MTT REPORT 65

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Part-financed by the European Union
(European Regional Development Fund
and European Neighbourhood and
Partnership Instrument)

ISBN: 978-952-487-405-2 (Printed)
ISBN: 978-952-487-406-9 (Electronic version)
ISSN:1798-6419
www.mtt.fi/mttraportti/pdf/mttraportti65.pdf

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Distribution and sale: MTT, 31600 Jokioinen
Printing year: 2012
Cover photo by: Tapio Salo

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Abstract

Soil erosion and nutrient leaching from terrestrial systems to rivers, lakes and marine environments cause deteriorating water quality and eutrophication. In all the countries of Northern Europe, agriculture is considered to be responsible for the greatest contribution of phosphorus (P) and high contribution of nitrogen (N) to coastal waters. Recently, there has been great pressure from both the environmental and agricultural sector to target the environmental measures at the areas with the highest risk for nutrient leaching and loading. Topographic, hydrologic, geomorphologic and agronomic factors often combine to make erosion and leaching from certain areas higher and more detrimental to the aquaculture than from others. Therefore, methods to identify and prioritise agri-environmental measures on these nutrient-vulnerable areas are desirable. This report examines data availability and methodology to identify the critical source areas in the Baltic Sea Region (BSR) countries. Here critical source areas are comprised mainly of erosion- and phosphorus-vulnerable areas that can often also be related to the biosecurity risk of animal husbandry.

Availability, determination methods and quality in basic background data required for the inventories vary widely in the Baltic Sea basin countries. Background data should include spatially detailed information from elevation, river networks, soil (soil type, P status etc.) and agricultural management (plant cover, fertiliser rates, livestock density etc.). Risk assessments are usually made at the municipal or catchment level, depending on which regional level the statistical data are available. The differences in the soil classification systems, soil P analysis and accuracy of the data needed for the mapping prevent uniform assessments and comparisons between the countries. The accuracy of the existing risk maps is difficult to verify with water quality observations, since the observations are scarce, especially from individual risk areas.

Erosion risk maps are produced mostly with USLE based methods, which are also suitable for mapping areas at risk of P leaching. In USLE-maps, the risk areas are mainly located on steeply sloped fields. USLE describes the high risk areas by surface processes. Thus, the transport of solids and P through soil matrix and via the macropores is ignored in USLE examinations. If the calculation takes into account the distance to water and if the channel map is accurate, also fields further away from the water bodies can be classified as risk areas. Meanwhile, when topographic mapping is used as the index calculation methodology, flat areas will be classified as risk areas because this method puts weight on gentle slopes with fairly large catchment areas above them. The third option is based on physical GIS-based models, which can model simultaneously hydrology and nutrient transport. In general, these models require a lot of input data and in lack of them the possibility of erroneous results increases.

The P-index is often considered to be a cost-effective tool to reduce P leaching. The major challenges are lack of data (mainly on soil P status), and uncertainties and the need for additional validation of the model. Areas with high animal density and high risk of surface runoff or erosion are potential high-risk areas as regards biosecurity. By combining relevant maps, such as animal density and erosion risk areas, potential high-risk biosecurity areas can be identified.

It would be important to improve the availability of more accurate, larger-scale data for the use of researchers and designers. The central issues in presenting the risk areas are accuracy, objectivity and clarity. High-risk areas and fields should be shown as objectively as possible and after solving their locations, possible mitigation measures to reduce risks in the problematic areas could be discussed and agreed with the stakeholders.

Contents

1 Introduction

Mobilisation and transport of nutrients from terrestrial systems to rivers, lakes and marine environments cause deteriorating water quality and eutrophication. In all the countries of Northern Europe, agriculture is considered to be responsible for the greatest contribution of phosphorus (P) to coastal waters (Kronvang et al. 1995; Rekolainen et al. 1997; Ekholm and Mitikka 2006; HELCOM 2012). A great deal of effort, both economic and political, has been put into reducing agricultural loading in recent years. Unfortunately, controlling nutrient losses has been more difficult than anticipated (MVB 2005). Humborg et al. (2007) claim that the only significant potential for reducing the P load to the Baltic Sea lies in reductions of diffuse emissions from agricultural land. In November 2007, ministers in the countries bordering the Baltic Sea agreed on national allocations with respect to P loads which included ambitious reduction targets. At the same time, a lack of reliable and cost-effective measures for the reduction of P losses from agriculture has been identified in several studies (Naturvårdsverket 2006; Bergström et al. 2007). According to a report from the Swedish Environmental Protection Agency (Naturvårdsverket 2006), more countermeasures, primarily within agriculture, are needed to reduce P.

Regrettably, the effectiveness of mitigation measures has so far been demonstrated in only a few cases. One of them is small Swedish catchments where the areal coverage of arable land and the measures implemented have been large enough to enable the influence to be observed. In addition, these measures in small Swedish catchments were implemented many years ago and therefore the delay in the purification process has probably been long enough to be observable (Kyllmar et al. 2006). If the measures function as intended, the improvement is seen in the water quality as a decrease in nitrogen and phosphorus concentrations.

Many studies have shown that the effectiveness of the measures is observable at the field plot scale (Koskiaho et al. 2003; Kronvang et al. 2005; Puustinen et al. 2005; Uusi-Kämppä 2005; Uusitalo et al. 2007), but due to the fact that waters at the outlet of a river basin are a mixture of natural waters and waters affected by human activities, the effect of a single measure is small and therefore not easily seen using the prevailing monitoring strategies. Recently, there has been great pressure from both the environmental and agricultural sector to target the measures at the areas with the highest risk for nutrient leaching and loading. Not all sources of nonpoint loading produce equal amounts of nutrients in the receiving water bodies. In fact, many of them only produce a little load or are sometimes even insignificant, while other sources contribute substantially to water quality degradation. Topographic, hydrologic, geomorphologic and agronomic factors often combine to make some sources more detrimental to the aquaculture than others. Therefore, methods to (1) identify and (2) prioritise the treatment of these nutrient-vulnerable areas are desirable. Identifying and treating the areas that most adversely affect the water resources helps to speed up the restoration process and may save time and money if the same reduction in nutrient loading can be achieved by treating fewer sources.

This report first examines data availability in the Baltic Sea Region (BSR) countries to identify the critical source areas, which here are comprised of erosion- and phosphorus-vulnerable areas. Secondly, the report presents and discusses methods to identify the erosion- and phosphorus-risk areas, as well as the biosecurity risk of animal husbandry. Examples of the identified nutrient-vulnerable areas are shown at different scales from a number of selected countries. Finally, we reflect on the question of whether some agricultural water protection measures are more efficient than others for these vulnerable areas.

2 Essential data to identify the agricultural risk areas

2.1 DEM – Digital elevation map

In environmental research, the digital elevation model (DEM) is typically needed for two reasons: to delineate the watersheds for selected monitoring stations and to calculate slope steepness or other topographical indices for both agricultural fields and entire catchments. DEM is also helpful when selecting suitable plots for buffer zones or identifying the sites where to establish a constructed wetland. Additionally many catchment-scale models require the DEM as input data for the model. The pixel size and vertical resolution determine how well the slope steepness of a field or flow direction and its accumulation can be calculated, and therefore also affect the delineation of a watershed. For example, Räsänen (2010) studied the difference between flow direction grids prepared from different DEMs for the same area. The coarser 25 m grid produced large areas of even surfaces (see Figure 1b), whereas the 2 m grid distinguished very fine-featured surfaces (Figure 1a). As a result, the flow accumulation grids, which show the location where a stream might appear, look somewhat different (Figure 1c and 1d).

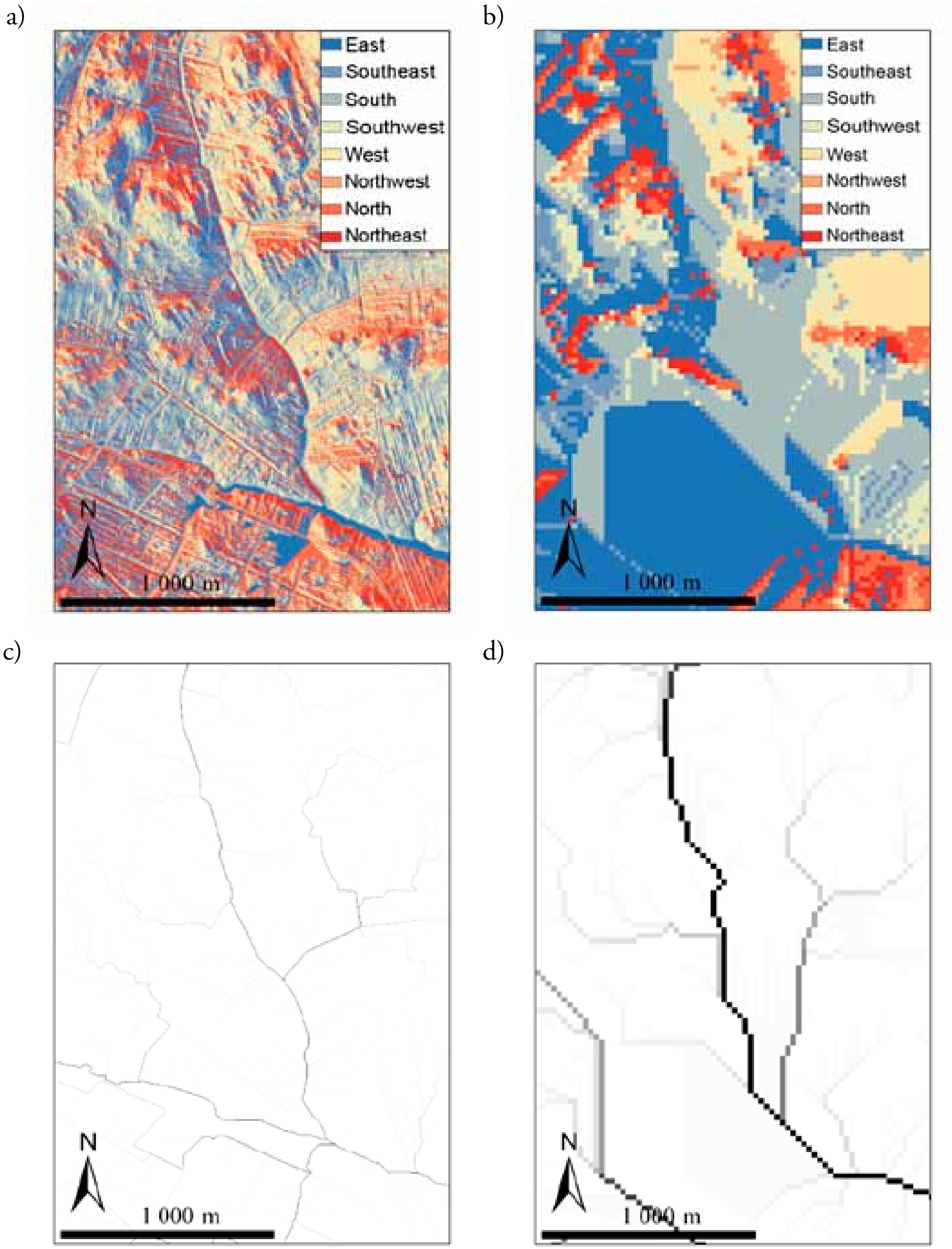


Figure 1. Flow direction grids (a) and (b) and flow accumulation grids (c) and (d) prepared from (a,c) 2 m grid based on Lidar data and (b,d) 25 m grid based on contour lines.

Räsänen (2010) also studied the differences in stream networks in grids prepared from different DEMs. Both DEMs were capable of creating the main channel, but in the case of the upper reaches of the stream, the coarser DEM in particular had problems following the real stream (Figure 2).

Lin et al. (2010) have estimated how the DEMs generated from different data sources affect the catchment-scale nutrient load model predictions for runoff, sediment, total phosphorus (TP) and nitrogen (TN). They concluded that predictions of TP and TN loads decreased substantially with a coarser resampled resolution. Thus the graduated pressure to identify agricultural high-risk areas for better targeting of the best practices means that there is a greater need to use DEM data that really have a capacity to pinpoint the nutrient and erosion vulnerable areas. As seen from Table 1 (for more detail, see Appendix 1), the grid and vertical resolution varies from country to country and also within countries. The best grid resolution, 2 x 2 m, covers only a part of the total area. Due to the fact that each country has its own data format, such as different coordinate systems and pixel sizes, the data must be transformed before different DEMs can be combined. At the BSR level, grid resolution is 100 x 100 m and vertical resolution 16 m.

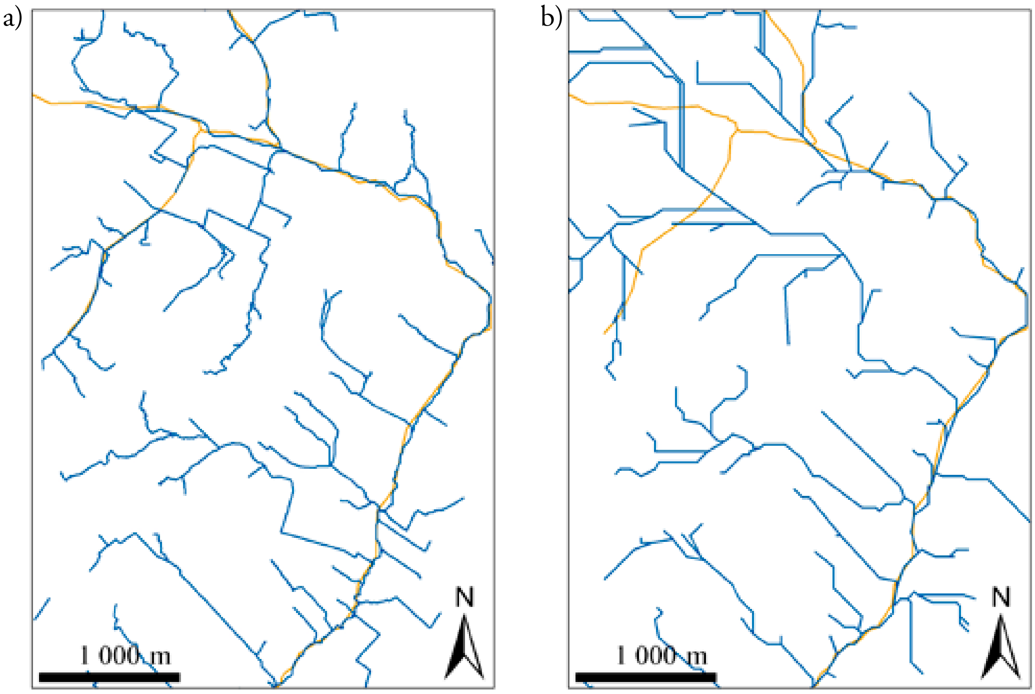


Figure 2. An example of a stream network as calculated from (a) 2 m grid based on Lidar data and (b) 25 m grid based on contour lines. The yellow line is the real network.

Table 1. The resolution information of the digital elevation models in the BSR countries.

Country	Grid resolution or pixel size	Vertical resolution
Finland	25 x 25 m, 10 x 10 m, 2 x 2 m	2 m, 1.4 m, 0.3 m
Sweden	50 x 50 m; 2 x 2 m	±2 m; ±0.5 m
Denmark	1.6 x 1.6 m	0.1 m
Estonia	5 x 5 m	no model, only raw data, 1-2 m
Lithuania	10 x 10 m, 2 x 2 m	-
Poland	25 x 25 m	±1-1.5 m
Germany	SH: 1 x 1 m (or lower resolution)	0.15-0.25 m for DEM1
Belarus	25 x 25 m	-
Whole BSR	100 x 100 m	16 m

2.1.1 River network

The river network used here was ECRINS (= European Catchments and RIvers Network System) hydrology database, prepared by the European Environmental Agency (EEA). The term describes an approach for spatially determining rivers, lakes, catchments and related objects as a topological network. ECRINS has been built on the Catchment Characterisation and Modelling (CCM) system developed by the European Commission's Joint Research Centre (JRC) with a resolution of 1:250 000. The CCM is based on a 100 m DEM so the river network is thus lineated from a hydrological corrected DEM comparable to the DEM used in the RUSLE Model. ECRINS has two main components:

- Drainage lines: these indicate in which direction the water is flowing through the valleys. The more tributaries they receive, the bigger their Strahler order.
- Elementary catchments: the polygons that represent the surface drained by each of those segments. In order to build a more manageable system and reduce its size, elementary catchments are aggregated into FECs (Functional Elementary Catchments).

2.1.1.1 Drainage density

A drainage density index (DDI) was calculated with EEA's 10 km statistical grid (Figure 3). The index is usually calculated at the catchment scale, but we wanted to retain comparability with RUSLE (see Chapter 4.1.1) and therefore used grid scale. The DDI of a basin is the total line length of all streams divided by the basin area. It is largely independent of slope. A high density may indicate one or more of the following: a "mature", well-developed channel system exists, surface runoff moves rapidly from hillslopes (overland flow) to channels, thin/deforested vegetation cover exists, or basin rocks/soils/surface generally have a low infiltration rate (highly impervious geology or abundant impervious manmade surfaces). It also describes the soil texture of a stream network.

It can be summarised that the length of streams and channels in an area can also be considered as an index to describe soil erodibility. Although their precise relationship has not been established, there is agreement that drainage in an area can be considered as an index of soil erodibility (Zakrzewska 1967). The critical value of drainage density per square km that may cause soil erosion by water is 0.90 km per square km of area. Leopold et al. (1969) are of the view that on average 2.59 square km of drainage area is enough to maintain 2.24 km of channel length. A lower value of drainage length per square kilometre of area is therefore safe, as it approaches the threshold limit of erosion: values higher than this will automatically make for greater soil erosion, adversely affecting agricultural land use.

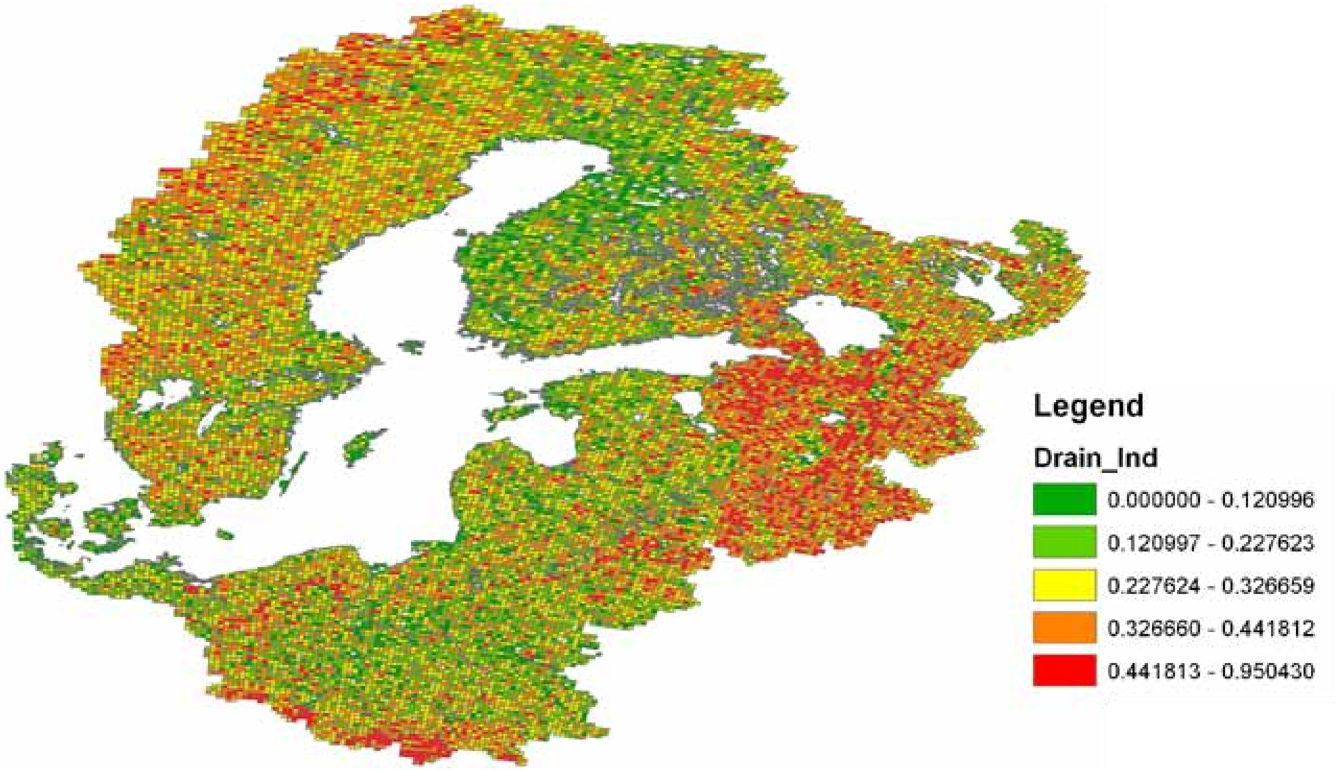


Figure 3. Drainage density index for the whole BSR.

With a 10 km x 10 km EEA grid cell, there is only one cell in which the value is greater than 0.90 km/km^2. The mean DDI is 0.26, standard deviation being 0.13.

The areas with a high DDI differ from erosion risk areas identified by the RUSLE method. However, there are exceptions; for example, southern Poland is highlighted by both methods. On the other hand, Leningrad Oblast (Russia) has notable erosion risk based on the DDI, but not in RUSLE.

2.2 Soil

2.2.1 General

The only soil database providing complete coverage of the BSR region is European Soil Database 2, http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDB/index.htm. Its nominal scale is 1:1 000 000 and it uses International WRB soil classification. The availability of medium- and large-scale soil data in BSR countries varies greatly. Finland and Estonia have GIS databases and WMS services with full coverage and with international soil classification, but the scales are different; the smallest mapping unit is 1:10 000 in Estonia and 1:250 000 (1:80 000) in Finland. Germany has nearly complete coverage with a 1:200 GIS database, but it does not have international WRB classification. In Latvia, Lithuania and Russia, large-scale maps provide good coverage, but they are not available in digital form. In Belarus and Poland the situation is pretty similar. Denmark has its own raster-based system and Sweden has only small-scale data (see the clayey areas in BSR in Figure 4).

Currently, there are 3 competing global systems for soil classification:

1. World Reference Base (IUSS Working Group WRB 2007)
2. US Soil Taxonomy
3. Référentiel Pédologique (Baize, D. and Girard, M.-C. (Eds.) 2008)

Without going into the details of each system, they all aim to classify profiles into soil typological units.

In the nutrient models the soil texture is often considered important. The texture determinations (triangles) and particle sizes vary from country to country. Firstly, it must be noted that different sets of sieves were used in the former Soviet Union (Russia) and Western countries.

Comparison of the GOST 25100-95 (Russia) and the EN ISO (Western) 14688-1:2002 soil classifications. Differences in sieve sizes in mm and the shapes of sieve openings

GOST: //200 //10// 2 //0.5 //0.25// 0.1// 0.05// 0.005
EN ISO: // 200// 63// 20 //6.3// 2// 0.63 //0.2// 0.063// 0.02// 0.0063// 0.002

GOST fine-grained soil classification is based on the content of sand particles (2-0.05 mm) and plasticity index (IP). In EN ISO all soils are classified by the content of fine particles (<0.06 mm) and by the content of clay (<0.002 mm) in it.

Online services:
(WMS, WFS), http://eusoils.jrc.ec.europa.eu/wms/wms.htm

2.2.1.1 Finland

Soil mapping:
About one-third of the country, including about half of the cultivated land, has been mapped at scales of 1:20 000 to 1:50 000. Initially the mapping was undertaken by the Geological Survey, which produced maps at a scale of 1:100 000, 1:400 000 with an emphasis on the nature of the geological deposits. The Agricultural Research Centre later became involved, producing maps at scales of 1:20 000 (southern Finland) and 1:50 000 (northern Finland), Lilja et al. 2005.

Soil and land information systems:
The Finnish Soil Database: 1:250 000, complete coverage, international classification (FAO, WRB 1998). There is also a map of quaternary deposits (1:200 000) with national classification. It is a sister product of the Finnish Soil Database (1:250 000).

Soil classification in Finland is strongly influenced by two main substrates: glacial till (most widespread; primarily covered by forests) and peatlands (formed in depressions in glacial till). Accordingly, in the Finnish soil classifion, soils are separated into till soils (moraine), sorted mineral soils (gravel, sand, fine sand, silt and clay) and organic soils. Genetic aspects are less important. Agricultural soils are more clayey, and quite common on silty and loamy deposits and on fine sands. The Finnish soil classification system is mainly based on organic matter content and particle size classification (Aaltonen et al. 1949).

The following conclusions can be presented:

1. Rocky soils are classified as Leptosols
2. Coarse-textured mineral soils are classified as Podzols and Arenosols
3. Medium- to coarse-textured soils qualified by water are classified as Regosols
4. Clay soils are classified as Cambisols and Gleysols
5. Peatlands are classified as Histosols.

Texture: Particle size class limits for sand, silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Finland	<2	2-20	>20

Online services:

The Finnish Soil Database 1:250 000, WMS service,
http://gssoil-portal.eu/ingrid-portal/portal/main-maps.psml;jsessionid=A44F23924B84C525BBCCF17F98828BEA
Map of quaternary deposits 1:200, WMS service,
http://geomaps2.gtk.fi/geo/

2.2.1.2 Germany

Soil mapping:

In the past, much of the soil mapping has been carried out by the 16 state geological surveys and this has varied greatly between states in terms of scale and coverage. Approximately half of the country has been mapped by these state organisations at scales ranging from 1:25 000 to 1:200 000. Also 1:10 000 and 1:5 000 scale maps have been produced but mostly as case studies. The national soil survey (BGR) is now collaborating with the state surveys to produce a 1:200 000 scale map for the whole of Germany. By the end of 2004, 17 of the 59 sheets were published, 7 draft sheets were under preparation at federal state level and one was prepared at national level by BGR. Buek 200, Complete coverage 2014, http://www.bgr.bund.de/EN/Themen/Boden/Projekte/Informationsgrundlagen_laufend/BUEK200/BUEK200_en.html. Small-scale maps at 1:1 000 000, 1:2 000 000 and 1:5 000 000 scale show German soils at European and global levels (Wittman et al. 1997).

Soil and land information systems:

The systematic development of soil information systems in the Federal Republic of Germany began in 1979. The State Geological Surveys and the Federal Institute for Geosciences and Resources manage the project. The soil information system, FISBo BGR, consists of three main components: the spatial database containing all small-scale maps for nationwide needs, the laboratory and soil profile database, including physical and chemical properties and contaminants, and the methods database. It is part of a geoinformation network that includes and connects geoinformation systems, e.g. geology, soils, hydrology, so the information obtained from this network can be very complex.

Classification systems:

The German soil classification distinguishes six hierarchical levels. In Germany, soil maps often represent combinations of soil types and parent material types or associations (substrate type); this combination is called “Bodenform” (soil form). Associations of soil forms in the landscapes then follow the classic concept of aggregation, by forming major soil forms and grouping into communities and associations.

With regard to the identification of a common taxonomic level between the German system and WRB: the translation of German soil types into WRB-soil types (reference soil groups) is feasible in many cases but sometimes also very difficult because a translation is not done by using the name of a soil type and assign it to the same of the other classification. The obvious reason for this is the differences in the nature of these classification systems. The German classification is based on soil genesis whilst the World Reference Base for soil resources is meant to be a reference system.

Texture: Particle size class limits for sand, silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Germany	<2	2-63	63-2000

Online services:
WMS service, http://www.bgr.de/Service/soil/

2.2.1.3 Denmark

Soil mapping:
A set of maps for the whole agricultural area in Denmark was published at a scale of 1:50 000 in 1980. Soil types were not differentiated on forested or urban land. About 90% of the country is covered by maps of surface geology, which include some soil attributes. Subsequently there have been improvements to the soil maps by incorporating further soil data, particularly information on soil texture, and combining existing topographic, geological and landscape maps to delineate geographical units having similar soil types. A pedological soil map at 1:1 000 000 has also been derived (Greve et al. 2007).

Soil and land information systems:
Between 1975 and 1979, 36 000 sites were sampled (1 per 0.7 km^2). The descriptions of these sites and data from the analyses are stored in the Danish Soil Profile Database, making it possible to combine the results of profile investigations with soil maps and physical and chemical properties associated with mapping units. This information provides a basis for responding to needs for soil information relating to agricultural and environmental problems and planning.

Classification systems:
The DSPM06 consists of five GIS layers, each representing one texture class for the topsoil (0–20 cm depth): clay, silt, fine sand, coarse sand and organic matter covering the entire land surface of Denmark in a spatial resolution of 250 m x 250 m grid cells. The soil property map is based on approximately 45 000 soil samples from which the texture classes are interpolated by well-documented geostatistical methods and hence the calculation of statistics on which the interpolation is based.

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Denmark	<2	2-63	63-2000

Online services:
There is a GEUS geological map 1:200 000, which is included in the WMS service,
http://gssoil-portal.eu/ingrid-portal/portal/main-maps.psml;jsessionid=A44F23924B84C525BBCCF17F98828BEA
DJF geodata WMS service,
http://www.djfgeodata.dk/website/DJFGeodata/viewer.htm

2.2.1.4 Estonia

Soil mapping:
Soil mapping in Estonia was originally based on the use of geological maps. The first comprehensive soil map was at scale 1:800 000 (1923). A 1:400 000 scale soil map was later generalised to 1:1 500 000. In the late 1940s, more detailed soil mapping started (at scale 1:50 000 and 1:10 000) and also special-purpose soil mapping, e.g. soil acidity map for liming purposes. Today the whole territory of Estonia is mapped at 1:10 000 scale. Estonia is also covered at medium (1:100 000; 1:200 000) and small scales (1:1 000 000, 1:1 500 000 and 1:2 500 000 SOVEUR) (Reintam et al. 2005).

Soil and land information systems:
Many of the soil maps including the maps at 1:10 000 scale have been digitised and contributed to the Estonian Soil Database, along with profile data. The digital soil map of Estonia was produced at the scale 1:10 000 in the coordinate system of Lambert-EST. The available maps at the scale 1:5 000 were reduced and generalised to correspond to the scale 1:10 000. Original graphic data, i.e. the digital soil map, are in DGN format and the soil database in MS Access. The designed GIS interface allows different queries, calculations of soil areas according to soil properties, making of soil explications, etc. The Estonian Land Board needs the Estonian Soil Map mostly for land valuation purposes. Other users include the Ministry of Agriculture, agricultural advisers, forest managers, etc. The project was initiated in 1997 and the works were outsourced through public tendering. The data cover the whole territory of Estonia except the land of towns and settlements; the total covered area is 43 300 km^2. The data (graphical and attributes) are also loaded into an Oracle spatial database and can be used as a background map in the Cadastral Information System. Since the end of the project in 2000, no map updates have been produced.

Classification systems:
International classification FAO/WRB. The soil map of 1:500 000, compiled by Igna Rooma and Vello Voiman using Estonian nomenclature in the legend, was converted to USDA Soil Taxonomy by Raimo Kõlli and Illar Lemetti, and digitised at Cornell University, USA, under the guidance of Ray B. Bryant.

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Estonia	<2	2-50	50-2000

Online services:
WMS service, http://xgis.maaamet.ee/xGIS/XGis

2.2.1.5 Latvia

Soil mapping:
The first generalised soil maps of Latvia were published at a scale of 1:400 000 in 1945 and 1958. After the Second World War, all family farms were nationalised, becoming State or Collective Farms. For each farm, detailed soil maps at scale 1:10 000 were made, showing soil types, texture, land use and soil water conditions. Extensive land reclamation (1972-1976) led to a second soil mapping cycle. Medium-scale maps from 1:75 000 to 1:500 000 scale have been created at regional or country level. The most recent is a 1:1 000 000 scale soil map elaborated for incorporation into the European Soil Database (Karklins 2005; 2007).

Soil and land information systems:
The main soil archive, including data from 1959 until now, is at the State Land Service. The Agrochemical Research Centre maintains the computerised Soil Fertility database of Latvian agricultural land – AGRO. The Soil Profile Database of Latvia is under development at the Latvia University of Agriculture where Latvia's Reference Soil Profile descriptions will be stored. Scale 1:10 000 and related soil data currently exist only as hand-drawn materials at the archives.

