WAGENINGEN UNIVERSITY
ENVIRONMENTAL SCIENCES

ASSESSMENT OF THE DESIGNATION OF NITRATE VULNERALBLE ZONES IN POLAND

Alterra
Environmental Sciences
Wageningen University & Research Centre
Wageningen

ASSESSMENT OF THE DESIGNATION OF NITRATE VULNERALBLE ZONES IN POLAND

Contract 2006/441164/MAR/B1
Implementation of the Nitrates Directive (91/676/EEC)
Task 3

Alterra
Environmental Sciences
Wageningen University & Research Centre

Wageningen, November 2007

Administrative summary

CONTRACT for Outsourcing of technical and administrative assistance:
2006/441164/MAR/B1, FIRST RENEWAL YEAR 2006

Co-ordinating institution:
Alterra
BV (Besloten Vennootschap)
09113175 Centraal Gelderland
P.O. Box 47; NL-6700 AA Wageningen, The Netherlands
VAT number: NL811383696B03

Person that signed the contract on behalf of the consortium:
Prof. dr. W. van Vierssen, general director of Alterra

Person authorised to manage the contract:
Prof. dr. Oene Oenema

Contact information:
Alterra
Prof. Dr. Oene Oenema
P.O. Box 47; NL-6700 AA Wageningen, The Netherlands
Oene.Oenema@wur.nl

Contents

Executive summary

Background

The EU Nitrates Directive aims at reducing water pollution caused or induced by nitrate from agricultural sources and, further, at preventing such pollution. The Nitrates Directive obliges member states to take several actions, including '*the designation of areas in the territory of Member States that: a) drain into fresh surface waters and/or groundwater (Article 3, Annex 1) that contain, or could contain more than 50 mg/l nitrate if actions prescribed in the Nitrates Directive are not taken, and 'b) drain to water which are eutrophic or may become eutrophic if action are not taken*. These areas are called Nitrate Vulnerable Zones or NVZs.

Poland has become member of the EU by 2004. To comply with the Nitrates Directive, Poland has designated in 2004 a total of 21 areas in 6 regions as NVZs, on the basis on water monitoring data from 1990-2002. The total area of the NVZ is 6263 km^2, which comprises ~2% of the total area. The European Commission, DG Environment, has requested Alterra to review the existing designations on the basis of available data, including new evidences or updated monitoring data since the first designation in 2004 (CONTRACT 2006/441164/MAR/B1). This draft report briefly summarizes nitrogen (N) leaching pressure indicators, the monitoring results about the pollution of groundwater and surface waters by nitrates from agriculture, and the fact-findings about the designation of NVZs in Poland. The results of this study are based on literature studies, interviews and field visits.

Nitrate Vulnerable Zones must be designated on the basis of monitoring results that indicate that the groundwater and surface waters in these zones are or could be affected by nitrate pollution from agriculture. This obligation of the Nitrates Directive requires Member States to monitor the nitrate concentrations in groundwater and surface waters.

Agriculture in Poland is a main source for the leaching of nitrates to groundwater and surface waters. Municipalities and households are also major local and regional sources of nutrient enrichment of groundwater and surface waters. Currently, slightly more than 55% of the households are connected to sewage treatment plants, suggesting that 45% of the households directly discharges their sewage to surface waters. Moreover, a large number of people live in villages in rural areas and can be considered as diffuse sources of nutrients through direct discharges of sewage into surface waters.

Because of the presence of different nutrient sources, spatially detailed information about agricultural pressure data are needed to be able to assess whether groundwater and surface waters are affected by nitrates from agricultural sources. Without accurate nitrogen source apportion, no effective remedial measures can be undertaken. Therefore, considerable efforts have been made in this study to collect agricultural pressure data, apart from groundwater and surface water quality data.

Pressure indicators

Total nitrogen (N) loading per unit of surface area via fertilizers and animal manure is an important indicator of nitrate leaching losses, but the amount of nitrate leached ultimately depends also on the withdrawal of N with harvested crop and N losses via ammonia volatilization and denitrification. The latter two processes are heavily influenced by soil type, hydrology and climate. Hence, the assessment of pollution of groundwater and surface waters by nitrates from agriculture requires the analysis of pressures resulting from N from agricultural sources on the basis of farming systems, livestock density and productivity, fertilizer use, soil type and hydrology, and climate, per region.

Following the political changes by the end of the 1980s and the beginning of the 1990s, livestock density and fertilizer N use have decreased. Livestock density has continued to decrease since then, but mean N fertilizer use has started to increase slightly again from 1991/1992 onwards, to a mean of 56 kg per ha per year in 2004. At NUTS-2 level (at the level of voivodships), fertilizer N use and livestock density are rather homogenously distributed over the country, but a few hot spots can be found at country level, with more than 2 LSU per ha. Mean N surpluses (total N input minus total N output via harvested crops) have remained rather stable during the last ten years at a level of on average 75 kg per ha per year, and are rather homogenously distributed over the country. Surpluses of N are slightly higher on the more productive soils in the north-west half of Poland compared to the low-productive sandy soils in the south-west part of the country.

Agriculture in Poland is in transition. Current farm size distribution shows a bi-modal or tri-modal frequency distribution, depending on the statistical data base. More than half of the total number of farms has less than 2-3 ha of agricultural land currently. These farms are managed by subsistence farmers, part-time farmers and/or hobby farmers. In general, these 'farmers' have a low level of education and the management is relatively poor. The second peak in the frequency distribution is made by farms in the size category of 5 to 30 ha. These are private farmers that feel the pressure to produce more and to lower the cost through up-scaling, specialization and intensification, to be able to compete in the globalizing market. Some of these farmers are well-educated and manage their farms well, but a significant fraction of the farmers in this group is not well-educated and the management on these farms is relatively poor. The third peak in the frequency distribution is made by farms in the size category of >100 ha and often > 1000 ha. These are co-operate farms and former state-own farms. In theory, these farms have the best possibilities to compete in the globalizing market, because of the large farm size and also because most of these farms are situated on the relatively good soils. The farmers on these farms are well-educated.

Most farms in Poland are mixed farms, i.e. have a crop production component and an animal production component. The crops produced are fed to the animals and the animal products (milk, meat and eggs) are sold to the market. There are also specialized crop production farms, i.e., farms that produce only crops (cereals, potatoes, rape seed, vegetables), but there are only very few specialized livestock farms. Hence, livestock is predominantly kept on mixed farming systems, and the livestock is mainly fed with farm-produced animal feed. Livestock density on these farms is therefore a function of crop production level; the higher the crop yields, the higher the livestock density. Recently, some specialized hog farms have been established by companies from Western European countries, and here the livestock is fed to a large extent through animal feed from elsewhere. These farms have high livestock density and may have problems with proper manure disposal. However, the number of such specialized livestock farms is still small.

Summarizing, the mean pressure of agriculture on the environment is less in Poland than in the EU-27. The indicators livestock density, fertilizer use and N surpluses are on average lower in Polish agriculture than in EU-27 agriculture. Moreover, the spatial distribution of livestock density, fertilizer use and N surpluses are rather evenly over the country, though agriculture is most intensive and productive in the western half of the country.

Point sources and diffuse sources of pollution
Within most mixed farming systems in Poland, a distinction can be made between point sources of nitrate pollution and diffuse sources of nitrate pollution. On specialized crop production farms, there are essentially only diffuse source of nitrate pollution.

Many barns, farm-yards, and manure heaps can be considered as 'point sources' of nitrate pollutions, as 'micro hot spots'. Our study suggests that these point sources are relatively important. Various studies have been made at farm level, but no attempt has been made to estimate the contribution of point sources at regional, provincial and national levels. Estimates by the model MITERRA-EUOPE suggests that leaching losses from farm-yards and manure heaps constitute up to 40% of the total leaching losses. Also, no publication has been found that quantitatively relates the nitrate leaching losses from farm-yards and manure heaps to farm size and farm structure. On average, small farms have less proper facilities for leak-tight housing of livestock and for leak-tight storing livestock manure than large farms. However, the large farms are often more intensive, with more productive animals that excrete more nitrogen per animal. It is reasonable to suggest that priority should be given at improving the housing of livestock and the storage of livestock manures on the large farms (>15 ha), because of cost-effectiveness and also because the small farms will likely merge into large farms in the near future.

Diffuse sources of nitrate leaching losses are agriculture fields. Poland has large areas of light-textured sandy soils, which are vulnerable to nitrate leaching (because of the relatively low production potential, drought sensitivity, and low denitrification potential). However, these soils are managed by small farmers and fertilizer input is rather low and therefore leaching losses are not excessively high. In contrast, the loam and clay soils in Poland are managed intensively by predominantly large farms. These soils have relatively good moisture and nutrient retention capacities, receive relatively high doses of fertilizer and livestock manure, and provide high crop yields. The visits to such farms learn that little account is being made of the N in applied animal manure, even though the farmers of large farms are well-educated and relatively good managers. As a consequence, nitrate leaching losses may be relatively high on the most productive soils, because of the incomplete account of the manure N applied.

The assessments made in this report suggest indeed that there are no *large* hot spots of nitrate pollution in Poland, as the regional distributions of livestock density and N fertilizer use is rather homogenous, while mean livestock density and mean fertilizer N use are both relatively low. On the other hand, many mixed farms can be considered as 'micro hot spots' of nitrate pollution (point sources), judged on the basis of studies about nitrate concentrations in groundwater wells near farm houses. There are still many animal manure storage systems that leak N (and other nutrients) to groundwater and surface waters. The remediation of such point sources of nitrate pollution should receive priority, because they are a burden for human health (through contaminated drinking water) and the environment. This is exaggerated by the nature of the soils in Poland; the light-textured soils are vulnerable to nitrate leaching loss. Further, the agricultural land in Poland is intersected by many streams and lakes and drainage ditches, especially in the northern half of the country. As a consequence there is an intricate relationship between agriculture and surface waters. Studies in the famous peat wetlands of the Biebrza National park in the eastern part of Poland show seasonal variations in nitrate and ammonia concentrations in the groundwater, and again high nitrate concentration in groundwater well near farm houses.

Nitrate concentrations in groundwater and surface waters
Results of the monitoring networks by the Regional Water Management Boards suggest that few surface waters sampling stations (<1%) have nitrate concentrations that exceed 50 mg per litre. However a significant number of surface water monitoring stations record values exceeding the criteria for eutrophication. Eutrophication is a significant issue in Polish lakes and in coastal and marine waters and river sections exceeding criteria for eutrophication are recorded overall in Poland.

Maps of the location of surface waters monitoring stations suggest that a relatively large number of stations are affected by (vulnerable to) N from agricultural sources. These stations seem to be distributed randomly throughout the country, i.e. everywhere in the country where there are surface water monitoring stations.

The percentage groundwater sampling stations with nitrate concentrations that exceed 50 mg per litre ranges from 2 to 20%, depending on the depth of sampling and the year. Especially shallow groundwater stations have a relatively large percentage of stations with more than 50 mg per litre. The number of stations with nitrate concentrations exceeding 50 mg per litre is decreasing over time, and the number of stations with nitrate concentrations less than 50 mg per litre is increasing over time. This indicates that the nitrate leaching losses have decreased during the last 10 years. This decrease may be related to improvements in farm management and the strong decrease in fertilizer use and livestock density following the political changes by the end of the 1980s and beginning of the 1990s.

Measurements of nitrate concentrations in the groundwater at various places at livestock farms suggest that leakages of N from stables, manure heaps and farm yards are major sources of N in groundwater and also surface waters The mean nitrate concentration of 342 groundwater samples taken close to manure heaps was 25 mg NO_3-N per litre (~ 110 mg NO_3 per litre), with a range of 0 to 312 mg NO_3-N per litre (~ 0 to ~1400 mg NO_3 per litre). This suggests that barns and manure storage systems are hot spots of nitrate pollution. Model calculations indicated that the N losses from barns and manure storage systems account as much as ~40% to the estimated total N leaching loss from agriculture in Poland. Though this estimate has a relatively large uncertainty and requires further underpinning through field surveys and experimental measurements, it is clear that leaching and run off of nutrient from barns and manure storage systems have a relatively large share in the total leaching loss. Various medium-sized and large livestock farms have made investments during the last decade so as to properly house livestock and store animal manure in leak-tight pits and silos. However, there is little quantitative information about the percentage of farms and the location of farms with proper manure storage and handling. It is also unclear to which extent the groundwater sampling stations of Regional Water Management Boards capture the influence of leaking livestock housings and farm-yard manure heaps.

Mean nitrate concentration of drainage water (from drainage pipes) range from 1 to 12 mg NO_3-N per litre (~ 5 to 50 mg NO_3 per litre). Highest nitrate concentrations were observed in the central areas around Warszawa. These relatively high nitrate concentrations in this area may reflect the effect of irrigation practices.

Modelling studies indicate that the mean N leaching losses range from 8 to 20 kg per ha per year. With a mean rainfall surplus of about 200 - 300 mm per year, these numbers suggest that the mean nitrate concentrations in the drainage waters are in the range of 10 to 40 mg per litre. The highest concentrations are predicted for Wielkopolskie, Kujawsko-Pomorskie, Lodzkie and Mazowieckie, i.e. the central provinces in Poland.

Assessment of the groundwater and surface water monitoring networks

The number of surface waters monitoring stations in Poland in 2005 was 2790 and the number of groundwater monitoring stations 858. With a total surface area of 312,685 km^2, these numbers translate into a density of 8.9 and 2.7 stations per 1000 km^2. Sampling frequency of the groundwater monitoring networks in Poland is once per year. Sampling frequency for surface waters ranges from 4 (once per season) to 12 (once per month) times per year. Surface water monitor stations do monitor the concentrations of N (often also P), but the monitoring of ecological indicators (chlorophyll-a, algal blooms, macrophytes and species shift) is limited.

The groundwater monitoring stations are rather evenly distributed over the country. This holds for the monitoring of the relatively deep groundwater as well as the monitoring of the relatively shallow groundwater. The spatial distribution of the surface water monitoring stations is less even; in some areas in the south and north conglomerations of monitoring stations can be found, while there are large areas in the eastern half and also in the north and west with very few monitoring stations (e.g. Figure 28, Chapter 11). Discussions with representatives of the Ministry of Environment Protection and with Regional Water Boards indicate that the monitoring of groundwater and surface waters is under evaluation and revision, based also on the results that have been obtained so far.

It is as yet unclear whether the official monitoring stations include sampling stations close to farm-yards and manure heaps; groundwater near these yards and heaps have high nitrate concentrations (e.g. Tables 20 and 21).

Based on the assessments, three recommendations for the monitoring networks have been formulated:

Recommendation 1*: In view of the relatively low density and uneven distribution of monitoring stations for shallow groundwater, and in view of its importance for underpinning the designation of NVZs, we recommend increasing the number of monitoring stations for shallow groundwater, especially in areas with large areas of utilized agricultural land. The stations should be positioned in such a way that they capture the influence of current agricultural practices as much as possible. Furthermore, the depth of groundwater monitoring, the frequency of sampling, and the extent to which the samples collected are considered to be representative (e.g. as a function of agricultural practices, flow or location in a river) should be indicated.*

Recommendation 2*: In view of the relatively low density and uneven distribution of monitoring stations for small streams and lakes, and in view of the likeliness that these surface waters are relatively strongly affected by nutrients from agricultural sources, we recommend reconsidering the distribution of monitoring stations for surface waters, especially in areas with large areas of utilized agricultural land. Again, the stations should be positioned in such a way that they capture the influence of current agricultural practices as much as possible.*

Recommendation 3*: In view of the regional execution of some of the water quality monitoring and complex organization and in view of the availability of additional information from various universities and research institutes, it is recommended to consider an extended search for so far 'hidden' information, and to use this additional information for a possible revision of the current monitoring program, including its organization).*

Assessment of the NVZs in Poland

Poland has designated a total of 21 areas in 6 regions as NVZ. The total area of the NVZ is 6263 km^2, equivalent to about 2% of the total surface area. The NVZs have been designated on the basis of data of the water monitoring data from 1990-2002 and information of local experts, but the decisions of the delineations have been made ultimately by the Ministry of Environment.

From the discussions with the representatives of the Ministry of Environment and Regional Water Boards, it has become clear that the borders of current NVZs follow the hydrological borders of catchments of rivers and streams (see also Table 1 and Figure 1). Only two NVZs are in part designated on the basis of sensitive groundwater[1] (Ground Water Basin GZWP 327 in the Wroclaw region and some groundwater bodies of Gliwice region). This indicates that the designation has been mainly based on the pollution of surface waters with nitrates from agriculture, as in the Plonia catchment (Figure 39; Chapter 12). Comparison of the locations of the NVZs with the maps with sensitive groundwater and surface waters[2] indicates that the designation of these NVZs has solid

[1] See main text, paragraph 10.1

grounds; most of the current NVZs have sensitive waters or are situated near sensitive waters (Figures 24 and 28).

However, a significant fraction of the shallow groundwater monitoring stations have nitrate concentrations exceeding 50 mg per liter (e.g. Figure 24, 26 and 27), but many of these stations are not situated in NVZs. The same holds for sensitive surface waters; very few catchments of sensitive surface waters are situated in NVZs (e.g. Figure 28). This suggests that there is room for improving the designation of NVZs in Poland.

The largest NVZ are in the western part of the country where the most productive soils and moist intensive agriculture is situated. This NVZ includes many surface waters that are qualified as sensitive to pollution by nitrates from agriculture (e.g. Figure 28). However, there is no clear relationship between the regional distribution of NVZs and the regional distributions of crops, N surpluses, livestock density, nitrate concentration in drainage waters and calculated N leaching losses on the other hand. For the NVZs in Wielkopolskie, which has the highest calculated leaching losses (e.g. Table 28, Chapter 12), there is a positive relationship with N pressure indicators livestock density and N surpluses. However, there are also other areas (counties) within Wielkopolskie and within neighbouring voivodships with a relatively high livestock density and a relatively high calculated leaching loss, but without NVZs. Similarly, the measured drainage water concentrations suggest that relatively high losses occur in central Poland (Figure 38) but no NVZs have been designated here. Further, the spatial distribution of sensitive surface waters (e.g. Figure 28) and locations of rivers and streams with relatively high nitrate, total N and total P concentrations (Figures 30 and 31) also indicate that there is room for improving the designation of NVZs.

The spatial distribution of N pressure indicators (livestock density, fertilizer N use, N surpluses; soil types) suggest that the nitrate leaching potential is rather evenly distributed throughout the country, but on average not excessively high. Maps suggest that polluted groundwater (Figure 24) and surface waters (Figure 28) are also fairly evenly distributed over the country. The mean nitrate concentrations in sensitive groundwater and the mean total N and total P concentrations in sensitive surface waters are near or above threshold values, and are decreasing (Figures 25, 26 and 27). Calculated leaching losses (Table 28) also suggest that the regional variations in nitrate leaching are relatively small, suggesting also that Polish agriculture is a diffuse source of nitrate pollution, evenly distributed over the country side.

Referring to the large number of farms with inappropriate facilities for the storage of animal manure and for the collection of surface run off from farm yards, the rather even distribution of sensitive groundwater and surface waters over the country side, and the huge eutrophication of the Baltic Sea and the relatively large contribution of Polish agriculture to the nutrient loading of the Baltic Sea through the rivers Odra and Vistual, one may argue to designate the whole Polish territory as NVZ. Indeed, there are solid grounds and various practical arguments for taking such position. It would target all farms

[2] See main text, paragraph 10.1. Definition of "sensitive waters" established in Order of Ministry of Environment of Poland 23 December 2002

as potential source of nitrate pollution, independent of its location, and it would demand from all farms to take remedial actions in a uniform way, without giving any competitive disadvantage of farms within NVZs relative to farms outside NVZs.

In case of designation specific nitrates vulnerable zones only, it is clear that a detailed monitoring network and great understanding of the groundwater hydrology is required. Such a detailed network is currently not available. The field visits and discussions with local experts and regional water managers have made clear that the designation of the NVZs in the Plonia catchment and catchment Zgłowiączka can be justified on the basis of results of detailed monitoring programs and also on the basis of the agricultural intensity in those catchments. However, such underpinning is as yet absent for many areas with sensitive waters that are not designated as NVZs.

Based on the assessments of this study, the following recommendations have been formulated

Recommendation 4*: In view of the suggested large leakages of nutrients from barns, manure storages and farm-yards, it is recommended to quantitatively assess the importance of these micro hot spots of pollution of groundwater and surface waters, and to develop and implement measures to decrease these leakages. Priority should be given to the relatively large livestock farms (e.g. >15 ha per farm and/or > 15 LSUs per farm).*

Recommendation 5*: The current designation of NVZs in Poland seems incomplete and must be reconsidered. The designations must address all the territories draining to fresh surface waters and groundwater, which are polluted or could become polluted with nitrates from agriculture, and to lakes, estuaries, coastal waters and marine waters that are eutrophic or may become eutrophic (see Annex 1 of the Nitrates Directive). In view of the diffuse nature of the pollution of groundwater and surface waters by nitrates from Polish agriculture, the wide-spread occurrence of sensitive groundwater and surface waters, the nitrate pollution of groundwater and eutrophication of surface waters and the relatively large contribution of Poland to the eutrophication of the Baltic Sea, there are many arguments to suggest designating the whole Polish territory as NVZ. Alternatively, if the designation of the whole territory is not considered feasible for whatever reason, the designation of the following specific territories must be considered as NVZ:*

- *Lakes with water quality classes III and IV, especially in the northwestern part of Poland. The territory draining to those lakes shall be designated as NVZ;*
- *Rivers with concentrations of Chlorophyll a of more than 25 mg/m3 (see Figures 30 and 31). This holds especially for the catchment of the Odra rivers, Notec river, Warta river(southern Warta up to the junction with Odra), Wistula (Section southern of Pulawy), Nareli , Bug (section southern Polowce)*
- *Territories polluting the groundwater monitoring stations as shown in Figure 24 of this report.*
- *Agricultural territories that contribute to the eutrophication of the Baltic Sea.*

Recommendation 6*: Designation of NVZs is an obligation following from the EU Nitrates Directive. It is recognized though that there are various other possible nitrogen losses from agriculture, including ammonia and nitrous oxide emissions, for which other EU Directives and obligations arising from international conventions apply. From the perspectives of effective and efficient abatement of N losses, it might be desirable to developing a strategic and integrated approach to N loss abatement.*

Conclusions

Based on the assessments of this study, the following conclusions have been formulated:

- Mean livestock density in Poland is relatively low (on average <0.5 livestock units per ha, and not (yet) much regional concentrated (29 counties have a livestock density of > 1 per ha, 3 counties > 2 per ha; and 1 county has 7.5 LSU per ha).
- Most farms in Poland are very small farms and many farmers have a low education level. In general, animal manure and farm-yards are managed poorly. Farmers lack the funds and the incentives for investments in proper manure storage facilities and in proper manure management.
- Mean fertilizer N use is 55 kg per ha and is slightly increasing during the last ten years. Most of the fertilizer N is applied in the north-west half of Poland, but there are no large 'hot-spots' of fertilizer N use.
- Mean N surpluses are about 75 kg N per ha per year and were rather stable over the last ten years. Highest N surpluses are found in the north-west half of Poland.
- Based on the regional distribution of livestock and fertilizer use, there are no large, regional, "hot spots" of nitrate pollution in Poland.
- Most soils in Poland are light-textured sandy soils and are vulnerable to nitrate leaching losses.
- Agricultural land is intersected by many streams, lakes and drainage ditches and these surface waters have variable water levels due to seasonal variations in rainfall and evapotranspiration. As a result, temporary flooding and intimate contact between land and surface waters often occurs on many places, providing lots of opportunities for the transfer of nitrate from agricultural land to surface waters.
- Many manure storage systems are not leak-tight and contribute to N leaching to groundwater and surface waters. The highest nitrate concentrations in groundwater are found near farms and farm-yards and manure heaps. Assessments made in this study, using MITERRA-EUROPE, suggest that leaching losses from manure storages and farm-yards contribute as much as 40% to the total leaching loss from Polish agriculture. However, this estimate is uncertain and requires underpinning through fields surveys and experimental measurements.
- A large percentage of surface water monitoring stations are influenced by nitrates from agricultural sources, and quite a few of these monitoring stations have nitrate concentrations near or exceeding 50 mg per litre.
- Measured N leaching losses via drainage are largest in the central parts of Poland. Measured NO_3-N concentrations range from 1 to 11.8 mg per litre, equivalent to 5 to 50 mg NO_3 per litre.
- Calculated N leaching losses are largest in the central provinces Wielkopolskie, Kujawsko- Pomorskie, Lodzkie and Mazowiecki.

- Mean N leaching losses in Poland range from 8 to 20 kg N per ha per year. These numbers translate to 20 to 40 mg NO_3 per litre. Roughly 40% of the total N leaching losses originate from leakages of manure N from manure heaps.
- The number of surface waters monitoring stations in Poland in 2005 was 2790 and the number of groundwater monitoring stations 858. With a total surface area of 312,685 km^2, these numbers translate into a density of 8.9 and 2.7 stations per 1000 km^2 land area.
- The distribution of the monitoring stations for groundwater is rather homogeneously distributed throughout the country. However, surface water monitoring stations are not equally distributed; it is recommended to re-assess the location of the monitoring stations. Especially in the north-eastern half of the country monitoring stations are lacking.
- The current designation of NVZs in Poland seems incomplete. The total area of the 21 designated NVZs in Poland covers 2% of the total area. Some of these NVZs are situated near high-density livestock areas, and the designation underpinned/motivated by the contamination of surface waters and groundwater with nitrate from agriculture. However, for many other areas with sensitive waters, it is unclear why these areas have not been designated. It is recommended to re-assess the current designation of NVZs in Poland.
- There are arguments to suggest to designating the whole territory of Poland under one Action Program of the EU Nitrates Directive. These arguments include the dominance and vulnerability of the sandy soils, the omnipresence of (sensitive) lakes and streams and the large areas of wet soils, the relatively large contribution of livestock manure to N leaching losses and its diffuse distribution in the country, the omnipresence of irrigation, the increasing use of fertilizer N, and the contribution of polish territory to the euthrophication of the Baltic Sea.
- A major obstacle for improving manure management in Poland is the poor manure storage facilities. As manure storage facilities and manure application contribute roughly 40% to the total N leaching losses according to calculations with MITERRA-EUROPE, priority should be given to improving the manure storage and manure management. This is a challenging task, given the large number of small farms. Priority should be given to the larger farms (farms having more than 10 ha or more than 5 LSU. This relates to 7% of the total number of farms, equivalent to about 200,000 farmers. Though only 7% of the number of farmers, they cultivate more than 50% of the area.

1. Introduction

Council Directive 91/676/EEC (further referred to as the Nitrates Directive) concerning the protection of waters against pollution caused by nitrates from agricultural sources was adopted on 12 December 1991. The Nitrate Directive aims at reducing water pollution caused or induced by nitrate from agricultural sources and, further, at preventing such pollution. The Nitrates Directive obliges member states to take several actions to realise this objective. One of these obligations is '*the designation of areas in the territory of Member States that: a) drain into fresh surface waters and/or groundwater (Article 3, Annex 1) that contain, or could contain more than 50 mg/l nitrate if actions prescribed in the Nitrates Directive are not taken; and b) drain to water which are eutrophic or may become eutrophic if action are not taken*. These areas are called Nitrate Vulnerable Zones or NVZs. This is valid for freshwater bodies, estuaries, coastal waters and marine waters that are now eutrophic or that in the near future may become eutrophic if actions prescribed in the Nitrates Directive are not taken.

Member states that have designated NVZs shall, for the purpose of designation and revising the designation of NVZs, monitor nitrate concentrations in fresh waters and groundwater for at least one year, within two years of notification of the Nitrates Directive, i.e., the end of 1993, and repeat the monitoring programme at least every four years. Member states that apply their Action Programme to their entire territory shall monitor the nitrate concentration in fresh waters and groundwater to establish the extent of nitrate pollution in waters from agricultural sources. NVZs must be designated on the basis of monitoring results which indicate that the groundwater and surface waters in these zones are or could be affected by nitrate pollution from agriculture.

Poland has become member of the EU by 2004. To comply with the Nitrates Directive, Poland has designated 21 areas in 6 regions as NVZ, on the basis on water monitoring data from 1990-2002. The total area of the NVZ is 6263 km^2, which comprises ~2% of the total area. The 6 regions and 21 areas are listed in Table 1, and shown on the map in Figure 1.

The European Commission, DG Environment, has requested Alterra to review the existing designations on the basis of available data, including new evidences or updated monitoring data since the first designation in 2004 (CONTRACT 2006/441164/MAR/B1). The request also includes assessments of the quality of water monitoring programmes and assessments of the replies to DG ENV from the Polish Authorities. In particular, the request includes:

- Assessment of the quality of monitoring programme in place, including the extent at which eutrophication status, in different water body types, is addressed and taken into account
- Search and review additional data (research papers, data from local Authorities, Institutes, Organisations)
- Assessment of possible further documents provided by the Commission received from Polish Authorities in the context of bilateral meetings;
- Analysis of agricultural pressures to identify the area of the territory which may contribute to nitrate pollution and eutrophication.

- Assessment of the possible linkages between waters with high nitrate concentration or eutrophic waters and the areas with high agricultural pressures, on the basis of the results of the study on "hot spots carried" in 2005 within the present contract,
- Assessment of all available data to conclude if the designation are sufficient;
- Identification of gaps and, if appropriate new vulnerable zones
- Assessment of the area of the Polish territory which, on the basis of objective criteria, would require designation as NVZ.

Table 1. Designated Nitrate Vulnerable Zones (NVZs) in Poland [Anonymous, 2006]

Water region	**Catchments where nitrate vulnerable zones were designated**	**Surface of nitrate vulnerable zones**		**Gminas located within nitrate vulnerable zones**
		km^2	**% surface. RZGW**	
GDAŃSK catchment of lower Wisła	**rivers**: Kotomierzyca, Struga Żaki, **lakes:** Kornatowskie, Płużnickie, Wieczno Południowe Wieczno Północne	721,70	2,03	Pruszcz, Dobrcz, Lisewo, Stolno, Chełmno, Płużnica
WARSAW catchment of the central Vistula	**rivers:** Zgłowiączka, Sona and the tributary from Przedwojewo **wells** in the towns of Doba, Ludwin, Przegaliny Duże, Pniewnik	575,50	0,05	Bytoń, Osięciny, Radziejów, Ciechanów, Regimin, Opiniogóra Górna, Gołymin Ośrodek, Sońsk, Giżycko, Ludwin, Komarówka Podlaska, Korytnica
SZCZECIN cathchments of the lower Oder and Western Maritime Province	**rivers** Płonia	1098,70	5,36	Barlinek, Pełczyce, Dolice, Stargard Szczec., Stargard miasto, Kobylanka, Przelewice, Warnice, Pyrzyce, Kozielice, Lipiany, Bielice, Banie, Gryfino, Stare Czarnowo, Szczecin miasto
WROCŁAW catchment of the central Oder	**rivers:** Orla, Rów Polski **Ground Water Basin** GZWP 327	2823,31	7,14	Góra, Wąsosz, Cieszków, Milicz, Żmigród, Krobia, Pępowo, Piaski, Pogorzela, Poniec, Kobylin, Koźmin Wlkp., Krotoszyn, Rozdrażew, Zduny, Rydzyna, Dobrzyca, Bojanowo, Jutrosin, Miejska Górka, Pakosław, Rawicz, Niechlów, Wąsosz, Szlichtyngowa, Wschowa, Gostyń, Krzemieniewo, Lipno, Osieczna, Święciechowa, Wielowieś, Pawonków, Lubliniec, Kalety, Miasteczko Śląskie, Tworóg
GLIWICE catchment of the small Vistula and the upper Oder	**ground waters in catchments of the rivers:** Troja, Psina i Cisek	317,14	4,07	Kietrz, Baborów, Polska Cerekiew
POZNAŃ catchment of Warta	**rivers:** Kopla, Pogona, Dąbrówka, Sama, Olszynka, Samica Stęszewska, Mogilnica, Rów Racocki **lakes:** Chrzypskie i Radziszewskie	726,90	1,33	Kleszczewo, Kostrzyń Wlkp., Kórnik, Swarzędz, Mosina, Poznań, Borek Wlkp., Koźmin Wlkp., Szamotuły Obrzycko, Czempiń, Duszniki, Dopiewo, Buk, Opalenica, Krzywiń, Śrem, Chrzypsko

Figure 1. Designated Nitrate Vulnerable Zones in Poland [Anonymous 2006]

Nitrate pollution of groundwater and surface waters is a complex process and depends on many interacting factors. Total nitrogen (N) loading per unit of surface area via fertilizers and animal manure is an important indicator, but the amount of nitrate leached ultimately depends also on the withdrawal of N with harvested crop and N losses via ammonia volatilization and denitrification. The latter two processes are heavily influenced by soil type, hydrology, management and climate. Hence, assessment of hot spots for nitrate pollution of groundwater and surface waters requires the analysis of pressures resulting from N from agricultural sources on the basis of fertilizer use, crop production, livestock density, N surpluses, soil type, hydrology, management and climate, per region.

