WATER MANAGEMENT INSTITUTE OF THE
LITHUANIAN UNIVERSITY OF AGRICULTURE

ANNEX I

INVESTIGATION OF NUTRIENT LOSSES FROM AGRICULTURAL SOURCES THROUGH LAND DRAINAGE TO MINIJA RIVER AT KARTENA MONITORING POST

Final Report

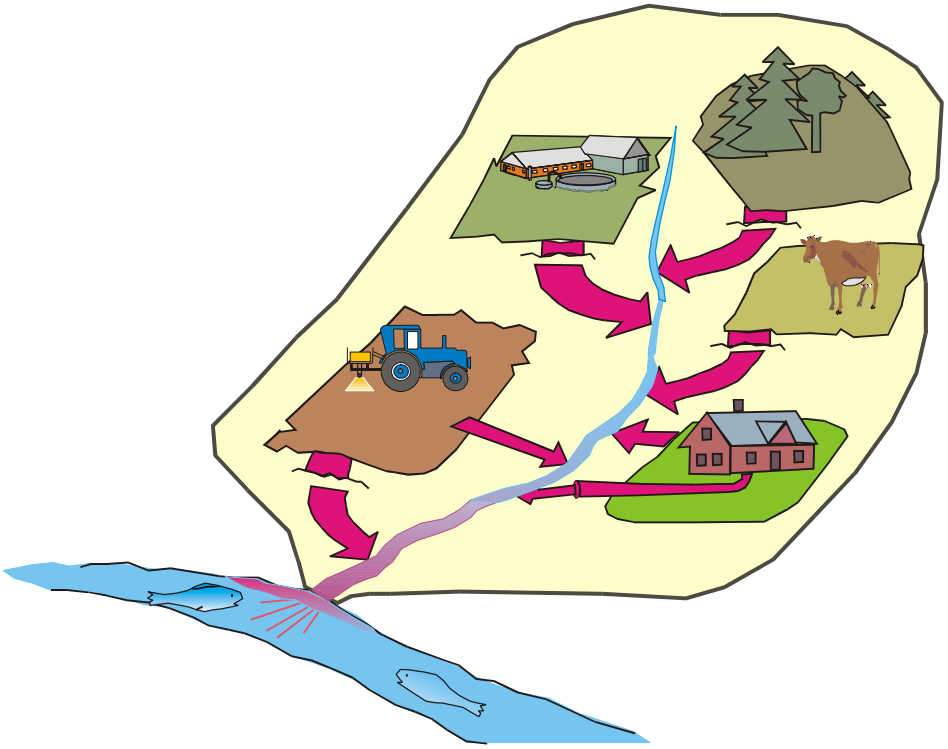

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Table of Content

1 INTRODUCTION

The Project designed to define the nutrient (Ntot and Ptot) losses during 2001-2003 at sources (gross losses) from agricultural land to the subsurface land drainage in the Minija River catchment at Kartena monitoring post (Minija_Kartena catchment).

The Project implementation is based on WMI investigations of nutrient losses in small agricultural watersheds and field plot trials in various Lithuanian geographical conditions. Statistical information of crops area and animals number in districts entering the Minija_Kartena catchment was used for calculation of crops area and animal number in the catchment during the period 2001-2003.

The main objective of the project is to define Ntot and Ptot losses from agricultural sources through land drainage to Minija River at Kartena monitoring post.

Activities include:

- Create GIS 1:50000 resolution topographic and administrative maps of the Minija_Kartena catchment.
- To design Corine Minija_Kartena catchment map for land cover types calculation.
- To find districts' area and percentage of area from total district area entering to the Minija_Kartena catchment.
- To determine land drainage area in the Minija_Kartena catchment.
- To determine crop area according crop types (sprig crops, winter crops, row crops (potatoes and sugar beet) and perennial grass as well as number of animals (livestock and pigs) in the Minija_Kartena catchment.
- To determine the amount of precipitation for 2001-2003 in the Minija_Kartena catchment.
- From long-term drainage monitoring data in Western Lithuania to derive land drainage specific runoff for 2001-2003 and agree it with drainage specific runoff in the Lyzena (Silale district) catchment land drainage.
- To calculate Ntot and Ptot yearly specific load for 2001-2003 in drainage flow from different types of crops (spring crops, winter crops, row crops (potatoes and sugar beet) and perennial grass) as well as from animal (livestock and pigs) husbandry for the Minija_Kartena catchment.
- To calculate Ntot and Ptot yearly loads through land drainage flow to the Minija_Kartena catchment from various types of crops (sprig crops, winter crops, row crops (potatoes and sugar beet) and perennial grass as well as from animal (livestock and pigs) husbandry.

