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THE INFLUENCE OF REDUCED TILLAGE ON WATER REGIME AND NUTRIENT LEACHING IN A LOAMY SOIL

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Abstract

The effect of tillage technologies and terms on soil moisture regime and nitrate leaching was studied in field trials carried out on 0.76-1.36-ha fields. The study site was arranged in Pikeliai village (Kėdainiai district). The soil prevailing in the study site is *Endocalcari – Endohypogleic Cambisol*, sandy light loam and sandy loam on deeper layers of sandy loam and sandy light loam. The arable horizon contains sandy light loam, which is characteristic of the soils prevailing in the Middle Lithuania Plain.

Average annual soil moisture content at the 0-20 cm depth during the period 2000-2005 was the highest in the treatments, where fields had been ploughed. In the fields ploughed early in autumn, average soil moisture was 25.0 mm, variation coefficient 0.29, while in treatments ploughed late in autumn average soil moisture was 24.3 mm, variation coefficient 0.28. Lower soil moisture was in reduced tillage treatment, where average soil moisture was 23.6 mm, variation coefficient 0.27.

Having summarized the study results of drainage run-off that ultimately affects nitrogen leaching, it was determined that the impact of soil cultivation time on the run-off coefficient was more significant under the conditions of run-off formation during the snow thaw period in winter. In the winter of 2005, the run-off coefficient was 2.17 in the treatment ploughed early in autumn and 1.59 in the treatment ploughed late in autumn.

During the study period (2000-2005) nitrogen leaching was the highest in the treatment, where fields had been ploughed early in autumn. In this treatment total leaching for the 2000-2005 period amounted to 148 kg N ha^{-1}. The lowest leaching (98.0 kg N ha^{-1}) was in the treatment, where fields were ploughed late in autumn. In reduced tillage, leaching amounted to 103 kg N ha^{-1}. Of the total nitrogen leached, nitrate nitrogen (NO_3-N) in the treatment, where fields had been ploughed early in autumn, accounted for 109 kg N ha^{-1} (average annual 18.2 kg N ha^{-1}). In the treatment, where fields had been ploughed late in autumn it accounted for 77.8 kg ha^{-1} (average annual 12.9 kg N ha^{-1}). In reduced tillage, it accounted for 84.8 kg ha^{-1} (average annual 14.2 kg N ha^{-1}).

Key words: land tillage, soil moisture, drainage run-off, nitrate and phosphate concentrations, nitrate leaching.

Introduction

Farming activity is a very important factor determining nutrient leaching and pollution of water bodies. The reason is that the largest amounts of nutrients get into water bodies in the shape of non-point source pollution together with water flowing from land use areas /Šileika, 1997/. The study results suggest that the largest amount of nitrogen is leached from areas ploughed in autumn where annual crops are cultivated /Aksomaitienė et al., 2002/.

Reduced tillage system, where ploughing is replaced by shallower land cultivation with the help of a disk harrow, or heavy cultivators under the conditions of dry or semi-dry climate, has been applied for a long time already. One of the factors determining the expansion of such technologies is the economy of moisture.

As it was determined using a sphere time reflectometer, in the topsoil layer (0-20 cm) of undisturbed loams the moisture content of the soil within a reduced long tillage period (>15 years) was higher compared to reduced short tillage period (1 year). In both reduced tillage treatments moisture content in the soil was higher than that in the conventional tillage period, particularly during the vegetation period /Zhai et al., 1990/.

In the topsoil layer (0-8 cm) of reduced tillage the moisture content was significantly higher than that in the conventional tillage in the middle of vegetation period (moisture difference made up about 10-15 % of volume units).

Less intensive land cultivation results in better filtration qualities of the soil due to the so-called "macropores factor" /Shipitalo, Edwards, 1993/. This has a significant influence on chemical matter leaching from the soil. As the studies show, having applied no-tillage, 200mm more water penetrated when column method was applied, and 50 mm more water penetrated when tests were carried out under field conditions, compared to the treatments where conventional tillage was applied.

Higher drainage run-off occurred in treatments that experienced minimal land disturbance: in conventional tillage – 41 cm, ridge tillage – 52 cm, in chisel tillage and no-tillage – 55 cm. Conventional tillage reduces drainage run-off by 2 cm on the average, compared to the no-tillage /Weed, Kanwar, 1996/.

Drainage run-off was higher in no-tillage plot than that in the plot where chisel cultivator was applied (on the average 26 and 16 cm / day in no-tillage and chisel tillage) /Allmaras et al., 1977/.

In the USA, the effect of land cultivation and N fertilization on the amount of nitrogen contained in the soil and its leaching into deeper water bodies in a 12-year system of spring wheat – fallow was investigated. No-tillage /Ardell et al., 2001/ reduced nitrate leaching potential, compared to conventional and reduced tillage in Great Northern Plains of the USA. For example, as McCracken reports /McCracken et al./ common land cultivation results in the leaching of 25 kg NO_3-N, while applying no-tillage its leaching is 34 kg NO_3-N.

In the subsoil layer the decrease in nitrate concentration was 23.5 mg l^{-1} in conventional tillage, 17 mg l^{-1} in no-tillage, and 17 mg l^{-1} having ploughed the land plot /Drury et al., 1993/.

Under the climatic and relief conditions of our country, no detailed studies have been performed on the effect of tillage on the quality of water discharged by drainage and on hydrophysical qualities of the soil, although it is not a new issue. Most studies performed in Lithuania aim to determine the effect of tillage (reduced tillage, usually with no ploughing) on the yield of crops. As the results of long-term research (1956-1991) carried out in Lithuania showed /Arlauskas, 1993/, reduced tillage had no adverse effect on agrochemical and agrophysical qualities of the soil.

