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Abstract

Nitrogen concentration time trends from Lithuanian rivers were analyzed to provide information on the amount, sources, and causes of nitrate runoff to the Baltic Sea from Lithuania. This investigation focused on the impact of large-scale agricultural production on nitrate concentration in the rivers. Long-term water quality changes were determined using the national monitoring data from the Lithuanian Ministry of Environmental Protection.

Disciplines

Agriculture | Water Resource Management

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THE EFFECT OF AGRICULTURE NITROGEN ON WATER QUALITY IN LITHUANIAN RIVERS

Introduction

Nitrogen's role as one of the most important elements in aquatic ecosystems is undisputed. It occurs in several forms, and participates in a large number of processes, primarily biological, including atmospheric gas exchanges. Annual nitrogen loading in the Sound, the Belt Sea, and the Kategat and Skagerrak Rivers from Sweden, Denmark, Norway, and Germany is currently about 260,000 tons. Approximately 50 percent is agricultural and 30 percent is atmospheric. The loading on the Baltic Proper is even higher at 1,350,000 tons annually. Agricultural activities are responsible for between 40 and 50 percent of this amount.

In Lithuania, agricultural nitrogen and phosphorus runoff have been estimated to contribute 77 percent (44,000 tons) and 50 percent (1,800 tons) of the total annual nutrient load to the Nemunas River. To improve this situation, Baltic Sea basin countries at the HELCOM convention decided to reduce nitrogen runoff to 50 percent of the 1987 level.

These estimates are based on assumptions of nitrogen and phosphorus losses of 20 kg N/ha and 0.35 kg P/ha from arable lands. However, there are great uncertainties regarding these figures; therefore, the calculated loads must be considered rough estimates, possibly representing an average value for a period of many years with relatively high agricultural production and poor production techniques.

With this background, we analyzed nitrogen concentration time trends from Lithuanian rivers. The investigation's goal was to provide information on the amount, sources, and causes of nitrate runoff to the Baltic Sea from Lithuania.

In a natural stream, water commonly enters through surface runoff and subsurface flow; in a channeled stream where the water table has been lowered, most of the subsurface water flows through drainage tiles. Nitrogen is usually transported as nitrate (NO_3-N), mainly subsurface flows.

Therefore, our analysis focused on the impact of large-scale agricultural production on nitrate (NO_3-N) concentration in rivers.

To survey long-term changes in water quality, we used the Lithuanian Ministry of Environmental Protection national monitoring data. For our analysis we selected 12 monitoring posts (Table 1).

Table 1. Watershed characteristics at monitoring posts

River and location of the monitoring post	Watershed area, km^2	Forests, km^2	Forest, percent of watershed	Wet-lands, km^2	Wetlands, percent of watershed
Þeimena, upstream from Kaltanënai	765.2	201.4	26.32	74	9.67
Skroblus, outlet	78.8	75.9	96.32	1.95	2.47
Veivirþas	685.7	160.2	23.4	10.1	1.47
Tatula, upstream from Birþai	465.6	5.8	1.25	37	7.95
Vyþuona, at Juodupë	130.2	41.0	31.5	12.2	9.37
Ðuðvë, at Ðiaulënai	261.85	57	21.77	57.6	22.00
Ðyða, upstream from Ðilutë	175.5	1.85	1.05	2.44	1.39
Minija, upstream from Plungë	414.7	90.4	21.80	38.4	9.26
Ðventoji, upstream from Anykðèiai	3565.4	354.6	9.95	356.5	10.00
Ðeðupë, upstream from Marijampolë	1364.5	144.2	10.57	256.2	18.78
Nevëþis upstream from Këdainiai	2839	498.9	16.9	117.2	4.2
Levuo, upstream from Pasvalys	1560.0	255.3	16.36	117.7	7.54

Three of the selected posts were established on natural rivers and nine were located to represent all Lithuanian geographical zones (Figure 1).

Preliminary analysis of the data indicated that time-related trends could be determined only from a long series of data. Therefore, we used monthly data for water discharge, ammonium nitrogen (NH_4-N), and nitrate nitrogen (NO_3-N) for 1981 to 1994. Water samples were taken both upstream and downstream from cities and in two of the cleanest Lithuanian rivers, the Þeimena and the Skroblus. Nitrogen load in these rivers was considered to be natural. Nitrate concentration difference between downstream and upstream from cities demonstrates the industry and city load. To determine the nitrate load, we subtracted the nitrate concentration in the natural background rivers from the nitrate concentration upstream from cities. In this case, nitrogen from rural settlements and large animal barns was included in the agricultural load. Water discharge was calculated by measuring the water velocity and a cross-section of the river at the monitoring post. The photometry method was used to determine nitrate concentrations.

