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Influence of organic agricultural production on the condition of surface water

Rasa Žolynaitė*,

Skirmantas Pocius,

Laima Česonienė

Vytautas Magnus University,
K. Donelaičio St. 58,
44248 Kaunas, Lithuania

Agriculture and its methods of operation constantly influence the quality of water of surface water bodies. It was established in 2021 that in Lithuania, 63% of water bodies of the river and 64% of the lake categories are classified as risk water bodies and do not meet the good condition criteria. One of the main factors leading to the deterioration of the condition of surface water bodies is the continuing and increasing diffuse pollution, mainly from agricultural activities, together with pollution from agriculture; also, the condition in some water bodies deteriorates because of concentrated pollution, persistent effects of hydromorphological changes in surface water bodies, natural processes, and changing climatic conditions. This study aimed to determine the degree at which the ecological method of agricultural production affects the nearby surface water bodies. The obtained results show that the larger the area of organic farms from the entire area of the nutrient basin of a lake, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus, nitrate nitrogen, and total nitrogen concentrations. The ecological method of agricultural production has a positive effect on the condition of surface water bodies.

Keywords: water body, condition class, organic farm

INTRODUCTION

According to various researchers, the increasing level of the use of water resources and their pollution with wastewater from domestic, industrial and agricultural sectors, pose a great challenge to human health, especially in economically developed areas (Jiang et al., 2020). Diffuse and other water pollution is a major problem in many agroecosystems, especially in irrigated areas associated with ecosystems of high ecological value (Alcon et al., 2020). Various studies show that excessive use of chemical fertilisers and pesticides has caused serious non-point source water pollution (Xiao et al., 2021). Modern agriculture is increasingly dependent on chemical fertilisers, especially in developing countries (FAOSTAT, 2021). Fertilisers and manures applied to crops to increase yields are often lost through surface erosion, soil leaching, and runoff, and water quality is degraded as nutrients are added to surface and groundwater (Waller et al., 2021).

According to the requirements of the General Water Policy Directive (Environmental Protection

* Corresponding author. Email: rasazolynaite86@gmail.com

Agency under the Ministry of Environment), surface water bodies are divided into the categories of rivers, lakes, intermediate and coastal water bodies and are assigned to river basin districts (RBD). After assessing the condition of water bodies in 2021, it was found that in Lithuania, 63% of water bodies in the category of rivers and 64% in the category of lakes were classified as risk water bodies and did not meet the criteria of good condition. About 57% of river and 62% of lake water bodies in the Nemunas RBD, 94% and 95% in the Lielupe RBD, 66% and 90% in the Venta RBD, and 22% and 44% in the Daugava RBD did not meet the criteria of good condition (Environmental Protection Agency under the Ministry of Environment, 2022).

The condition of surface water bodies is most negatively affected by diffuse pollution, mainly from agricultural activities (42% of significantly affected bodies). Diffuse agricultural pollution consists of leaching of nitrogen and phosphorus compounds into the soil with animal manure and mineral fertilisers into surface water bodies. The extent of the impact is determined by the intensity of agricultural activity. Crop production in Lithuania has greatly intensified compared to the period of 2010–2013 (Environmental Protection Agency under the Ministry of Environment, 2022). According to statistics, on average, in the period of 2016–2022, agricultural land was used 5.3% more than before 2016. The area of intensively cultivated crops (cereals and rape) also increased by 21%. Compared to the previous period, the sales of mineral nitrogen fertilisers increased by 14%, phosphorus – by as much as 31% in Lithuania. Also, the areas of extensively used crops (grasses and herbaceous plants) decreased by 14%. The number of contracted animals decreased by about 9%. Since the areas of intensively cultivated crops increased, the use of mineral fertilisers also increased. These changes led to the increasing impact of agriculture and a significant impact on water bodies. To assess the impact of ecological methods of agriculture on the quality of underground and surface water, surface water of rivers or other water bodies and drainage water is usually analysed in Lithuania (Živatkauskienė, 2020; Adamonytė et al., 2018; Povilaitis, 2016).

Phosphorus (P) and nitrogen (N) compounds added to the soil with organic and mineral fertilisers have the greatest impact on the quality of and eutrophication processes in surface water (Robles-Rodriguez, 2021; Sena et al., 2021), therefore, in order to assess the impact of agricultural production on the quality of surface water, phosphorus and nitrogen content in the soil were assessed.

