NITROGEN AND PHOSPHORUS LEACHING FROM THE HYDROMORPHIC SOILS OF BIDJ-BOSUT FIELD IN CROATIA

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ABSTRACT

Aim of this study was to investigate nitrogen (N) and phosphorus (P) leaching from five hydromorhic soils of Bidj-Bosut field in the 2004-2008 period. Total ten lysimeters were installed for percolate collection. Area covered by percolate flowing to 55 cm of depth was 0.2 m^2 in form of plate (ø 50 cm). Average yearly applied fertilization (kg/ha) for the crops in different rotations (alfalfa, maize, wheat, barley and soybean) was 195 and 104, for N and P_2O_5, respectively. Average collected percolate was 172 mm with average variations among the years from 58 to 264 mm and among the sites from 135 to 201 mm. In average 172 mm or close to one fourth part of total precipitation (740 mm) were removed by percolation. Average N and P leaching by percolation (kg/ha) were 20.83 (N) and 0.77 (P) with average variation among the years from 9.11 to 43.46 (N) and from 0.45 to 1.34 (P) and among the sites from 7.22 to 29.51 (N) and from 0.52 to 0.98 (P), respectively. Average 13.79 kg N/ha or 66.2% of total N and 0.36 kg P/ha or 46.8% were leached in the autumn-winter period. Depended on the year, from 6.6% to 20.5% N and from 1.16 to 2.30% P added by fertilization were leached by percolation. General conclusion is that management practice of tested area is potential danger regarding ground and surface water pollution with nitrogen and considerably lower with phosphorus.

Keywords: nitrogen, phosphorus, lysimeter, leaching, hydromorphic soils

INTRODUCTION

World's human population has the increasing trend. According to FAO data in the period from 1961 to 2008 the world's population grew from 3.1 to 6.8 billion. Because the world's population is growing, it has been projected that we may need to produce 50% more food by 2050 to meet the needs of nine billion people (Tomlinson 2011). By 2050, the human population would require a 70% increase in global agriculture output compared to that between 2005 and 2007. Now, chronic hunger still haunted the existence of one-sixth of the world's people with aggravating trend in future (FAO, 2009, 2012). Increase of world fertilizers consumption from 1961 to 2008 period from 30 to over 150 million tones considerably contributed to world food production.There is estimation that without fertilizers use world cereal production would be halved (IFA, 2011; Bruuselma et al., 2012).

Nitrogen (N) and phosphorus (P) are the most important nutrients that also function as environmental pollutants. Although the natural levels of these nutrients in soils are mainly low, their long-term use as poultry manures or chemical fertilizers in intensive plant production can lead to leaching of nitrate (NO_3^-) and phosphate (PO_4^{3-}) from soil in the groundwater and surface waters.High nitrate and phosphate levels in surface waters are factors contributing degradation of water quality makes the water unsafe for animal and human consumption (Logan, 2000, Toor et al., 2003; Magahudand Asio, 2009).For this reason, using of N and P fertilizers in agriculturehave been the subject of many environmental reports because theirpossible risks and negative consequences to the soil and water ecosystems (Follett and Delgado 2002; Galloway et al. 2004; Schlesinger et al. 2006; IFA 2007; Davidson et al. 2012).Losses of nitrate-nitrogen (NO_3-N) by percolation via subsurface drainage may exceed 30 to 35 kg N/ha/year (Randal et al., 2010).Leaching of P is generally low except in sandy, acid organic, or peaty soils with low P fixation capacity (Sharpley et al., 2003).

Mesić et al. (1994) found that total nitrogen accumulation by watercoursein Danube basin was estimated by 33,400 tonnes/year with 53% contribution from agricultural sources. Balanced environmentally and economically friendly application of mineral and organic nitrogen balanced for main arable crops could be from 170 to 200 kg N/ha (Mesić et al., 2007).

Aim of our study was to investigate nitrogen and phosphorus leaching by percolation under environmental conditions of intensive arable crops production in Bidj-Bosut Field as continuity of the previous published studies (Petošić, 2007, 2008; Petošić et al., 2004, 2011)

MATERIAL AND METHODS

Description of the investigated area

The investigated area covers soils of Babina Greda and Gundinci villages and itis situated in the Bidj-Bosut Field which is a geomorphologic part of the eastern Croatian plain (Mogaš, 2013). In general, soil and climate of this area are favorable for intensive field crops growing. For this reason, it is first of all agricultural area with about 75% of rural and agricultural population. Arable land is dominant structure of agricultural land with wheat. Maize, soybean barley, sunflower and sugar beet as main field crops.