Classification systems:
Traditionally, Latvia uses a genetic approach to soil classification. Quantitative morphological criteria are not yet employed to separate soil taxonomic units. Such a soil classification system is officially recognised and widely used for different purposes at the national scale. Soil types and subtypes alone or in the form of different associations are basically used as mapping units for large-scale (1:10 000) soil maps. This approach is quite suitable for meeting the local information need, which up to now has been mainly agriculture-oriented. Unfortunately, it does not meet requirements for international communication or for domestic use when new types of information should be integrated into the national system and advanced interpretations have to be applied, such as modelling of natural processes for environmental applications, remote sensing and indirect measurement methods of certain soil properties.

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Latvia	<2	2-50	50-2000

Online services:
-

2.2.1.6 Poland

Soil mapping:
Soil science in Poland has traditions dating back to the 19th century. The first complex soil map of Poland, at 1:500 000 scale, was created in 1906. Soil quality class maps at scale 1:5 000 cover the whole agricultural area. Soil agricultural maps (soil suitability classes) are available for Poland's agricultural area at scales 1:5 000, 1:25 000 and 1:100 000. Soil maps at a scale of 1:25 000 demonstrating spatial variability of soil types (genetic map) covered 60 per cent of the entire Polish agricultural land in 2000 (Białousz et al. 2004; 2005).

Soil and land information systems:
The BIGLEB system was the first complex soil database and its development started in the 1970s together with soil monitoring. Nowadays the most important soil database is the Geographic Soil Database at 1:1M scale, which is also part of the European Soil Database. In 1999, work started on a similar, more detailed database based on data appropriate at the scale 1:500 000, using the same methodology as the 1:1M database. Many other soil databases

have been created according to different purposes and needs, including flood prediction, soil productivity evaluation, marginal soils and marsh characteristics.

Classification systems:
There are 3 aspects of soil classification and the associated soil maps in Poland: (i) soil quality/productivity classes, (ii) soil agricultural maps (soil suitability classes) and (iii) soil taxonomy classes (based on soil genesis).

Polish SgP 2011	WRB 2006
Initial soils	Leptosols
Weakly developed soils	Leptosols, Regosols
Brown forest soils	Cambisols
Rusty soils	Arenosols
Brown forest podzolic soils	Luvisols, Albeluvisols
Podzol soils	Podzols
Chernozemic soils	Chernozems, Phaeosems
Gley soils	Gleysols
Vertisols	Vertisols
Organic soils	Histosols
Anthropogenic soils	Anthrosols, Technosols

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Poland	<2	2-100	100-1000

Online services:
WMS service, http://osip.opole.pl/wms_gleb/wmsservice.aspx

2.2.1.7 Lithuania

Soil mapping:
Soil maps of Lithuania are based mainly on the results of large-scale field surveying. Detailed large-scale (1:10 000 and 1:5 000) maps exist at farm level. At regional level, maps are at the scale of 1:50 000 and at country level at a scale of 1:300 000. Nowadays the land reform programme is ongoing, necessitating soil mapping at various scales (Buivydaite 2005).

Soil and land information systems:
Currently, the main problem is the lack of a computerised system for storage and manipulation of the data, and the information is stored mainly as maps in paper form and as manuscripts in archives. The establishment of the Land Resources Information System of Lithuania (LTlrIS) has been started with FAO support. Simultaneously, the Soil Database of Lithuania (LTdDB) is under construction.

Classification systems:
Now when newly independent European countries are integrating into the EU and the science of other countries of the world, it is necessary to compare and use for different purposes international (FAO-Unesco) soil classification. The main purpose of the new classification of Lithuanian soils (LTDK-99) is to group the soils by origin, texture, thermo and hydro characteristics, and other regimes, and soil fertility. The most promising way to systematise the available information is database (DB) creation. A soil database and GIS-based soil map of Totorkiemis at Vilkaviskis Reg. (Lithuania) has been made. The most prevalent soils in this area are Arenosols (AR), Histosols (HS) and Luvisols (LV).

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Lithuania	<2	2-50	50-2000

Online services:
No WMS services available

2.2.1.8 Sweden

Soil mapping:
There have been a number of approaches to mapping the soils of Sweden. Agrogeological maps of arable areas at a scale of 1:20 000 have so far been prepared for 3% of the arable land. Geological maps, which include a few soil properties, have been published at a scale of 1:50 000 for about 20% of the country. Quaternary and petrological maps at 1:100 000 and 1:400 000 have been created for the whole country. They also reflect soil properties. Nationwide surveys of forest soils, undertaken since the 1960s, involve surveying and sampling a set of national plots at periodic intervals. A soil geochemical map based on analysis of some 30 major and trace elements has been prepared at a scale of 1:250 000 for 30% of the land. A medium-scale map (1:500 000 scale) and small-scale maps at 1:1 000 000 and 1:2 000 000 have been prepared at the regional or national level, using ordinary kriging. They reflect many soil properties (Olsson 2005).

Soil and land information systems:
A number of important datasets have been collected in the form of maps, soil analyses and monitoring of both forest and arable soils. Some of these datasets are available on the Internet. Currently environmental surveys are carried out by different organisations and the effectiveness of data collection and data organisation could benefit from a greater degree of coordination.

Classification systems:
A national system for classification of soil types is used in Sweden. This covers among other things different forms of podsols, brown forest soils, waterlogged soils and lithosoles. Other countries or regions of the world apply their own locally developed systems for soil type classification. The system developed in the US, called "Soil Taxonomy", is so comprehensive and so general that it can be applied worldwide, for example in the Nordic countries. The system comprises 11 main groups, for example, Spodosols, Inceptisols, Entisols and Histosols. FAO-Unesco has compiled an international soil type classification, the Soil Map of the World, revised legend. This system comprises 28 main groups, for example, Podsols, Cambisols, Histosols, Gleysols, Leptosols, Regosols and Arenosols. These are, in turn, divided into subgroups. FAO-Unesco's system is, in addition to the national system, applied within the Swedish Survey of Forest Soils.

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Sweden	<2	2-60	60-2000

Online services:
http://www-markinfo.slu.se/eng/soildes/jordman.html

2.2.1.9 Russia

Soil mapping:
Basic concepts and methodology of soil mapping have been developed by Dokuchaev and Sibirtsev. The first soil maps of the European part of Russia were drafted (at a scale of 1: 8 400 000) and published in 1851, edited by K.S. Veselovsky, and then edited by I. Chaslavskii in 1879 (at a scale of 1: 2 520 000). Subsequently, Dokuchaev and his students created science-based soil maps of European Russia and map soil zones of the Northern Hemisphere. After the Revolution, soil mapping was developed under the guidance of Glinka, and then Prasolov (Shoba 2008, Korolyuk 2010).

In terms of scale, the soil maps are divided into detailed (1: 5 000 and larger), large (1: 10 000 - 1: 50 000), medium (1: 100 000 - 1: 300 000), small (1: 500 000 - 1: 2 000 000) and survey (1: 2 500 000 and smaller).

Small-scale maps
The materials of the soils are summarised in a series of small-scale soil maps: Soil map of European Russia M 1:2 500 000 (E.N. Lobova and N.N. Rozanov 1947). Soil map of the USSR M 1:4 000 000 (N.N. Rozanov 1954). Soil maps of the physical and geographical atlas of the world (ed. I.P. Gerasimova 1964). Soil map of Asia M 1:4 500 000 (ed. V.A. Kovdy and E.V. Lobovoy 1970). Soil map of the Non-Chernozem Zone of the RSFSR 1:1 500 000 M (ed. V.M. Fridland 1978). Soil map of the world M 1:15 000 000 (M.A. Glazovskaya and V.M. Fridland 1980). Map of soil and zoning M 1: 1 500 000 (ed. G.V. Dobrovolskogo and I.S. Urusevskoy 1980).

Notable small-scale maps drawn recently include a soil map of Russia 1:2 500 000 (V.M. Fridland, E.N. Rudneva and D.V. Shishov 1988) and a soil map of Russia and the neighbouring states M 1:4 000 000 (G.V. Dobrovolsky and I.S. Urusevskaya 1995).

Agrochemical maps, large scale

The "agronomisation" of soil maps began in 1929. Those agrochemical maps show the data content in % S, Ca + Mg, Soil Carbon %, Volume, P, K, N, grading, etc. They were planned to be used for guiding proper use of fertilisers in cotton areas and areas of sugar beet cultivation.

By the end of 1936 under the leadership of the All-Union Institute of Fertilisers, agricultural and soil science and other institutions made soil and agrochemical maps for the 11 republics and 16 areas on a scale of 1:500 000 covering an area of about 79 million hectares, and a scale of 1:10 000, 1:20 000 and 1:25 000 covering about 10 million hectares. The lack of experience of large-scale soil maps for agricultural use meant that the need for a link with the soil survey of agricultural production goals was neglected, leading to a number of errors in the implementation of these works.

In 1937, work began on the preparation of detailed, scale 1:2 000 soil maps of the state network for testing crops. This extensive work that covered the whole farming territory of the USSR was carried out under the direction of the Research Institute for Soil Science, Moscow State University (Prof. I. Shulga) with the participation of almost all collective soil scientists of the Soviet Union.

Despite the setbacks encountered during the implementation of soil mapping, they provided significant assistance to socialist agriculture. Accumulated experience allowed them to proceed to all collective and state farms of the RSFSR, the Ukrainian SSR, the Byelorussian SSR and the other republics.

Example of a soil map of a collective farm: http://dic.academic.ru/pictures/bse/jpg/0280740673.jpg

Soil and land information systems:

A soil map of the Russian Federation (1:2.5 M scale) edited by V.M. Fridland (1988) and a map of the soil- ecological zoning of Russia (1:2.5 M scale) edited by G.V. Dobrovol'skii and I.S. Urusevskaya (2007) are available. At the same time, there is no unified geographic information system for Russian soils, which complicates the sustainable use of soil resources and the development of soil conservation strategies.

A large part of the soil data in Russia is stored in paper form (in the form of tables and textual soil descriptions). In such a form, these data cannot be used in modern geographic information systems and agricultural technologies adapted to soil variability within relatively short distances.

Classification systems:

RSCS 2004

Open hierarchical substantive-genetic system. Priority of soil properties' diagnostic horizons and diagnostic features controlled by genetic concepts. Sets of diagnostic horizons identify soil types. Diagnostic features identify subtypes. Continuity in genetic perception of soils and preservation of most of the soil names. Quite a new approach to humanly-altered soils: classified by properties more than by history, perceived as a continuum.

Common and different properties of WRB and RSCS:

- genetic control over the definition of horizons;
- reference groups (WRB) are close to orders (RSCS) in essence and number, being 30 and 27, respectively;
- character and functions of qualifiers for lower-level units and for subtypes have much in common;
- RSCS – many-level hierarchical system;
- RSCS – strict for horizons' taxonomic functions and flexible for horizons' quantitative boundaries;
- in RSCS, there are more horizons (and features).

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Russia	<2	2-50	50-2000

Online services:

-

2.2.1.10 Belarus

Soil mapping:
Large-scale soil mapping of the agricultural land of Belarus was carried out in 1957-1964. This resulted in large-scale (1:10 000) soil maps of all collective farms of Belarus, the administrative regions (1:50 000) and regions (1:200 000) (Klebanovich et al. 2009).

Classification systems:
The first information on the classification of soils in Belarus – «On soils of Belarus», by V.G. Kasatkin – was published in 1923. This work stated that the republic belongs to the podzolic zone and the degree of podsolisation depends on the particle size and the relief. In the summarising monograph under the release And. S. Lupinovich and P. P. Rogovogo (1952), six types of soils are selected: turf, derno-podzolic, including swamped, turf-bog, peat-bog and alluvial-meadow.

In 2004, the publication of "Diagnostic of soils of Byelorussia and their classification in the FAO-WRB system", a monograph by A. Romanovoy, caused a lot of discussion among soil scientists.

№	**Type of soils**
1	Turf-carbonate (Regosols)
2	Brown forest (Cambisols)
3	Podzolic (Podzols)
4	Derno-podzolic (Luvisols)
5	Podzolic swamped
6	Derno-podzolic swamped (Podzoluvisols, Albeluvisols)
7	Bog-podzolic
8	Turf swamped (Gleysols)
9	Peat-bog on low-laying area (Terric Histosols)
10	Peat-bog up-river (Ferric Histosols)
11	Alluvial turf and turf swamped (Fluvisols)

Texture: Particle size class limits for sand silt and clay:

Size Fraction [in µm]	Clay	Silt	Sand
International System	<2	2-20	20-2000
Belarus	<2	2-50	50-2000

Online services:
National Atlas of Belarus: An electronic version is available. It will be edited as well. It is expected to be turned into a geo-information system that will be regularly updated. It also includes a soil section.

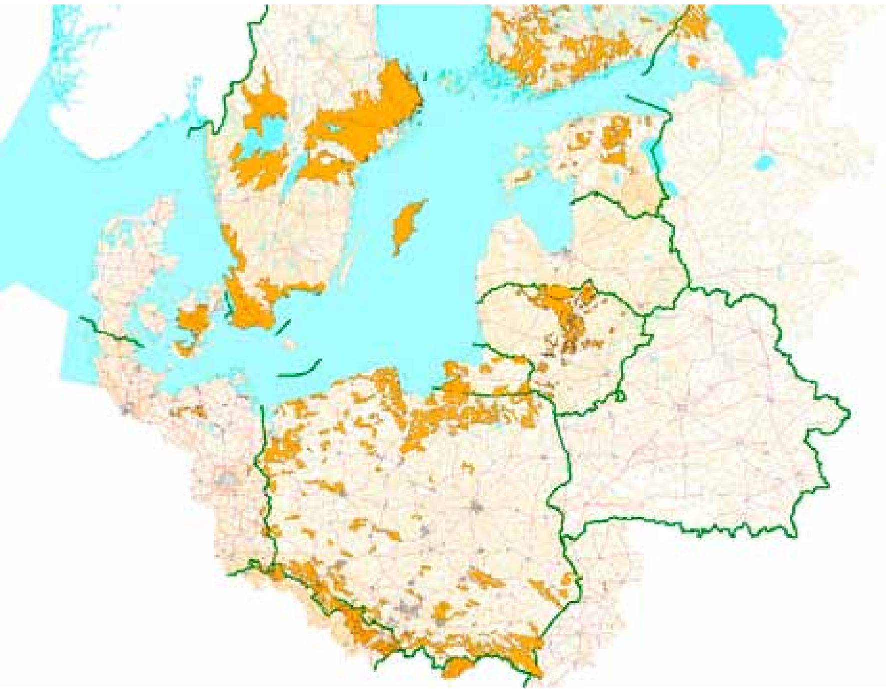


Figure 4. Clayey areas identified as FAO soil class Cambisol with EU soil map.

2.3 Agricultural land

According to FAO classification, agricultural area is the sum of areas under (a) arable land, (b) permanent crops and (c) permanent meadows and pastures. It must be noted that abandoned land resulting from shifting cultivation is not included into this category. Data describing land use changes are essential in assessing the loads from the agricultural sector. Often a small change in land use offsets the reductions achieved via best agricultural measures.

The top five crops in the BSR are almost alike (Table 2). Wheat ranks first in all of the countries apart from Finland and Estonia, where barley is the most cultivated crop. However, the share of total area accounted for by utilised agricultural area varies greatly between countries, being highest in Denmark, Poland and Germany and clearly lowest in Finland and Sweden (Figure 5). The density of agricultural land within the BSR is shown in Figure 6.

Table 2. The top three cultivated crops in each BSR country.

Finland	**Sweden**	**Denmark**	**Estonia**	**Germany**	**Poland**	**Latvia**	**Lithuania**
Barley	Wheat	Wheat	Barley	Wheat	Wheat	Wheat	Wheat
Oats	Barley	Barley	Wheat	Barley	Oats	Barley	Barley
Wheat	Oats	Rape and turnip rape	Rape and turnip rape	Rape and turnip rape	Rye	Rape and turnip rape	Rape and turnip rape

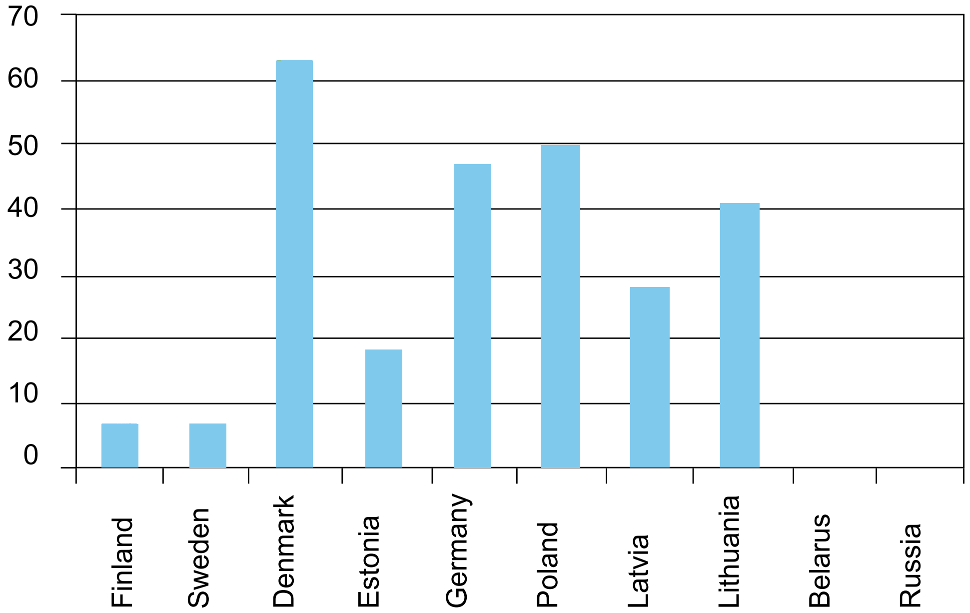


Figure 5. Total land area accounted for by utilised agricultural area in BSR countries (%).

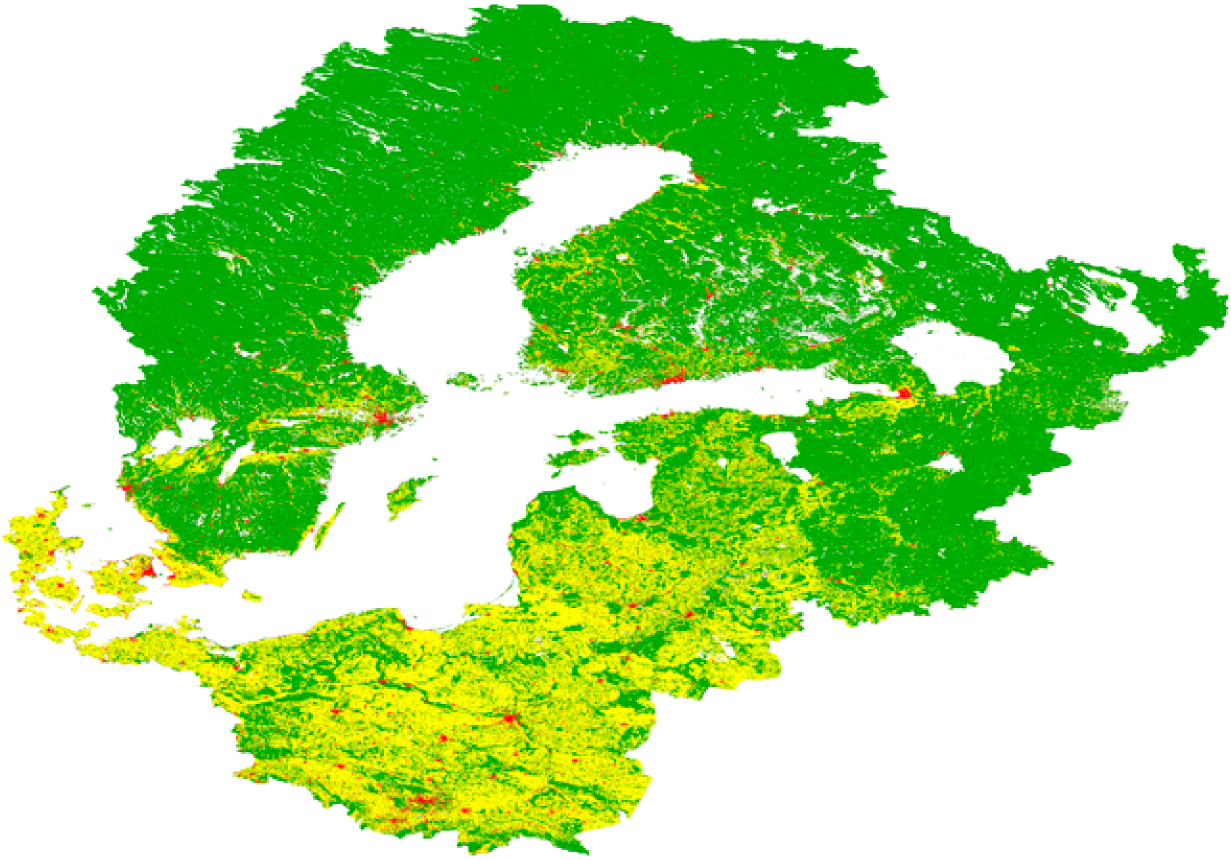


Figure 6. The density of the agricultural land in the BSR (yellow indicates high density, green indicates forest land, red indicates population centres).

2.3.1 Arable land data in Finland

The Corine land cover data encompass the area of the European Union. The Corine land cover map for the year 2006 (CLC2006) was produced by integrating the data on land cover changes during 2000-2006 with the land cover map from the year 2000. The map of changes in land cover is based on visual image comparison using satellite data from 2006 (+/- 1 year). The satellite data used for CLC2006 are SPOT-4 and/or IRS LISS III from two dates, the geometric accuracy of the satellite images is ≤ 25 m and the geometric accuracy of CLC data is better than 100 m. CLC2006 has 11 classes for agricultural land, arranged in a three-level hierarchy (see Table 3).

Table 3. The Corine land cover map, classes for agricultural land.

CODE	LABEL1	LABEL2	LABEL3
211	Agricultural areas	Arable land	Non-irrigated arable land
212			Permanently irrigated land
213			Rice fields
221		Permanent crops	Vineyards
222			Fruit trees and berry plantations
223			Olive groves
231		Pastures	Pastures
241		Heterogeneous agricultural areas	Annual crops associated with permanent crops
242			Complex cultivation patterns
243			Land principally occupied by agriculture, with significant areas of natural vegetation
244			Agro-forestry areas

Some countries, such as Finland, use national classifications where the CLC2006 is, among some classes, further divided into a fourth level by combining e.g. soil information on forest land. In addition, the Agency for Rural Affairs (Mavi) maintains a field plot register, where all the field plots that have received area-based subsidies are digitised. With additional field data provided by the Information Centre of the Ministry of Agriculture and Forestry (Tike), it is possible to link information, such as the dominant plant and its share of the field plot, to the field plot register. These data are licensed to use under the Environmental Administration of Finland. For more information about the agricultural GIS data in each BSR country, see Appendix 2.

Figure 7 shows a comparison of CLC2000 data for the Savijoki catchment (a sub-basin of the Aurajoki river basin) and Mavi field plot data (year 2008) separated into 5 classes. Mavi field plot data provide more detailed information concerning the location of different crop types than the CLC data. In the figure, all crop types (i.e. more than 100 different crops) have been classified into 5 separate classes but naturally all the original data are available for use.

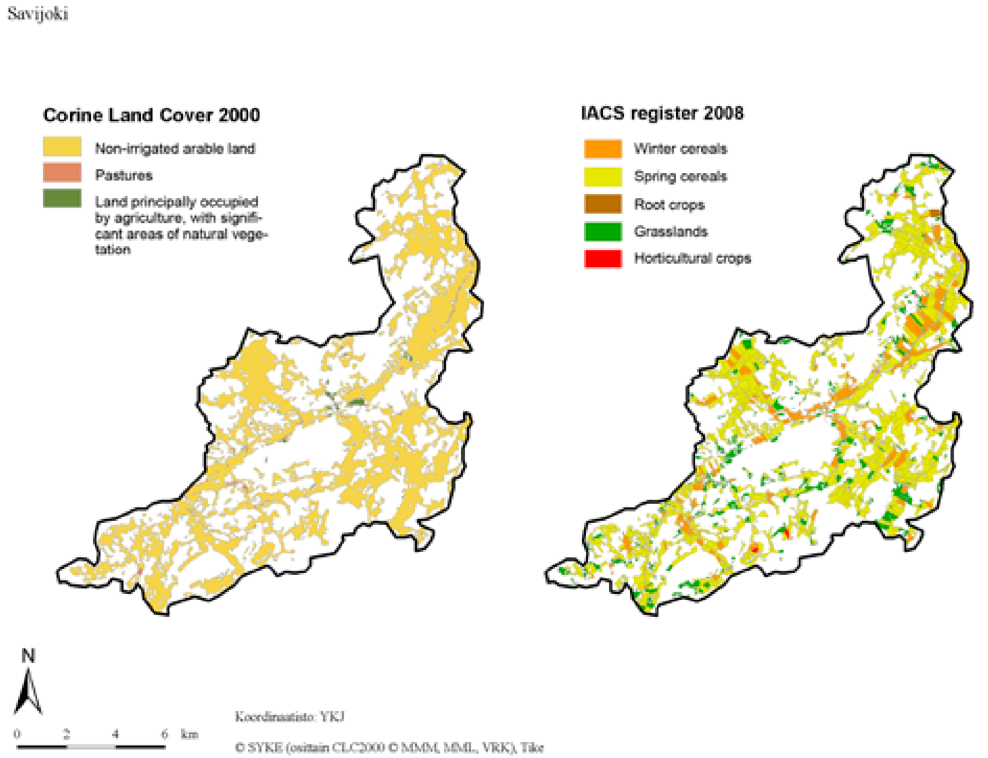


Figure 7. Land use classification based on Corine Land Cover 2000 and more detailed field data provided by the Information Centre of the Ministry of Agriculture and Forestry.

2.3.2 Cultivation practices

Each farmer knows precisely which practices are used on his/her own farm; however, such farm-level data are usually not available for research use. Within the MYTVAS project, Finnish cultivation practices (sowing and harvesting, ploughing dates, used tillage machines and the use of fertilisers) have been collected by interviewing local farmers in four selected catchments in Finland (Grönroos et al. 2010). However, these data are not freely available. There are also some examples of using satellite images in identifying the development stage of vegetation on fields; however, such data do not reveal anything about the actual management practices. In the future, however, satellite images could provide one opportunity to obtain more information on the vegetation coverage of the fields. It would be highly important to know the cultivation measures used in each field, e.g. when and with which machine, as well as the used amount of fertilisers, both mineral and manure. Unfortunately, for now, these data are not generally available within the BSR, which makes it difficult to identify the nutrient-vulnerable areas thoroughly.

2.3.2.1 The use of organic and mineral fertilisers, example from Belarus and Lithuania

The Nemunas river basin (97 928 km^2), draining the territories of Belarus, Lithuania, Russian Federation (Kaliningrad region), Latvia (only about 100 km^2) and Poland, is a major Eastern European river basin. The Lithuanian part of the basin covers 46 626 km^2 and the Belarusian 46 587 km^2. The longest and the largest (by their catchment size) tributaries of the Nemunas in Lithuania are Merkys, Neris, Nevėžis, Dubysa, Šešupė, Jūra and Minija. The main tributaries of the Nemunas in Belarus are Berezina, Viliya and Shchara (Figure 8). Nemunas is the 14th largest river in Europe, the largest in Lithuania and the 3rd largest in Belarus. Here, the Nemunas river is used as an example from Eastern Europe.

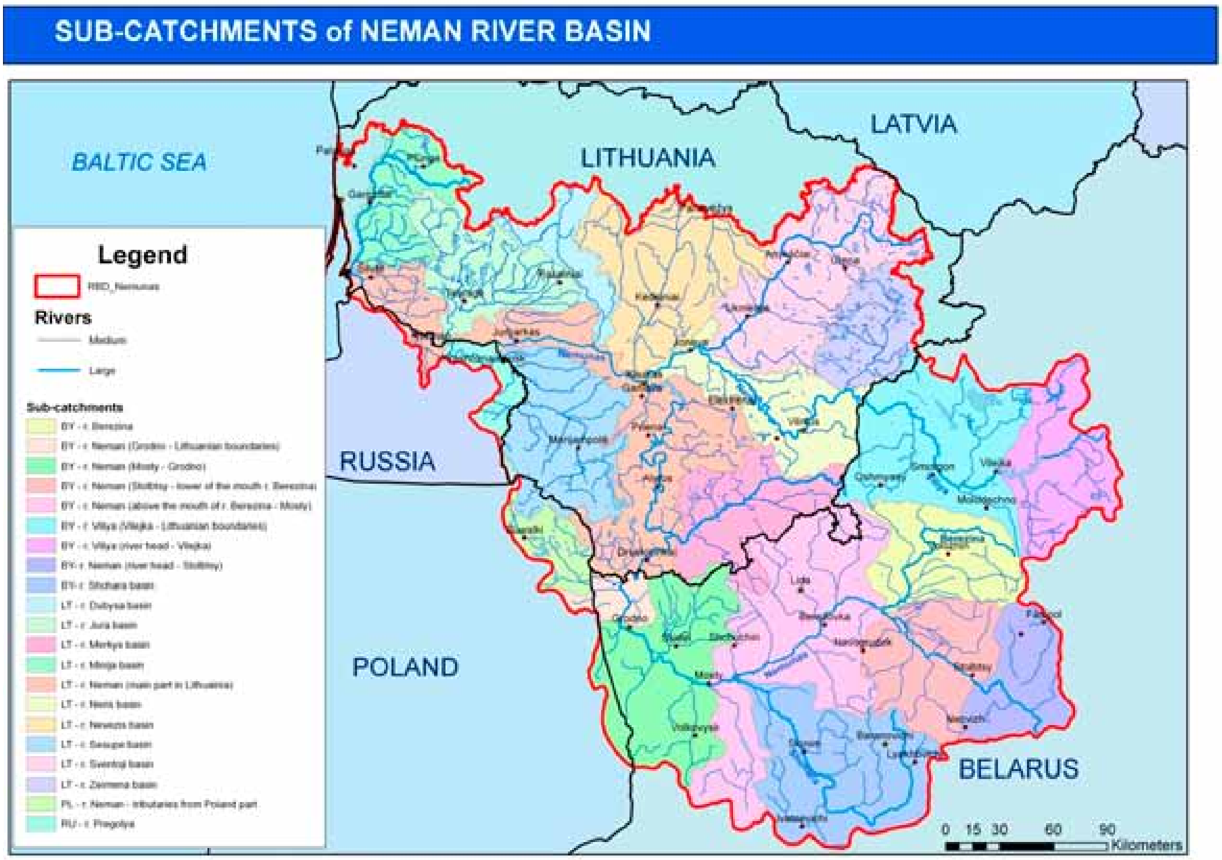


Fig. 8. Sub-basins (21) of the Nemunas river basin.

The Nemunas catchment plays an important role in Belarusian industry and agriculture. Indeed, virtually all of the main industrial centres of the transboundary countries are located in this catchment. The Nemunas catchment covers almost 53% of the total Belarus land area. The arable land covers 38% of the catchment and meadows and pastures 14%, respectively. In the basin, there are 182 organisations engaged in agriculture, public utilities and industry. The Nemunas catchment covers four municipalities, namely Grodna, Brest, Vitebsk and Minsk. The Minsk region is the largest one, with some 88 organisations and farms engaged in agricultural activity. The latter municipality covers 600 000 ha, of which 400 000 ha are arable lands. In the Brest municipality, there are 58 agricultural enterprises covering 222 000 ha, of which 150 000 ha are arable lands. Vitebsk is the smallest municipality, covering 30 000 ha, of which 16 000 ha are arable lands. Animal farming is the main activity in the catchment, constituting 60% of total production. The main animals raised are cattle, pigs and poultry.

The use of both mineral and organic fertilisers has increased in Belarus in recent years (Table 4). In fact, the rate of application of mineral fertilisers increased in the Nemunas catchment from 154 kg/ha in 2000 to 236 kg/ha in 2010, i.e. it grew by a factor of 1.5. Meanwhile, organic fertilisers were also applied at a higher rate of 9.1 t/ha in 2010, as compared to 7.9 t/ha in 2000. These data reflect the intensification of crop and animal farming in the area. In Lithuania, the average application rate of mineral fertilisers was some 170 kg/ha in 2010, whereas that for organic fertilisers was 20 t/ha.

Table 4. Application of mineral and organic fertilisers in the Belarusian part of the Nemunas catchment.

	2000	2005	2008	2010
Mineral, kg/ha	153.8	174.8	203.7	235.8
Organic, t/ha	7.9	7.2	8.4	9.1

The highest application rate of mineral fertilisers in 2010 was seen in the eastern corner of the Nemunas catchment in Belarus (Figure 9). However, the highest application rate of manure per hectare of arable land was observed in the western part of Lithuania (Figure 10).