This report summarizes the N pressure indicators and the pollution of groundwater and surface waters by nitrates from agriculture in Poland. The results of this study are based on literature studies, interviews with scientists, farmers, policy makers and surface water managers, and field visits.

2. Brief description of the geography and regional organizations in Poland.

Poland (Polish: *Polska*), officially the Republic of Poland, borders Germany to the west, the Czech Republic and Slovakia to the south, Ukraine and Belarus to the east, and the Baltic Sea, Lithuania, and Russia (in the form of the Kaliningrad Oblast exclave) to the north. Poland shares a maritime border with Denmark in the Baltic Sea.

Poland's total area is 312,683 km^2, including inland waters. The average elevation is 173 meters above sea level (m.a.s.l.) Only 3 % of Polish territory, along the southern border, is higher than 500 m.a.s.l. The lake region in the northern half includes the only primeval forests remaining in Europe and much of Poland's shrinking unspoiled natural habitat. Most of Poland's 9,300 lakes larger than 10 km^2 are located in the northern part of the lake region, where they occupy about 10 % of the surface area.

Polish regional structure and organization has been shaped during a series of reforms. Until 1975 Poland was administratively subdivided into 49 voivodships. From 1998 onwards, the country is divided into 16 voivodships, 380 poviats (administrative districts) and 2 489 gminas (communes). The current division into voivodships is shown in Figure 2. Some characteristics of the current voivodships are presented in Table 2.

Figure 2. The administrative division of Poland in 16 voivodships (provinces). See also Table 2.

At the regional level, Sejmik, a regional parliament headed by the chairman (Przewodniczący), deals with programming of regional policies. The Voivodship Board (Zarząd Województwa) is an executive body on the regional tier, headed by the Marshal (Marszałek). Among the Marshals duties are those connected with making development policies and control over regional self-government executive bodies. In particular, Marshals are responsible for creating a proper environment for regional development, education, R&D, innovation, environmental protection and culture (Kosarczyn, 2001).

In a region there is also a representative of the central government - a Voivod (the governor of a voivodship) who acts as the supervisor of regional policies from legal point of view. Voivods also represent the State Treasury, being responsible, among other things, for public safety, standards and conformity of laws, and financial budgets. Source: http://www.stat.gov.pl/gus.

About 60% of the land in Poland is in use by agriculture. The division of the agricultural land is roughly as follows:
- arable land: 47%
- permanent crops: 1%
- permanent pastures: 13%
- forests and woodland: 29%
- other: 10%

Table 2. Some characteristics of the 16 voivodships.

No	**Voivodships**	**Population in thousands**	**Area in km²**	**Density of population**	**Number of territorial units**	
					gminas	**poviats**
1	Dolnośląskie	2 972,0	19 948	149,5	169	30
2	Kujawsko-pomorskie	2 099,7	17 970	116,8	144	23
3	Lubelskie	2 232,0	25 114	89,16	213	24
4	Lubuskie	1 023,9	13 984	73,1	83	14
5	Łódzkie	2 643,3	18 219	146,1	177	24
6	Małopolskie	3 233,7	15 144	212,4	182	22
7	Mazowieckie	5 072,3	35 579	141,8	325	42
8	Opolskie	1 084,6	9 412	115,7	71	12
9	Podkarpackie	2 128,6	17 926	118,6	160	25
10	Podlaskie	1 221,1	20 180	60,6	118	17
11	Pomorskie	2 198,3	18 293	119,4	123	20
12	Śląskie	4 847,6	12 294	396,6	166	36
13	Świętokrzyskie	1 322,8	11 691	113,6	102	14
14	Warmińsko-mazurskie	1 468,3	24 203	60,4	116	21
15	Wielkopolskie	3 360,8	29 826	111,9	226	35
16	Zachodniopomorskie	1 733,8	22 912	75,19	114	21
Poland		38 644,2	312 385	123,5	2 489	380

Nearly all of Poland is drained northward into the Baltic Sea by the Vistula, the Oder, and the tributaries of these two major rivers. About half the country is drained by the Vistula, which originates in the Tatra Mountains in far south-central Poland. The Vistula Basin includes most of the eastern half of the country and is drained by a system of rivers that mainly join the Vistula from the east. The Vistula river drains 54% of Polish territory into the Baltic Sea, the river Oder 34%, and the rivers of the sea-coast of the Baltic Sea 11% and the river-basin Niemen 0.8%.

Responsible for the management of the water resources in Poland is the National Water Management Board (KZGW). The KZGW directs the seven Regional Water Management Boards (RZGW), which are responsible for the regional water resources. These seven RZGW's are shown in Figure 3, and are as follows:

RZGW Gliwice (the part of the river-basin of upper Oder and Vistula),
RZGW Kraków (the river-basin of upper Vistula),
RZGW Wrocław (the river-basin of central and upper Oder),
RZGW Poznan (the river-basin of the Warta, which flows into the Oder),
RZGW Warszawa (the river-basin of central Vistula),
RZGW Szczecin (the river-basin of lower Oder),
RZGW Gdańsk (the river-basin of lower Vistula and eastern Przymorze).

Figure 3. Areas of the Regional Water Management Boards.

Most of the surface waters monitoring stations are in the western and southern half of the country, with few stations in the eastern half of Poland. According to the EU Nitrates Directive and the monitoring guidelines of the Directive, water monitoring networks need to cover all groundwater (also sites not used for drinking water), rivers, lakes and dams, coastal and marine waters (Art. 6 of the Directive). Criteria to monitor are nitrogen (nitrate, ammonia and total N) and eutrophication (chlorophyll-a, algal blooms, macrophytes and species shift).

The number of surface waters monitoring stations in Poland in 2005 was 2790 and the number of groundwater monitoring stations 858. With a total surface area of 312,685 km^2, these numbers translate into a density of 8.9 and 2.7 stations per 1000 km^2. Sampling frequency of the groundwater monitoring networks in Poland is once per year. Sampling frequency for surface waters ranges from 4 (once per season) to 12 (once per month) times per year. Surface water monitor stations do monitor the concentrations of N (often also P), but the monitoring of ecological indicators (chlorophyll-a, algal blooms, macrophytes and species shift) is limited.

3. Soils in Poland

Large areas in Poland have light-textured (sandy) soils (Figure 4; Table 2). The share of light-textured soils is in Poland two times larger than that in EU-27. Light-textured soils often have a low soil organic carbon content and have a low soil moisture retention capacity and a low nutrient retention capacity. As a result, the agricultural production capacity of these soils is relatively low (Figure 5). Moreover, light-textured soils are vulnerable to nitrate leaching. Soils 3, 4. 5 and 8 in Figure 4 have the highest potential for agricultural production

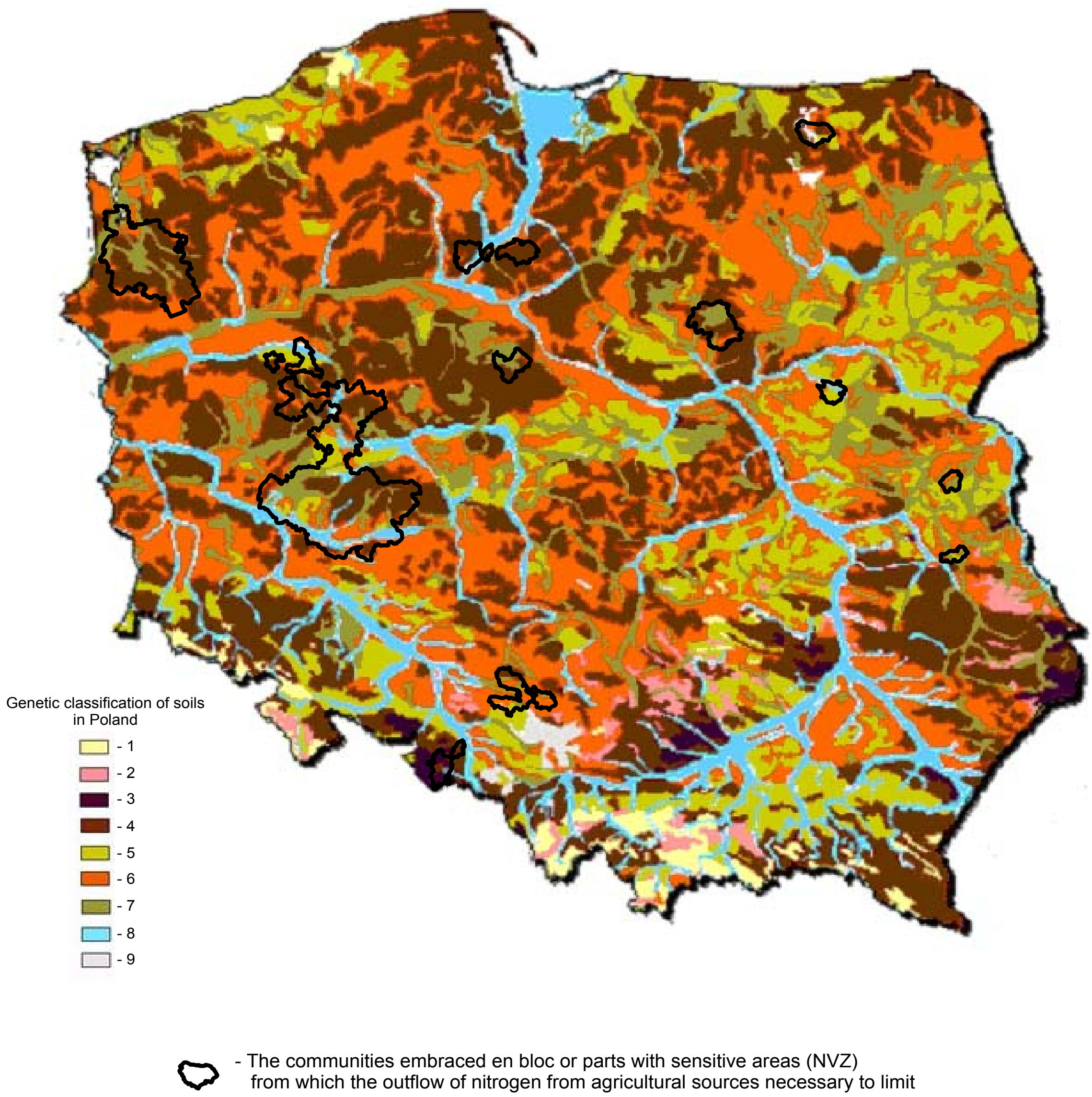

Figure 4. Genetic classification of soils in Poland [Genetyczna…]; explanations to the figure 3: 1- Initial mineral soils; 2 - Calcareous soils; 3 - Chernozem soils; 4 - Brown soils; 5 - Swamp soils; 6 - Podsolic (podzolic) soils; 7 - Bog and post-bog soils; 8 - Alluvial soils; 9 - Anthropogenic soils.

Table 2. Explanations to the map "Genetic classification of soils in Poland"

Number on the legend	**Polish classification**	**References of the classification FAO/UNESCO**
1	Gleby mineralne początkowego stadium rozwoju	Lithic Leptosols, Distric Regosols, Clayi-Distric Regosols, Haplic Arenosols
2	Gleby wapniowcowe	Rendzic Leptosol, Calcaric Regosols
3	Gleby czarnoziemne	Haplic phaeozems
4	Gleby brunatnoziemne	Calarcic Regosols, Dystric Cambisols, Haplic Luvisols
5	Gleby zabagniane	Stagni-Eutric Gleysols, Eutric Gleysols
6	Gleby bielicoziemne	Cambic Arenosols, Haplic Podzols, Haplic Podzols (Ferris Podzols)
7	Gleby bagienne i pobagienne	Terric Histosols, Eutri-Terric Histosols, Histi-Mollic Gleysols
8	Gleby napływowe	Dystric Fluvisols, Salic Fluvisols, Fluvi-Eutric Gleysols
9	Gleby antropogeniczne	Fimic Anthrosols, Anthropic Regosols, Urbic Anthrosols, Urbi-Calcaris Regosols, Urbi-Haplic Solonchaks

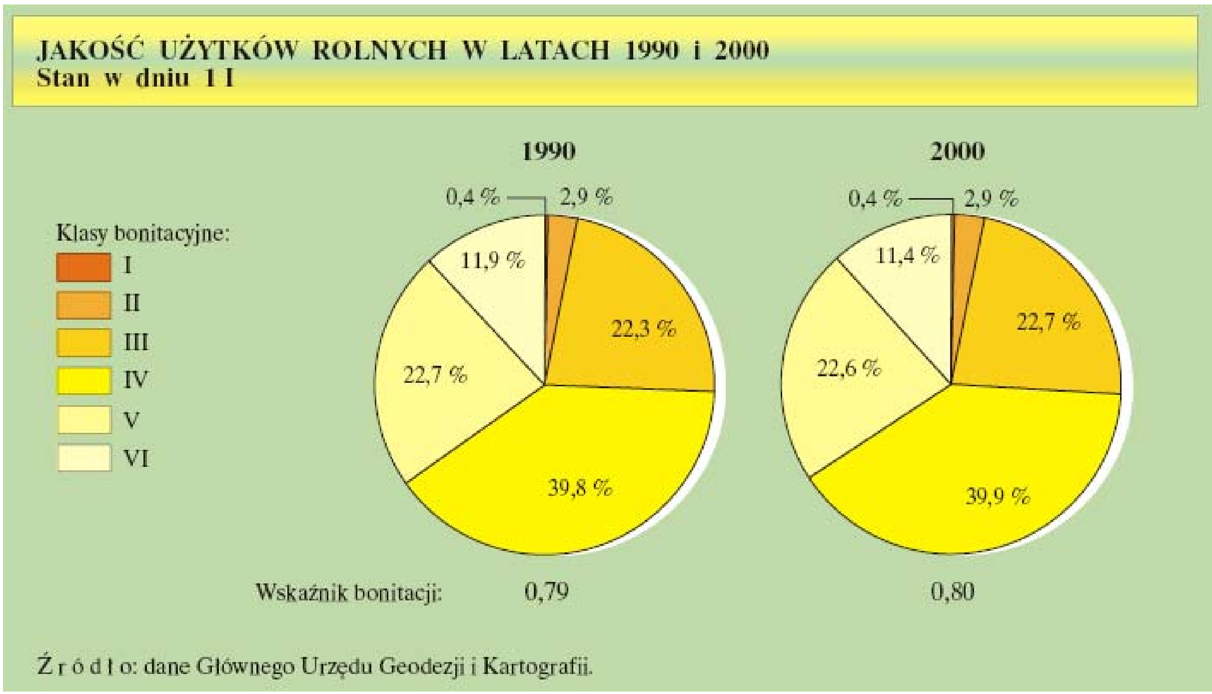

Figure 5. The quality of soils used by farmers in 1999 and 2000 (I – the best soils; VI – the worst soils). The percentage of class I and class II soils is low [Ochrona…, 2006].

4. Rainfall and temperature regimes in Poland

Average temperature in Poland is 8ºC (Figure 6). Mean temperature is slightly higher in the western half than in the eastern half. The average annual precipitation is 600 mm, but isolated mountain locations receive as much as 1300 mm (Figure 7). The total rainfall is slightly higher in the southern uplands than in the central plains. A few areas, notably along the Vistula between Warsaw and the Baltic Sea and in the far northwest, receive on average less than 500 mm. On average, precipitation in summer is twice that in winter, which is beneficial for crop production and also limits N leaching losses outside the non-growing season.

Because of the relatively low rainfall, especially in the central part of Poland, large areas are irrigated. The FDPA Report Rural Poland 2000 states that 36% of the agricultural area, equivalent to 6.7 million ha of agricultural land, is irrigated. The irrigation systems are sometimes criticized because of the excessive leaching and drainage, the lowering of the groundwater table and the regional changes in water balance.

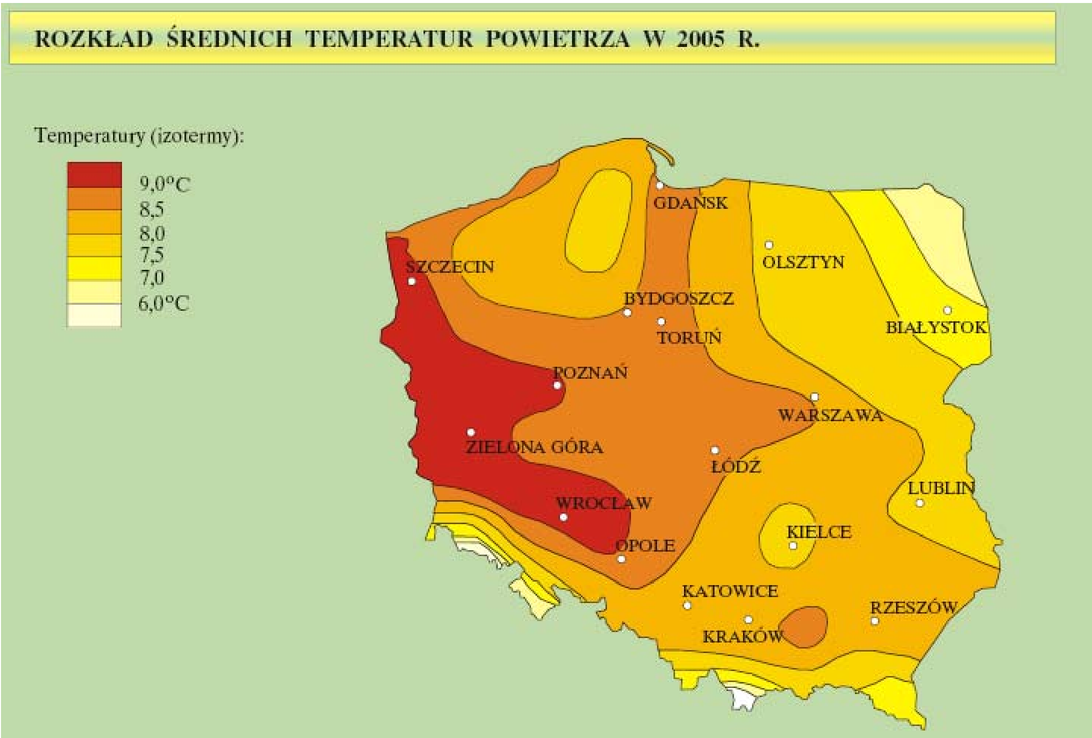

Figure 6. Average air temperature in Poland in 2005 [Ochrona…, 2006]

Figure 7. Average total rainfall in Poland in 2005 [Ochrona…, 2006]

5. Crop production in Poland

Farmland in Poland is dominated by crop production (77%). Out of 13 million ha of farmland used for crop production, 82% is actually cultivated, and 18% (1.9 million ha) is unused. Further, out of 2.5 million ha of grazing land, 0.8 million ha is unused, and out of 1.0 million ha of meadow 0.3 million ha lies idle. Together, out of 16.9 million ha in 2002 as much as 3.4 million ha were idle for some or all of the time (20%). It can therefore be estimated that crop production takes place on 13.5 million ha of farmland in Poland.

The most common crops in Poland are cereals grain (rye, oats, barley and wheat), covering 77% of arable land. Grain is produced on 1.67 million farms and the average area planted is 5 ha. Most of the cereals are grown in the western half (Figures 8, 9 and 10; Table 3). The second most popular crop is potatoes cultivated by 1.56 million farms (Figure 11; Table 4), but the area planted here is far smaller than that for grain. The total area used for potato production is 0.8 million ha and the average area plated is 0.5 ha, only one tenth of that of grain.

The area of rape seed (Figure 12; Table 5) is increasing. According to the statistical information from the year 2002, most rape seed is grown in the western half on 2-8% of the area. During the visit in May it was clear that this area had increased on average to >10% and in some areas to ~25%, mainly in response to the governmental objective to increase biofuel production and the associated economical incentives.

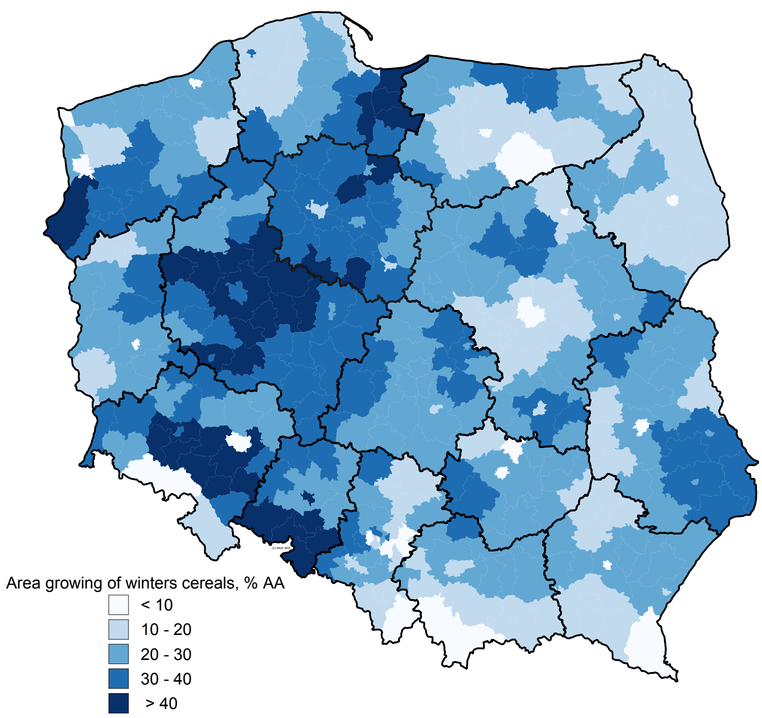

Figure 8. Area growing of winter cereals in different administrative districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

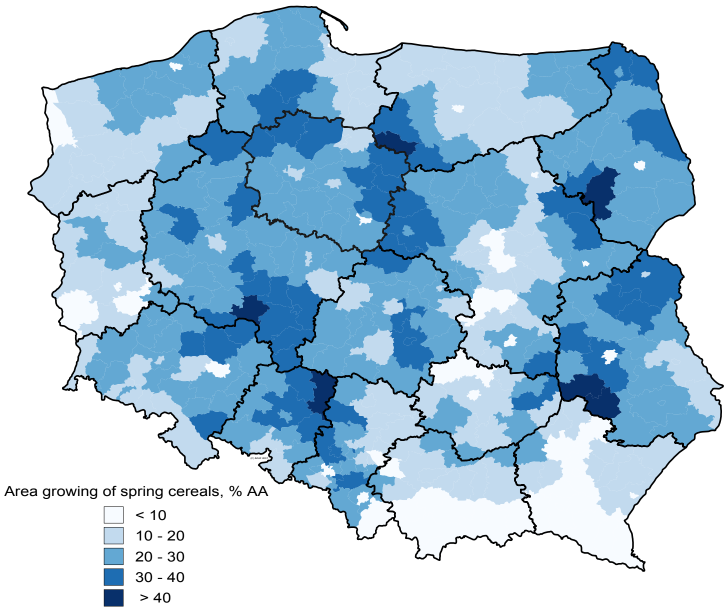

Figure 9. Area growing off spring cereals in different administrative districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

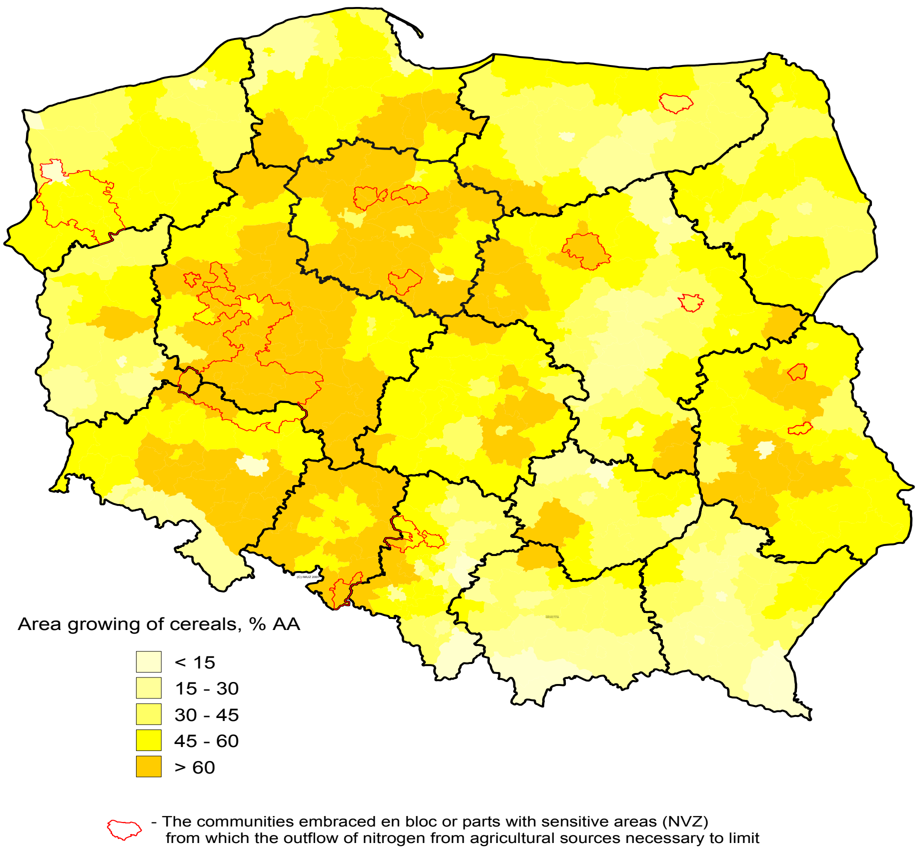

Figure 10. Area growing off spring and winter cereals in different administrative districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

Table 3. Administrative districts (counties) in which the acreage of cereals 60% of agriculture lands (AL) 2002 [adapted from: Powszechny…]. Districts are listed according to increasing area of cereals.

Administrative districts	Province	AL, ha	AL /total area in %	Area growing of cereals in % of AL
Lipsko	Mazowieckie	55363	74,1	60,1
Krasnystaw	Lubelskie	84588	74,3	60,2
Tomaszów	Łódzkie	60650	59,1	60,3
Działdowo	Warmińsko-Mazurskie	58161	61,0	60,5
Gostynin	Mazowieckie	42296	68,7	60,6
Kalisz	Wielkopolskie	83507	72,0	60,7
Namysłów	Opolskie	47527	63,6	60,7
Oława	Dolnośląskie	34990	66,8	60,8
Malbork	Pomorskie	40669	82,2	60,9
Świdnica I	Lubelskie	37070	79,0	61,1
Górowo	Dolnośląskie	45453	61,6	61,1
Głogów	Dolnośląskie	27412	61,9	61,1
Włocławek	Kujawsko-Pomorskie	102754	69,8	61,2
Bydgoszcz	Kujawsko-Pomorskie	64813	46,5	61,2
Inowrocław	Kujawsko-Pomorskie	93531	76,4	61,3
Wieruszów	Łódzkie	37916	65,8	61,4
Sierpc	Mazowieckie	66184	77,6	61,5
Płock	Mazowieckie	129528	72,0	61,6
Łosice	Mazowieckie	55718	72,2	61,9
Strzelce	Opolskie	37237	50,0	61,9
Chodzież	Wielkopolskie	37017	54,4	62,0
Kutno	Łódzkie	75985	85,7	62,0
Ciechanów	Mazowieckie	79824	75,1	62,0
Parczew	Lubelskie	60087	63,1	62,2
Kraśnik	Lubelskie	71525	71,1	62,2
Stargard	Pomorskie	93457	61,5	62,3
Chełmno	Kujawsko-Pomorskie	42480	80,5	62,5
Sztum	Pomorskie	53195	72,8	62,5
Miechów	Małopolskie	50731	75,0	62,5
Radzyń	Lubelskie	68916	71,4	62,8
Aleksandrów	Kujawsko-Pomorskie	39045	82,1	62,9
Ostrów II	Wielkopolskie	70212	60,5	63,1
Lublin	Lubelskie	138188	82,3	63,2
Kościan	Wielkopolskie	54462	75,4	63,2
Człuchów	Pomorskie	65464	41,6	63,3
Toruń	Kujawsko-Pomorskie	69769	56,7	63,3
Zwoleń	Mazowieckie	44318	77,6	63,3
Świebodzin	Lubuskie	44849	47,8	63,4
Racibórz	Śląskie	33462	61,5	63,5
Opole	Opolskie	69431	43,8	63,8
Gliwice	Śląskie	35428	53,4	63,9
Tczew	Pomorskie	49812	71,4	64,2
Jędrzejów	Świętokrzyskie	84989	67,6	64,4
Złotów	Wielkopolskie	75003	45,2	64,5
Piotrków	Łódzkie	95313	66,7	64,5
Ostrzeszów	Wielkopolskie	44277	57,3	64,8
Tuchola	Kujawsko-Pomorskie	44224	41,1	64,8
Dzierżoniów	Dolnośląskie	33529	70,0	64,8
Żnin	Kujawsko-Pomorskie	69632	70,7	64,9

Złotoryja	Dolnośląskie	40789	70,9	65,1
Poznań	Wielkopolskie	116601	61,4	65,2
Janów	Lubelskie	9704	71,9	65,4
Gliwice	Śląskie	35428	53,4	65,4
Wrocław	Dolnośląskie	84416	75,6	65,6
Golub-Dobrzyń	Kujawsko-Pomorskie	43771	71,4	65,6
Brodnica	Kujawsko-Pomorskie	68767	66,2	65,8
Kalisz	Wielkopolskie	83507	72,0	66,1
Grodzisk II	Wielkopolskie	42832	66,5	66,1
Strzelin	Dolnośląskie	50682	81,4	66,2
Kluczbork	Opolskie	53276	62,6	66,2
Świdnica II	Dolnośląskie	54166	72,9	66,6
Rawicz	Wielkopolskie	41390	74,8	66,9
Września	Wielkopolskie	50527	71,8	66,9
Jaworze	Dolnośląskie	40643	69,9	67,1
Nysa	Opolskie	88035	71,9	67,1
Oleśnica	Opolskie	62111	59,2	67,3
Brzeziny	Łódzkie	27964	78,0	67,4
Wschowa	Lubuskie	32320	51,7	67,5
Radziejów	Kujawsko-Pomorskie	41218	70,2	67,5
Śrem	Wielkopolskie	37963	66,1	67,6
Słupca	Wielkopolskie	62355	74,4	67,7
Głubczyce	Opolskie	57367	85,2	67,8
Legnica	Dolnośląskie	53846	72,3	67,9
Brzesko I	Opolskie	61102	69,7	67,9
Wąbrzeźno	Kujawsko-Pomorskie	40551	80,9	68,3
Gostynin	Wielkopolskie	42296	68,7	68,6
Ząbkowice	Dolnośląskie	56712	70,7	68,9
Leszno	Wielkopolskie	16341	19,6	69,3
Gniezno	Wielkopolskie	92060	73,4	69,6
Kępno	Wielkopolskie	43821	72,0	70,0
Środa II	Dolnośląskie	53908	76,6	70,4
Leszno	Wielkopolskie	1340	42,0	70,5
Sępolno	Kujawsko-Pomorskie	51708	65,4	70,9
Świecko	Kujawsko-Pomorskie	77404	52,6	71,0
Mogilno	Kujawsko-Pomorskie	49418	73,1	71,2
Międzychód	Wielkopolskie	31170	42,3	71,2
Kędzierzyn-Koźle	Opolskie	38229	61,1	71,3
Oborniki	Wielkopolskie	42013	59,0	71,4
Krapkowice	Opolskie	26519	60,0	71,7
Jarocin	Wielkopolskie	42397	72,1	73,0
Nowo Miasto	Warmińsko-Mazurskie	47030	67,7	74,2
Wągrowiec	Wielkopolskie	73230	70,4	74,7
Krotoszyn	Wielkopolskie	51836	72,6	74,9
Pleszewo	Wielkopolskie	51307	72,1	75,3
Środa I	Wielkopolskie	46178	74,1	76,6
Szamotuły	Wielkopolskie	66653	59,5	94,8

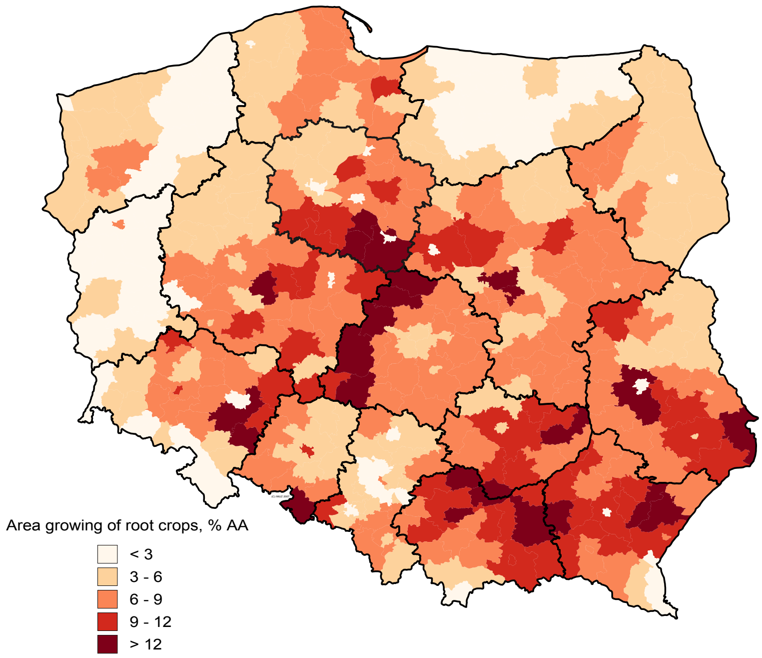

Figure 11. Area growing of root crops in different administrative districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

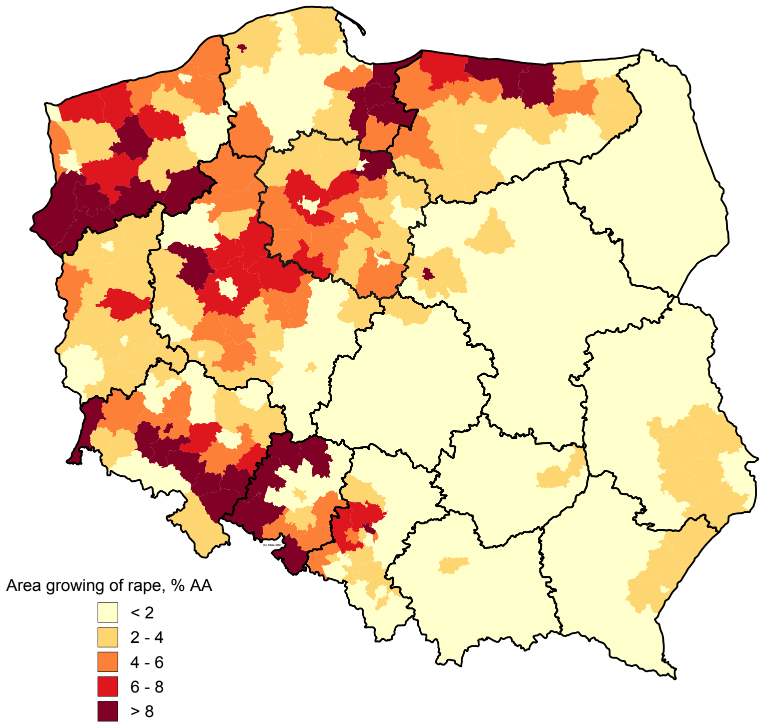

Figure 12. Area growing of rape in different administrative districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

Table 4. Administrative districts (counties) in which the acreage of root crops exceeds 12% of agriculture lands (AL) in 2002 [adapted from: Powszechny…] Districts are listed according to increasing area of root crops.

