Nutrient losses from Agriculture in Lithuania*)

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Introduction

The objective of the demonstration watersheds in Lithuania is to reduce agricultural run-off and to improve local surface and ground water bodies by implementing immediate actions as well as water quality of the Baltic Sea in the more long strategy.

Implementation of the 1988 Ministerial Declaration in HELCOM revealed that none of the Contracting Parties had achieved the overall target to reduce the nutrient load to the Baltic Sea by 50 % until 1995 [1, 2].

The current status of nutrient loads to the Baltic Sea (presented in **Table 1**) shows, that the phosphorus discharge decreased by 17.6 % from 1990 to 1995 but the nitrogen load even increased by 15 %. The highest increase was in Lithuania and Poland. It is difficult to say, if this figure is correct for Poland, but in Lithuania increase of nitrate nitrogen load during transition period was for sure (**Table 2**).

The phosphorus load from 1986 to 1998 decreased four times, while in the meantime nitrate nitrogen discharge increased 1.6 times. There could be some inaccuracy of the presented data, especially during high floods because of monthly sampling of water quality and discharge measurement in the river Nemunas. In any case, this figure does not prepossess us optimistically concerning our expectations to reduce nitrogen load.

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Table 1. Nutrients discharges into the Baltic Sea from the territories of Contracting Parties

Countries	P, thousand tons			P, kg/ha agric. land			N, thousand tons			N, kg/ha agric. land		
	1990	1992	1995	1990	1992	1995	1990	1992	1995	1990	1992	1995
Denmark	5.3	3.9	2.6	1.89	1.39	0.93	83	70	68.7	29.6	25.0	24.5
Estonia	2.8	1.6	1.3	1.12	0.64	0.52	59	51	46.5	23.6	20.4	18.6
Finland	3.4	4.7	3.6	1.31	1.81	1.38	72	85	66	27.7	32.7	25.4
Germany	1.2	1.6	0.6				14	16	21.4			
Latvia	3.2	1.8	2.2	0.94	0.53	0.65	94	89	91	27.6	26.2	26.8
Lithuania	1.7	1.6	1.4	0.49	0.46	0.40	19	20	36.8	5.4	5.7	10.5
Poland	15	12	14.2	0.77	0.62	0.73	120	140	214.8	6.2	7.2	11.0
Russia	9.5	6.5	7.1				81	32	84.6			
Sweden	4	4.3	4.7	1.18	1.26	1.38	119	134	130.9	35.0	39.4	38.5
Total	46.1	38	37.7				661	637	760.7			

Table 2. Nutrient load at the outlet of the river Nemunas from territory of Lithuania [3, 4]

Year	NH_4-N load, tonnes	NO_3-N load, tonnes	PO_4-P load, tonnes
1986	1773	7137	2799
1987	467	4712	1959
1988	3405	7231	840
1989	2846	6578	1260
1990	2519	6998	1400
1991	2986	6858	373
1992	2239	13155	746
1993	1586	10496	653
1994	3825	15628	840
1995	2519	11989	700
1996	1493	5645	280
1997	2986	9517	233
1998	2706	18753	560

This paper reports on the evaluation of possible nutrient loads from agriculture by case studies on data from the upper regions of Lithuanian rivers (**Fig. 1**, monitoring posts 1-9).

Table 3. Agricultural production in Lithuania

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Livestock production									
Livestock, thou head			2196	1458	1384	1152	1065	1054	1068
Milk product, thou t		2916	2421	2067	1896	1819	1832	1950	1930
Crop production									
Arable land, thou ha	2980	2922	2972	2885	2828	2590	2866	2866	2878
Winter grain, thou t	3,39	2,93	2,64	2,19	1,82	2,2	2,4	2,8	2,6
Barley, thou t	3,0	3,2	1,4	2,0	1,8	1,6	2,5	2,4	2,4
Sugar beet, thou t	28,5	27,1	18,5	22,0	17,3	28,4	25,5	28,4	31,6
Potatoes, thou t	14,0	13,2	6,9	10,0	9,6	12,8	16,3	15,1	13,6
Fertilization									
N, kg/ha	67,2	56,0	105,9	20,0	14,6	11,1	10,1	11,4	
P, kg/ha	46,7	49,5	7,8	10,0	6,4	5,9	5,1	5,3	

Results and Discussion

The ammonium nitrogen and phosphorus load in upper regions of the river, where agricultural run-off is dominat-