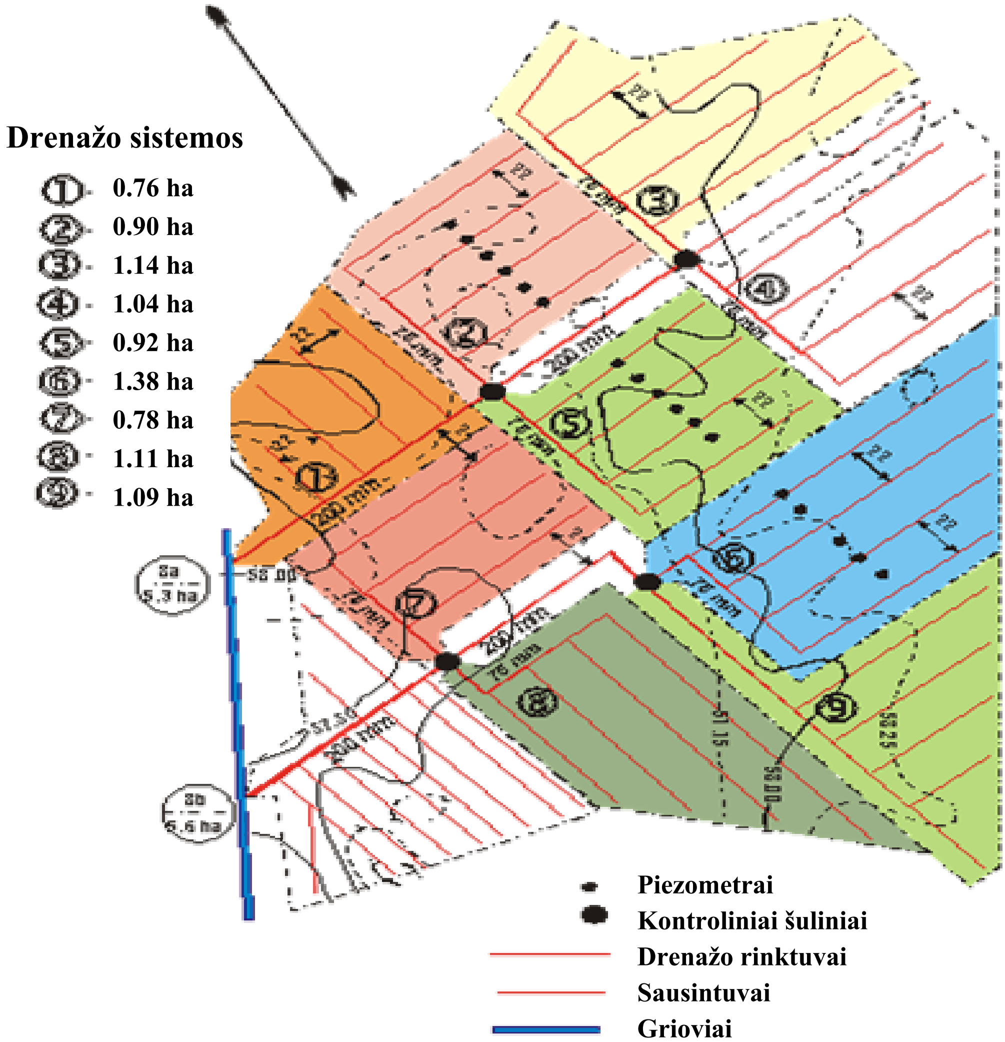
Relevance of the studies is increasing along with the changing tillage technologies in Lithuania due to better Western techniques and its usage during the implementation of EU environment protection requirements for agriculture. The discussed literature resources show that tillage is one of the most important factors affecting soil moisture regime, drainage run-off and Nmin. concentrations. However, the effect also depends on certain local soil and climatic conditions. In the Middle Plain of Lithuania, where mostly annual crops are grown (wheat and sugar beet) and where tillage is rather intensive every year, this question is topical from the point of view of environmental protection as well as agriculture.

The objective of the work was to determine the changing tendencies of soil moisture regime, drainage water pollution and N leaching in respect of the changing tillage technologies and terms.

Materials and methods

The studies were carried out in the Middle Plain of Lithuania, on a light loam soddy-gley soil. The study site was set up in Kėdainiai district, nearby Dotnuva, in the basin of the Graisupis stream, in Pikeliai site of the Experimental Department of Water Management Institute of the Lithuanian University of Agriculture. Having reconstructed the drainage in 1994, test fields were drained with the help of individual drainage systems arranged within the area of 0.76-1.36 ha and draining depth 96-135 cm. More detailed description of drainage systems is given in transaction of Water Management Institute of the Lithuanian University of Agriculture /Rimidis, 2000/. In the upper soil layer (0-20 and 20-40 cm deep) mid-heavy loams are prevailing containing 50.8 and 50.9 % of sand particles, 14.3 % of clay particles in both layers, and 34.8 and 34.9 % of dust particles, respectively. In the subsoil layer (40-150 cm deep) sandy light loam is prevailing containing 57.0 to 59.2 % of sand particles, 18.4 to 19.6% of clay particles and 21.2 to 24.6 % of dust particles.

Similar land cultivation and crop growing treatments were arranged in the land area divided into small plots. Each separate land plot was drained by a separate drainage system. This helped to study nutrient leaching processes in several replications. Areas drained by 1, 7 and 8 drainage systems were ploughed early (in August-September) with the help of PLN – 3-35 plough pulled by a 1.4 (14) class tractor at the depth of 22-25 cm (conventional tillage). Another part of test field was ploughed every year in late autumn (in the end of October-beginning of November) (Figure 1). In the area drained by 2, 5 and 6 systems barley was grown with ryegrass as undercrop in 2001-2002. Since 2004 fields were started being ploughed by disc harrows (reduced tillage). In the area drained by 3, 4 and 9 drainage systems barley was grown without intermediate crops. Land was ploughed with the help of PLN –3-35 plough pulled by 1.4 (14) class tractor at the depth of 22-25 cm (conventional tillage).