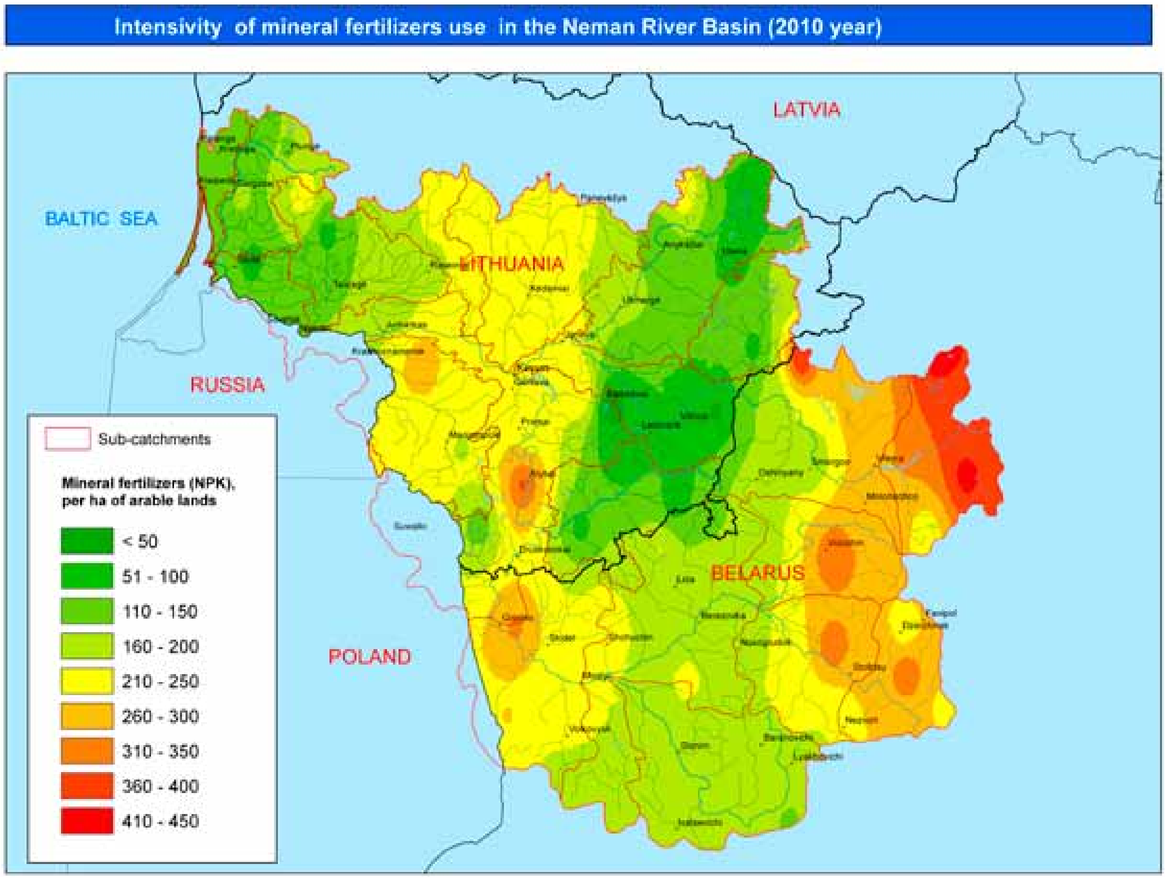


Figure 9. Use of mineral fertilisers in kilograms per ha of arable land in the Nemunas river basin in 2010.

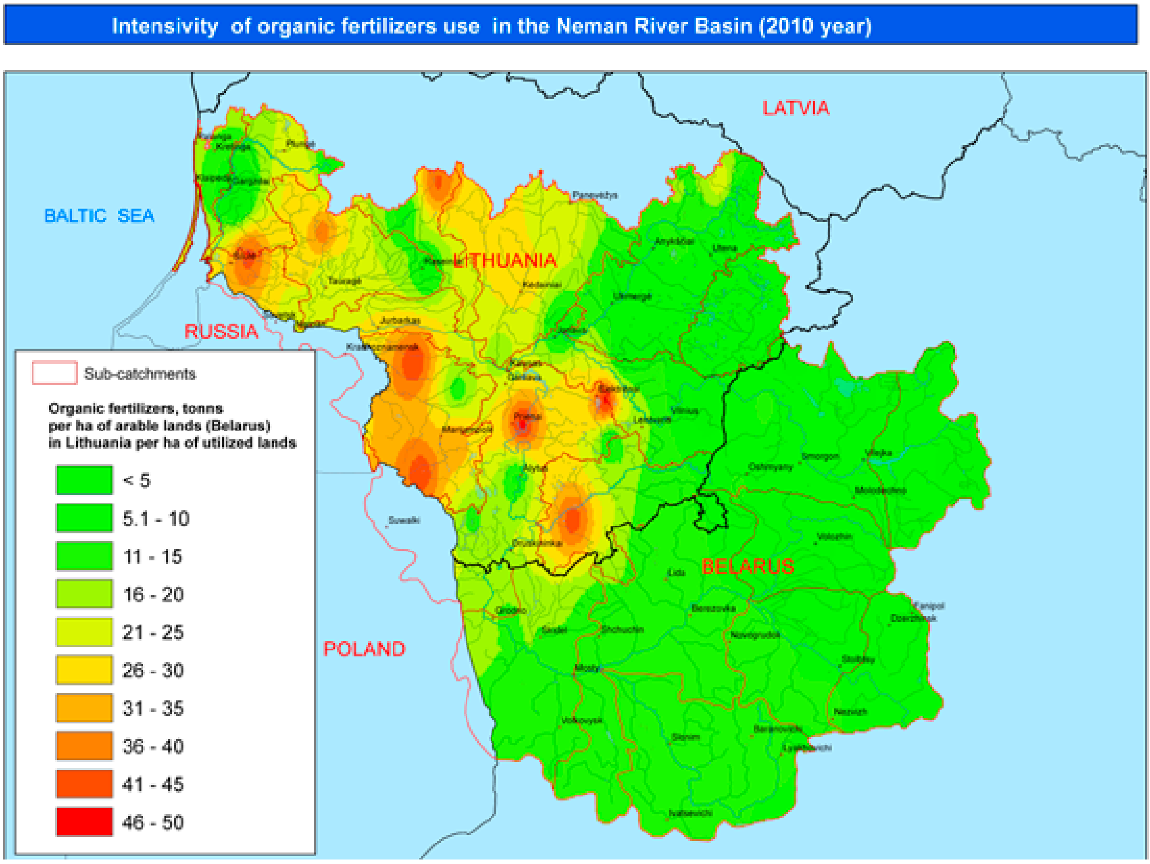


Figure 10. The use of organic fertilisers in tonnes per hectare of arable land in the Nemunas river basin in 2010.

2.4 Animal data

2.4.1 General

High livestock densities relate to high quantities of manure generated. Pastures, animal sheds, manure storage systems and fertilised agricultural fields are sources of nutrient leaching. Depending on local conditions and farming and manure handling practices, a high animal density can indicate increased risk of nutrient leaching.

Nutrients found in animal manure are vital in fertilising agricultural crops. Distributing manure over a large enough agricultural area can decrease leaching. Unfortunately, the manure production sources and the parties that need organic fertilisers are not always located close to each other. Some regions produce surplus manure while the need for fertilisers is bigger somewhere else. Intensive livestock systems, especially pig and poultry production, are often sources of nutrient surpluses.

2.4.2 Data availability

Comprehensive data are available on animal density in the BSR. The European Union statistics body Eurostat provides livestock information covering a major part of the watershed (http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database). Harmonised livestock statistics are compiled for various purposes. Eurostat data are available from an open-access database on the Internet. This database requires the user to register and agree to comply with its terms of usage. Data can be processed in the “Regional Agriculture Statistics” section of the database, and downloaded in selected format.

Personal support for database use is provided in multiple languages. Data on the cattle, pig, sheep and goat populations are available at the accuracy of NUTS2 regions. Also, the database provides the Utilised Agricultural Area (UAA) in hectares, which enables calculation of the livestock density index (LDI). A deficiency of the data in research use is that they are not updated frequently for all member countries. At present, the last complete data set for the whole area is 5 years old.

GIS Boundary files for NUTS areas and Local Administrative Units (LAU) are freely downloadable from the web service of GISCO (Geographic Information Systems of the European Commission http://epp.eurostat.ec.europa.eu/portal/page/portal/gisco_Geographical_information_maps/geodata/). Together with attribute information from the Eurostat database, livestock densities and livestock density indices can be calculated and shown as thematic maps, as in Figure 11.

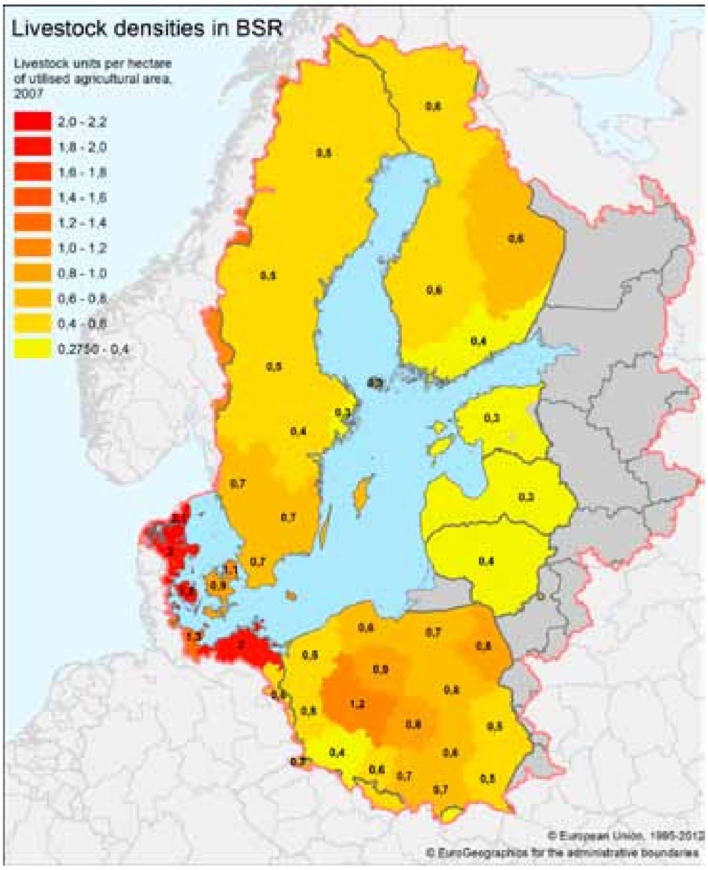


Figure 11. Livestock units per hectare of utilised agricultural area in 2007 in the Baltic Sea Region.

National statistics are available at varying levels of detail and spatial accuracy. In the case of Finland, livestock data are available for research at farm level. An animal registry database is governed by the Agency for Rural Affairs (Mavi), operating under the Ministry of Agriculture and Forestry. An animal registry stores confidential farm-unit information. Permission to access these data for research use is often granted separately for each project, and requires the user to agree to protect privacy of information. Data should be processed with care, and individual farms should not be identifiable in the outcome of analysis. The location of each farm and farm animal is stored in the database, and can be connected to the animal registry (numbers of animals in each of the accurate livestock classes). This enables full use of GIS in data analysis.

In Sweden, animal data are collected at farm level. Geographical co-ordinates are registered for each farm or location where animals are kept (i.e. animal holdings such as farms, pastures or collection centres). The farm and animal registers are maintained by the Swedish Board of Agriculture and may only be accessed by special permission under specific agreements for each use. For this report, the Swedish maps were made using easily accessible municipal-level data for 2010, obtained from the Swedish Board of Agriculture.

2.4.3 Livestock units

Livestock numbers are commonly standardised by converting population to livestock units (LSU) on the basis of coefficients. The LSU is a reference unit that facilitates aggregation of livestock from various species and ages. Originally, the coefficients were related to the animals' food requirements, the reference being a dairy cow with an annual yield of 3000 kg milk.

Several sets of livestock unit coefficients co-exist in the Baltic Sea Region, and new coefficients are developed to better fit the context of each aggregation. Livestock units for the Finnish and Swedish animal database were calculated using Eurostat values from the Concepts and Definitions Database. The contents of the accurate animal registry classes were thus aggregated into animal classes as shown in the coefficients table below (Table 5).

Table 5. The Eurostat coefficients used to calculate the LSU units.

Bovine animals		
	Under 1 year old	0.400
	1 but less than 2 years old	0.700
	Male, 2 years old and over	1.000
	Heifers, 2 years old and over	0.800
	Dairy cows	1.000
	Other cows, 2 years old an over	0.800
Sheep and goats		
	Sheep and goats	0.100
Equidae		
	Equidae	0.800
Pigs		
	Piglets having weight of under 20 kg	0.027
	Breedings sows weighing 50 kg and over	0.500
	Other pigs	0.300
Poultry		
	Broilers	0.007
	Laying hens	0.014
	Ostriches	0.350
	Other poultry	0.030
Rabbits		
	Rabbits, breeding females	0.020

Source: Eurostat

Livestock numbers were calculated for different areal units including municipalities (both countries) and river basins (only in Finland). The resulting thematic maps (Figures 12) show how livestock are spread over the landscape. Some areas of high livestock density can be highlighted.

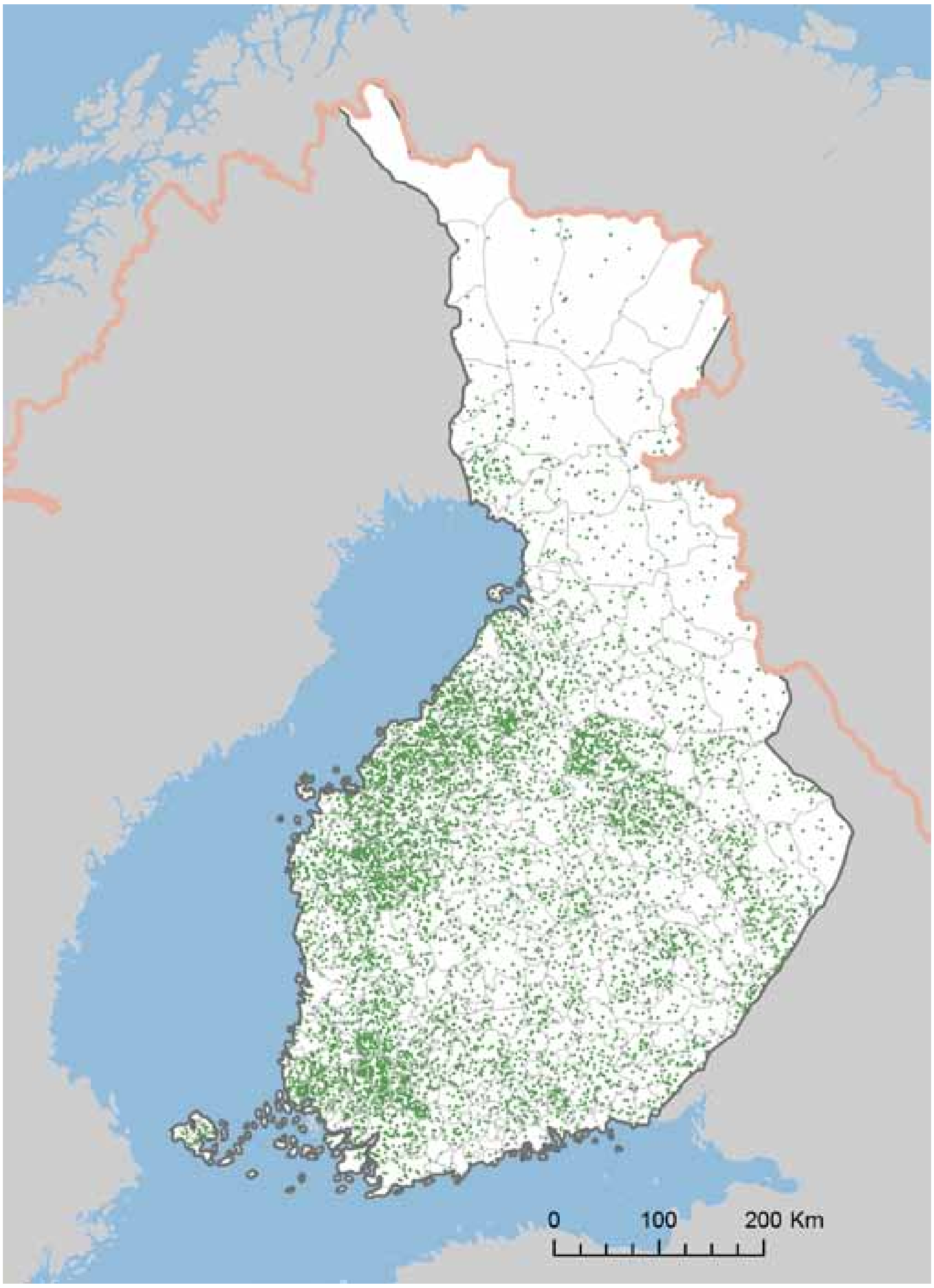
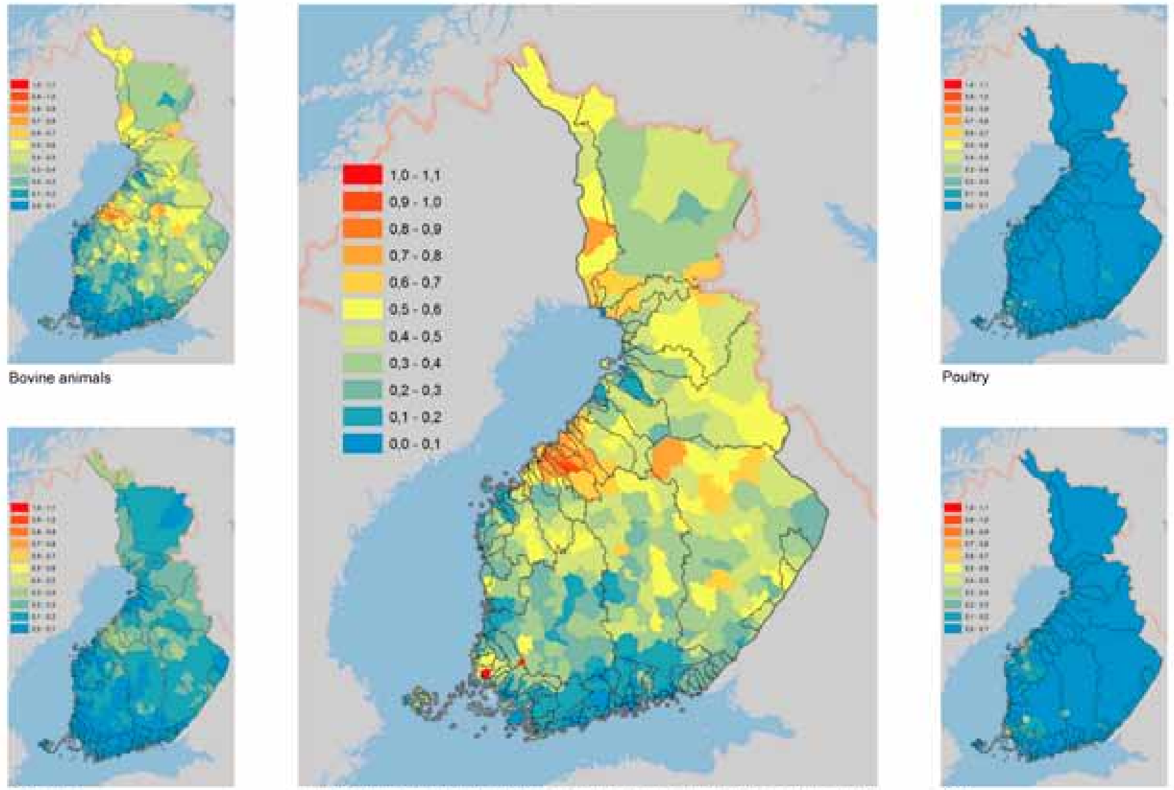


Figure 12. Livestock units in Finland (1 dot = 100 livestock units). Location of dots within each municipality is randomised.

2.4.4 Livestock density index

Indications of possible nutrient surpluses can be obtained by relating animal densities to available agricultural areas. The livestock density index (LDI) measures the stock of animals (LSU) per hectare of utilised agricultural area. Utilised agricultural areas were acquired from the Eurostat database and Mavi field plot database. The effects of different farming and manure handling practices or the share of mineral fertilisers were not considered in the index.

Livestock density indices were first calculated for different areal units (Baltic Sea drainage area, country level, Finnish and Swedish municipalities, and watersheds, see Figures above 11-12 and below 13-15). In Figure 15, the data from Sweden and Finland is joined and equally classified. There, the Southern Sweden stands out with the highest indices.



Bovine animals

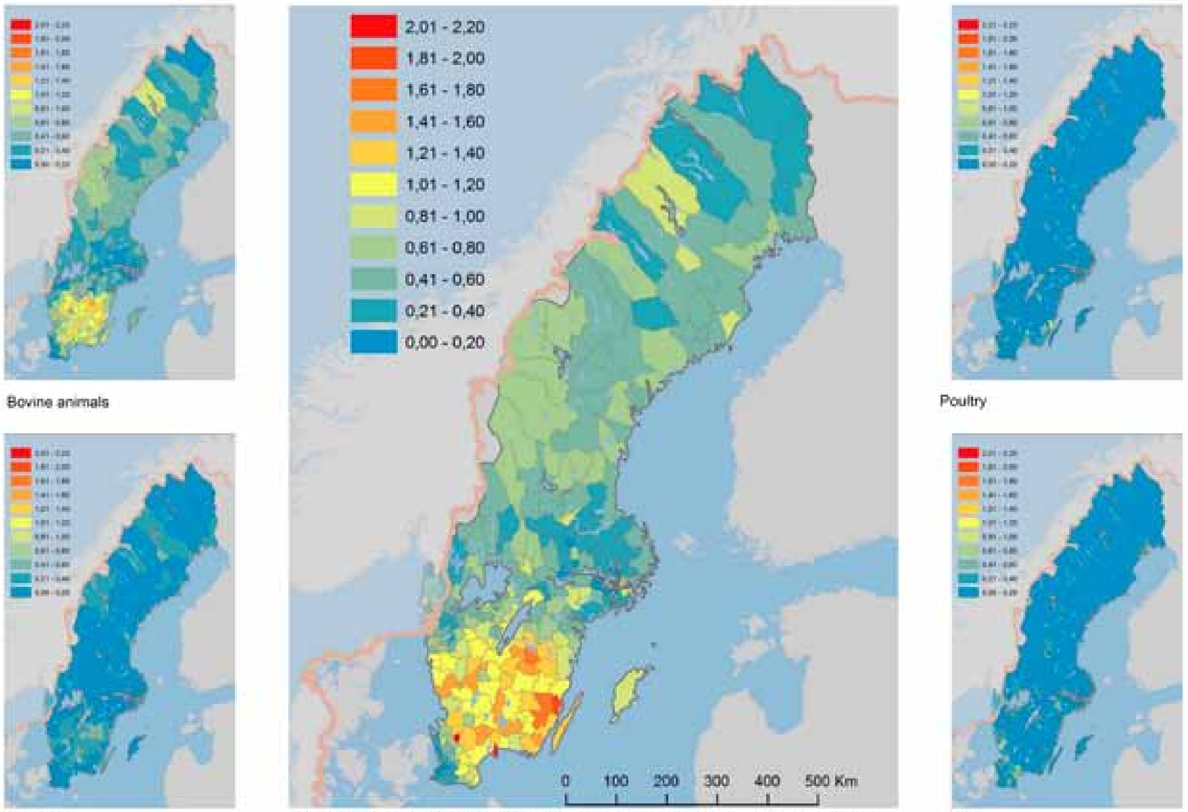
Poultry

Dairy cows

Livestock density indices (livestock units per ha of utilised agricultural area) per municipality in 2010, all farm animals.

Pigs

Figure 13. Livestock density index (livestock units per ha of utilised agricultural area) per municipality in 2010 in Finland. The centre figure shows the total for all farm animals, and the pictures on the sides show the contribution of relevant sub-classes. Dairy cows are included in bovine animals. Black lines show the boundaries of the main river basins.



Bovine animals

Poultry

Dairy cows

Livestock density indices (livestock units per ha of utilised agricultural area) per municipality in 2010, all farm animals.

Pigs

Figure 14. Livestock density index (livestock units per ha of utilised agricultural area) per municipality in 2010 in Sweden. The centre figure shows the total for all farm animals, and the pictures on the sides show the contribution of relevant sub-classes. Dairy cows are included in bovine animals.

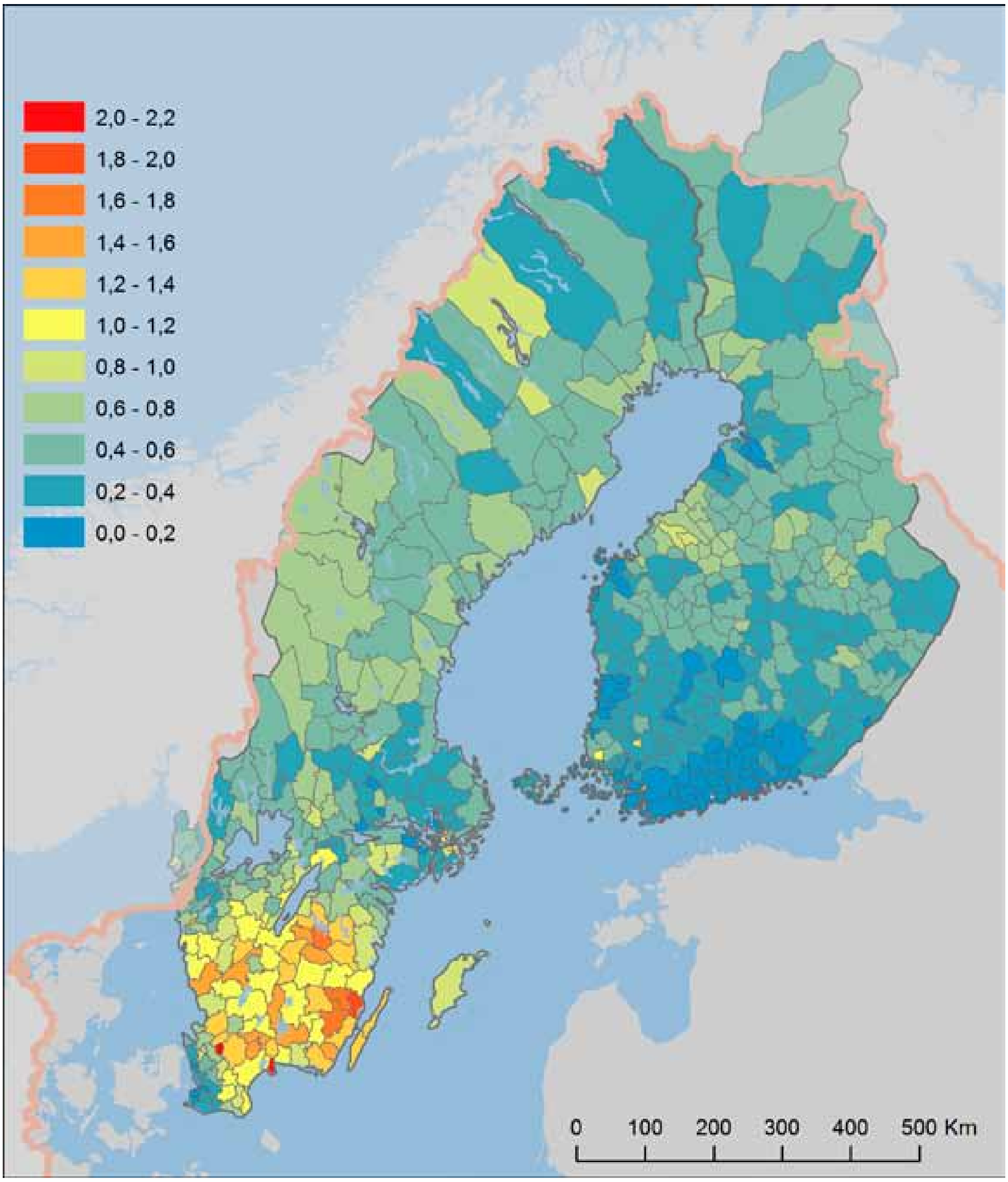


Figure 15. Livestock density index (livestock units per ha of utilised agricultural area) per municipality in 2010 in Sweden and in Finland.

A detailed calculation was carried out with geo-located livestock and field plot data. Both data sets were converted into a 10 km x 10 km resolution raster for calculations. Livestock numbers were divided by utilised agricultural area so that the resulting grid contains livestock density indices for each 100 km^2 grid cell. Resolution is in line with the scale of typical manure transport distances in Finland. Grid cells with less than 7 farms were here excluded from the presented map (see Figure 16). Use of this aggregation method enabled us to show data that are originally not public, and the regular grid structure portrays data in a more consistent way than modifiable areas such as municipalities. This effect is pronounced in the heterogeneous landscapes of Finland, where spatial variation in the share of utilised agricultural area is high (see Fig. 6 in Chapter 2.3).

