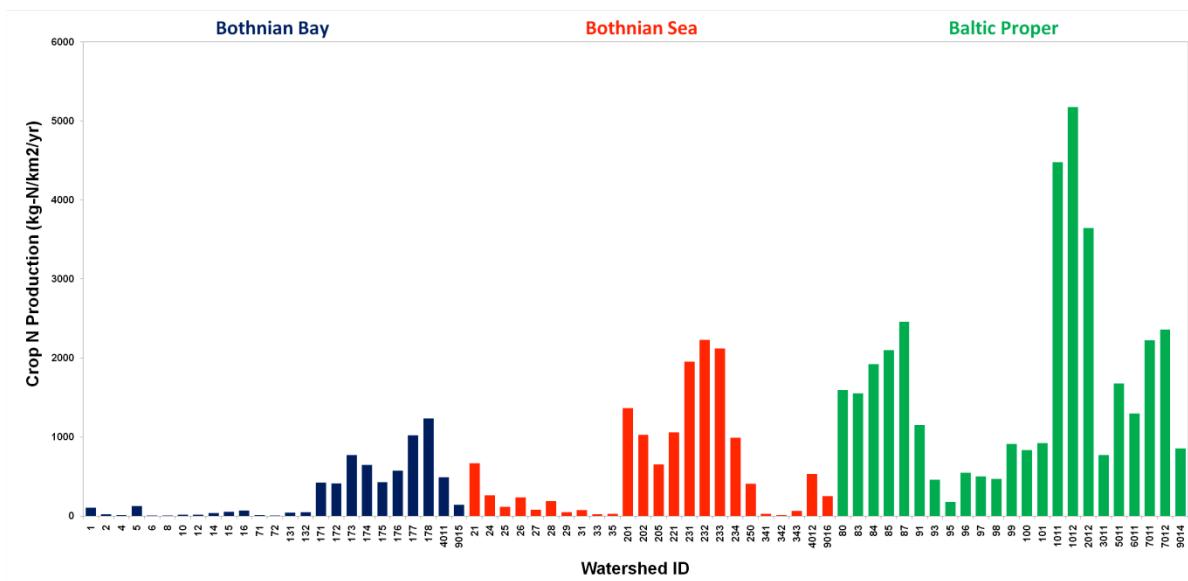


Figure 5.3.6.A. Crop N production in Baltic Sea catchments.

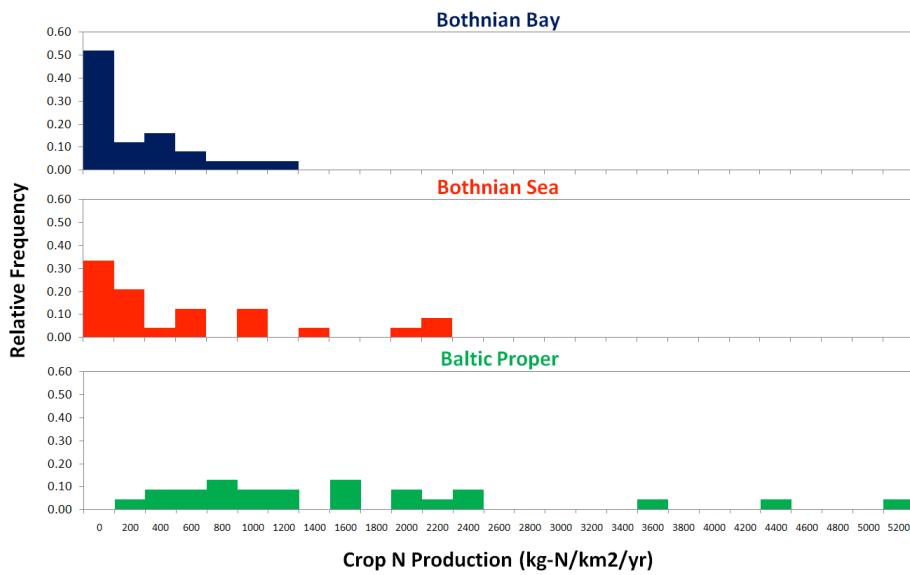


Figure 5.3.6.B. Relative frequencies of crop N production in Baltic Sea catchments.

Figure 5.3.6.C shows the watershed crop N production by crop type (area-weighted averages over all watersheds).