The project data

The project "Water regime and water quality monitoring of agricultural land in area of irrigated canal of Bidj-Bosut field" started 2001 by realization of Faculty of Agriculture in Zagreb, Department of melioration under financial support of Croatian Water institution.

The soil caharacteristics of the investigatin area

Soils of five selected localities (L1 and L2: area of Babina Greda village; L3-L5: Gundinci village) are the arable lands hydromeliorated by pipe drainage during 80-ies of the last century as hypogley (Kladavac and Konjsko), eutric cambisol (Jasinje) and amphygles (Crpiliste) soil, while locality Dobrovo is partialy hidromelioratedswampy gley/hypogley soil.Three selected soils are powder clay loam (L1- L3) and twoarepowder clay (L4 and L5). Water permissions and porosities were from 0.11 to 0.17 m day^{-1} and from 40 to 48%, respectively. The soils are neutral / slight alkaline reaction, mainly low suuplied with organic matter and low /moderate supplied with nitrogen and plant available phosphorus and potassium (Table 1).

Main performances of the applied lysimeters

Total ten lysimeters were installedin spring of 2002 at five localities (two lysimeters at each location). First, a vertical trench was excavated to the depth of 2 m.

Table 1. Main chemical and physical properties of the soils

The properties of the hydromeliorated soils at starting of the study†										
Locality		PSU	pH		%				Mobile	Tex-
		of the soil	H_2O	KCl	Humus	N	Clay	Por.	P_2O_5	ture
L1	Kladavac	Hypogley	7.84	7.25	1.4	0.17	33	40	10.3	pcl
L2	Konjsko	Hypogley	7.81	7.14	1.9	0.18	37	41	7.2	pcl
L3	Jasinje	Eutric cambisol	7.71	6.89	2.5	0.22	34	43	21.5	pcl
L4	Dobrovo	Swampy gley	7.24	6.34	5.2	0.24	41	44	12.0	pc
L5	Crpiliste	Amphygley	7.55	6.45	1.2	0.40	43	48	13.5	pc

† PSU = pedosystematic unit before amelioration by pipe drainage; Por. = porosity; P_2O_5= (AL-method: mg/100 g); pcl = povder clay loam, pc = povder clay)

From the trench a horizontal slot was unearthed at a depth of 50 cm and a round lysimeter plate was inserted into the soil in order to leave the soil profile above the lysimeter plate undisturbed and the plate was filled with soil from that depth. PVC net in combination with geotextile (fleece) were applied on the lysimeter plate for preventing washing of small soil particles with leachate. Area covered by percolate flowingwas 0.2 m^2 in form of plate (ø of 50 cm). The percolate flowed to 0.55m of depth. Soil volume covered by percolate migration to lysimeter was 0.11 m^2(0.55 m x 0.2m^2).

Crop rotation and fertilization of the investigated parcels

Alfalfa, maize, winter wheat, winter barley and soybean crops were applied in crop rotation. Average yearly applied fertilization (kg/ha) was 195 and 104, for N and P_2O_5, respectively with 5-year average variations among the years from 114 and 246 (N) and from 90 to 140 (P_2O_5) and among the sites from 178 to 214 (N) and from 85 to 114 (P_2O_5), respectively (Table 2).

Table2. Crop rotation and fertilization

Crop rotation and fertilization by nitrogen and phosphorus in five localities															
	Crop rotation †					Fertilization (kg N/ha) ‡					Fertilization (kg P_2O_5/ha) ‡				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
L1	A	A	A	A	S	74	200	200	250	260	80	80	80	90	130
L2	W	W	M	W	M	76	220	300	135	255	90	55	200	55	130
L3	M	B	M	M	M	174	225	280	200	190	100	75	170	120	105
L4	W	M	M	M	M	186	260	290	255	55	100	50	200	145	30
L5	B	M	B	M	B	69	110	160	270	280	80	150	50	125	120
	Average fertilization					**114**	**203**	**246**	**202**	**208**	**90**	**82**	**140**	**107**	**103**

†alfalfa (A), wheat (W), maize (M), barley (B), soybean (S);
‡ fertilization for the calendar year (for example: for maize i and winter wheat in autumn 2006 at L2)

The weather conditions

The meteorological data (seasonal precipitation and mean air temperature regimes) for Gradiste Weather Bureau were used for characterizing the weather conditions (elevation above sea level: 77m; geographical coordinates: 45.32 °N, 18.41 °E; distance from Gundinci

17 km toward E and from Babina Greda 14 km in E/NE direction. These data were collected by courtesy the State Hydrometerological Service (SHS) in Zagreb.