1, 7, 8 – Fields ploughed up in early autumn / *Laukai ariami anksti rudenį;*
2, 5, 6 – Reduced tillage (barley was grown with ryegrass as undercrop in 2000-2001, since 2004 year fields were started being ploughed by disc harrows) / *Sumažintas žemės dirbimas (2000-2001 metais miežiai buvo auginami su daugiametėmis svidrėmis kaip tarpiniais augalais, nuo 2004 metų laukai buvo pradėti arti diskinėmis akėčiomis);*
3, 4, 9 – Fields ploughed up in late autumn / *Laukai ariami vėlai rudenį*

Figure 1. Pikeliai site of the Experimental Department of WMILAU
1 paveikslas. *LŽŪU VŪI Bandymų skyriaus Pikelių objektas*

In the whole territory one type of crops was grown every year. In 2004, crop rotation cycle was completed. The following crop rotation and fertilization were applied in the fields:

In 2000 – barley, fertilized with 200 kg ha^{-1} of N;

In 2001 – barley, fertilized with 200 kg ha^{-1} of N;

In 2002 – rape, fertilized with 200 kg ha^{-1} of N;

In 2003 – winter wheat, fertilized with NPK, ratio 10:18:26 per 200 kg ha^{-1};

In 2004 – sugar beet, fertilized with Kemira Gausa NPK, ratio 5:10:34 per 400 kg ha^{-1} and ammonium nitrate 300 kg ha^{-1} ;

In 2005 – spring wheat, fertilized with 200 kg ha^{-1} of N.

Drainage discharge was measured in each drainage system (in a volumetric way) and samples were taken for the determination of N concentration. The following indices were determined in the laboratory: pH, NH_4-N, NO_3-N, N_b, PO_4-P ir P_b.

During the crop vegetation period soil samples for the determination of moisture content were taken each 10 days from the depth of 10 cm to 40 cm in every test field.

Study results are presented in tables; also arithmetical means, variation coefficient and average square deviations were calculated.

Results and discussion

Soil moisture regime of the tillage experimental field and nitrate leaching during the test period varied mostly due to the weather conditions. Average annual precipitation during the test period corresponded to average perennial rate of the precipitation in the region. Total precipitation amount during the test period (2000-2005) was 3123 mm, or 88.2 % from perennial average value. During the first study year (2000 and 2001) the precipitation amount (581 and 571 mm) was similar to the perennial average value and made up 98.5 and 96.8 %, respectively. The next two years were dry: in 2002 – 78.8 and 2003 – 77.3 % (465 mm in 2002 and 456 mm in 2003). In 2004 annual precipitation was again little lower than average perennial rate – 564 mm (95.6%). In 2005 the precipitation amount was 486 mm, which made up 82.4 % of the perennial average value. This year as well as 2002 and 2003 were drier compared to the years 2000, 2001 and 2004. Rainfall distribution over individual months during the 2000-2005 period compared with the perennial rate is presented in Figure 2.

Changes of dry and wet years reflect the changes in soil moisture content within the study period. During the investigated period (2000-2005) the greatest soil moisture variation was in the surface arable (0-20 cm) layer compared with deeper layers. Average yearly soil moisture, fluctuation limits and variation coefficient in the surface arable layer are presented in Table 1. Average annual soil moisture amount (0-20 cm deep) during 2000-2005 was the highest in the treatments, where fields were ploughed. In fields ploughed early in autumn, average soil moisture was 25.0 mm, variation coefficient – 0.29, while in treatments ploughed late in autumn average soil moisture was 24.3 mm, variation coefficient – 0.28. Lower soil moisture was in reduced tillage. In this treatment average soil moisture was 23.6 mm, variation coefficient – 0.27.

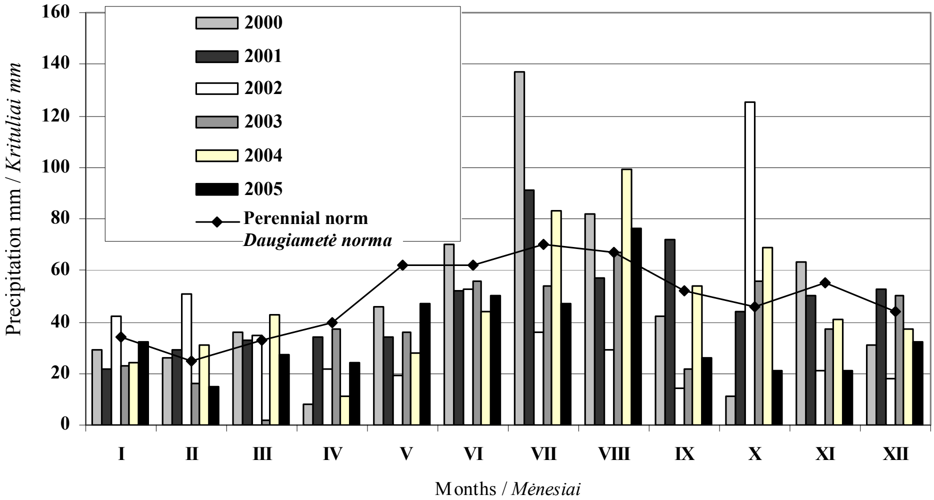


Figure 2. Precipitation (mm) and its distribution over individual months during the period 2000-2005 (columns), compared to the perennial rate (line)
2 paveikslas. *Krituliai (mm) ir jų pasiskirstymas atskirais mėnesiais 2000-2005 m. (stulpeliai), lyginant su daugiamete norma (linija)*

Table 1. Yearly averaged soil moisture data in experimental field of Pikeliai, vegetation period's soil moisture, fluctuation limits and variation coefficients in the surface arable layer
1 lentelė. *Vidutiniai metiniai dirvožemio drėgmės duomenys Pikelių eksperimentiniame lauke vegetacijos periodo dirvožemio drėgmė, svyravimų ribos ir variacijos koeficientai viršutiniame ariamajame sluoksnyje*

Cultivation *Dirbimas*	Average water content in the soil mm *Vidutinis vandens kiekis dirvožemyje mm*	Range *Svyravimas*	Variation coefficient *Variacijos koeficientas*
1	2	3	4
	2000		
Ploughed up in early autumn Conventional tillage (CT) *Ariama anksti rudenį* *Įprastas žemės dirbimas*	25.9	18.5-31.4	0.15
Reduced tillage (RT) *Sumažintas žemės dirbimas*	26.0	19.2-30.2	014
Ploughed up in late autumn Conventional tillage (CT) *Ariama vėlai rudenį* *Įprastas žemės dirbimas*	21.9	18.5-26.7	0.15