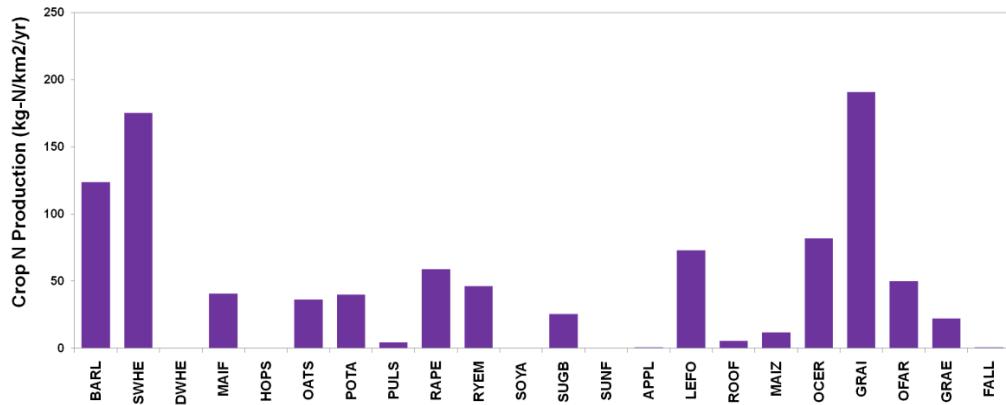


Figure 5.3.6.C. Crop N production by crop type.

## 5.4. Net Food and Feed Imports

After calculating human N consumption (Section 5.1), animal N production and N consumption (Section 5.2), and crop N production (Section 5.3) in the “People”, “Animals”, and “Crops” worksheet, respectively, net food and feed imports (calculated as human N consumption + animal N consumption – animal N production – crop N production) were reported in the “Food\_Feed\_N” worksheet of the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xls” by clicking the “Net Food and Feed Imports” button (Figure 5.4.A). Figure 5.4.B shows the watershed net food and feed imports in three regions of Baltic Sea catchment areas calculated by NANI toolbox. Relative frequencies of net food and feed imports are shown in Figure 5.4.C.

Worksheet	Description	2000	Net Food and Feed Imports (kg-N/km2/yr)					2000	2000	2000	2000
			watershed	human and animal requirements	crop and animal production	net human food imports	net animal feed imports	net food and feed imports			
1	Crops	crops		2000							
2	Animals	animals			2000						
3	People	people									
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

Figure 5.4.A. Calculating net food and feed imports using NANI-accounting tool.

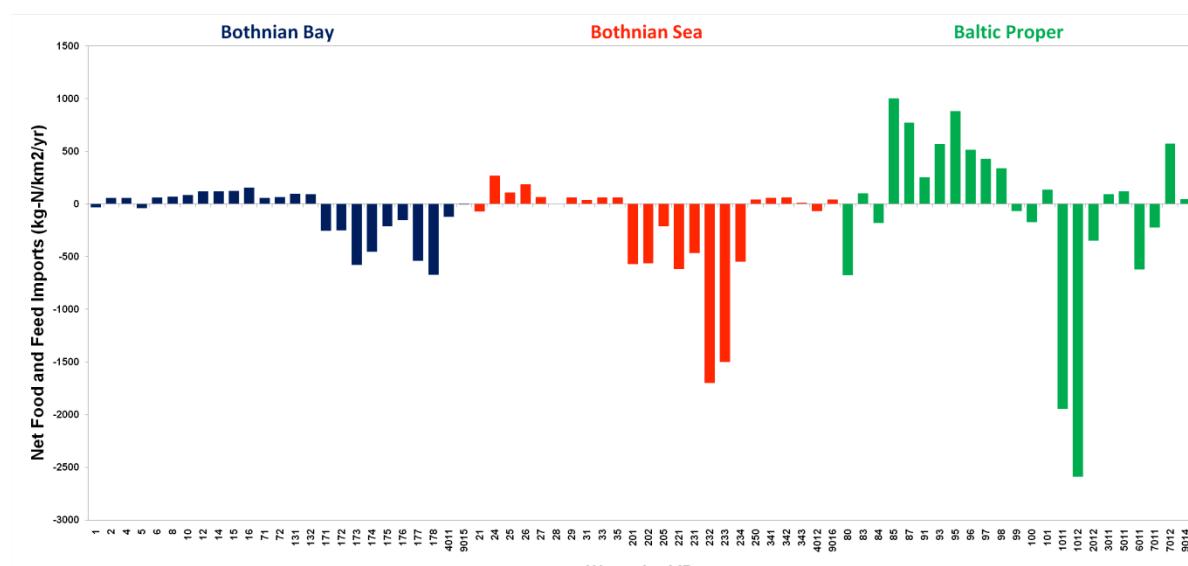


Figure 5.4.B. Net food and feed imports in Baltic Sea catchments.