2 STUDY AREA AND INVESTIGATION METHODOLOGY

The study area is Minija River catchment upstream Kartena water measurement post. To determine rivers and streams network entering in the Minija_Kartena catchment scheme of the catchment was drawn (Fig. 1) using Minija River catchment scheme (Gailiusis et al., 2001).

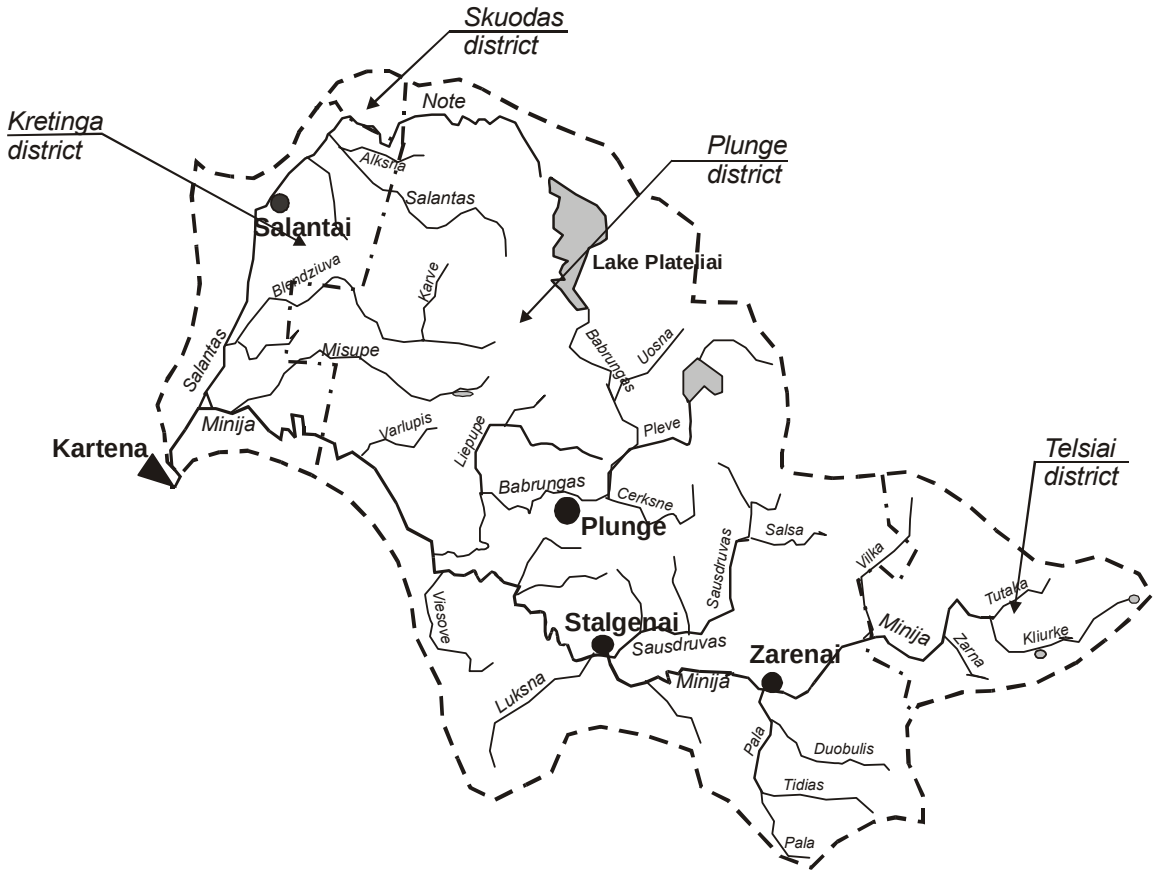

Figure 1. Scheme of the Minija_Kartena catchment.

According Gailiusis et al. (2001) area of the Minija catchment upstream Kartena is 1220.1 km^2.

Firstly it was analysed structure, content and conformity of data owned by our institute and possible statistical data to the data format needed to this project. It was defined that available data cannot be directly used for gross Ntot and Ptot load calculation for Minija_Kartena catchment. Because of that it was need additional work of GIS specialist to make up the Minija_Kartena catchment GIS maps according requested format.

Minija_Kartena catchment GIS map was created using the digital map of the Lithuania (LTDBK50000, 1998) and Lithuanian CORINE land cover M 1: 100 000 map (JRC, 1995).