Table 1 continued
1 lentelės tęsinys

1	2	3	4
	2001		
Ploughed up in early autumn Conventional tillage (CT) *Ariama anksti rudenį* *Įprastas žemės dirbimas*	28.5	22.7-33.3	0.15
Reduced tillage (RT) *Sumažintas žemės dirbimas*	28.0	21.2-35.1	0.16
Ploughed up in late autumn Conventional tillage (CT) *Ariama vėlai rudenį* *Įprastas žemės dirbimas*	28.1	21.1-34.6	0.18
	2002		
Ploughed up in early autumn Conventional tillage (CT) *Ariama anksti rudenį* *Įprastas žemės dirbimas*	19.0	7.04-30.0	0.42
Reduced tillage (RT) *Sumažintas žemės dirbimas*	18.8	6.20-30.5	0.50
Ploughed up in late autumn Conventional tillage (CT) *Ariama vėlai rudenį* *Įprastas žemės dirbimas*	19.9	6.59-33.9	0.51
	2003		
Ploughed up in early autumn Conventional tillage (CT) *Ariama anksti rudenį* *Įprastas žemės dirbimas*	23.4	13.3-36.6	0.35
Reduced tillage (RT) *Sumažintas žemės dirbimas*	20.4	12.0-32.4	0.30
Ploughed up in late autumn Conventional tillage (CT) *Ariama vėlai rudenį* *Įprastas žemės dirbimas*	21.5	10.3-30.1	0.29
	2004		
Ploughed up in early autumn Conventional tillage (CT) *Ariama anksti rudenį* *Įprastas žemės dirbimas*	31.5	27.4-43.1	0.15
Reduced tillage (RT) *Sumažintas žemės dirbimas*	23.9	21.7-28.0	0.097
Ploughed up in late autumn Conventional tillage (CT) *Ariama vėlai rudenį* *Įprastas žemės dirbimas*	28.7	24.6-37.9	0.14

Table 1 continued
1 lentelės tęsinys

1	2	3	4
	2005		
Ploughed up in early autumn Conventional tillage (CT) *Ariama anksti rudenį* *Įprastas žemės dirbimas*	21.4	11.8-31.1	0.27
Reduced tillage (RT) *Sumažintas žemės dirbimas*	24.5	13.9-35.6	0.25
Ploughed up in late autumn Conventional tillage (CT) *Ariama vėlai rudenį* *Įprastas žemės dirbimas*	25.2	15.9-37.7	0.27

In wet years (2000, 2001 and 2004) higher soil moisture was observed in the treatment, where fields were ploughed early in autumn. Average soil moisture was 28.6 mm (25.9, 28.5 and 31.5 mm in the 2000, 2001 and 2004, respectively), variation coefficient was 0.15, 0.15 and 0.15. The lowest average soil moisture was in the reduced tillage. Average soil moisture was 26.0 mm (26.0, 28.0 and 23.9 mm in 2000, 2001 and 2004, respectively), variation coefficient was 0.14, 0.16 and 0.10. In fields ploughed late in autumn average soil moisture was 26.2 mm (21.9, 28.1 and 28.7 mm in 2000, 2001 and 2004, respectively), variation coefficient was 0.15, 0.18 and 0.14.

In dry years (2002, 2003 and 2005) higher soil moisture was in treatments where fields were ploughed. In fields ploughed early in autumn average soil moisture was 21.3 mm (19.0, 23.4 and 21.4 mm in 2002, 2003 and 2005, respectively), variation coefficient was 0.42, 0.35 and 0.27, while in treatments, where fields were ploughed late in autumn average soil moisture was 22.2 mm (19.9, 21.5 and 25.2 mm in 2002, 2003 and 2005, respectively), variation coefficient was 0.51, 0.29 and 0.27. In reduced tillage average soil moisture was 21.2 mm (18.8, 20.4 and 24.5 mm in 2002, 2003 and 2005, respectively), variation coefficient was 0.50, 0.30 and 0.25.

Drainage run-off formation greatly depends not only on precipitation, but also on soil moisture, moisture receptivity and frozen ground. Monthly run-off (mm) and errors of the years 2000-2005 are presented in Table 2.

In wet years (2000, 2001 and 2004) higher drainage run-off was observed in fields with reduced tillage. Average drainage run-off was 202 mm (148, 209 and 250 mm in 2000, 2001 and 2004). Lower run-off occurred in the treatments, where fields were ploughed. In the treatment with fields ploughed early in autumn, average drainage run-off was 147 mm (123, 106 and 213 mm in 2000, 2001 and 2004, respectively). In the treatment with fields ploughed late in autumn, average drainage run-off was 148 mm (133, 119 and 212 mm in 2000, 2001 and 2004, respectively).

Table 2. Drainage run-off (mm) monthly mean values and standard deviation during 2000-2005

2 lentelė. *Drenažo nuotėkio aukščio (mm) 2000-2005 m. mėnesiniai vidurkiai ir paklaidos*