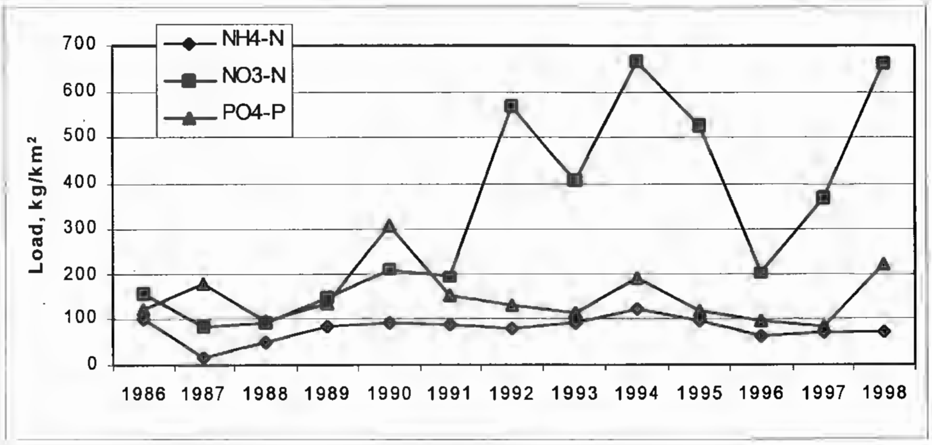

Fig. 2. Nutrient load in the upper regiones of Lithuanian rivers

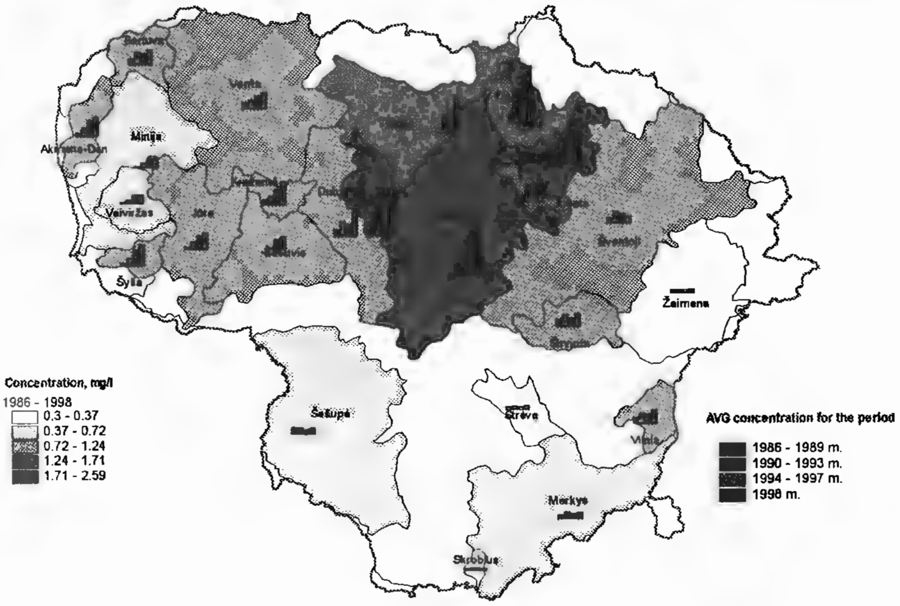

Fig. 3. Distribution of nitrate nitrogen concentration in Lithuania

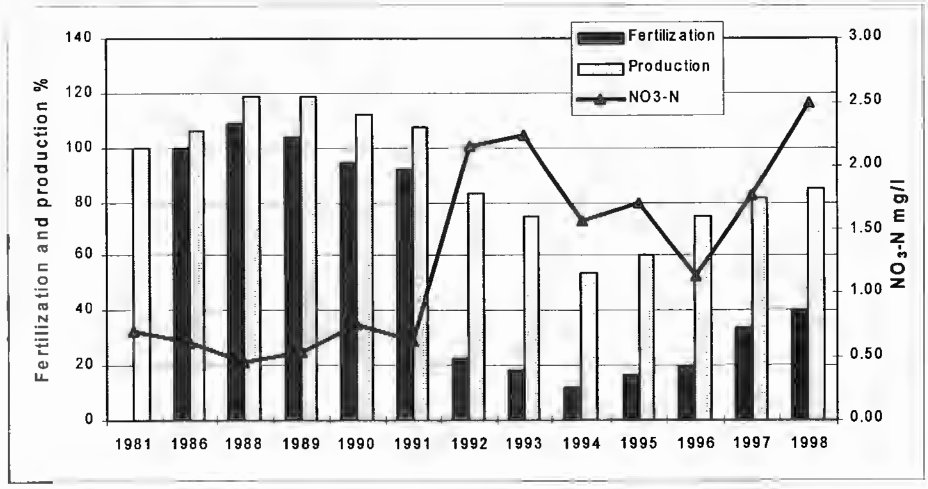

Fig. 4. Agricultural production, nitrogen fertilization and nitrate nitrogen concentration in the upper region of the rivers

ing, had changed very little but the load of nitrate nitrogen has increased very much. The decrease of nitrate nitrogen load in 1996 was resulted by the very dry year in Lithuania (**Fig. 2**). The most unexpected for us were data showing an increase in nitrogen load from 1991.

To determine the most polluted basins and to check if increase of the load was really caused by increase of concentration, a map of nitrate nitrogen distribution in Lithuania was made up (**Fig. 3**).

Time changes of nitrate nitrogen concentration are presented using bar charts in the Fig. 3. Concentration of nitrate nitrogen as well as the load has increased since 1986. The concentration for the period 1986-1998 was not very high. The highest one for this period ranged between 1.7 – 2.59 mg/l. It is far below permitted limit of 10 mg/l but sharp increase of the nitrate nitrogen concentration is troublesome. Suspicion on agricultural impact on this negative change was increased by the fact, that the biggest nutrient run-off took place in the most intensive agricultural area – basin of the river Nevezis.