Because lack of agricultural runoff monitoring data in the Minija_Kartena catchment nutrient specific load (NSL) for the study area were calculated taking our field plot trials data and monitoring data in small

agricultural watersheds located in various areas of Lithuania. It was accepted that for the same year concentration of Ntot and Ptot in land drainage flow from the same type of crops and animals in our monitoring areas was similar to the Minija_Kartena catchment. Land drainage specific runoff for each study year was calculated using analogy method and our drainage monitoring data in Western part of Lithuania (Lyzena catchment in Silale district). NSL to the drainage flow is a product of concentration and drainage specific runoff.

The main problem for Ntot and Ptot gross load calculation in the Minija_Kartena catchment was absence of data on crops area and animal number in the study area. Statistical annals gives district data but only part of the Kretinga, Skuodas, Plunge and Telsiai districts enter in the Minija_Kartena catchment. It was accepted that crops and animals are spread evenly in the district and study area agricultural land. Under this precondition for Ntot and Ptot gross load calculation it was needed to define percent of districts' agricultural land area within the Minija_Kartena catchment.

Firstly the Minija_Kartena catchment map was designed using the Lithuanian digital map (LTDBK50000, 1998). River network, location of Kartena monitoring post, district boundaries, roads and land use types of the Kretinga, Skuodas, Plunge and Telsiai districts were converted from ARC/INFO database to Arc View shape files for catchment area delineation. After catchment area delineation Arc View themes needed for further investigation were clipped from the districts digital map. Area of designated catchment was agreed with the area of the Minija_Kartena catchment calculated by Gailiusis et al. (2001).

Data of agricultural land area are rather old in the Lithuanian digital map (LTDBK50000, 1998), therefore it was decided for further calculations to use Lithuanian CORINE land cover M 1: 100 000 map (JRC, 1995).

For calculation of agricultural land area of the districts' within the study area catchment boundaries from the Lithuanian digital map (LTDBK50000, 1998) were transported to CORINE land cover Arc View shape files converted from ARC/INFO database. Agricultural land area of each district within the Minija_Kartena catchment was calculated after clipping study area from CORINE land cover map.

Crops area and animals number in the Minija_Kartena catchment was calculated after that proportionally to agricultural land area of each district entering to the study area.

Within the Minija_Kartena catchment there are no meteorological stations. But nearby the watershed there are four stations and continuous monitoring of meteorological phenomenon (air temperature, rainfall, air humidity and soil temperature) is performed. To the northwest of the Minija_Kartena catchment there is Skuodas meteorological station; to the southwest – Vezaiciai, to the east – Telsiai and to the southeast – Laukuva meteorological station.

To calculate rainfall method of medians was used. Watershed area is divided to as many parts as the number of stations, i.e. the boundary of the area of every part is in the middle of the distance between the neighbouring stations. The area of the catchment attributed to the station shows the share of that station data to the average rainfall value in the watershed, therefore this method is often called the method of weighted average (Cebotariovas, 1983).

Land drainage specific runoff for the Minija_Kartena catchment was calculated using drainage runoff data from Silale district (Western Lithuania) published in Hydrological annals (Balciunas et al., 1997). In the Nuomininkai experimental site (Kaltinenai experimental station) there had been installed and monitored 10 subsurface drainage systems. Calculated average drainage runoff depth of 10 drainage systems for 31-year period (1964-1994) was **225 mm**. It was assumed that drainage runoff for each investigated year fluctuated accordingly to changes of Minija river runoff at Kartena station.

One more land drainage monitoring station is in Lyzena catchment (Silale district). Two drainage systems are monitored there. During evaluation of the drainage runoff results it was determined that the drainage systems had been damaged and surface runoff was entering the drainage systems. Therefore the drainage runoff data of the Lyzena watershed were rejected.

Water quality in about 50 subsurface drainage systems was investigated every spring in 2001-2003 years in the Graisupis watershed (Kedainiai district). The drainage systems were grouped according to the grown crops and Ntot and Ptot concentrations for winter, spring, row crops and pasture were obtained.

Ntot and Ptot specific load in the drainage flow from animal husbandry was calculated using investigations in Bariunai agricultural company (Joniskis district). Drainage water discharge and nutrient concentration in the water are monitored in two subsurface drainage systems draining territory of two cow barns. Ntot and Ptot specific drainage losses per livestock were calculated for 2001, 2002 and 2003 years. Water quality in pig farm is monitored in Skabeikiai piggery (Akmenre district). Since drainage flow is not measured there, Ntot and Ptot specific drainage losses for per pig were calculated using N and P concentration ratio in manure of pigs and livestock (MoA et al., 2000) and Ntot and Ptot specific drainage losses for one livestock in Bariunai.