Climate of the area is temperately continental (Mogaš, 2013) characterized by about 60 : 40% seasonal distribution of precipitation between spring – summer and autumn – winter periods (Table 3). This relation was also found in average of the 2004 - 2008 period but with zhe higher amplitude among the years between these two periods from 43% to 67%.

Table 3. Precipitation and mean air temperature regimes at Gradiste (SHS, 2008)

Gradiste: seasonal regime of precipitation and air temperature in the 2004-2008 period †												
	Precipitation (mm)						Mean air temperature (^oC)					
	2004	2005	2006	2007	2008	LTA*	2004	2005	2006	2007	2008	LTA*
Winter	159	146	132	196	99	**119**	3.1	2.9	2.0	7.5	5.8	**3.2**
Spring	376	165	220	190	202	**210**	15.7	16.3	16.5	18.2	17.8	**15.9**
Summer	195	340	158	158	166	**194**	19.7	19.5	20.4	20.4	20.1	**19.5**
Autumn	226	98	74	264	136	**168**	7.5	6.5	8.5	4.9	8.5	**6.2**
Total	**956**	**749**	**584**	**808**	**604**	691	**11.5**	**11.3**	**11.9**	**12.8**	**13.0**	11.2

† winter: Januar-March; spring: April-June; summer: July-September; autumn: October-December;
LTA = the long-term average 1961-1990

The weather conditions in the five-year 2004-2008 period was characterized by considerable fluctuation compared to the long-term average (LTA) 1961-1990 (Table 3). For example, yearly precipitation quantities were in range from 584 to 956 mm with amplitude from 85% to 138% compared to the LTA. On the other hand, mean yearly air temperature were 12.1 ^oC with amplitudeamong the years from 11.3 to 13.0 ^oC and fluctuation from 101% to 116% comparedto the LTA.). Our data are in accordance with recent global climatic change which has often adverse influences on field crop yields (IPCC, 2001; Chi-Chung et al., 2000; Lobel and Field, 2007; Kovačević et al., 2013; Majdančić et al., 2016).

The soil and water analysis

The soil and water analysis were made in Department of melioration, Faculty of Agriculture in Zagreb. Air-dried soil samples were grinded and sieved at 2-mm. Soil pH was determined according ISO (2005a), organic carbon bysulfochromic oxidation (ISO, 2004), available P_2O_5 by the ammonium lactate (AL) method (Egneretal. 1960) and particle size distribution according ISO (2009). Water quality parameters were also determined by the ISO standars as follows: total mineral nitrogen as the sum of NO_3-N (ISO,1996), and NH_3-N (ISO, 2005b) and orthophosphate (ISO, 2003) by flow analysis (Sklara San ++ System, Breda).

Interpretation of percolate pollution by N and P was made based on the State Regulation of water classification (NN, 1998 and 2008a) and Principles of health quality of drinking water (NN, 2008b).

RESULTS AND DISCUSSION

Average collected percolate by the lysimeters in the 5-year period was 172 mm with average variations among the years from 58 to 264 mm and among the sites from 135 to 201 mm. In average 172 mm or close to one fourth part of total precipitation (740 mm) were removed by percolation with average variations among the years from 9.5% to 29.6% and among the sites from 17.9% to 26.5% (Table 4).