The study aimed to evaluate the influence of the ecological methods of agricultural production on the condition of surface water.

MATERIALS AND METHODS

To assess the influence of ecological methods of agriculture on the quality of surface water, the surface water bodies of southern Lithuania, the Nemunas RBD, located near farms whose agricultural production method is ecological and meets the established requirements (certified), were studied in this work. A comparative analysis of the results was carried out. The lakes researched included Alovė, Aviris, Galstas, Pabezninkai, Giluitis, Dusia, and Guostus (Figure).

The studied surface water bodies were analysed according to the data obtained from the database of the Environmental Protection Agency under the Ministry of Environment, from the research results of the state programme of monitoring of rivers, lakes and ponds. The ecological condition of surface water was assessed according to physico-chemical quality indicators: total nitrogen (N), total phosphorus (P), phosphate phosphorus (PO_4-P), nitrites (NO_2), nitrate nitrogen (NO_3-N), biochemical oxygen consumption during Day 7 (BDS7).

The assessment of surface water is based on the methodology for determining the condition of surface water bodies (total nitrogen (N), total phosphorus (P) and biochemical oxygen consumption within seven days (BOD_7), criteria for classes of the ecological condition of lakes based on the values of the indicators of

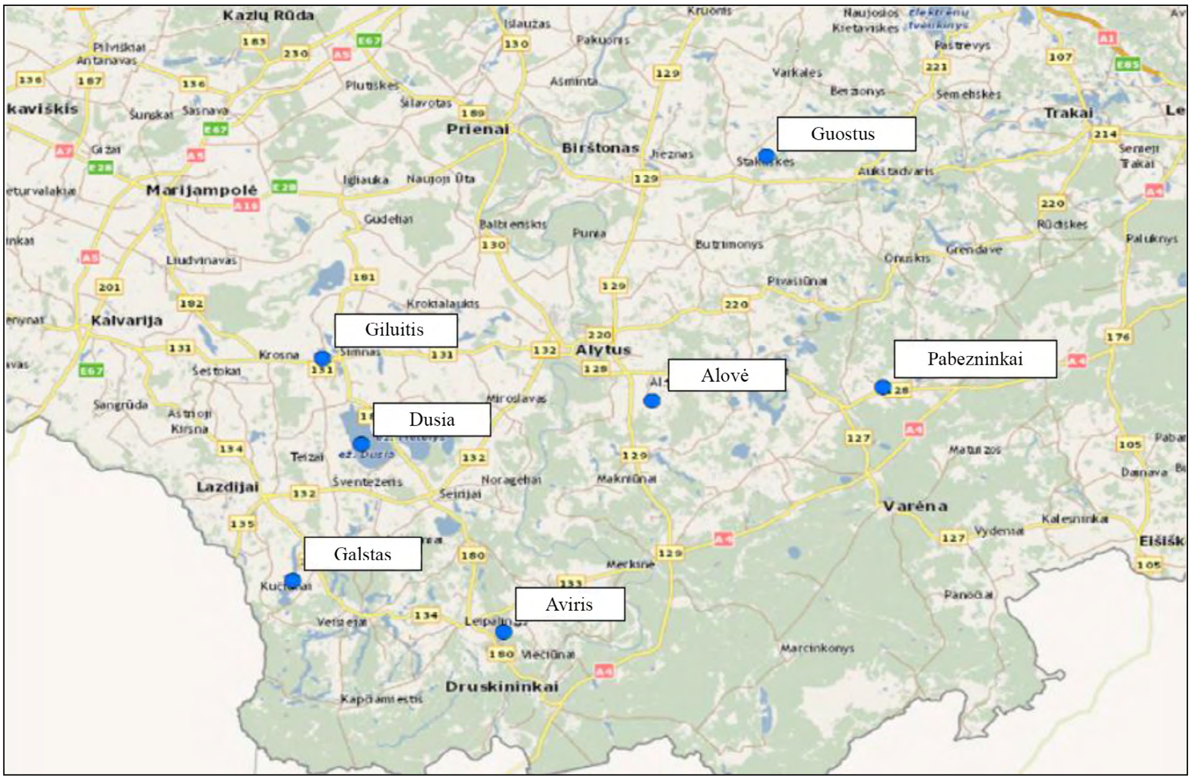

Figure. Surface water bodies researched

physico-chemical quality element. Phosphate phosphorus (PO_4-P) and nitrites (NO_2) were evaluated according to the requirements for the protection of surface water bodies where freshwater fish can live and breed.