Having crops area and animals number within the Minija_Kartena catchment and corresponding specific Ntot and Ptot loads, nutrient losses from agricultural sources through land drainage were calculated as a product of these two variables.

3 CROPS AREA AND ANIMALS NUMBER WITHIN THE CATCHMENT

3.1 Districts and agricultural land area

Kretinga, Skuodas, Plunge and Telsiai districts area and land use in the districts presented in the table 1 (Lithuanian Department of Statistics, 2000,

Table 1. Districts' land area structure

District	Area, thous. ha	Agricultural land, thous ha	Forest, thous. ha	Water, thous. ha	Built area, thous. ha	Roads, thous. ha
Plungė	169.1	79.70	65.10	4.70	4.99	1.71
Telsiai	143.9	76.20	43.00	5.30	3.19	2.91
Skuodas	91.1	64.80	15.40	2.20	2.00	2.00
Kretinga	99.1	53.01	34.93	2.20	2.50	2.00

Agricultural land in districts makes up 47-71 % of the total district territory area. The least part of agricultural land is in Plunge district (47.1%) and the largest – in Skuodas district (71.1%). Agricultural land in Telsiai and Kretinga districts makes up 52.9 and 53.5% of the total territory area correspondingly.

3.2 Land drainage and crops area

Crops area was taken from yearbooks of the Lithuanian Department of Statistics (2002 and 2003). To estimate if all crops are sown on drained land, drained land area in districts were taken from the publication of the State Land Survey Institute (2004).

Part of Plungte district in 2000 was separated and Rietavas district was organised. Since Lithuanian digital map (LTDBK50000, 1998) was designed before Plunge district separation and to draw the border of new organised district was impossible, statistical data of Plunge and Rietavas districts in 2001-2003 were joined to one – Plunge district (Table 2).

Table 2. Drainage and crops area in districts, ha

	2001	2002	2003	2001	2002	2003
		Kretinga			**Skuodas**	
Drainage	52589	52589	52589	58928	58928	58928
Winter crops	6292	5767	5228	8714	5623	3868
Spring crops	9049	11586	10476	14634	18343	12062
Row crops	3538	3751	3047	4275	3974	2591
Pastures	16348	17100	20518	25734	24191	29397
Total crops	35227	38204	39269	53357	52131	47918
		Plunge			**Telsiai**	
Dranage	58732	58732	58732	53855	53855	53855
Winter crops	5545	1539	3550	5614	2989	4359
Spring crops	12055	14160	9675	9636	11797	9097
Row crops	3742	2686	3440	2556	2522	3764
Pastures	33883	39763	36167	17577	19988	36110
Total crops	55225	58148	52832	35383	37296	53330

3.3 Catchment area and districts area within catchment

As it was mentioned in the methodology Minija_Kartena catchment border and districts borders were designed using river network and administration partition themes in the Lithuanian digital map (LTDBK50000, 1998). Catchment, river network, district borders and main cities are shown in Fig. 2. District area within catchment and percent of the total district area is presented in the table

Table 3. District area within catchment.

District	District area, thou ha	Area within basin, thou ha	Part of district area, %
Plunge	169.10	93.17	55.10
Telsiai	143.91	12.41	8.62
Skuodas	91.10	2.94	3.23
Kretinga	99.09	13.49	13.62