Table 4. The amounts of percolateand precipitation removed by percolation

The amounts of percolate (mm) collected by the lysimeters in five localities†												
	Year						Year					
	2004	2005	2006	2007	2008	x	2004	2005	2006	2007	2008	x
	The collected percolate by lysimeters (mm)						Precipitation removed as percolate (% of total)					
L1	213	168	151	112	31	**135**	22.2	22.4	25.9	13.9	5.1	**17.9**
L2	245	199	175	137	56	**163**	25.6	26.6	30.0	17.0	9.3	**21.7**
L3	252	224	187	150	56	**174**	26.4	29.9	32.0	18.6	9.3	**23.3**
L4	304	223	178	177	66	**190**	31.2	29.8	30.5	21.9	10.9	**24.9**
L5	308	242	174	202	79	**201**	32.2	32.3	29.8	25.0	13.1	**26.5**
x	**264**	**211**	**173**	**156**	**58**	172	**27.6**	**28.2**	**29.6**	**19.3**	**9.6**	22.9
†L1 = Kladavac; L2 = Konjsko; L3 = Jasinje,							Yearly quantity of precipitation (mm) = 100%					
L4 = Dobrovo; L5= Crpiliste							956	749	584	807	604	740

Average N and P leaching by percolation (kg/ha) were 20.83 (N) and 0.77 (P) with average variation among the years from 9.11 to 43.46 (N) and from 0.45 to 1.34 (P) and among the sites from 7.22 to 29.51 (N) and from 0.52 to 0.98 (P), respectively (Table 5). Also, considerable variations of N and P leaching were found calculated in the values as percent of the nutrients added by fertilization as follows: from 6.6% to 20.5% N and from 1.16 to 2.30% P (the year effect), from 5.2 to 14.5% N and from 1.36% and 2.69% P (the site effect) with average values 12.2% N and 1.83% P, respectively (Table 5).

Very considerable variations of the seasonal N and P leaching both among the years and aong the sites (Table 6). With that regard, in general N leaching (Table 6) was more close related to seasonal precipition regime (Table 3) compared tp P leaching. For example, average 13.79 kg N/ha or 66.2% of total leached N was removed by percolation in autumn-winter period. At the same period was removed average 0.36 kg P/ha or 46.8%.

Table 5.Year and locality effects on mineral nitrogen and phosphorus leaching by percolation

Total mineral N and P leaching: impacts of year and location												
	Year						Year					
	2004	2005	2006	2007	2008	x	2004	2005	2006	2007	2008	x
	Nitrogen leaching (NO_3-N+ NH_4-N): kg N /ha						Phosphorus leaching (kgP/ha)					
L1	10.86	6.94	4.10	6.99	7.22	**7.22**	0.31	0.99	0.46	0.32	0.52	**0.52**
L2	21.91	13.64	31.28	29.84	11.43	**21.62**	0.43	0.51	2.28	0.49	0.68	**0.88**
L3	38.30	17.92	27.04	55.21	9.08	**29.51**	0.66	0.61	1.39	1.05	0.29	**0.80**
L4	9.08	17.32	19.22	63.00	8.74	**23.47**	0.28	0.73	1.93	1.30	0.68	**0.98**
L5	22.03	11.06	7.26	62.26	9.09	**22.34**	0.59	0.85	0.67	1.07	0.30	**0.70**
x	**20.43**	**13.38**	**17.78**	**43.46**	**9.11**	20.83	**0.45**	**0.74**	**1.34**	**0.84**	**0.49**	0.77
	N leaching (% of added by the fertilization)						P leaching (% of added by the fertilization)					
L1	14.7	3.5	2.1	2.8	2.8	**5.2**	0.89	2.84	1.32	0.81	0.92	**1.36**
L2	28.8	6.2	10.4	22.1	4.5	**14.4**	1.09	2.12	2.61	2.04	1.20	**1.81**
L3	22.0	7.9	9.7	27.6	4.8	**14.4**	1.51	1.87	1.87	2.00	0.63	**1.58**
L4	4.9	6.7	6.2	24.7	15.9	**11.7**	0.64	3.35	2.21	2.05	5.19	**2.69**
L5	31.9	10.0	4.5	23.0	3.3	**14.5**	1.69	1.30	3.07	1.96	0.57	**1.72**
x	**20.5**	**6.9**	**6.6**	**20.0**	**6.9**	12.2	**1.16**	**2.30**	**2.22**	**1.77**	**1.70**	1.83

Petošić et al (2011) investigated impact of fertilization (from 70 to 365 kg N/ha and from 35 to 185 kg P_2O_5/ha, depending on the year, locality and crop) on quality of the leaching water in Bidj-Bosut Field area for the 2002-2009 period. The leachate quantities ranged from 158 mm to 262 mm. The leachate was not significantly polluted by heavy metals, but that the mean values of NH_4-N, NO3-N and total N and P concentrations in the leachate occasionally exceeded the values of maximum permissible concentrations (MPCs) in all locations during the monitoring period (annually leaching from 4.10 to 63.0 kg N/ha and from 0.16 to 2.28 kg P/ha).