Administrative districts	Province	AL, ha	AL /total area in %	Area growing of of root crops in % of AL
1	2	3	4	5
Poddębice	Łódzkie	64275	73,0	12,1
Tarnów	Małopolskie	85980	60,8	12,0
Wrocław	Dolnośląskie	84416	75,6	12,1
Proszowice	Małopolskie	34981	84,4	12,1
Kutno	Łódzkie	75985	85,7	12,1
Kraków	Małopolskie	81560	66,3	12,2
Lublin	Lubelskie	138188	82,3	12,2
Włocławek	Kujawsko-Pomorskie	102754	69,8	12,4
Radziejów	Kujawsko-Pomorskie	41218	70,2	12,4
Hrubieszów	Lubelskie	99496	78,4	12,6
Przeworsk	Podkarpackie	47261	67,7	12,8
Jarosław	Podkarpackie	70168	68,2	12,9
Opatów	Świętokrzyskie	67304	73,8	12,9
Łęczyca	Łódzkie	65999	85,3	13,1
Strzelin	Dolnośląskie	50682	81,4	13,7
Miechów	Małopolskie	50731	75,0	13,8
Warszawa Zachód	Mazowieckie	32523	61,0	13,8
Aleksandrów	Kujawsko-Pomorskie	39045	82,1	14,4
Środa I	Wielkopolskie	46178	74,1	14,5
Kazimierz	Świętokrzyskie	35593	84,2	14,5
Głubczyce	Opolskie	57367	85,2	14,7
Dębica	Podkarpackie	49285	63,5	15,2
Wieluń	Łódzkie	62303	67,2	15,4
Sieradz	Łódzkie	105775	70,9	18,0

Table 5. Administrative districts (counties) in which the acreage of rape exceeds 8% of agriculture lands (AL) in 2002 [adapted from: Powszechny…] Districts are listed according to increasing area of rape.

Administrative districts	Province	AL, ha	AL /total area in %	Area growing of of rape in % of AL
Łobez	Zachodniopomorskie	61126	57,4	8,1
Jawor	Dolnośląskie	40643	69,9	8,1
Nowy Dwór II	Pomorskie	40035	61,3	8,2
Myślibórz	Zachodniopomorskie	53052	44,9	8,2
Tarnów	Małopolskie	85980	60,8	8,2
Choszczno	Zachodniopomorskie	66368	50,0	8,2
Tczew	Pomorskie	49812	71,4	8,4
Namysłów	Opolskie	47527	63,6	8,6
Złotoryja	Dolnośląskie	40789	70,9	8,6
Świdnica II	Dolnośląskie	54166	72,9	8,9
Malbork	Pomorskie	40669	82,2	9,0
Płock	Mazowieckie	129528	72,0	9,0
Zgorzelec	Dolnośląskie	31892	38,1	9,1
Dzierżoniów	Dolnośląskie	33529	70,0	9,3
Pyrzyce	Zachodniopomorskie	57894	79,8	9,6
Włocławek	Kujawsko-Pomorskie	102754	69,8	9,6
Wałcz	Zachodniopomorskie	49224	34,8	9,8
Brzeg	Opolskie	61102	69,7	10,2
Bytom	Śląskie	1571	22,6	10,3
Szamotuły	Wielkopolskie	66653	59,5	10,6
Legnica	Dolnośląskie	53846	72,3	10,7
Bartoszyce	Warmińsko-Mazurskie	89236	68,2	10,8
Kluczbork	Opolskie	53276	62,6	11,0
Kętrzyn	Warmińsko-Mazurskie	87443	72,1	11,1
Gryfin	Zachodniopomorskie	65941	64,8	11,8
Sztum	Pomorskie	53195	72,8	12,0
Nysa	Opolskie	88035	71,9	13,1
Ząbkowice	Dolnośląskie	56712	70,7	13,4
Grudziądz	Kujawsko-Pomorskie	54725	75,1	13,7
Słupsk	Pomorskie	116507	50,6	13,9

Vegetable production (Figure 13; Table 6) is mainly concentrated around the larger cities, e.g. near Warszawa, Lodz, Krakow, Gdansk, Poznan, etc., so as to supply local markets. Most of the vegetables are grown in the open air, although greenhouses are also used in some places. The export of fruit and vegetable production to Eastern Europe has ceased following the political changes in the early 1990s.

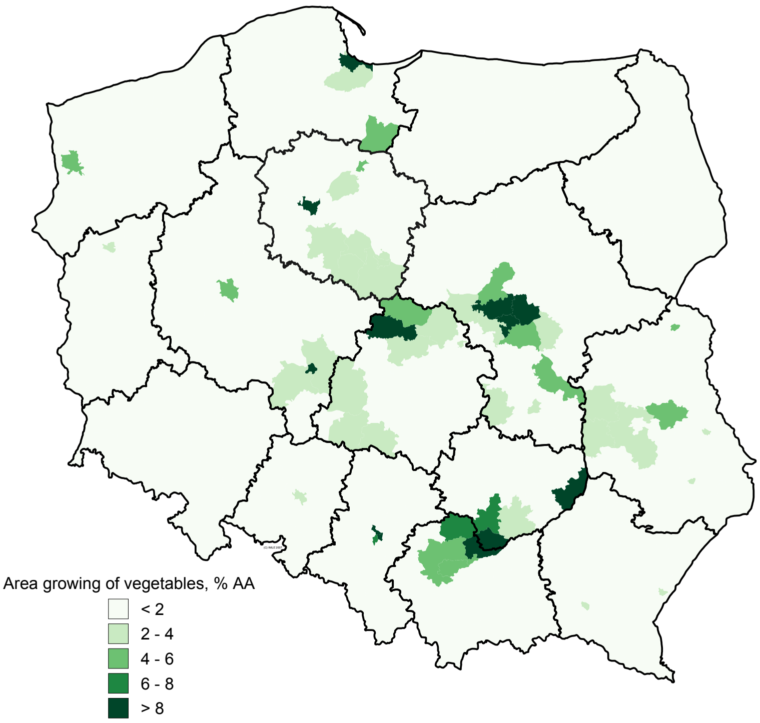

Figure 13. Area growing of vegetables in different administrative districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

Table 6. Administrative districts (counties) in which the acreage of vegetables exceeds 6% of agriculture lands (AL) [adapted from: Powszechny…]

Administrative districts	Province	AL, ha	AL /total area in %	Area growing of vegetables in % of AL
Miechów	Małopolskie	50731	75,0	6,2
Chorzów	Śląskie	533	15,9	7,5
Pińczów	Świętokrzyskie	40674	66,6	7,7
Sandomierz	Świętokrzyskie	51072	75,6	8,7
Warszawa	Mazowieckie	14683	29,7	9,2
Bydgoszcz	Kujawsko-Pomorskie	64813	46,5	9,2
Kalisz	Wielkopolskie	83507	72,0	9,9
Kazimierz	Świętokrzyskie	35593	84,2	10,7
Siemianowice Śląskie	Śląskie	914	36,3	10,8
Pruszków	Mazowieckie	16007	65,0	11,4
Gdańsk	Pomorskie	52131	65,7	12,2
Łęczyca	Łódzkie	65999	85,3	13,0
Proszowice	Małopolskie	34981	84,4	15,8
Warszawa Zachód	Mazowieckie	32523	61,0	16,6
Piekary Śląskie	Śląskie	1950	49,2	16,8

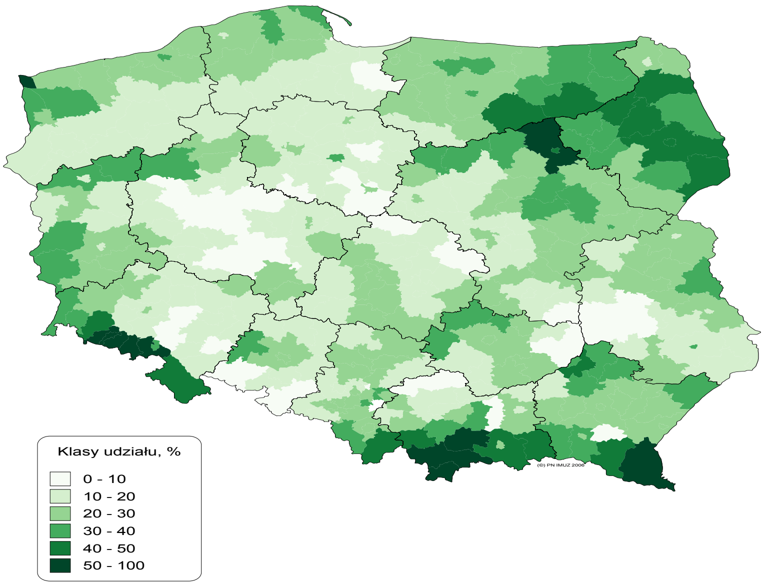

Figure 14. Area of grassland in different administrative districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

Table 7. Administrative districts (counties) in which the acreage of grasslands exceeds 40% of agriculture lands (AL) [adapted from: Powszechny…]

Administrative districts	Prowince	AL, ha	AL /total area in %	Area of grassland in % of AL
Białystok	Podlaskie	149891	50,2	40,0
Susz	Małopolskie	28445	41,5	40,4
Hajnówka	Podlaskie	67588	41,6	40,5
Kłodzko	Dolnośląskie	80491	49,0	42,0
Sanok	Podkarpackie	49040	40,0	42,0
Ostrołęka miasto	Mazowieckie	928	32,0	42,1
Augustów	Podlaskie	69678	42,0	42,2
Mońki	Podlaskie	79779	57,7	42,8
Białystok miasto	Podlaskie	2599	27,7	43,1
Lwówek	Dolnośląskie	40170	56,6	43,5
Nowy Sącz	Małopolskie	66493	42,9	44,1
Pisz	Warmińsko-mazurskie	53384	30,1	44,6
Tarnobrzeg	Podkarpackie	25540	49,1	44,7
Grajewo	Podlaskie	63677	65,8	45,3
Szczytno	Warmińsko-mazurskie	72755	37,6	47,0
Gorlice	Małopolskie	42119	43,5	48,2
Żywiec	Śląskie	36368	35,0	48,9
Limanowa	Małopolskie	48731	51,2	52,0
Wałbrzych	Dolnośląskie	24508	47,7	52,4
Jelenia Góra miasto	Dolnośląskie	4358	40,2	53,5
Ostrołęka	Mazowieckie	130668	62,2	56,1
Jelenia Góra	Dolnośląskie	24752	39,4	58,3
Kamienna Góra	Dolnośląskie	21335	53,9	60,1
Nowy Targ	Małopolskie	71509	48,5	70,8
Ustrzyki Dolne	Podkarpackie	23920	21,0	75,7
Świnoujście miasto	Zachodniopomorskie	1309	6,7	87,3
Zakopane	Małopolskie	15318	32,5	90,0

6. Livestock number and livestock density in Poland

The numbers of livestock and livestock density in Poland have decreased steadily following the political changes in the early 1990s (Figures 15 and 16). Mean livestock density was 0.44 LSU per ha in 2004, which is below the averages of the EU-15 (~0.88) and EU-27 (~0.8). However, there is often considerable discussion about the definition of Livestock Units (LSU); for example data presented by Eurostat (www.epp.eurostat.ec.europa.eu) in Table 8 suggest that the mean livestock density in Poland was 0.72 LSU per ha in the year 2005. This difference (0.44 versus 0.72) must be attributed to differences in definitions of LSU and agricultural land.

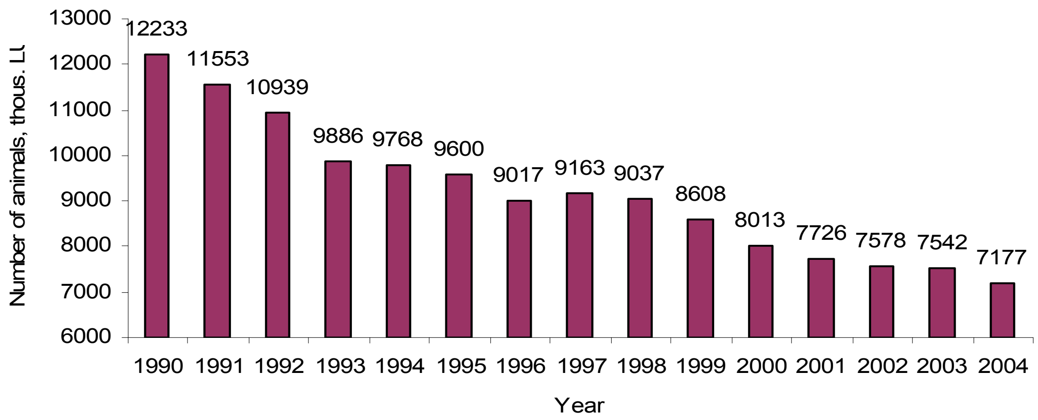

Fig. 15. Dynamics of changes number of farm-animals in Poland (in thousand Livestock Units) [Rocznik…, 1998; Rocznik…, 2001; Rocznik…, 2005]

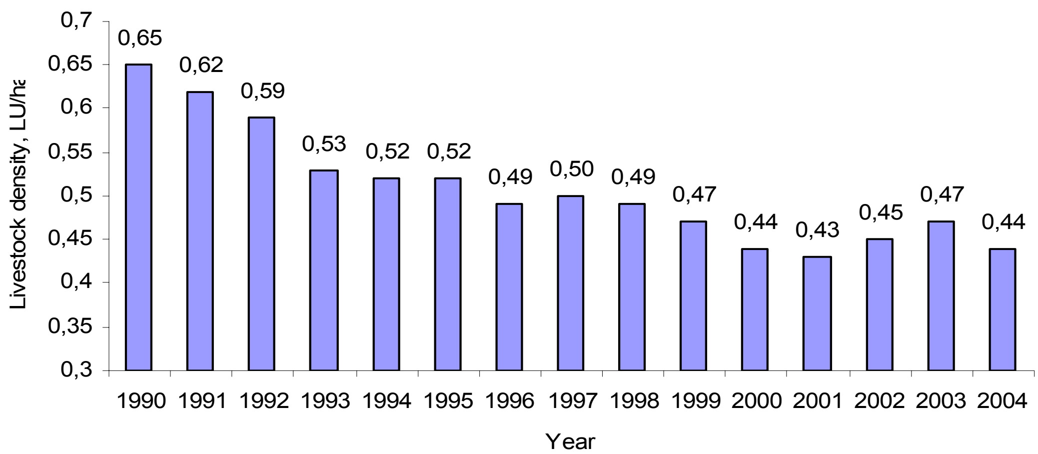

Figure 16. Dynamics of changes livestock density in Poland (in Livestock Units per per 1 ha of agricultural land) [Rocznik…, 1998; Rocznik…, 2001; Rocznik…, 2005].

Table 8. Livestock densities (in LSU per ha agricultural land) in EU and in Member States of the EU for the years 1990-2005, Eurostat, (www.epp.eurostat.ec.europa.eu).

Countries	1990	1993	1995	1997	2000	2003	2005
EU (27 countries)						0.82	0.8
EU (25 countries)						0.85	0.83
EU (15 countries)			0.9	0.9	0.93	0.89	0.88
Belgium	3.16	3.22	3.26	3.19	3.13	2.84	2.8
Bulgaria						0.56	0.49
Czech Republic						0.63	0.58
Denmark	1.41	1.66	1.58	1.61	1.65	1.71	1.75
Germany	1.27	1.14	1.11	1.1	1.13	1.1	1.07
Estonia						0.41	0.38
Ireland	1.46	1.52	1.5	1.58	1.45	1.46	1.47
Greece	0.67	0.63	0.63	0.65	0.71	0.66	0.62
Spain	0.43	0.43	0.43	0.44	0.57	0.56	0.58
France						0.84	0.82
Italy	0.76	0.74	0.72	0.71	0.76	0.76	0.75
Cyprus						1.64	1.61
Latvia					0.31	0.31	0.27
Lithuania						0.47	0.46
Luxembourg	1.4	1.34	1.37	1.37	1.35	1.24	1.22
Hungary					0.68	0.61	0.58
Malta						4.53	4.5
Netherlands	3.94	4.01	3.86	3.82	3.62	3.07	3.26
Austria			0.83	0.82	0.79	0.77	0.75
Poland						0.77	0.72
Portugal	0.61	0.6	0.6	0.61	0.66	0.63	0.56
Romania						0.52	0.47
Slovenia					1.26	1.2	1.08
Slovakia					0.46	0.45	0.42
Finland			0.58	0.61	0.55	0.53	0.51
Sweden			0.67	0.67	0.64	0.59	0.57
United Kingdom	1.01	1.01	1	1.02	1	0.9	0.9
Norway					1.21	1.21	1.21

Figure 17 shows that most of the districts have (much) less than 1.5 LSU per ha. Note also that areas with more than 1.5 LSU/ha are in part districts with a relatively small area of agricultural land (Table 9). The absence of conglomerations of livestock in high densities suggests that livestock production in Poland is predominantly land-based, i.e. the livestock is fed with locally produced feed and forages.

Figure 17 also shows that some areas with relatively high livestock density are situated in designated NVZs, but in general there is no clear relationship between areas with relatively high livestock density and designated NVZs.

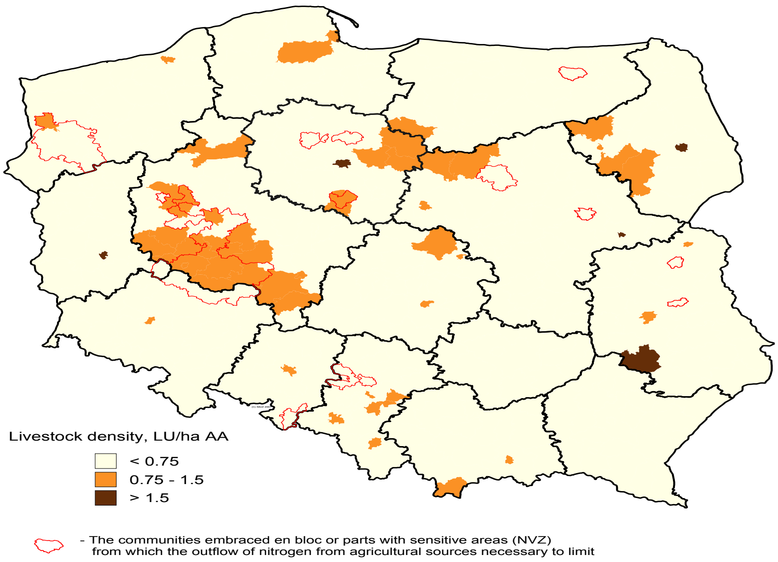

Figure 17. Livestock density in Livestock Units (LSU) per 1 ha of agricultural land in districts (counties) of Poland in 2002 [Pietrzak, Nawalany, Wilczyńska, 2007 on the base Powszechny…]

Table 9. Administrative districts (counties) in which livestock density is 1 or more LSU per 1 ha of agriculture lands (ALl) [adapted from: Powszechny…]

Administrative districts	Province	AL, ha	AL /total area in %	Livestock density, LU/ha AL
Kościan	Wielkopolskie	54462	75,4	1,0
Biała Podlaska	Lubelskie	101454	73,2	1,0
Skierniewice	Łódzkie	54224	71,7	1,0
Legnica	Dolnośląskie	53846	72,3	1,0
Nowy Sącz	Małopolskie	66493	42,9	1,1
Katowice	Śląskie	2391	14,5	1,1
Grodzisk II	Wielkopolskie	42832	66,5	1,1
Leszno	Wielkopolskie	1340	42,0	1,1
Piekary Śląskie	Śląskie	1950	49,2	1,1
Żuromin	Mazowieckie	58367	72,5	1,2
Tarnów	Małopolskie	85980	60,8	1,2
Leszno	Wielkopolskie	50747	63,1	1,2
Piotrków Trybunalski	Łódzkie	3253	48,4	1,2
Dąbrowa Górnicza	Śląskie	533	15,9	1,2
Płock	Mazowieckie	129528	72,0	1,3
Wolsztyn	Wielkopolskie	38064	56,0	1,3
Gostynin	Wielkopolskie	62258	76,8	1,3
Opole	Opolskie	69431	43,8	1,3
Krotoszyn	Wielkopolskie	51836	72,6	1,3
Poznań	Wielkopolskie	116601	61,4	1,3
Sosnowiec	Śląskie	2105	23,1	1,4
Rawicz	Wielkopolskie	41390	74,8	1,5
Łomża	Podlaskie	95389	70,5	1,5
Białystok	Podlaskie	2599	27,7	1,5
Zielona Góra	Lubuskie	61048	38,9	1,7
Toruń	Kujawsko-Pomorskie	69769	56,7	1,9
Janów	Lubelskie	9704	71,9	2,2
Siedlce	Mazowieckie	117025	73,0	3,9
Sopot	Pomorskie	69	4,0	7,5

7. Farm structure in Poland

In June 2005, there were about 1.1 million agricultural holdings that had an economic size of at least 1 European Size Unit (ESU) according to Statistics in Focus (2006). These holdings employed 1.7 million persons working full time. They made use of about 13.1 million ha of agricultural area, which is on average 12.1 hectare per holding. Amongst these 1.1 million agricultural holdings 27% made use of less than one full time worker, while 30% made use of 2 or more full-time workers. Slightly more than 50% of the agricultural holdings (mainly the small farms) were situated in so-called less-favored or mountain areas.

Farm size distribution is bimodal with a relatively large number of farms smaller than 20 ha and a relatively large number of farm larger than 100 ha (Figure 18). The larger farms are former state-owned farms or co-operative farms.

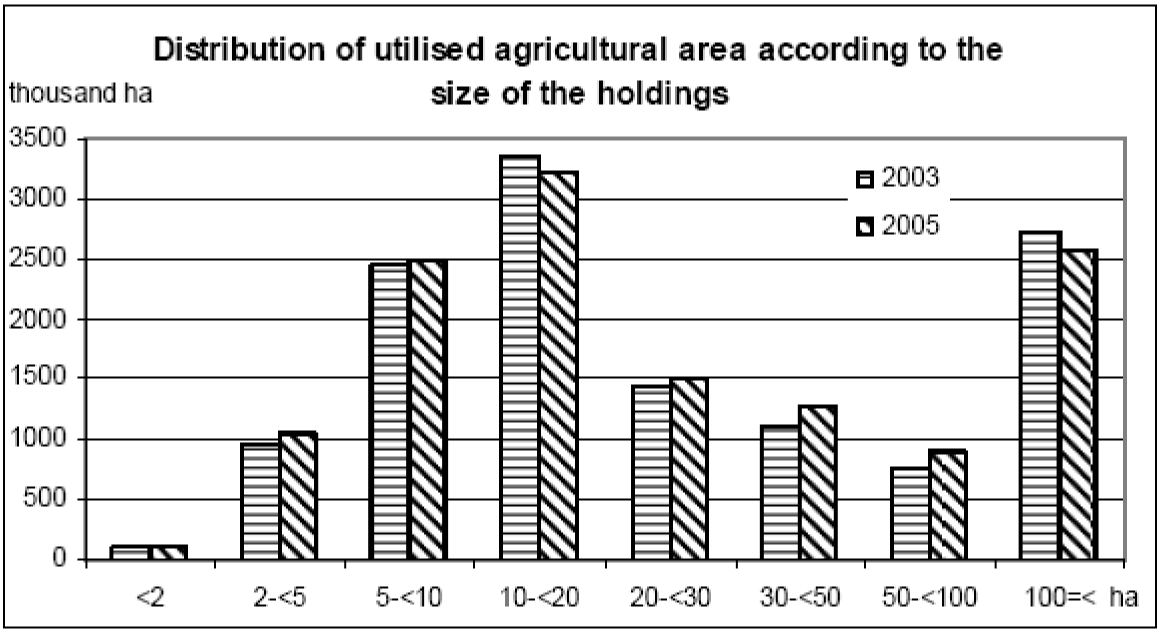

Figure 18. Farm size distribution in Poland in 2005 according to Statistics in Focus (2006).

Again, the number of farms and the farm size distribution highly depends on the definition of a farm. Overviews presented by the Foundation for the Development of Polish Agriculture (FDPA, 2004) arrive at a much higher (almost by a factor of 3) number of farms (Table 10). The difference is mainly related to the counting of small farms (<2 ha). Table 10 shows that almost 1 millions of farms have less than 1 ha of agricultural land, and half a million have between 1 and 2 ha. Together, farms with less than 2 ha account for more than 50% of the total number of farms according to the data presented in Table 10. The large number of small farms, and the low education level of most farmers are major obstacles for improving the management and the productivity of Polish agriculture (FDPA, 2004, 2006).

Table 10. Farm structure characteristics (after FDPA, 2004).

By type	Farms			Area of cultivation		
	number	%		Thou. ha	%	
		structure	aggregated		structure	aggregated
Total	2933228	100	x	16899,3	100	x
Private sector	2931962	100	x	15965,7	94,5	x
Individual farms in area	2928578	99,8	x	14858,4	87,9	x
Sizes UR						
0-1 ha	976852	33,3	33,3	396,5	2,3	2,3
1-2	516836	17,6	50,9	725	4,3	6,6
2-3	280996	9,6	60,5	684,6	4,1	10,7
3-5	348466	11,8	72,3	1353,4	8,0	18,7
5-7	216664	7,4	79,7	1278,3	7,6	26,3
7-10	209876	7,2	86,9	1750,8	10,4	36,7
10-15	182505	6,2	93,1	2213,7	13,1	49,8
15-20	83790	2,9	96,0	1437,8	8,5	58,3
20-30	64080	2,2	98,2	1536,6	9,1	67,4
30-50	31432	1,1	99,3	1171,8	6,9	74,3
50-100	11977	0,4	99,7	799,7	4,7	79,0
100-200	2907	0,1	99,8	394,2	2,3	81,3
200-500	1525	0,0	99,8	480,5	2,8	84,1
500-1000	515	0,0	99,8	351,5	2,1	86,2
1000 ha and more	177	0,0	99,8	283,9	1,7	87,9
Agriculture producing coops	1328	0,0	99,9	323,9	1,9	89,8
Other private	2146	0,1	100	783,5	4,7	94,5
Public sector	1266	0,0	100	933,5	5,5	100
State farms	935	0,0	x	16,7	5,4	x
Average area size of farm (ha)	Total land			Cultivated land		
All farms	6,59			5,76		
Above 1 ha UR	9,60			8,44		

According to Statistic in Focus (2006), 22% of the 1.1 million agricultural holders were women, 21% of the holders were aged 55 or more, and only 18% younger than 35 years. A total of 29% had another activity as major occupation.

Table 11 shows that the percentage of the working population active in agriculture ranges from 17 to 29%, depending on the statistical source. Differences between voivodships are large. Voivodships in the western and south-western half have the lowest percentage of people working in agriculture. Despite the large number of people involved in agriculture, the contribution of the agriculture to the gross added value of the Polish economy is on average less than 4% (Table 11).

Table 11. Gross added value of agriculture by voivodship and the share of people employed in agriculture per voivodship (after FDPA, 2004).