Years *Metai*	Soil tillage treatments *Žemės dirbimo variantai*					
	Ploughed up in early autumn *Ariama anksti rudenį*		Reduced tillage *Sumažintas žemės dirbimas*		Ploughed up in late autumn *Ariama vėlai rudenį*	
	Monthly run-off *Mėnesinis nuotėkis*	Standard deviation *Standartinė paklaida*	Monthly run-off *Mėnesinis nuotėkis*	Standard deviation *Standartinė paklaida*	Monthly run-off *Mėnesinis nuotėkis*	Standard deviation *Standartinė paklaida*
			Yearly / *Metų*			
2000 V-XII	123	13.2	148	17.9	133	16.3
2001 (I-XII)	106	16.2	209	16.8	119	17.5
1	2	3	4	5	6	7
2002 (I-VI)	190	34.7	158	29.9	117	27.4
2003 (I-XII)	59.1	19.0	65.2	16.2	56.1	15.2
2004 (I-XII)	213	28.3	250	30.3	212	27.6
2005 (I-VI)	202	47.5	184	37.3	145	30.8
			Spring period / *Pavasario laikotarpis*			
2000	0.64	0.007	1.33	1.16	0.90	0.65
2001	42.9	15.7	49.4	14.7	42.5	13.1
2002	52.6	28.1	54.0	27.9	51.1	27.3
2003	13.2	3.77	18.8	5.08	12.7	4.38
2004	83	39.2	81.2	36.4	77.4	35.7
2005	158	58.8	133	47.4	105	38.9
			Summer period / *Vasaros laikotarpis*			
2000	50.8	16.8	62.7	26.3	58.1	24.3
2001	0.74	0.11	1.86	0.19	1.54	0.41
2002	0.002	0.000141	0.039	0.0429	0.12	0.144
2003	-	-	-	-	-	-
2004	0.35	0.0647	0.66	0.0469	0.51	0.0149
2005	0.12	0.00141	0.15	0.00141	0.21	0.0149
			Autumn period / *Rudens laikotarpis*			
2000	49.9	13.8	63.4	16.3	53.3	14.1
2001	94.8	23.6	103	19.2	104	16.1
2002	-	-	-	-	-	-
1	2	3	4	5	6	7
2003	-	-	-	-	0.81	0.00109
2004	16.0	6.95	29.0	7.61	16.2	9.86
2005	-	-	-	-	-	-
			Winter period / *Žiemos laikotarpis*			
2000	22.2	0.282	20.7	2.36	20.8	2.83
2001	49.0	11.1	54.3	11.4	49.3	11.2
2002	137	10.4	104	25.9	65.6	38.9
2003	45.9	28.4	46.4	23.9	42.6	26.2
2004	114	30.8	140	36.8	118	31.2
2005	44.0	0.042	46.0	29.7	39.4	27.4

In dry years (2002, 2003 and 2005) in fields with reduced tillage average drainage run-off was 136 mm (158, 65.2 and 184 mm in 2002, 2003 and 2005, respectively). In the treatment with fields ploughed early in autumn, average drainage run-off was 150 mm (190, 59.1 and 202 mm in 2002, 2003 and 2005, respectively). In the treatment with fields ploughed late in autumn, average drainage run-off was 106 mm (117, 56.1 and 145 mm in 2002, 2003 and 2005, respectively).

During the study period, in May, June and July of 2000, in June, July and August of 2001, in June and October of 2002, in June of 2003, in July and August of 2004 and in August of 2005 the territory received large amounts of precipitation. However, the run-off of the months mentioned above was rather low or was absent at all. This may be explained by the fact that due to low soil moisture content large part of precipitation accumulated in upper soil layers. Average monthly drainage run-off values (mm) and standard deviation of the period 2000-2005 are presented in Table 2.

During the study period (2000-2005) in spring the precipitation amount was significantly less. Therefore in summer periods of 2002-2005 the decrease in soil moisture content was observed. During this period drainage run-off was relatively low or absent at all in all treatments. Drainage run-off observed in fields with reduced tillage was 0.039, 0, 0.66 and 0.15 mm. Run-off occurred in the treatment where fields were ploughed late in autumn. It was 0.12, 0, 0.51 and 0.21 mm. In the treatment with fields ploughed early in autumn drainage run-off was 0.002, 0, 0.35 and 0.12 mm. In spring and summer of 2000-2001, the territory received larger amount of precipitation, therefore larger amount of it was adsorbed in the soil. In summer periods soil moisture content was higher compared to that in spring periods. In 2001, drainage run-off was relatively low or absent at all in all treatments. Higher run-off was observed in fields of reduced tillage and it was 1.86 mm. Lower run-off was observed in the treatment where fields were ploughed early in autumn. It was 0.74 mm. In treatment where fields were ploughed late in autumn it was 1.54 mm. In the summer of 2000, the increase in soil moisture content was observed resulting in higher drainage run-off. Higher run-off occurred in fields with reduced tillage and it was 62.7 mm. Lower run-off was observed in the treatment where fields were ploughed early in autumn. It was 50.8 mm. In the treatment where fields were ploughed late in autumn the drainage run-off was 58.1 mm.

In autumn considerably less precipitation was observed, thus soil moisture increased in all treatments. This was influenced by considerably high precipitation amount. Drainage run-off occurred only in wet years. In those years in autumn period higher drainage run-off was in treatments where fields were ploughed. In fields ploughed early in autumn, average drainage run-off was 54.6 mm (49.9, 97.8 and 16.0 mm in 2000, 2001 and 2004, respectively), while in treatments ploughed late in autumn average drainage run-off was 57.8 mm (53.3, 104 and 16.2 mm in 2000, 2001 and 2004, respectively). In reduced tillage average drainage run-off was 65.1 mm (63.4, 103 and 29.0 mm in 2000, 2001 and 2004, respectively).

In dry years drainage run-off in all treatments was relatively low or did not form completely. In dry years in autumn drainage run-off was only in the November of 2003, in the treatment where fields were ploughed late in autumn it was 0.81mm. In spring the drainage run-off was higher where fields were ploughed. In fields ploughed early in autumn, average run-off was 74.6 mm (52.6, 13.2 and 158 mm in 2002, 2003 and 2005, respectively), while in fields ploughed late in autumn it was 56.3 mm (51.1, 12.7 and 105 mm in 2002, 2003 and 2005, respectively). In the reduced tillage average run-off was 68.6 (54.0, 18.8 and 133 mm in 2002, 2003 and 2005, respectively).

Lower air temperature and less evaporation resulted in increased soil moisture, however drainage run-off decreased. Temperature effect on drainage run-off is particularly obvious when temperature changes from negative to positive during thaw period in winter or in spring. In the winter, when temperature is negative, moisture rises from deeper soil layers to surface layers (there is lower temperature) and usually is higher than soil moisture receptivity. Mean annual, winter and summer seasons' drainage flow coefficients in the treatments Table 3. In dry years in winter (when the average of a 10-day period was below zero) run-off coefficients were highest, though variation between single years was very large (from 0.11in 2003 to 1.91 in 2005), while in summer the variation of drainage run-off coefficients was similar in different years (from 0.11 in 2005 to 0.14 in 2002). In winter of wet years the variation of drainage run-off coefficients in separate years was from 0.74 in 2001 to 1.40 in 2004, while in summer the variation of drainage run-off coefficients was higher in different years (from 0.19 in 2004 to 0.28 in 2000) compared to dry years of the same period.