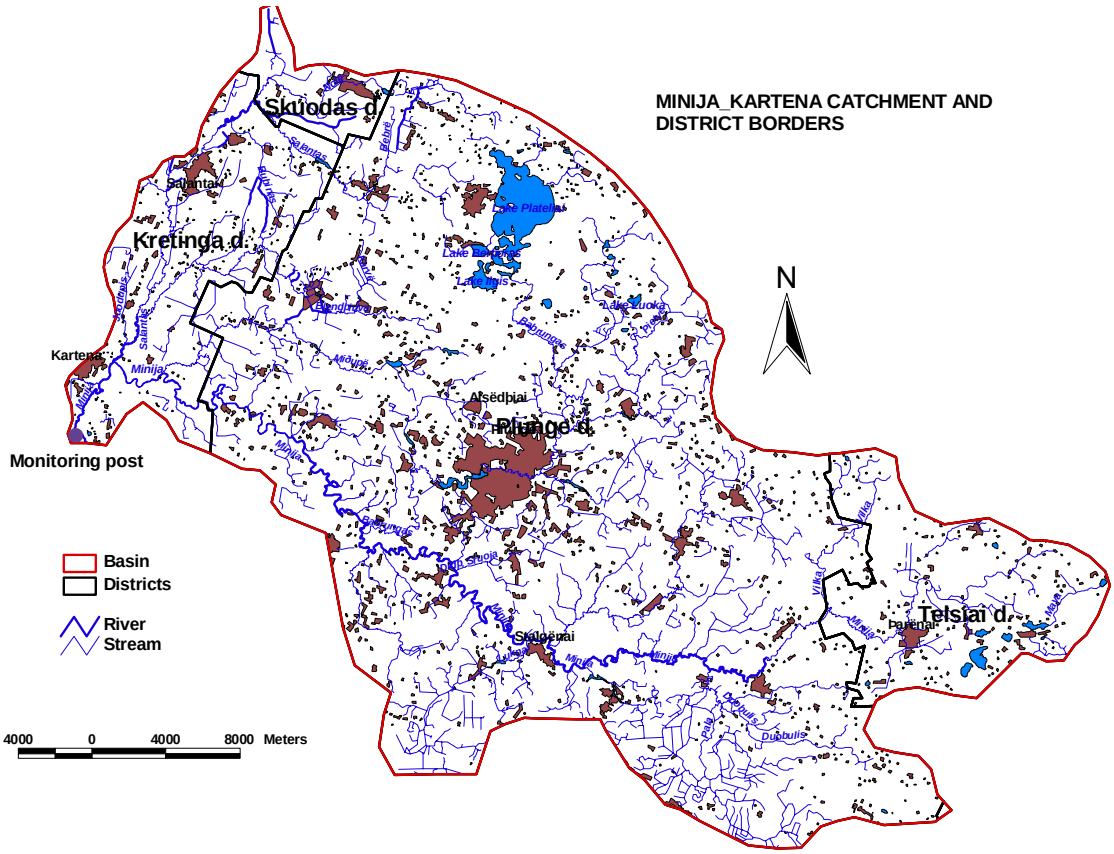

Figure 2. Minija_Kartena catchment and districts.

3.4 Districts' agricultural land area within the catchment

Districts' agricultural land area within the catchment was determined using CORINE land cover M 1: 100 000 map (JRC, 1995) of the catchment (Fig. 3). Land cover types of each district within catchment are presented in the table 4.

Table 4. Land cover types within catchment.

Land cover	Kretinga	Skuodas	Plunge	Telsiai
Built area	622.5	20.9	2450.4	161.5
Industry area	56.2	101.1	537.6	21.9
Roads and railway land	13.4	0	33.8	0
Dump area	0	0	26.5	0
City green area	0	0	75.3	0
Arable land	6185.3	1555.8	27456.0	0
Pasture	1851.3	308.7	11153.6	2778.2
Agro multi purpose land	1564.8	113.7	4568.8	986.1
Arable with lay land	1332.4	316.9	11914.7	327.7
Deciduous forest	697.9	59.9	3286.0	1078.5
Coniferous forest	379.7	75.6	14583.0	402.8
Mixed forest	788.5	215.1	14000.4	2976.1
Abandoned land	0	50.7	0	3011.2
Natural meadow	0	0	56.5	0
Scrub land	0	124.0	1121.3	413.4
Marsh	0	0	75.1	29.8
Peat land	0	0	220.3	29.2
Water bodies	0	0	1608.9	190.3
Total area	**13491.9**	**2942.5**	**93168.1**	**12406.6**

Arable land, pasture, agro multi purpose land, arable with lay and natural meadows were aggregated to one type of land use – agricultural land, which further was used as a base for calculation of agricultural land area percent within the basin from total district area.

Table 5. Agricultural land in districts and within basin

District	Agricultual land area in the district, ha	Agricultural land area in the basin, ha	Agricultural land in basin, %
Kretinga	55690	10933.74	19.6
Skuodas	64800	2295.03	3.5
Plunge	79700	55149.6	69.2
Telsiai	76200.00	5170.5	6.8

The largest part of the Minija_Kartena catchment occupies Plunge district agricultural land (69.2 %) and the smallest Skuodas district – 3.5 %.

Percentage of agricultural land in the districts was used for crops area and number of animals calculation within the Minija_Kartena catchment.