The 2021–2022 data on the areas of organic farms from certification institutions (databases) are used, which include all declared and certified areas of organic farms in Lithuania located near the surface water bodies studied.

The water bodies studied are evaluated according to the values of hydromorphological indicators: the water body area, in square kilometres; maximum depth, in metres; average depth, in metres; the area of the nutrient basin, in square kilometres; length of coastline, in kilometres. The intensity of economic activity in the basin is assessed according to the area of organic farms in the basin, in square kilometres; the area of organic farms in the total area of the basin, as a percentage, and the number of organic farms in the basin of the water body.

The obtained research data were processed using the Microsoft Office Excel 2010 program. Correlation coefficients were calculated to assess the relationship between the values of surface water quality indicators and the area, maximum and average depth of water bodies, the area of the nutrition basin, the length of the shoreline, the area of organic farms in the basin, the area of organic farms in the total area of the basin, and the number of organic farms in the water body basin, $p < 0.05$, with STATISTICA 10 software.

RESULTS AND DISCUSSION

The 2006-to-2022 results of the lakes researched were examined. The state of surface water was assessed by systematising physicochemical quality indicators: total nitrogen (N), total phosphorus (P), phosphate phosphorus (PO_4-P), nitrites (NO_2), nitrate nitrogen (NO_3-N), biochemical oxygen consumption within seven days (BOD_7) and dissolved oxygen concentration (O_2). The assessment of the condition of the studied surface water bodies is presented in Table 1.

After analysing the data and based on the decision of 12 April 2007 of the Minister of the Environment of the Republic of Lithuania

Table 1. **The condition of the investigated surface water bodies**

Years of research	N mg/lN	P mg/lP	PO_4-P mg/l P	NO_3-N mg/l N	NO_2^- mg/l N	BDS_7 mg/l O_2	Oxygen saturation %
				Alovė			
2009	2.45	0.088	0.037	0.29	0.025	5.52	0.97
2013	1.44	0.055	0.008	0.55	0.007	5.75	1.24
2016	1.65	0.041	0.006	0.18	0.138	5.65	1.27
2019	1.13	0.057	0.014	0.58	0.007	4.48	1.21
2022	1.01	0.046	0.022	0.23	0.0065	3.95	0.91
				Aviris			
2006	1.38	0.038	0.009	0.27	0.007	3.62	1.102
2011	0.75	0.024	0.012	0.05	0.003	3.18	1.087
2016	0.5	0.027	0.007	0.10	0.001	2.75	1.069
2022	0.7	0.027	0.012	0.09	0.003	2.2	1.091
				Galstas			
2010	0.75	0.044	0.031	0.04	0.004	2.65	1.045
2014	0.65	0.022	0.009	0.04	0.001	2.38	1.007
2022	0.32	0.024	0.009	0.08	0.005	2.23	1.004
				Pabezninkai			
2008	1.48	0.055	0.051	0.35	0.003	4.1	0.891
2016	1.35	0.074	0.009	0.24	0.006	4.8	0.972
2019	1.55	0.073	0.015	0.19	0.006	2.08	1.015
2022	1.6	0.064	0.015	0.14	0.009	3.3	0.697
				Giluitis			
2010	1.73	0.025	0.012	0.54	0.007	2.98	1.116
2014	0.95	0.032	0.013	0.3	0.006	2.38	1.001
2022	1.65	0.024	0.008	1.16	0.030	3.2	1.023
				Dusia			
2007	0.9	0.028	0.010	0.03	0.002	2.53	0.956
2013	0.45	0.0195	0.005	0.02	0.005	1.05	0.978
2017	0.45	0.024	0.003	0.02	0.007	2.23	0.964
2022	0.41	0.029	0.009	0.05	0.003	2.08	0.973
				Guostus			
2008	1.15	0.021	0.007	0.11	0.003	2.73	0.944
2012	0.88	0.017	0.005	0.05	0.003	1.78	0.962
2015	0.5	0.011	0.006	0.03	0.001	1.53	1.041
2022	0.66	0.033	0.013	0.14	0.005	3.05	1.013

Very good ecological status class   Good ecological status class   Average ecological status class

No. D1-210 'On the approval of the methodology for determining the condition of surface water bodies', the surface water bodies tested in terms of N and P concentrations corresponded to the values of the classes of very good and good ecological status, except for N and P indicators of 2009 for Alovė, which corresponded to the values of the class of average ecological status; in terms of P concentrations in 2016, 2019, and 2022, Pabezninkai corresponded to the values of the average ecological status class. According to BOD_7 values, all studied water bodies corresponded to the values of the classes of very good and good ecological status, with the exception of Alovė, which in 2009, 2013, 2016, and 2019 corresponded to the values of the class of average ecological status; Pabezninkai corresponded to the values of the class of average ecological status in 2016.