To determine how changes of agricultural production and a fertilization respond to nitrate nitrogen concentration in the agricultural rivers the data on agricultural production was assembled (**Table 3**) and the **Fig. 4** drawn.

All variables were rather stable from 1981 to 1991. During the next period from 1991 to 1993, fertilization and agricultural production decreased dramatically but nitrate nitrogen concentration in rivers increased very much. After that in 1993 – 1998 a correspondence of agricultural production with nitrate nitrogen concentration was restored. Fig. 4 shows that fertilization not always is the main

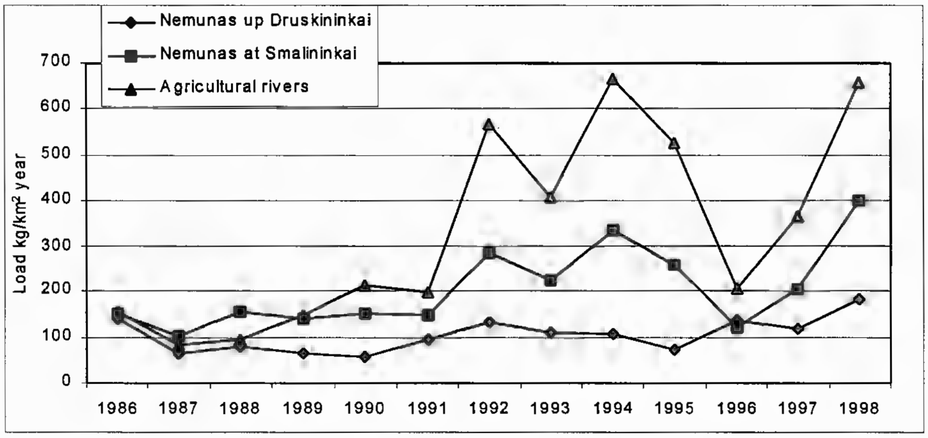

Fig. 5. Nitrate nitrogen load in the river Nemunas at the border with Byelorussia (Druskininkai), close to mouth (Smalininkai) and in the agricultural rivers

factor causing increase in nitrogen leaching. The Importance of other agricultural factors on increase of nitrogen load to the Baltic Sea confirms **Fig. 5**.

At the border of Byelorussia nitrate nitrogen load has changed very little. The reason could be absence of structural changes in agriculture in Byelorussia. Correspondence of agricultural rivers load changes with the load of the river Nemunas at outlet shows rather big input from Lithuanian agriculture on the nutrient load to the Baltic Sea. As a contribution to the Baltic Sea Environmental Action Programme the Government of Sweden in 1994 allocated 25 million SEK to the Swedish University of Agricultural Science to be used to carry out the Baltic Agricultural Run-off Action Programme (BAAP) in the Baltic Countries, Poland and Russian Part of Baltic Sea Area. To implement the Programme in Lithuania 4.0 million SEK were allocated. After finishing a first phase of the project, the interim period followed and from the year 2000 the second phase of the BAAP programme started.

The overall objective of the project was to determine and implement the most effective measures for reduction of the nutrient load from agriculture to the Baltic Sea. The project focuses on monitoring, demonstration field trials, education, information and legislation activities. Swedish consultants proposed the small agricultural watershed approach as a main tool for investigation of agricultural run-off. Two demonstration watersheds, one in the middle plain of Lithuania (Graisupis) and another in the eastern hilly part of Lithuania (Vardas) were selected **(Fig. 6)**.

The middle plane was selected as an area which is most affected by agricultural run-off. The other watershed represents an area vulnerable to pollution from agriculture because of light soils and steep hill slopes. Area of Graisupis watershed is 14,1 km^2 and area of Vardas watershed – 7,5 km^2.

Our project was based on the hypothesis that investigation of nitrate nitrogen migration and transformation processes at sources could help to work out the best prevention measures for improvement of water quality in the Baltic Sea.