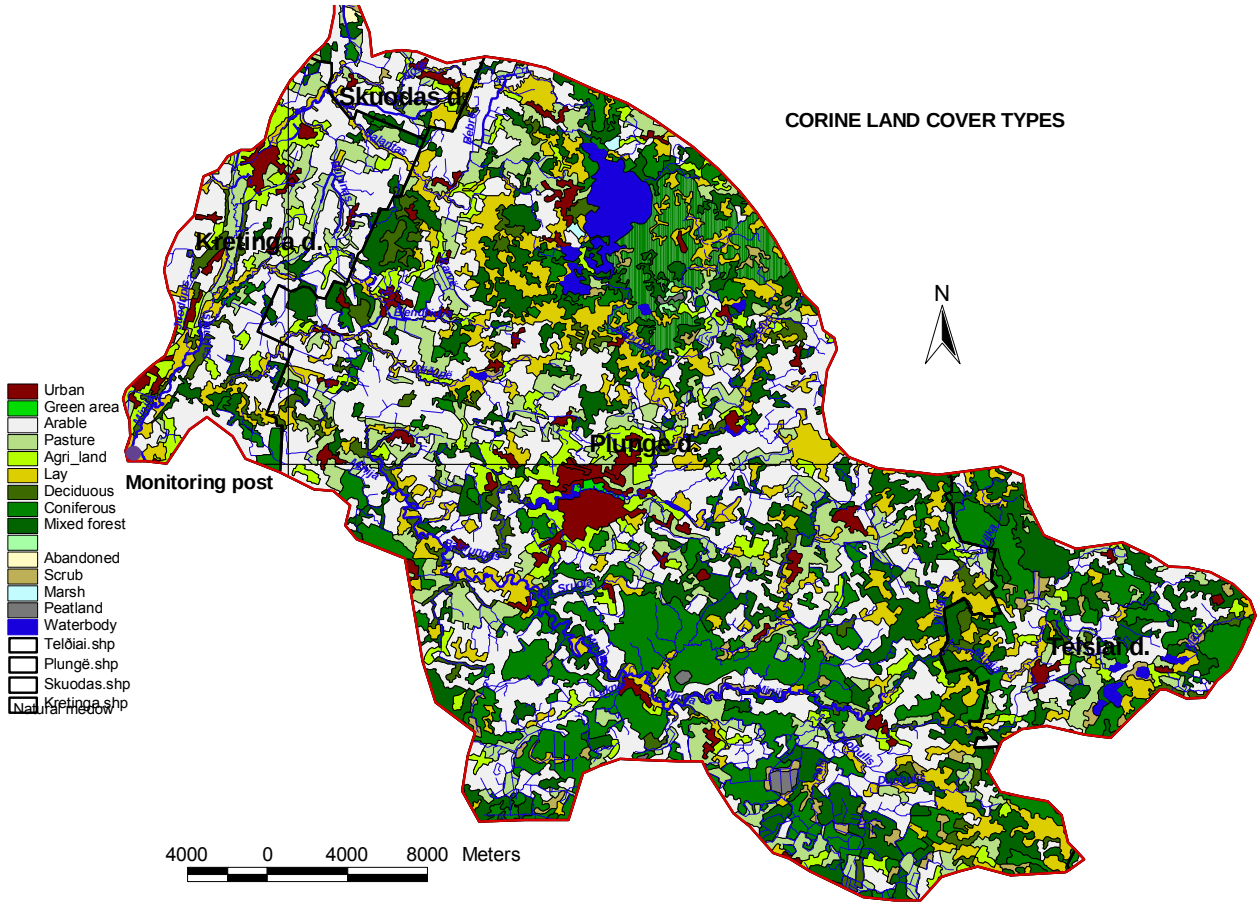

Figure 3. CORINE land cover mapCrops area and animals number within the catchment

Crops area and animals number in the catchment was estimated as a power of crops area in a district and percentage of agricultural land in the same district (Table 6 and Table 8).

Table 6. Crops area within the catchment, ha

	2001	2002	2003
	Kretinga		
Land drainage	10325.0	10325.0	10325.0
Winter crops	1235.3	1132.2	1026.4
Spring crops	1776.6	2274.7	2056.8
Row crops	694.6	736.4	598.2
Pastures	3209.6	3357.3	4487.2
Total crops	**6916.2**	**7500.7**	**8168.6**
	Skuodas		
Land dranage	2087.0	2087.0	2087.0
Winter crops	308.6	199.2	137.0
Spring crops	518.3	649.7	427.2
Row crops	151.4	140.7	91.8
Pastures	911.4	856.8	1091.2
Total crops	**1889.8**	**1846.3**	**1747.2**
	Plunge+Rietavas		
Land drainage	40642.8	40640.7	40640.7
Winter crops	3837.1	1064.9	2456.5
Spring crops	8342.1	9798.2	6694.8
Row crops	2589.5	1858.6	2380.4
Pastures	23447.0	27514.6	29059.7
Total crops	**38215.7**	**40236.3**	**40591.3**
	Telsiai		
Land drainage	3654.3	3654.3	3654.3
Winter crops	380.9	202.8	295.8
Spring crops	653.8	800.5	617.3
Row crops	173.4	171.1	255.4
Pastures	1192.7	1356.3	2709.2
Total crops	**2400.9**	**2530.7**	**3877.7**

Table 6 shows that not all drained land was used for crops or pastures. This agricultural land was abandoned during the agrarian reform and still is not in use. Area of abandoned land in districts within the Kartena Minija basin is presented in the table 7.