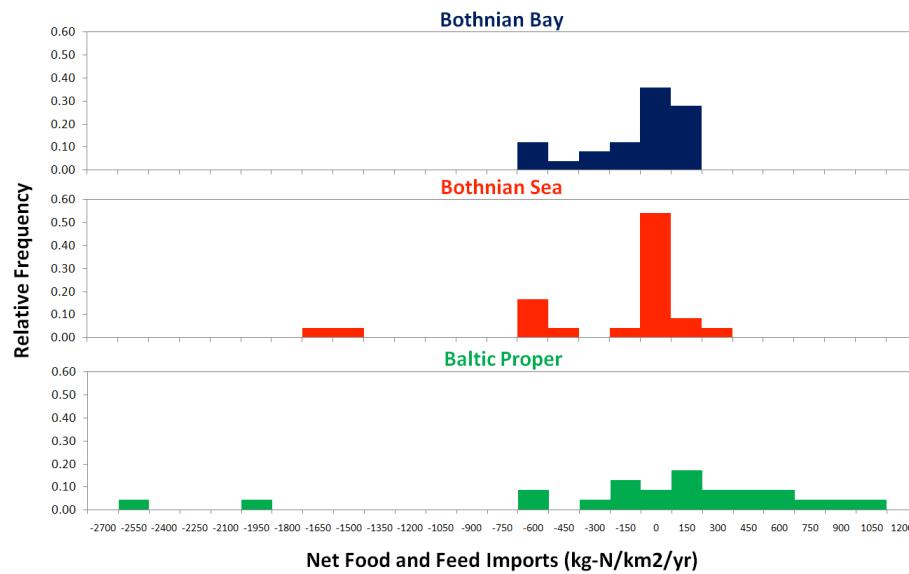


Figure 5.4.C. Relative frequencies of net food and feed imports in Baltic Sea catchments.

## 6. NANI

After calculating atmospheric N deposition (Section 2), fertilizer N application (Section 3), agricultural N fixation (Section 4), and net food and feed imports (Section 5) in the “Atm\_N\_Dep”, “Fert\_N\_App”, “Ag\_N\_Fix”, and “Food\_Feed\_N” worksheet, respectively, NANI (calculated as the sum of the above four components) were reported in the “NANI” worksheet of the NANI-accounting tool “NANI\_Accounting\_Tool\_Version\_2.xls” by clicking the “NANI” button (Figure 6.A). Atmospheric N deposition, with the year number indicated as “9999” (Figure 2.4.F), included only the oxidized form, assuming that most of the ammonia/ammonium emission from a watershed is redeposited on the same watershed. Figure 6.B shows the watershed NANI in three regions of Baltic Sea catchment areas calculated by NANI toolbox. Relative frequencies of NANI are shown in Figure 6.C.

Worksheet	Description	2000	NANI (kg-N/km <sup>2</sup> /yr)
			watershed net anthropogenic nitrogen input
Food_Feed_N	net food and feed imports		2000
Ag_N_Fix	agricultural N fixation		W9018 1730.80232
Fert_N_App	fertilizer N application	W9019	938.196175
Atm_N_Dep	atmospheric N deposition	9999	W2017 9925.69816
			W9019 3040.32137
			W149 1710.29682
			W2018 10844.5938
			W9020 2086.63428
			W142 3126.4277
			W143 1656.06658
			W145 1565.09007
			W147 1585.19338
			W2013 7033.50901
			W9021 3145.70805
			W2014 8577.41213
			W1013 8981.42494
			W2015 9599.33563
			W2016 14111.3935

Figure 6.A. Calculating NANI using NANI-accounting tool.