Table 3. Mean annual, winter and summer seasons' drainage flow coefficients in the treatments

3 lentelė. *Vidutiniai per metus ir žiemos bei vasaros laikotarpių drenažo nuotėkio koeficientai tyrimų variantuose*

Indicators *Rodikliai*	Wet years / *Drėgni metai*			Dry years / *Sausi metai*		
	2000	2001	2004	2002	2003	2005
1	2	3	4	5	6	7
Period month *Laikotarpis mėnesiais*	V - XII	I - XII	I - XII	I - XII	I-XII	I-XII
Precipitation mm *Kritulių mm*	482	571	564	465	456	418
Average run-off coefficient *Vidutinis nuotėkio koeficientas*	0.28	0.35	0.40	0.33	0.13	0.42
Run-off coefficient ploughed up in early autumn (conventional tillage) *Nuotėkio koeficientas, ariama anksti rudenį (įprastas žemės dirbimas)*	0.26	0.33	0.38	0.41	0.14	0.48
Run-off coefficient (Reduced tillage) *Nuotėkio koeficientas, sumažintas žemės dirbimas*	0.31	0.37	0.44	0.34	0.12	0.44
Run-off coefficient ploughed up in late autumn (conventional tillage) Nuotėkio koeficientas, ariama vėlai rudenį (įprastas žemės dirbimas)	0.28	0.34	0.38	0.25	0.13	0.35

Table 3 continued
3 lentelės tęsinys

1	2	3	4	5	6	7
Period month Laikotarpis mėnesiais		I - IV	I-III	XII - II	XII - III	I-III
Precipitation mm *Kritulių mm*		118	98	130	59	74
Average run-off coefficient *Vidutinis nuotėkio koeficientas*		0.74	1.40	0.82	0.11	1.91
Run-off coefficient ploughed up in early autumn (conventional tillage) *Nuotėkio koeficientas, ariama anksti rudenį (įprastas žemės dirbimas)*		0.72	1.39	1.09	0.07	2.17
Run-off coefficient (Reduced tillage) *Nuotėkio koeficientas, sumažintas žemės dirbimas*		0.79	1.48	0.84	0.17	1.97
Run-off coefficient ploughed up in late autumn (conventional tillage) *Nuotėkio koeficientas, ariama vėlai rudenį (įprastas žemės dirbimas)*		0.71	1.33	0.53	0.08	1.59
Period month *Laikotarpis mėnesiais*	V - XII	V -XI	IV-XII	III - XII	IV -XII	IV-XI
Precipitation mm *Kritulių mm*	482	400	466	388	415	312
Average run-off coefficient *Vidutinis nuotėkio koeficientas*	0.28	0.26	0.19	0.14	0.13	0.11
Run-off coefficient ploughed up in early autumn (conventional tillage) *Nuotėkio koeficientas, ariama anksti rudenį (įprastas žemės dirbimas)*	0.26	0.25	0.17	0.14	0.13	0.13
Run-off coefficient (reduced tillage) *Nuotėkio koeficientas, sumažintas žemės dirbimas*	0.31	0.28	0.23	0.14	0.13	0.12
Run-off coefficient ploughed up in late autumn (conventional tillage) *Nuotėkio koeficientas, ariama vėlai rudenį (įprastas žemės dirbimas)*	0.28	0.27	0.18	0.13	0.12	0.09

In winter run-off coefficients differed between treatments more significantly than in summer. After autumn soil moisture content was also different. The greatest differences were determined in winter of 2002 and 2005, as fields ploughed up in early autumn run-off during period from December of 2001 to March of 2002 and from January to March of 2005 year was greater than precipitation amount, run-off coefficients were 1.09 and 2.17, respectively. During this period when fields were ploughed late in autumn, run-off coefficients were 0.53 and 1.59, respectively.

Relation between nitrate concentration and drainage run-off is weak, because the correlation analysis showed that the correlation ratio between these two factors is less than 0.17-0.31. The greatest correlation coefficient ($R^2 = 0.0526$) was in the treatments, where fields had been ploughed early in autumn. Smaller ($R^2 = 0.0015$) correlation coefficient was in the treatments, where fields had been ploughed later in autumn. In the reduced tillage system the correlation coefficient was $R^2 = 0.012$.

During the investigation period (2000-2005) nitrate concentration was the greatest in the treatments, where fields were ploughed. In the fields ploughed early in autumn, average concentration was 6.20 mg l^{-1}, the concentration ranged from 1.64 to 28.0 mg l^{-1}. Variation coefficient was 1.03 in the fields ploughed late in autumn; average concentration was 6.16 mg l^{-1}, the concentration ranged from 1.60 to 29.0 mg l^{-1}, variation coefficient was 1.02. Reduced tillage average concentration was 5.42 mg l^{-1}, concentration ranged from 1.57 to 23.3 mg l^{-1}, variation coefficient was 0.99.

During the investigation period (2000-2005) the highest average phosphate concentration (14.0 mg l^{-1}) was in the treatments, where fields had been ploughed later in autumn, variation coefficient was 1.55. Lower average phosphate concentration (9.87 mg l^{-1}) was in the treatments, where fields had been ploughed early in autumn, variation coefficient was 1.72. In the reduced tillage system the average phosphate concentration was 13.0, variation coefficient was 1.48.

During the investigation period (2000-2005) nitrogen leaching was highest in the treatment, where fields were ploughed early in autumn. In this treatment total leaching for the period of 2000-2005 was 148 kg Nha^{-1}. The lowest leaching (98.0 kg N ha^{-1}) was in the treatment, where fields were ploughed late in autumn. In reduced tillage leaching amounted to 103 kg N ha^{-1}. Of the total nitrogen leached, nitrate nitrogen (NO_3-N) in the treatment, where fields had been ploughed early in autumn, accounted for 109 kg Nha^{-1} (average annual 18.2 kg N ha^{-1}). In the treatment, where fields had been ploughed late in autumn, it accounted for 77.8 kg ha^{-1} (average annual 12.9 kg N ha^{-1}). In reduced tillage, it accounted for 84.8 kg ha^{-1} (average annual 14.2 kg N ha^{-1}).