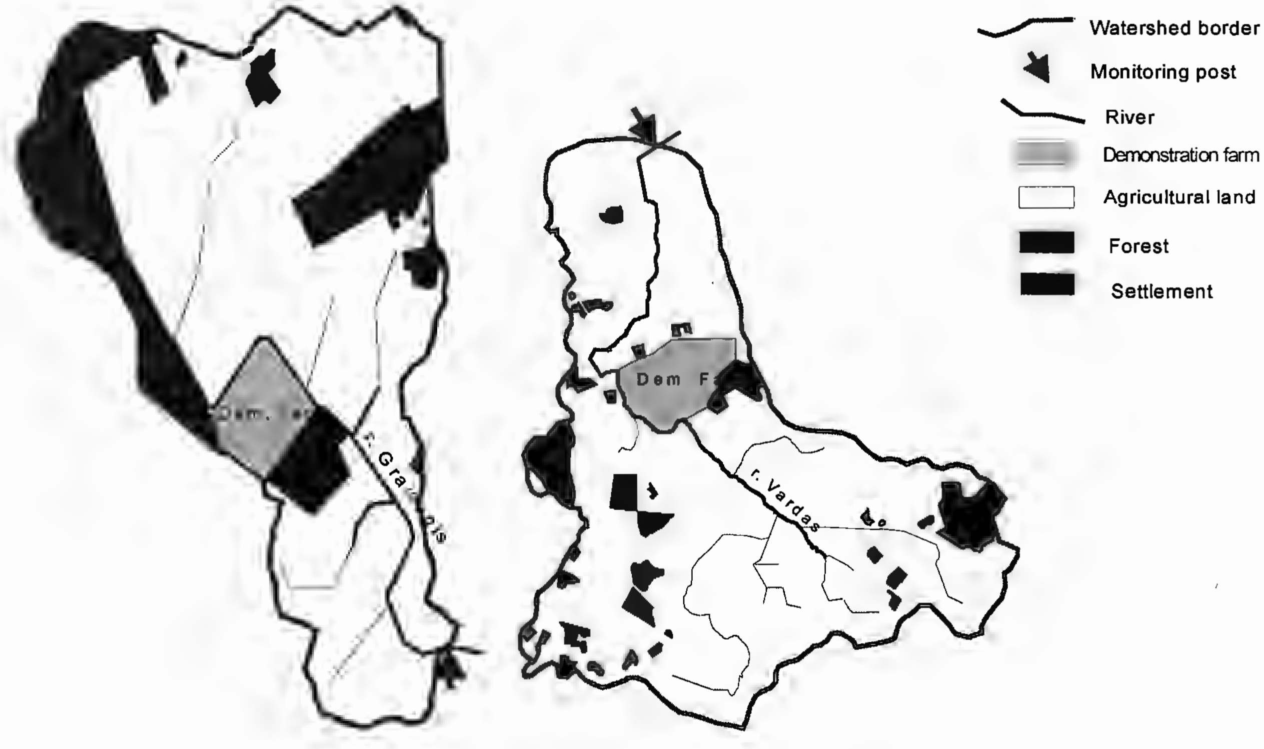

Fig. 6. Graisupis and Vardas demonstration watersheds

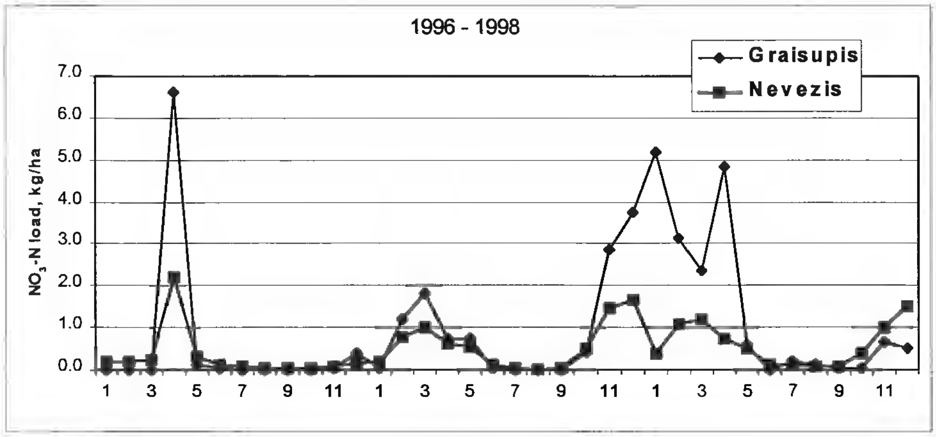

Fig. 7. Nitrate nitrogen load in the river Nevezis and Graisupis

Fig. 5 confirms the correspondence of nitrate nitrogen load in agricultural rivers with the river Nemunas but the other question was how the nitrate nitrogen load in the rivulets of a small agricultural watershed corresponds with rivers.

We got many remarks from various specialists that measures effective for small watersheds will give no effect on large rivers because they are influenced more by industry and urban load than agriculture. Comparison of three years monitoring data shows very good correspondence of nitrate nitrogen load changes in the rivulet Graisupis at the agricultural monitoring post 1 (see Fig. 1) with the river Nevezis monitoring post 2 (see Fig. 1). Data of comparison presented in **Fig. 7**.

Fig. 7 shows a very good agreement between changes of the load of nitrate nitrogen in the river Nevezis and its third rank tributary Graisupis. More expressed peaks of the load in the river Graisupis shows that small water receivers react faster on the increase of the agricultural run-off. Data obtained let us affirm that measures effective for small agricultural watersheds would improve water quality of large rivers. High winter-early spring peaks shows that the main attention when looking for prevention measures should be made to lower these peaks.

Investigations of nitrate nitrogen load dependence on various possible factors shows that the closest relation is a multifactor relation with river discharge, concentration of nitrate nitrogen in precipitation and especially weather temperature. But all these factors could not be changed. Therefore, the main attention was made on investigating the farming methods impact on nutrients leaching. The following farming methods were investigated:

- Manure handling;
- Crop rotation and fertilization;
- Establishment of pastures;Buffer zones.

Possibility to reduce nutrient losses by building proper manure storage was investigated in demonstration farm in Graisupis watershed. Construction of manure storage went together with construction of barns and increased number of animals on farm. Barn and manure storage area is drained by the drainage system draining pasture in Graisupis watershed demonstration farm (see Fig. 6). This experiment shows that increased number of cows from 4 to 30 did not increase nitrate nitrogen losses to drainage. Manure storage is effective measure for prevention of nutrient leaching when the number of animals are increasing in new farms.