Long-Term Water Quality Changes in Lithuanian Rivers

Nitrogen changes in the Lithuanian natural background rivers are presented in Figures 2 and 3.

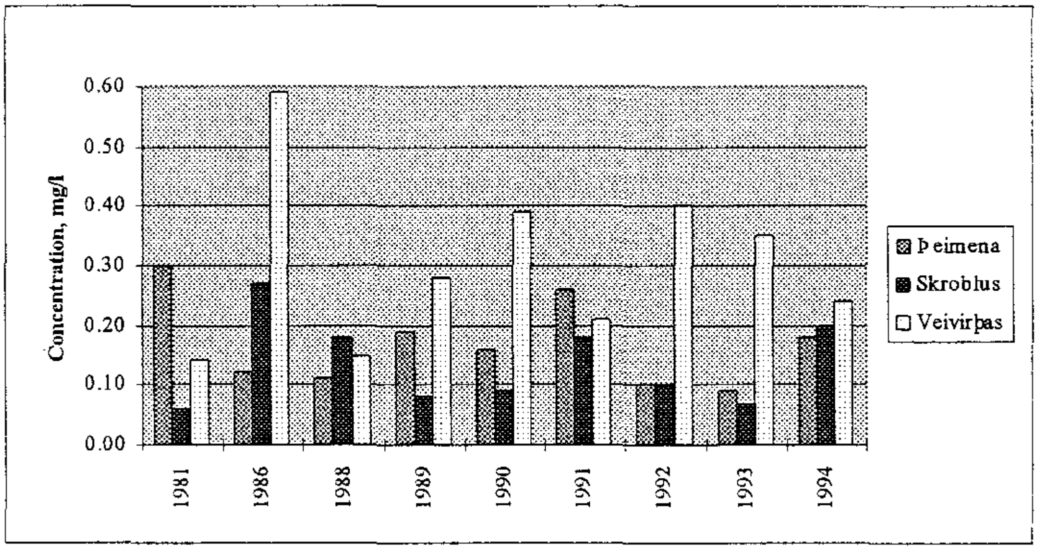

Figure 2. Ammonium nitrogen (NH_4-N) transport in natural rivers with little impact from human activity

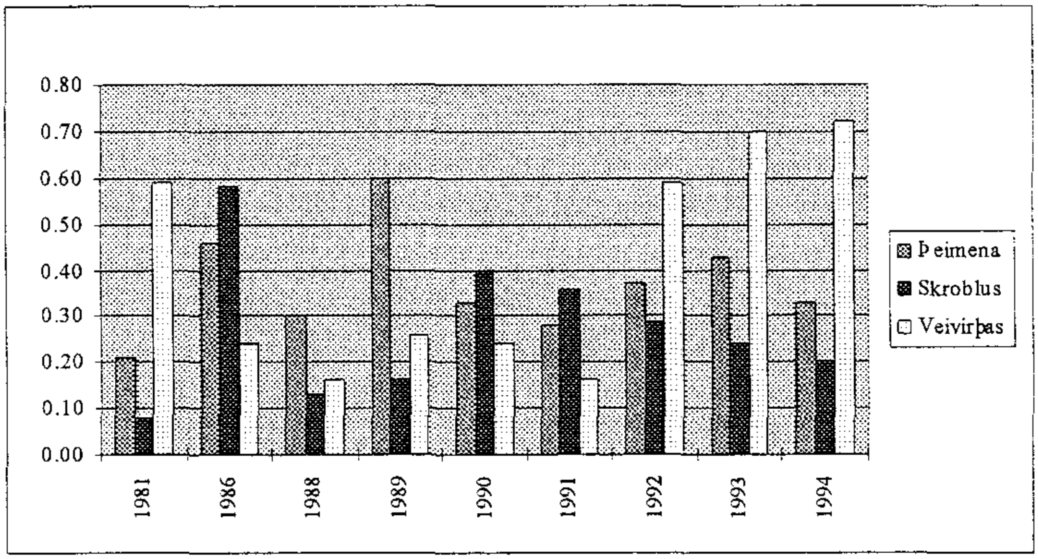

Figure 3. Nitrate nitrogen (NO_3-N) transport in natural rivers with little impact from human activity

Figure 3 shows that nitrate nitrogen concentration in the Þeimena and Skroblus Rivers increased in 1986 and then declined after 1989, stabilizing over the last four years at an average of 0.3 mg/l. Rather small concentration in the Veivirþas River began to increase after 1991.

The time trend of the nitrogen load in agricultural rivers is shown in Figures 4 and 5.