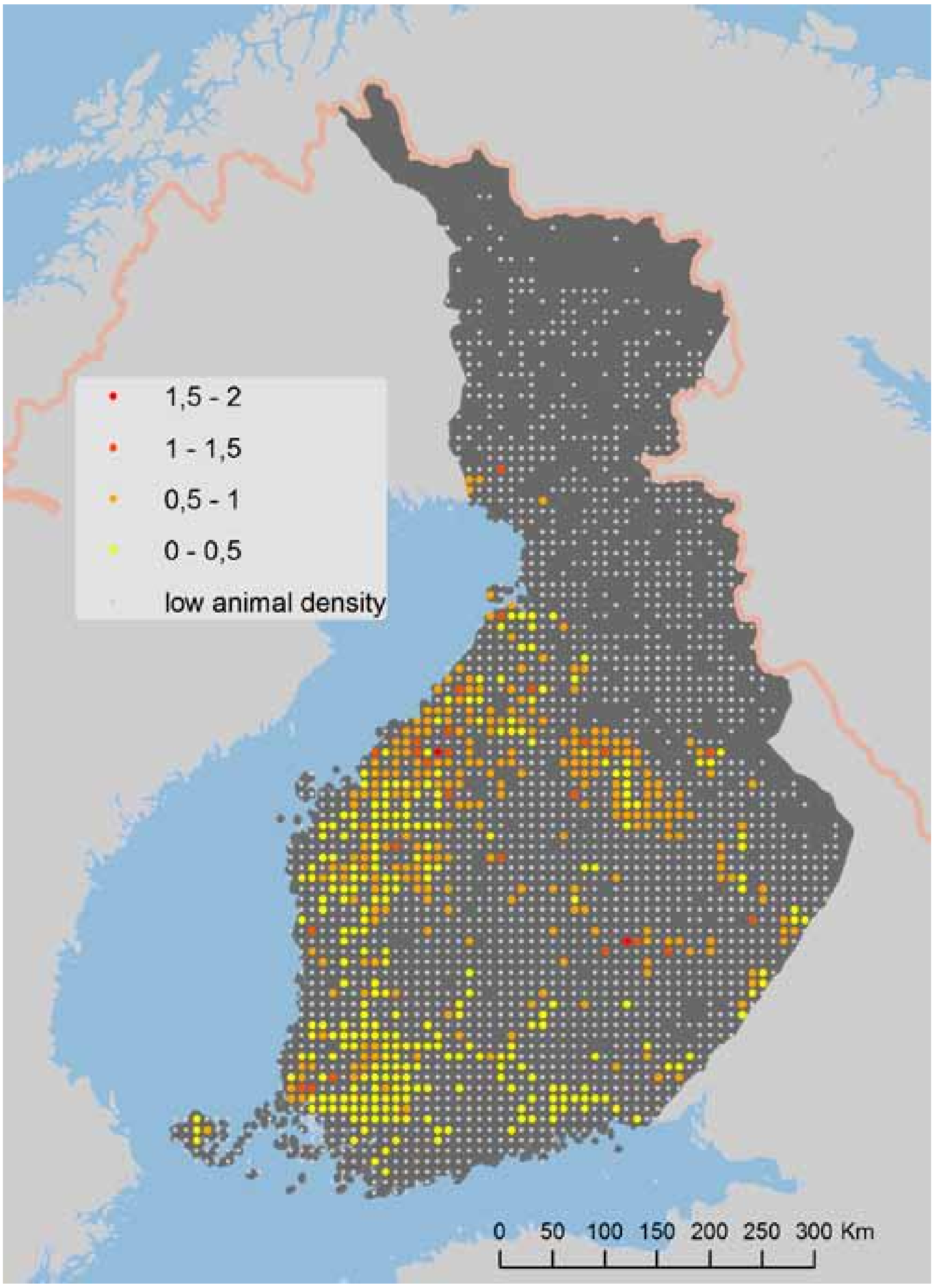
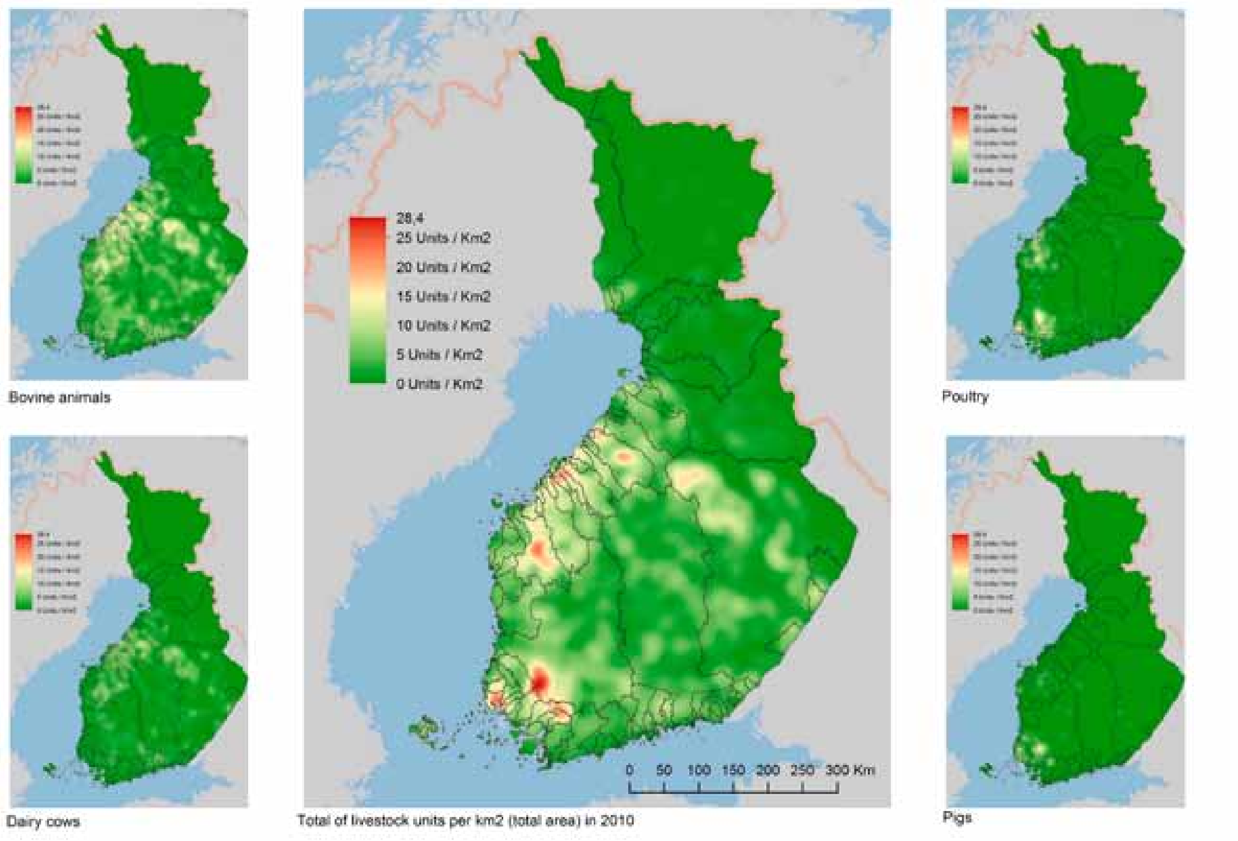


Figure 16. Livestock density index in 10 km grid cells. Small grey dots indicate low animal densities.

In the interpretation of the livestock density index, the limits of this theoretical unit should be taken into account. When high index values are connected with very low levels of agriculture, then the animal numbers tend to be low and nutrient leaching risks are likely to be only local.

To complement the thematic maps, animal locations were processed into density surfaces. If accurate information on animals and their location is available, density surfaces are an effective way to illustrate animal concentration. Kernel density mapping is a Geographic Information Systems (GIS) analysis technique that creates a continuous surface map based on point livestock data. Here each animal was represented by a point feature, and the Kernel density mapping function available in ESRI ArcGis was used to create density maps (see Figure 17). The use of this generalisation method allowed us to show detailed spatial trends in data yet comply with the terms of usage and not show data from individual farms.



Bovine animals

Dairy cows

Total of livestock units per km2 (total area) in 2010

Poultry

Pigs

Figure 17. Livestock density surface (animal units per km^2 of total area) in 2010 in Finland. The centre figure shows the total for all farm animals, and the pictures on the sides show the contribution of relevant sub-classes. Dairy cows are included in bovine animals.

2.4.5 Animal density in the Nemunas catchment

In the Nevėžis and Šešupė sub-basins, the utilised agricultural land represents as much as half of the total area of each sub-basin. In the Dubysa and Jūra sub-basins, agricultural land accounts for more than 40% of the area, while in the Šventoji, Nemunas small tributaries and Minija sub-basins, as well as in the Lithuanian coastal rivers and Prieglius basins, agricultural lands occupy 30–40% of their total area. The smallest area of agricultural land is situated in the Žeimena, Neris small tributaries and Merkys sub-basins, only 17–22%.

In the Republic of Belarus, animal data are collected every year at three levels using special forms for (i) agricultural enterprises (industrial complexes), (ii) private farms and (iii) households. The first- and second-level data are collected and aggregated at *raion* (i.e. district) level by the National Statistical Committee of the Republic of Belarus. This data does not include the coordinates of agricultural enterprises. During periodical, third-level surveys of households, information about various aspects of animal production household activities is collected with a questionnaire about the presence and movement of livestock and poultry on a quarterly basis.

In Lithuania, data on number of livestock units are collected on the basis of reports from all agricultural entities. Agricultural entities are private farms, agricultural companies, cooperative companies (cooperatives) and other enterprises registered under a procedure established by law, as well as other users of agricultural land engaged in the production of marketable agricultural products. All agricultural companies and enterprises submit statistical reports of different periodicity (quarterly, annual). Data from private farms are collected using a sampling method. Data are presented on the national level as well as by county and municipality. Data are collected and published by Statistics Lithuania.

The total number of cattle in Belarus has increased from some 3.5 million heads in 2001 to 3.9 million in 2011. Meanwhile, the number of cows grew from 1.2 million in 2001 to 1.3 million in 2011. Some 37% of cattle in Belarus were located in the Nemunas catchment. The number of pigs has also increased by 38% to 2.95 million, whereas poultry farming grew by 52% from 2001 to 2011. These data, however, cover solely the activities of the agricultural enterprises.

In order to obtain comparable LSUs between Belarus and Lithuania, the following coefficients were used to convert the numbers of individual animals to livestock units: cows 1, other cattle 0.57, pigs 0.5, horses 0.8 and poultry 0.007 (see the difference from EuroStat, Chapter 2.4.2.1).

More intensive animal farming is maintained in the Belarusian part of the Nemunas catchment. As Figure 18 depicts, animal farming is mainly concentrated in the raions of the Grodno, Brest and Minsk oblasts (i.e. provinces). Indeed, the Grodno region is located near the borders of the neighbouring states, namely Lithuania and Poland, and thus offers favourable conditions for exports of agricultural production.

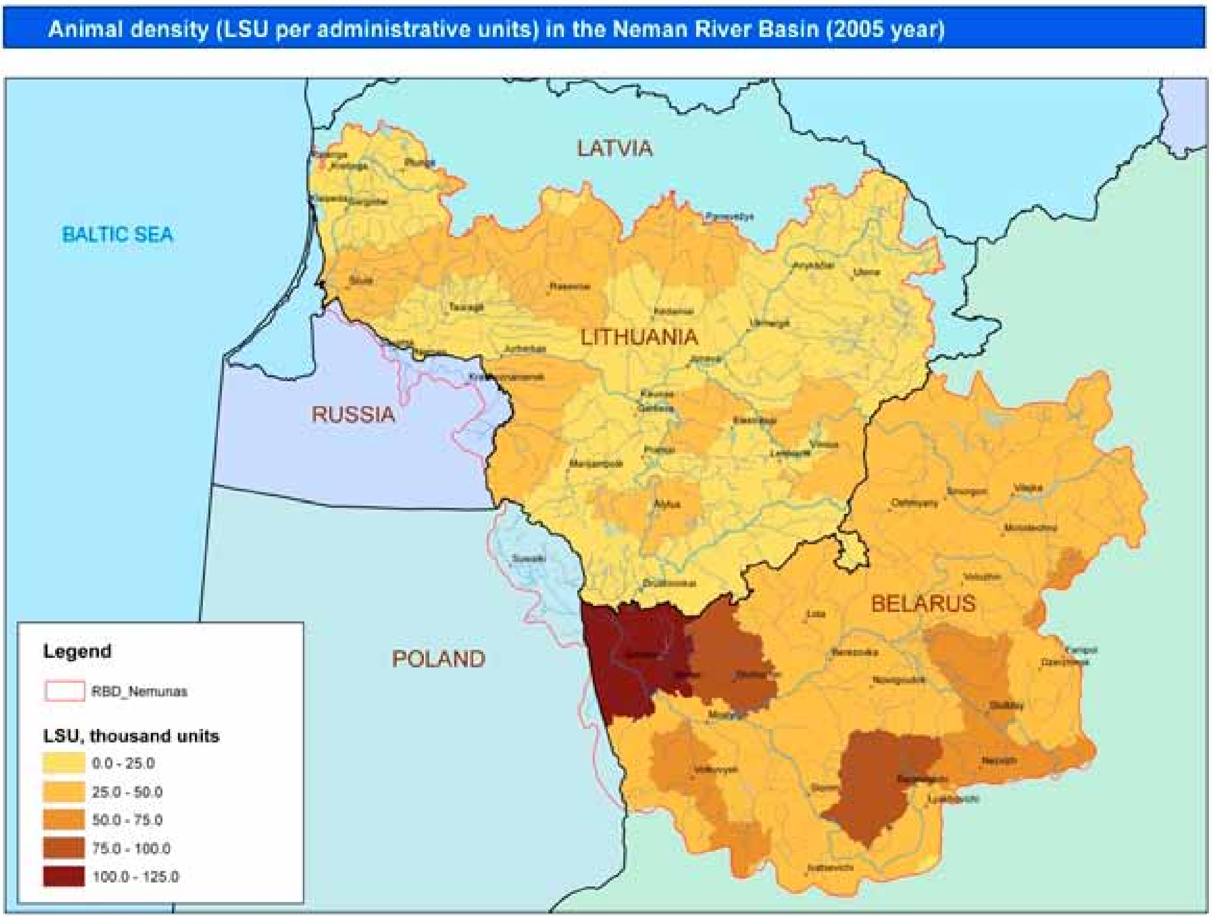


Figure 18. Animal density in livestock units per administrative unit in 2010.

Animal farming is concentrated in north-west Lithuania. As of 2010, there were some 596 thousand livestock units (LSU) on Lithuanian farms, whereas pigs accounted for 187 thousand LSU. Indeed, cattle farming is mainly located in western Lithuania and swine Concentrated Animal Feeding Operations (CAFOs) are spread across both north and central Lithuania (for instance, the counties of Marijampolė, Panevėžys, Kaunas and Šiauliai). In accordance with environmental standards, the manure from CAFOs is spread in the neighbouring areas. Poultry farming is found in east Lithuania, namely the county of Vilnius. The resulting manure is sold as fertiliser and hence does not contribute to water pollution in the region of production. The data for mapping distribution of cattle LSU, cows LSU, pigs LSU and poultry LSU collected at raion (in Belarus 39 raions) and municipality (60 in Lithuania) level for the year 2010 are presented in Figures 19-23.

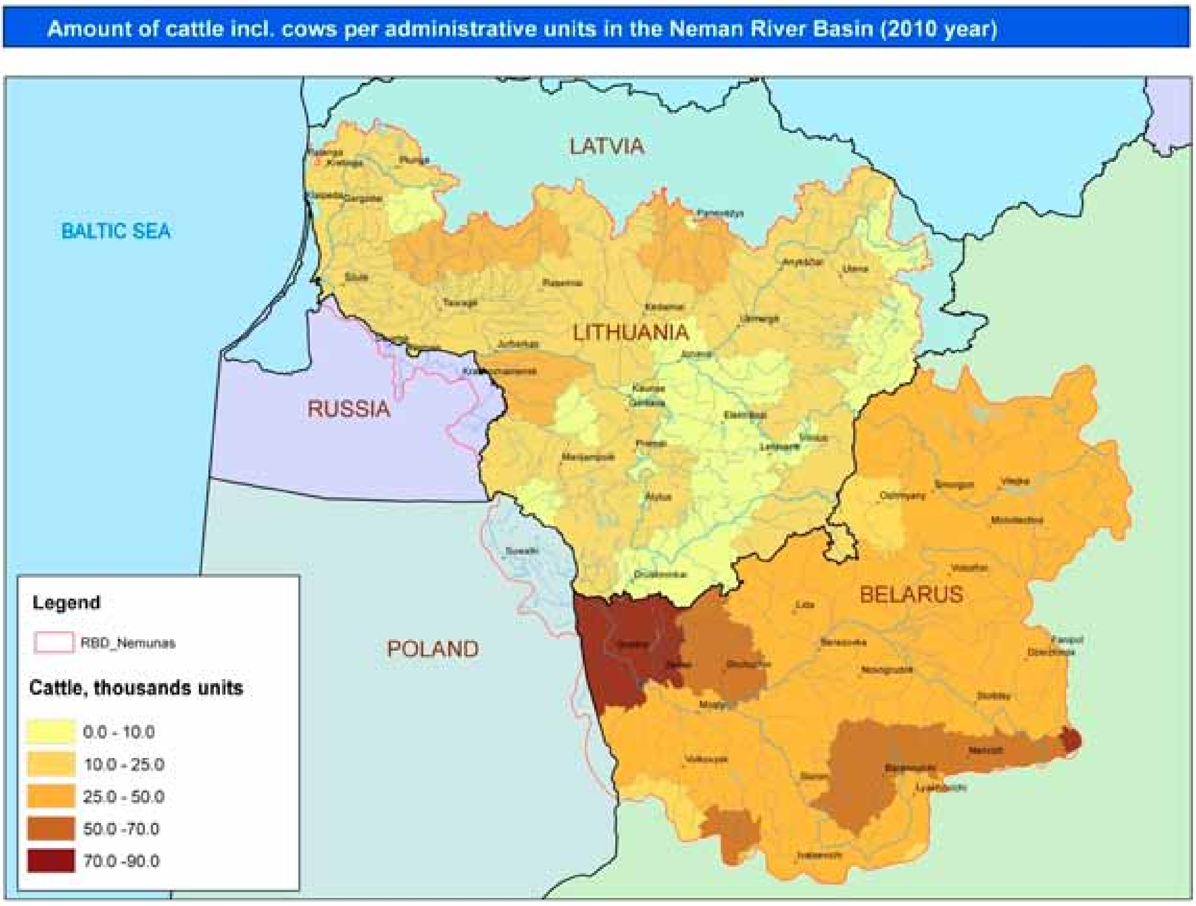


Figure 19. Amount of cattle including cows per administrative unit in 2010.

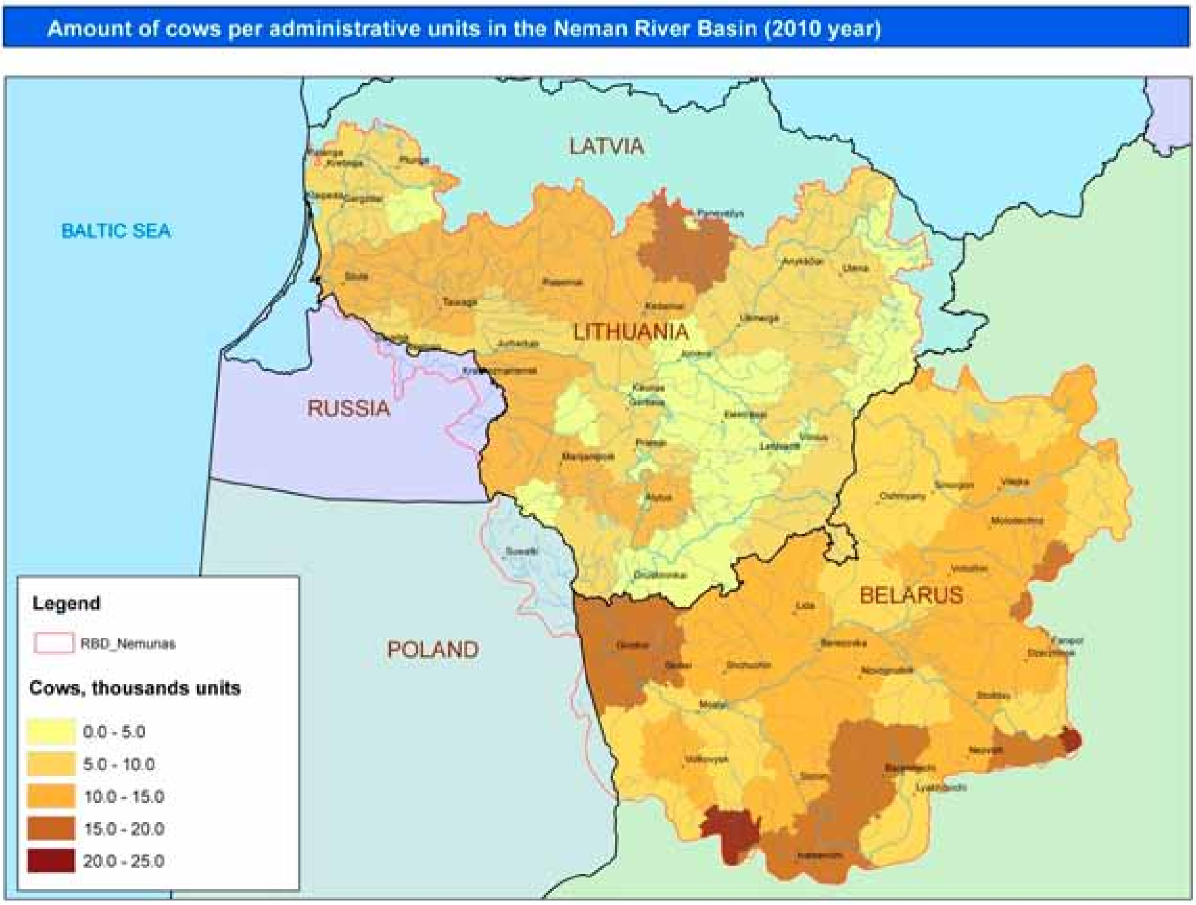


Figure 20. Amount of cows per administrative unit in 2010.

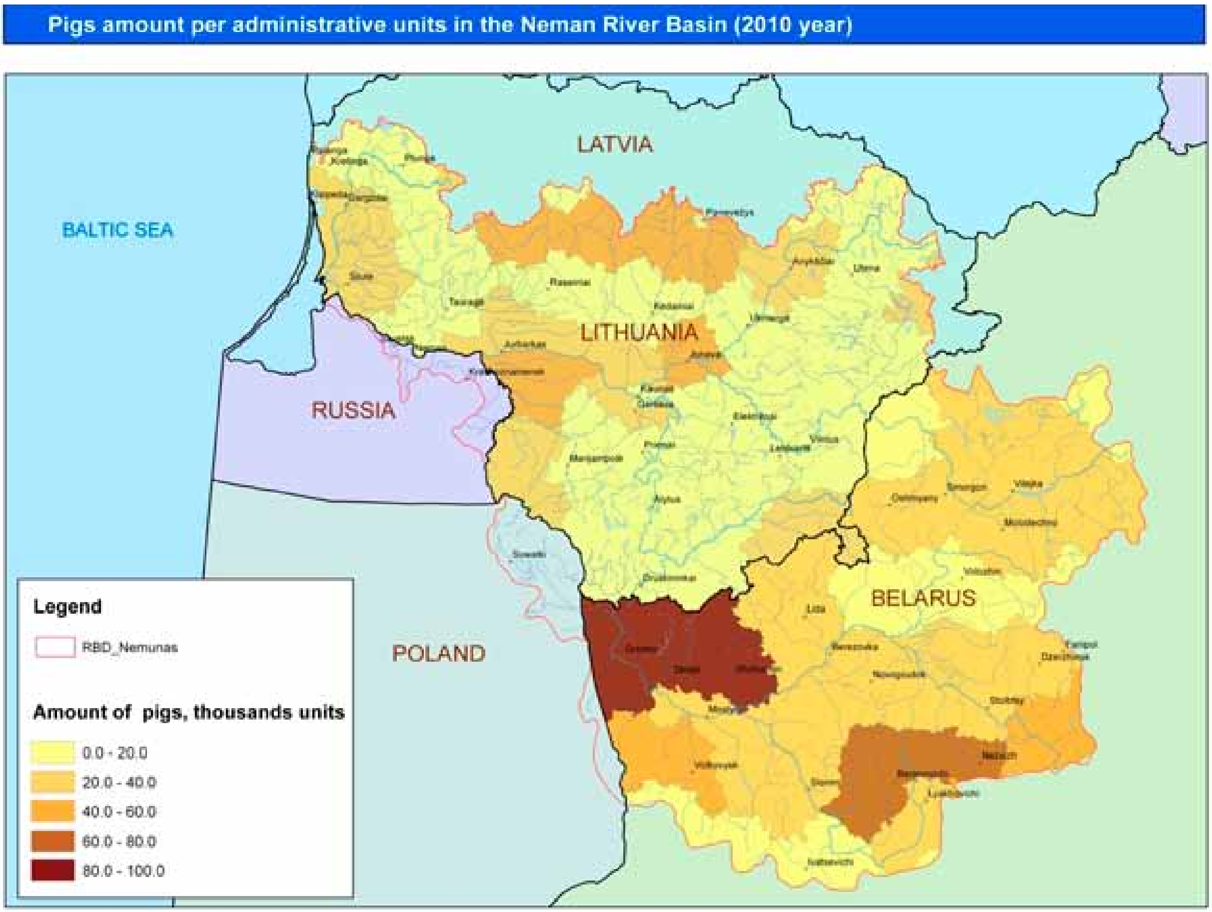


Figure 21. Amount of pigs per administrative unit in 2010.

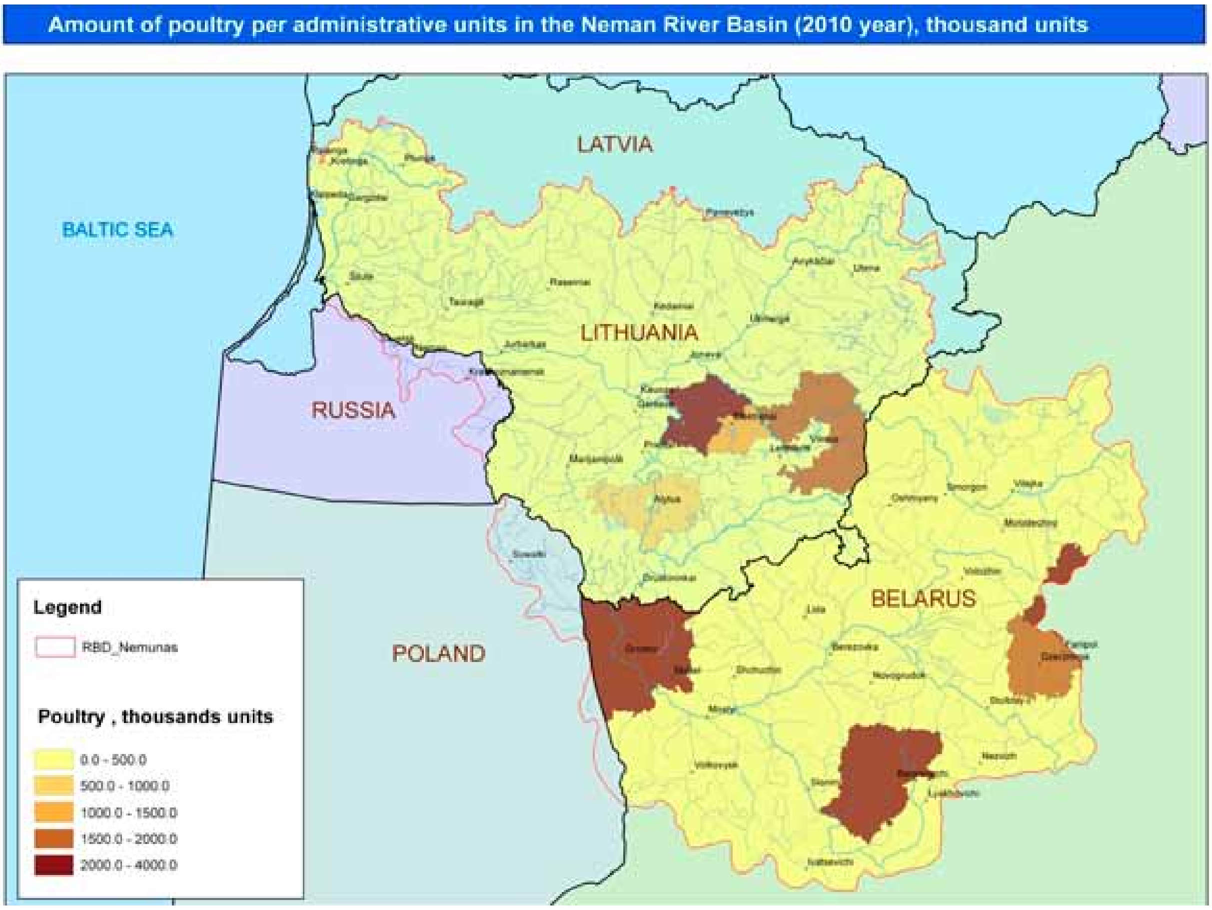


Figure 22. Poultry amounts per administrative unit in 2010.

Livestock density was higher in the Nemunas catchment if compared to the respective indicator value for Belarus during 2001–2011. As of 2011, the mean livestock density was 0.57 LSU/ha in the Nemunas catchment (Table 6) whereas it remained equal to 0.51 LSU/ha for the whole of Belarus.

After reaching its peak in 2007, the number of livestock has been declining in Lithuania (Table 7). Meanwhile, the area of agricultural land reached 2.68 million ha in 2010. Thus, livestock density fluctuated around the rate of 0.35 LSU/ha, which is a rather low value, particularly in terms of the European Union Member States.

Table 6. Livestock units and density in Belarus and the Belarusian part of the Nemunas catchment.

	2001	**2006**	**2010**	**2011**
LSU in 1000 units				
Belarus	3862	3997	4394	4533
Nemunas catchment	1504	1610	1742	1778
Agricultural land, 1000 ha				
Belarus	9258	9012	8927	8898
Nemunas catchment	3095	3095	3095	3095
Livestock density LSU/ha				
Belarus	0.42	0.44	0.49	0.51
Nemunas catchment	0.49	0.52	0.56	0.57

Table 7. Livestock units and density in Lithuania

	2005	**2006**	**2007**	**2008**	**2009**	**2010**
LSU in 1000 units	1001	1019	1033	972	943	926
Agricultural land, 1000 ha	2802	2791	2696	2672	2689	2684
Livestock density LSU/ha	0.36	0.37	0.38	0.36	0.35	0.35

The highest livestock density is observed in the Neris small tributaries and Minija sub-basins, where it totals 0.4 LSU/ha. In the Nemunas small tributaries and the Šešupė and Jūra sub-basins, the livestock density is a little lower, 0.37 LSU/ha, and in the Dubysa, Žeimena, Nevėžis and Merkys sub-basins, the Lithuanian coastal rivers basin and the Prieglius basin it ranges from 0.3 to 0.33 LSU/ha. The lowest density is in the Šventoji sub-basin, only 0.28 LSU/ha. Although the average livestock density at the country and tributary level is rather low, there are some areas where animal production is more intensive.

Figure 23 presents the livestock density at a smaller scale and here the highest density is between 1.5 to 1.9 LSU/ha.

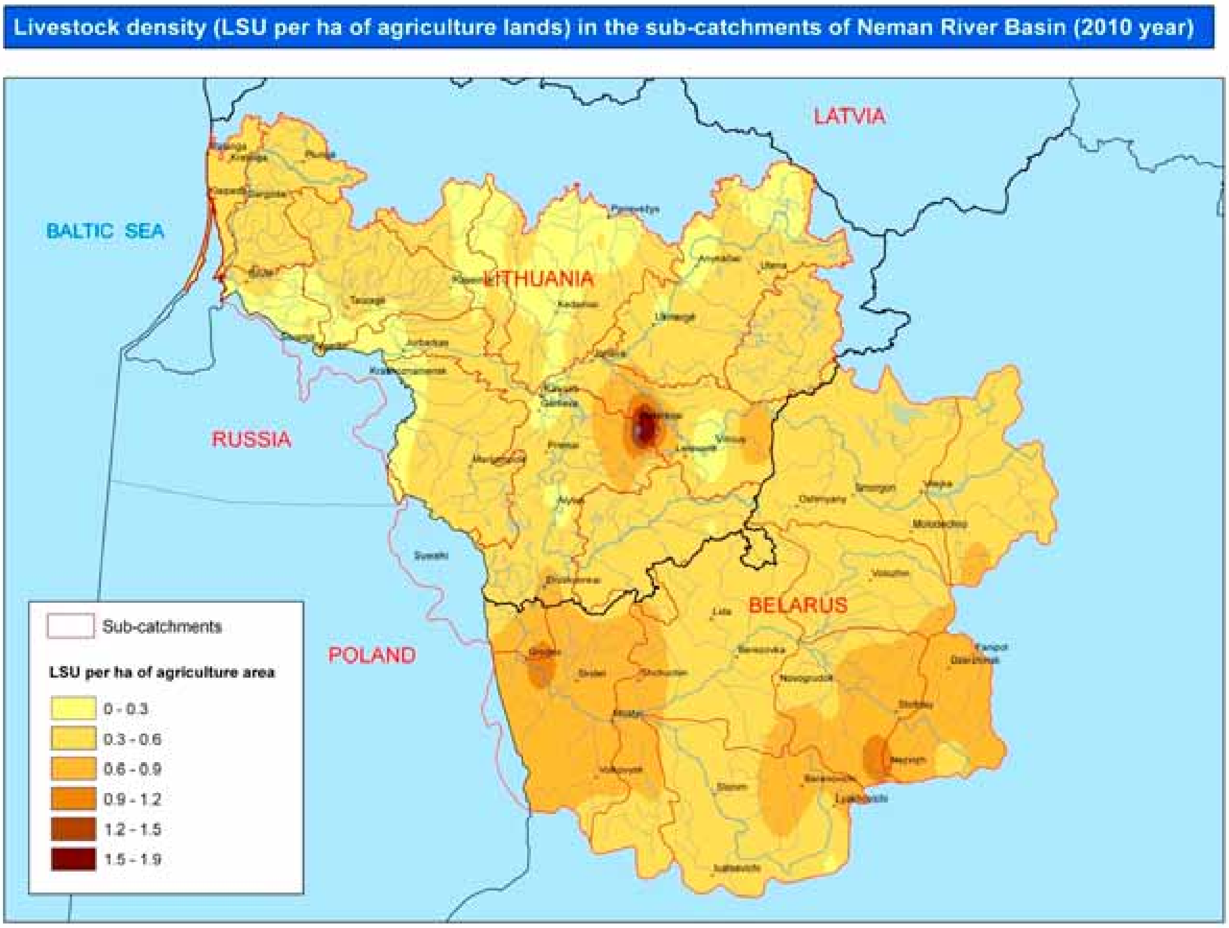


Figure 23. Livestock density (LSU per ha of agricultural land) in 2010.

2.5 Soil phosphorus status

Phosphorus (P) is an essential plant nutrient, and its deficiency in soils severely restricts crop yields. Therefore, it is important to know the true phosphate levels to plan a proper fertilising programme. Soil may have a much higher amount of P present as a total amount than as the amount available to the plant. Phosphorus availability is commonly lower in strongly acidic and alkaline soils due to increased P reactivity with soil and formation of insoluble compounds with aluminium and iron in acid soils and with calcium in alkaline soils. The pH associated with the maximum P availability in soils usually ranges from 6.0 to 7.0.