More often the situation in Lithuania is when animal barns with big number of animals are still used from the soviet times without proper manures storage. To evaluate nutrient losses from such farms new demonstration watershed is under establishment in Bariunai AC in Joniskis district **(Fig. 8)**.

Observation of nutrient load was started in November 1999, before construction of the manure storage. Water quality of the drainage system draining 400 cows, 200 calves and 3000 pigs barn territory is very poor. Concentration of total nitrogen was up to 201 mg/l (permitted limit for drainage water draining barn territory is 12 mg/l) and that corresponded to 30 kg of nitrogen per day. Highest concentration of total phosphorus during the first five

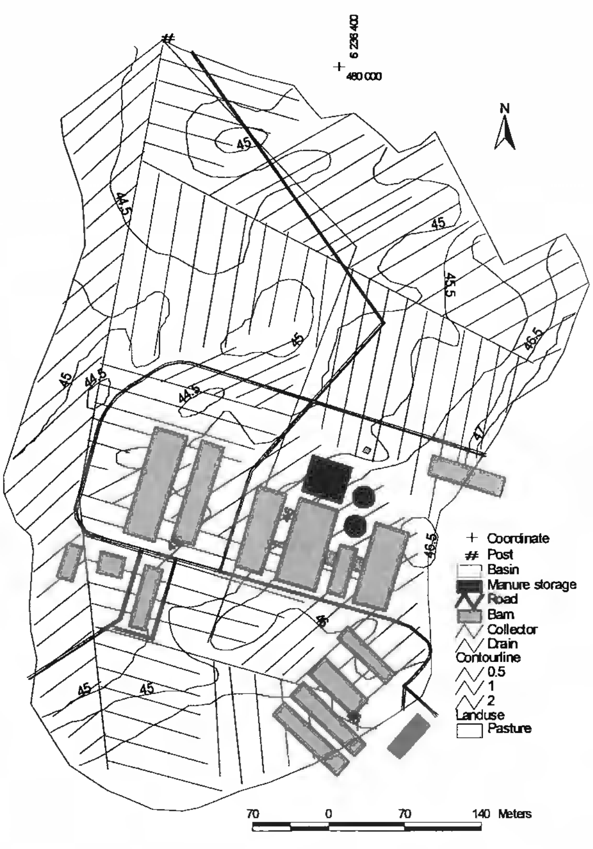

Fig. 8. Monitoring watershed at Bariunai AC barns territory

Table 4. Crop rotations and fertilization field trial in 1996-1999

	1996		1997		1998		1999	
Field	Crop	N kg/ha	Crop	N kg/ha	Crop	N kg/ha	Crop	N kg/ha
1	Sugar Beets	113	Barley+ clover	0	Clover+ Winter wheat	0	Winter wheat	70
2	Sugar Beets	113	Fodder beans	0	Sugar beets	230	Spring wheat	72
3	Winter Wheat	40	Barley	62	Barley	95	Triticale	70
4	Barley+ Clover	0	Clover	0	Clover	0	Clover+ Winter wheat	0
5	Fodder Beans	0	Winter wheat	68	Triticale	70	Rope	70

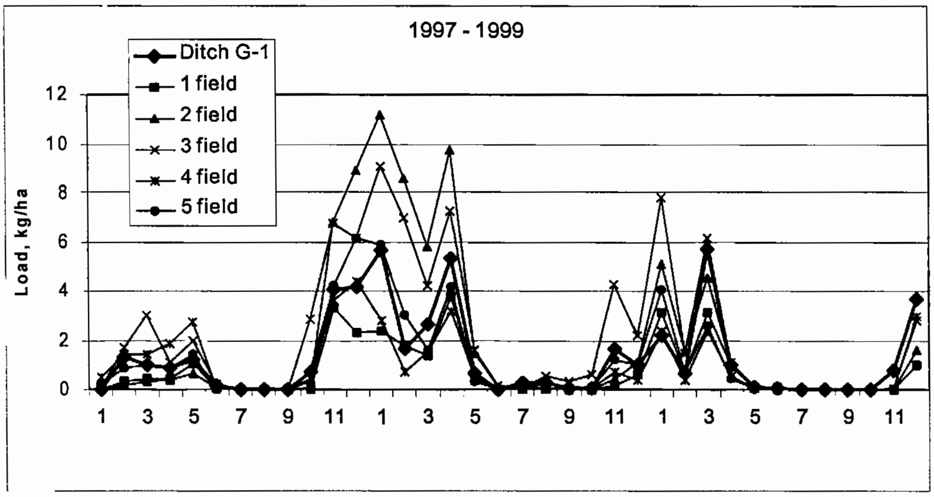

Fig. 9. Results of nitrate nitrogen load to drainage in crop rotation and field trial

months of observation were 15 mg/l (the limit is 1.5 mg/l). Very high concentration of BOD_7 and ammonium nitrogen in the drainage water (up to 850 mgO_2/l and 106 mgN/l) confirmed that sewage from the barn was directed to the drainage system. How construction of manure storage will respond on water quality will be seen after some years. Positive changes will help to accept decision for implementation of this measure to all big animal farms.