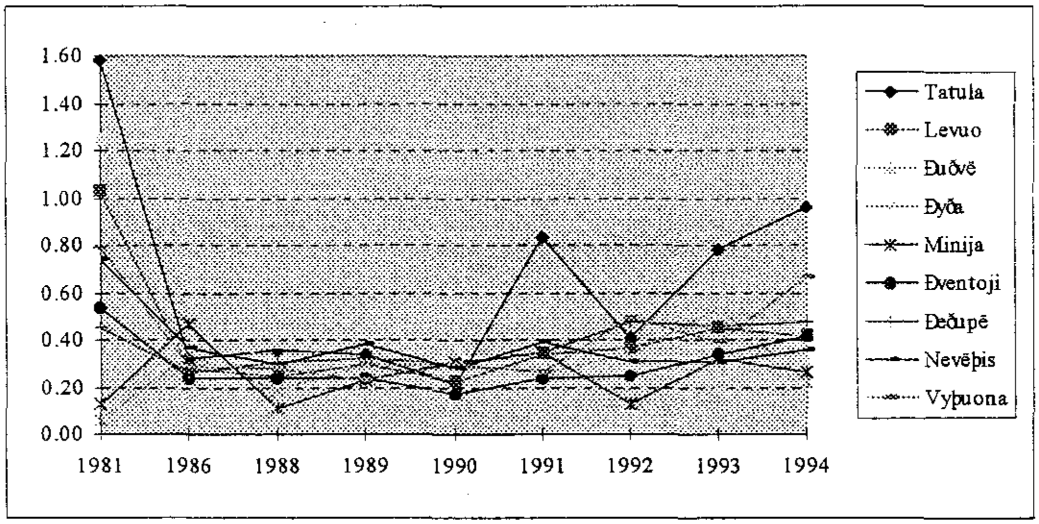

Figure 4. Ammonium nitrogen (NH_4-N) transit in rivers flowing through agricultural lands

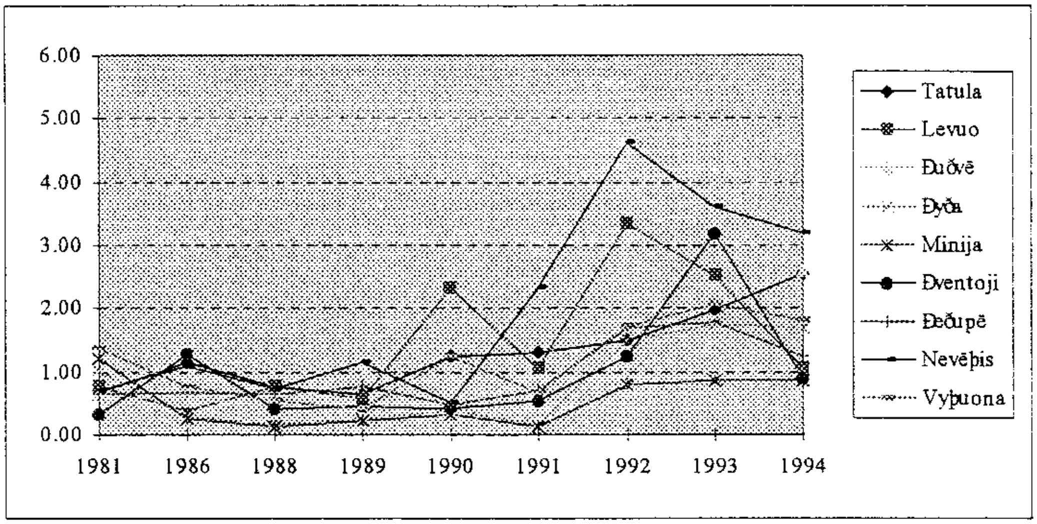

Figure 5. Nitrate nitrogen (NO_3-N) transit in rivers flowing through agricultural lands

Data analysis shows that the agricultural nitrogen load was stable between 1981 and 1990. Agricultural ammonium and nitrate nitrogen loads dramatically increased after 1990. The maximum nitrate nitrogen concentration was reached in 1992 and 1993 and then declined slightly in 1994. The ammonium nitrogen concentration is still increasing. The largest ammonium nitrogen load is in the Tatula River, which flows through the karst region. Extensive agricultural and karstic conditions with direct contact between surface water and groundwater is the primary reason for the high contamination level.

The next most contaminated rivers, according to the nitrogen load, are the Nevëþis and Ðuðvë Rivers. They flow through intensive agriculture areas and the data demonstrate that agriculture has a great impact on water quality; therefore, watersheds of rivers flowing through agricultural regions must be analyzed in more detail.

Industry and city nitrogen loads can be seen by comparing Figures 4 and 5 with Figures 6 and 7.