Region	Gross added value[a] 2001	Gross assets[a] 2001	Investments[a] 2001	Employed[b,c] 2002	
				A	B
Dolnośląskie	2,7	6,4	1,4	16,8	8,7
Kujawsko-pomorskie	4,6	10,8	3,3	27,3	18,5
Lubelskie	7,0	14,7	4,1	53,0	28,3
Lubuskie	4,0	7,0	2,3	18,6	9,9
Łódzkie	3,9	9,4	2,7	33,2	21,7
Małopolskie	2,3	5,4	0,9	36,8	18,4
Mazowieckie	3,5	4,6	0,7	25,7	15,9
Opolskie	5,0	8,5	3,8	29,8	17,2
Podkarpackie	3,0	9,6	2,0	48,3	25,0
Podlaskie	7,1	16,6	5,6	47,5	35,5
Pomorskie	2,4	6,4	2,7	15,5	9,4
Śląskie	1,2	2,6	0,6	12,6	4,8
Świętokrzyskie	5,0	10,6	3,7	50,2	33,3
Warmińsko-mazurskie	6,3	14,5	5,7	27,4	17,8
Wielkopolskie	6,7	11,2	3,1	26,2	17,9
Zachodniopomorskie	4,3	8,9	3,5	15,7	9,3
Poland	**3,8**	**7,6**	**1,9**	**29,3**	**17,3**

a- including hunting, forestry, fishing and fishery, b- including forestry and hunting; c -, A - GUS estimates based on 1996 NC, B - based on 2002 NC

Source: Annual Yearbook, GUS Warsaw 2003, Gross National Product, Statistical Office in Katowice, 2003.

8. Fertilizer N use and N surpluses in Poland

The N fertilizer use in Poland has decreased rapidly following the political changes in the late 1980s and early 1990s (Figures 19), but thereafter increased again slightly but steadily. Mean fertilizer use was 56 kg per ha in 2004, which is below the averages of the EU-15 (~76) and EU-27 (~66 kg per ha). Results presented Table 12 suggest that mean N fertilizer use in Poland in year 2000 was 59 kg per ha, i.e. almost 20% more than the 50.3 kg per ha presented in Figure 19. Evidently, there are differences between statistical databases in fertilizer use

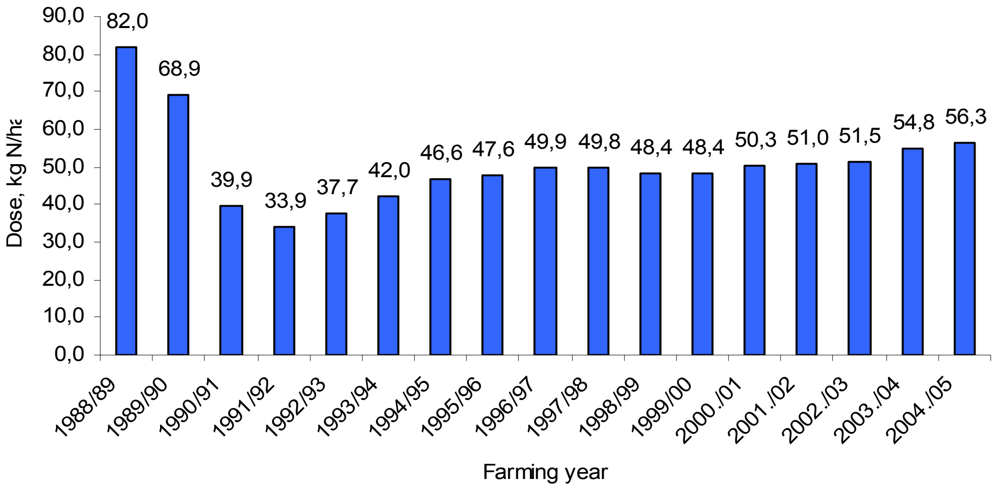

Figure 19. Consumption of nitrogenous fertilizers in terms pure ingredient and per 1 ha of agricultural land in Poland [Rocznik…, 1999, Rocznik…, 2001, Rocznik…, 2005]

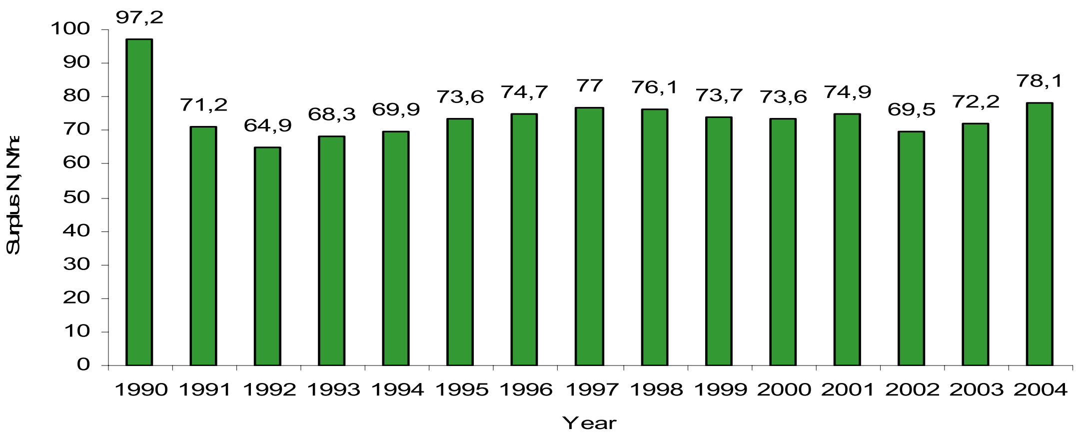

Figure 20. Surplus of nitrogen in terms per 1 ha of agricultural land in Poland (acc. method of farm gate balance) [Pietrzak, 2007].

Table 12. Area of agricultural land and fertilizer N use in the Member states of the EU-27 in the year 2000 (From FAOstat; Velthof et al., 2007).

Country	Agricultural land, million ha	Fertilizer N use in 2000, Kg per ha
Austria	3.22	37
Belgium	1.35	110
Bulgaria	4.72	31
Cyprus	0.11	69
Czech. Rep	3.74	70
Denmark	2.57	91
Estonia	0.73	31
Finland	2.02	83
France	27.33	85
Germany	16.00	115
Greece	4.89	58
Hungary	5.48	58
Ireland	4.36	85
Italy	13.52	61
Latvia	1.48	19
Lithuania	2.57	38
Luxembourg	0.12	108
Malta	0.01	43
Netherlands	1.89	159
Poland	15.07	59
Portugal	3.10	36
Romania	14.08	17
Slovakia	2.22	37
Slovenia	0.49	71
Spain	20.08	55
Sweden	2.83	70
United Kingdom	16.88	66
Eu-27	170.86	66

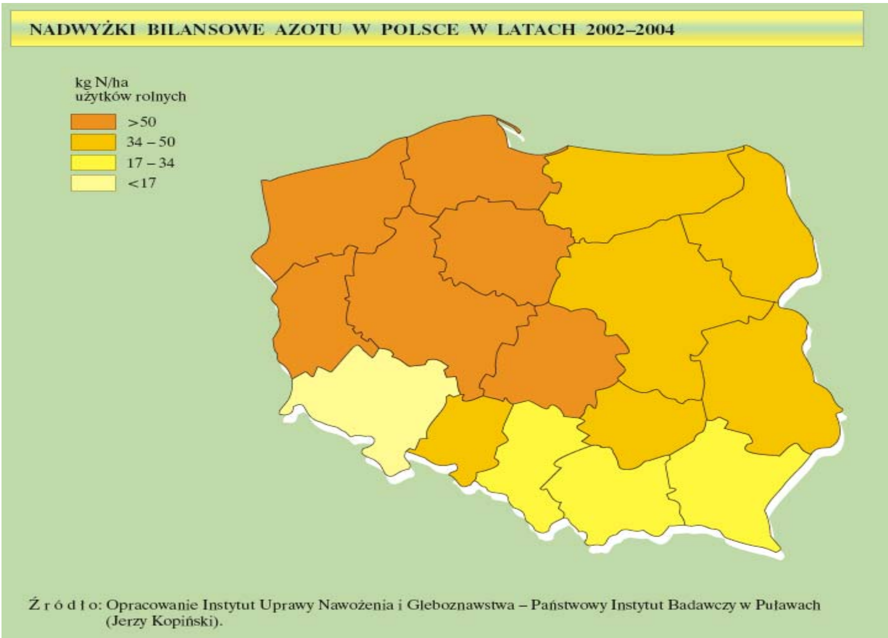

Figure 21. Surplus of nitrogen in kg per ha of agricultural land in Poland and provinces in 2002-2004 (acc. method of field surface balance) [Ochrona, 2006]

Changes in the calculated mean N surpluses (Figure 20), in kg per ha agricultural land, show similar trends as the changes in N fertilizer use presented in Figure 19. Mean N surplus was 78 kg per ha in 2004. Surpluses were highest in the northwestern part and lowest in the southeastern part of Poland (Figure 21). However, regional variation was relatively small.

Commonly, there is a considerable uncertainty in the estimated N surpluses. Table 13 shows estimates of N surpluses for Member states of the EU-27 using three different sources. OECD estimated a N surplus in Poland for 1997 of 30 kg N per ha, which is more than a factor 2 lower that the N surplus estimated by Pietrzak (2007), as shown in Figure 20. Again, differences in definition of agricultural land and in the N inputs included in the balance calculations will have contributed to the large differences. MITERRA-EUROPE estimated a N surplus of 58 kg per ha in 2000, i.e. about 20 kg less than calculated by Pietrzak (2007). Data presented in Table 13 also suggests that the mean N surplus in Poland is below the averages of the EU-15 and EU-27.

A partitioning of the N surplus in Poland over the various possible N loss pathways to the environment is presented in Table 14. Pietrzak (2007) estimated that 68.8% of the N surplus is lost via gaseous N emissions to the atmosphere and that 31.2% of the N surplus is lost via leaching to groundwater and surface waters. Hence, the estimated mean N leaching losses are 24.4 kg per ha per year according to Pietrzak (2007). Evidently, the uncertainty in these estimates is large. For example, the mean N leaching losses estimated by Pieterzak (2007) will be halved when the OECD estimate of the N surplus (30 kg per ha; Table 13) is used as starting point.

Table 13. Estimated N surpluses in kg N per ha agricultural land as calculated with MITERRA-EUROPE for the year 2000, and as estimated by Eurostat/European Environmentl Agency (EEA) (also for the year 2000), and by OECD (for the year 1997). After Velthof et al., 2007.

	MITERRA-EUROPE 2000	EEA/Eurostat 2000	OECD 1997
Austria	45	43	29
Belgium	158	174	178
Bulgaria	26		
Cyprus	181		
Czech. Rep	58		52
Denmark	104	77	112
Estonia	24		
Finland	78	51	59
France	91	39	51
Germany	108	105	56
Greece	63	69	30
Hungary	49		-17
Ireland	102	44	75
Italy	64	37	29
Latvia	16		
Lithuania	25		
Luxembourg	111	117	
Malta	255		
Netherlands	248	226	248
Poland	58		30
Portugal	43	42	62
Romania	13		
Slovakia	17		
Slovenia	79		
Spain	57	39	44
Sweden	58	38	36
United Kingdom	65	45	87

Table 14. Nitrogen surplus and its fate in the Polish agriculture in 2004 [Pietrzak, 2007]

Partitioning of the N surplus	Nitrogen flows		Data source
	thousand tons N year^{-1}	kg N·ha^{-1} AA	
Nitrogen surplus (N)	1276	78,1	Pietrzak, 2007
Gaseous emission of nitrogen:	900	53,7	
- ammonia (NH_3)	232	14,2	Pietrzak, 2006
- nitrous oxide (N_20)	48	2,8	Pietrzak and all., 2002
- nitrogen oxides (NO_x)	20	1,2	Sapek and all., 2000
- molecular nitrogen (N_2) as result of the denitrification	600	35,5	$=N_20\cdot(0,08)^{-1}$ (N_2O emits in the quantity 3-10% N_2 [Sapek, 1998])
Flow of nitrates (NO_3) to waters	376	24,4	= surplus N – gaseous emission N

9. Nitrogen and phosphorus loads from Poland to the Baltic Sea

The Baltic Sea is highly eutrophic. Rivers are by far the largest sources of N and P in the Baltic Sea, and Polish rivers contribute as much as 25 to 50% to the total riverine input of N and P to the Baltic (see also section 11.4, figure 34). It has been estimated that 60% of the total N load and 40% of the total P load, from Polish territory into the Baltic Sea, originate from agricultural sources [Ilnicki, 2004]. During recent years, total N and P loads tended to decrease (Figures 22 and 23), mainly because of the implementation of sewage treatment. Mean N discharges are in the range of 100-250 million kg per year (Inspection for Environmental Protection, 2003). Assuming that 60% is from agriculture, and that the area of agricultural land is 13 million ha, this suggests that mean N leaching losses to the Baltic Sea are in the range of 5 to 12 kg N per ha of agricultural land per year. Evidently, the designation of NVZs in Poland has to reflect the severe eutrophication of the Baltic Sea and the large contribution of agriculture to the N and P loading of the Baltic Sea. Currently, this is not the case.

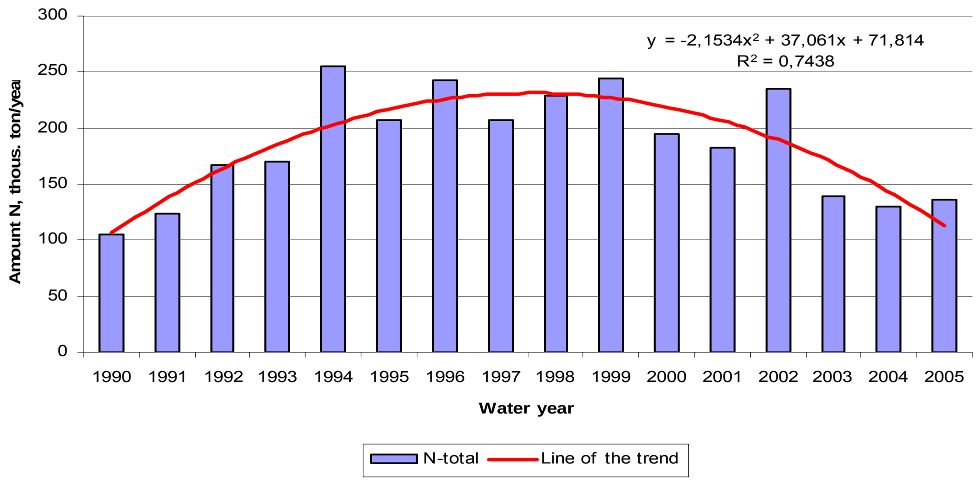

Figure 22. Changes in the amounts of nitrogen from the area of Poland discharged into the Baltic Sea in the period 1990-2005 [on the base: Ochrona , 1999, Ochrona …, 2005]

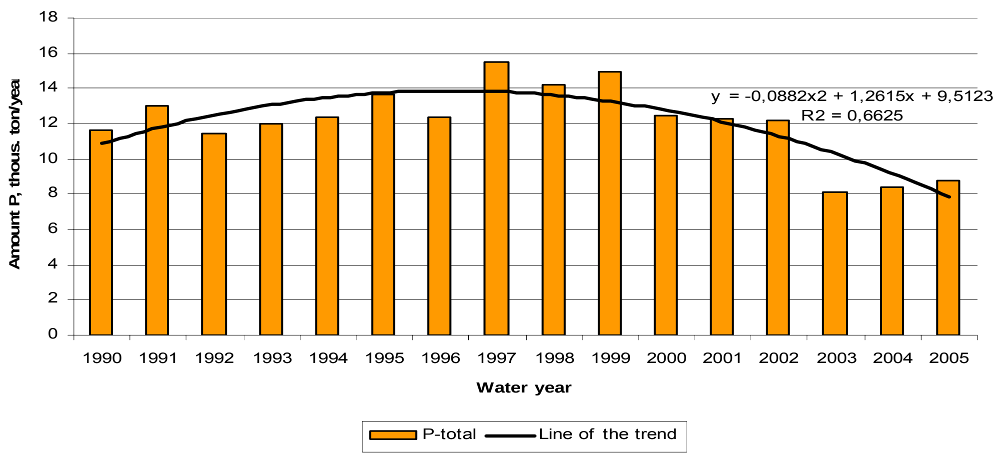

Figure. 23. Changes in the amounts of phosphorus from Poland discharged into the Baltic Sea in the period 1990-2005 [on the base: Ochrona , 1999, Ochrona , 2005]

10. Assessment of groundwater and surface water quality monitoring in Poland

10.1. Overview of the groundwater and surface waters monitoring in Poland

Monitoring of the quality of surface waters and underground waters is the responsibility of the Inspection of the Environment Protection, and is organized within the framework of State-Monitoring of the Environment (PMŚ). The State-Monitoring of the Environment includes the measurement, estimations and prognoses of state environments. Coordinator of the State-Monitoring of the Environment is the Chief Inspector of the Environment Protection, which is a central organ of the government- administration of the Ministry of Environment. Regional inspectors coordinate the monitoring of regional water resources. For the monitoring of surface waters and groundwater, the Main Inspectorate of the Environment Protection cooperates with:

- Institute of Meteorology and Water Management in Warsaw Katowice Division (for rivers),
- Polish Geological Institute in Warsaw (for groundwater resources),
- Institute of Environmental Protection - in Warsaw (for lakes).

In 2004, there were in total 3955 monitoring points divided over rivers, lakes, reservoir and groundwater reservoirs. In 2005, there were 3648 points (Table 15). Most of the monitoring stations are coordinated at regional levels.

Table 15. The number of monitoring points of the national and province inspectorates of the protection of the environment in years 2004 and 2005 [Informacja …2005 roku]

The component of the environment	Number of monitoring points in networks							
	National		Regional		Local		Total	
	2004	2005	2004	2005	2004	2005	2004	2005
Rivers	-	-	2054	2034	47	36	2101	2070
Lakes	40	39	529	599	-	-	569	638
Barrage- reservoirs	-	-	72	76	2	6	74	82
Underground waters	-	-	1084	668	127	190	1211	858

The monitoring of rivers is managed by province inspectorates of the environmental protection. In 2005, there were in total 2070 monitoring points (diagnostic monitoring points, monitoring points of dangerous matters, points of the EIONET-Waters network, points appointed on NVZ, points appointed for the waters use of - occurrence of fish in natural conditions, bathes' and waters used to the supply of people, and 20 points consequential from residue the Accessional Treaty).

The monitoring of lakes in the national network embraced 9 lakes in 2005, with 39 monitoring points. In addition, there were 599 monitoring points in lakes coordinated by regional and province networks. In total, the water quality of 147 lakes was monitored. In the years 1994-2001 a total of 792 lakes representing ~60% of Polish lakes have been monitored. The assessment of the water quality of these lake is indicated in the report of the Inspection for Environmental Protection (2003), showing that only 4% of the lakes have class I, 37% of the lakes have class II, 39% of the lakes have class III and as much as 21% of the lakes have class IV (excessively polluted). Eutrophication is the most serious threat to Polish lakes. This is caused by the input of N and P from the catchment area. The main sources of additional N and P inputs are industrial, municipal wastewater, crop production and livestock production (Inspection for Environmental Protection, 2003; page 116).

Monitoring of groundwater is also coordinated by the Chief Inspector of the Environment Protection. In addition, there are regional networks coordinated by province inspectors of the environment. The monitoring network consists of a range of sampling sites, including bore-holes, dug wells and piezometers. Concentrations of nitrate (NO_3^-) in groundwater are usually categorized in three classes, namely

- < 25 mg NO_3^- per liter
- 25 – 50 mg NO_3^- per liter
- > 50 mg NO_3^- per liter

In some cases the intermediated class 25 – 50 mg NO_3^- per liter is split into 25 – 40 and 40 – 50 mg NO_3^- per liter.

For surface waters, monitoring programs exist for lakes, rivers, reservoirs and coastal waters (see also Table 15). A distinction is made between large lakes and rivers, and small lakes and rivers and streams, in part also for organization reasons as the Regional Water Management Boards (RZGW) are responsible for the monitoring of the small lakes and rivers and streams and the State Water Management Board for the large rivers and lakes.

Surface waters affected by nitrates from agriculture are termed “sensitive waters”. The Ministry of Environment has defined “sensitive waters” as follows:
§ 1. Sensitive waters for pollution of nitrogen compounds from agricultural sources include polluted waters and waters threatened by pollution, unless restrictive actions are taken.

Polluted surface waters include:
1) Inland surface waters, in particularly waters used for the preparation of drinking water, in which the content of nitrates is >50 mg NO_3/dm^3;
2) Inland surface waters, including estuaries and coastal sea waters, demonstrating signs of eutrophication, which efficiently can be diminished by reducing the input of nitrogen.

Threatened surface waters include:
1) Inland surface waters, in particularly waters used for the preparation of drinking water, in which the content of nitrates is 40 to 50 mg NO_3/dm^3 and which shows a tendency to increase;
2) Inland surface waters, including estuaries and coastal sea waters, demonstrating signs of eutrophication, which efficiently can be diminished by reducing the input of nitrogen.

Source: The Order of the Ministry of Environment from 23 December 2002 on the matter of criteria of marking of sensitive waters on pollution by nitrogen compounds from agricultural sources. (The Law Gazette. No. 241, item 2093)

Common criteria for the classification of the trophic status of surface waters are shown in Table 16. In total 5 common criteria are used, namely total phosphorus, total nitrogen, nitrate-nitrogen, chlorophyll a and Secchi depth. Threshold values have been defined above with surface waters are classified as eutrophic. A distinction is made between stagnant waters (lakes, reservoirs), flowing waters (rivers, streams), inland marine waters and coastal waters.

Table 16. Threshold values for total phosphorus, total nitrogen, nitrate-nitrogen, chlorophyll a and Secchi depth above which stagnant waters, flowing waters, inland marine waters and coastal waters are classified as eutrophic.

Indicators	Units	Stagnant waters (summer season)	Flowing waters[1] (annual average)	Sea- internal waters[2]	Coastal waters
Total phosphorus	mg P/dm^3	> 0,1	> 0,25	> 0,3	> 0,1
Total nitrogen	mg N/dm^3	> 1,5	> 5	> 7	> 4
Nitrate nitrogen	mg NO_3-N $/dm^3$	-	> 2,2	> 3,4	> 1,8
Nitrates	mg NO_3/dm^3	-	> 10	> 15	> 8
Chlorophyl a	mg/m^3	> 25	> 25[1]	> 50 / > 30[3]	> 10
Secchi depth	m	< 2	-	< 4	< 2

[1] Rivers where the water has sufficiently long residence time for the development of algae.
[2] With the exclusion of the sea- internal waters of the Gdańsk Gulf.
[3] On the section at the river mouth of Odra > 50 / on sections at the river mouth in catchment remaining rivers >30.

Additional indicators for eutrophication include:
- prolonged blossoming of waters caused often by cyanosises in lakes, and by diatoms and chlorophyta in rivers and estuaria;
- massive development of aerophyte algae;
- oxygen depletion of the hypolimnion in lakes, and the possible formation of hydrogen sulfides;
- strong diurnal changes of the oxygen partial pressure of rivers and coastal sea waters;
- reduction of the diversity and the abundance of macro-phytobenthos, invertebrate, and fish.

Source: The Order of the Ministry of Environment from 23 December 2002 in the matter of criteria of marking of sensitive waters on pollution nitrogen compounds from agricultural sources. (The Law Gazette. No. 241, item 2093)

10.2 Overview of the guidelines for water quality monitoring - Nitrates Directive

Assessment of the quality of the monitoring of groundwater and surface water in Poland has to be done relative to the requirements of the Nitrates Directive. Therefore, this section provides a short overview of the monitoring requirements of the Nitrates Directive.

Surface waters

Under the Nitrates Directive, surface waters must be monitored at least monthly and more frequently during flood periods. Surface waters should be monitored at those times when elevated nitrate levels are expected (October to March).

For this mandatory monitoring Member States will use those sampling sites (or a representative selection of them) established under directive 75/440/EEC, i.e. at the sites used for drinking water abstraction before it is sent away for treatment, and other sampling stations that are representative of their surface waters. Member States should take care to ensure that their sampling network is sufficient for the purposes of Annex I. In practice this means that they will have to supplement their drinking water abstraction sites with extra, sampling points to arrive at a representative sampling network. As a guide, in this context, one point per 300 to 1000 km^2 of land area in a river basin or 1 point per 5 to 30 km^2 of water surface will normally be sufficient.

Member States will need to increase the density of their surface water sampling network inside and at the borders of designated vulnerable zones and "at risk” zones (e.g. intensively cropped watersheds). This will enable them to revise the borders of the zones if necessary and to make an accurate assessment of the impacts of changes in agricultural practice on nitrate concentrations in the waters within the zones

It is not mandatory to collect historical information for the purposes of complying with the Nitrates Directive. However, where historical data is easily available and comparable with modem data, Member States should compile long time series data sets and examine them for trends in average annual; winter and maximum peak nitrate concentrations in surface waters. This will enable Member States to evaluate if waters could be affected by nitrate pollution, in the meaning of Article 3.1 (long term trends). In this context 'long time series' means the last 20.or 30 years or so.

Groundwater

Under the Nitrates Directive, groundwater must be sampled at regular intervals taking into account the provisions of Directive 80/778/EEC. In practice, to ensure representative sampling, Member States should sample at the most appropriate frequency according to local geological conditions and with regard to the effects of abstraction. As a guide, at each monitoring station samples should be taken at least twice a year. Samples should be taken more frequently if appropriate for the local hydrogeology. If the area can be described as having slow infiltering groundwater or low nitrate levels, sampling once a year could suffice. In this context 'slow' means less than 1 m/year vertical infiltration speed.

Member States should choose their groundwater sampling points so as to get a good picture of the nitrate concentration in their groundwater aquifers. The selection of sampling points will depend on the land use and the hydrogeological conditions. Both shallow and deep groundwater should be included in the monitoring network.

The depth of sampling points within the aquifer should be appropriate to the land use, physical conditions and the type of aquifer. For example, both the upper and lower parts of the aquifers that are connected to the soil should be sampled as the upper parts (the first 5 m of the saturated zone) will tend to be more reactive to changes in agricultural practice. It is also important to monitor nitrate concentrations in the upper layers of aquifers because they tend to drain directly into rivers and other surface waters. Samples from the deeper parts of aquifers can give an indication of long term trends.

Eutrophication

According to Article 6 of the Nitrates Directive, Member States are required to review the eutrophic state of their surface fresh, coastal and estuarine waters every four years. It is considered that the open sea must also be covered by this review, and that this review will necessitate some monitoring. In practice, this means that Member States should collect and examine biological and chemical monitoring data to determine the eutrophic state of their waters.

The word "eutrophication" has its root in two Greek words: "eu", which means "well", and "trope", which means "nourishment" (BSEP 100, 2005). The modern use of the term eutrophication is related to the inputs and effects of nutrients in aquatic systems. Many European surface waters do not have a pristine or good ecological status. This is due to discharges, losses, and emissions of nutrients and their effects in the aquatic environment. Until now, the management of surface water eutrophication has focused on (i) discharges from point sources, (ii) losses from cultivated land, and (iii) emissions to the atmosphere and the subsequent deposition to surface waters. The measures have focused on the sources and sectors causing eutrophication. Consequently, eutrophication has been defined in relation to sources and/or sectors, and these definitions have been discussed greatly, mainly owing to the strong focus on nutrients and also because it is not defined what an "undesirable disturbance" might be. In the EU legislation, eutrophication has been defined as:

"*the enrichment of water by nutrients, especially nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of water* concerned" (Council Directive concerning Urban Waste Water Treatment (91/271/EEC; . Official Journal L 135)) , and

"*the enrichment of water by nitrogen compounds causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of water concerned*" (Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Nitrates Directive. Official Journal L 375).

The Nitrates Directive defines eutrophication only in terms of nitrogen input and so a Member State need only take remedial action under this Directive (i.e. designate NVZs) if nitrates from agricultural sources make a significant contribution to the problem. Nitrogen is implicated as a main basic nutrient in the development of algal blooms, whether in fresh, estuarine, coastal or marine waters, even if it is not the factor limiting the size and duration of the bloom. Therefore, Member States must take action in all cases where nitrogen from agricultural sources is significantly implicated in eutrophication phenomena.

The Nitrates Directive defines eutrophication as "the accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water." The fact that eutrophic conditions may have been persistent in a location for several years does not remove the need to assess the condition or its causes. Eutrophication is a complicated phenomenon. There are various indicators for detecting eutrophication in fresh and salt waters. Those that have shown to be good indicators of actual or potential eutrophication in coastal and marine waters are listed below. For each parameter it is necessary to assess whether the factors described below are in operation and, for the purpose of taking actions in the framework of the Nitrates Directive, whether agricultural sources are making a significant contribution to the problem.

1. Degree of nutrient enrichment, i.e., discharges of
   - Total N,
   - Total P,
   - Total BOD,
   - Total COD.
2. Dissolved nutrient concentrations in surface waters in winter
   - Dissolved inorganic nitrogen (DIN)
   - Dissolved inorganic phosphorus (DIP)
   - N/P ratio in winter;
   - Nitrate
3. Direct effects of nutrient enrichment.
   - Chlorophyll a
   - Phytoplankton indicator species
   - Total organic matter concentration
4. Indirect effects of nutrient enrichment
   - Degree of oxygen deficiency
   - Changes/kills in zoobenthos and fish kills
   - Decrease in Secchi depth
5. Other possible effects of nutrient enrichment
   - Algal toxins.

A classification scheme for assessing the eutrophic status of coastal waters has been proposed by HELCM (BSEP 104, 2005). For inland surface waters, similar criteria and indicators have been derived. For example, for assessing the trophic status of rivers the following criteria are being used in Poland:

- Chlorophyl a > 25 mg per m^3

- Total P > 0.25 mg per liter
- Total $P\text{-}PO_4$ > 0.1 mg $P\text{-}PO_4$ per liter (or > 0.3 mg PO_4 per liter)
- $N\text{-}NO_3$ > 2.25 mg per liter (or > 10 mg NO_3 per liter)

In practice this will include looking at all the relevant factors including trying to establish the relative contributions of other sources of nitrate and phosphates to the problem. Member State's monitoring should also be directed at establishing whether surface waters could become eutrophic in the future, and Member States should examine past trends and make predictions about future developments.

10.3 Assessment of groundwater and surface water quality monitoring in Poland

The existing monitoring programme for Poland's surface and groundwater was assessed as part of the NVZ assessment process *sensu strictu*. This assessment of the comprehensiveness (including frequency, coverage, and measured parameters) of the monitoring programme was carried out taking the local conditions into consideration.

The number of surface waters monitoring stations in Poland in 2005 was 2790 and the number of groundwater monitoring stations 858. With a total surface area of 312,685 km^2, these numbers translate into a density of 8.9 and 2.7 stations per 1000 km^2 land area.

The groundwater monitoring stations are rather evenly distributed over the country. This holds for the monitoring of the relatively deep groundwater as well as the monitoring of the relatively shallow groundwater. Apart from nitrate concentrations, many other constituents of the groundwater are measured and reported. For assessing the appropriateness of the designation of NVZs in Poland, the shallow groundwater monitoring stations are most relevant as these stations do reflect the management practices of the recent past must better than the deep groundwater monitoring stations. However, the density of shallow groundwater monitoring stations is relatively low and not evenly distributed over the country (Figure 24). Moreover, a relatively large percentage of samples from shallow groundwater monitoring stations has nitrate concentrations exceeding 50 mg per liter (see below).

Recommendation: In view of the relatively low density and uneven distribution of monitoring stations for shallow groundwater, and in view of its importance for underpinning the designation of NVZs, we recommend increasing the number of monitoring stations for shallow groundwater, especially in areas with large areas of utilized agricultural land. The stations should be positioned in such a way that they capture the influence of current agricultural practices as much as possible. Furthermore, the depth of groundwater monitoring, the frequency of sampling, and the extent to which the samples collected are considered to be representative (e.g. as a function of agricultural practices, flow or location in a river) should be indicated.