Field trials of crop rotation and fertilisation impact on nutrients leaching to drainage were established in Graisupis watershed [5]. Every field of size from 6,6 to 16 ha was drained by separate drainage system. Five-fields crop rotation system was established. Rotation of crops and fertilization is presented in **Table 4**.

The most intensive crop production was on the second and third field. Sugar beet was sown on the first field and in the third year of the experiment in the second field. 113 kg/ha of nitrogen were applied in the first year and 230 kg/ha in the third year. Spring wheat was sown in the fourth year applying 72 kg/ha nitrogen. On the third field fertilization rates were not very high, they ranged between 95 on the third year and 40 kg/ha on the first year, but catch crops were not included in the rotation. Cereals followed after cereals in this field. No fertilizers were used

Table 5. NO_3-N load from the r. Graisupis, drainage and precipitation, kg/ha

Treatment	1997	1998	1999	Total	Average
r. Graisupis	11.55	17.64	6.87	36.05	12,0
Ditch G-1	13.44	19.22	14.09	46.75	15,6
1 field	7.81	10.39	6.67	27.07	9,0
2 field	17.67	38.73	13.88	70.28	23,4
3 field	23.83	37.23	19.55	80.61	26,9
4 field	16.28	10.19	8.72	35.19	11,7
5 field	14.77	17.55	8.79	41.11	13,7
Pasture	6.69	5.34	4.38	16.41	5,5
Precipitation	4.93	1.94	5.27	12.14	4,0

during the three year period of the experiment in the forth field. Nitrate nitrogen leaching to the drainage is presented in **Fig.** 9.

The bold line represents nitrogen load from the ditch G-1 that is the receiver of drainage water from experimental fields. Line of the nitrate nitrogen load in the ditch is between lines of the second–third and first-forth fields during winter-spring time. There is no loss of nitrate nitrogen in summer time because no discharge from drainage occur. The experiment shows that catch crops are needed even at low fertilization rates in the crop rotation. Secondly, load from sugar beets field to the drainage is significant not looking on its long growing season. Nitrate nitrogen load decreases when non-fertilized ley is included in the crop rotation.

To define how much of nitrate nitrogen leaches from pasture another experiment was established [6, 7]. Clover-grass ley 7,2 ha field was transformed to grazing pasture with yearly nitrogen application rate 30-40 kg/ha in Graisupis demonstration farm. Drainage monitoring post for water discharge measurement and water quality sampling were constructed on the drainage system in the experimental field. Three years of measurement data of nitrate nitrogen load from precipitation, drainage and the river Graisupis, which is the receiver of the drainage water from the experimental field, are presented in **Fig. 10.**

Peak nitrate nitrogen losses from grazing pasture to the drainage do not exceed 2 kg/ha. Comparison of the data in the Fig. 9 and Fig. 10 shows that little fertilized grazing pasture is the best measure to reduce nitrate nitrogen leaching during most dangerous for water pollution winter-spring time.

Three year integrated nitrate nitrogen run-off data from drainage of the experimental fields, precipitation, ditch G-1 and the river Graisupis are joined in **Table 5**.

Loads in the ditch G-1, tributary of the river Graisupis, are a little higher than in the river Graisupis because crop fields are dominating in its basin. Nitrate nitrogen loss-coefficients change from year to year

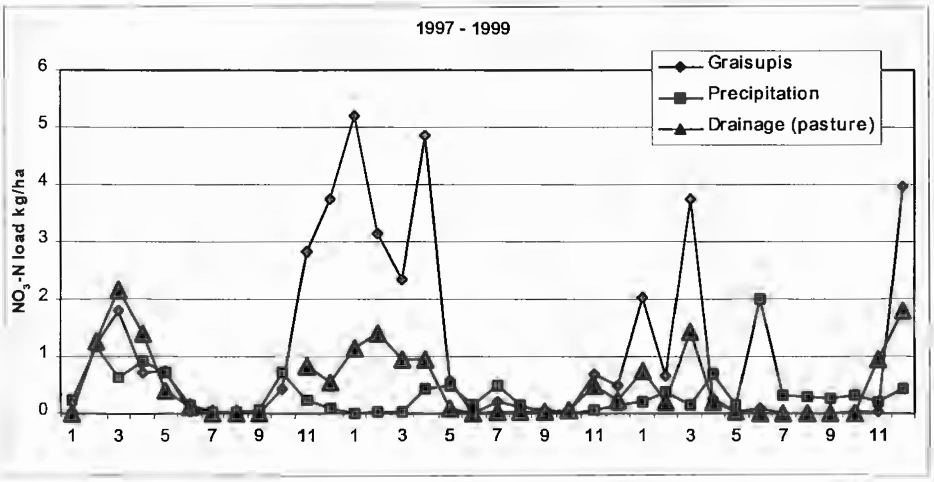

Fig. 10. Nitrate nitrogen load from precipitation, drainage of pasture and the river Graisupis