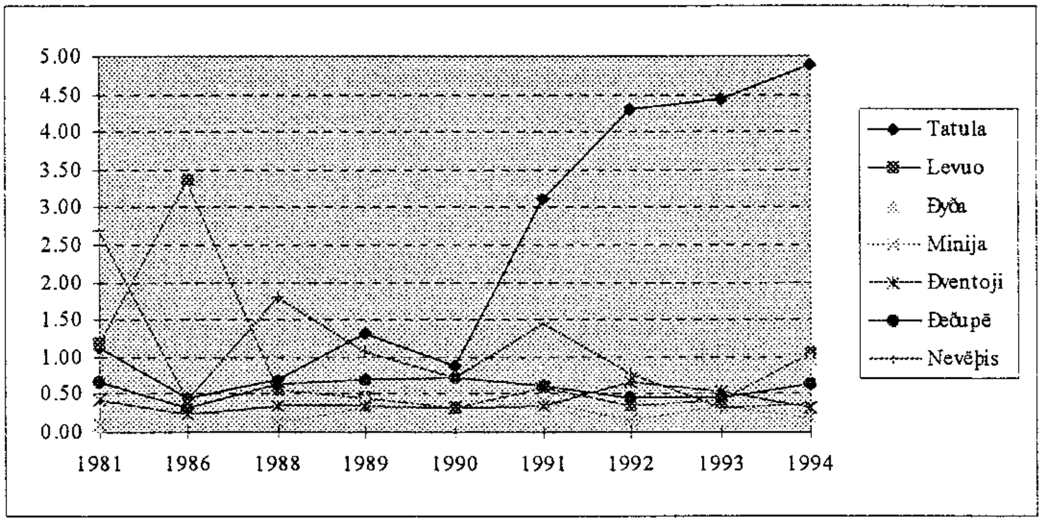

Figure 6. Ammonium nitrogen (NH_4-N) concentration in rivers downstream from cities

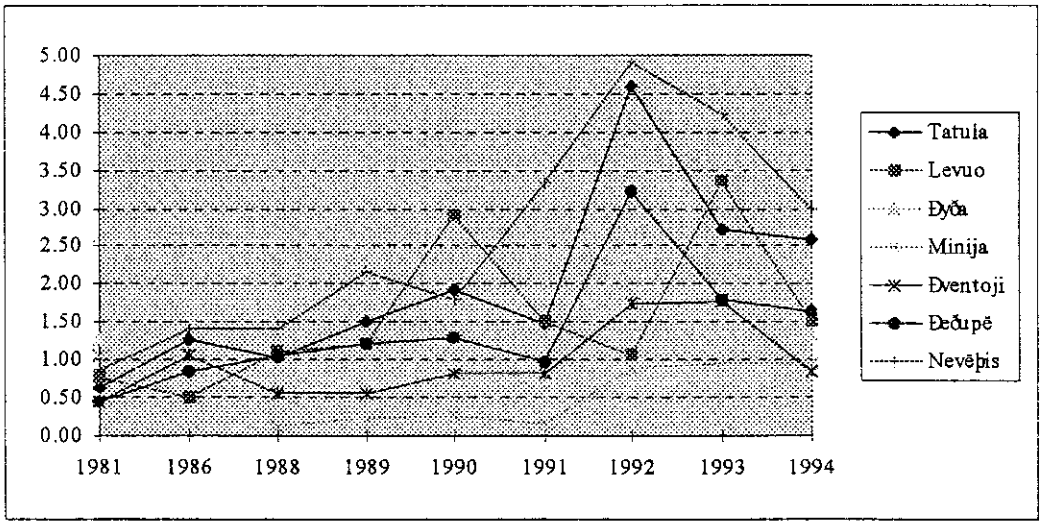

Figure 7. Nitrate nitrogen (NO_3-N) concentration in rivers downstream from cities

To find the nitrate nitrogen (NO_3-N) load derived only from agriculture practices and rural households, we subtracted the concentration found in natural rivers from that found in agricultural rivers. Both natural and agricultural nitrate nitrogen (NO_3-N) concentrations are shown in Figure 8.