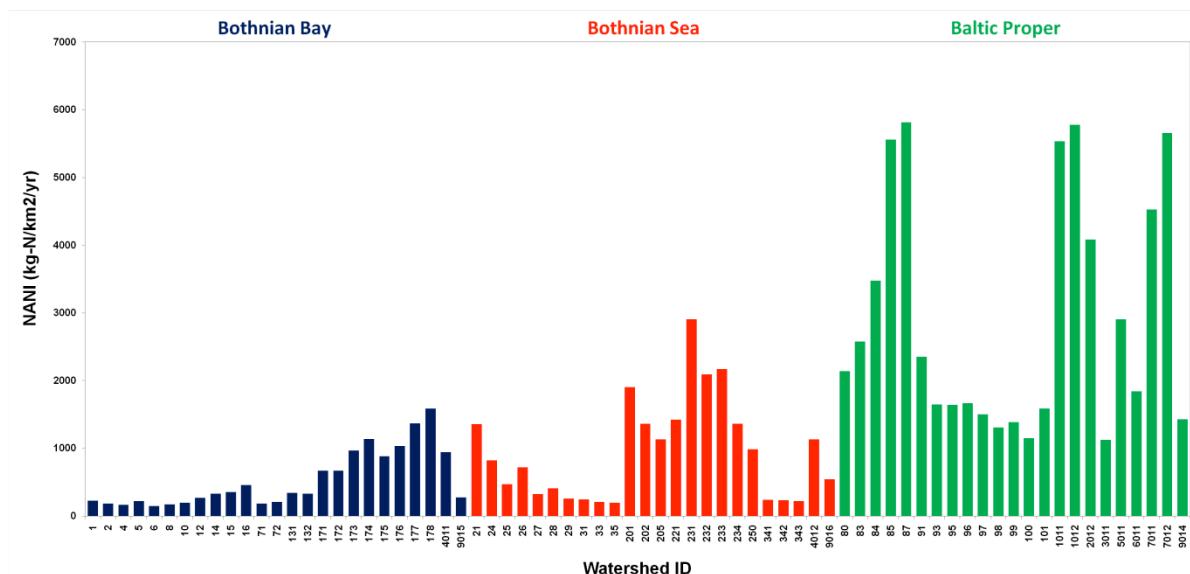


Figure 6.B. NANI in Baltic Sea catchments.

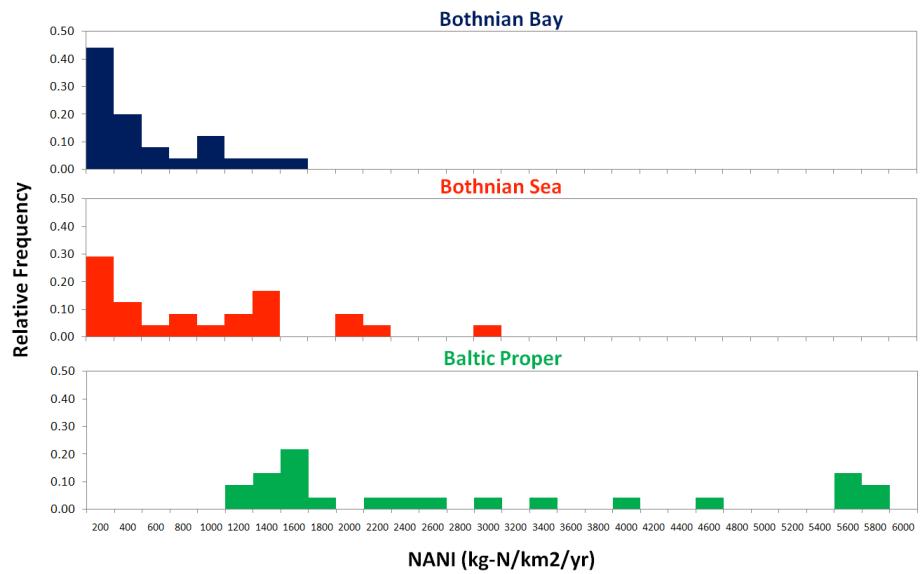


Figure 6.C. Relative frequencies of NANI in Baltic Sea catchments.

## **7. Acknowledgements**

Development of version 2.0 of the NANI/NAPI Calculator Toolbox and calculation of net anthropogenic nutrient inputs in the Baltic Sea catchments were supported by funding from Baltic Nest Institute and the EU BONUS plus project RECOCA (<http://www.bonusportal.org>). The authors would like to acknowledge Bob Howarth of Cornell University, Luc Maene and Patrick Heffer of the International Fertilizer Industry Association (IFA), and Svetlana Ivanova of the International Plant Nutrition Institute (IPNI) for assistance in obtaining Russian fertilizer data, and Fayçal Bouraoui of the Joint Research Centre of the European Commission for making the ISPRA crop and fertilizer data available. We also would like to thank Gitte Blicher-Mathiasen and Hans Estrup Andersen for reviewing the documentation and providing helpful discussions and valuable feedback.