There are several methods to test for soil P levels (Moody 2011). Each has its own advantages and disadvantages. Comparing results from different testing methods can be confusing because each P testing method has its own scale. The results of laboratory tests can vary widely even in the case of soils with the same true available phosphate levels, since the scales vary with testing method. When interpreting the soil testing results, it is important to know which method was used and why.

Because commonly used soil P tests were developed to estimate P availability for crops, researchers are looking at alternative soil P tests that could better predict the loss of dissolved P to water systems.

Although the amount of P extracted from soil samples varies greatly between tests, all tests show that increasing soil P to very high levels increases the risk of P loss. Table 8 shows the different analysing methods for soil P that are used in the BSR countries. For a more detailed description, see Appendix 3.

2.5.1 Processing P analyses

In Finland, soil P analyses from agricultural soils are made by private companies such as Viljavuuspalvelu Oy and the data are processed further by SYKE and MTT for research purposes. The source data include P analyses of Finnish field plots. Although most fields are analysed every 5th year, all data are not available or cannot be identified for certain field plots. An average P-value of the field plots in the municipality where the plot is situated is assigned to these unanalysed plots. One field plot can also have more than one analysis because the analyses have been made during a long period (2000-2010). Moreover, soil samples might have been taken from several smaller parts of a single field plot. Every analysis is merged with the coordinates of the field plot where it is situated. The outcome of this merging is a geodatabase where the analyses are presented as point features (altogether 1 084 026 points). From these points a raster has been made with a cell size of 5 000 m. Here, the cell value is an average of the analysis points inside the cell. Thus it is impossible to identify exactly where an individual analysis is from, which fulfills also the data privacy terms. To make a map with P-values for the whole of Finland, this raster has been converted to point features, and from those points (9 888 points) a new raster with a 2 500 m cell size has been interpolated using the kriging method. The final result is a raster map where P-values have been classified in 7 classes (Figure 24). The map of south-west Finland has been made by means of a similar process, but the first raster has a 1 000 m cell size and the final map a 2 000 m cell size (Figure 25).

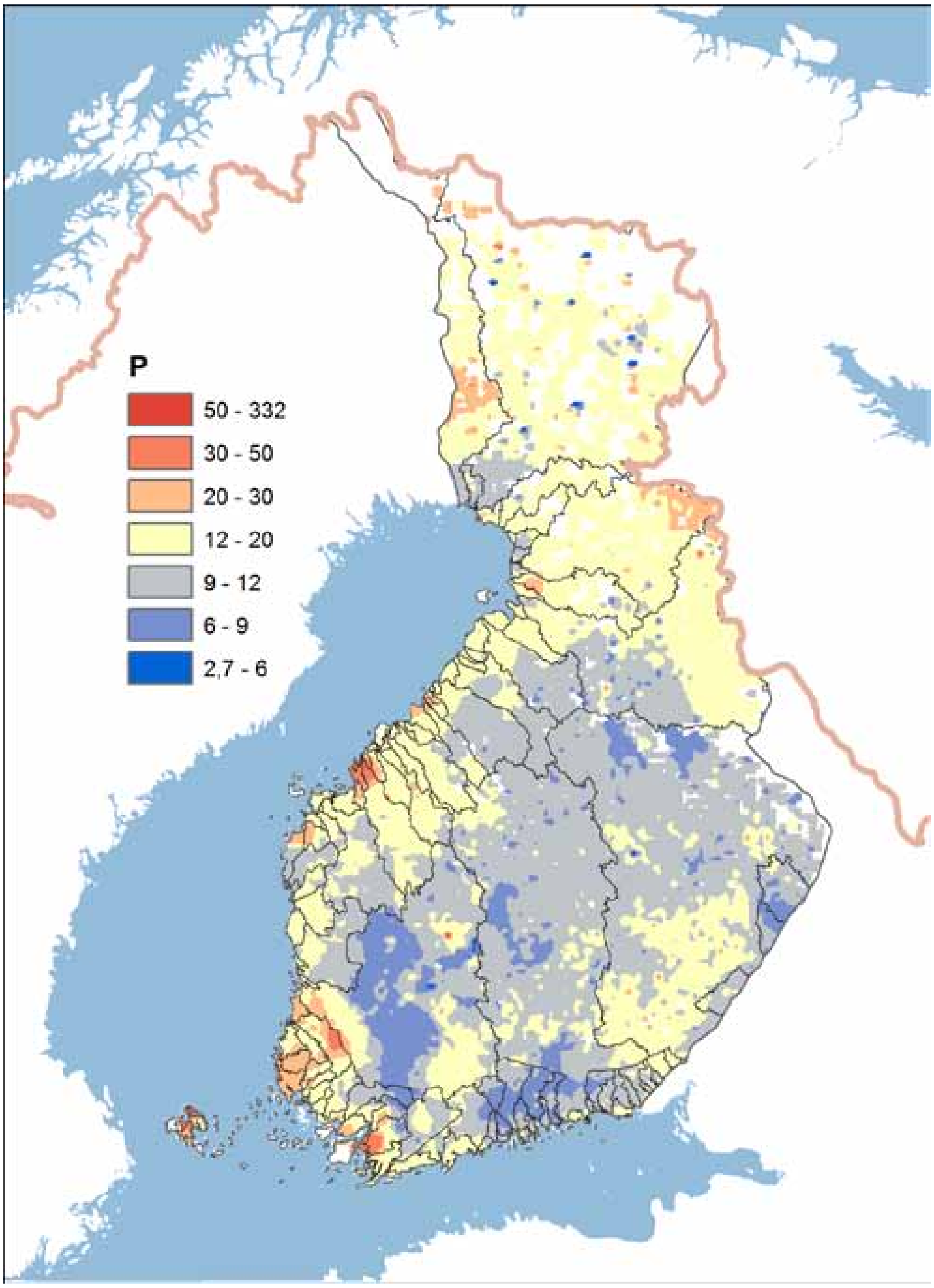


Figure 24. Phosphorus (P) content in Finnish agricultural soils. Missing data is replaced by the average value for the respective municipality.

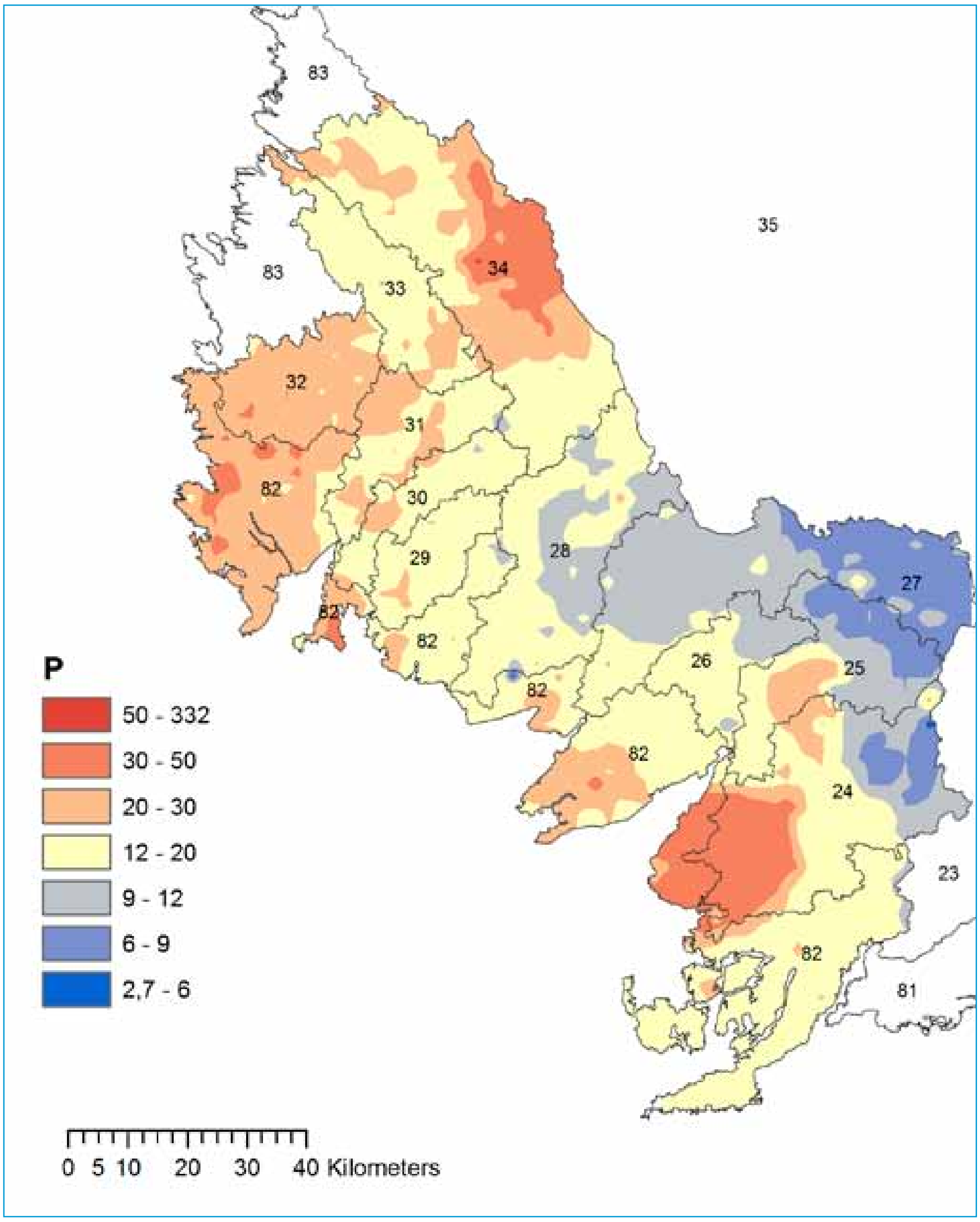


Figure 25. Phosphorus (P) content of agricultural soils for the Archipelago Sea area in south-western Finland. The 1st level river basins are shown as black lines.

Table 8. Different analysing methods for plant available P in the BSR countries.

Country	Method
Finland	Ammonium acetate
Sweden	Ammonium lactate/acetic acid
Denmark	Olsen-P/ Sodium bicarbonate extraction
Estonia	Mehlich 3
Lithuania	Egner-Riehm-Domingo (A-L)
Poland	Egner-Riehm
Germany	Lactate extraction
Belarus	Kirasanov

3 Erosion, P risk areas and biosecurity risks

3.1 Methods to identify the phosphorus and erosion risk areas

The concept of "critical source areas" denotes problem areas, i.e. those with (i) a high source potential and (ii) a high transport risk. Areas with high source potential include, for example, those with leaking manure storage facilities or fields that have received an excess amount of nutrients (either in manure or commercial fertilisers) in regard to crop yields. By turn, in order to have a high transport risk, the field or manure storage has to have a hydrological connectivity via surface runoff, drainage flow or groundwater flow to a body of water. For successful implementation of agri-environmental mitigation measures in the Baltic Sea Region (BSR), it is crucial that critical source areas for P loss are known and mapped. Therefore, methods and approaches for the assessment of the risk of P losses from agricultural land are needed. In the Nordic countries, a number of index-type risk assessment tools for diffuse P losses have been developed. Typically they are empirical, user-friendly tools with low data requirements. The differences between the countries in terms of soil, climate and agriculture naturally result in different average annual agricultural P load estimates to the sea. For example, for the Nordic countries the figures varied from 0.3 (Denmark) to 1.1 (Finland) kg total P ha^{-1} (Heckrath et al. 2008). Although P indices usually explain a large degree of variance in P losses at a field or catchment scale, more thorough evaluations of the performance of these indices are still needed. Both farmers and the environmental sector have cost constraints, which call for user-friendly, qualitative tools for mitigation planning compatible with current incentive policy. The P index may help to identify what management and mitigation actions need to be taken and where they should be targeted. Nordic experiences of the performance of P-index tools have been positive, and they have been used as a part of the implementation of the EU's Water Framework Directive (WFD).

3.1.1 Examples from BSR and Nordic countries

In Denmark, the P-index tool has been tested in cooperation with the farm extension services. Farmers and extension services have been rather satisfied with the tool, while the environmental authorities have been more hesitant, probably for fear of the costs of full-scale enforcement of the tool. The Danish index tool is rather complicated in its structure, and its use requires learning of a use and deeper knowledge (see Chapter 4.2.1). The major challenges of the tool are lack of data and uncertainties.

The Swedish P-index tool has been tested in practice, but not yet implemented for agricultural practices. The index is advanced, but the practical adaptations have failed as both farmers and extension service officers have shown doubts regarding relatively large input data requirements and necessity to install special software on one's computer. Further, the Swedish P index tool has been developed in 2004 and should be updated, above all with the new possibilities offered by the new high-resolution LIDAR-derived Digital Elevation Model (DEM).

The Norwegian P-index has been used voluntarily by farmers and extension service officers. This online tool has a simple and effective structure and a user-friendly interface.. When farmers and extension service officers tried it out in practice, they were able to use it for functions such as testing the effects of different management practices.

In Finland, no specific P-index has been developed, but a tool developed for the management of runoff waters from arable land in general (VIHMA, Puustinen et al. 2010) can be used to estimate the P load from agricultural land and to target the mitigation measures. The VIHMA tool is based on field-scale data, but it has proved to be reliable for estimating agricultural erosion and nutrient loading from entire catchments. In VIHMA, the risk of P loss is determined as a function of field slope, soil type, cultivation practice and P status – all of which are generally accessible data in Finland. The relationship between P loss and the above variables can be separately examined for 'mild' (more loading) and 'cold' (less loading) winters. This division is based on climatic and hydrological factors for each hydrological year starting from 1 September.

Although Germany is one of the most regulated BSR countries in terms of P use, no specific P-index has been developed. There are, however, two easy-to-use tools available: "risk maps associated with compulsory use of cultivation practices" and "the P-balance calculation".

3.1.2 Future needs in the identification of P indices

One of the activities needed to reach the overall objective, i.e. reduction of agricultural P losses, is the further development of P-index models and algorithms in order to include the effects of mitigation measures. Other important issues include balancing the algorithms (relevant factors) with the data availability, transparency of the index calculations and the ways of presenting the calculation results and their interactivity. In the P-index workshop in Stockholm in January

2011, it was proposed that interregional cooperation for the exchange of experiences and the investigation of possibilities for sharing best practices in design and use of the P-indices should be practiced. Availability of cost-efficient and high-quality input data (soil P content, effects of field cultivation/mitigation measures, manure standards, erosion parameters) should be improved. As for water quality and flow, appropriate data is needed for validation, i.e. testing whether the P-index models correspond to practice. The development process of a P-index tool should account for relevant framework conditions, including but not limited to legislation and subsidies, as well as the involvement of farmers and their advisers.

The original P-index, developed by USDA, used factors that could have unfavourable impacts on water bodies because of P movement, such as soil erosion, runoff, soil test P, P fertiliser and manure application rate. Thus, the original P-index included the potential contributions of each site characteristic. A summation of the weighted site characteristics then yielded a site vulnerability rating (Lemunyon and Gilbert 1993). A variety of modified P-indices have evolved from the original approach, taking more local conditions and policy into account. Additional factors include e.g. flooding frequency, conservation practices and proximity of receiving waters (Sharpley et al. 2003).

3.2 Biosecurity risk

The objective of adding biosecurity/health considerations to the work on agricultural nutrient runoff risk areas within the Baltic Compass is to provide additional impetus for measures, investments and integration of policies. As defined in a previous Baltic COMPASS report (Salomon and Sundberg 2012), biosecurity aspects in this context focus on the transmission of infectious disease agents from manure to the aquatic environment and consequent risks for animal and human health. Some aspects may also have an impact on other disease agents with other transmission routes but this will be only briefly touched upon. Various species and subtypes of viruses, parasites and bacteria occur in manure, both indicator (e.g. coliforms and enterococci) and pathogenic (cause disease). The infectious disease agents considered most relevant here are zoonotic pathogens (can be transmitted between animals and humans), with a faecal-oral transmission route such as *Salmonella* spp., *Campylobacter* spp., verotoxin-producing *Escherichia coli* (VTEC/EHEC) and *Cryptosporidium* spp. Bacteria carrying multiple antimicrobial resistance traits, as well as different genes encoding for antimicrobial resistance, may also multiply in and spread from animal production units. For further discussions on the relevant pathogens see Salomon and Sundberg (2012).

As for the risk of leakage of nutrients, the spread of disease agents from manure to the environment will depend on both source potential and transport risk. For biosecurity, areas with high source potential include those with high risk of disease outbreak (high pathogen load) and, for the spread of resistance, areas with extensive use of antimicrobials.

Concentrations of indicator and pathogenic microorganisms in manure depend on animal type and the duration and conditions of storage before land application. Transport risk of microorganisms to surface waters is mainly related to surface runoff, erosion, and bypass or drainage flow (Tyrrel and Quinton 2003, Oliver et al. 2005).

3.2.1 Biosecurity risk factors

Indicators for biosecurity risk areas that have been identified in the project include animal density (both herd and individual), infectious animal disease prevalence, routines in animal husbandry and animal production systems, and routines for manure handling. These indicators all affect, in different ways, the risk of spreading disease from animal farms to the environment.

Animal density may in itself affect biosecurity as infectious diseases spread more easily and rapidly in dense populations. Moreover, the frequency of animal movements and the consequent risks for introducing infectious diseases is strongly associated with animal population density. It is not possible to estimate a critical threshold for animal density. The association between herd size and disease risk has been demonstrated in various studies on infectious animal disease and the so-called DPLAs (Densely Populated Livestock Areas), defined in Council directive 2003/85/EC Annex X, point 3, have been associated with higher risk for and more severe effects of large disease outbreaks in the EU. However, animal density is only one of the many factors that affect biosecurity risks and the critical threshold is likely to be different in different situations.

The prevalence of infections in the animal population evidently affects the risk of transmission of such infections from the animals. Inappropriate animal husbandry and production systems result in reduced general health of the animals and thus their susceptibility to becoming infected and shedding pathogens.

Routines for manure handling, i.e. transport, storage and use of manure, affect the risk of pathogen transmission from the manure to the environment. In areas with high livestock density, transport of excess manure to other regions may be necessary, thereby increasing the risk of disease transmission. Improper storage of manure is regarded as being one of the main causes of hot-spot pollution as regards leaching of nutrients from intensive livestock production (Foged 2010), and is also considered as a risk factor for the spread of disease agents from manure to the environment. Improper storage of manure can lead to severe consequences; one example was the outbreak of *E. coli* in Sweden 2005 when 117 people fell ill after eating lettuce irrigated with manure-contaminated water (Söderström et al. 2008). One key control measure in this regard is inspections by environmental and health officers in order to ensure that farms live up to the regulations set for storage tanks and handling of manure.

The spread of disease agents from manure to the environment also depends on how, where and when manure is applied. Application of manure to fields with high transport risk, for example when the ground is frozen or flooded, increases the risk of water contamination.

3.2.2 Data availability

Data on animal density are available from most countries within the BSR, although at different levels (see Section 2.4). Details on animal husbandry and manure handling may be more difficult to obtain, especially as several practices may be applied in parallel in the same herd. Data on disease prevalence are available for most highly contagious transboundary animal diseases, such as swine fever and foot and mouth disease, but detailed geographic data on endemic diseases such as salmonella are not collected in all regions.

3.2.3 Monitoring biosecurity risks

Monitoring biosecurity risks is important, as the prevention of such risks is more practical and requires fewer resources than mitigation or counteraction. An improved ability to identify risk areas will allow for risk-based monitoring, which is more cost-effective than general monitoring. Improved data collection, in particular as regards animal disease prevalence, is important if biosecurity risks are to be prevented. The risk-based monitoring of endemic animal diseases, with a focus on areas with high animal density, could provide a basis for providing advice on preventing biosecurity risks by means of changes in animal husbandry and manure handling.

Monitoring the prevalence of infectious animal diseases is the most efficient way to monitor the risk of such infections spreading from the animals. Sampling sensitivity is affected by the distance from the source of the infection, and sampling the infected animals will thus give a higher detection probability than sampling manure or the environment. For many pathogens, on-farm control has been shown to be the most cost-effective method. One example is the Swedish salmonella control programme, in which a recent study estimated that the saved public health costs well exceeded the costs of controlling animals and animal feed. A comprehensive animal disease control system would in many situations be the most cost-efficient way to prevent environmental biosecurity risks.

However, sampling animals on farms is not always possible due to legal, financial or practical constraints. Another alternative is to sample manure on farms or, if this is not possible due to the same constraints, monitoring the water quality in high-risk areas. Monitoring the risks is important not only as a basis for advice on how to mitigate risks but also for motivating such measures.

Water quality is determined by enumerating faecal indicator bacteria, e.g. *E. coli* and enterococci, for example in the Bathing Water Directive (2006/7/EC). In potential biosecurity high-risk areas we suggest quantification of these indicators as a control measure of the microbiological status of the water. Faecal indicators in surface water indicate that enteric pathogens also may be present, especially in an area with high probability of infected animals, and therefore present a health risk. Enumeration of indicator bacteria will give information about faecal contamination as an indirect measure of the health risk (FAO 1994). Further there are standardised methods for the enumeration of *E. coli* and enterococci in water that can be provided by laboratories within the BSR. Repeated sampling in a monitoring programme can give an indication of how microbiological status improves after the implementation of measures to reduce N, P and pathogen leaching.

3.2.4 Biosecurity risk areas

Due to lack of sufficient baseline data for faecal indicators in surface water influenced by agricultural activities, and in the absence of biosecurity-relevant data, such as data on disease prevalence, animal husbandry and manure handling practices, risk areas may initially be identified on available data such as animal density, and the assessment can be reiterated as more information becomes available. Factors determining the risk of transport of nutrients to surface waters, such as surface runoff and erosion, may be applied also for microorganisms. Consequently, areas with a high risk of surface runoff or nutrient leakage from manure may also be high-risk areas as regards biosecurity. Identification of potential biosecurity risk areas within the BSR may therefore be done by combining data on animal density and the information on agricultural risk areas discussed in Chapter 4, e.g. agricultural diffuse and point source hot spot areas and erosion risk areas. To confirm the potential biosecurity high-risk areas, monitoring of biosecurity risks will be necessary.

4 Identification of agricultural risk areas at different scales

4.1 Baltic Sea region scale

HELCOM has been collecting information about the high-risk areas classified into four sectors: agriculture (both diffuse and point loads), industry, municipalities and the coastal programme. Altogether 68 sites (situation in June 2011) are listed as hot spot areas (Figure 26). The criterion for the inclusion of point source agricultural hot spots (*agricultural farm/installation) has been sites where the animal number exceeds:

- 40 000 places for poultry,
- 2 000 places for production pigs (over 30 kg)
- 750 places for sows or
- 400 animal units for cattle

If the handling of manure is not done properly and according to the best available technique, the site has been classified as a hot spot area (for detailed information, see the HELCOM site http://www.helcom.fi/projects/jcp/hotspots/en_GB/hotspots/).

Large areas of the BSR have been identified as agricultural hot spots; e.g. in Finland the whole catchment area of the Archipelago Sea. The list of JCP (Baltic Sea Joint Comprehensive Environmental Action Programme) hot spots drawn up in 1992 contained 17 agricultural hot spots. The list also contains five coastal lagoon/wetlands hot spots, that are influenced by agricultural activities and where relevant management programmes are needed. Out of these 22 hot spots, 13 are located in former countries of transition.

So far nine hot spots have been deleted from the list: three in Estonia, one shared by Estonia and Latvia, one in Finland, one in Latvia, one in Germany and two in Sweden. The main reason for deletion has been a remarkable decrease in agricultural activities in Estonia and Latvia due to economic recession. In Sweden, the measures used to reduce the nutrient load have been quite efficient and the improvements have also been verified by measurements. Therefore, some of the Swedish hot spots have been recently deleted from the hot spot list.

Since there is no common methodology or criteria (except agricultural point hot spot areas) to identify the agricultural nutrient-vulnerable areas, the HELCOM hot spot areas have not been identified in a similar manner. There might be several hot spot areas that are not included in the HELCOM list. Small area hot spots are particularly difficult to identify due to the lack of data.

Assessment of diffuse pollution loading from agriculture can be typically carried out on three scales: plot scale, field scale and small catchment scale. The monitoring of larger rivers could provide data for source apportionment of different pathways, including diffuse and point load from agriculture, but in the case of such a large area some generalisations are always needed, which evidently leads to some uncertainties in the results.

Agricultural data from Russia have been collected recently within the BaltHazar project (HELCOM 2010). It was estimated that the 208 animal farms in the Leningrad and Kaliningrad regions produced a total of 9 600 t/y of manure phosphorus in 2008 (all animal farms in the whole of Finland produce approx. 18 000 t/y manure phosphorus). The animal farms were sorted on the basis of their phosphorus production, and the 26 largest contributors were selected for inclusion on a hot spots list. Combined they were responsible for 72% of the manure phosphorus, i.e. 6,900 t/y.

4.1.1 Mapping based on the revised universal soil erosion model RUSLE

Erosion modelling is one way to assess critical source areas having high source potential and transport risks. In this study, soil erosion in the BSR was described using RUSLE. RUSLE was preceded by the Universal Soil Loss Equation USLE (Wischmeier, Publication of USDA Agriculture Handbook 282 in 1965), an equation that was based on extensive experimental field study of more than 10 000 field plots carried out in the United States. USLE is a framework that connects factors affecting erosivity to a single robust model. Output of the model is the amount of annual erosion expressed in tonnes/hectares/year. USLE can utilise various types of measurements, evaluations and interpolations as source data. Factors are described by series of formulas. One reason for the wide use of the model is good availability of documentation.

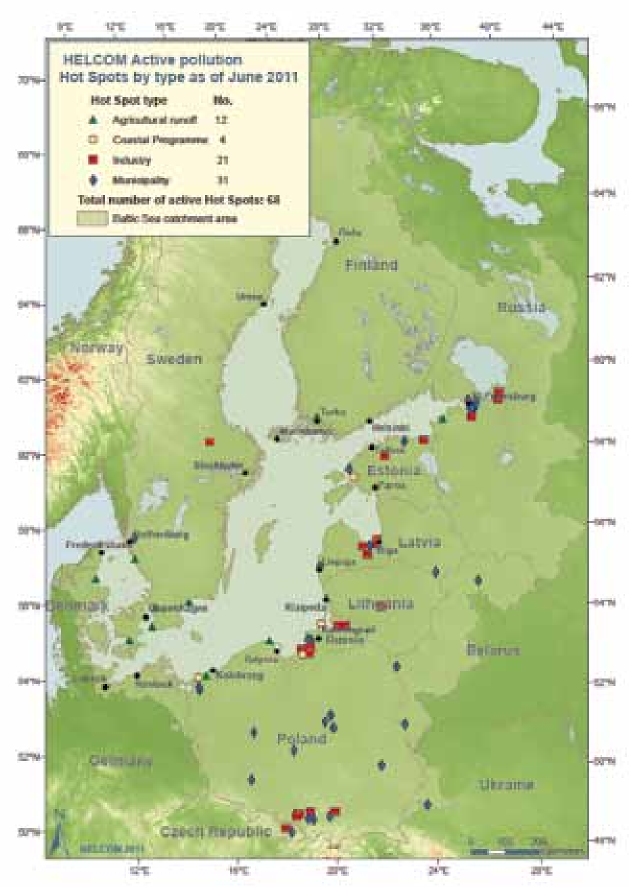


Figure 26. The HELCOM active pollution hot spots by type (situation in June 2011). Green triangles represents agricultural hot spots.

The revision of USLE in the early 1990's to RUSLE (Renard) included many enhancements, such as the ability to change the values of factors on a monthly basis. Slope shape (convex/concave) can also be included by segmenting the irregular slopes. RUSLE can also be run with specific software or spreadsheet solutions. Here we run it as a GIS grid calculation application that utilises e.g. high-resolution elevation data.

4.1.1.1 Calculation method

RUSLE expresses soil average annual loss (A) in tonnes/hectare/year as:

$A = R*K* LS *C* P$,

where

- R = rainfall factor: (MJ mm ha^{-1} h^{-1} yr^{1}). The more intensive the rain, the larger the factor
- K = soil factor (t ha MJ^{-1} mm^{-1}). K has several subfactors and it is usually calculated from soil databases.
- LS = Topographical factor (dimensionless). Combination of slope gradient and length. The longer and steeper the slope, the bigger the LS factor.
- C = the cover factor (dimensionless). Several subfactors. The greater the value, the less there is vegetation cover such as grass**.**
- P = farming system/protection by means of buffer strips, terraces and other such methods (dimensionless). The greater the value, the fewer protection methods are used.

4.1.1.2 Data and methods

Individual factors for the model were generated as follows:

Rainfall factor R: The long-term rainfall measurement data were provided by the http://www.worldclim.org/current (1950-2000). Precipitation data for a one kilometre grid were was used to calculate the R-factor with the equation: $R = [38.46+(3.48*P)]$,where P is the average annual rainfall (Lo et al. 1985). There are also alternative formulas available, like that of Renard and Freimund (1994): $R = 0.0483 *P\ 1.61$. This equation works best in Finland. We selected Lo's equation because it has been used in earlier RUSLE models made by JRC.

Soil factor K: At the moment, the European soil map is the only product covering the whole of the BSR. Despite its known problems in heterogenic accuracy, European Soil Database 2 was used to calculate the K-factor. The procedure followed the one described by JRC: http://eusoils.jrc.ec.europa.eu/ESDB_Archive/serae/grimm/italia/start.htm.

Topography factor LS: Calculation of LS requires digital elevation models (DEM). For latitudes below 60 degrees, DEM SRTM 90 m (Shuttle Radar Topography Mission, http://srtm.csi.cgiar.org) is available, and it was selected for use. For the northern area of the BSR (latitudes above 60 degrees), the DEMs were created from Russian military topographic maps 1:100K and 1:200K. (http://www.viewfinderpanoramas.org/ website). ArcGIS software was utilised for the calculation of LS. Unfortunately the efforts to create a hydrologically correct DEM in ArcGIS failed, which may reduce the accuracy of the results. There are areas below sea level in the Kaliningrad region, but the elimination of these areas did not help. Also we could not isolate the problem in any special area of the DEM.

Cover factor C: Harmonised data that cover the whole BSR (Grida 1981-1992) represent a fairly low resolution for this application (1 km). While other potential source data Corine Land Cover (2000) and Larse data (1986-1995), have much better resolutions, 100 m and 28 m, respectively, they only provide partial coverage of the Baltic Sea Drainage Basin. The C factor grid was created by combining Corine Land Cover 100 m, Larse data 28 m (Leningrad Oblast) and Balans data 200 m which was used for the rest of the area (Belarus, Russia) The result was a compromise between resolutions and processing time. However, with this approach, most of the area had the best possible land cover information.

Farming system P: the factor was not used, because sufficient data were not available.

4.1.2 Example maps and future needs

RUSLE was used as a tool to assess the relative susceptibility of areas, and locate the ones that are more sensitive with respect to the factors. RUSLE could also provide quantitative estimates of soil loss, but then the model would have to be properly calibrated, and might still lead to unsatisfactory results. The results are presented here in the form of maps where A is calculated at a resolution of 100 m, the results are then averaged for each of a EEA index grid cells (10 km x 10 km). The total amount of EEA index grid cells of the BSR area was 18933. The value of most cells was zero. The 3576 cells having a value above zero were ranked from 1 to 3576 where 1 means the highest erosion and 3576 the lowest.