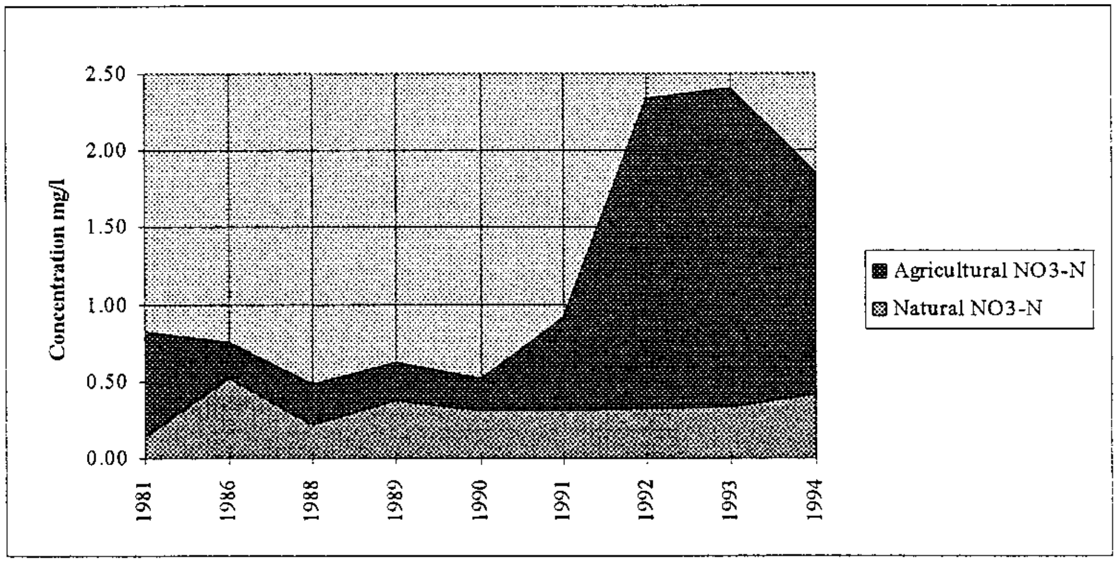

Figure 8. Nitrate nitrogen (NO_3-N) time trend in agricultural and natural background rivers

Nitrate nitrogen (NO_3-N) concentration in natural background watersheds changed very from 1980 to 1996. But, NO_3-N concentration in agricultural land has increased eight times from 1990 to 1993. Only in 1994 was a 33 percent decrease in nitrate concentration recorded.

For the last three years, nitrate nitrogen (NO_3-N) from agricultural land was 80 percent of the total nitrate concentration in agricultural watersheds (Figure 9).

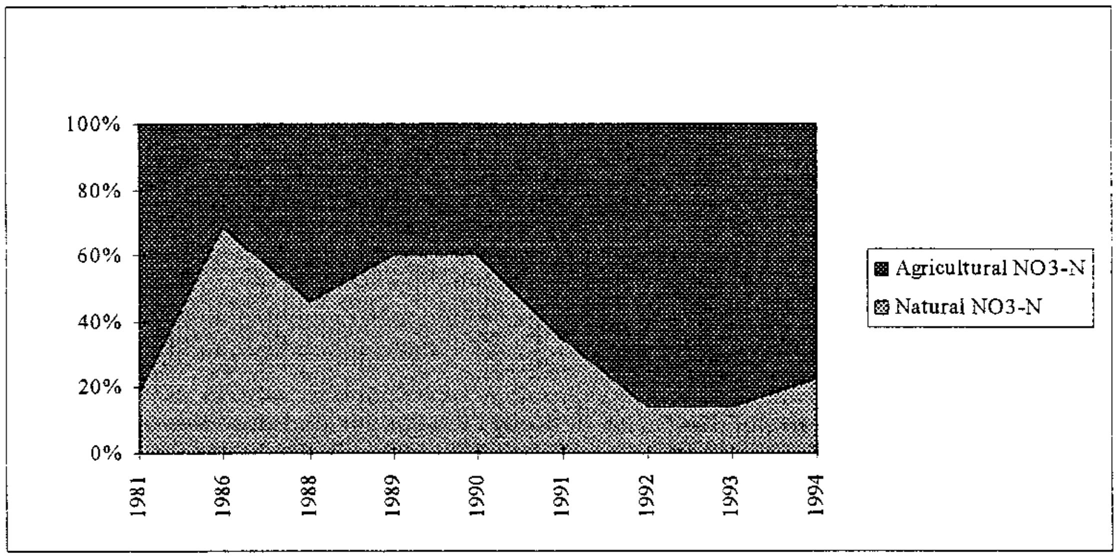

Figure 9. Nitrate nitrogen (NO_3-N) ratio in agricultural and natural land rivers

To determine the relationship between agricultural production and stream nitrate nitrogen (NO_3-N) concentration, we combined corresponding data in one chart (Figure 10).