During 2000-2001 undersown annual ryegrass (*Lolium multiflorum*) reduced nitrogen leaching by 23 % (from 21.6 kg N ha^{-1} to 18.1 kg N ha^{-1}) and in the second year the effectiveness increased to 38 % (from 28.0 kg N ha^{-1} to 11.2 kg N ha^{-1}). Approximate effectiveness was 30 %.

In spring of dry years average nitrate leaching in the treatment, where fields were ploughed early in autumn, was 5.53 kg ha^{-1} (5.16, 2.50 and 8.92 kg ha^{-1} in 2002, 2003 and 2005, respectively). In the fields ploughed late in autumn, average leaching was 3.33 kg ha^{-1} (4.08, 3.02 and 2.88 kg ha^{-1} in 2002, 2003 and 2005, respectively). In fields of reduced tillage average leaching was 3.68 kg ha^{-1} (2.71, 3.54 and 4.79 kg ha^{-1} in 2002, 2003 and 2005, respectively).

In spring of wet years average nitrate leaching in the treatment, where fields were ploughed late in autumn, was 5.13 kg ha^{-1} (0.0513, 5.06 and 10.3 kg ha^{-1} in 2000, 2001 and 2004, respectively). In the fields ploughed early in autumn average leaching was 5.48 kg ha^{-1} (0.0326, 6.51 and 9.91 kg ha^{-1} in 2000, 2001 and 2004, respectively). In reduced tillage average leaching was 4.92 kg ha^{-1} (0.0777, 4.90 and 9.78 kg ha^{-1} in 2000, 2001 and 2004, respectively). In the autumn period in the fields ploughed early in autumn, average nitrate leaching was 15.4 kg ha^{-1} (3.14, 9.71 and 33.5 kg ha^{-1} in 2000, 2001 and 2004, respectively), when ploughed late in autumn average leaching was 13.4 kg ha^{-1} (3.06, 9.53 and 27.7 kg ha^{-1} in 2000, 2001 and 2004, respectively). In the reduced tillage average leaching was 5.25 kg ha^{-1} (3.70, 7.12 and 4.93 kg ha^{-1} in 2000, 2001 and 2004, respectively).

Conclusions

1. During the period 2000-2005, average annual soil moisture content at the 0-20 cm depth was the highest in the treatments, where fields had been ploughed. In the fields ploughed early in autumn, average soil moisture was 25.0 mm, variation coefficient was 0.29, while in the treatments ploughed late in autumn average soil moisture was 24.3 mm, variation coefficient was 0.28. Lower soil moisture was in reduced soil tillage. In this treatment average soil moisture was 23.6 mm, variation coefficient was 0.27.

2. In the fields ploughed in autumn, the formation of drainage run-off mostly depended on precipitation amount when temperatures were low (when evaporation decreased).

In dry years in winter (when the average of a 10-day period was below zero) run-off coefficients were the highest, though variation between separate years was very large (from 0.11 in 2003 to 1.91 in 2005), while in summer the variation of drainage run-off coefficients was similar in different years (from 0.11 in 2005 to 0.14 in 2002). In the winters of wet years the variation of drainage run-off coefficients in separate years was from 0.74 in 2001 to 1.40 in 2004, while in summer the variation of drainage run-off coefficients was higher in different years (from 0.19 in 2004 to 0.28 in 2000) compared to dry years of the same period.

During the long-lasting dry periods soil moisture content decreased, therefore even with larger amount of precipitation than the long-term rate the run-off did not occur or was insignificant.

3. During the investigation period 2000-2005 nitrate concentration was the highest in the treatments, where the fields had been ploughed. In the fields ploughed early in autumn, average concentration was 6.20 mg l^{-1}, the concentration ranged from 1.64 to 28.0 mg l^{-1}, variation coefficient was 1.03; in the fields ploughed late in autumn average concentration was 6.16 mg l^{-1}, concentration ranged from 1.60 to 29.0 mg l^{-1}, variation coefficient was 1.02. In reduced tillage average concentration was 5.42 mg l^{-1}, concentration ranged from 1.57 to 23.3 mg l^{-1}, variation coefficient was 0.99.

4. During the investigation period 2000-2005 the highest average phosphate concentration (14.0 mg l^{-1}) was in the treatments, where fields had been ploughed later in autumn, variation coefficient was 1.55. Lower average phosphate concentration (9.87 mg l^{-1}) was in the treatments, where fields had been ploughed early in autumn, variation coefficient was 1.72. In the reduced tillage system the average phosphate concentration was 13.0, variation coefficient was 1.48.

5. During the investigation period 2000-2005 nitrogen leaching was the highest in the treatment, where fields had been ploughed early in autumn. In this treatment the total leaching for 2000-2005 amounted to 148 kg N ha^{-1}. The lowest leaching (98.0 kg N ha^{-1}) was in the treatment, where the fields had been ploughed late in autumn. In reduced tillage leaching amounted to 103 kg N ha^{-1}. Of all nitrogen leached, nitrate nitrogen (NO_3-N) in the treatment, where fields had been ploughed early in autumn, accounted for 109 kg N ha^{-1} (average annual 18.2 kg N ha^{-1}). In the treatment,

where fields had been ploughed late in autumn it accounted for 77.8 kg ha^{-1} (average annual 12.9 kg N ha^{-1}). In reduced tillage it accounted for 84.8 kg ha^{-1} (average annual 12.9 kg N ha^{-1}).