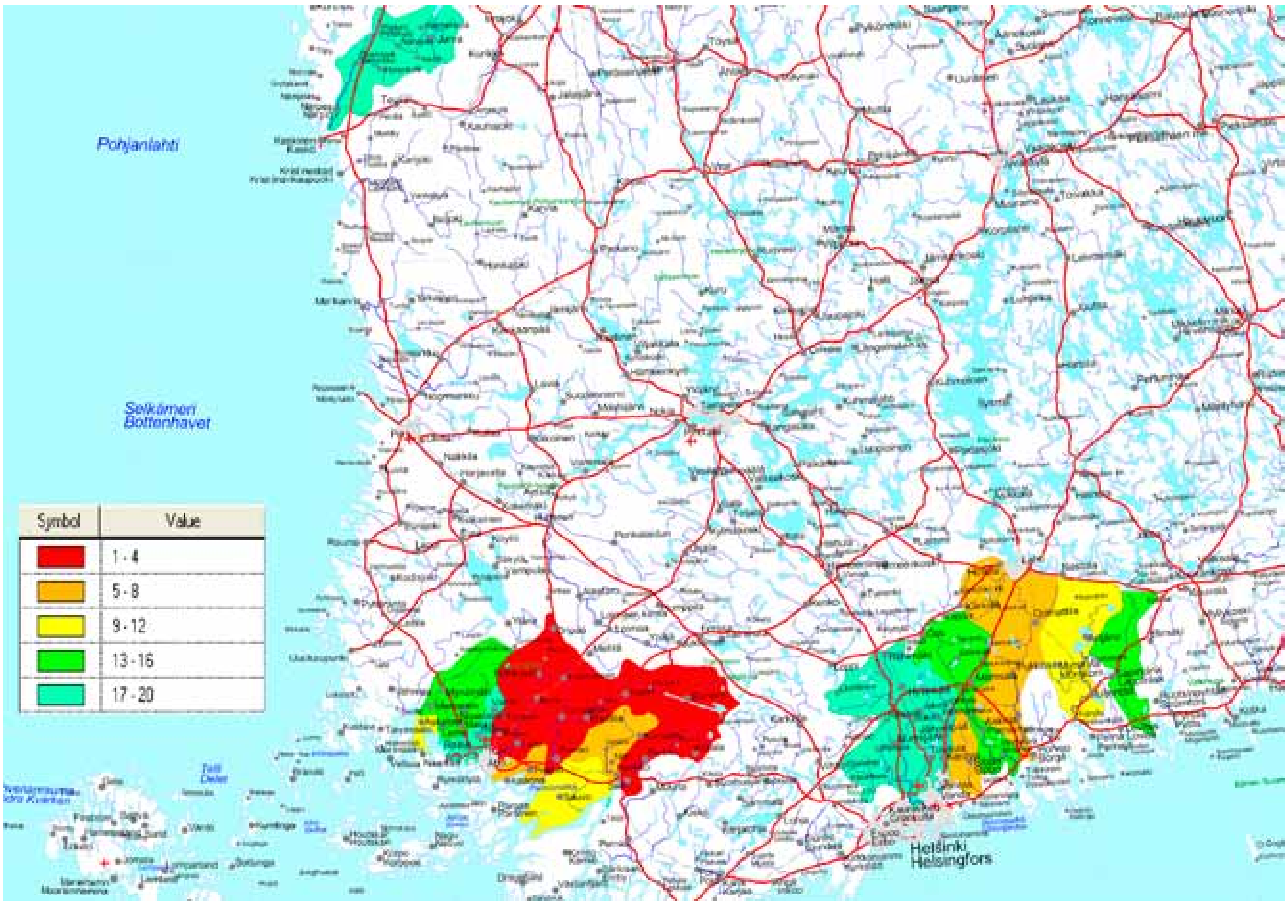


Figure 27. The Finnish river basins with the highest erosion, as modelled by the RUSLE approach.

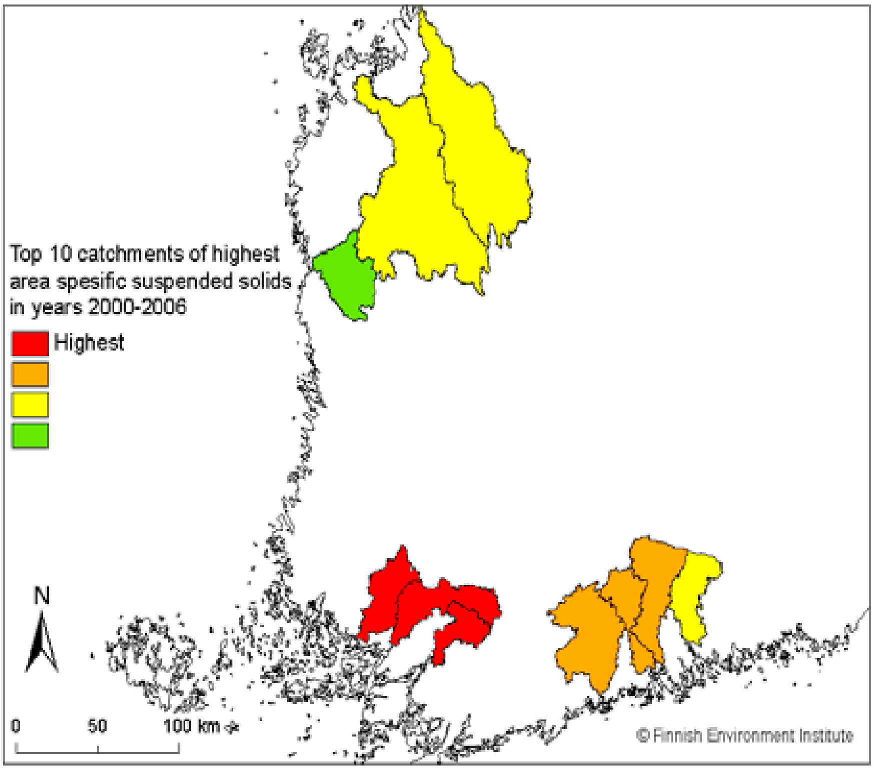


Figure 28. The Finnish river basins with the highest suspended solid loads according to monitoring.

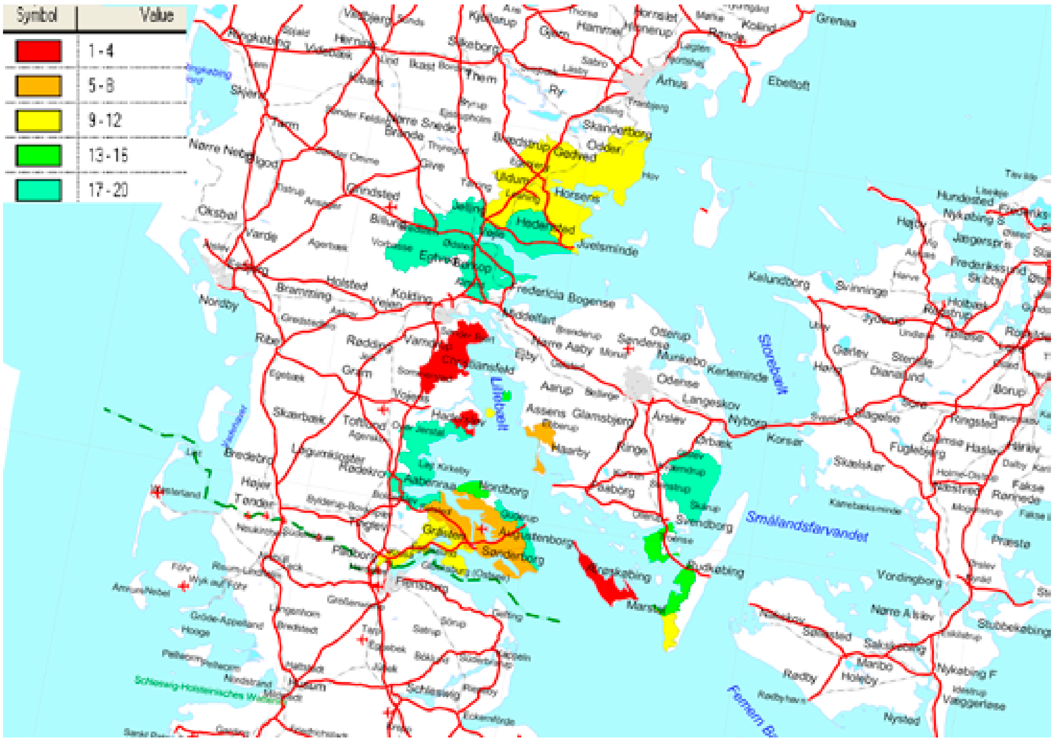


Figure 29. The Danish river basins with the highest erosion, as modelled by the RUSLE approach.

Baltic Sea RUSLE might work as a “neutral background model” for various models used in the BSR drainage area. However, there is a great need to validate the results and it is noteworthy that accurate quantitative results (t/ha/y) cannot be achieved without proper calibration/testing data. As seen from Figures 27-28 the Finnish RUSLE application produced results that are quite similar to the monitored data, which is probably due to the fact that clayey coastal soil with relatively steep field slopes causes high erosion and phosphorus load predominantly in this area. One way to utilise models such as RUSLE is to use them qualitatively to produce ranking lists of erosion vulnerable municipalities and river basins within the BSR (see Figures 27 and 29).

4.1.3 Area-specific diffuse loads based on the HELCOM PLC data

The Helsinki Commission (HELCOM) needs reliable data on inputs into the Baltic Sea from land-based sources to be able to achieve the objectives of the Helsinki Convention. To satisfy this need, Baltic Sea wide water-borne Pollution Load Compilations (PLCs) have been carried out. The latest PLC report, PLC-5, concerns monitoring of waterborne pollution loads from the year 2006, and covers both point and non-point sources of pollution. The report includes both a source-oriented and a load-oriented approach in quantifying the pollution inputs into the Baltic Sea. However, there are some deficiencies concerning its completeness and the lack of fully comparable methodologies. In addition, the point source inventories were not extensive enough in many cases. Thus, the results must be interpreted with reservations (HELCOM (PLC-5) 2012). In the Baltic COMPASS, we used the same monitored data for each monitored river basin, but instead of using the diffuse load values given by each contracting party, we tried to use a common approach for every catchment in assessing the diffuse loading (here considered to originate mostly from agricultural and wetland areas).

The PLC data that were used here included the reported total loads of total nitrogen (TN) and total phosphorus (TP) in the outlets of the biggest rivers in 2006. In addition, the point source loading (municipal waste water treatment plants, industry + fish farms) and the approximated retention within those catchments were picked from the database. The retention was first summed to the total load, as otherwise the loads that would be later calculated for the source areas of the diffuse loading (kg km^{-2}) would be too small, neglecting the nutrients that have been sedimented to the streams and lakes in the catchments. Next, the reported point source loads were subtracted from the total load of each river station. Finally, also the transboundary loading was also subtracted and the diffuse loading was calculated only for the part of the catchment that belonged to the country in which the river outlet was located.

To be able to approximate the diffuse loading, we needed to subtract background loading as well. The natural background leaching was first calculated by summing the area of "openland", "natural wetland" and "forest" from the raster land cover data BALANS (200 x 200 m grid; Malmberg 2001; http://www.grida.no/baltic/htmls/related1.htm#basin) with GIS tools and then multiplying this by annual specific leaching of 140 kg km^{-2} for TN and 5.4 kg km^{-2} for TP (Mattsson et al. 2003). The estimated background leaching was subtracted from the load, and the rest was assumed to represent the diffuse load. The specific leaching values for TN and TP were based on Finnish experiments, and it turned out that for plenty of catchments the background load was greater than the diffuse load in total, leading to a situation where the diffuse load ended up being negative. Thus, we decided to use the background loads that each country had reported for their rivers. Nevertheless, several Swedish rivers had negative values. This was due to the fact that in Sweden, the natural background losses and retention have been normalised for the water flow during 1985-2004, and 2006 was quite a dry year in northern Sweden.

For each catchment, the agricultural and wetland areas were summed from raster data that combined three different land use data sets in order to obtain the best possible data: Larse data 28 m (Leningrad Oblast, Russia, http://www.fsl.orst.edu/larse/russia/), Balans data 200 m (Belarus and Kaliningrad, Russia) and CLC2006 (the rest). The wetland area was taken into account due to the fact that at the time there was no proper point source load information available for the peat industry from every country, which may have a major impact on nutrient loading. Finally, the diffuse TN and TP load was calculated by dividing the remaining load by that area. In summary, the diffuse load for each catchment was calculated by:

Area-specific diffuse load = (Total load + retention – point load – background leaching) / (agricultural + wetland area).

The maps of the area-specific diffuse loads are shown in Figure 30. Since the data were from one specific year (2006) only, it should be kept in mind that the weather conditions play a big role in the load origin and the situation does not necessarily look like this every year. Here it turned out that for TP, six out of the "Top 10" catchments were located in Finland. The others were in Estonia, Poland and Sweden. In case of TN, the catchments were mostly Estonian, Danish and German catchments, with one from Sweden.

4.1.4 Nitrate vulnerable zones

According to the EU's Nitrate Directive (91/676/EEC), nitrate-vulnerable zones (NVZ) have been designated in member states around the Baltic Sea for territories draining into waters that are, or could be, affected by high nitrate levels or eutrophication (Figure 31). Within NVZ, there are regulations regarding when and where to spread manure to avoid risk of leakage of nutrients to water. Information about the extent to which NVZ have been designated could shed light on manure handling practices. Within NVZ, manure should not be spread in periods when lands are frozen or water saturated, which indirectly means that sufficient manure storage is a necessity. Farms that are not within NVZ may avoid manure storage requirements, which, in addition to increasing risk of nutrient leakage, could affect biosecurity negatively.

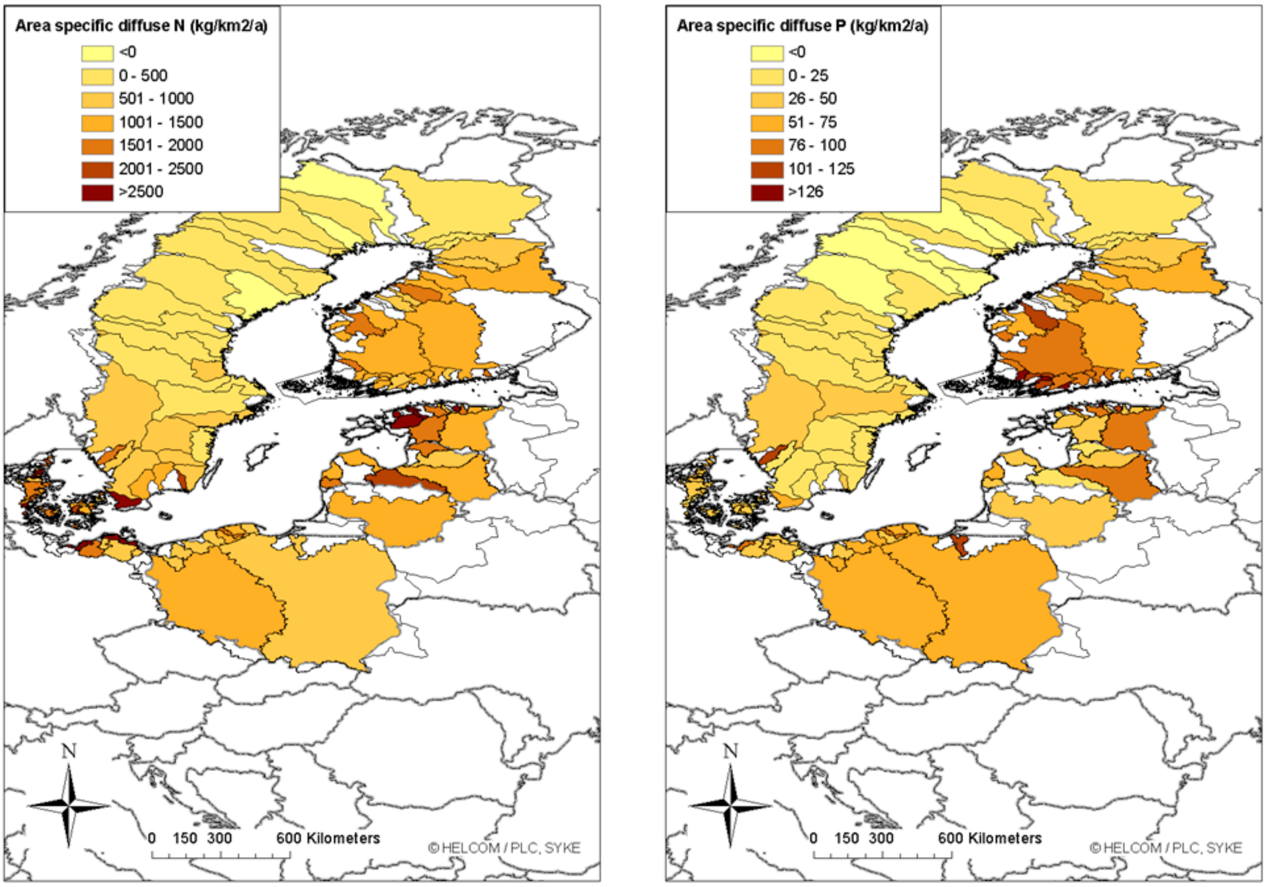
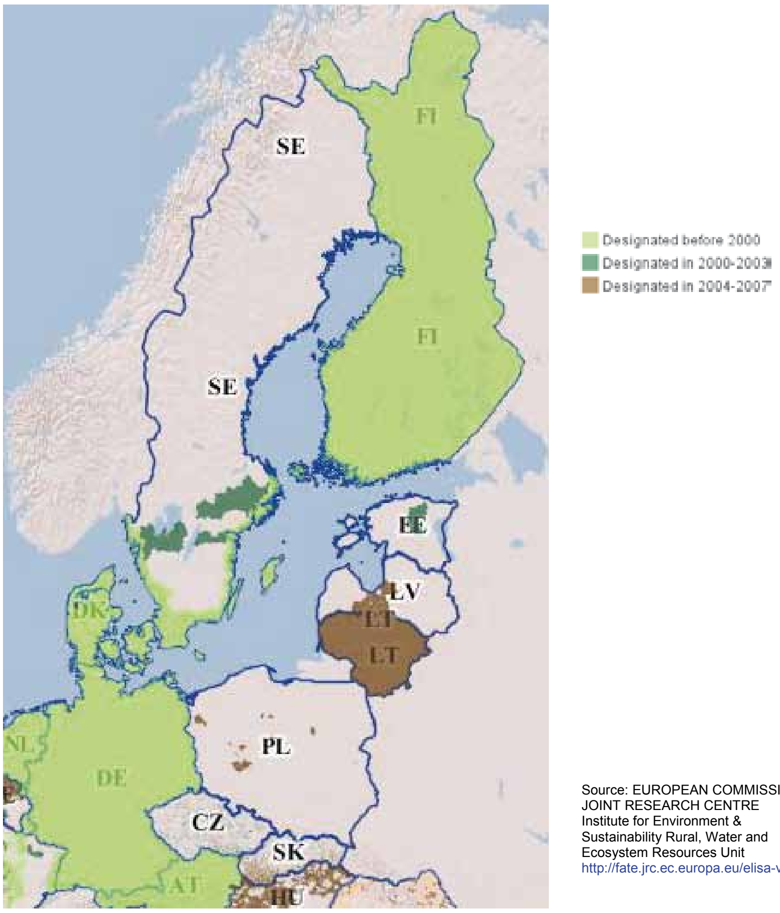


Figure 30. The area specific diffuse loads of nitrogen and phosphorus for the year 2006.



Source: EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Institute for Environment &
Sustainability Rural, Water and
Ecosystem Resources Unit
http://fate.jrc.ec.europa.eu/elisa-viewer

Figure 31. Nitrate vulnerable zones (NVZ) designated in member states around the Baltic Sea.

4.2 Example from Denmark

In Denmark, the first attempts to use the P-index concept (Andersen and Kronvang 2006) were based on the Pennsylvania P-Index (Sharpley et al. 2003). Due to Danish topography, agricultural practices and the high degree of artificial drainage, the index has been adapted and modified to better suit the conditions in Denmark (Heckrath et al. 2008). The soil type-dependent leaching factor was introduced to the model to express the risk of P being transported from the root zone to tile drains or to a shallow groundwater table. Loamy soils were attributed a higher weight than sandy soils due to the risk of macropore flow and rapid transport of both particulate and dissolved P to drains. Macropore transport has also been added to the index, which now consists of four sub P indices: soil erosion, surface runoff, leaching and macropore transport (Figure 32).

Lowland soils make up more than 15% of the Danish area and these soils are intensely used for agriculture. Unfortunately these soils are presently not yet included in the index. This is due to the lack of knowledge and detailed information on these soils and the processes governing P retention and release in them. The main purpose of the Danish P-Index is to rank fields according to their risk of P loss. It is designed to utilise generally available data, such as farm data (e.g. soil P status, buffer zones and inputs of mineral and manure fertilisers), public databases (e.g. soil type, P binding capacity) and landscape data (e.g. DEM, water theme). Basically, it is a mapping tool for targeted and cost-effective mitigation planning. It is designed to enable users (e.g. farmers) to access the pre-calculated P-Index maps and background data and type in their own values (i.e. correct the pre-calculations to better suit the local conditions) and use a guided mitigation planning for estimating the reduction potential of P loss on their fields. However, the tool is not yet open for users, but Aarhus University has used a prototype of the index for the whole of Denmark and is currently in discussions with Danish authorities on implementing the index as an official tool for environmental planning.

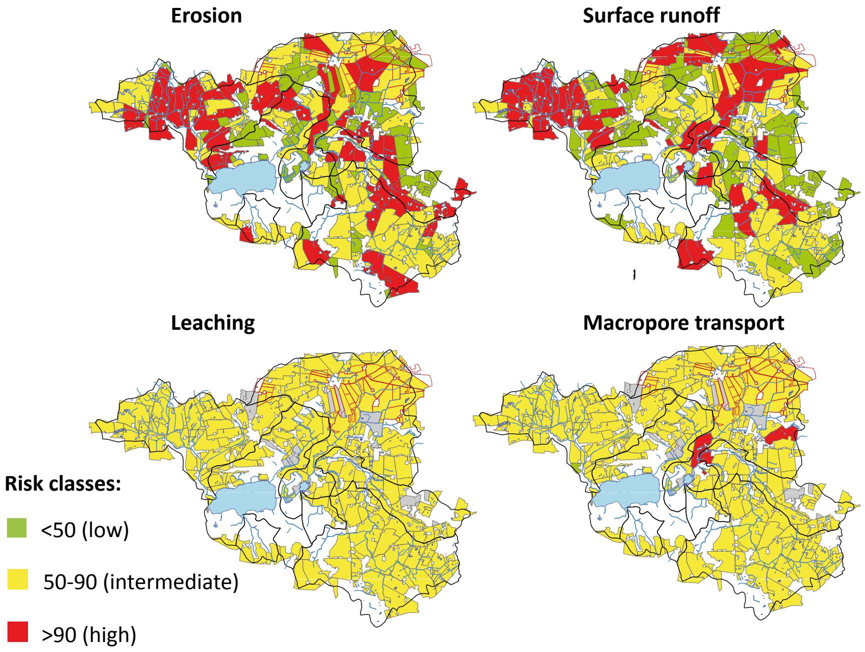


Figure 32. An example of the four sub P indices as calculated for the catchment of Lake Ravnsø in Denmark. Red indicates high risk of P loss, yellow intermediate and green low risk (Goswin Heckrath, personal communication).

4.3 Example from Sweden

Losses of P from agriculture are of two types: point sources mainly in connection with animal husbandry and diffuse sources from agricultural soils. In Sweden, systematic measures to minimise outflows of P and other nutrients from animal manure to surface waters have been introduced during the past three decades, but further efforts are needed. The other source, P losses from agricultural soils, has only recently come into focus with the presentation of an international evaluation of the factors that have led to increased eutrophication of the Baltic Sea (Boesch et al. 2006). Since P in soil is involved in both biological and chemical processes, losses from soils vary considerably over time and between fields.

Special attention needs to be given to highly significant problem fields and critical leaching episodes occurring in conjunction with extreme weather events (Withers et al. 2003). There are indications that a few problem fields within a catchment may account for as much as 90% of the total P load (Sharpley and Rekolainen 1997). Furthermore, nutrient vulnerable areas may change in time and space as a result of the interactions between agricultural management, weather and hydrological conditions. Kleinman et al. (2011) state that strategies to mitigate diffuse losses of P must consider chronic (edaphic) and acute, temporary (fertiliser, manure, vegetation) sources.

4.3.1 Scales and transport pathways

In Sweden, research, environmental monitoring and modelling of P transport from agriculture have been conducted on several scales ranging from soil profiles, plots, single fields and small agricultural watersheds to river basins. At smaller scales (experimental plots), P transport has been modelled with the focus on P chemistry and soil properties as explanatory variables (Larsson et al. 2007). At larger scales (river basins), the main focus has been on hydrology, with weather parameters and topography as driving forces, while description of nutrient cycling on a regional or national scale is drastically simplified by the use of average or default values (Brandt et al. 2009). Taken together, this means that the quality of input data at the larger scale is rather poor since spatial variation is not included, and as a result those data are insufficient for further analysis regarding implementation of countermeasures to reduce P losses. At the other end of the scale spectrum, results from plot and field experiments are difficult to scale up, as the mechanisms involved in P losses are not satisfactorily understood. Consequently, a knowledge gap exists especially at the medium scale (1-50 km^2), where an equally accurate description of both hydrology and P biogeochemistry is needed for proper understanding of nutrient (phosphorus) mobilisation and delivery processes. Furthermore, the medium scale is not only a natural meeting point for scientists from different fields, it is also the most important scale for water management according to the guidelines in the EU Water Framework Directive.

Many studies have focused on the chemical controls of P release from soils and applied P amendments to water. In general it can be concluded that high soil P status and high P amendments lead to higher P release (Sims 2000; Vadas et al. 2005), causing high variations in P release as a consequence of heterogeneous soil P content and uneven spreading of P amendments (mainly manure). Simultaneously, transport and delivery of mobilised P from fields to water recipients are also highly variable, dynamic and governed by site location and hydrology. In other words, variable source area hydrology within a given watershed can also cause high variations in P losses, usually with surface runoff areas being identified as vulnerable (hotspot) zones. Identification of these hotspots, if they exist, is a key for a cost-effective mitigation options that may help us to target counter measures to the parts of watersheds where the highest reductions can be achieved.

There is however a critical question regarding the proper scale and resolution at which erosion- and nutrient-vulnerable areas can be identified. Since the sources of variation within a given watershed might be caused both by site location and hydrology, as well as by management driven preconditions (soil P content and P fertilisation strategy), it is still unclear at which scale vulnerable areas can be detected and verified. Whereas differences in soil P content and P amendments occur between management units (parcels, fields, farm borders), the differences in hydrological response might occur both within fields/parcels, within a small catchment and between subcatchments within a watershed or river basin. The size/area and resolution of identified hotspots will therefore be closely related to the scale at which the analysis is performed. Obviously, as the area of the studied catchment increases, the resolution of identified hotspots usually decreases due to the lower availability of high resolution input data needed for hotspot identification. Also the focus and purpose as well as the interest from different stakeholders may change as the scale shifts (Table 9).

Table 9. Scale and approximate area of studied objects, resolution of identified hotspots, important stakeholders and main purpose with hotspot identification

Scale	Area	Resolution	Important stakeholders	Purpose
Regional (Baltic Sea catchment)	> 2 million km²	National / River basins (100 - >1000 km²)	HELCOM	Apportionment between countries, sea basins & river basins
National (e.g. Sweden)	~ 476 000 km²	Subcatchments – River basins (30 – 1000 km²)	EPA, national water authority	Apportionment between water districts and river basins
Water district	37000 – 147000 km²	Subcatchments – River basins (30 – 1000 km²)	Water authorities at district level	Identification of catchments and subcatchments with highest contribution
Catchment	100 – 1000 km²	Subcatchments (5-100 km²)	EPA, water authorities at district level	Identification of catchments and subcatchments with highest contribution. Targeting and prioritisation of these catchments in abatement strategy
Subcatchment	1-100 km²	Blocks, fields (2-100 ha) Sub-field scale (<100 m²)	Board of agriculture, county board of administration, extension services, farmers	Targeting and prioritisation of identified hotspots in abatement strategy
Farm	2 - >100 ha	Blocks, fields (2-100 ha) Sub-field scale (<100 m²)	County board of administration, extension services, farmers	Targeting and prioritisation of identified hotspots in abatement strategy
Field	1 ~ 100 ha	Fields (2-100 ha) Sub-field scale (<100 m²)	Extension services, farmers	Targeting and prioritisation of identified hotspots in abatement strategy

4.3.2 Catchment scale

Identification of catchments that contribute most to the eutrophication of surrounding seas in Sweden has been performed by water authorities responsible for the Northern Baltic Proper, the Southern Baltic Proper, Skagerrak and Kattegatt (Vattenmyndigheten, Norra Östersjöns vattendistrikt 2009; Vattenmyndigheten, Södra Östersjön 2009; Vattenmyndigheten, Västerhavet 2009). These studies were based to a high degree on Pollution Load Compilation 5 (Brandt et al. 2009) and therefore could identify catchments at rather coarse resolution. PLC5 calculations are based on 13500 sub-catchments with an average area of 35 km² but even larger catchments have been used in the abovementioned studies. Identification of areas at a higher resolution was not possible due to the limitations regarding the resolution of input data such as low-resolution soil maps and lack of soil P status measurements.

While it is important to rank and prioritise implementation of countermeasures between different catchments in order to achieve the most cost-efficient reduction strategies, identification of hotspots at such a coarse scale is of little help for farmers and extension services that need support regarding optimal placement of potential countermeasures at a very local level, usually at the field or sub-field scale.

One of the catchments identified by the Northern Baltic Proper Water authority (Vattenmyndigheten Norra Östersjöns vattendistrikt 2009) as a major contributor to areal losses of both nitrogen and phosphorus was the Svärtaån catchment (Figure 33). The Svärtaå catchment has an area of 372 km² and is dominated by forest (57%) but with a considerable area of arable land (20.7%). With a goal to reduce nutrient losses from this particular catchment, the “Svärtaå project” financed by the Swedish EPA was started in 2009 (Svärtaåprojektet 2012). Within the framework for this project a comprehensive monitoring programme was implemented,including measurements of water chemistry in 36 water courses and 13 lakes (Figure 33). This data set was used to study possibilities for the identification of hotspots at the catchment and subcatchment level.

At a higher resolution, a new national high-resolution digital elevation model (DEM) based on airborne laser scanning (LIDAR) with a resolution of approximately 2 m was used to test possibilities to identify hotspots at very local scale (field and within field level). For this purpose, three different tools/models were used to identify risk for surface runoff (calculation of flow accumulation), ponding water (calculation of topographic wetness index) and erosion (Unit Stream Power Erosion Deposition, USPED model).

4.3.3 Subcatchment scale

The first step in the identification process of erosion and P vulnerable areas was to delineate catchment areas based on the location of water sampling points and high resolution DEM (Figure 33). Each subcatchment was thereafter characterised in terms of measured water quality and land use characteristics (Table 10). Large variations in catchment size and characteristics are noticeable. Catchment areas varied from a few square kilometres for some of the headwater subcatchments and increased up to 342.8 km^2 for the lowest downstream sampling point. Similarly, temporal and spatial variations in measured P concentrations were also high, ranging from 16 to 375 µg P/l.

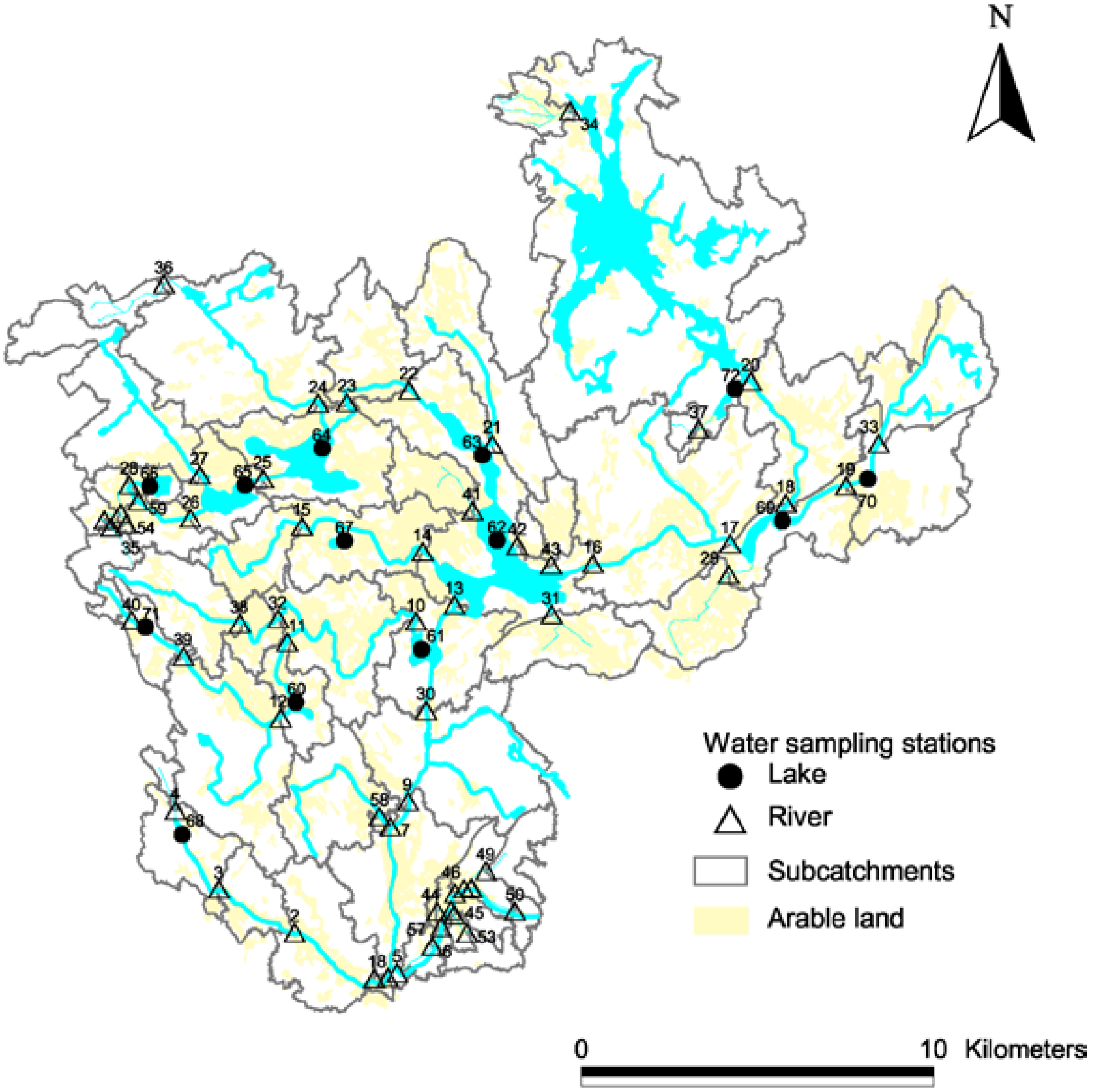


Figure 33. Svärtaå catchment with subcatchments delineated based on water quality sampling points in water courses.