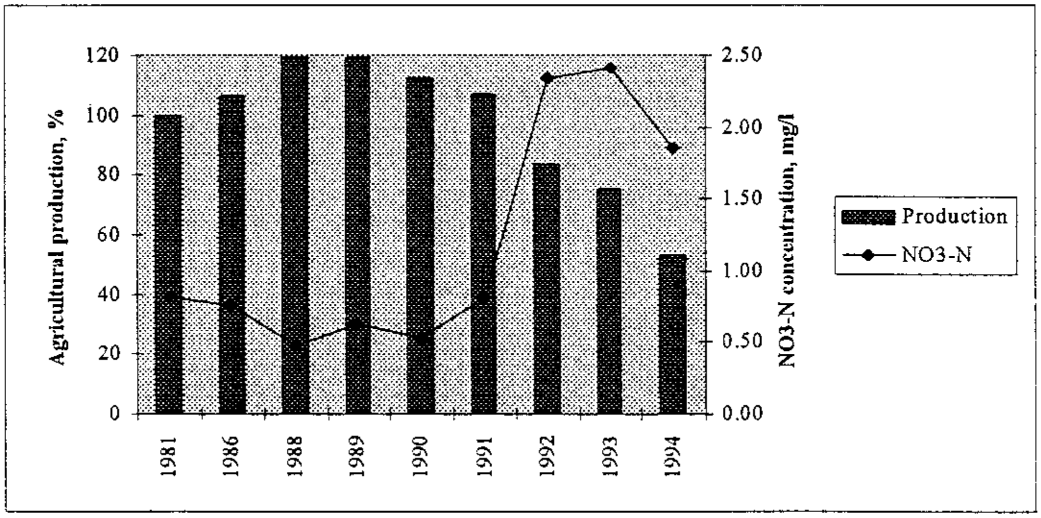

Figure 10. Changes in the gross agricultural output (annual average) in all categories of farms, and NO_3-N concentration in the rivers flowing through agricultural territories

Agricultural production declined almost 50 percent from 1990 to 1993. At the same time, NO_3-N concentration in the rivers flowing through agricultural territories increased by 5 times. These data contradict the general opinion that nitrogen load from agriculture has declined since the start of agricultural reform in 1990. The prevailing opinion among scientists and officials is that water quality improved when collective farms were dismantled, agricultural production was reduced, and mineral fertilizer use decreased. Figure 10 indicates the opposite. Therefore, to find the main cause for this phenomenon, more detailed investigation of all possible reasons is needed. One of the reasons could be that the nitrogen load in rivers depends more on farming culture than on fertilization level. When the agrarian reform began, many new farmers were without agricultural management skills. Improper animal management, open manure storage, and large areas of unharvested yield could have caused large nutrient losses. Another reason could be fertilizer oversupply, which is supported by fertilizer use data (Figure 11).

There appears to be a minimal relationship between fertilization rates and crop production. Other reasons, such as change from standpoint to water quality analysis, could be a possibility. Under Soviet rule, proof of no environmental contamination was required. More data are needed on the change of nitrogen concentration in precipitation and on the influence of large animal farms and manure handling on agricultural runoff. Therefore, we cannot ignore agricultural water pollution. The prevailing opinion that decreasing fertilizers use will automatically solve rural water contamination problems is incorrect. Only a detailed investigation can explain causes of increased water pollution from agriculture and offer possibilities for a proper solution.

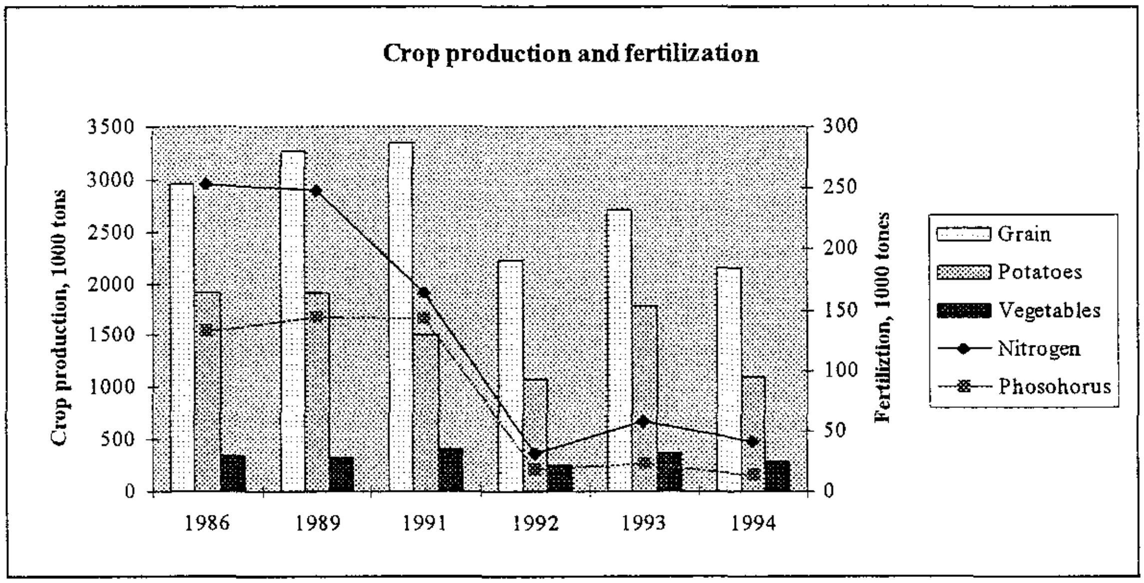

Figure 11. Relationship between crop production and fertilization in Lithuania

Nitrogen loss usually increases in autumn, depending on the climate. A mild climate, leading to extensive mineralization of crop residues even during late autumn and winter, plays an important role (Figures 12 and 13). Using data from a 15 year period, we defined seasonal nitrate concentrations changes in Lithuania (Figure 12); the largest nitrate nitrogen (NO_3-N) losses are from November to May.