Table 7. Abandoned land area in the Minija Kartena basin, ha

	2001	2002	2003
Kretinga	3408.8	2824.3	2156.4
Skuodas	197.3	240.7	339.9
Plungė+Rietavas	2427.1	404.4	49.4
Telšiai	1253.4	1123.6	-223.4
Total area	**7287**	**4593**	**2322**

Table 8. Animals number within the catchment

	2001	2002	2003
	Kretinga		
Livestock	2335	2292	2269
Pigs	2583	3048	3092
	Skuodas		
Livestock	736	734	779
Pigs	455	576	496
	Plunge+Rietavas		
Livestock	15880	19218	17640
Pigs	11393	12902	13330
	Telsiai		
Livestock	1274	1302	1387
Pigs	1671	2076	1964

4 GROSS Ntot and Ptot AGRICULTURAL LOSSES IN THE CATCHMENT

4.1 Ntot and Ptot concentration in the drainage flow

Ntot and Ptot concentration in the drainage flow for different crop types of the Graisupis watershed (Kedainiai district) were used for the Minija_Kartena catchment (Table 9).

Table 9. Ntot and Ptot concentration (mg l^{-1}) in the drainage flow for every crop type

	2001		2002		2003	
	N	P	N	P	N	P
Winter crops	10.6	0.031	3.9	0.038	12.3	0.037
Spring crops	13.5	0.040	6.5	0.065	8.7	0.084
Row crops	13.3	0.031	9.7	0.062	9.6	0.043
Pastures	3.2	0.016	5.5	0.057	5.2	0.081

4.2 Rainfall

Table 10 presents rainfall in four meteorological stations neighbouring the Minija_Kartena catchment. The data shows that the measured rainfall differs among the stations quite much, e.g. the wettest year was 2001 year in all three stations, and the driest year was 2002 year in Skuodas, 2003 year in other stations. Quite big differences are among the monthly values that are shown in Table 10.

Table 10. Rainfall in the meteorological stations nearby the Minija_Kartena catchment in 2001-2003 years

Station	01	02	03	04	05	06	07	08	09	10	11	12	year
							2001						
Telsiai	42	66	23	49	20	153	81	80	115	84	135	68	916
Laukuva	48	61	43	54	20	86	120	101	125	98	127	50	933
Skuodas	50	92	36	24	14	66	79	90	117	64	135	71	838
Vezaiciai	43	58	39	44	20	157	100	78	156	87	132	82	996
							2002						
Telsiai	98	114	74	26	27	92	161	1	69	112	49	48	871
Laukuva	94	93	56	23	28	79	105	0	54	119	46	31	728
Skuodas	109	103	65	17	10	62	85	0	46	87	63	18	665
Vezaiciai	124	134	62	14	20	63	133	0	101	102	64	47	864
							2003						
Telsiai	61	8	14	42	52	67	58	128	50	85	47	66	678
Laukuva	51	6	7	39	56	49	38	107	41	98	51	70	613
Skuodas	42	5	13	42	60	62	84	203	48	86	45	94	784
Vezaiciai	56	8	16	48	43	73	49	117	66	144	48	104	772

Using medians method it was determined a part of the catchment belonging to each of the meteorological stations. The results showed that about 0.125 of the catchment belong to each of the Skuodas and Laukuva meteorological stations and about 0.375 – to each of the Vezaiciai and Telsiai stations. The following formula was used to calculate the depth of rainfall in the Minija_Kartena catchment:

$$h_{Kartena} = 0.125\ (h_{Skuodas} + h_{Laukuva}) + 0.375\ (h_{Vezaiciai} + h_{Telsiai})$$

Table 11. The depth of rainfall in the Minija_Kartena catchment

	Rainfall depth, mm
2001	940
2002	825
2003	719

The depth of rainfall was biggest in 2001 year (940 mm), smaller in 2002 year (825 mm) and smallest in 2003 year (719 mm).

4.3 Specific drainage runoff

Long-term (1925-1996 year) average Minija river water flow at Kartena was 15.9 $m^3\ s^{-1}$ (Gailiusis et al., 2001). Long-term average specific water runoff calculated from average Minija river water flow at Kartena was 12.9 $l\ s^{-1}\ km^{-2}$ and runoff depth was 407 mm.