## **8. References**

- Bleken, M.A., Bakken, L.R., 1997. The nitrogen cost of food production: Norwegian society. *Ambio* 26 (3), 134-142.
- Boyer, E.W., Goodale, C.L., Jaworski, N.A., Howarth, R.W., 2002. Anthropogenic nitrogen sources and relationships to riverine nitrogen export in the northeastern U.S.A. *Biogeochemistry* 57/58, 137-169.
- Claesson, S., Steineck, S., 1991. Växtnäring, Hushållning-Miljö. Sveriges Lantbruksuniversitet, speciella skrifter 41. Uppsala.
- FAO, 2003. Fertilizer use by crop in Poland. <ftp://ftp.fao.org/docrep/fao/005/y4620E/y4620E00.pdf>.
- FAOSTAT, 2005. Food Balance Sheets. <http://faostat.fao.org/site/368/default.aspx#ancor>.
- Grizzetti, B., Bouraoui, F., Aloe, A., 2007. Spatialised European Nutrient Balance. EUR Report 22692 EN. pp98.
- GUS, 2001/02. Poland Central Statistical Office, Statistical Yearbook of Agriculture 2009, Warszawa, ISSN 2080-8798.
- Hong, B., Swaney, D.P., Howarth, R.W., 2011. A toolbox for calculating net anthropogenic nitrogen inputs (NANI). *Environmental Modelling & Software* 26, 623-633. doi:10.1016/j.envsoft.2010.11.012.
- Howarth, R.W., Billen, G., Swaney, D.P., Townsend, A., Jaworski, N., Lajtha, K., Downing, J.A., Elmgren, R., Caraco, N., Jordan, T., Berendse, F., Freney, J., Kudayarov, V., Murdoch, P., Zhao-liang, Z., 1996. Riverine inputs of nitrogen to the North Atlantic Ocean: fluxes and human influences. *Biogeochemistry* 35, 75-139.
- Jones, D.B., 1941. Factors for Converting Percentages of Nitrogen in Foods and Feeds into Percentages of Protein. United States Department of Agriculture, Circular No. 183. Slightly revised edition 1941 (Original version 1931).
- Lander, C.H., Moffitt, D., Alt, K., 1998. Nutrients available from livestock manure relative to crop growth requirements. Resource Assessment and Strategic Planning Working Paper 98-1, United States Department of Agriculture, Natural Resources Conservation Service.  
<http://www.nrcs.usda.gov/technical/NRI/pubs/nlweb.html>.
- NRC, 2001. Nutrient Requirements of Dairy Cattle: Seventh Revised Edition.  
[http://www.nap.edu/openbook.php?record\\_id=9825&page=275](http://www.nap.edu/openbook.php?record_id=9825&page=275).
- NRC, 2001. Nutrient Requirements of Swine: Seventh Revised Edition.  
[http://www.nap.edu/openbook.php?record\\_id=6016&page=117](http://www.nap.edu/openbook.php?record_id=6016&page=117).
- NRC, 2001. Nutrient Requirements of Poultry: Seventh Revised Edition.  
[http://www.nap.edu/openbook.php?record\\_id=2114&page=23](http://www.nap.edu/openbook.php?record_id=2114&page=23).

OECD, 2001. Nitrogen Balance Database. [http://www.oecd.org/agr/env/ind\\_data.htm](http://www.oecd.org/agr/env/ind_data.htm).

OECD, 2004. Agriculture, Trade and the Environment: The Dairy Sector.

[http://www.oecd.org/document/22/0,3343,en\\_2649\\_33791\\_33791830\\_1\\_1\\_1,00.html](http://www.oecd.org/document/22/0,3343,en_2649_33791_33791830_1_1_1,00.html).

Russell, M.J., Weller, D.E., Jordan, T.E., Sigwart, K.J., Sullivan, K.J., 2008. Net anthropogenic phosphorus inputs: spatial and temporal variability in the Chesapeake Bay region. *Biogeochem.* 88, 285-304.

Sosulksi, F.W., Imafidon, G.I., 1990. Amino acid composition and nitrogen-to-protein conversion factors for animal and plant foods. *J. Agric. Food Chem.* 38, 1351-1356.

Statistics Denmark, 2001. Agricultural Statistics 2000. p287.

Statistics Denmark, 2001. Livestock density in agriculture 2000. *Statistisk Efterretning No. 13.* p41.

Statistics Sweden, 2002. Use of fertilizer and manure in agriculture in 2000/2001. Report MI 30 SM 2002. (In Swedish, summary in English). p94.

## **Appendix 1: Details of NAPI Calculations**

Most of the procedures for calculating NAPI are identical to those for calculating NANI as described in the above sections. This appendix notes some details of the NAPI (Net Anthropogenic Phosphorus Inputs) calculation, and notes the data and parameters that are different from those of the NANI calculation.

### **A1. Atmospheric Deposition**

No atmospheric deposition of P was assumed.

### **A2. Fertilizer Application**

The national fertilizer P application rate of  $283.96 \text{ kg-P/km}^2/\text{yr}$  was reported by FAO ( $59 \times 10^6 \text{ kg-P}$  application divided by Belarusian area of  $207,757 \text{ km}^2$ ). Fertilizer P from Belarus was calculated as shown below (see Table 3.3.2.A in NANI documentation for more detail):

Table A2.A. Mineral fertilizer P estimated for watersheds intersecting with areas of Belarus.