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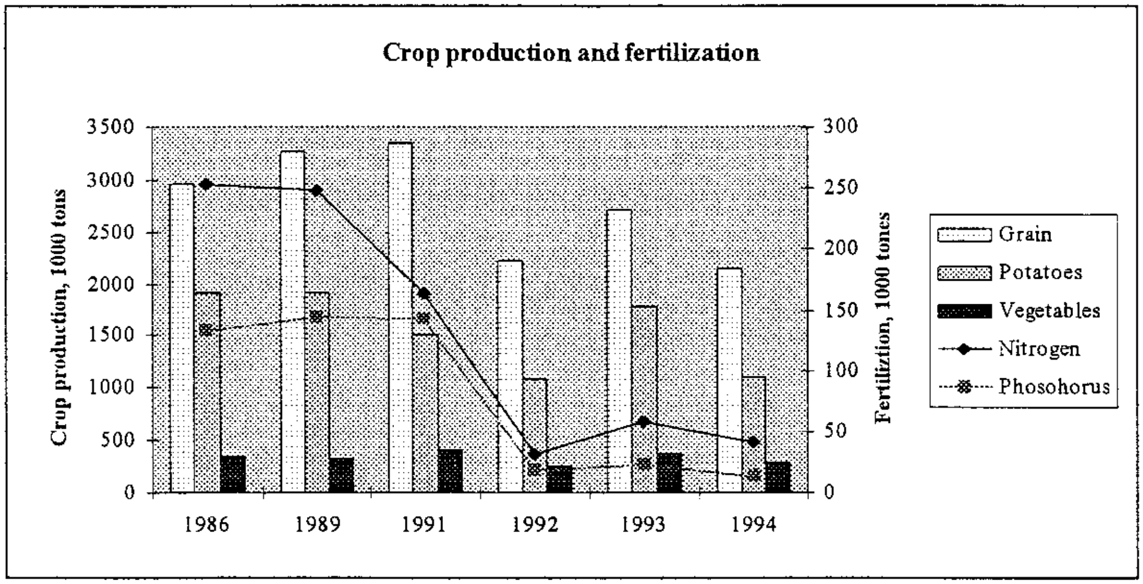

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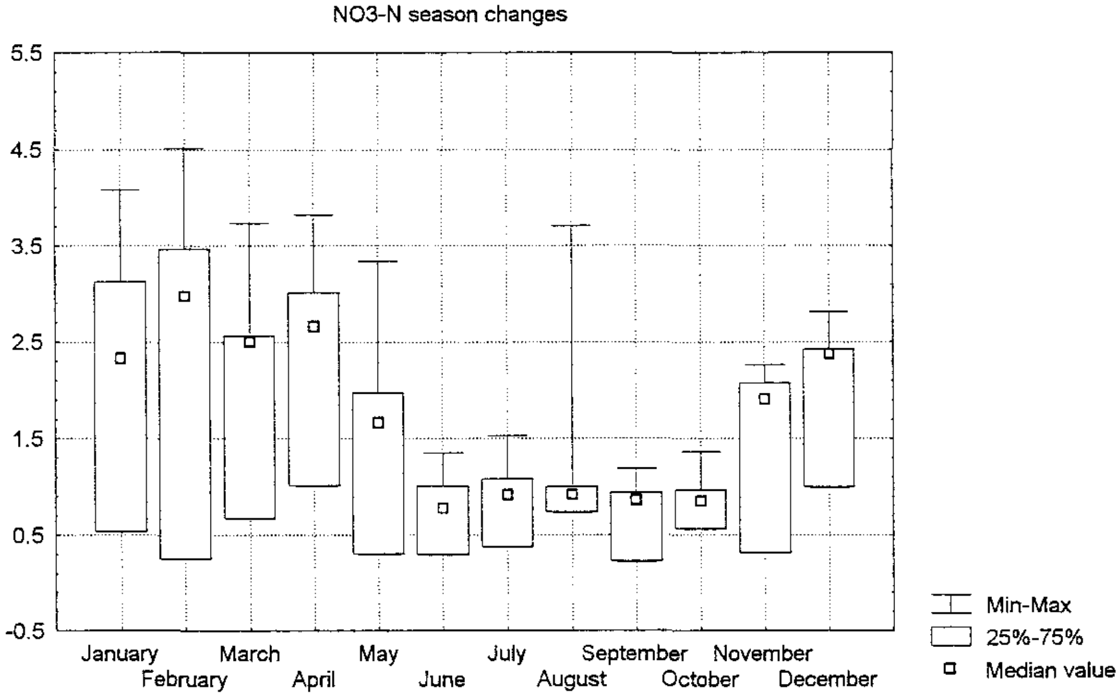