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REFERENCES

1. Aksomaitienė R., Kutra G., Petrokienė Z. Productivity of crop rotations and their impact on NPK migration in agroecosystem. Water management engineering (summary) / Sėjomainų produktyvumas ir poveikis NPK migracijai agroekosistemoje // Water managment engineering: scientific articles / Vandens ūkio inžinerija: mokslo darbai / LŽŪU VUI. - 2002, t. 19 (41), p. 3-13. - In Lithuanian

2. Allmaras R. R., Rickman R. W., Ekin L.G., Kimball B. A. Chiselling influences on soil hydraulic properties // Soil Sciences Soc. Am. Journal. - 1977, No. 41, p.796-803

3. Ardell D., Halvorson, Brian J. et al. Black tillage and nitrogen fertilisation influence grain and soil nitrogen in an annual cropping system // Agronomy Journal / American Society of Agronomy (Abstract). - 2001, vol. 93, p. 836-841

4. Arlauskas M. The influence of different tillage systems on soil properties and crop yield. Proceedings of NJF – seminar No. 228 Soil tillage and environment. - Jokioinen, 8-10 June 1993, p. 307-312

5. Blevins R. L., Doyle Cook, Phillips S. H., Phillips R. E. Influence of no-tillage on soil moisture // Agronomy Journal. - 1971, No. 63, p. 593-596

6. Drury C. F., Mckenney D. J., Findlay W. I., Gaynor J. D. Influence of tillage on nitrate loss in surface run-off and tile drainage // Soil Sciences Soc. Am. Journal. - 1993, No. 57, p. 797-802

7. Mc Cracken D. V., Hargrove W. L., Box J. E. et al. Influence of tillage and cover cropping on nitrate leaching. http://www.elsevier.nt/gej-ng/29/65/

8. Rimidis A. The efficiency of filtering materials of reconstructed drainage systems. Water management engineering (summary) / Filtruojančiųjų medžiagų efektyvumas rekonstruoto drenažo sistemose // Water managment engineering: scientific articles / Vandens ūkio inžinerija: mokslo darbai / LŽŪU VUI.- 2000, t. 3 (25), p. 67-76. - In Lithuanian

9. Shipitalo M. J., Dick W. A., Edwards W. M. Conservation tillage and macropore factors that affect water movement and the fate of chemicals // Soil & Tillage Research. - 2000, vol. 53, p. 167-183

10. Shipitalo M. J., Edwards W. M. Seasonal patterns of water and chemical movement in tilled and no-till column lysimeters // Soil Sciences Soc. Am. Journal. - 1993, No. 57, p. 218-223

11. Šileika A. S. Environmental policy in the agricultural sector of Lithuania. Sustainable agriculture and rural area development // Institute for Land Reclamation and Grassland Farming (IMUZ). IMUZ Publisher. - 1997, p. 67-79

12. Švedas A., Tarakanovas P. Fertilisation planning. Computer programme “Fertilisation” / Tręšimo planavimas. Kompiuterinė programa „Tręšimas”. - Akademija, 2000. - 34 p. - In Lithuanian

13. Zhai J., Kachanoski R. G., Voroney R. P. Tillage effects on the spatial and temporal variations of soil water // Soil Sciences Soc. Am. Journal. - 1990, No. 54, p. 186-192

14. Weed D. A. J., Kanwar R. S. Nitrate and Water present in and flowing from root-zone soil // Journal Environ. Qual. - 1996, vol. 25, p. 709-719

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SUPAPRASTINTO ŽEMĖS DIRBIMO ĮTAKA VANDENS REŽIMUI IR NITRATŲ IŠSIPLOVIMUI PRIEMOLIO DIRVOŽEMYJE

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Santrauka

Bandymų laukuose (plotas – 0,76-1,36 ha), sausinamuose atskirų drenažo sistemų, tirta žemės dirbimo technologijų ir terminų įtaka nitratų išplovimui.

Tyrimo objekto, įrengto Kėdainių r. Pikelių kaime, dirvožemis – karbonatingas giliau glėjiškas rudžemis (RDg–4-K_2), smėlingas lengvas priemolis bei priesmėlis ant priesmėlio ir smėlingo lengvo priemolio. Armuo – smėlingas lengvas priemolis – atitinka Lietuvos vidurio lygumoje vyraujančius dirvožemius.

Vidutinis kasmetis dirvožemio drėgnio kiekis (0-20 cm gylyje) 2000-2005 m. buvo didesnis variantuose, kur laukai buvo ariami. Laukuose, artuose anksti rudenį, vidutinis dirvožemio drėgnis buvo 25,0 mm, variacijos koeficientas – 0,29, tačiau variantų laukuose, artuose vėlai rudenį, vidutinis dirvožemio drėgnis buvo 24,3 mm, variacijos koeficientas – 0,28. Žemesnis dirvožemio drėgnis buvo sumažinto žemės dirbimo variante, kur vidutinis dirvožemio drėgnis buvo 23,6 mm, variacijos koeficientas – 0,27.

Apibendrinus drenažo nuotėkio, turinčio lemiamą reikšmę azoto išplovimui, tyrimų rezultatus, nustatyta, kad arimo laiko poveikis nuotėkio koeficientui buvo didesnis nuotėkiui susidarius žiemos atlydžių metu. Laukuose, artuose anksti rudenį, 2005 m. nuotėkio koeficientas žiemą buvo 2,17, o laukuose, artuose vėlai rudenį tuo pačiu metu – 1,59.

Tyrimų laikotarpiu (2000-2005 m.) azoto išsiplovimas buvo didesnis variante, kur laukai ariami anksti rudenį. Šiame variante 2000-2005 m. azoto iš viso išsiplovė 148 kg N ha^{-1}. Mažiau išsiplovė variante, kur laukai ariami vėlai rudenį – atitinkamai 98,0 kg N ha^{-1}. Sumažinto žemės dirbimo variante azoto išsiplovė 103 kg N ha^{-1}. Išsiplovusio azoto nitratų azotas (NO_3-N) variante, kur laukai ariami anksti rudenį, sudarė 109 kg N ha^{-1} (vidutinis kasmetis – 18,2 kg N ha^{-1}), kur laukai ariami vėlai rudenį – atitinkamai 77.8 kg N ha^{-1} (vidutinis kasmetis – 12,9 kg N ha^{-1}). Sumažinto žemės dirbimo variante sudarė 84,8 kg N ha^{-1} (vidutinis kasmetis – 14,2 kg N ha^{-1}).

Reikšminiai žodžiai: žemės dirbimas, drenažo nuotėkis, nitratų ir fosfatų koncentracijos, nitratų išplovimas.