Table 6. The seasonal leaching of N and P by percolation

Seasonal total mineral N and P leaching in 2004-2008 period†												
	Year						Year					
Period	2004	2005	2006	2007	2008	Mean	2004	2005	2006	2007	2008	Mean
	Total mineral-N leaching (kg N/ha)						Total P leaching (kg P/ha)					
Winter	5.90	6.31	3.26	9.78	4.39	**5.93**	0.12	0.31	0.19	0.29	0.11	**0.20**
Spring	3.31	1.39	3.54	7.11	1.44	**3.36**	0.10	0.10	0.38	0.05	0.15	**0.16**
Summer	3.68	3.14	10.98	0.00	0.63	**3.69**	0.13	0.20	0.77	0.00	0.14	**0.25**
Autumn	7.54	2.54	0.00	26.57	2.65	**7.86**	0.10	0.13	0.00	0.50	0.09	**0.16**
Total	**20.43**	**13.38**	**17.78**	**43.46**	**9.11**	20.83	**0.45**	**0.74**	**1.34**	**0.84**	**0.49**	0.77
	Percent of total mineral N leaching						Percent of total P leaching					
Winter	28.9	47.1	18.3	22.5	48.2	**28.5**	26.7	41.9	14.2	34.5	22.4	**26.0**
Spring	16.2	10.4	19.9	16.4	15.8	**16.1**	22.2	13.5	28.3	6.0	30.6	**20.8**
Summer	18.0	23.5	61.8	0.0	6.9	**17.7**	28.9	27.0	57.5	0.0	28.6	**32.4**
Autumn	36.9	19.0	0.0	61.1	29.1	**37.7**	22.2	17.6	0.0	59.5	18.4	**20.8**
Total %	100	100	100	100	100	100	100	100	100	100	100	100

† winter: Januar-March; spring: April-June; summer: July-September; autumn: October-December;
LTA = the long-term average 1961-1990

Josipović et al. (2006) tested impacts of soybean growing season (2001, 2003 and 2005), nitrogen fertilization (0, 100 and 200 kg N/ha) and irrigation (non-irrigated and irrigation starting on 80% soil moisture compared to field water capacity) on total N leaching on Osijek eutric cambisol. Under drought conditions of 2003 (212 mm precipitation in May-September period) not found leachate, while in remaining two years average total N leaching were 3.40 and 13.14 kg N/ha, for 2001 and 2005, respectively. Considerable difference of N leaching between these two growing season could be atributed to precipitation quantities in July and August (84 mm and 335 mm, for 2001 and 2005, respectively) because total precipitation in May-September were similar (578 mm and 558 mm, respectively). Average ontribution of NO_3-N in total N leaching was 98.1%. N fertilization had considerably higher impact on N leaching compared to irrigation as follows: 2-year averages 2.39 and 14.12 kg N/ha for the control and application 200 kg N/ha, respectively; 7.38 and 9.10 kg N/ha, for non-irrigated and irrigated soil, respectively.

Schwarzel and Swaiger (2005, cit Petošić et al., 2011) reported that annual leaching from agricultural soil was 33 kg N/ha and 0.61 kg P/ha and similar results were found by Petošić(2007, 2008).In general, nitrates leaching from the surface soil layer under agroecological conditions of Croatia are the higher during autumn and winter period (Vidacek et al. 1999; Mesić et al., 1994, 2003;Petošić et al., 2004). Similar results were found in the central part of Hungary (Nemeth, 1996; Nemeth and Kadar, 1999).

Nemcic et al. (2007) analysed nitrate concentrations in drinking water from three weels of the northwestern Croatia and they were ranged from of 4.6 mg/ L in Kalnik (location without impact of agriculture and urbanization) to 28.7 mg/L in Koprivnica (location of intensive agriculture). . Ground water samples were collected weekly in the period from April 1st 2005 to April 1st 2006.

Mesić et al. (2017) applied during two growing seasons for maize total 180 kg N/ha on Vukovareutric cambisol by four ways of its distribution (180 in either in autumn or in spring before sowing, 70 in autumn and 110 in spring, 70 in autumn + 70 in spring + 40 by topdressing). Although the autumn nitrogen applications is not recommended due to greater risk of N loss, results of nitrogen content up to 90 cm soil depth show that different nitrogen application time did not significantly influenced on nitrogen accumulation in soil. Autumn fertilizer application has relatively contributed an increscent of nitrate nitrogen accumulation in soil.