Figure 12. Seasonal nitrate nitrogen (NO_3-N) concentration changes in rivers of agricultural land, 1981–94

Our analyses have been conducted in watersheds with areas of more than 100 km^2. Long-term data from large watersheds allow us to determine natural trends, but do not allow us to identify pollution sources. To identify pollution sources and to evaluate the impact of fertilization time, rate, and cropping system, it is necessary to establish monitoring systems on smaller watersheds. This will be the main objective of our future investigation.

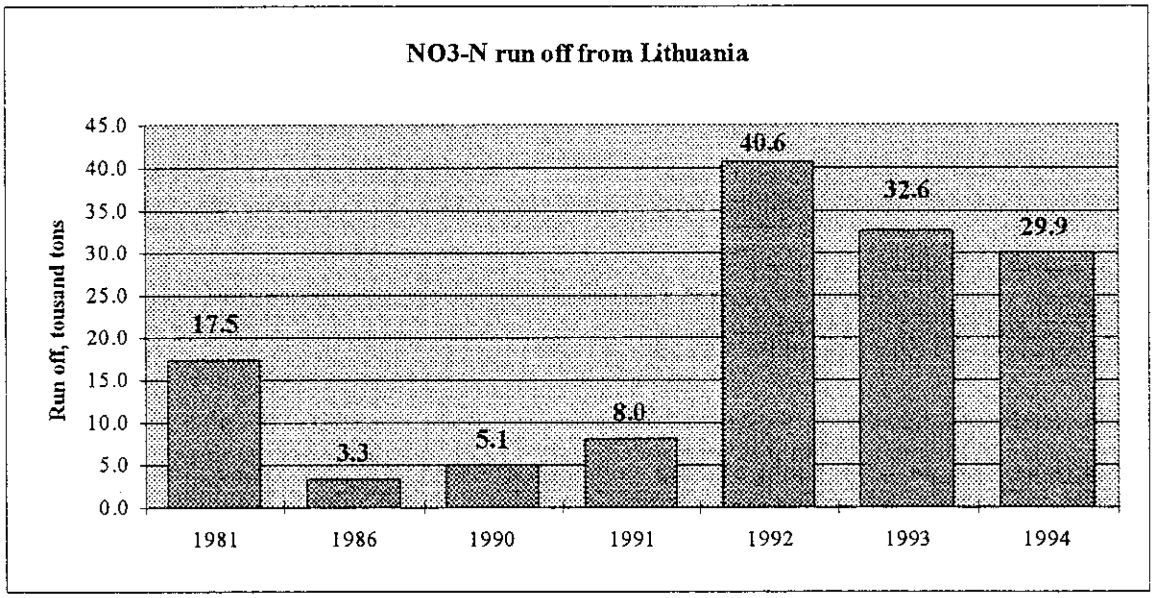

Figure 13. Nitrate nitrogen (NO_3-N) runoff changes for 1981–1994 in Lithuania.

The largest amount of nitrate nitrogen (40,000 tons) transported to the Kurðiø lagoon and Baltic Sea was in 1992. Nitrate nitrogen runoff has stabilized in the last two years and now averages about 30,000 tons per year.

Conclusions

Water quality data from large watersheds allow evaluation of water pollution time trends. Long-term changes of nitrogen compounds in precipitation as well as statistical analysis is needed for a more exact evaluation of agricultural runoff. Mineral fertilizer use has decreased 50 to 80 times since 1989; but analysis of the nitrate nitrogen (NO_3-N) concentration data shows an unexpected ncrease in Lithuanian river water pollution from agricultural runoff. To identify actual pollution sources and evaluate the effects of various practices and land management options, more detailed investigations are needed on smaller watersheds, farms, and other possible sources of water pollution.

Lithuanian agriculture contributes significantly to the pollution of Lithuanian rivers and the Baltic Sea. To fulfill the requirements of the HELCOM Convention, it is necessary to establish monitored watersheds and demonstration farms for teaching farmers best management practices in all Lithuanian geographic zones. These activities should be primarily in the Middle Plain of Lithuania and the karst zone. Monitoring programs, field trials, education programs, and advisory services have to be organized on the demonstration farms.

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