Table 10. Subcatchment characteristics and average values of measured concentrations of total and phosphate phosphorus.

Subcatch No	No water samples	Mean TP (µg/l)	SD	Mean PO4-P (µg/l)	SD	Area (km^2)	Arable land (%)	Forest (%)	Water (%)
1	10	173	99	84	56	18.4	21.9	63.9	0.5
2	9	185	86	81	45	9.7	19.0	69.0	0.9
3	9	168	50	74	36	6.2	15.3	72.4	1.3
4	10	114	107	40	15	0.8	0.0	97.9	0.0
5	10	142	79	73	26	11.8	18.0	65.5	0.0
6	9	151	58	77	27	10.3	17.9	66.8	0.0
7	9	151	58	77	27	8.4	32.1	49.0	0.0
8	10	130	45	63	13	342.8	25.9	53.7	7.3
9	10	112	22	54	14	268.8	25.8	52.9	9.1
10	10	256	146	127	67	41.5	34.5	50.4	1.0
11	10	156	72	73	41	22.7	24.8	62.0	1.7
12	10	184	68	90	26	18.9	23.2	65.6	0.6
13	10	100	32	40	13	246.1	25.3	52.8	9.5
14	10	375	252	198	84	13.5	58.2	22.3	1.0
15	10	332	192	174	63	4.9	54.5	25.8	0.0
16	9	130	83	57	32	123.4	19.0	58.9	10.5
17	9	136	109	58	39	99.0	16.7	59.6	13.1
18	10	75	84	23	23	68.1	10.5	63.5	17.2
19	10	134	98	62	41	18.7	23.0	60.1	2.5
20	10	16	5	5	4	57.7	6.9	65.6	20.3
21	9	183	67	84	36	11.2	26.8	56.9	0.8
22	10	129	94	57	28	65.1	23.4	57.5	7.2
23	10	124	106	48	32	57.8	22.7	57.9	8.1
24	9	125	113	51	32	21.8	12.6	73.6	3.0
25	10	86	22	28	11	25.5	23.0	59.7	6.8
26	10	176	107	92	52	8.5	30.3	50.3	4.4
27	10	154	166	71	65	12.2	10.9	79.7	2.9
29	10	244	163	143	111	6.3	54.9	28.0	0.0
30	8	106	22	42	17	296.8	26.7	52.4	8.2
31	11	201	234	80	77	6.6	43.7	45.7	0.0
32	7	275	122	145	96	8.7	40.8	40.1	0.0
33	7	74	42	30	15	8.8	20.4	57.0	4.8
34	6	349	170	224	116	2.3	38.0	44.4	0.0
35	7	100	101	34	15	2.1	1.3	91.5	0.0
36	6	71	18	30	11	2.2	0.1	96.9	0.0

Evaluation of the data in Table 10 showed that the mean concentrations of both total P and dissolved P were strongly correlated to the land use characteristics of the subcatchments. A higher percentage of arable land resulted in a strong increase in P concentrations, confirming that diffuse loss from agriculture is one of the main sources of P in Svärtaån. However, upstream areas with greater lake areas lead to increased retention processes in these subcatchments and to lower P concentrations in streams.

So in spite of the high spatial variations in measured P concentrations, a major part of the variation can be described by the land use characteristics of the subcatchments. In other words, identification of hotspots at this scale can be successfully done by accounting for the land use characteristics, primarily the proportions of arable land and water/lake area (Figure 34). We should bear in mind that the soil type may also have an important role in nutrient losses but the soil type distribution in the Svärtaå catchment is rather uniform, dominated by silt loam and silty clay loam. The above mentioned strong correlations strengthen the results of source apportionment models which are able at least at this rather coarse scale to account for the main sources since the available input data regarding land use in general and arable land in particular is of satisfactory quality and resolution for such purposes.

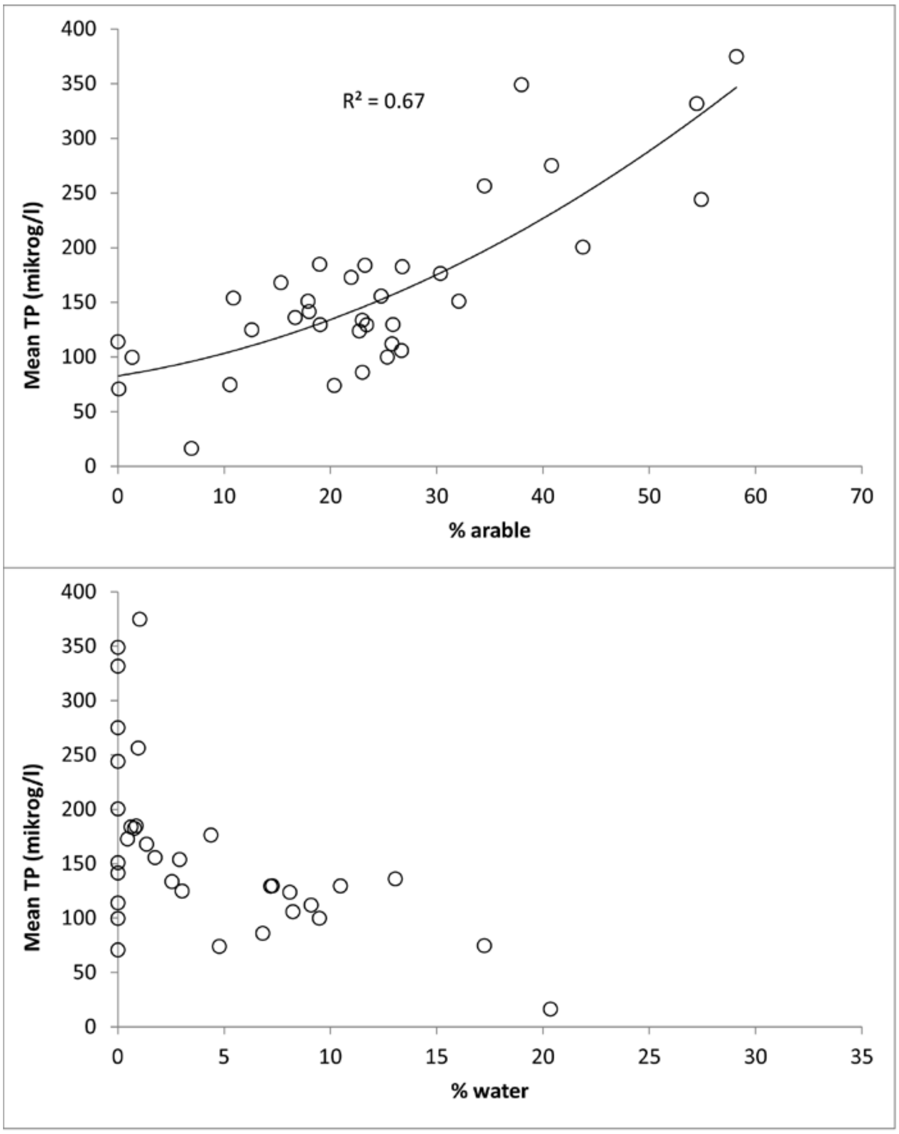


Figure 34. Mean concentrations of total phosphorus as a function of subcatchment land use characteristics.

However, at a finer scale where P losses presumably vary both between and within arable fields and parcels, the above mentioned correlations are of little help for those people at county boards of administration, extension services or farms who are responsible for making decisions about appropriate abatement measures. Identifying hotspots at a high resolution requires other tools and it is clear that synoptic water sampling campaigns at a rather coarse scale will not be able to solve that problem.

4.3.4 Field scale

Identification of areas sensitive to surface runoff and erosion are often based on an assessment of the topography and soil distribution in a given catchment. Topography, elevation, slope intensity, length and shape, flow accumulation and various topographic indices as well as a number of other more complex empirical tools and models (e.g., USLE (Wischmeier and Smith 1978), WATEM (Van Oost et al. 2000), USPED (Mitasova et al. 2001)) are used to develop risk maps for surface runoff and erosion based on elevation data. There are also several dynamic models (ANSWER, LISEM, EUROSEM, SWAT, WEPP, etc.) that quantify erosion based on more or less process-based equations. A large number of parameters included in these models and comprehensive input data requirements limit the use of these models, while lack of spatially distributed validation data makes it nearly impossible to verify the modeling results at a high resolution spatial scale. Empirical tools and models based on the application of the Universal Soil Loss Equation (USLE) including a number of more or less modified versions (e.g. MUSLE or RUSLE (Revised USLE, see Chapter 4.1.1) have been developed to calculate the mobilisation of soil particles as affected by five factors; rain intensity (R), land use (C), slope length and intensity (LS), existing measures for erosion control (P) and soil erodibility (K). One major limitation with USLE-based methods is that they usually lead to an overestimation of erosion because no account is taken of the deposition processes.

A high-resolution (2 m) digital elevation model (DEM) was used in the Svärtaå catchment as input data for erosion modeling with the Unit Stream Power Erosion Deposition (USPED) model (Mitasova et al. 2001). USPED is a simple model for prediction of spatial distribution of erosion and deposition where net erosion and deposition rate is estimated as a divergence of sediment flow. USPED accounts therefore for the upslope contributing area and both the profile and tangential curvatures. In addition to high-resolution DEM, input data required by the USPED model includes the climate (R), soil erodibility (K) and crop (C) factors from the RUSLE equation. Thus, while the USPED is similar to the RUSLE, the USPED is able to take into account to a higher degree terrain complexity and is therefore better able to utilise the high-resolution digital elevation model. A uniform value was used for the climate factor R as it was assumed that there are only small variations in weather conditions in the Svärtaå catchment, whereas K and C values were allowed to vary according to soil distribution and land use in the catchment, respectively. Since arable fields and parcels within the catchment are included in a crop rotation, usually with leys and spring cereals, a uniform C value for all arable fields was used for erosion modeling to reduce the importance of crop distribution for one specific year. The USPED model was implemented in ArcView 3.3, Environmental Systems Research Institute (ESRI), Inc.

Identification of areas at risk for surface runoff was made by calculating the drainage direction and then flow accumulation for each 2x2 m grid cell. Thus, cells with larger catchment areas were assumed to pose a higher risk for surface runoff. The calculations were made with Map Calculator in Arc View 3.3, Environmental Systems Research Institute (ESRI), Inc.

Identification of risk areas of standing water were modeled by the calculation of a topographic wetness index (TWI = ln (a / tan b) where a denotes drainage area and b denotes slope. Cells situated in the lower parts of the landscape and / or flat sections received a higher index, which indicates higher soil moisture and generally wetter areas. Higher soil moisture may result not only in saturation excess surface runoff (Beven and Kirkby 1979) but also in more active macropores and fast P-enriched water through the soil profile (Skaggs et al. 1994). Even though the TWI does not account for the existence of tile drains the result might indicate where in the landscape it might be especially important to have well-functioning tile drain systems. Topographic wetness index (TWI) was calculated in ArcGIS 9.3 with Model Builder.

Detailed spatial variation high-resolution data are difficult to illustrate for a large catchment such as Svärtaå. Therefore, the results of the analyses described above have been calculated and are presented for the Katgaljebäcken subcatchment (subcatchment 5 in Table 10, 11.8 km^2), situated in the southeast part of the Svärtaå catchment (Figure 36). The Katgaljebäcken subcatchment is dominated by forest but around 18% of the catchment area is classified as arable land and situated in the lower parts of the landscape.

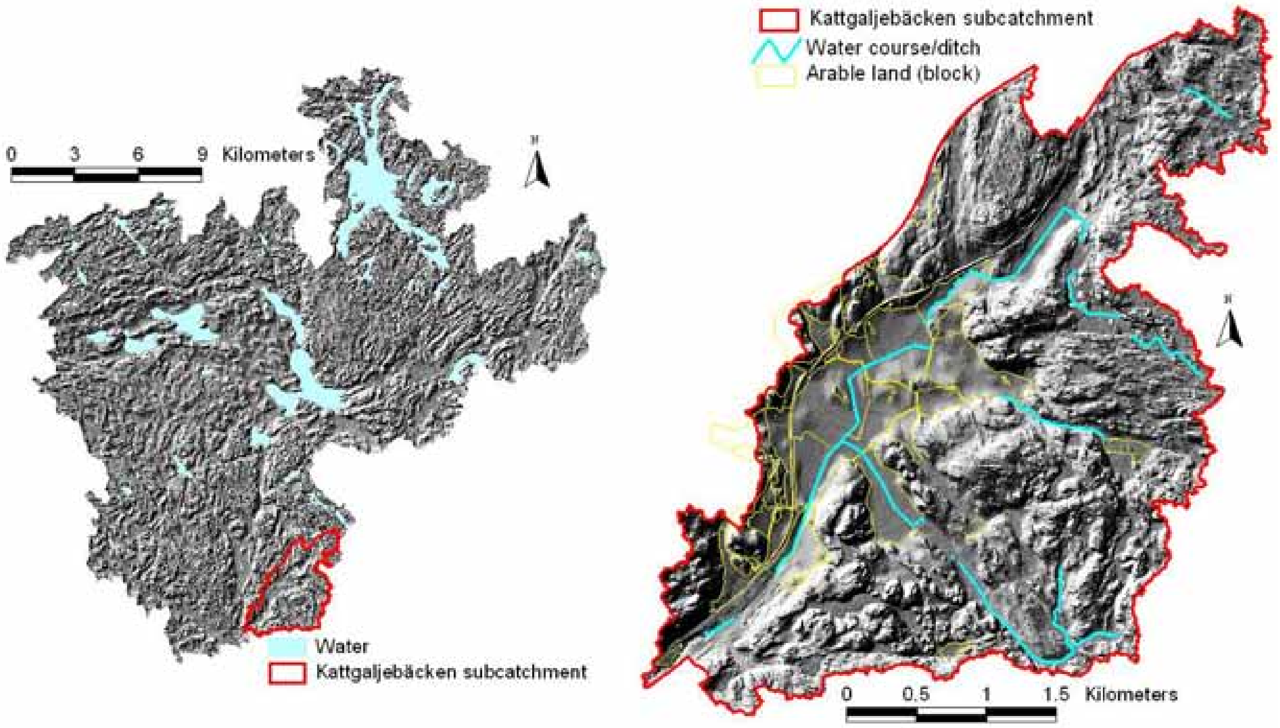
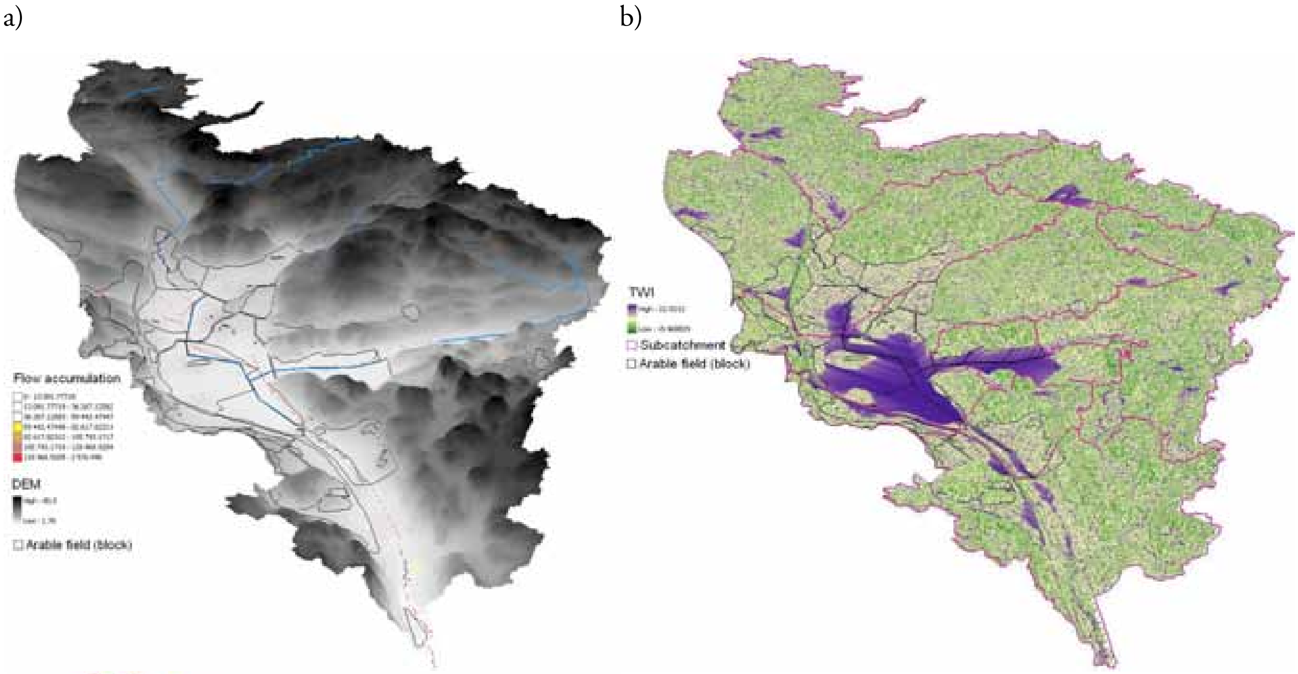


Figure 35. Hillshade of Svärtaå catchment with the location of Katgaljebäcken subcatchment (left) and hillshade of Katgaljebäcken subcatchment (right).

The results of the calculations are shown in Figure 36. While it is rather obvious that the results shown in Figure 36 illustrate high spatial variability of the studied parameters (flow accumulation, topographic wetness index and erosion/deposition patterns) and offer numerable possibilities of interpretation of these results at a very high-resolution, there are also some differences regarding the type of the spatial variability of different parameters. Whereas both flow accumulation and erosion/deposition areas vary to a high degree locally, the topographic wetness index is of a more zonal character, identifying lowland flat fields or group of fields as being wetter than the surrounding sloping parts of the catchment. Generally, data for verification of these high resolution calculation results are lacking. Therefore the methods/tools and models are yet to be verified by measurements or other comparable verification methods. However, before much time and effort is spent on verification, there is an obvious need for discussion among different stakeholders with respect to the appropriate scale and resolution of results to ensure the proper use of such analyses.

The main purpose of hotspot identification is to target those areas that contribute most to nutrient loading but different tools and models identify hotspots at different scales, varying here from distinct within-field areas covering smaller parts of the fields and parcels (e.g. USPED), to hotspot zones covering whole or several fields in certain parts of the catchment (e.g. TWI). Some stakeholders, farmers for example, may be equally interested in both scales but other stakeholders may have different priorities. For instance, since both USPED and flow accumulation calculations show variation within arable fields, the appropriate placement and location of buffer strips might be expected to be determined by these results, leading to wider buffer strips in hotspot areas and narrower or no buffer strips in those parts of fields where topographic preconditions for initiation of surface runoff and erosion are low. Howe-



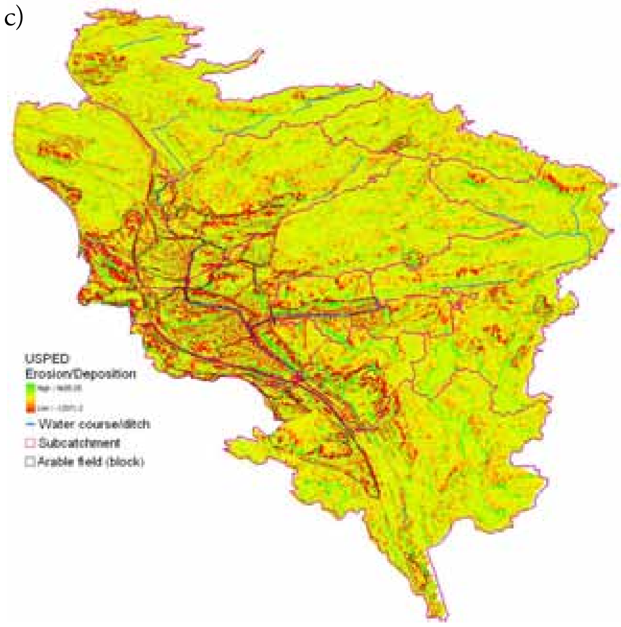


Figure 36. Flow accumulation (a), Topographic Wetness Index (TWI, b) and erosion (red colored areas) and deposition (green coloured areas) calculated with USPED model (c).

ver, such high-resolution risk classification might be difficult to administrate and follow-up on by the responsible authorities. The data showing high local variations could by geo-statistical methods be aggregated to certain natural or management units (fields or parcels) but this raises the question of the representativeness of the calculated mean (or other statistical) values and introduces a risk of smoothing the results and loosing the sharpness of hotspot identification. Therefore a coherent view from the involved stakeholders on the most appropriate and feasible choices for scale and resolution would be valuable and offer a cost-effective way to proceed with scientific verification of the achieved results. Such verification will probably require high-resolution and high-frequency measurements but their design and even cost could be adjusted based on the selection of appropriate scale and resolution.

Finally, risk maps can also be made based on the soil P content and combined with the above mentioned risk maps based on topography (Figure 37). In Sweden plant-available soil P content is usually determined by extraction with ammonium lactate/acetic acid at pH 3.75 (Egnér et al. 1960). The results from the use of this technique have been shown to be strongly correlated to easily soluble P and P (Börling et al. 2004; Djodjic and Mattsson 2011) and therefore might be a good indicator of risk for P mobilisation and losses. As can be seen in Figure 37, soil P content varies in the Katgaljebäcken subcatchment over all the 6 P-AL classes used in Sweden to describe soil P status; from unsatisfactory (class I and II, less than 2 and 2-4 mg P per 100 g soil, respectively), to strongly exceeding crop optimum (>16 mg P per 100 g soil). Within the context of the P index concept (Lemunyon and Gilbert 1993; Djodjic and Bergström 2005) P source factors (e.g. soil P status) are combined with P transport factors (e.g. erosion, surface runoff etc). However, combining these factors into one P risk index is difficult and uncertain, and would demand detailed high resolution measurements of water flow and chemistry for verification. Therefore, it might be more appealing to first look at different risk maps individually and thereafter simultaneously, but not necessarily by combining them into one risk map. In that way, the underlying causes for P losses might be more transparent, and therefore easier to communicate to farmers. Additionally, different causes for high P loss risk might demand different counter measures. Coincidentally, in the case of Katgaljebäcken, it seems that high soil P status does not overlap to a high degree with other risk maps (Figure 37).

According to the P-index concept, those areas where source and transport factors overlap should be addressed first in mitigation efforts. In any case, it can be argued that appropriate measures might be different for different fields; erosion protection and prevention of surface runoff (e.g. buffer strips, no tillage, liming) might be more suitable for hotspots identified by erosion modeling whereas adjusted P fertilisation management (i.e. no manure or fertiliser additions) might be most suitable for fields with high soil P status.

Even if the scientific verification of calculated results in the Katgaljebäcken catchment has not yet been achieved, high-resolution risk maps might be a useful basis for discussion and communication. For instance, modeled results

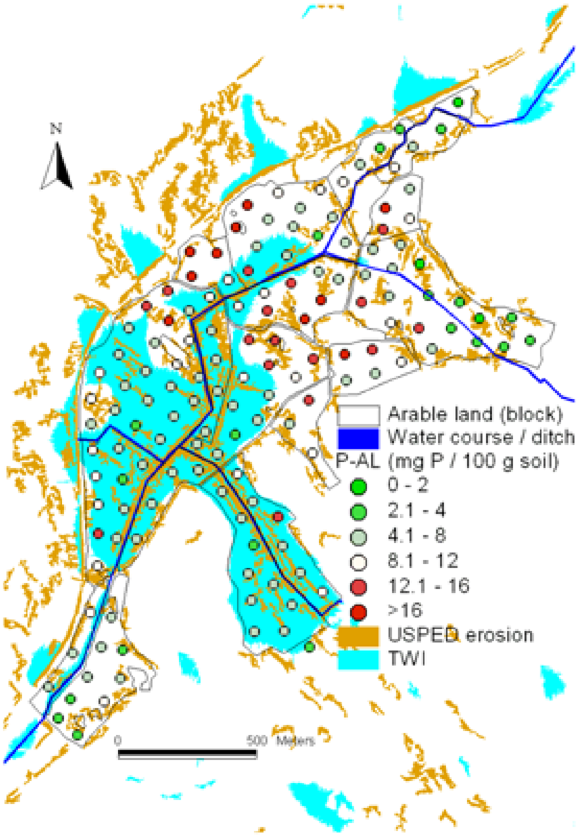


Figure 37. Areas susceptible to high erosion as modeled by USPED, areas with high soil moisture according to topographically-derived wetness index (TWI) and soil P status according to P-AL method.

offer an important communication tool between farmers and extension workers. Discussions between a farmer and extension/advisory staff might be concretised where risk maps produced from modeling can be discussed in the light of direct observations and experience of the farmer (Djodjic and Spännar, In press). Therefore, raising all stakeholders (advisory workers, farmers, water authorities) awareness and participation in the development of mitigation strategy at field, farm and even catchment level might be a cost-efficient way to reduce losses. To achieve that, scientific evidence regarding reliability of the produced risk maps ("know-why") is important but better communication between stakeholders and in particular the participation of farmers and utilising their experience ("know-how") in the discussions, will be decisive for the success of mitigation efforts.

4.4 Example from Finland

Mapping of critical source areas is relatively new in Finland, but there are a few examples, such as a study to identify sediment and particulate phosphorus risk areas in the Aurajoki river basin in southwestern Finland (Räsänen 2010). Aurajoki river basin belongs to the catchment area of the Archipelago Sea, that is regarded as a HELCOM non-point agricultural hot spot area. To be able to improve the quality of the river, it is important to locate the source areas of nutrients.

Räsänen (2010) assessed the USLE (Universal Soil Loss Equation) method, where *the erosion risk* (K) is usually calculated as *soil erodibility* (E) * *slope* (S) * landuse (L). In this work, the effect of other variables, such as the distance from the nearest water way (W) and manure application as fertiliser (M), were tested as well. These variables, together with e.g. buffer strips, needed to be simulated, as no empirical data exist. Räsänen (2010) prepared the maps based on data from The Finnish Environment Institute, The Geological Survey of Finland, The National Land Survey of Finland, and The Agency for Rural Affairs.

The basic idea of USLE is to describe different variables on different map layers and then multiply the layers to give the overall risk factor of each raster.

When erosion and P index maps are shown, it would be valuable to know how the different factors are weighted in the calculations. As an example, the weighting factors of erodibility, slope and land use that were used in the work by Räsänen (2010) for the Aurajoki river basin are presented in Table 11:

Table 11. The weighting factors of erodibility, slope and land use used for the Aurajoki river basin.

	Soil class	**Coefficient**
ERODIBILITY	Clayey soils	3
	Rock exposures	1
	Coarse soils	2
	Silt	4
	Peat	1
	Others	1
SLOPE	**Slope class**	**Coefficient**
	0-0.5	1
	0.5-1.5	2
	1.5-3.0	3
	3.0-6.0	6
	> 6.0	10
LANDUSE	**Landuse class**	**Coefficient**
	Spring cereal	10
	Winter cereal	8
	High value crop	10
	Grass	3
	Other agri land	6
	Built areas	1
	Forest	1
	Wetlands	1
	Water	1

With USLE assessments, various risk maps of sediment erosion in the Aurajoki river basin were created. These were then used as a basis for nutrient risk maps. Although we show only some of the maps here, it is important to keep in mind that although the initial data would be the same, it is possible to have different-looking maps just by categorising (e.g. natural breaks vs. quantiles) and visualising (black and white vs. colour map) the results in a different way (Figure 38). In other words, depending on the manner of presentation, different places may be shown as risk areas. In Figure 38, the erosion risk was created by *soil erodibility* (E) * *slope* (S) * *landuse* (L).

The results from K=E*S*L showed that the erosion risk was mainly focused on field areas. The observed risk areas were also sited close to the stream network, possibly due to the fact that usually those are the places where fields are located. This result stood out even more, when the *distance from the nearest waterway* (W) was added to the equation, i.e. K = E*S*L*W (Figure 39). The fields close to streams stood out Fmore clearly. This is seen in Figure 39, where all the fields are coloured (also those with no risk). According to the results, land use type and slope steepness have a greater impact on the erosion risk than soil type.

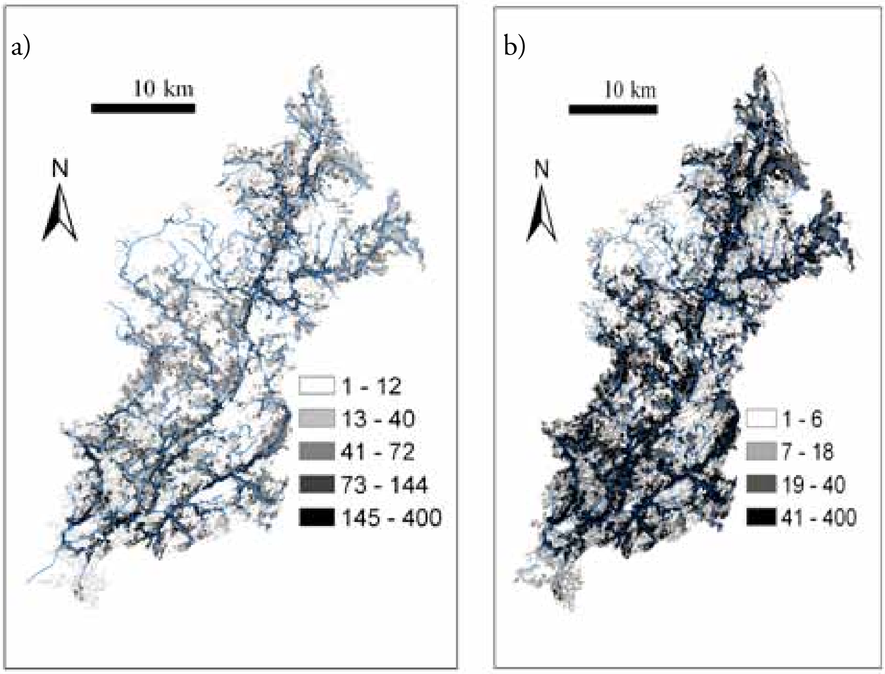


Figure 38. The erosion risk (K) =E*S*L classified in two ways: a) based on natural jenks b) based on quantiles.