The spatial distribution of the surface water monitoring stations is much less even that the spatial distribution of groundwater. In some areas in the south and north conglomerations of monitoring stations can be found, while there are large areas in the eastern half and also in the north and west with very few monitoring stations (e.g. Figure 28). It is still uncertain whether all monitoring results of Regional Water Management Boards are reported to the Chief Inspector of the Environment Protection and/or to the European Commission under the Nitrates Directive. Discussions with representatives of the Ministry of Environment Protection and with Regional Water Management Boards indicate that the monitoring of groundwater and surface waters is under evaluation and revision, based also on the results that have been obtained so far. The monitoring is heavily focused on large rivers and large lakes (Table 15), which are likely also influenced by sewage discharges from households and industry, apart from the possible influence of nutrients from agricultural sources. There are very few monitoring sites in small rivers and lakes (Table 15), which are likely in more 'remote' areas and therefore relatively less influenced by sewage discharges from households and industry, and possible more by agricultural sources. The big challenge for the surface water monitoring in Poland is to make a proper distinction between nutrient sources, to be able to define proper mitigation strategies. In the current situation, sewage discharges from households and industry are still a large source, apart from agriculture. Within agriculture, there are point sources (e.g., leakages from stables and manure storage systems) and diffuse sources (through leaching and runoff from agricultural land). These two sources require different remediation strategies. The current monitoring programs are not well equipped to address source specification.

Recommendation: In view of the relatively low density and uneven distribution of monitoring stations for small streams and lakes, and in view of the likeliness that these surface waters are relatively strongly affected by nutrients from agricultural sources, we recommend reconsidering the distribution of monitoring stations for surface waters, especially in areas with large areas of utilized agricultural land. Again, the stations should be positioned in such a way that they capture the influence of current agricultural practices.

The surface water monitoring programmes must include both winter averages (October to March) and the concentrations in early spring (February/March), measured just before the onset of significant algal growth. During spring, algal growth will remove nitrates from the water. Thus it is more useful to measure total nitrogen, total phosphorus, chlorophyll, oxygen and pH, rather than nitrate from the onset of the algal growth through to the end of the growing season. Total nitrogen measured during the growing season is a useful parameter to assess the potential for eutrophication, together with total phosphorus.

The organization of the monitoring of water quality in Poland is complex. The Chief Inspector of the Environment Protection is co-ordinating the activities at national level, but the Regional Water Management Boards are rather autonomous. It was not easy to obtain a good overview of the organization, and it remains unclear whether all relevant monitoring data are reported to the Chief Inspector of the Environment Protection and/or to the European Commission under the Nitrates Directive. In addition, universities and research institutes also perform additional measurements in surface waters and groundwater for various purposes (see chapter 11), and these incidental data should be considered also, when reconsidering the appropriatness and revision of the current monitoring netword, and when considering the appropriateness of the current designation of NVZs in Poland.

Recommendation: In view of the regional execution of some of the water quality monitoring and complex organization and in view of the availability of additional information from various universities and research institutes, it is recommended to consider an extended search for so far 'hidden' information, and to use this additional information for a possible revision of the current monitoring program, including its organization).

It must be borne in mind that the above assessment is based on information made available without much contact with local authorities responsible for specific water bodies. It is possible that some of the recommendations are already under consideration.

11. Assessment of groundwater and surface water quality in Poland

11.1. Groundwater

In groundwater, mean nitrate concentrations are in the range of 10 and 20 mg NO_3 per l. The number of stations with nitrate concentrations exceeding 50 mg per litre ranges from 2 to 20% depending on the depth of the monitoring (Figures 24, 25, 26 and 27), and are evenly distributed over the country. There is no spatial correlation between samples with high nitrate concentrations and designated Nitrate Vulnerable Zones (NVZs; Figure 24.)

The percentage samples with high nitrate concentrations has been decreasing steadily during the last 15 years (Figures 25, 26 and 27), probably as a result of the decreasing fertilizer N input and improved management. High nitrate concentrations (>>50 mg per litre) in wells and groundwater are observed near farms and manure heaps (see also below).

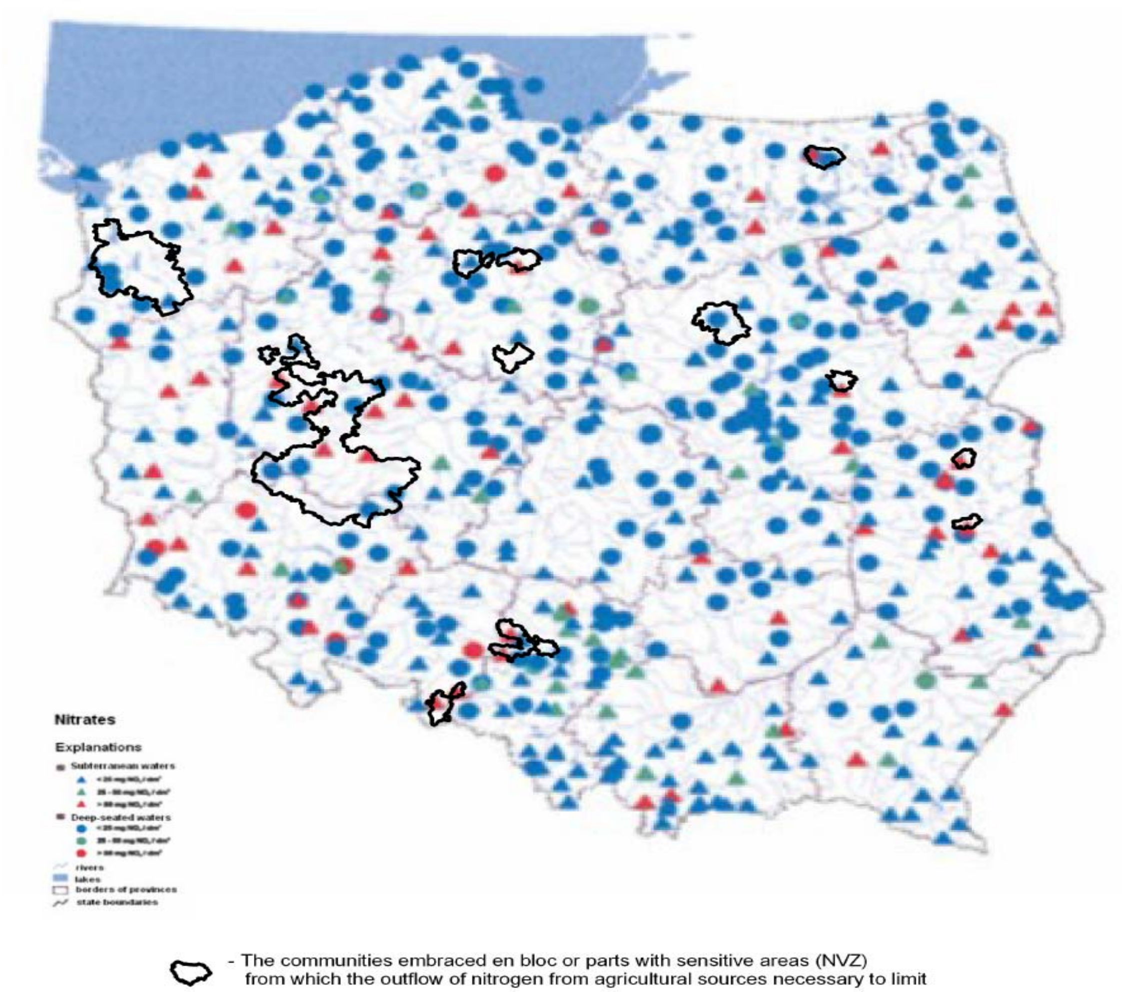

Figure 24. Spatial distribution of groundwater monitoring stations, and the mean nitrate concentration in groundwater. Locations of NVZs are also shown [Raport ..., 2003]

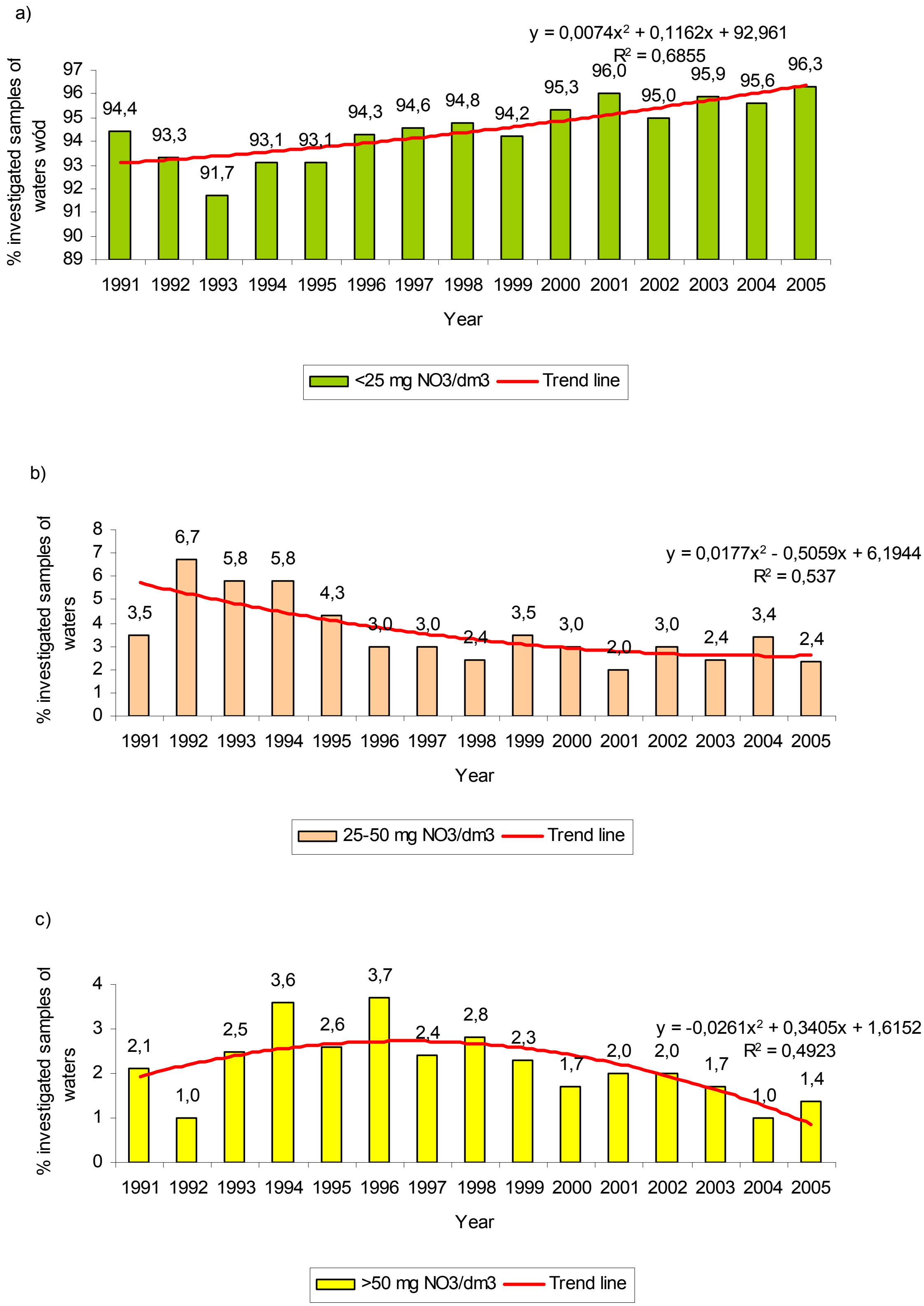

Figure 25. Percentage samples taken from deep groundwater reservoirs in the period 1991-2005 with nitrate concentrations: a) <25 mg $NO_3 \cdot dm^{-3}$, b) 25-50 mg $NO_3 \cdot dm^{-3}$, c) > 50 mg $NO_3 \cdot dm^{-3}$ [on the base: Raport ..., 2003, Informacja ...2003 roku, Informacja ...2005 roku]

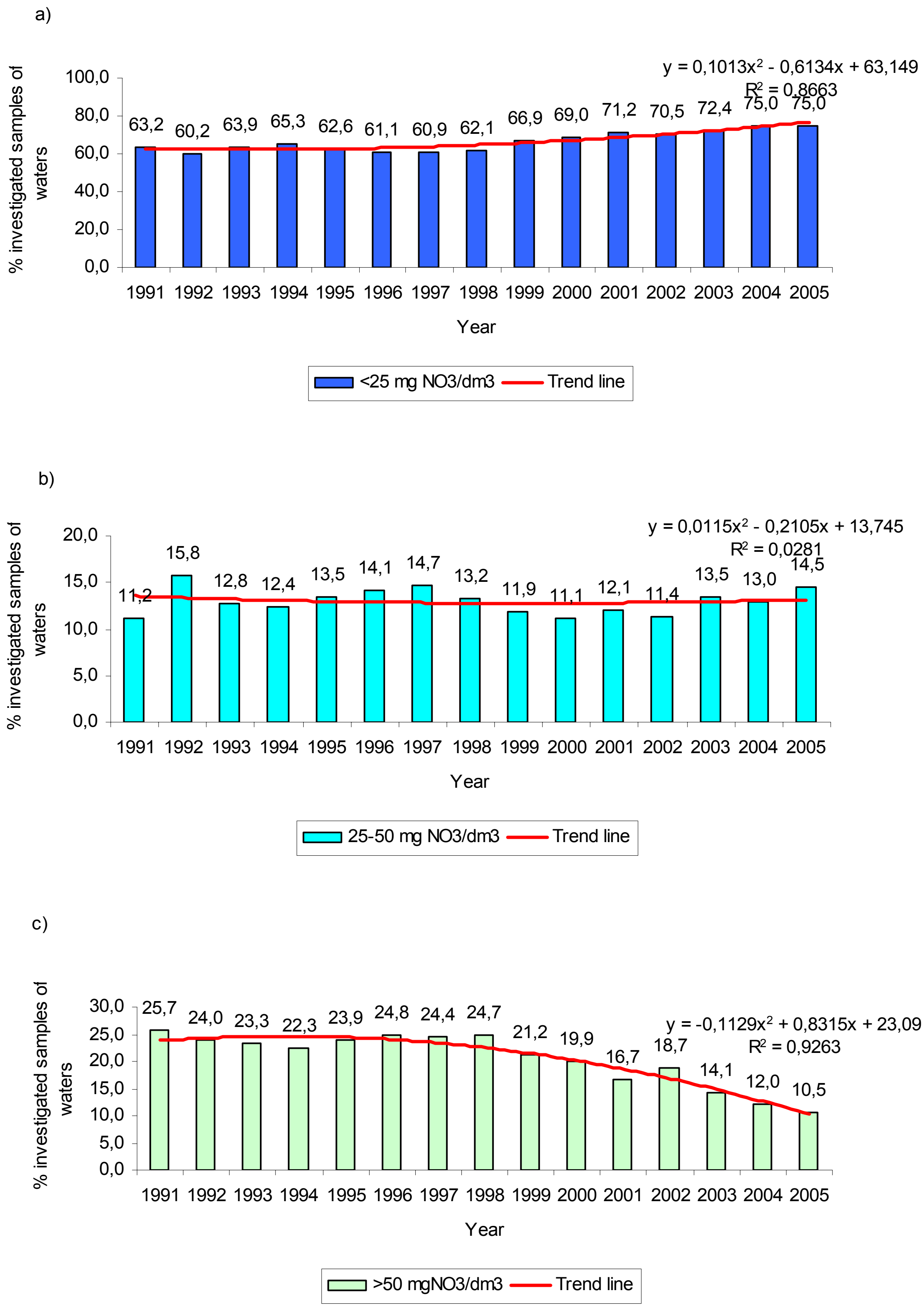

Figure 26. Percentage samples taken from shallow groundwater in the period 1991-2005 with nitrate concentrations: a) <25 mg $NO_3 \cdot dm^{-3}$, b) 25-50 mg $NO_3 \cdot dm^{-3}$, c) > 50 mg $NO_3 \cdot dm^{-3}$ [on the base: Raport ..., 2003, Informacja ...2003 roku, Informacja ...2005 roku]

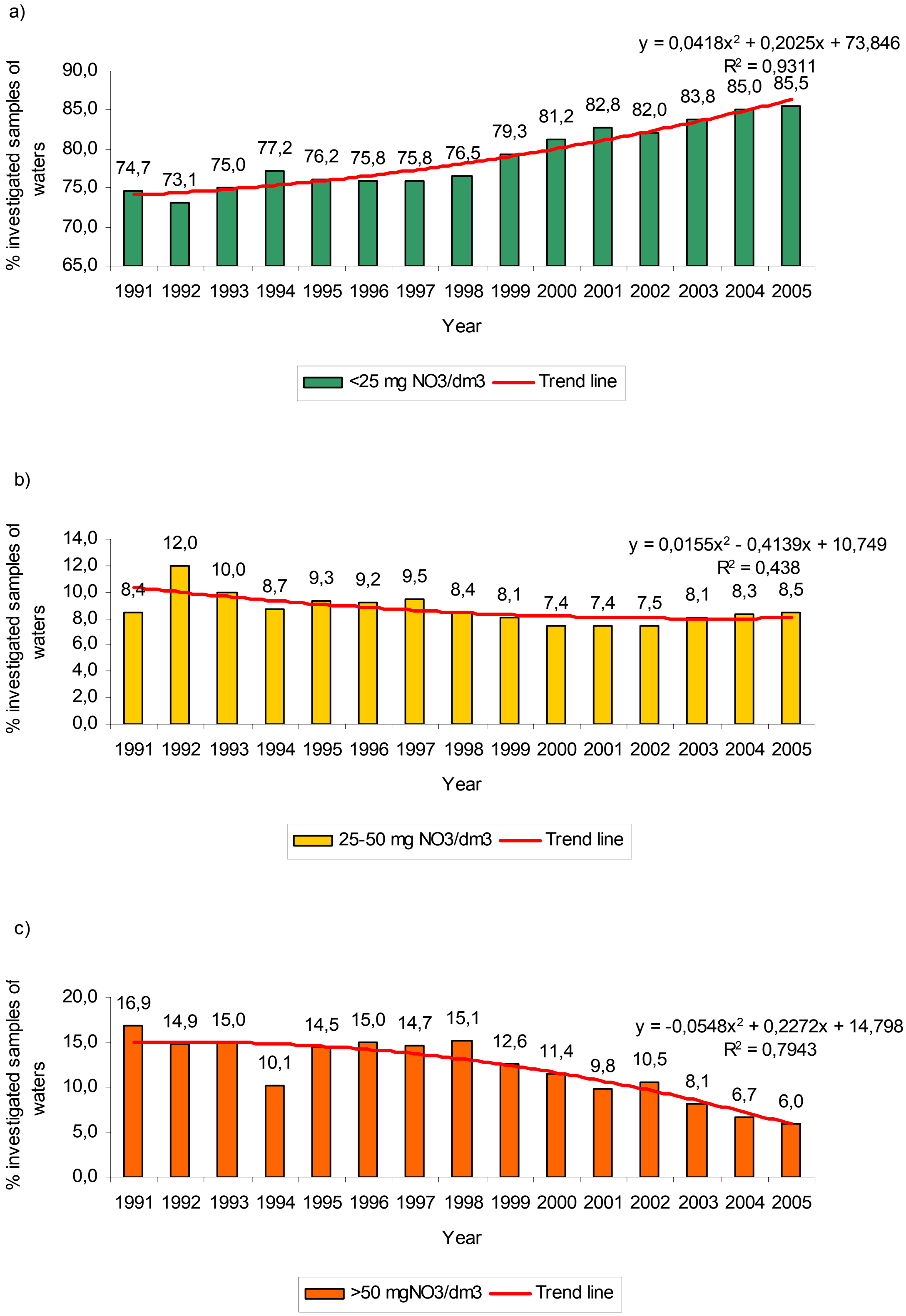

Figure 27. Percentage samples taken from groundwater in the period 1991-2005 with nitrate concentrations: a) <25 mg $NO_3 \cdot dm^{-3}$, b) 25-50 mg $NO_3 \cdot dm^{-3}$, c) > 50 mg $NO_3 \cdot dm^{-3}$ [on the base: Raport ..., 2003, Informacja ...2003 roku, Informacja ...2005 roku]

11.2. Lakes and reservoirs

Average nitrate concentrations in most surface waters are far below 50 mg per litre. In the period 1990-1999, on average 0.38% of the total number of samples analysed (95523) had nitrate concentration exceeding 50 mg NO3 per l and 0.26% of the samples had nitrate concentration in the range of 40-50 mg NO3 per l (Table 17).

Table 17. Percentage samples taken from surface waters with relative high nitrate concentrations [Informacja…, 2003]. Total number of samples was 95523 during the period 1990-1999.

Concentration of nitrates in surface waters	Number of samples, %
- 40–50 mg $NO_3 \cdot dm^{-3}$	0.26
- >50 mg $NO_3 \cdot dm^{-3}$	0.38

An overview of the monitoring stations and the results of the monitoring of surface waters in the years 2004 and 2005 are shown in Tables 18 and 19. The number of monitoring stations in surface waters influenced by nitrates from agriculture is approximately half of the total number of monitoring stations (Table 18). The number of monitoring stations with nitrate concentrations exceeding 50 mg per liter and exceeding 40 mg per liter is about 1% of the total number. However, the number of stations that show signs of eutrophication by N from agriculture is rather high (Table 19).

Table 18. Number of surface water monitoring stations managed by Regional Water Management Boards (RZGW), and the number of stations that have "sensitive" surface waters in 2004 and 2005 [Ochrona środowiska, 2005; 2006]

Regional Water Management Board (RZGW)	Number of monitoring station: total		not sensitive waters		sensitive waters	
	2004	2005	2004	2005	2004	2005
Gdańsk	95	100	72	54	23	46
Gliwice	43	52	21	18	22	34
Kraków	163	149	101	89	62	60
Poznań	60	60	18	13	42	47
Szczecin	85	73	58	44	27	29
Warszawa	98	95	42	43	56	52
Wrocław	64	62	32	12	32	50
Total	608	591	344	273	264	318

Table 19. Results of the monitoring of surface waters in 2004 and 2005 See also Table 16 [Informacja …2005 roku]

RZGW	Number of stations with > 50 mg $NO_3 \cdot dm^{-3}$	Number of stations with 40-50 mg $NO_3\ dm^{-3}$	Number of stations which exceeded eutrophication threshold values: NO_3 2004	N_t 2005	NO_3 2004	N_t 2005	Chlorophyl a
Gdańsk	1	1	6	6	15	8	11
Gliwice	0	0	9	10	13	15	3
Kraków	0	0	53	54	35	22	8
Poznań	1	2	34	36	20	23	3
Szczecin	0	0	14	14	13	3	10
Warszawa	3	3	45	46	29	35	17
Wrocław	0	1	28	29	21	16	1

The spatial distribution of the 'sensitive' and 'non-sensitive' surface waters is shown in Figure 28. Clearly, most of surface water monitoring station are in the south of the country, with relatively few stations in the eastern part. Surface waters sensitive to nitrates from agriculture are found in all areas with surface water monitoring stations. Figure 28 also shows that many surface waters are so-called "sensitive" surface waters, i.e. polluted or affected by nitrates from agricultural sources. Only a fraction of these surface waters are situated in designated Nitrate Vulnerable Zones (NVZs).

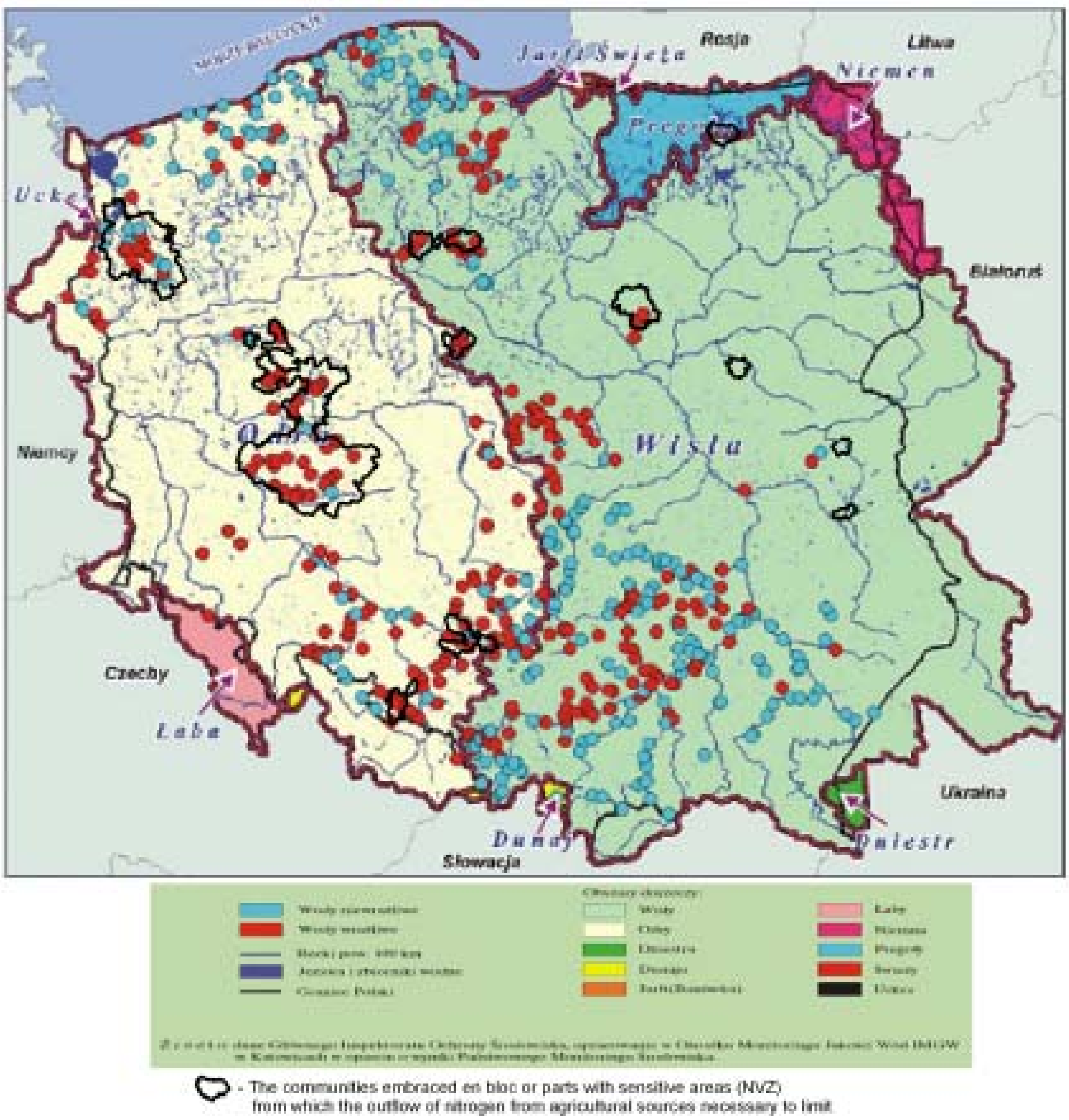

Figure 28. Spatial distribution of surface waters, sensitive to nitrogen compounds from agricultural sources in 2005 [Ochrona..., 2006]. Note that blue dots mean surface waters not sensitive waters, and red dots mean sensitive surface waters.

Monitoring results during the period 1990-2003 suggest that the water quality has remained stable (Figure 29). Information about the trophic status of lakes is provided by the Ministry of Environment on their website *(http://www.bip.gios.gov.pl/dokumenty/; Informacja o realizacji zadań Inspekcji Ochrony Środowiska w 2006, 2005, 2004, 2003 roku).* These reports indicate that the seasonal variations in the concentrations of total phosphorus, total nitrogen, nitrate-nitrogen, and chlorophyll a in and Secchi depth are relatively large. Annual mean concentrations of total phosphorus and total nitrogen concentration are above the threshold value for eutrophication of 0.10 mg P and 2.0 mg N per liter respectively, in about 25 % of the lakes. Annual mean concentrations chlorophyl a do exceed 30,0 mg/m^3, in about 35 % of the lakes and about half the number of lakes has a Secchi depth of less than 1.5 m. Over the last couple of years, no significant trends occurred in the trophic status of lakes. Hence, a considerable number of lakes can be classified as euthrophic lakes.

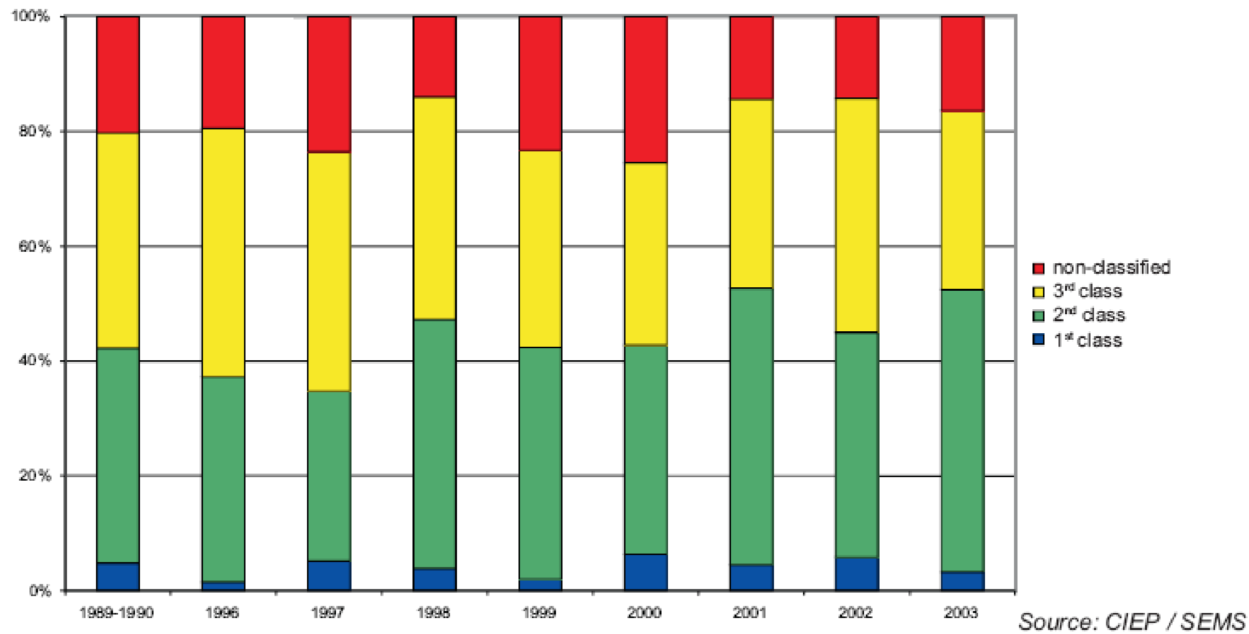

Figure 29.Changes in lake water quality between 1990-2003 (State of the Environment in Poland 2004).

In the years 1994-2001 a total of 792 lakes representing ~60% of Polish lakes have been monitored. The assessment of the water quality of these lake is indicated in the report of the Inspection for Environmental Protection (2003), showing that only 4% of the lakes have class I, 37% of the lakes have class II, 39% of the lakes have class III and as much as 21% of the lakes have class IV (excessively polluted). Eutrophication is the most serious threat to Polish lakes. This is caused by the input of N and P from the catchment area. The main sources of additional N and P inputs are industrial, municipal wastewater, crop production and livestock production (Inspection for Environmental Protection, 2003; page 116).

11.3. Rivers and streams

Figures 30 shows that eutrophic rivers with a high chlorophyl a concentration (>25 mg per m^3) in general also have high nitrate concentration >2.25 mg NO_3-N or >10 mg NO_3 per liter). Similarly, rivers that have a low chlorophyl a concentration (<25 mg per m^3) in general also have low nitrate concentration <2.25 mg NO_3-N or <10 mg NO_3 per liter). High nitrate concentrations are especially found upstream in (side branches of) the Odra river.