Shuman (2003) found by greenhouse and lysimeter testing that P and N leached from high-porosity soil and adversely affect surface anf groundwater quality. The soluble NPK 20-20-20 and the 16-25-12 sources each resulted in 43% of the added P eluting in the leachate, whereas the others varied from 15 to 25%. The lowest cumulative mass of nitrate-N was for the controlled-release NPK 13-13-13 and sulfur-coated urea.

According Petošić et al. (2018) the surface waters of Bidj-Bosut watercourses are considerable polluted by N and P substances because average concentrations of total N and P in the lysimeter water were above maximal permissible 11.3 mg N/l and 0.3 mg P/l. Also, the underground water in solum of agricultural soils were classified in the group III of ecological quality according criteria NN (1998) and NN (2008a). This phenomenom could be explained by domination of maize in crop rotation and its high requirements for fertilization, particulary with nitrogen.

CONCLUSION

The weather conditions in investigated 2004-2008 period were considerably deviated from 1961-1990 averages in accordance with recent climatic change. In general, onsiderable variations among the years and among the the sites were found were found in amounts of collected percolate and leaching of N and Pby percolation. Yearly collected percolate were in average range from 58 to 264 mm. In average, one fourth part of precipitation was removed by percolation. Average N and P leaching by percolation were close to 21 kg N/ha and bellow 1.00 kg P/ha. About two third part of total N and close to half of total P were leached in autumn-winter period. Also, average about 12% of N by and bellow 2% of added P by fertilization were removed by percolation.

Soil and crop management practice, particularly domination of maize and the other crops with high N-requirements and correspondingle fertilization are potentially risk for soil and water pollution above maximal permissible amounts. Adequate crop rotation with lower percent of maize and inclusion the other crops characterized by lower N demands could be contribute to mitigate pollution of underground and surface waters by NO_3 and NH_4 ions. Also, in our study soil type was important factor of percolater amounts and N leaching by percolation. However, by available soil data we cannot to explain reasons of these differences.

According our results, the risk of N pollution by the influence of agriculture is considerably higher than that of P contamination. Minorising this problem could by resulted in future by a serious environmental, economic and health problems for human population.

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IZVOD

ISPIRANJE AZOTA I FOSFORA IZ HIDROMORFNOG ZEMLJISTA BIDJ-BOSUTA U HRVATSKOJ

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Cilj ovoga rada je istraživanje ispiranja azota (N) i fosfora (P) s pet hidromorfnih zemljišta Biđ-Bosut polja u periodu od 2004 do 2008. Ukupno deset lizimetara je instalisano za prikupljanje perkolata. Područje pokriveno proticanjem perkolata do 55 cm dubine iznosilo je 0,2 m^2 u obliku plate (ø 50 cm). Prosečno đubrenje tokom godine (kg/ha) za useve u različitom plodoredu (lucerka, kukuruz, pšenica, ječam i soja) iznosilo je 195 kg N/ha i 104 kg P_2O_5 /ha. Prosečna količina prikupljenog perkolata bila je 172 mm s rasponom između godina od 58 do 264 mm i između pet mesta od 135 do 201 mm. U proseku 172 mm ili blizu jedne četvrtine padavina (740 mm) bilo je procеđeno perkolacijom. Prosečno ispiranje N i P perkolacojim iznosilo je 20,83 kg N/ha i 0,77 kg P/ha s rasponima između godina od 9,11 do 43,46 (N), odnosno 0,45 do 1,34 (P) i između mesta od 7,22 do 29,51 (N) i od 0,52 do 0.98 (P). Prosečno 13,79 kg N/ha ili 66,2% od ukupnog i 0,36 kg P/ha ili 46,8% od ukupnog isprano je u jesenskom i zimskom periodu. Zavisno o godini, od 6,6% do 20,5% N i od 1,16 do 2,30% P dodanog đubrenjem je isprano perkolacijom. Generalni zaključak je da agrotehnika analiziranog područja predstavlja potencijalnu opasnost u pogledu onečišćenja podzemnihi površinskih voda azotom, a znatno manje fosforom.

Ključne reči: azot, fosfor, lizimetri, ispiranje, hidromorfna zemljišta

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