Drainage runoff derived from Silale district (Western Lithuania) monitoring data (Balciunas et al., 1997) and adopted for Minija Kartena catchment comprise 225 mm Long-term drainage runoff makes up **0.553** of long-term Minija river runoff depth at Kartena.

Every year river water discharge is different. During the analysed year the average yearly river water flow at Minija_Kartena was as following:

2001 year – 18.22 $m^3\ s^{-1}$, specific water runoff – 14.8 $l\ s^{-1}\ km^{-2}$.

2002 year – 19.04 $m^3\ s^{-1}$, specific water runoff – 15.4 $l\ s^{-1}\ km^{-2}$.

2003 year – 11.47 $m^3\ s^{-1}$, specific water runoff – 9.3 $l\ s^{-1}\ km^{-2}$.

The wettest year according to the rainfall was 2001 and the highest river water flow was in 2002 year. The driest year according to both the rainfall and the river water flow was 2003.

Assuming that each year drainage water discharge comprises the same part of the river discharge, drainage specific water runoff is a power of each year river specific water runoff at Minija_Kartena and drainage runoff coefficient 0,553:

2001 year: 14.8 * 0.553 = 8.18 l s^{-1} km^{-2}.

2002 year: 15.4 * 0.553 = 8.52 l s^{-1} km^{-2}.

2003 year: 9.3 * 0.553 = 5.14 l s^{-1} km^{-2}.

4.4 Specific Ntot and Ptot losses

Ntot and Ptot concentration in the drainage flow for all crop types (Table 9) and drainage specific water runoff for each year were used to calculate specific Ntot and Ptot losses from different types of crops (spring crops, winter crops, row crops (potatoes and sugar beet) and pastures) (Table 12).

Table 12. Specific Ntot and Ptot drainage losses (kg ha^{-1} $year^{-1}$) from different types of crops for the Minija_Kartena catchment

	2001		2002		2003	
	N	P	N	P	N	P
Winter crops	27.3	0.08	10.5	0.10	19.9	0.06
Spring crops	34.8	0.10	17.5	0.17	14.1	0.14
Row crops	34.3	0.08	26.1	0.17	15.6	0.07
Pastures	8.3	0.04	14.8	0.15	8.4	0.13

Specific Ntot and Ptot losses from animal husbandry (Table 13) were calculated from the data of nutrient losses from barns territory.

Table 13. Specific Ntot and Ptot drainage losses (kg $animal^{-1}$ $year^{-1}$) from animal husbandry for the Minija_Kartena catchment

	2001		2002		2003	
	N	P	N	P	N	P
Livestock	0.681	0.107	0.464	0.143	0.327	0.037
Pigs	0.085	0.021	0.058	0.029	0.041	0.007

4.5 Ntot and Ptot gross agricultural losses

Crops area (Table 6), animals number (Table 8) and area of abandoned land in the districts within the Minija_Kartena catchment and corresponding specific Ntot and Ptot losses (Table 12 and Table 13) were used to calculate gross agricultural losses (Table 14). For calculation nutrient losses from abandoned land specific drainage losses of non fertilised pastures were used.

Table 14. Ntot and Ptot gross agricultural losses (tonnes^{-1} year^{-1}) for the Minija_Kartena catchment

	2001		2002		2003	
	N	P	N	P	N	P
Crops	912.0	3.10	828.1	8.18	582.8	6.07
Animals	4.9	0.86	2.0	0.76	1.7	0.22
Abandoned land	60.5	0.14	68.0	0.42	19.5	0.28
Total losses	**977.4**	**4.1**	**898.1**	**9.36**	**604**	**6.57**

5 CONCLUSIONS

Nitrogen and phosphorus losses through land drainage originate mainly from crop fields. Nutrient losses from territories of animal farms are small and do not have a big impact on the catchment level.

Ntot gross agricultural losses through land drainage in the Minija_Kartena catchment comprised **977.4** tonnes per 2001 year, **898.1** tonnes per 2002 year and **604.0** tonnes per 2003 year. The reduction in the losses happened due to increase in the area of pastures (that have lowest Ntot concentration in the drainage water) and due to differences in hydrological conditions (lowest drainage runoff happened during the last year).

Phosphorus losses from agricultural sources through land drainage are not high: **4.1**, **9.36** and **6.57** tonnes per 2001, 2002 and 2003 year correspondingly.

Increasing the area of pastures and winter crops, which have lowest Ntot losses, can further reduce drainage nitrogen losses from crop fields.

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