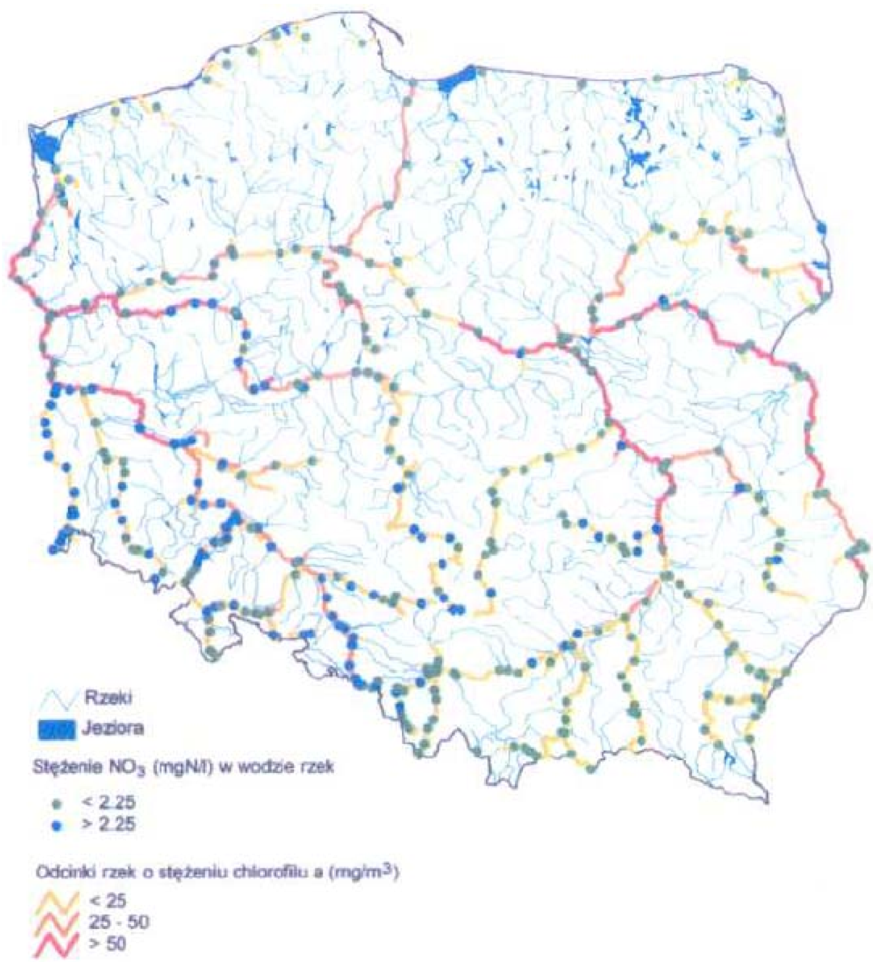

Figure 30. Nitrate concentrations (green dots <2.25 mg NO_3-N or < 10 mg NO_3 per liter and red dots > 10 mg NO_3 per liter) and chlorophyl a concentrations (yellow, orange and red lines) in rivers in Poland in 2005 [Ochrona…, 2006].

Figures 31 shows that eutrophic rivers with a high chlorophyl a concentration (>25 mg per m^3) in general also have high ortho-phosphate concentration >0.1 mg PO_4-P (or >0.3 mg PO_4 per liter). Similarly, rivers that have a low chlorophyl a concentration (<25 mg per m^3) in general also have low nitrate concentration <0.1 mg PO_4-P (or <0.3 mg PO_4 per liter).

Figure 32 shows that the water quality in rivers has slightly improved during the period 1990-2003.

Figure 31. Correlation between ortho-phosphate concentrations (green dots <0.3 mg PO_4 or <0.1 mg PO_4-P per liter and red dots > 1 mg PO_4 per liter) and chlorophyl a concentrations (yellow, orange and red lines) in rivers in Poland in 2005 [Ochrona…, 2006].

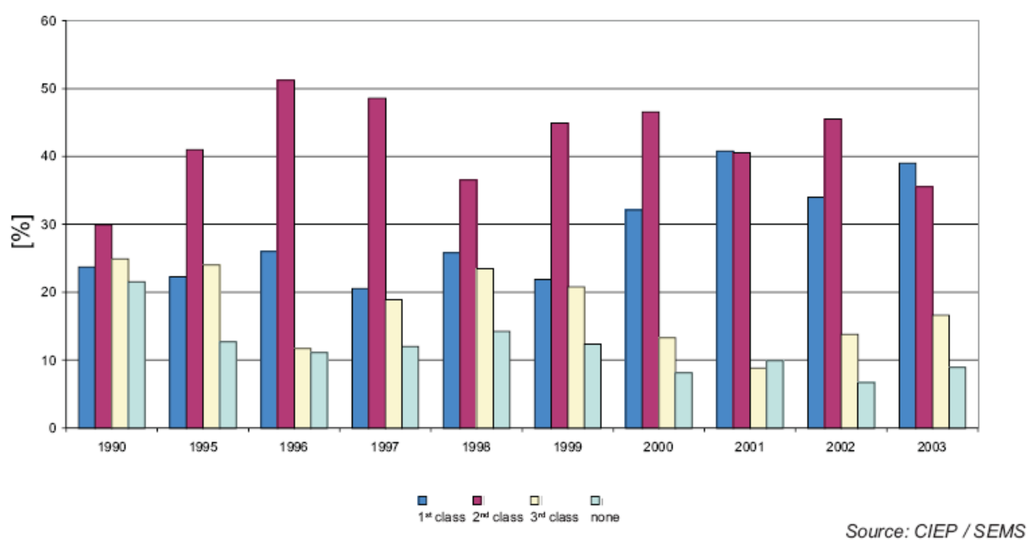

Figure 32.Changes in river water quality between 1990-2003; the relative number of class 1 and class 2 rivers increased and those of class 3 decreased. (State of the Environment in Poland 2004).

11.4. Coastal waters

Poland has a relatively large influence on the Baltic Sea. The total Baltic catchment area is more than 1.7 million km^2 and is inhabited by more than 80 million people (i.e. 47 people per km^2). More than 99 % of the Polish territory lies within the Baltic Sea catchment area, covering 311.900 km^2 (which is ~18% of the total catchment area) and approximately 40 million inhabitants (~50% of the total number of people). The hydrological configuration of the country is also very important since almost 90 % of the river outflow is carried by the Vistula and Odra rivers, while 10 Pomeranian rivers contribute the rest 10 %. Figure 33 provides an overview of the Baltic Sea Catchment area.

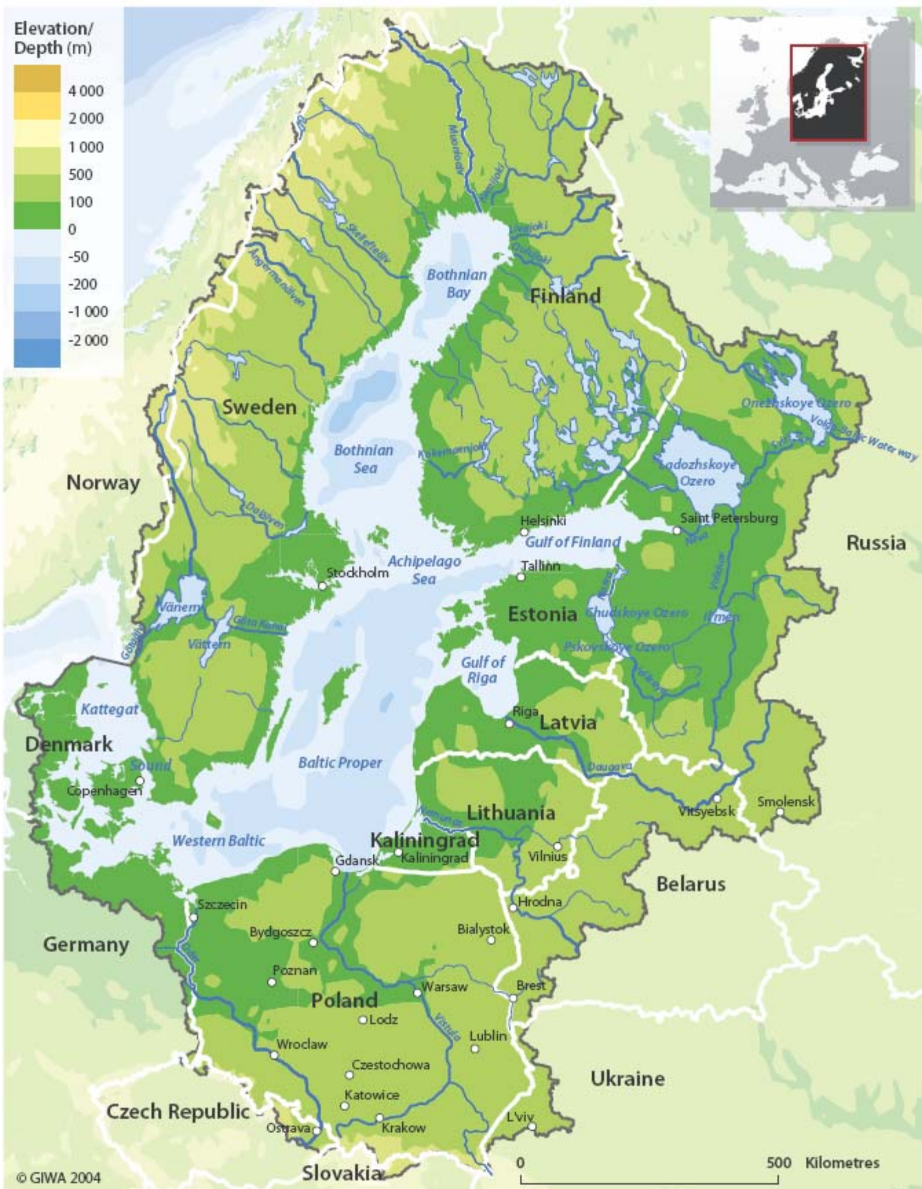

Figure 33. Map of the catchment area of the Baltic Sea (BSEP 104, 2002)

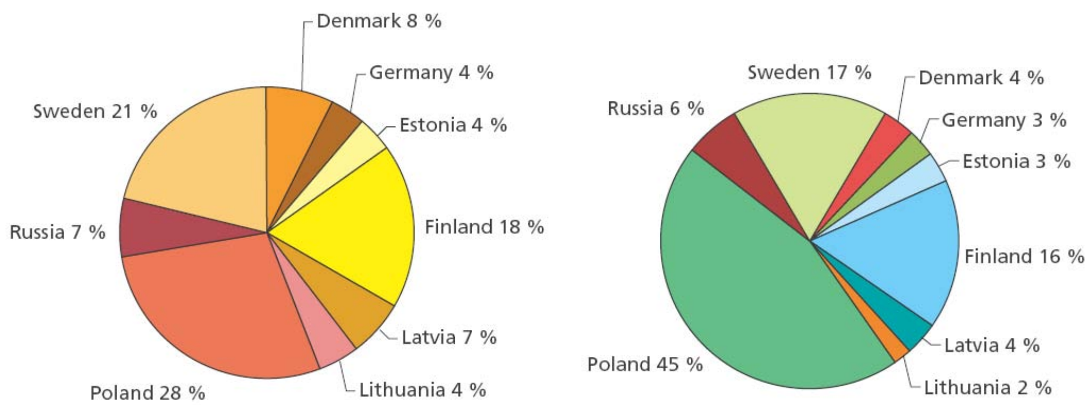

Figure 34. Contribution of the Baltic states to the loading of the Baltic Sea with nitrogen (left figure) and phosphorus (right figure) in 2000 (BSEP 100, 2005)

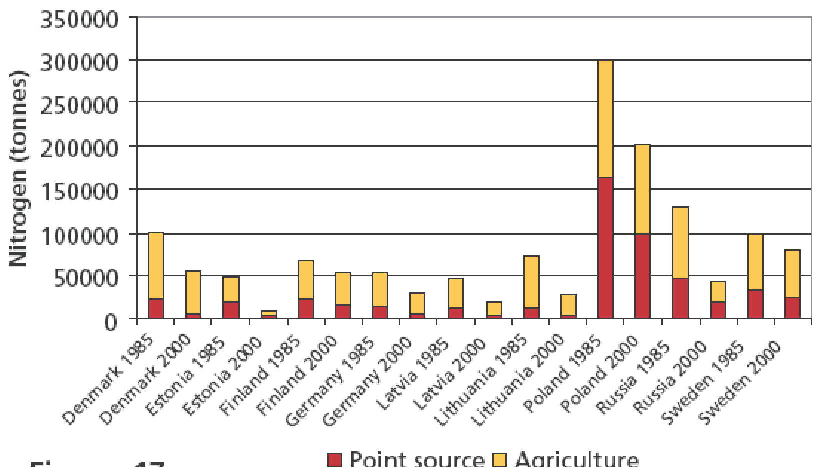

Figure 35. Contribution of the Baltic states to the loading of the Baltic Sea with nitrogen from point sources and agricultural sources in 1985 and 2000 (BSEP 100, 2005)

Poland is a relatively large contributor of N (~28%) and P (~45%) to the Baltic Sea (Figure 34). Between 1985 and 2000, the total discharge has decreased, mainly because of various remedial measures in municipalities (sewage treatment) and industry (Figure 34) The data indicate that the contribution of agriculture has also decreased, from ~140 million kg N in 1985 to ~100 million kg in 2000 (BSEP 100, 2005). Yet, Poland has the largest share in the loading of N into the Baltic Sea of all Baltic States. The same holds for phosphorus (Figure 36).

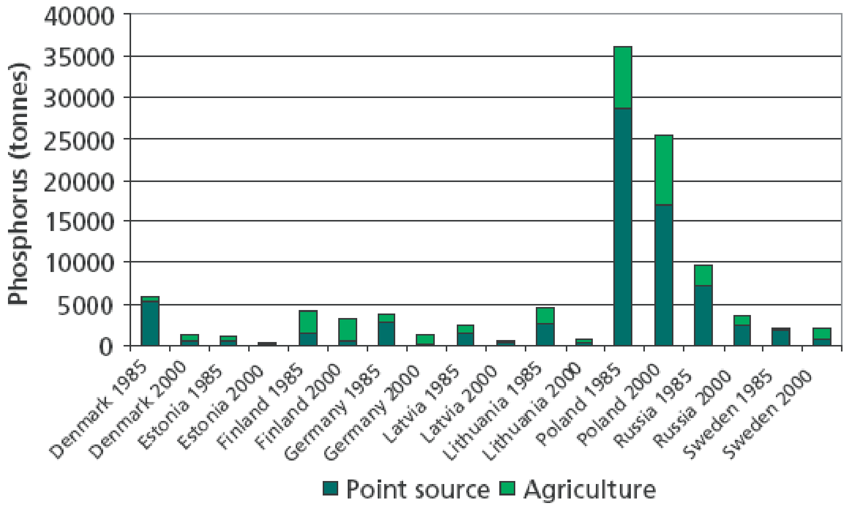

Figure 36. Contribution of the Baltic states to the loading of the Baltic Sea with phosphorus from point sources and agricultural sources in 1985 and 2000 (BSEP 100, 2003)

Within the framework of the Baltic Sea Declaration and the Baltic Sea Joint Comprehensive Environmental Action Programme (JCP), adopted by the Baltic Sea Conference in Ronneby (Sweden), in 1999, "hot spots" of industrial, municipal and agricultural nature have been identified. The Hot Spots include point sources of pollution associated with municipal and industrial source, non-point source pollution from agriculture and rural settlements as well as special management priority areas related to coastal lagoons and wetlands (co-operative development of management plans for key sites of international, regional and local significance).
At present, there are 18 Polish hot spots, comprising 28 sources and locations, which include (BSEP 91, 2003, Figure 37):

- 24 point sources of pollution (8 industrial and 16 municipal);
- 2 diffuse sources (agricultural hot spots);
- 2 coastal lagoons.

Clearly, the main sources of pollution of the Baltic Sea are of industrial and municipal origin. The two agricultural Hot Spots located in Poland are known as:

- Hot Spot No. 95 – Agriculture and Livestock Farming / Agriculture Run-off Programme for the Vistula River Basin, and
- Hot Spot No. 112 – Agriculture and Livestock Farming / Agriculture Run-off Programme for the Odra River Basin.

These two hot spots of diffuse pollution cover almost the whole Polish territory. This does not mean that Polish agriculture is a hot spot of pollution. It means that the discharge of pollutants from agricultural sources are carried to the Baltic sea via the Vistula and Odra Rivers, and that these rivers are considered as hot spots of pollution (BSEP 91, 2003).

Both, the severe eutrophication of the Baltic Sea and the large contribution of agriculture to the N and P loading of the Baltic Sea through the rivers Vistula and Odra are clear arguments to suggest that the catchments of the Vistula and Odra in Poland shall be considered as NVZs.

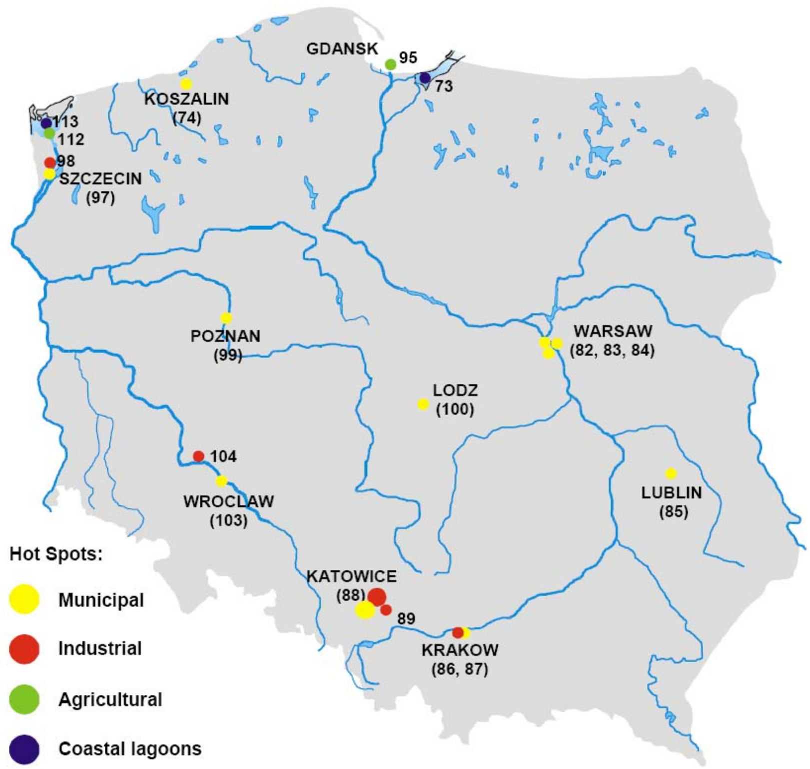

Figure 37. Map of "hot spots" of pollution of the Baltic environment (Source BSEP 91, 2003)

Information about nutrient concentrations in the Polish territory of the Baltic Sea can be examined at EIONET database (http://dd.eionet.europa.eu/). There are 24 monitoring stations in the Polish territory of the Baltic Sea, and some of these stations are sampled once a month at various depth. The annual total number of samples analysed for dissolved ammonium, nitrate, nitrite, total nitrogen, ortho-phosphate, total phosphate, silica, salinity, and dissolved oxygen is ~680. Most samples are taken from the upper water layers (1, 2.5 and 5 metres). Maximum sampling depth is 104 m. Concentrations of nutrients vary greatly with sampling depth, location and month of the year. Mean nitrate concentration in 2005 was 0.5 mg NO_3 per liter (range 0-16.4). Mean total nitrogen concentration in 2005 was 0.5 mg N per liter (range 0-4.8). Mean total phosphorus concentration in 2005 was 0.05 mg P per liter (range 0-4). Mean ratio of N/P in 2005 11±9 (rage 2-87). High N/P ratios relative to the Redfield ratio (~16) suggest surplus nitrogen; relative low ratios suggest surplus phosphorus. Both, the relatively high mean total phosphorus concentrations (0.05 mg P per liter) and the relatively low N/P ratio (~11) suggest that the Polish territory of the Baltic Sea is relatively rich in phosphorus. Average concentrations of N and P though are below the threshold values for eutrophication of coastal sea waters (4 mg N per liter and 0.1 mg P per liter, respectively; see Table 16).

11.5. Eutrophication of the Baltic Sea.

The excessive nitrogen and phosphorus loads coming from land-based sources are the main cause of the eutrophication of the Baltic Sea. About 75% of the nitrogen load and at least 95% of the phosphorus load enter the Baltic Sea via rivers or as direct waterborne discharges. About 25% of the nitrogen load comes as atmospheric deposition. Eutrophication is a major problem in the Baltic Sea. Since the 1800s, the Baltic Sea has changed from an oligotrophic clear-water sea into a eutrophic marine environment. Nitrogen and phosphorus are among the main growth limiting nutrients and as such do not pose any direct hazards to marine organisms. Eutrophication, however, is a condition in an aquatic ecosystem where high nutrient concentrations stimulate the growth of algae which leads to imbalanced functioning of the system, such as:

- intense algal growth: excess of filamentous algae and phytoplankton blooms;
- production of excess organic matter;
- increase in oxygen consumption;
- oxygen depletion with recurrent internal loading of nutrients; and
- death of benthic organisms, including fish.

A conceptual model of eutrophication is shown in the figure below (Figure 37b). The arrows indicate the interactions between different ecological compartments. A balanced coastal ecosystem in the southwestern Baltic is supposedly characterized by: (1) a short pelagic food chain (phytoplankton → zooplankton → fi sh), (2) a natural species composition of plankton and benthic organisms, and (3) a natural distribution of submerged aquatic vegetation.

HELCOM (Helsinki Commission; Baltic Marine Environment Protection Commission) plays a leading role in the assessment of eutrophication in the Baltic Sea and in the realization of the vision of a healthy Baltic Sea by deciding on internationally agreed protective measures. There are a large number of assessment reports that describe the eutrophication in the Baltic Sea as well the changes in the eutrophication. Despite the efforts undertaken, the water quality status of the Baltic is still poor (HELCOM, 2006; Eutrophication in the Baltic Sea; HELCOM Thematic Assessment). The Ecological Objectives and associated indicators of the Baltic Sea environment are (i) clear water, (ii) Natural levels of algal blooms, (iii) Natural oxygen concentrations, (iv) Natural levels of nutrients, and (v) Proper distribution of plants and animals. These targets are further discussed below.

Clear water

The clarity of seawater integrates many of the concrete effects of eutrophication such as disappearance of perennial plants and algae and intensification of algal blooms. The dramatic decrease in water clarity during the 20th century has awakened much of the public concern about the Baltic Sea environment and caused profound changes in the Baltic littoral communities. For instance Bladder wrack (*Fucus vesiculosus*) and eelgrass (*Zostera marina*) have become less common along many shorelines. Water transparency integrates several direct effects of elevated nutrient concentrations, mainly the turbidity caused by phytoplankton and other particles. Since it is also affected by dissolved humic substances, sub-regional background is important. Several methods can be used to reliably measure water transparency. *Water transparency* defined by e.g. Secchi depth is proposed to be considered as an indicator for clear water.

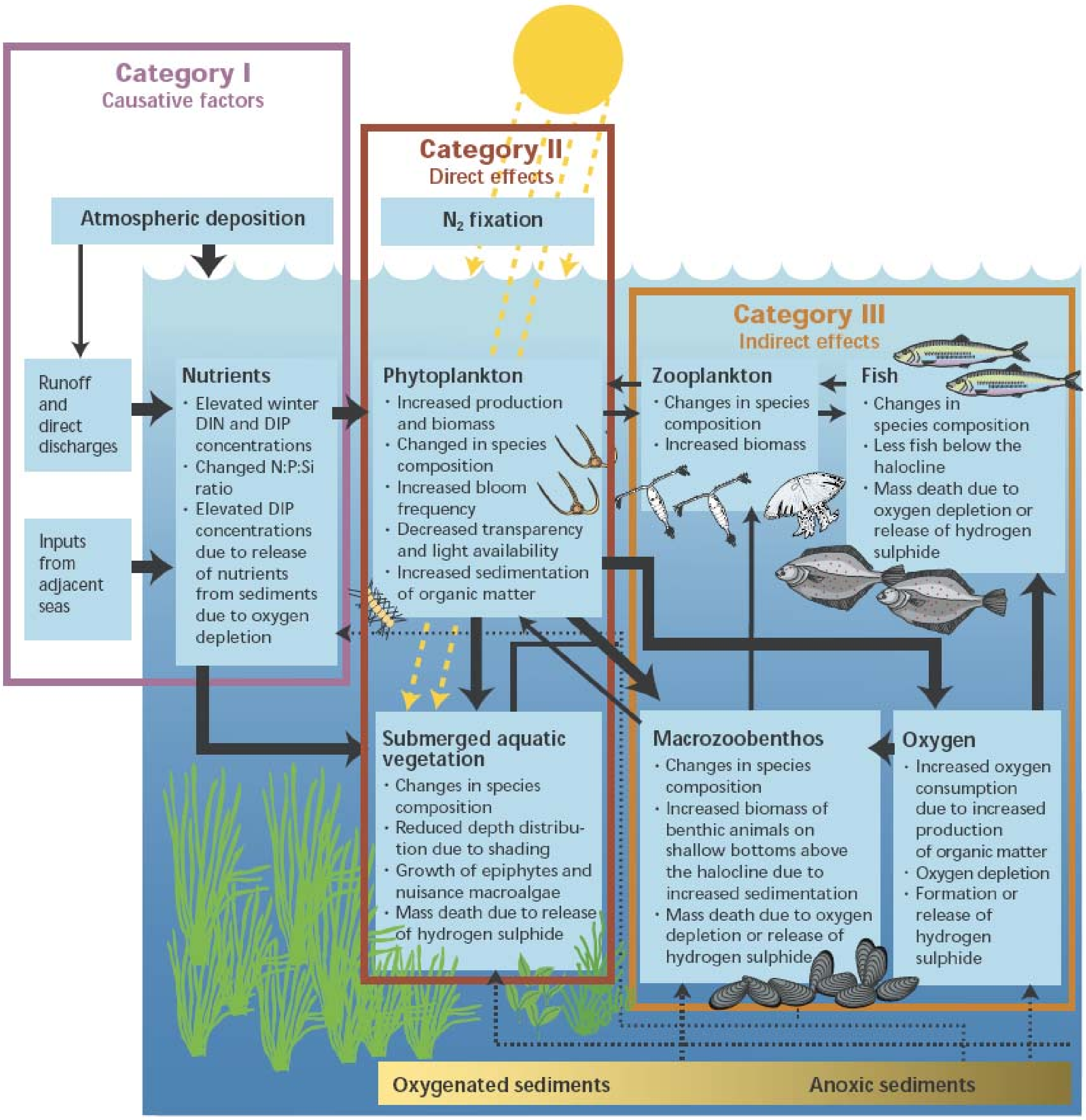

Figure 37b. Conceptual model of eutrophication. The arrows indicate the interactions between different ecological compartments. A balanced coastal ecosystem in the southwestern Baltic is supposedly characterized by: (1) a short pelagic food chain (phytoplankton → zooplankton → fi sh), (2) a natural species composition of plankton and benthic organisms, and (3) a natural distribution of submerged aquatic vegetation. Nutrient enrichment results in changes in the structure and function of marine ecosystems, as indicated by bold lines. Dashed lines indicate the release of hydrogen sulphide (H2S) and phosphorus, which is positively linked to oxygen depletion.

Natural levels of algal blooms

Algal blooms, mainly in the northern Baltic and in the Baltic Proper in the form of cyanobacteria, have closed beaches and caused frequent public concern about the future suitability of the Baltic Sea as a site for recreation purposes. The occurrence and intensity of cyanobacterial blooms in the Baltic Sea have increased since the 1960 according to sediment samples. Ecosystem effects of these blooms are likely to be important; especially the nitrogen-fixing activity of cyanobacteria contributes to the nutrient budget. Also other phytoplankton species have changed in their abundances due to the increased nutrient levels. This has generated a general excess in photosynthetic production which the ecosystem is not able to process. The excess material sinks to the seabed where natural bacterial consumption uses up available oxygen. *Plankton spring blooms*, *late-summer cyanobacterial blooms*, and *amount of harmful species* are indicators in defining natural levels of algal blooms.

Natural oxygen concentrations

Partly due to the increased input of organic matter the oxygen levels in most Baltic Sea deeper bottoms and also in the shallower coastal waters have decreased during the 20th century. This is evident as an increase in area covered with laminated sediments, indicating dead, lifeless bottoms. It should be noted that much of the observed changes in oxygen levels, especially in the deeper bottoms, are due to natural variation but the geological record in laminated sediments seem to indicate that oxygen levels deviate from natural mean concentrations. Anoxic conditions directly kill animals and plants requiring oxygen but it also causes selfreinforcing of eutrophication through the process of internal loading of especially phosphorus. Organic matter, nutrients and also hazardous substances bound to sediments are released back to the water column causing intensified internal loading and circulation of toxic material. The area of bottom waters with low O_2 levels (O_2 concentration <2 ml/l), anoxic bottoms (O_2 concentration 0 ml/l) and hydrogen sulphide (H2S) in bottom water during autumn are proper indicators.

Natural levels of nutrients

Concentrations of nutrients in the Baltic Sea have increased in most sub-basins during the last century deviating today markedly from the natural levels. The nutrient concentrations are strongly affected by seasonality. During winter nitrogen and phosphorus concentrations are peaking as a result of remineralisation, vertical mixing of the water column and lack of phytoplankton activity. In spring phytoplankton bind the dissolved nutrients in the surface waters. In summer surplus of phosphorus promotes the blooms of nitrogen fixing cyanobacteria, also called blue-green algae.

Distribution of plants and animals

Many of the Baltic Sea communities, such as littoral perennial species, coastal fish stocks and zooplankton communities have experienced radical changes during the 20th century due to eutrophication. Soft-sediment macrobenthic communities are central elements of Baltic Sea ecosystems and provide excellent indicators of environmental health. Most macrobenthic animals are relatively long lived (several years) and thus integrate changes and fluctuations in the environment over a longer period of time. Variations in species composition, abundance and biomass can be used to assess environmental disturbance.

12. Incidental measurements of nitrate concentrations in groundwater and surface waters

In addition to the monitoring by the national institutions through the Regional Water Management Boards, various measurements have been made by research institutions and Universities. These data are briefly summarized in this paragraph.

The Institute of Grassland Farming and Land Reclamation in Falenty (IMUZ) near Warsawa has carried out a number of studies on nitrate in groundwater in dairy farms in Poland. In general, they have found a wide range of concentrations, with very high nitrate concentrations nearby farms. These high concentrations were related to N leaching losses from manure heaps. In most cases, the nitrate concentrations in the wells used for drinking water also exceeded the limit of 50 mg per liter [Sapek A, Sapek B, Rzepiński, 1993; Sapek A, 1996; Ostrowska i in., 1996].

The results of these measurements are summarized in Table 20 and 21. Apart from high nitrate concentrations, the results presented also indicate that the ammonium concentrations and total dissolved phosphorus concentrations in groundwater near and under manure heaps can be very high.

Table 20. Average concentrations of nitrogen and the phosphorus in groundwater on different monitoring points in farms from the region Ostrołęka [Sapek B., 1998; 2000]

Monitoring points	Number of samples	Value	Concentrations, mg·dm^{-3}		
			P	$N\text{-}NO_3$	$N\text{-}NH_4$
Next door to the place of the storage of animal excrements	342	average	3,5	25,1	8,1
		min.	0,001	0,01	0,01
		max.	250,0	312,0	250
At the cow-shed	212	średnia	0,68	18,4	0,40
		min.	0,001	0,02	0,01
		max.	5,24	120,0	14,8
Farm- well	282	średnia	0,23	10,6	0,5
		min.	0,001	0,01	0,01
		max.	4,27	128,0	12,6

Table 21. Average concentrations of nitrogen and phosphorus in groundwater on different monitoring points on 12 farms in the provinces Kujawsko-pomorskie, Podlaskie and Mazowieckie [Sapek B., 2002]

Monitoring points	Number of samples	Valueć	Concentrations, mg·dm^{-3}		
			P	$N\text{-}NO_3$	$N\text{-}NH_4$
Farm- well	40	average	0,50	26	0,46
		min.	0,001	0,12	0,01
		max.	2,0	88,8	3,4
Next door to the place of the storage of animal excrements	40	average	2,65	9,6	7,63
		min.	0,01	0,02	0,09
		max.	27,5	67,9	70,7
Control well ca 50 m from the place storage of excrements animal	21	average	2,58	12,1	7,20
		min.	0,03	0,03	0,13
		max.	17,1	87,9	42,8

Results of a survey of nitrate concentrations in the drainage water from drainage pipes are presented in Figure 38 as NO_3-N in mg per liter. Mean concentrations per region range from < 1 mg N per liter to ~11 mg NO_3-N per liter. Highest concentrations were found in the central part of the country. This may reflect the sampling of irrigated and drained vegetable growing sites. It should be noted that the number of samples per region differed greatly, from 3 to 40.