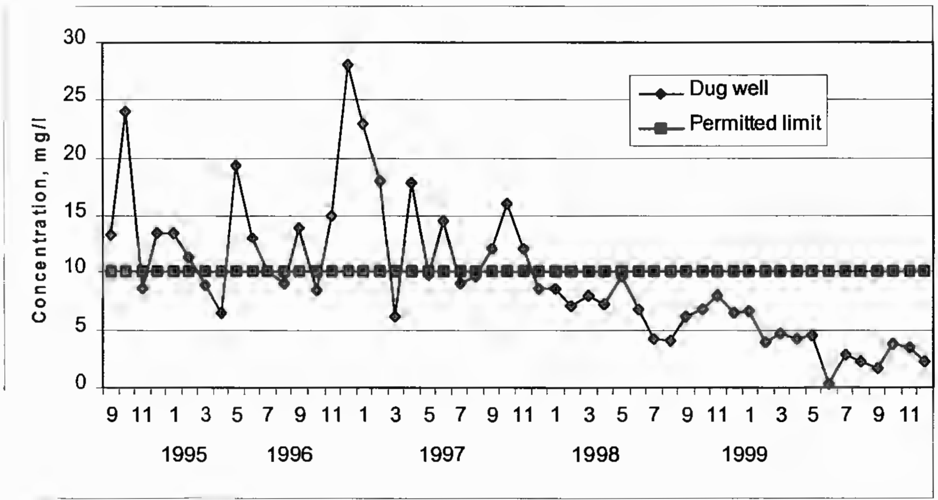

Fig. 11. Change of nitrate nitrogen concentration in the drinking water well

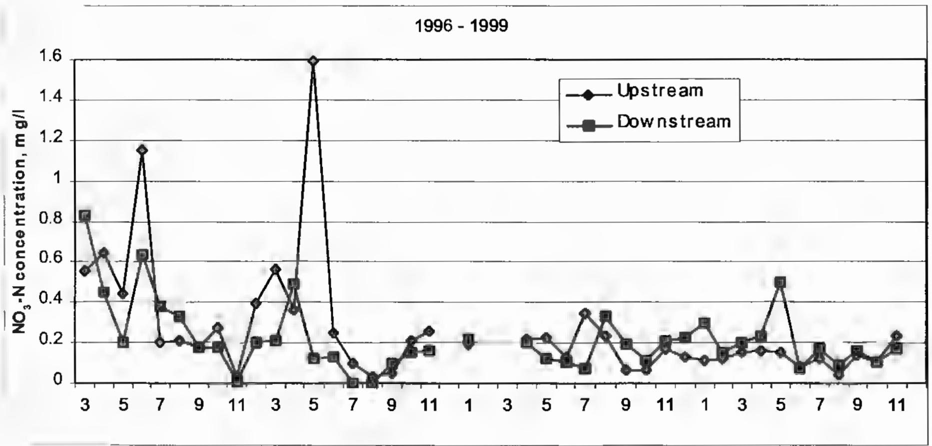

Fig. 12. Influence of birch trees and willows buffer strip to intercept nitrate nitrogen

for the same field but dependence on land use and fertilization are evident. The least nitrate nitrogen losses are from pasture and non-fertilized ley. The highest are from intensively fertilized sugar beet fields and sowing crop after crop.

Accumulation of nitrogen in pasture gives an idea to check what would happen after ploughing of pasture. The experiment was carried out in one permanent (more than 40 years without reseeding) and one ploughed (21 year old) pasture in Valinava experimental site of Lithuanian Institute of Agriculture close to Graisupis watershed [6]. During the first five month after ploughing 23,9 kg/ha of nitrate nitrogen was transported within drainage run-off from non-ploughed pasture, while 59,6 from ploughed on average. On average the yearly nitrate nitrogen losses-coefficient derived from two and half-year observation was for ploughed pasture – 94,2 kg/ha, while for non-ploughed 12,8 kg/ha. It shows that ploughing of pastures can increase nitrate nitrogen losses significantly for some years. It could be one of the main reasons of sudden increase of nitrate nitrogen load in the rivers from 1991. After dismantling former soviet farms, land use has changed very much. Big parts of agricultural land was abandoned at that time but new farmers ploughed pastures not less. The best time for ploughing of pastures from the point of view of nitrogen losses is a question that we are planning to determine during the second phase of the BAAP programme.

Impact of land use change reflects very well the experiment with drinking water well at demonstration farm in Graisupis watershed [6]. When we started the project in 1995 water quality was very poor in the well. Some times nitrate nitrogen concentration twice exceeded the permitted limit. We asked the farmer to pull down the greenhouse that was very close to the drinking water well and to establish protective zones of grass around the well. How this measure responded on the concentration of nitrate nitrogen could be seen in **Fig. 11**.

To determine possibility to use buffer zones as a nitrogen traps we established birch trees and willows plantations at the river in Vardas demonstration watershed [8]. Width of birch trees and willow strips were equal 10 m. Birch trees were planted at the river edge and willows after trees to the side of crop field. For determination of water quality six sets of 3 and 5 m depth piezometers were installed upstream and downstream buffer strip. Average sampling data are presented in the **Fig. 12**.

Four years of observation did not reveal noticeable decrease of nitrate nitrogen concentration after establishment of protective zones. The reason could be sub-surface drainage draining the area. Drainage intercepts and transports agricultural run-off directly to a ditch not letting to reach ground water.