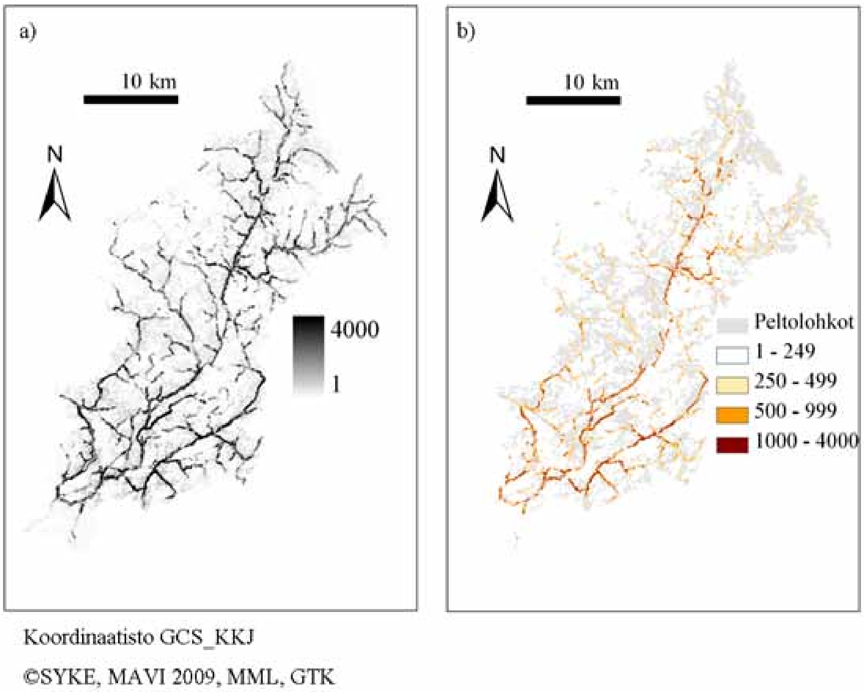


Figure 39. The erosion risk (K) =E*S*L*W scaled in two ways: a) Stretched based on standard deviation and b) manually divided to four classes. In Figure 41b, the fields with lowest risk category are also coloured.

Räsänen (2010) also added *manure application as fertiliser* (M) to his risk assessment. Since the amount and location of manure application is not known, it was estimated based on the location of the animal farms and their livestock numbers. The animal numbers were converted to nutrients based on the guidelines of the Ministry of the Environment (Ympäristöministeriö 2009). The field area where the manure might have been spread was calculated based on the restrictions of Ympäristöministeriö (2009), which permit the spreading of a maximum of 20 kg/ha/year of plant-available P. Here, it is presumed that 85% of the P in manure is plant available. Räsänen approximated the manure fields by creating zones of a certain distance around each farm by using the ArcGIS Buffer tool. Since it was not certain how much the manure application affects the nutrient loading, Räsänen tested two M factors, 3 and 7, for the fields under probable manure application (Figure 40). Neither the timing of manure application nor the P status of the fields could be taken into account. When the M factor is 7, the risk of the manure fields naturally stands out more.

Räsänen (2010) also studied hydrological risks in the Aurajoki river basin by forecasting flooded and waterlogged areas and by further modelling these with a topographic index. In addition, the risks for both surface and ground waters were studied based on the hydraulic conductivity of the soil. The more accurate DEM (based on Lidar data) was available only for the sub-basin of Aurajoki (a tributary river called Savijoki), and therefore the flooding analysis was only done for that part. First, a layer of vertical distance from land to the nearest stream was calculated. Next, another layer was created to show the potential of the soil to accumulate water. This was done to decrease the risk- weighting factor of upstream areas and increase the risk-weighting factor downstream. This layer of "the water accumulation potential" was decreased from the vertical distance layer to make it possible to forecast the change in the water level in metres and to see which fields are flooded when the water rises to a certain level. Another way to approach hydrological risks is to calculate a topographic index that shows where the water accumulates when the soil is saturated. Räsänen ignored the soil type by assuming that the soil is always fully saturated. If the soil is not saturated, the index gives an estimate of which areas will be the first to saturate. In Aurajoki, these easily waterlogged areas were located mostly in the forested areas further away from the streams. Only in the upper reaches of the Savijoki catchment were there fields at a higher risk of becoming waterlogged.

Räsänen (2010) extended the hydrological risk assessment to ground water and leaching risk by evaluating the ability of soil to penetrate water. In Savijoki, some of the ground water areas had soils that easily penetrate water. Some of these soils were located in field areas that had a high topographic index, so there exists some risk of agriculture-induced groundwater contamination in Savijoki.

Only recently, new data on animal farms and soil P statuses have become available for research in Finland (See Chapter 2.5.1). Thus, the risk assessment in Aurajoki could be developed further to also take this information into account in more detail.

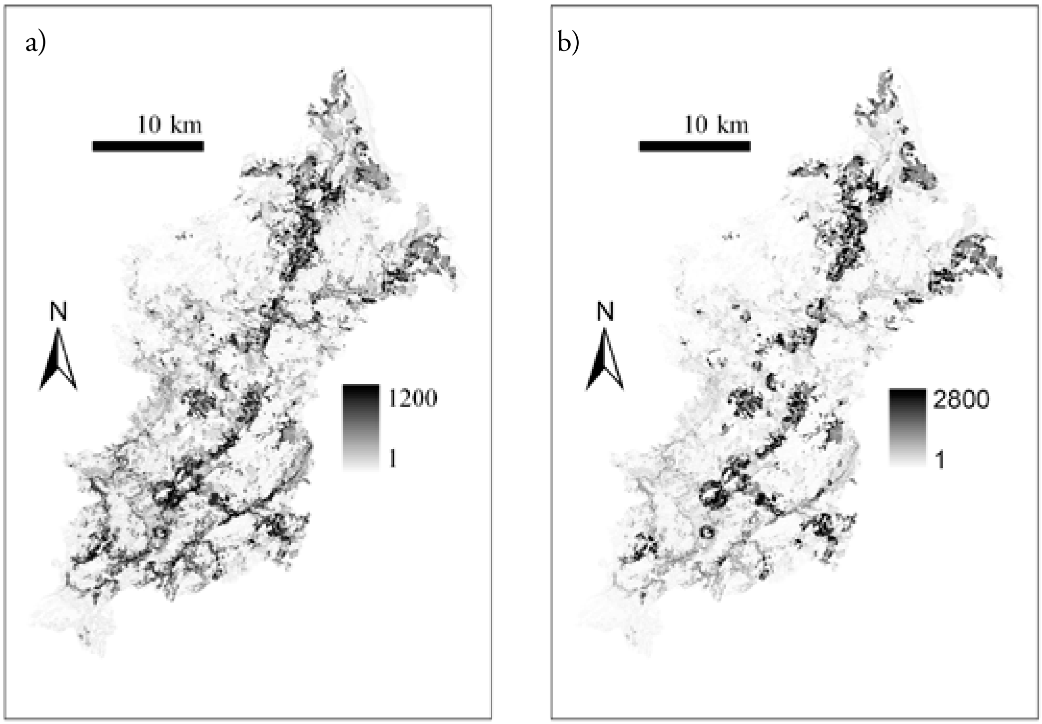


Figure 40. Phosphorus risk calculated as K=E*S*L*M, and by using two different M factors: a) 3 and b) 7. Both figures are scaled and stretched based on standard deviation.

4.5 Measures to reduce erosion and P risk

Typically the mitigation measures decreasing the runoff of solid matter and nutrients from field cultivation can be divided into measures taken (i) on the field, (ii) at the edge of the field and (iii) outside the field. As for the measures taken on the fields, fertilisation levels of P and N have decreased significantly in recent years in all BSR countries. At the same time the total area ploughed in autumn has decreased as it has been replaced by reduced tillage and direct sowing systems. This has been shown to reduce especially erosion and particulate P runoff but also the runoff of total N. The problems related to dissolved P runoff, especially from fields with soils rich in P, still call for separate solutions, e.g. reducing the overall P content of fields.

The reduction in nutrient load achieved by buffer zones depends not only on the extent of the measure itself but also on the other, on-field measures implemented on the portion of the field remaining in cultivation. The efficiency of wetlands depends on how much field area is included in the upstream catchment area and the size of the wetland area in relation to the catchment area. In Finland, both of these factors were set as criteria for wetlands to be eligible for agri-environmental subsidy; at least 20% of the upstream catchment must be in agricultural use, and the wetland area must be at least 0.5% of the upstream catchment´s area.The total effect of wetlands and buffer zones is less than that of the measures taken on the fields. However, wetlands and buffer zones bring ancillary benefits like increased biodiversity and enlivened rural landscape.

According to the P index concept, those areas where source and transport factors overlap should be addressed first in mitigation efforts. In any case, it can be argued that appropriate measures might be different for different fields; erosion protection and prevention of surface runoff (e.g. buffer strips, no tillage, catch crops, different liming methods) might be more suitable for hotspots identified by erosion modeling whereas adjusted P fertilisation management (i.e. no manure or fertilizer additions) most suitable for fields with high soil P status.

4.6 Measures to reduce biosecurity risks

Measures to reduce biosecurity risks are linked to the indicators mentioned above. Reducing the pathogen load in animal herds will reduce the risk of spread from those herds. This can be achieved by biosecurity practices that reduce the risk of pathogen introduction to the farm and the separation of different animal categories on the farm so as to reduce the risk of within-farm spread of pathogens. Other animal husbandry routines that affect the overall health of the animals may reduce the risk by making the animals less susceptible to infection and thus less prone to high shedding of pathogens. Manure handling practices affect the risk of pathogen transmission from the manure by influencing pathogen survival and persistence as well as leakage into the environment.

Proper storage of manure reduces the risk of manure leakage, and mainly depending on time and temperature, storage may also result in inactivation of pathogens (e.g. Guan and Holley 2003, Meals and Braun 2006). For liquid cattle manure, a storage time of 90 days at 25 °C is expected to reduce the major bacterial and protozoan pathogens to acceptable levels (Guan and Holley 2003). A more controlled inactivation of pathogens can be achieved by manure treatment such as composting of solid manure, thermophilic anaerobic digestion and disinfection with urea or lime (Albihn et al. 2012). However, manure treatment is a costly investment and may not be justifiable in a normal situation, but could be considered in high-risk areas and should be implemented after an outbreak is detected (Epizootic Act SFS 1999:657). Sufficient capacity for manure storage also makes it possible to avoid application of manure during high-risk periods, e.g. when lands are frozen or water-saturated, which is an important measure to reduce both nutrient and pathogen losses from agriculture (Salomon and Sundberg 2012). Another important measure is delay between manure application and rainfall and runoff. A 50% reduction of *E. coli* in runoff can be achieved by application 3 days before rainfall instead of 1 day before (Meals and Braun 2006). In potential biosecurity high-risk areas, measures that reduce the risk of surface runoff to watercourses, such as incorporation/ injection of manure, and construction of buffer zones, can reduce the risk of pathogen leakage (Larsen et al 1994, Coyne et al. 1995, Hutchison et al. 2004). For a more detailed discussion on measures to reduce biosecurity risks see Salomon and Sundberg (2012).

5 Discussion & conclusions

In this study, erosion- and nutrient-vulnerable areas mean areas from which substantial quantities of solids and phosphorus (P) can leach. The methods presented in the report are based on USLE equation or P-index-based assessments. Moreover, the use of leaching models in the risk area inventories is briefly discussed.

Erosion risk maps are produced mostly with USLE based methods, which are also suitable for mapping areas at risk of P leaching. In USLE-maps, the risk areas are mainly located on steeply sloped fields. However, if the calculation takes into account the distance to water and if the channel map is accurate, also fields further away from the water bodies can be classified as risk areas. Meanwhile, when topographic mapping is used as the index calculation methodology, flat areas will be classified as risk areas because this method puts weight on gentle slopes with fairly large catchment areas above them. The third option is based on physical GIS-based models, which can model simultaneously hydrology and nutrient transport. In general, these models require a lot of input data and in lack of them the possibility of erroneous results increases. In some models (e.g. SWAT; Arnold et al. 1998) sediment transport is calculated using modified USLE method.

While most of the runoff discharged into water bodies typically originates from forest areas, the bulk of nutrients and suspended solids transported by the runoff usually come from agricultural areas. Agricultural areas are often located near water bodies and are efficiently drained, which makes significant changes to the runoff mechanisms of the original, natural state of the area. Drainage systems, such as subsurface and open drainage effectively link the cultivated fields to water, allowing rapid movements of water and nutrients into the surface waters. Subsurface drainage has many benefits in cultivation and is more commonly used than open drainage. In terms of water pollution, this division between surface runoff and subsurface drainage is indeed noteworthy. Unfortunately, the ability of the models to describe the distribution of runoff into these two flow paths is inadequate due to the lack of input data. USLE describes the high risk areas mostly by surface processes, and so the transport of solids and P through soil matrix and via the macropores is ignored in USLE examinations. Therefore, e.g. the method used in Denmark is preferable, because it accounts for the soil and nutrient transport carried by both surface runoff and subsurface drainage and thus the risk areas can be mapped more diversely and reliably.

The P-index is often considered to be a cost-effective tool to reduce P leaching. This empirical model emphasises different risk parameters to form a combined risk factor number (P-index), which can be used as a guiding factor when selecting practices and policies that reduce P leaching at both field and catchment level. The first P-index was developed in the United States in the 1990s and the P-index has been subsequently developed, inter alia, by Nordic researchers. For example, in Denmark a P-index has been tested in practice in cooperation with the farm advisory service. Farmers and their advisers are apparently satisfied with the tool, while the authorities are hesitant, probably because they fear the costs of its enforcement. The index tool is web-based, consisting of pre-calculated P-index maps covering the whole of Denmark as well as P mitigation planning tools. The major challenges are lack of data (mainly on soil P status), and uncertainties and the need for additional validation of the model. Furthermore, it requires some practice by the user to interpret the P-index results.

A P-index has also been developed in Norway, and it is used voluntarily by farmers and their advisers. This online tool has a simple and effective structure and a user-friendly interface. It has been shown to be useful in practice. Farmers and their advisers can test the effects on the P-index calculation of different management practices. In Sweden a P-index has been developed and tested in practice, but it has not yet been implemented in agricultural practices. The index is advanced and it requires a relatively large amount of data and the installation of special software on one's computer. The Swedish regulation on maximum animal density is, in combination with the flat-rate P norm, acknowledged within the research community as a very effective way to avoid high P surpluses. In Finland, indexes are used in some research projects but not yet widely outside the pilot areas. However, researchers have, through modelling and research on erosion, gained experience and competence in assessing risks for P losses and their mechanisms. This experience in combination with a good understanding of the effects of mitigation measures forms valuable bases for developing P-indices in Finland. In other Baltic Sea Region countries the systematic identification of erosion- or nutrient-vulnerable areas is still in embryo.

A large part of the area of agricultural P loading comes from not only the current level of fertilisation, but also, particularly in some countries, from the history of fertilisation. In addition to manure and mineral fertilisers, key sources of P risk are the same factors that apply to solid matter transport, i.e. soil type, slope, plant cover and the distance from the nearest water body. Livestock density, i.e. the number of animals per area, is used in many countries as an explanation for the risk of nutrient leaching. Number of animals is in itself an unambiguous indicator (livestock unit) but the other term, the area, can be based of several different options such as (i) the total agricultural land area, (ii) the agricultural area owned by farms with animal husbandry or even (iii) the entire examined area. As a result, the density figures presented by different countries are usually not directly comparable. In general, it can also be argued that animal husbandry and related traditional manure application according to guidelines does not necessarily cause a greater P risk than the use of an equivalent amount of mineral fertilisers. Over-fertilisation may occur if the number of livestock units is high and the field area for manure application is small. Although several studies have found that the amount of fertiliser application itself is important as a P risk factor, in most of the Baltic Sea basin countries, even these data are available only as the amount of fertilisers sold in a municipality or larger region, not as the amount applied in field plots (kg/ha). However, in some countries more detailed information may be available in a few research areas in which the information has been collected directly from farmers. Generally, this information is not freely available, and often fertiliser limits and recommendations are the only source for determining fertiliser applications per hectare.

Possibilities of the Baltic Sea basin countries to identify the suspended solids and nutrient loads from erosion- and nutrient-vulnerable areas vary widely, mainly due to the differences in basic background data required for the inventories. Risk assessments are usually made at the municipal or catchment level, depending on which regional level the statistical data are available. In some countries these examinations have encompassed even larger administrative district levels. These examinations generally do not take weather variations into account, a factor that plays a central role in the formation of erosion and P loading. In addition, the differences in the soil classification systems and accuracy of the data needed for the mapping prevent uniform assessments and comparisons between the countries. These differences may be related to factors such as calculation methods or risk coefficients. In addition, the accuracy of the existing risk maps is difficult to verify with water quality observations, since the observations are scarce, especially from individual risk spots, such as arable plots. Overall, making conclusions on the basis of water quality data is difficult and very uncertain.

As an outcome of various risk assessments, the river basins or municipalities with high nutrient leaching risk can usually be identified. For more detailed mapping, the necessary country-wide data are barely available; as the best example one can mention the material available in Sweden and in Denmark. During the Baltic Compass project, progress has been made e.g. in Belarus, where the project collected detailed information from large livestock farms by means of a questionnaire survey. With more accurate map-based material, it may be possible in the future to identify the field parcels that pose the highest loading risk. One can rightly ask what is the benefit of locating the critical areas, as measures targeted only at those areas are not likely to be enough to restore the quality of waters to a good level. This kind of targeting is important, however, because not all of the recommendations can be implemented at one time due to inadequacy of financial resources. Thus, it makes sense to target measures primarily at those areas where nutrient loading is high.

The selected measures should mainly be scheduled for the period when most of the nutrient runoff occurs. Efficient targeting requires the identification of erosion- and nutrient-vulnerable areas which may be either field plots, individual catchments or complete river basins. This means that targeting of measures can involve either the implementation of measures in fields with the highest loading potential, simultaneous implementation of effective measures in catchments or implementation of wide-ranging water protection programmess in large river basins. There are clear viewpoint differences between these and they also differ when it comes to coordinating the planning and implementation of these measures. Examples include the farm-level implementation of agri-environmental mitigation measures, recycling of nutrients in the catchments discharging into the Archipelago Sea and WFD water protection programmes in large river basins. Key areas in solid matter transport and nutrient runoff are steep-sloped fields and fields that flood repeatedly. Fields with high soil P content and peat soil are also risk areas. The distance of the field parcel from a water body, the soil type of the field and the level of vegetative cover are also risk factors. Steep fields result in solid matter and particulate phosphorus transport, whereas flooding-vulnerable fields and peat land fields create dissolved phosphorus and nitrate-nitrogen leaching. A more accurate elevation model and more source information about the P content of the soil, the manure spreading areas and the vegetative cover outside the growing season would improve the reliability of risk assessment.

Healthy animals need less antibiotic treatment and produce more. Measures that improve animal health are beneficial for the farmer as well as for biosecurity. High animal density is associated with higher disease prevalence in the animal population and, consequently, the risk of transmission of infectious agents from the animals to the environment. Manure management is also crucial for biosecurity risks. Lack of or insufficient storage of manure will increase the risk of pathogen spread to the environment. Factors that increase erosion and surface runoff of nutrients may also increase the risk of pathogen spread via the runoff. Hence, areas with high animal density and high risk of surface runoff or erosion are also potential high-risk areas as regards biosecurity. Such areas can be identified by projecting the respective map layers on top of each other.

Risk factors for nutrient and pathogen leaching include improper or insufficient storage of manure (e.g. leaking tanks, too small tanks, leaking manure heaps, no or short storage time) and handling of manure (e.g. application time, place, techniques and amounts). To achieve better control of these factors, they may be included in the activity licence, and thus become objectives for inspection and control on a yearly (or longer time) basis.

Public and animal health is poorly protected in laws and directives on surface and ground water, one example being the Water Framework Directive (2000/60/EC) of the EU (WFD) stating the minimum standards for the chemical and ecological status of the water. However, from a microbiological point of view (faecal contamination), it appears in the Bathing Water Directive (2006/7/EC). One advantage of the WFD approach is that it rationalises the EU's water legislation by replacing directives on surface water, fish water, shellfish water, groundwater and the directive on discharges of dangerous substances. An inclusion of the bathing water directive to state a minimum level for "good microbiological status" would protect waters everywhere, not only where humans may be exposed when bathing at public beaches. Until this is a reality, we suggest that nations include a microbiological parameter (e.g. faecal indicator) in their own implementation of the WFD for the monitoring, classification and management of water quality, and provide more information on water quality to the public. The cost of an analysis package for enumeration of total coliforms (35 °C), *E. coli* and intestinal enterococci is < €50.

6 End-users view

From the end-user's point of view, the central issues in presenting the risk areas are accuracy, objectivity and clarity. It would be particularly important for decision-making that the nutrient-sensitive areas presented in the maps would be in right places. Similarly, in targeting the mitigation measures, accurate risk area maps, which unfortunately cannot yet be produced with the presently available material, would be needed. From the farmers' point of view, it is essential that individual farmers are not labelled, but that the high-risk fields are shown as objectively as possible. The main thing would be to give personal advice to the farmer himself on the location of the high-risk fields. At the same time, possible mitigation measures to reduce risks in the problematic areas could be presented.

It is already evident that in the future environmental support will be allocated more in the areas where the solids and nutrient loading risks are great. This raises the question of whether the selection of risk areas will be made at the regional, local, sub-regional or state level. On the basis of this report, the current available data are not yet sufficient for making farm-level reviews in any of the Baltic Sea basin countries with the exception of Denmark. Therefore, it would now be important to increase resources for the improvement of the availability and quality of the materials, and at the same time to produce maps with the currently available material to serve as the basis of wide-ranging debate. Risk area maps could be presented to various stakeholders and in addition the accuracy of maps could be examined by means such as questionnaires.

Raising all stakeholders (advisory workers, farmers, water authorities) awareness and participation in the development of mitigation strategy at field, farm and even catchment level might be a cost-efficient way to reduce losses. To achieve that, scientific evidence regarding reliability of the produced risk maps ("know-why") is important but better communication between stakeholders and in particular the participation of farmers and utilising their experience ("know-how") in the discussions, will be decisive for the success of mitigation efforts.

When better data are available, the risk areas can be mapped at the field-block level. Field block-level mapping requires knowledge of farming practices, soil P status, quality of soil, etc. In many countries, the necessary data needed for risk mapping are available only at the municipal or higher administrative area level. It would be important to ensure the availability of more accurate, smaller-scale data for the use of researchers and designers. For instance, in many countries, the field-block level data are subject to a licence and their use is limited. As an example of this, the soil P status data – the main factor for P leaching – could be mentioned.

Project information
Baltic Compass is a pan-Baltic EU-financed project where the 22 partners from all the riparian countries share their practical and scientific knowledge concerning agriculture and the environment. Baltic Compass has a broad approach to addressing the agri-environmental challenges, covering agricultural best practices, investment support and technologies, water assessment and scenarios, and policy and governance issues. More about the project and results can be found in www.balticcompass.org.

This report and its GIS-maps will be available for download in www.balticcompass.org and www.mtt.fi/mttraportti/pdf/mttraportti65.pdf.

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8 Appendices

Appendix 1. The availability of digital elevation models in the BSR countries.

Country	Grid resolution or pixel size	Vertical resolution	Coordinate system	Geometry type	Comments	Areal coverage 2011 (%)	Original source
Finland	25 x 25 m, 10 x 10 m, 2 x 2 m	2 m, 1.4 m, 0.3m	UTM 35 (Euref Fin)	Raster	2 m is Lidar-based	25m = 100, 10 m = 100 %, 2m = 34%	Contours, Lidar
Sweden	50 x 50 m; 2 x 2 m	±2m; ±0.5 m	RT 90; SWEREF 99	Raster	2 m is Lidar-based	50m = 100, 2m = ongoing, in Dec 2011 approx. 2 million km^2 finished	
Denmark	1.6 x 1.6 m	0.1 m	Horiz: ETRS89, UTM zone 32N Vert: EPSG: 5799	Raster	Lidar-based	100%	Lidar
Estonia	5x5 m	no model, only raw data, 1-2m	L-Est97(EUREF89) EPSG:3301	Raster	Lidar-based (different pixel size models released during the 2012)	Ongoing, one circle is completed (new flights to begin in spring 2012)	
Lithuania	10 x 10 m, 2 x 2 m	?	LKS 94	Raster	2 m is Lidar-based		
Poland	25 x 25m	±1-1.5m	PUWG 1992 (Vertical:Kronsztad)	TIN, Raster	1m x 1m Lidar will be available from 2013 only for flood-prone areas (approx. 44% of the country)	25m =100%, Lidar ongoing	
Germany	SH: 1 x1 m (or lower resolution)	0.15-0.25 m for DEM1	GK3(DHDN) or UTM32(ETRS89)	Raster	DEM1: Airborne Laser scanning		
Latvia							
Belarus	25 x 25 m		Pulkovo 1942 GK5	Raster	ASTER DEM2, SRTM 90 m		
Russia							
Whole BSR	100 x 100 m	16 m	WGS-84	Raster	SRTM below 60 latitude	100	SRTM, Contours

Appendix 2. Agricultural GIS data in each BSR country.

Country	Farm scale (high resolution)	Corine 2006 (low resolution)	Comments	Statistics for governmental units (please specify level, e.g. municipality)
Finland	x	x	The field plot register (i.e. "identification system of the fields") is a nationwide register, in which all the field plots that have received area-based subsidies are digitised. The field plot register is owned by the Agency for Rural Affairs (Mavi)	Municipality level
Sweden	x	x	High-resolution data exist for so-called agricultural "blocks". There are about 1.2 million blocks with average area of 2.95 ha and 1.3 parcels per block. Crop distribution exists for each block but it is not spatially distributed within a certain block.	Nation-wide, block data base is administered by the Swedish Board of Agriculture
Denmark				
Estonia	x	x	Land parcel and identification register LPIS, owner Agricultural Registers and Information Board (ARIB), about 1.2 million ha	
Lithuania	X	X	The field plot register (i.e. "identification system of the fields") is a nationwide register, in which all the field plots that have received area-based subsidies are digitised. The field plot register is owned by the Ministry of Agriculture	Municipality level
Poland	X	X	The agricultural identification system of the fields, buildings, animals (IACS) in which all the field plots that have received area-based subsidies are digitised. Owned by the Ministry of Agriculture (ARiMR).	Municipality (gmina) level - General census of Agriculture (Powszechny Spis Rolny)
Germany	SH: x (BasisDLM Vegetation)	SH: x		
Latvia				
Belarus	-	Territory of Belarus not covered	Land Cadaster System for every land owner (1:10 000 scale), also paper map for every municipal level	Raion and municipal level
Russia				

Appendix 3. Analyzing methods for plant available P in the BSR countries.

Country	**Method**	**Description**	**References**	**GIS data yes/no & comment**
Finland	Ammonium acetate	In the acid ammonium acetate extraction, 5 g air-dry soil is shaken end-over-end (37 rpm) with 250 ml of 0.5 M ammoniumacetate (pH 4.65) solution for 1 hour. Then the suspension is passed through a S&S 589 blue ribbon paper and the filtrate analysed for P using stannous chloride reduction of the phosphomolybdate complex.	Uusitalo, R., Jansson, H. 2002. Dissolved reactive phosphorus in runoff assessed by soil extraction with an acetate buffer. Agricultural and Food Science in Finland 11, 4: 343-353. Saarela, I. 2002. Phosphorus in Finnish soils in the 1900s with particular reference to the acid ammonium acetate soil test. Agricultural and Food Science in Finland 11, 4: 257-271.	Yes, but does not cover all field plots. Data is owned by farmers and requires a permission for usage.
Sweden	Ammonium lactate/acetic acid	In the acid ammonium lactate (AL) extraction, 5.0 ± 0.1 g air-dry soil is shaken (35 rpm) with 100 ml of ammonium lactate (pH 3.75) solution for 90 minutes. Then the suspension is passed through a filter paper and the filtrate analysed for P using either the molybdate method or inductively coupled plasma (ICP).	Egnér, H., Riehm, H., Domingo, W.R. 1960. Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nährstoffzustandes der Böden. II. Chemische Extraktionsmethoden zur Phosphor- und Kaliumbestimmung. (In German.) Kungliga Landbrukshögskolans Annaler, 26, 199-215. Svensk Standard SS028310. 1995. Soil analysis - Extraction and determination of phosphorous, potassium, calcium, magnesium and sodium from soils with ammonium lactate/acetic acid solution.	Yes, approximately 5163 points are collected and analysed in the Swedish environmental monitoring programme on arable soils with regard to organic matter content, acid/base status and potassium, phosphorus and trace element concentrations. Farmers own their own data.
Denmark	Sodium bicarbonate extraction (Olsen P)	With the Olsen method, phosphorus is extracted with a 0.5M $NaHCO_3$ solution adjusted to pH of 8.5. The soil suspension (at a ratio of 1:20 weight by volume) is shaken end-over-end for exactly 30 minutes and then filtered. Phosphorus is measured using a spectrophotometer measuring the blue colour developed from a complex between orthophosphate and ammonium molybdate in a sulfuric acid solution after addition of ascorbic acid.	Sørensen, N.K., Bülow-Olsen, A. (eds) 1994. Fælles arbejdsmetoder for jordbundsanalyser (Sørensen N.K., Bülow-Olsen, A., eds.) Plantedirektoratet, Landbrugsministeriet. Banderis, A., Barter, D.D., Henderson, K. 1976. The use of polyacrylamide to replace carbon in the determination of ”Olsen’s” extractable phosphate in soil. Journal of Soil Science 27:71-74. Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular 939, United States Department of Agriculture, Washington DC.	No public GIS data available. Each year more than 50,000 analyses are made for the farmers on agricultural soils, which presumably mostly are GEO-referenced, but these data are private property.
Estonia	Mehlich 3	In the Mehlich 3 extraction (0.2M CH_3COOH, 0.25 M NH_4NO_3, 0.015 M NH_4F, 0.013 M HNO_3 and 0.001 M EDTA), 5 g air-dry soil is shaken (180 osc/min) with 50 ml extraction solution for 10 minutes. The suspension is then passed through a filter paper (Whatman 42) and the filtrate analysed for P using either molybdate method or ICP (l(P)= 213.6 nm).	Carter, M.R. 1993. "Soil Sampling and Methods of Analysis" Canadian Society of Soil Science p.43-48.	Yes, during 5 years collected and analysed about 110 000 soil samples (about 500000 ha). Data saved in a GIS database and printed paper maps for farmers

Country	Method	Description	References	GIS data yes/no & comment
Lithuania	Egner-Riehm-Domingo (A-L)	Method is based on the use of mixture of acetate – lactate acids, buffered with ammonium acetate to pH 3.7. Soil sample and solution ratio 1:20. Dry soil samples are homogenised and then extracted using a 0.1M acetate-lactate solution. The mixture is agitated for 2 hours and filtrated immediately afterwards. P_2O_5 concentration in extraction is determined spectrophotometrically, using a colouring solution, wavelength 620 nm. Content of P_2O_5 is expressed in mg kg^{-1} of soil.	Egnér, H., Riehm, H., Domingo, W.R. 1960. Untersuchungen über die chemische bodenanalyse als grundlage für die beurteilung des nährstoffzustandes der boden. II. Chemische extraktionsmethoden zur phosphor- und kaliumbestimmung. Uppsala.	Yes. Data are in private ownership.
Poland	Egner-Riehm	Only content of P_2O_5 is expressed in mg kg^{-1} of soil. Additionally P_2O_4 in groundwater is being measured.	PN-R-04023:1996, Polish research on the way to the EU (http://books.google.pl/books?id=8vWsJYUa4rgC&pg=PA413&lpg=PA413&dq=PN-R-04023+references&source=bl&ots=fpEHI_OYen&sig=7Hh3IAW0v8p0c4VjRUKTmjOy40A&hl=pl&sa=X&ei=zY5pT9WnJeHb4QSe38GFCQ&ved=0CFcQ6AEwBg#v=onepage&q=PN-R-04023%20references&f=false)	No. Only table format with name of village. Polish law prohibits the administration of the exact location of research on private land.
Germany	X-ray fluorecence analysis (total contents), aqua regia extraction (total contents), lactate extraction (for plants available P)	In general the following methods are described in the literature cited under references: a) X-ray fluorecence analysis (total contents), b) hydrofluoric and perchloric acid extraction (total contents), c) aqua regia extraction (total contents) d) Ammonium acetate extraction (soluble part).	Reimann, C., Siewers, U., Taravien, T., Bityukova, L., Eriksson, J., Gilucis, A., Greogorauskine, V., Lukashev, V., Matanian, N., Pasieczna, A. 2003. Agricultural Soils in Northern Europe: A Geochemical Atlas. Geologisches Jahrbuch, Sonderheft, Reihe D, Heft SD5.	Data are available with full coordinates (7 digits). Data on plant available P have a high data density, but are limited to small areas only (according to the farmer´s projects). General soil P contents are available for the whole of Schleswig-Holstein.
Latvia				
Belarus	Kirasanov	Mobile P_2O_5 was determined by extraction in 0.2 M HCl at a ratio l, followed by colorimetric and flame emission spectrophotometry (FES) methods, respectively.	Soils. Determination of mobile compounds of phosphorus and potassium by Kirsanov method modified by CINAO	Digital database used for the calculation of agrochemical balances for every agricultural enterprise. These samples are collected for different level (agricult. enterprises, raion, oblast). Data collected every 4-5 years - at the moment we have a high diversity, up to 10 times, of P indexes of arable soils among the fields of different farms

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