Watershed Code	Watershed Name	Watershed Area ( $\text{km}^2$ )	Missing Area Intersecting with Belarus ( $\text{km}^2$ )	Fertilizer to be Added (kg-P)	Fertilizer to be Added ( $\text{kg-P}/\text{km}^2/\text{yr}$ )
W42	Neva	279,586	812	230,706	0.83
W46	Narva	58,126	179	50,790	0.87
W62	Daugava	84,608	31,119	8,836,418	104.44
W83	Neman	95,925	42,155	11,970,288	124.79
W85	Vistula	193,894	8,549	2,427,501	12.52

Fertilizer P from Russia was calculated as shown below (see Tables 3.2.B, 3.3.3.A, 3.3.3.B, and 3.3.3.C in NANI documentation for more detail):

Table A2.B. Mineral fertilizer P estimated for watersheds intersecting with areas of Russia (Oblasts with available data).

Watershed Code	Watershed Name	Watershed Area (km <sup>2</sup> )	Missing Areas (km <sup>2</sup> )	Leningradskaya	Kaliningradskaya	Karelia	Pskovskaya	Novgorodskaya	Fertilizer to be Added (kg-P)	
				2008 (1000 t)	0.851	0.694	0.031	0.161	0.148	
				2009 (1000 t)	0.572	0.585	0.026	0.135	0.153	
				Average (1000 t)	0.711	0.639	0.028	0.148	0.151	
				Area (km <sup>2</sup> )	84,500	15,100	172,400	55,300	55,300	
			Fertilizer (kg-P/km <sup>2</sup> /yr)		8.42	42.34	0.16	2.68	2.72	
W12	Kemijoki	52,513								
W16	Oulujoki	24,242								9
W42	Neva	279,586		56,747			74,974	16,708	45,204	657,942
W46	Narva	58,126			2,124			31,881	87	103,655
W62	Daugava	84,608								11,925
W83	Neman	95,925				806				34,138
W84	Pregolia	13,419				5,720				242,162
W5011	Coast LT & Baltic Proper	1,599				40				1,680
W7012	Coast PL & Baltic Proper	10,778				11				454
W8011	Coast RU & Baltic Proper	5,716				4,629				195,980
W8012	Coast RU & Gulf of Finland	23,832		18,883				19	1,582	163,320

Table A2.C. Mineral fertilizer P estimated for watersheds intersecting with areas of Russia (Oblasts without available data).

Watershed Code	Watershed Name	Watershed Area (km <sup>2</sup> )	Missing Areas (km <sup>2</sup> )	Tverskaya	Vologodskaya	Smolenskaya	St. Petersburg	Murmanskaya	Arkhangelskaya	Fertilizer to be Added (kg-P)
				Fertilizer (kg- P/km <sup>2</sup> /yr)	2.703	4.291	2.683	8.418	0.165	0.165
W12	Kemijoki	52,513							1,050	173
W16	Oulujoki	24,242								
W42	Neva	279,586		7,414	8,489			563		268
W46	Narva	58,126								61,253
W62	Daugava	84,608		13,260			7,717			56,545
W83	Neman	95,925								
W84	Pregolia	13,419								
W5011	Coast LT & Baltic Proper	1,599								
W7012	Coast PL & Baltic Proper	10,778								
W8011	Coast RU & Baltic Proper	5,716								
W8012	Coast RU & Gulf of Finland	23,832					843			7,100

Table A2.D. Mineral fertilizer P estimated for watersheds intersecting with areas of Russia (combined).

Watershed Code	Watershed Area (km <sup>2</sup> )	Fertilizer to be Added (kg-P)	Fertilizer to be Added (kg-P/km <sup>2</sup> /yr)
W12	52,513	173	0.0033
W16	24,242	9	0.00036
W42	279,586	719,195	2.57
W46	58,126	103,655	1.78
W62	84,608	68,470	0.809
W83	95,925	34,138	0.356
W84	13,419	242,162	18.05
W5011	1,599	1,680	1.05
W7012	10,778	454	0.042
W8011	5,716	195,980	34.29
W8012	23,832	170,421	7.15

Mineral P fertilizer extracted from the ISPRA data was used for other areas of Baltic Sea catchments (see Section 3 for more detail).

### A3. Agricultural Fixation

No agricultural fixation of P was assumed.