The area of water bodies studied, in square kilometres, the maximum depth, in metres m, the average depth, in metres, the area of the nutrition basin, in square kilometres, the length of the shoreline, in kilometres, the area of organic farms in the basin, in square kilometres, the area of organic farms in the total area of the basin, as a percentage, and the number of organic farms in the basin of the water body are presented in Table 2.

In terms of area, the largest is Dusia (23.46 km^2), the smallest is Pabezninkai (0.661 km^2). The deepest lakes in terms of maximum and average depth are Galstas (50/14.1 m), Aviris (32.8/9.6 m), Guostas (33.7/18.5 m), and Dusia (33.7/18.5 m). The shallowest lakes are Pabezninkai (3/1.9 m) and Alovė (4.4/2.5 m). The largest area of the nutrition basin is Dusia (107.8 km^2), the smallest is Alovė (7.75 km^2). Dusia has the longest shoreline length (23.43 km) and Pabezninkai the shortest (4.6 km). The largest area of organic farms is in the basin of Giluitis (2.72 km^2) and the smallest in the basin of Guostus (0.2019 km^2). After evaluating the area of organic farms as a percentage of the entire lake nutrition basin, it was found that the largest percentage of organic farms was in the basin of Giluitis (7.85%) and the lowest in the basin of Dusia (0.35%). Only one ecological farm of agricultural production was registered in each basin, with the exception of the basin of Aviris, which had two ecological farms.

Correlation coefficients were calculated in order to evaluate the relationships between the values of surface water quality indicators and the area of water bodies, the maximum and the average depth, the area of the nutrition basin, the length of the shoreline, the area of organic farms in the basin, the area of organic farms in the total area of the basin, and the number of organic farms in the basin of the water body. These results are presented in Table 3.

After calculating the correlation coefficients, a statistically strong negative relationship was found between the maximum lake depth and total nitrogen concentration (N) (r = –0.897, p = 0.006), total phosphorus concentration (P)

Table 2. **Hydromorphological and economic indicators of the surface water bodies studied**

Name of the lake	Lake area, km^2	Max depth, m	Average depth, m	Pool area, km^2	Area of organic farms, km^2	The area of organic farms in the total area of the basin, %	Length of the coastline, m	Number of organic farms, units
Alovė	0.797	4.40	2.5	7.75	0.5121	6.61	5.42	1
Aviris	1.500	32.8	9.6	26.2	1.4598	5.57	11.4	4
Galstas	3.918	50.0	14.1	68.0	2.1087	3.10	18.99	1
Pabezninkai	0.661	3.00	1.9	11.8	0.9119	7.73	4.6	1
Giluitis	2.350	22.0	8.9	34.8	2.7300	7.85	9.15	1
Dusia	23.46	32.4	15.4	107.8	0.3807	0.35	23.46	1
Guostus	0.756	33.7	18.5	23.2	0.2019	0.87	4.85	1

Table 3. **Correlation matrix of the values of surface water quality indicators and the area of water bodies, maximum and average depth, the area of the nutrition basin, the long shoreline, the area of organic farms in the basin, the area of organic farms in the total area of the basin, and the number of organic farms in the water body basin (statistically significant relationship are given in red)**