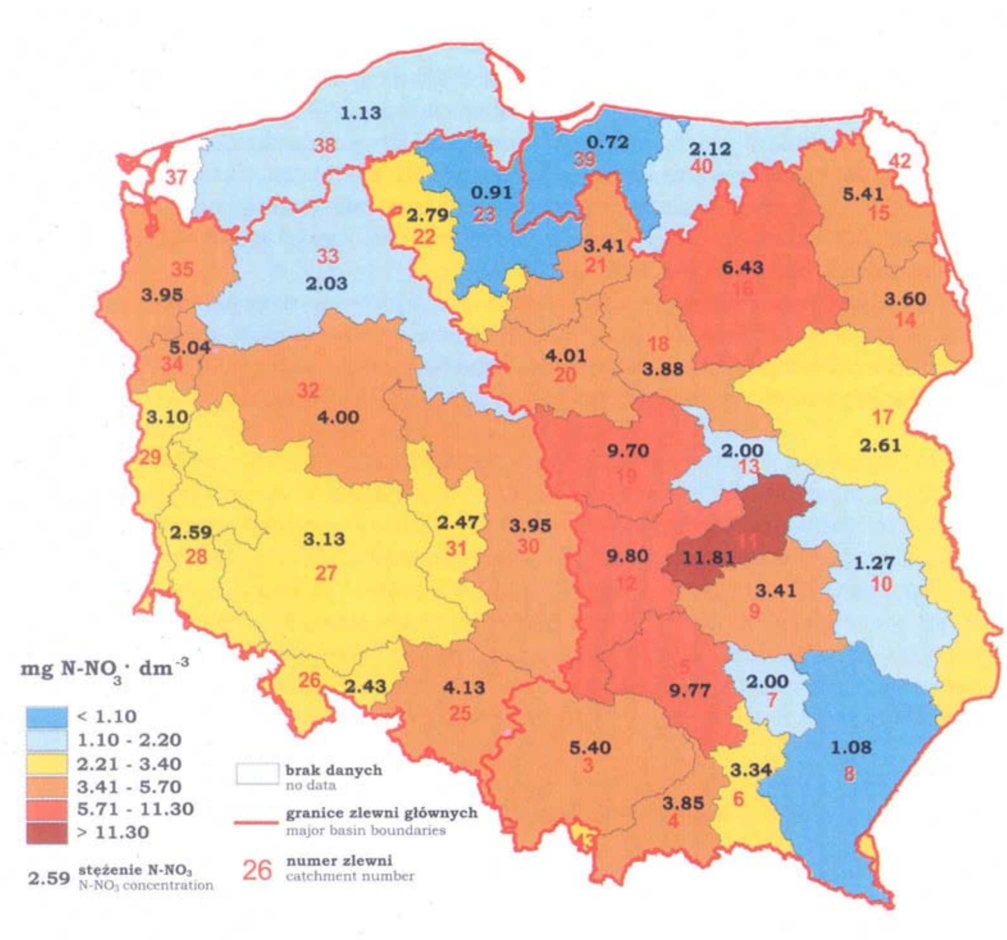

Figure 38. Average concentration of N-NO₃ in waters from drain-pipes [Igras, 2004]

An intensive monitoring has been set-up in the Plonia catchment in the northwestern part of Poland (Figure 39). This catchment has been designated also as Nitrate Vulnerable Zone (NVZ). It has a surface area of almost 1100 km^2 (Table 1). The catchment is a highly productive agricultural area with cereals (wheat and maize), rape seed, and cattle and hog farming. The river Plonia drains into lake with clear signs of eutrophication. The water of the lake is used for drinking water for the people of Szczecin and surroundings, while the lake is also used for fishing and recreation (bathing).

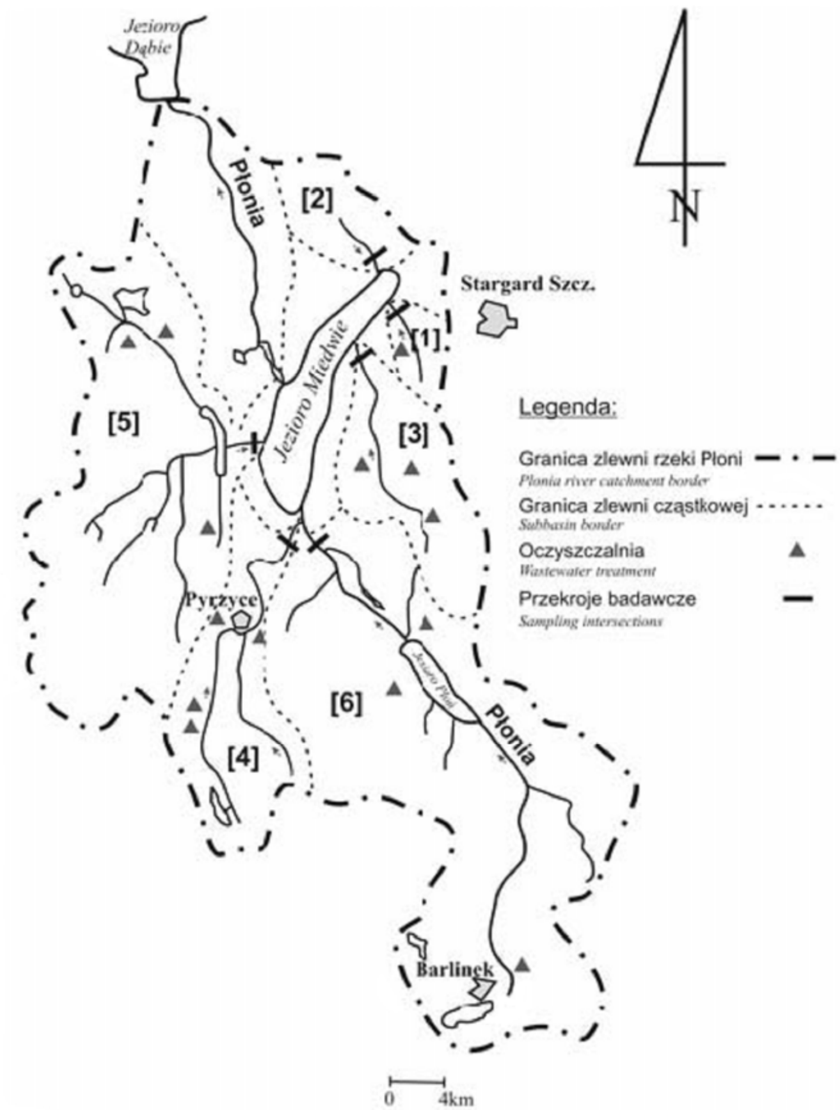

Figure 39. Catchment of the Płonia river, studied inflows to lake Miedwie; 1 – Kunowski Ditch, 2 – the Miedwinka, 3 – the Gowienica, 4 - Młyński Channel, 5 – the Ostrawica, 6 – the Płonia - inflow, 7 - Płonia – outflow from Lake Miedwie [Durkowski, Burczyk, Królak, 2006].

The mean results of the monitoring at the 7 monitoring sites in the years 2000-2004 are presented in Tables 22, 23 and 24. Samples were taken roughly once per month, and the results presented in Table 22 are averaged over a year. Differences between sites and years were often very large. The high nitrate, ortho-phosphate and potassium concentrations in the Kunowski Ditch suggest contamination by drainage water from farm yards.

Table 22. Mean pH, conductivity and concentration of nutrients in inflows and outflows from Lake Miedwie (2000–2004) [Durkowski, Burczyk, Królak, 2006]

Watercourse, catchment area	Years	pH value	Conductivity $\mu S \cdot m^{-1}$	Concentration, $g \cdot m^{-3}$			
				NO_3^-	NH_4^+	PO_4^{-3}	K^+
Kunowski Ditch 23 km^2	2000	7,67	1011	29,9	0,56	0,29	14,4
	2001	7,68	1161	30,4	0,93	0,45	17,7
	2002	7,53	1118	22,4	0,73	0,49	11,7
	2003	7,34	1042	5,8	0,22	0,35	10,8
	2004	7,51	972	27,4	0,45	0,14	21,7
Miedwinka 47,3 km^2	2000	7,61	549	2,6	0,54	0,10	5,9
	2001	7,73	598	3,3	0,75	0,13	6,1
	2002	7,46	574	3,2	0,31	0,08	6,2
	2003	7,46	638	2,8	0,32	0,06	5,9
	2004	7,29	596	0,8	0,13	0,09	6,7
Gowienica 53,7 km^2	2000	7,93	837	5,4	0,26	0,18	8,6
	2001	7,82	825	3,8	0,34	0,14	11,0
	2002	7,77	828	10,9	0,11	0,17	8,4
	2003	7,49	814	3,4	0,16	0,09	5,3
	2004	7,60	857	1,4	0,11	0,23	19,9
Młyński Channel 86,4 km^2	2000	7,81	1223	12,9	0,37	0,40	7,8
	2001	8,10	1836	2,8	0,26	1,66	11,4
	2002	7,78	921	13,8	0,39	0,40	12,7
	2003	7,38	741	4,4	0,32	0,12	7,8
	2004	7,77	1020	11,6	0,15	0,41	21,3
Ostrawica 284,3 km^2	2000	8,31	646	2,6	0,09	0,12	12,1
	2001	8,02	902	1,6	0,32	0,19	20,0
	2002	7,95	1500	6,5	0,27	0,58	11,7
	2003	7,23	856	2,1	0,37	0,21	12,1
	2004	7,30	802	3,8	0,12	0,12	11,2
Płonia – inflow 365,7 km^2	2000	8,44	520	1,2	0,09	0,20	4,8
	2001	8,28	569	1,3	0,24	0,25	5,3
	2002	7,80	692	4,1	0,19	0,07	6,1
	2003	7,55	711	2,0	0,22	0,11	4,8
	2004	7,76	667	0,8	0,13	0,10	21,8
Płonia – outflow from Lake Miedwie 1028,4 km^2	2000	7,89	833	2,0	0,22	0,15	6,5
	2001	7,97	652	0,6	0,19	0,20	8,1
	2002	7,90	835	2,0	0,30	0,17	6,4
	2003	7,24	834	2,3	0,22	0,20	4,9
	2004	7,71	634	1,6	0,27	0,16	20,9

Table 23. Selected values of pH, conductivity and concentration of nutrients in inflows and outflows from Lake Miedwie in the years 2000–2004. SD = standard deviation [Durkowski, Burczyk, Królak, 2006]

Watercourse	Parameters	pH value	Conductivity $\mu S \cdot m^{-1}$	Concentration, $g \cdot m^{-3}$			
				NO_3^-	NH_4^+	PO_4^{-3}	K^+
Kunowski Ditch	average	7,54	1062	22,9	0,58	0,35	15,0
	minimum	7,15	782	1,5	0,03	0,02	5,0
	maximum	8,18	1639	53,0	3,25	1,15	33,7
	SD	0,22	170	15,3	0,61	0,28	5,6
Miedwinka	average	7,52	591	2,6	0,42	0,09	6,2
	minimum	7,21	425	0,3	0,05	0,00	0,1
	maximum	8,30	819	7,1	1,15	0,23	19,6
	SD	0,23	80	1,6	0,29	0,06	3,6
Gowienica	average	7,73	832	7,0	0,20	0,16	10,3
	minimum	7,32	560	0,2	0,02	0,00	1,3
	maximum	8,31	1126	30,8	0,61	1,40	26,0
	SD	0,22	117	6,6	0,14	0,19	5,7
Młyński Channel	average	7,48	1139	7,9	0,26	0,66	13,5
	minimum	7,23	624	0,5	0,02	0,02	4,4
	maximum	8,40	3320	61,0	1,50	6,50	25,5
	SD	0,28	600	10,0	0,29	1,22	6,5
Ostrawica	average	7,78	936	3,2	0,24	0,24	13,8
	minimum	6,88	574	0,2	0,01	0,01	4,3
	maximum	8,80	7060	23,0	1,65	1,37	25,4
	SD	0,50	865	4,1	0,24	0,25	5,1
Płonia (inflow)	average	7,97	630	1,9	0,17	0,15	10,4
	minimum	7,21	426	0,1	0,02	0,00	2,8
	maximum	8,80	922	14,0	0,90	0,73	29,1
	SD	0,41	119	2,4	0,16	0,17	9,0
Płonia (outflow from Lake Miedwie)	average	7,70	743	1,6	0,25	0,18	9,9
	minimum	7,12	518	0,1	0,01	0,00	3,0
	maximum	8,43	1297	6,8	1,00	0,67	26,2
	SD	0,38	175	1,2	0,18	0,13	7,1

.

Table 24. Nutrient loads delivered with water of main tributaries to Lake Miedwie (2000–2004) Values above the line present ranges, value below the line are overall averages. [Durkowski, Burczyk, Królak, 2006]

Lp.	Watercourse	Load, 1000 kg per year			
		NO_3^-	NH_4^+	PO_4^{-3}	K^+
1	Kunowski Ditch	<u>4,6–25,6</u> 16,7	<u>0,13–1,17</u> 0,52	<u>0,09–0,37</u> 0,23	<u>5,6–15,7</u> 11,4
2	Miedwinka	<u>3,9–18,3</u> 11,5	<u>0,53–3,14</u> 1,76	<u>0,20–0,62</u> 0,40	<u>17,5–35,6</u> 23,9
3	Gowienica	<u>2,8–51,1</u> 18,0	<u>0,20–0,73</u> 0,48	<u>0,21–0,57</u> 0,37	<u>11,3–32,4</u> 23,6
4	Młyński Channel	<u>24,5–215,4</u> 99,5	<u>1,09–2,54</u> 2,07	<u>0,87–9,70</u> 3,90	<u>62,3–169,3</u> 109,0
5	Ostrawica	<u>29,8–267,9</u> 95,4	<u>2,06–8,07</u> 4,72	<u>2,26–15,81</u> 5,50	<u>163,4–481,4</u> 321,6
6	Płonia – inflow	<u>34,9–420,8</u> 140,9	<u>5,10–11,12</u> 8,45	<u>3,29–9,73</u> 6,28	<u>215,3–468,9</u> 385,9
7	Płonia (outflow from Lake Miedwie)	<u>20,8–235,9</u> 93,5	<u>6,28–41,77</u> 14,50	<u>4,10–16,80</u> 8,80	<u>122,0–862,6</u> 431,2
Mean balance Σ(1÷6) – 7 (Retention in lake)		288,5	3,5	7,9	444,2

13. Assessments of nitrate leaching by the modeling tool MITERRA-EUROPE

The integrated modeling tool MITERRA-EUROPE allows the assessment of ammonia, nitrous oxide and methane emissions to the atmosphere and the leaching of nitrate to groundwater and surface waters from all agricultural sources in EU-27 (Velthof et al., 2007). MITERRA-EUROPE has also been used to assess the nitrate leaching in Poland at regional level (voivodships) for the year 2020, without and with the implementation of strict balanced N fertilization. The results show that in the scenario with balanced N fertilization, the fertilizer N input decreases by on average 15 kg N per ha per year relative to the reference values for the year 2020. This suggests 'overfertilization' relative to crop demand, and also that there is scope for improving N management in various voivodships (relative to the crop yields as observed in statistical data. The reference fertilizer inputs for 2020 are based on national projections according to national experts, as provide to IIASA (personal communication Zbigniew Klimont, 2007). These experts predicted that the mean N fertilizer use in Poland will be 57kg per ha in 2020 (Table 25). Manure N application rates are shown in Table 26. This table indicates that mean N inputs via animal manure are in the range of 8 to 35 kg per ha in the voivodships, suggesting also that at voivodship level that there are no conglomerations of high livestock density farms (see also Chapter 6 and Figure 17). Phosphorus surpluses are shown in Table 27; they range from 6 to 43 kg P_2O_5 per ha.

Table 25. Fertilizer application in NUTS II regions in Poland in 2020 and after full implementation of balanced N fertilization** in 2020. Results of MITERRA-EUROPE, 2007*

NUTS II region	Fertilizer application, kg N/ha	
	2020	2020 + balanced N fertilization
PL01 Dolnoslaskie	61	54
PL02 Kujawsko-pomorskie	61	37
PL03 Lubelskie	57	46
PL04 Lubuskie	49	43
PL05 Lodzkie	52	33
PL06 Malopolskie	58	46
PL07 Mazowieckie	52	37
PL08 Opolskie	66	53
PL09 Podkarpackie	54	46
PL0A Podlaskie	61	48
PL0B Pomorskie	54	42
PL0C Slaskie	51	38
PL0D Swietokrzyskie	52	40
PL0E Warminsko-mazurskie	58	50
PL0F Wielkopolskie	59	35
PL0G Zachodniopomorskie	52	48
Average Poland	57	42

** based on agricultural projections made for the NEC directive (Amann et al., 2006) and assuming a 15% yield increase compared to 2000.*

*** at balanced N fertilization, the N fertilizer and manure application are adjusted, so that the total input of plant-available N via fertilizer, manure, grazing, atmospheric deposition, biological N fixation and mineralization of soil organic matter is equal to crop demand for plant-available N.*

Table 26. Manure application in NUTS II regions in Poland in 2020 and after full implementation of balanced N fertilization in 2020. Results of MITERRA-EUROPE, 2007

NUTS II region	Manure application, kg N/ha	
	2020	2020 + balanced N fertilization
PL01 Dolnoslaskie	10	13
PL02 Kujawsko-pomorskie	33	32
PL03 Lubelskie	16	16
PL04 Lubuskie	8	11
PL05 Lodzkie	26	24
PL06 Malopolskie	19	19
PL07 Mazowieckie	22	21
PL08 Opolskie	19	19
PL09 Podkarpackie	14	14
PL0A Podlaskie	24	24
PL0B Pomorskie	18	19
PL0C Slaskie	20	20
PL0D Swietokrzyskie	16	16
PL0E Warminsko-mazurskie	13	15
PL0F Wielkopolskie	43	35
PL0G Zachodniopomorskie	7	8
Average Poland	22	21

Table 27. Phosphorus application in NUTS II regions in Poland in 2020 after full implementation of balanced N fertilization in 2020. Results of MITERRA-EUROPE, 2007

NUTS II region	Phosphorus surplus, kg P2O5/ha	
	2020	2020 + balanced N fertilization
PL01 Dolnoslaskie	9	10
PL02 Kujawsko-pomorskie	30	29
PL03 Lubelskie	11	12
PL04 Lubuskie	3	4
PL05 Lodzkie	18	18
PL06 Malopolskie	8	9
PL07 Mazowieckie	14	15
PL08 Opolskie	21	20
PL09 Podkarpackie	4	5
PL0A Podlaskie	12	14
PL0B Pomorskie	12	12
PL0C Slaskie	12	12
PL0D Swietokrzyskie	8	9
PL0E Warminsko-mazurskie	5	7
PL0F Wielkopolskie	43	37
PL0G Zachodniopomorskie	6	6
Average Poland	16	16

Calculated mean leaching losses of N from agricultural land per voivodship are 13 kg per ha per year, with a range of 8 to 20 kg per ha per year (Table 28). Highest losses are in Wielkopolskie. Implementation of balanced fertilization decreases the N leaching losses on average by 4 kg per ha per year (range 0-7 kg per ha per year). Hence, mean leaching loss decreases by more than 30% relative to the situation without balanced N fertilization. This indicates that implementing balanced N fertilization is very effective in decreasing N leaching loss.

Table 28. Nitrogen leaching to groundwater and surface waters in NUTS II regions in Poland in 2020 and after full implementation of balanced N fertilization in 2020. Results of MITERRA-EUROPE, 2007

NUTS II region	N leaching, kg N/ha	
	2020	2020 + balanced N fertilization
PL01 Dolnoslaskie	11	10
PL02 Kujawsko-pomorskie	18	12
PL03 Lubelskie	13	10
PL04 Lubuskie	8	7
PL05 Lodzkie	15	10
PL06 Malopolskie	14	11
PL07 Mazowieckie	13	9
PL08 Opolskie	15	12
PL09 Podkarpackie	10	8
PL0A Podlaskie	12	9
PL0B Pomorskie	12	9
PL0C Slaskie	12	9
PL0D Swietokrzyskie	15	12
PL0E Warminsko-mazurskie	11	9
PL0F Wielkopolskie	20	12
PL0G Zachodniopomorskie	8	7
Average Poland	13	9

14. Discussion, conclusions and recommendations

14.1 Introduction

To comply with the Nitrates Directive, Poland has designated 21 areas in 6 regions as Nitrate Vulnerable Zone (NVZ), on the basis on water monitoring data from 1990-2002. The total area of the NVZ is 6263 km^2, which comprises ~2% of the total area. The 6 regions and 21 areas are listed in Table 1 and shown on the map in Figure 1 of Chapter 1. The European Commission has some questions about the justification and underpinning of designations and has requested Alterra to review the existing designations and to provide suggestions for new designations. This chapter provides a general discussion and synthesis of the findings of the reviews.

Nitrate Vulnerable Zones must be designated on the basis of monitoring results that indicate that the groundwater and surface waters in these zones are or could be affected by nitrate pollution from agriculture. This obligation of the Nitrates Directive requires Member States to monitor the nitrate concentrations in groundwater and surface waters.

Monitoring programs usually serve two objectives, namely (i) provide information about the state of the environment and the need for remedial measures, and (ii) provide information about trends in the status of the environment and the effectiveness of any remedial measures. For taking remedial measures, the sources of pollution need to be known, but monitoring programs usually can provide such information only indirectly, using additional (modelling) calculations and assessments. This holds also for the nitrate in groundwater and surface waters.

Agriculture in Poland is a main source for the leaching of nitrates to groundwater and surface waters. Municipalities and households are also major sources of nutrients. Currently, slightly more than 55% of the households are connected to sewage treatment plants (State of the Environment in Poland 2004), suggesting that 45% of the households directly discharges their sewage to surface waters. Moreover, a large number of people live in villages in rural areas and can be considered as diffuse sources of nutrients through direct discharges of sewage into surface waters.

Because of the presence of different nutrient sources, spatially detailed information about agricultural pressure data are needed to be able to assess whether groundwater and surface waters are affected by nitrates from agricultural sources. Without accurate nitrogen source apportion, no effective remedial measures can be undertaken. Therefore, considerable efforts have been made in this study to collect agricultural pressure data, apart from groundwater and surface water quality data.

14.2. Pressure indicators

Total nitrogen (N) loading per unit of surface area via fertilizers and animal manure is an important indicator of nitrate leaching losses, but the amount of nitrate leached ultimately depends also on the withdrawal of N with harvested crop and N losses via ammonia volatilization and denitrification. The latter two processes are heavily influenced by soil type, hydrology and climate. Hence, the assessment of pollution of groundwater and surface waters by nitrates from agriculture requires the analysis of pressures resulting from N from agricultural sources on the basis of farming systems, livestock density and productivity, fertilizer use, soil type and hydrology, and climate, per region.

Following the political changes by the end of the 1980s and the beginning of the 1990s, livestock density and fertilizer N use have decreased. Livestock density has continued to decrease since then, but mean N fertilizer use has started to increase slightly again from 1991/1992 onwards, to a mean of 56 kg per ha per year in 2004. At NUTS-2 level (at the level of voivodships), fertilizer N use and livestock density are rather homogenously distributed over the country, but a few hot spots can be found at country level, with more than 2 LSU per ha. Mean N surpluses (total N input minus total N output via harvested crops) have remained rather stable during the last ten years at a level of on average 75 kg per ha per year, and are rather homogenously distributed over the country. Surpluses of N are slightly higher on the more productive soils in the north-west half of Poland compared to the low-productive sandy soils in the south-west part of the country.

Agriculture in Poland is in transition. Current farm size distribution shows a bi-modal or tri-modal frequency distribution, depending on the statistical data base. More than half of the total number of farms has less than 2-3 ha of agricultural land currently. These farms are managed by subsistence farmers, part-time farmers and/or hobby farmers. In general, these ‘farmers’ have a low level of education and the management is relatively poor. The second peak in the frequency distribution is made by farms in the size category of 5 to 30 ha. These are private farmers that feel the pressure to produce more and to lower the cost through up-scaling, specialization and intensification, to be able to compete in the globalizing market. Some of these farmers are well-educated and manage their farms well, but a significant fraction of the farmers in this group is not well-educated and the management on these farms is relatively poor. The third peak in the frequency distribution is made by farms in the size category of >100 ha and often > 1000 ha. These are co-operate farms and former state-own farms. In theory, these farms have the best possibilities to compete in the globalizing market, because of the large farm size and also because most of these farms are situated on the relatively good soils. The farmers on these farms are well-educated and most of these farms are rather well-managed currently.

Most farms in Poland are mixed farms, i.e. have a crop production component and an animal production component. The crops produced are fed to the animals and the animal products (milk, meat and eggs) are sold to the market. There are also specialized crop production farms, i.e., farms that produce only crops (cereals, potatoes, rape seed, vegetables), but there are only very few specialized livestock farms. Hence, livestock is predominantly kept on mixed farming systems, and the livestock is mainly fed with farm-produced animal feed. Livestock density on these farms is therefore a function of crop production level; the higher the crop yields, the higher the livestock density. Recently, some specialized hog farms have been established by companies from Western European countries, and here the livestock is fed to a large extent through animal feed from elsewhere. These farms have high livestock density and may have problems with proper manure disposal. However, the number of such specialized livestock farms is still small.

Summarizing, the mean pressure of agriculture on the environment is less in Poland than in the EU-27. The indicators livestock density, fertilizer use and N surpluses are on average lower in Polish agriculture than in EU-27 agriculture. Moreover, the spatial distribution of livestock density, fertilizer use and N surpluses are rather evenly over the country, though agriculture is most intensive and productive in the western half of the country.

14.3. Point sources and diffuse sources of pollution

Within most mixed farming systems in Poland, a distinction can be made between point sources of nitrate pollution and diffuse sources of nitrate pollution. On specialized crop production farms, there are essentially only diffuse source of nitrate pollution.

Many barns, farm-yards, and manure heaps can be considered as 'point sources' of nitrate pollutions, as 'micro hot spots'. Our study suggests that these point sources are relatively important. Various studies have been made at farm level, but no attempt has been made to estimate the contribution of point sources at regional, provincial and national levels. Estimates by the model MITERRA-EUOPE suggests that leaching losses from farm-yards and manure heaps constitute up to 40% of the total leaching losses. Also, no publication has been found that quantitatively relates the nitrate leaching losses from farm-yards and manure heaps to farm size and farm structure. On average, small farms have less proper facilities for leak-tight housing of livestock and for leak-tight storing livestock manure than large farms. However, the large farms are often more intensive, with more productive animals that excrete more nitrogen per animal. It is reasonable to suggest that programs dealing with improving the housing of livestock and the storage of livestock manures should focus on the large farms (>15 ha), because of cost-effectiveness and also because the small farms will likely merge into large farms in the near future.

Diffuse sources of nitrate leaching losses are agriculture fields. Poland has large areas of light-textured sandy soils, which are vulnerable to nitrate leaching (because of the relatively low production potential, drought sensitivity, and low denitrification potential). However, these soils are managed by small farmers and fertilizer input is rather low and therefore leaching losses are not excessively high. In contrast, the loam and clay soils in Poland are managed intensively by predominantly large farms. These soils have relatively good moisture and nutrient retention capacities, receive relatively high doses of fertilizer and livestock manure, and provide high crop yields. The visits to such farms learn that little account is being made of the N in applied animal manure, even though the farmers of large farms are well-educated and relatively good managers, As a consequence, nitrate leaching losses may be relatively high on the most productive soils, because of the incomplete account of the manure N applied.

The assessments made in this report suggest indeed that there are no *large* hot spots of nitrate pollution in Poland, as the regional distributions of livestock density and N fertilizer use is rather homogenous, while mean livestock density and mean fertilizer N use are both relatively low. On the other hand, many mixed farms can be considered as 'micro hot spots' of nitrate pollution (point sources), judged on the basis of studies about nitrate concentrations in groundwater wells near farm houses. There are still many animal manure storage systems that leak N (and other nutrients) to groundwater and surface waters. The remediation of such point sources of nitrate pollution should receive priority, because they are a burden for human health (through contaminated drinking water) and the environment. This is exaggerated by the nature of the soils in Poland; the light-textured soils are vulnerable to nitrate leaching loss. Further, the agricultural land in Poland is intersected by many streams and lakes and drainage ditches, especially in the northern half of the country. As a consequence there is an intricate relationship between agriculture and surface waters. Studies in the famous peat wetlands of the Biebrza National park in the eastern part of Poland show seasonal variations in nitrate and ammonia concentrations in the groundwater, and again high nitrate concentration in groundwater well near farm houses.

14.4. Nitrate concentrations in groundwater and surface waters

Results of the monitoring networks by the Regional Water Management Boards suggest that only few surface waters sampling stations (<1%) have nitrate concentrations that exceed 50 mg per litre. However, maps of the location of surface waters monitoring stations suggest that a relatively large number of stations are affected by (vulnerable to) N from agricultural sources, though nitrate concentrations do not exceed 50 mg per litre. These stations seem to be distributed randomly throughout the country, i.e. everywhere in the country where there are surface monitoring stations.

The percentage groundwater sampling stations with nitrate concentrations that exceed 50 mg per litre ranges from 2 to 20%, depending on the depth of sampling and the year. Especially shallow groundwater stations have a relatively large percentage of stations with more than 50 mg per litre. The number of stations with nitrate concentrations exceeding 50 mg per litre is decreasing over time, and the number of stations with nitrate concentrations less than 50 mg per litre is increasing over time. This indicates that the nitrate leaching losses have decreased during the last 10 years. This decrease may be related to improvements in farm management and the strong decrease in fertilizer use and livestock density following the political changes by the end of the 1980s and beginning of the 1990s.

Measurements of nitrate concentrations in the groundwater at various places at livestock farms suggest that leakages of N from stables, manure heaps and farm yards are major sources of N in groundwater and also surface waters The mean nitrate concentration of 342 groundwater samples taken close to manure heaps was 25 mg NO_3-N per litre (~ 110 mg NO_3 per litre), with a range of 0 to 312 mg NO_3-N per litre (~ 0 to ~1400 mg NO_3 per litre). This suggests that barns and manure storage systems are hot spots of nitrate pollution. Model calculations indicated that the N losses from barns and manure storage systems account as much as ~40% to the estimated total N leaching loss from agriculture in Poland. Though this estimate has a relatively large uncertainty and requires further underpinning through field surveys and experimental measurements, it is clear that leaching and run off of nutrient from barns and manure storage systems have a relatively large share in the total leaching loss. Various medium-sized and large livestock farms have made investments during the last decade so as to properly house livestock and store animal manure in leak-tight pits and silos. However, there is little quantitative information about the percentage of farms and the location of farms with proper manure storage and handling. It is also unclear to which extent the groundwater sampling stations of Regional Water Management Boards capture the influence of leaking livestock housings and farm-yard manure heaps.

Mean nitrate concentration of drainage water (from drainage pipes) range from 1 to 12 mg NO_3-N per litre (~ 5 to 50 mg NO_3 per litre). Highest nitrate concentrations were observed in the central areas around Warszawa. These relatively high nitrate concentrations in this area may reflect the effect of irrigation practices.