Summarizing experiments carried out on demonstration watersheds and the following conclusions could be made:

1. Measures implemented for reduction of nitrogen load to the Baltic Sea are insufficient to achieve the target set by Contracting Parties;
2. The main attention should be made to reduce nitrate nitrogen losses from agriculture;
3. Increase of nitrate nitrogen losses can happen even at low application of fertilizers;
4. Establishment of pastures, selecting proper crop rotation and fertilization could reduce nitrate nitrogen losses very much;
5. Summer ploughing of pastures makes preconditions for nitrate nitrogen leaching. Sowing of catch crops should be investigated for nutrients trapping;
6. Trees and bushes in protective zones are not effective in drained areas;
7. Construction of manure storage is an effective measure for prevention of nutrient leaching when the number of animals are increasing in new farms. Monitoring of drainage water and special action plans for manure handling should be implemented on all big animal farms;
8. Legislation, financial support, demonstration and education measures should be integrated for countrywide implementation of agro environmental measures;
9. Extending of activity in both watersheds will be positive for farmers' economy and environment. Activities on demonstration watersheds without Swedish financial support would be impossible.

Summary

Implementation of the 1988 Ministerial Declaration revealed that none of the Contracting Parties had achieved the overall target to reduce nutrient load to the Baltic Sea at 50% by 1995. In Lithuania phosphorus load from 1986 to 1998 decreased four times, meantime nitrate nitrogen discharge increased 1.6 times. Ammonium nitrogen and phosphorus load in upper reaches of the rivers, where agricultural run-off is dominating, have changed very little but load of nitrate nitrogen have increased very much.

Results of investigation show that not always fertilization is the main factor causing increase of nitrogen leaching. Significant increase of nitrate nitrogen load at the outlet of the river Nemunas and its coincidence of agricultural rivers load shows rather big input of Lithuanian agriculture on the nutrient load to the Baltic Sea.

The overall objective of the Demonstration Watershed project was to determine and implement the most effective measures for reduction of nutrient load from agriculture to the Baltic Sea. The project focuses on monitoring, demonstration field trials, information and legislation activities. Small agricultural watershed approach was adopted as a main tool for investigation of agricultural run-off origination. Two Demonstration Watersheds, one in middle plain of Lithuania and another in the eastern hilly part of Lithuania were established.

Field trials of crop rotation and fertilisation impact on nutrients leaching to drainage established in Graisupis watershed shows that nitrate nitrogen loss-coefficients change from year to year for the same field but dependence on land use and fertilization is evident. The least nitrate

nitrogen losses are from pasture (5.5 kg/ha year) and non-fertilized ley (11.7 kg/ha year). The highest losses are from sowing crop after crop (26.9 kg/ha year) and from intensively fertilized sugar beet fields (23.6 kg/ha year). Load from sugar beet fields to the drainage are significant not looking on its long growing season. Nitrate nitrogen load decreases when non-fertilized ley is included in the crop rotation as well as perennial grass protective zone at a drinking water well

Four years observation of trees and bushes buffer strip established at the ditch did not reveal noticeable decrease of nitrate nitrogen concentration. The reason could be that sub-surface drainage intercept and transport of agricultural run-off directly to a ditch not letting to reach ground water.

Ploughing of pastures increases nitrate nitrogen losses significantly for some years. During the first five month after ploughing 23,9 kg/ha of nitrate nitrogen was transported within drainage run-off from non-ploughed pasture, while 59,6 from ploughed on average. Average yearly nitrate nitrogen losses-coefficient derived from two and half-year observation was for ploughed pasture – 94,2 kg/ha, while for non-ploughed 12,8 kg/ha.

Construction of manure storage is an effective measure for prevention of nutrient leaching when the number of animals are increasing in new farms. Water quality of the drainage system draining big barns' territory is very poor. Concentration of total nitrogen from 400 cows barn was up to 201 mg/l (permitted limit for drainage water draining barn territory is 12 mg/l). The highest concentration of total phosphorus during the first five months of observation were 15 mg/l (the limit is 1.5 mg/l). Very high concentration of BOD_7 and ammonium nitrogen in the drainage water (up to 850 mgO_2/l and 106 mgN/l) confirmed that sewage from the barn was directed to the drainage system. Monitoring of drainage water and special action plans for manure handling should be implemented on all big animal farms.

Nährstoffverluste aus der Landwirtschaft in Litauen

Die im Beschluß der Umweltminister von 1988 angestrebte Reduzierung der Nährstoffeinträge in die Ostsee um 50 % wurde bis zum Zieldatum 1995 nicht erreicht. In Litauen gingen im Zeitraum von 1986 bis 1998 zwar die Phosphateinträge auf 25 % zurück, die Stickstoffeinträge stiegen im gleichen Zeitraum jedoch um das 1,6 fache. Vor diesem Hintergrund wurden in Litauen Demonstrationsprojekte eingerichtet, um die Wirkung verschiedener produktionstechnischer und umweltpolitischer Maßnahmen auf die Nährstoffausträge darzustellen. Der Beitrag gibt eine Übersicht der bislang erreichten Ergebnisse.

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