### A4. Net Food and Feed Imports

#### A4.1. Human Consumption

Russell et al. (2008) assumed that 1 kg-P/capita/yr is excreted by humans. Boyer et al. (2002) used N intake rate of 5 kg-N/capita/yr. Assuming that human intake and excretion rates are approximately the same, the N/P ratio of human intake was estimated to be 5. In addition, 0.35 kg-P/capita/yr of non-food use of P by human (e.g., detergent), estimated for Europe, was assumed. Applying these assumptions, the following estimates of human P consumption was used (food and non-food use combined):

Table A4.1.A. Human P consumption parameters for European countries.

Country Name	Country Code	Human N Consumption (kg-N/capita/year)	Human P Consumption (kg-P/capita/year)
Belarus	BY/BLR	5.24	1.40
Germany	DE	5.75	1.50
Denmark	DK	6.52	1.65
Estonia	EE	5.23	1.40
Finland	FI	6.21	1.59
Lithuania	LT	6.61	1.67
Latvia	LV	5.37	1.42
Poland	PL	5.90	1.53
Russian Federation	RU	5.51	1.45
Sweden	SE	6.30	1.61
Czech Republic	CZ	5.68	1.49
Norway	NO	6.19	1.59
Slovakia	SK	4.15	1.18
Ukraine	UA	5.13	1.38

#### A4.2. Animal Consumption and Production

Using the animal N and P flux estimates available in Claesson and Steineck (1991), the N/P ratios of animal intake and excretion rates for the cattle, pigs, poultry, and sheep were assumed to be 6, 3, 4, and 5, respectively. Following this assumption, the animal P intake and P excretion parameters were estimated from animal N intake and N excretion parameters, respectively (see Tables 5.2.3.2.A, 5.2.3.3.A, and 5.2.3.4.A in NANI documentation):

Table A4.2.A. Animal P parameters for cattle (kg-P/animal/yr).

Country Code	Bovine Young (PC1 & PC2)		Bovine Male (PC3100)		Heifers (PC3210)		Dairy Cows (PC3221)		Other Cows (PC3222)	
	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion
BY	6.02	5	8.24	7	8.45	6.67	15.65	12.5	11.24	10
DE	8.13	6.75	11.57	9.83	9.3	7.33	22.97	16.83	15.73	14
DK	11.67	9.68	10.76	9.15	13.05	10.3	25.76	18.33	13.73	12.22
EE	6.02	5	8.24	7	8.45	6.67	20.69	15.5	11.24	10
FI	6.38	5.3	7.84	6.67	8.45	6.67	24.48	17.5	10.30	9.17
LT	6.02	5	8.24	7	8.45	6.67	17.43	13.67	11.24	10
LV	6.02	5	8.24	7	8.45	6.67	18.15	14.33	11.24	10
PL	6.48	5.38	8.24	7	12.67	10	18.19	14.33	11.24	10
RU	5.85	5	8.24	7	8.45	6.67	15.33	12.67	11.24	10
SE	7.48	6.22	11.37	9.67	9.93	7.83	26.13	18.67	11.80	10.5
CZ	7.47	6.2	15.41	13.1	12.35	9.75	22.18	16.33	14.72	13.1
NO	5.91	4.88	7.84	6.67	8.45	6.67	20.19	15.5	12.43	11.1
SK	6.02	5	8.24	7	8.45	6.67	13.90	11.67	11.24	10
UA	6.02	5	8.24	7	8.45	6.67	14.92	12.33	11.24	10

Table A4.2.B. Animal P parameters for pigs (kg-P/animal/yr).

Country Code	Piglets (PP1000)		Pigs (PP2000)		Fattening Pigs (PP3000)		Boars (PP4100)		Sows (PP4200)	
	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion
BY	2.44	0.667	7.14	3	10.53	3.67	3.60	3	8.50	6.33
DE	4.63	1.267	8.73	3.67	10.53	3.67	5.21	4.33	11.63	8.67
DK	2.44	0.667	4.92	2.07	15.61	5.43	9.21	7.67	11.49	8.57
EE	2.44	0.667	7.14	3	10.53	3.67	3.60	3	8.50	6.33
FI	6.82	1.867	7.14	3	10.53	3.67	3.60	3	8.50	6.33
LT	2.44	0.667	7.14	3	10.53	3.67	3.60	3	8.50	6.33
LV	2.44	0.667	7.14	3	10.53	3.67	3.60	3	8.50	6.33
PL	3.05	0.833	7.14	3	14.37	5	8.01	6.67	7.16	5.33
RU	2.44	0.667	7.14	3	10.53	3.67	3.60	3	8.50	6.33
SE	2.80	0.767	7.14	3	8.62	3	3.60	3	8.50	6.33
CZ	4.26	1.167	7.38	3.1	14.37	5	8.37	6.97	9.35	6.97
NO	2.44	0.667	7.14	3	10.53	3.67	5.57	4.63	9.88	7.37
SK	2.44	0.667	7.14	3	10.53	3.67	3.60	3	8.50	6.33
UA	2.44	0.667	7.15	3	10.53	3.67	3.60	3	8.50	6.33

Table A4.2.C. Animal P parameters for poultry and sheep (kg-P/animal/yr).