Modelling studies indicate that the mean N leaching losses range from 8 to 20 kg per ha per year. With a mean rainfall surplus of about 200 - 300 mm per year, these numbers suggest that the mean nitrate concentrations in the drainage waters are in the range of 10 to 40 mg per litre. The highest concentrations are predicted for Wielkopolskie, Kujawsko-Pomorskie, Lodzkie and Mazowieckie, i.e. the central provinces in Poland.

14.5. Assessment of the groundwater and surface water monitoring networks

The number of surface waters monitoring stations in Poland in 2005 was 2790 and the number of groundwater monitoring stations 858. With a total surface area of 312,685 km^2, these numbers translate into a density of 8.9 and 2.7 stations per 1000 km^2 land area.

The groundwater monitoring stations are rather evenly distributed over the country. This holds for the monitoring of the relatively deep groundwater as well as the monitoring of the relatively shallow groundwater. The spatial distribution of the surface water monitoring stations is less even; in some areas in the south and north conglomerations of monitoring stations can be found, while there are large areas in the eastern half and also in the north and west with very few monitoring stations (e.g. Figure 28, Chapter 11). Discussions with representatives of the Ministry of Environment Protection and with Regional Water Boards indicate that the monitoring of groundwater and surface waters is under evaluation and revision, based also on the results that have been obtained so far.

It is as yet unclear whether the official monitoring stations include sampling stations close to farm-yards and manure heaps; groundwater near these yards and heaps have high nitrate concentrations (e.g. Tables 20 and 21).

Based on the assessments, three recommendations for the monitoring networks have been formulated:

Recommendation 1*: In view of the relatively low density and uneven distribution of monitoring stations for shallow groundwater, and in view of its importance for underpinning the designation of NVZs, we recommend increasing the number of monitoring stations for shallow groundwater, especially in areas with large areas of utilized agricultural land. The stations should be positioned in such a way that they capture the influence of current agricultural practices as much as possible. Furthermore, the depth of groundwater monitoring, the frequency of sampling, and the extent to which the samples collected are considered to be representative (e.g. as a function of agricultural practices, flow or location in a river) should be indicated.*

Recommendation 2*: In view of the relatively low density and uneven distribution of monitoring stations for small streams and lakes, and in view of the likeliness that these surface waters are relatively strongly affected by nutrients from agricultural sources, we recommend reconsidering the distribution of monitoring stations for surface waters, especially in areas with large areas of utilized agricultural land. Again, the stations should be positioned in such a way that they capture the influence of current agricultural practices as much as possible.*

Recommendation 3*: In view of the regional execution of some of the water quality monitoring and complex organization and in view of the availability of additional information from various universities and research institutes, it is recommended to consider an extended search for so far* *'hidden' information, and to use this additional information for a possible revision of the current monitoring program, including its organization).*

14.6. Assessment of the NVZs in Poland

Poland has designated a total of 21 areas in 6 regions as NVZ. The total area of the NVZ is 6263 km^2, equivalent to about 2% of the total surface area. The NVZs have been designated on the basis of the water monitoring data from 1990-2002 and information of local experts, but the decisions of the delineations have been made ultimately by the Ministry of Environment.

From the discussions with the representatives of the Ministry of Environment and Regional Water Boards, it has become clear that the borders of current NVZs follow the hydrological borders of catchments of rivers and streams (see also Table 1 and Figure 1). Only two NVZs are in part designated on the basis of sensitive groundwater (Ground Water Basin GZWP 327 in the Wroclaw region and some groundwater of Gliwice region). This indicates that the designation has been mainly based on the pollution of surface waters with nitrates from agriculture, as in the Plonia catchment (Figure 39; Chapter 12). Comparison of the locations of the NVZs with the maps with sensitive groundwater and surface waters indicates that the designation of these NVZs has solid grounds; most of the current NVZs have sensitive waters or are situated near sensitive waters (Figures 24 and 28).

However, a significant fraction of the shallow groundwater monitoring stations have nitrate concentrations exceeding 50 mg per liter (e.g. Figure 24, 26 and 27), but many of these stations are not situated in NVZs. The same holds for sensitive surface waters; very few catchments of sensitive surface waters are situated in NVZs (e.g. Figure 28). This suggests that there is room for improving the designation of NVZs in Poland. It also appears that the eutrophication of rivers, lakes and the Baltic Sea have not been taken into account in the current designation.

The largest NVZ are in the western part of the country where the most productive soils and most intensive agriculture is situated. This NVZ includes many surface waters that are qualified as sensitive to pollution by nitrates from agriculture (e.g. Figure 28). There is no clear relationship between the regional distribution of NVZs and the regional distributions of crops, N surpluses, livestock density, nitrate concentration in drainage waters and calculated N leaching losses on the other hand. For the NVZs in Wielkopolskie, which has the highest calculated leaching losses (e.g. Table 28, Chapter 12), there is a positive relationship with N pressure indicators livestock density and N surpluses. However, there are also other areas (counties) within Wielkopolskie and within neighbouring voivodships with a relatively high livestock density and a relatively high calculated leaching loss, but without NVZs. Similarly, the measured drainage water concentrations suggest that relatively high losses occur in central Poland (Figure 38) but no NVZs have been designated here. Further, the spatial distribution of sensitive surface waters (e.g. Figure 28) and locations of rivers and streams with relatively high nitrate, total N and total P concentrations (Figures 30 and 31) also indicate that there is room for improving the designation of NVZs, although the source of the nutrients in rivers and streams is not clear.

The spatial distribution of N pressure indicators (livestock density, fertilizer N use, N surpluses; soil types) suggest that the nitrate leaching potential is rather evenly distributed throughout the country, but on average not excessively high. Maps suggest that sensitive groundwater (Figure

24) and sensitive surface waters (Figure 28) are also fairly evenly distributed over the country. The mean nitrate concentrations in sensitive groundwater and the mean total N and total P concentrations in sensitive surface waters are near or above threshold values, but are not excessively high, and are decreasing (Figures 25, 26 and 27). Calculated leaching losses (Table 28) also suggest that the regional variations in nitrate leaching are relatively small, suggesting also that Polish agriculture is a diffuse source of nitrate pollution, evenly distributed over the country side.

Referring to the large number of farms with inappropriate facilities for the storage of animal manure and for the collection of surface run off from farm yards, the rather even distribution of sensitive groundwater and surface waters over the country side, the severe eutrophication of the Baltic Sea and the relatively large contribution of Polish agriculture to the nutrient loading of the Baltic Sea, one may argue to designate the whole Polish territory as NVZ. Indeed, there are solid grounds and various practical arguments for taking such position. It would target all farms as potential source of nitrate pollution, independent of its location, and it would demand from all farms to take remedial actions in a uniform way, without giving any competitive disadvantage of farms within NVZs relative to farms outside NVZs.

In case of designation specific nitrates vulnerable zones only, it is clear that a detailed monitoring network and great understanding of the groundwater hydrology is required. Such a detailed network is currently not available. The field visits and discussions with local experts and regional water managers have made clear that the designation of the NVZs in the Plonia catchment and catchment Zgłowiączka can be justified on the basis of results of detailed monitoring programs and also on the basis of the agricultural intensity in those catchments. However, such underpinning is as yet absent for many areas with sensitive waters that are not designated as NVZs.

Based on the assessments of this study, the following recommendations have been formulated

Recommendation 4*: In view of the suggested large leakages of nutrients from barns, manure storages and farm-yards, it is recommended to quantitatively assess the importance of these micro hot spots of pollution of groundwater and surface waters, and to develop and implement measures to decrease these leakages. Priority should be given to the relatively large livestock farms (e.g. >15 ha per farm and/or > 15 LSUs per farm).*

Recommendation 5*: The current designation of NVZs in Poland seems incomplete and must be reconsidered. The designations must address all the territories draining to fresh surface waters and groundwater, which are polluted or could become polluted with nitrates from agriculture, and to lakes, estuaries, coastal waters and marine waters that are eutrophic or may become eutrophic (see Annex 1 of the Nitrates Directive). In view of the diffuse nature of the pollution of groundwater and surface waters by nitrates from Polish agriculture, the wide-spread occurrence of sensitive groundwater and surface waters, the nitrate pollution of groundwater and eutrophication of surface waters and the relatively large contribution of Poland to the eutrophication of the Baltic Sea, there are many arguments to suggest designating the whole Polish territory as NVZ. Alternatively, if the designation of the whole territory is not considered* *feasible for whatever reason, the designation of the following specific territories must be considered as NVZ (See also figures 40a and 40b):*

- *Lakes with water quality classes III and IV, especially in the northwestern part of Poland. The territory draining to those lakes shall be designated as NVZ;*
- *Rivers with concentrations of Chlorophyll a of more than 25 mg/m3 (see Figures 30 and 31). This holds especially for the catchment of the Odra rivers, Notec river, Warta river(southern Warta up to the junction with Odra), Wistula (Section southern of Pulawy), Nareli , Bug (section southern Polowce)*
- *Territories polluting the groundwater monitoring stations as shown in Figure 24 of this report.*
- *Agricultural territories that contribute to the eutrophication of the Baltic Sea.*

The maps 40a and 40b show two alternative sketches of NVZ designation in addition to the pragmatic way of considering the whole territory as NVZ.

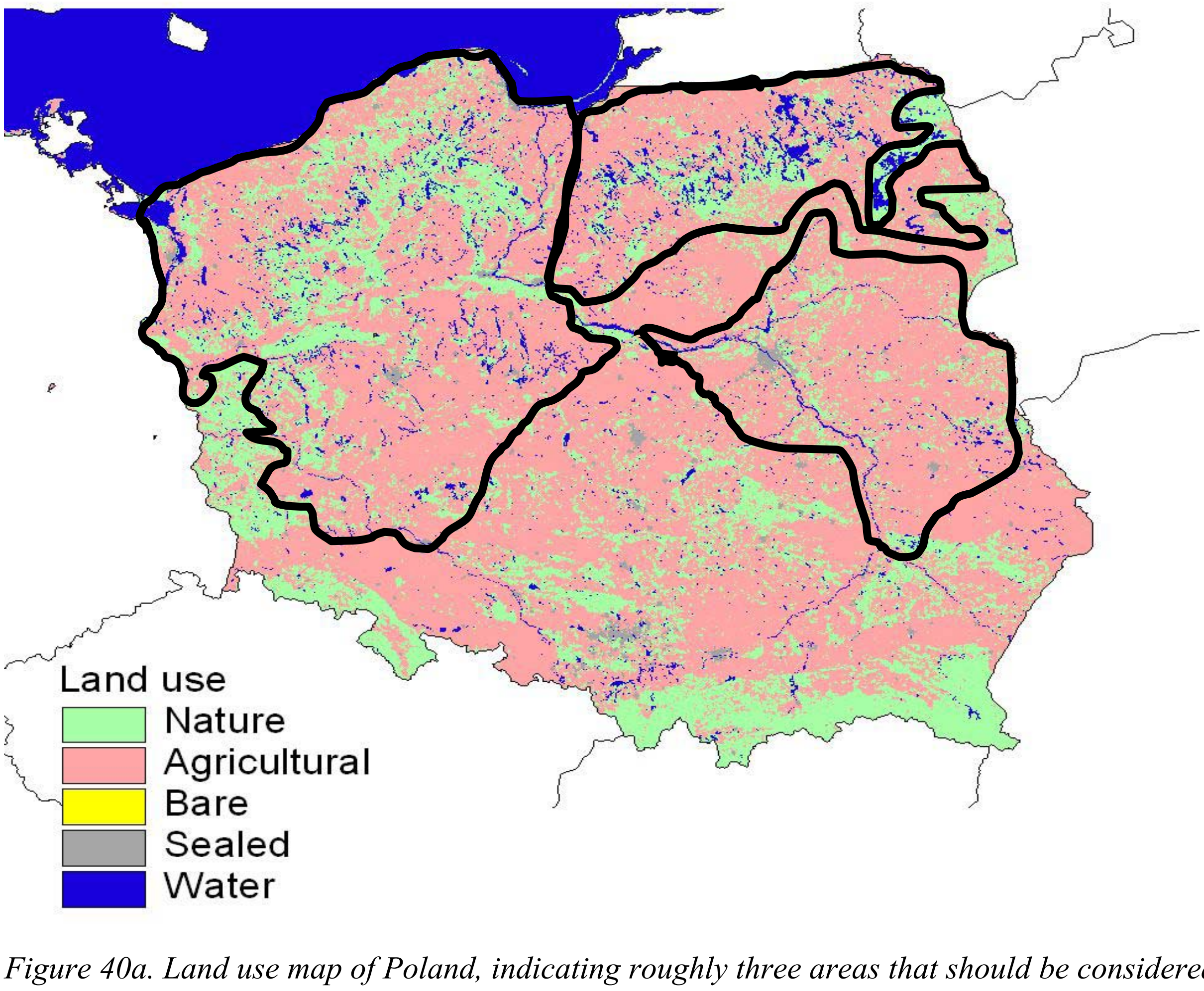

Figure 40a. Land use map of Poland, indicating roughly three areas that should be considered as NVZs, on the basis of the information from the groundwater and surface water quality monitoring and the statement in the Report "The State of Environment in Poland 1996-2001" that more that half of the 9000 lakes larger than 1 ha in Poland, especially in the northern half, are affected by nutrients from agriculture.

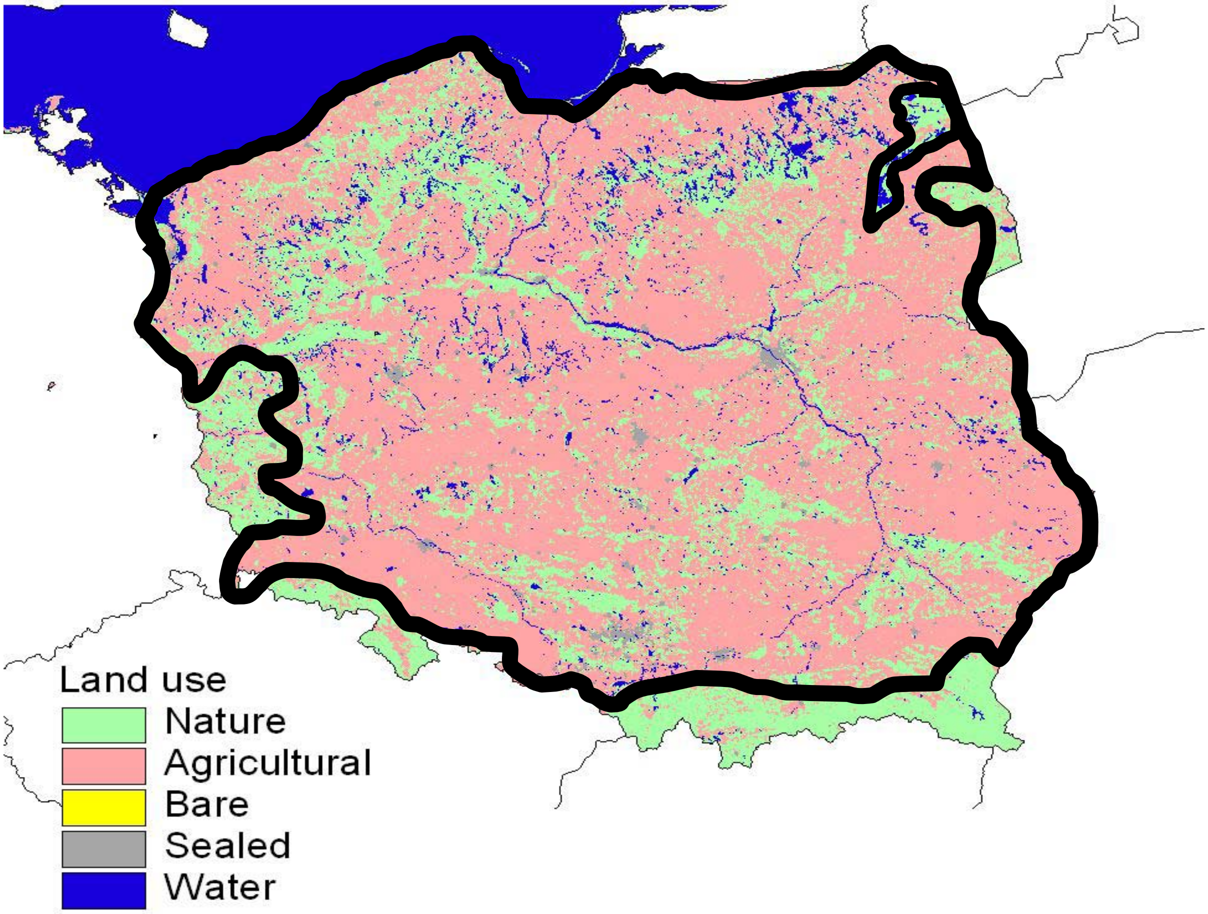

Figure 40a. Land use map of Poland, indicating roughly the area that should be considered as NVZs, on the basis of the information from the groundwater and surfacewater quality monitoring and the statement in the Report "The State of Environment in Poland 1996-2001" that more that half of the 9000 lakes larger than 1 ha in Poland are affected by nutrients from agriculture. The maps of high nitrate concentrations groundwater (Figure 24) and surface waters (Figure 28) indicate that agriculture is basically everywhere in the country a source of nitrate pollution.

***Recommendation 6**: Designation of NVZs is an obligation following from the EU Nitrates Directive. It is recognized though that there are various other possible nitrogen losses from agriculture, including ammonia and nitrous oxide emissions, for which other EU Directives and obligations arising from international conventions apply. From the perspectives of effective and efficient abatement of N losses, it might be desirable to developing a strategic and integrated approach to N loss abatement.*

14.7. Conclusions

- Mean livestock density in Poland is relatively low (on average <0.5 livestock units per ha, and not (yet) much regional concentrated (29 counties have a livestock density of > 1 per ha, 3 counties > 2 per ha; and 1 county has 7.5 LSU per ha).
- Most farms in Poland are very small farms and many farmers have a low education level. In general, animal manure and farm-yards are managed poorly. Farmers lack the funds and the incentives for investments in proper manure storage facilities and in proper manure management.
- Mean fertilizer N use is 55 kg per ha and is slightly increasing during the last ten years. Most of the fertilizer N is applied in the north-west half of Poland, but there are no large 'hot-spots' of fertilizer N use.
- Mean N surpluses are about 75 kg N per ha per year and were rather stable over the last ten years. Highest N surpluses are found in the north-west half of Poland.
- Based on the regional distribution of livestock and fertilizer use, there are no large, regional, "hot spots" of nitrate pollution in Poland.
- Most soils in Poland are light-textured sandy soils and are relatively vulnerable to nitrate leaching losses.
- Agricultural land is intersected by many streams, lakes and drainage ditches and these surface waters have variable water levels due to seasonal variations in rainfall and evapotranspiration. As a result, temporary flooding and intimate contact between land and surface waters often occurs on many places, providing lots of opportunities for the transfer of nitrate from agricultural land to surface waters.
- Many manure storage systems are not leak-tight and contribute to N leaching to groundwater and surface waters. The highest nitrate concentrations in groundwater are found near farms and farm-yards and manure heaps. Assessments made in this study, using MITERRA-EUROPE, suggest that leaching losses from manure storages and farm-yards contribute as much as 40% to the total leaching loss from Polish agriculture. However, this estimate is uncertain and requires underpinning through fields surveys and experimental measurements.
- A large percentage of surface water monitoring stations are influenced by nitrates from agricultural sources, and quite a few of these monitoring stations have nitrate concentrations near or exceeding 50 mg per litre.
- Measured N leaching losses via drainage are largest in the central parts of Poland. Measured NO_3-N concentrations range from 1 to 11.8 mg per litre, equivalent to 5 to 50 mg NO_3 per litre.

- Calculated N leaching losses are largest in the central provinces Wielkopolskie, Kujawsko- Pomorskie, Lodzkie and Mazowiecki.
- Mean N leaching losses in Poland range from 8 to 20 kg N per ha per year. These numbers translate to 20 to 40 mg NO_3 per litre. Roughly 40% of the total N leaching losses originate from leakages of manure N from manure heaps.
- The number of surface waters monitoring stations in Poland in 2005 was 2790 and the number of groundwater monitoring stations 858. With a total surface area of 312,685 km^2, these numbers translate into a density of 8.9 and 2.7 stations per 1000 km^2 land area.
- The distribution of the monitoring stations for groundwater is rather homogeneously distributed throughout the country. However, surface water monitoring stations are not equally distributed; it is recommended to re-assess the location of the monitoring stations. Especially in the north-eastern half of the country monitoring stations are lacking.
- The total area of the 21 designated NVZs in Poland covers 2% of the total area. Some of these NVZs are situated near high-density livestock areas. For most of the other NVZs, the mechanistic underpinning for its designation is unclear. However, for many other areas with sensitive waters, is unclear why these areas have not been designated. It is recommended to re-assess the current designation of NVZs in Poland.
- A major obstacle for improving manure management in Poland is the poor manure storage facilities. As manure storage facilities and manure application contribute roughly 40% to the total N leaching losses according to calculations with MITERRA-EUROPE, priority should be given to improving the manure storage and manure management. This is a challenging task, given the large number of small farms. Priority should be given to the larger farms (farms having more than 10 ha or more than 5 LSU. This relates to 7% of the total number of farms, equivalent to about 200,000 farmers. Though only 7% of the number of farmers, they cultivate more than 50% of the area.
- There are arguments to suggest to designating the whole territory of Poland under one Action Program of the EU Nitrates Directive. These arguments include the dominance and vulnerability of the sandy soils, the omnipresence of (sensitive) lakes and streams and the large areas of wet soils, the relatively large contribution of livestock manure to N leaching losses and its diffuse distribution in the country, the omnipresence of irrigation, and the increasing use of fertilizer N. Important aspects in such an Action Program would be improving manure storage and management. When doing so, the priority should be given to the larger (livestock) farms.

15. References.

Amann et al. (2006) Emission control scenarios that meet the environmental objectives of the Thematic Strategy on Air Pollution. NEC Scenario Analysis Report Nr. 2. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, 115 pp.

Anonymous 2006. Information on state of implementation of the council directive 91/676/EEC in Poland. Undated document obtained from DG Environment.

Durkowski T., Burczyk P, Królak B., 2006. Ocena odpływu składników nawozowych ze zlewni rolniczych jeziora Miedwie w okresie restrukturyzacji rolnictwa. Woda Środowisko Obszary Wiejskie t. 6 z. 2 (18) s. 51–63

FDPA, 2005. Rural Poland 2004. Rural Development Report. Foundation for the Development of Polish Agriculture. Warsaw.

Genetyczna klasyfikacja gleb. [http://www.gridw.pl/raport_pl/caly/rys34a.htm aftr: Narodowy Atlas Polski, 1994

Igras J., 2004. Zawartość składników mineralnych w wodach drenarskich z użytków rolnych w Polsce. Monografie i Rozprawy Naukowe 13. Puławy: IUNG ss 124.

Ilnicki P, 2004. Polskie rolnictwo a ochrona środowiska. Poznań: Wydawnictwo AR ss. 485.

Informacja na temat wyznaczania w Polsce obszarów szczególnie narażonych na azotany pochodzenia rolniczego i niezbędnych działań z tym związanych, 2003. Warszawa: Ministerstwo Środowiska ss. 25 (maszynopis)

Informacja o realizacji zadań Inspekcji Ochrony Środowiska w 2003 roku [www.gios.gov.pl/dokumenty/moni.doc]

Informacja o realizacji zadań Inspekcji Ochrony Środowiska w 2005 roku [www.bip.gios.gov.pl/dokumenty/iorzios2005/rozdz6.doc]

Kosarczyn,, H. 2001. Regional Development in Poland. An Overview. Warsaw.

Ochrona środowiska 1999, 1999. Warszawa: GUS. ss 510

Ochrona środowiska 2005, 2005. Warszawa: GUS. ss 540

Ochrona środowiska 2006, 2006. Warszawa: GUS. ss 521

Ostrowska B. E., Wesołowski P., Marcinkowski T., Smoroń S., 1996. Azotany i amoniak w wodzie do picia z ujęć własnych w gospodarstwach rolnych. W: Nadmiar azotu w rolnictwie czynnikiem zagrożenia zdrowia człowieka. Falenty: Wydawnictwo IMUZ s. 58-64.

Pietrzak S. Sapek A., Oenema O., 2002. Emisja podtlenku azotu (N_2O) ze źródeł rolniczych w Polsce. Nawozy i nawożenie, nr 1/2002 s. 135-147.

Pietrzak S., 2006. Metoda inwentaryzacji emisji amoniaku ze źródeł rolniczych w Polsce i jej praktyczne zastosowanie. Woda-Środowisko-Obszary Wiejskie t. 6 z. 1 (16) s. 319-334.

Pietrzak S., 2007. Not published data.

Pietrzak S., Nawalany P., Wilczyńska J., 2007. Not published data.

Powszechny Spis Rolny 2002. www.stat.gov.pl

Raport stan środowiska w Polsce w latach 1996-2001. Warszawa: Inspekcja Ochrony Środowiska, 2003 ss. 268

Rocznik statystyczny rolnictwa 1998, 1999. Warszawa: GUS ss. 481

Rocznik statystyczny rolnictwa 2001, 2001. Warszawa: GUS. ss. 315

Rocznik statystyczny rolnictwa i obszarów wiejskich 2005, 2005. Warszawa: GUS ss. 485

Sapek A., Sapek B., Rzepiński W., 1993. Wstępne rozpoznanie zanieczyszczenia wody do picia z ujęć własnych w gospodarstwach rolnych na terenie województwa ostrołęckiego. Falenty: IMUZ, Ostrołęka: ODR ss. 8

Sapek A, 1996. Udział rolnictwa w zanieczyszczaniu wody składnikami nawozowymi. Zeszyty Edukacyjne 1/96. Falenty: Wydawnictwo IMUZ s. 9-33.

Sapek A., 1998. Emisja gazów cieplarnianych z rolnictwa. Zeszyty Edukacyjne 5/98. Falenty: IMUZ s 17-26.

Sapek A, Sapek B, Pietrzak S., 2000. Rola produkcji zwierzęcej w rozpraszaniu składników nawozowych z rolnictwa do środowiska. W: Dobre praktyki w rolnictwie. Sposoby ograniczenia zanieczyszczeń wód. Pr. zbior. Red. S. Pietrzak. Przysiek: RCDRRiOW s. 5-31.

Sapek B., 1998. Farm as a source of soil, water and air pollution with nitrogen, phosphorus and potassium. Bibliotheca Fragmenta Agronomica t. 3/98 s. 124-144. (in English)

Sapek B, 2000. Wpływ zagrody i jej otoczenia na jakość wody. W: Dobre praktyki w rolnictwie. Sposoby ograniczenia zanieczyszczeń wód. Pr. zbior. Red. S. Pietrzak. Przysiek: RCDRRiOW s. 60-68.

Sapek B., 2002. Jakość gleby i wody w gospodarstwach demonstracyjnych. W: Cele i sposoby ograniczenia rozproszenia składników nawozowych z gospodarstwa rolnego do środowiska. Zeszyty Edukacyjne 7/2002. Falenty: Wydawnictwo IMUZ s. 57-71.

The supplementary literature

Baldock, D & Tar, F. (2002). Potential consequences of EU enlargement on agriculture and environment in the accession countries. Discussion paper. IEEP, London. http://www.ieep.org.uk

Bennett, H. (2003). Good Farming Practice in Central and Eastern European Countries. Seminar report. IEEP, London. http://www.ieep.org.uk

Brzozowski, J, 2002. Proposal of splitting large Polish Agricultural Hot Spots into agricultural sub hots spots in the framework of the HELCOM Baltic Program. Paper presented at 6th Meeting of the HELCOM Working Group on Agriculture in Kiel, Germany, October 2002.

BESP, 2006a. Nutrient Pollution to the Baltic Sea in 2000. Baltic Sea Environment Proceedings No. 100. Helsinki Commission. (www.helcom.fi)

BESP, 2006b. Development of tools for assessment of eutrophication in the Baltic Sea. Baltic Sea Environment Proceedings No. 104. Helsinki Commission. (www.helcom.fi)

CEC (1998). Agricultural situation and prospects in the Central and Eastern European Countries. Ten volumes. Commission of the European Communities, Brussels.

FDPA, 2001. Rural Poland 2000. Rural Development Report. Foundation for the Development of Polish Agriculture. Warsaw.

FDPA, 2003. Rural Poland 2002. Rural Development Report. Foundation for the Development of Polish Agriculture. Warsaw.

FDPA, 2005. Rural Poland 2004. Rural Development Report. Foundation for the Development of Polish Agriculture. Warsaw.

FDPA, 2006. Rural Poland 2006. Rural Development Report. Foundation for the Development of Polish Agriculture. Warsaw.

Fotyma M., Igras J., Kopiński J., Głowacki M., 2000. Nitrogen, phosphorus and potassium balance in Polish agriculture. In: Pamiętnik Puławski z. 120/I. p. 91-99. (in Polish)

HELCOM, 2006. Eutrophication in the Baltic Sea Draft HELCOM Thematic Assessment in 2006 Helsinki Commission. (www.helcom.fi)

Igras J., Kopiński J. Lipiński W., 2003. Nutrient balances in Polish agriculture. Annales of the Polish Chemical Society. Lublin. Vol. 2, Part II, 713-718. (in English)

Kopiński J., Tujaka A., Igras J., 2006. Nitrogen and phosphorus budgets in Poland as a tool for sustainable nutrients management. Acta agriculturae Slovenica, 87 - 1, april 2006 pp. 173 – 181 (in English)

Łabętowicz J., Sosulski T., 2005. Próba ilościowego oszacowania rozproszenia azotu z obszarów rolniczych w świetle literatury. W: Zanieczyszczenie środowiska azotem. Olecko: Wydawnictwo Wszechnicy Mazurskiej s. 11-26.

Sapek A., Pietrzak S. Nawalany P., 2001. The balance of nutrients in the country and region scale in 2000. Report. Falenty: IMUZ pp. 32 /the typescript/ (in Polish)

Sapek A., Pietrzak S. Nawalany P., 2001. The balance of nutrients in the country and region scale in 1999. Report. Falenty: IMUZ pp. 30 /the typescript/ (in Polish)

Sapek B., 1998. Monitoring zanieczyszczeń gleby i wody składnikami nawozowymi w skali gospodarstwa. W: Monitoring środowiska. Pr. zbior. Red. I. Wiatr, H. Marczak. Lublin: Wydaw. Ekoinżynieria p. 165-174. (in Polish)

Sapek B., Sapek A, Kalińska D., Pietrzak S., 2000. Identifying regions of various risk of water pollution by agriculturally derived nitrogen, phosphorus and potassium in Poland. W: Scientific basis to mitigate the nutrient dispersion into the environment. Pr. zbior. Red. A. Sapek. Falenty: Wydawnictwo IMUZ s. 170-185. (in English)

Sapek B., 2002. The impact of farmstead operation on ground water quality. W: Agricultural effects on ground and surface waters: Research at edge of science and society. Pr. zbior. Red. J. Steenvoorden, F. Claessen, J. Willems. IAHS Publ. no. 273 p 125-130.

Sapek B., Sapek A., 2005. Mineral nitrogen in the soil and groundwater dunder the farnstad and its vicinity on the background some nutrients and dissolved organic matter (DOM). In: Zanieczyszczenia środowiska azotem. Olecko: Wszechnica Mazurska p. 113-128. (in Polish).

Sapek A., Sapek B., 2005. Mineral nitrogen in groundwater from the mineral land organic soils of permanent grassland. In: Zanieczyszczenia środowiska azotem. Olecko: Wszechnica Mazurska p. 129-142. (in Polish).

Statistical yearbook of agriculture and rural areas, 2005. Central Statistical Office. Warsaw pp. 486. (in Polsh)

Soil Map (s) of Europe > Soil Map (s) of Poland *(Compiled by: Senthil-Kumar Selvaradjou)* http://eusoils.jrc.it/esdb_archive/EuDASM/lists/poland.htm

Urban, R., T. Chudoba, J. Drosdz, E. Rosiak, J. Rowinski, I. Szczepaniak, M. Wigier. 2001. Polish Food Industry. Polish Federation of Food Industries. Warsaw. 2001.