Country Code	Broilers (J14)		Hens (J15)		Other Poultry (J16)		Sheep (PS0000)	
	Intake	Excretion	Intake	Excretion	Intake	Excretion	Intake	Excretion
BY	0.808	0.39	0.231	0.15	0.485	0.33	2.24	2
DE	0.808	0.39	0.281	0.183	0.349	0.238	2.24	2
DK	1.383	0.667	0.286	0.186	0.485	0.33	2.24	2
EE	0.808	0.39	0.231	0.15	0.485	0.33	2.24	2
FI	0.898	0.433	0.193	0.125	0.485	0.33	3.81	3.4
LT	0.808	0.39	0.231	0.15	0.485	0.33	2.24	2
LV	0.808	0.39	0.231	0.15	0.485	0.33	2.24	2
PL	1.047	0.506	0.270	0.175	0.404	0.275	2.47	2.2
RU	0.808	0.39	0.231	0.15	0.485	0.33	2.24	2
SE	0.868	0.419	0.247	0.16	0.485	0.33	2.69	2.4
CZ	1.047	0.506	0.231	0.15	0.625	0.425	2.20	1.96
NO	1.030	0.497	0.235	0.153	0.485	0.33	1.95	1.74
SK	0.808	0.39	0.231	0.15	0.485	0.33	2.24	2
UA	0.808	0.39	0.231	0.15	0.485	0.33	2.24	2

#### A4.3. Crop Production

The percent P content was assigned for each crop type using the same source of information available in crop N calculation (see Table 5.3.3.A in NANI documentation). Other crop parameters (e.g., percent distribution to human, percent loss during the food processing, etc.) were not changed from crop N calculation.

Table A4.3.A. Percent P content assigned for each crop type.

ISPRA Crop Code	ISPRA Crop Description	EuroStat Code	EuroStat Description	Parameter Used (% P in Crop)	Notes and References
BARL	Barley	C1160	Barley	0.372	Derived from US values
SWHE	Common Wheat and Spelt	C1120	Common Wheat and Spelt	0.34	Eriksson-Hägg
DWHE	Durum Wheat	C1130	Durum Wheat	0.373	Derived from US values
MAIF	Green Maize: Other Green Fodder: Forage Plant	C2625	Green maize	0.053	Derived from US values
HOPS	Hops	C1560	Hops	0.35	Derived from US values
OATS	Oats	C1180	Oats	0.33	Eriksson-Hägg
POTA	Potatoes	C1360	Potatoes	0.055	Johnes
PULS	Pulses - Total	C1885	Pulses	0.38	Eriksson-Hägg average
RAPE	Rape and Turnip: Other Oil-Seed or Fiber Plants	C1420	Rape - Turnip rape	0.565	Derived from US values
RYEM	Rye	C1150	Rye	0.31	Eriksson-Hägg
SOYA	Soya: Other Oil-Seed or Fiber Plants	C1470	Soya bean	0.597	Derived from US values
SUGB	Sugar Beet	C1370	Sugar Beet	0.04	Johnes average
SUNF	Sunflower: Other Oil-Seed or Fiber Plants	C1450	Sunflower seed	0.584	Derived from US values
APPL	Fruit and Berry Plantations - Total	C2009	Total Fruit (including all olives, all grapes, wild products and fruits from kitchen gardens)	0.007	Sosulksi and Imafidon (1990)
LEFO	Leguminous Plants: Other Green Fodder: Forage Plants	C2671, C2672, C2673	Clover and mixtures, Lucerne, Other legumes (sainfoin, sweet clover)	0.236	Derived from US values
ROOF	Fodder Roots and Brassicas	C1381, C1383	Fodder Beet, Fodder Kale	0.04	Johnes average
MAIZ	Maize	C1200	Grain Maize	0.275	Derived from US values
OCER	Other Cereals			0.39	Johnes
GRAI	Pasture and Meadow: Permanent Grassland and Meadow			0.357	Derived from US values (N/P ratio = 7)
OFAR	Forage Plants - Temporary Grass			0.357	Derived from US values
GRAE	Rough Grazing: Permanent Grassland and Meadow			0.286	Derived from US values
FALL	Fallow Land without Subsidies			0.286	Derived from US values
SETA	Fallow Land with No Economic Use: Set-Aside Areas Under Incentive Schemes				No grazing or harvest assumed