Water quality indicator	Lake area, m	Max. depth, m	Average depth, m	Length of the coast-line, m	Pool area, km^2	Area of organic farms, km^2	The area of organic farms in the total area of the basin, %
N, mg/l N	$r = -0.538$ $p = 0.213$	$r = -0.897$ $p = 0.006$	$r = -0.854$ $p = 0.014$	$r = 0.750$ $p = 0.042$	$r = 0.73$ $p = 0.049$	$r = 0.122$ $p = 0.795$	$r = -0.862$ $p = 0.013$
P, mg/l P	$r = -0.339$ $p = 0.458$	$r = -0.828$ $p = 0.021$	$r = -0.899$ $p = 0.006$	$r = 0.488$ $p = 0.266$	$r = 0.53$ $p = 0.217$	$r = -0.197$ $p = 0.672$	$r = -0.739$ $p = 0.042$
PO_4-P, mg/l P	$r = -0.487$ $p = 0.268$	r = −0.554 $p = 0.197$	$r = -0.779$ $p = 0.039$	$r = 0.395$ $p = 0.381$	$r = 0.48$ $p = 0.272$	$r = 0.115$ $p = 0.806$	$r = -0.744$ $p = 0.020$
NO_3-N, mg/l N	$r = -0.374$ $p = 0.409$	$r = -0.519$ $p = 0.233$	$r = -0.520$ $p = 0.232$	$r = 0.451$ $p = 0.310$	$r = 0.43$ $p = 0.331$	$r = 0.535$ $p = 0.216$	$r = -0.755$ $p = 0.049$
NO_2-N, mg/l N	$r = -0.247$ $p = 0.593$	$r = -0.632$ $p = 0.128$	$r = -0.613$ $p = 0.144$	$r = 0.391$ $p = 0.385$	$r = 0.43$ $p = 0.337$	$r = -0.093$ $p = 0.842$	$r = -0.469$ $p = 0.289$
BDS_7, mg/l O_2	$r = -0.494$ $p = 0.259$	$r = -0.786$ $p = 0.036$	$r = -0.858$ $p = 0.014$	$r = 0.598$ $p = 0.156$	$r = 0.69$ $p = 0.047$	$r = -0.131$ $p = 0.779$	$r = -0.676$ $p = 0.045$

($r = -0.828$, $p = 0.021$), and biochemical oxygen consumption values (BOD_7) ($r = -0.786$, $p = 0.036$): the greater the maximum water depth, the lower the values of biochemical oxygen consumption, total phosphorus, and total nitrogen concentrations.

A statistically strong negative correlation was found between the average lake depth and total nitrogen concentration (N) ($r = -0.858$, $p = 0.014$), total phosphorus concentration (P) ($r = -0.899$, $p = 0.006$), phosphate phosphorus concentration (PO_4-P) ($r = -0.779$, $p = 0.039$), and biochemical oxygen consumption values (BOD_7) ($r = -0.858$, $p = 0.014$): the greater the average water depth, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus, and total nitrogen concentrations.

A statistically strong positive relationship between the length of the shoreline and the concentration of total nitrogen (N) was established ($r = 0.750$, $p = 0.042$): the longer the shoreline, the higher the concentration of total nitrogen.

A statistically strong positive relationship was established between the area of the nutrient pool, the concentration of total nitrogen (N) ($r = 0.730$, $p = 0.049$), and the value of biochemical oxygen consumption (BOD_7) ($r = 0.690$, $p = 0.047$): the larger the area of the nutrient basin of the water body, the higher the values of biochemical oxygen consumption and total nitrogen concentrations.

A statistically strong negative correlation was found between the area of organic farms in the total basin area and total nitrogen concentration (N) ($r = -0.862$, $p = 0.013$), total phosphorus concentration (P) ($r = -0.739$, $p = 0.042$), phosphate phosphorus concentration (PO_4-P) ($r = -0.744$, $p = 0.020$), nitrate nitrogen concentration (NO_3-N) ($r = -0.755$, $p = 0.049$), and biochemical oxygen consumption values (BOD_7) ($r = -0.676$, $p = 0.045$): the larger the area of organic farms in the total basin area, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus, nitrate nitrogen and total nitrogen concentrations.

CONCLUSIONS

1. It was established that in terms of N, P and BOD_7 values, the surface water bodies studied correspondeded to the values of the classes of very good and good ecological status, with

the exception of Alovė, which, in terms of N and P in 2009, corresponded to the values of the class of average ecological state; in terms of P concentrations in 2016, 2019, and 2022, Pabezninkai corresponded to the values of the average ecological status class. According to BDS7 values, Alovė in 2009, 2013, 2016 and 2019, and Pabezninkai in 2016 corresponded to the values of the medium ecological status class.

2. After calculating the correlation coefficients, a statistically strong negative relationship was found between the maximum lake depth and N (r = –0.897, p = 0.006), P (r = –0.828, p = 0.021), BOD_7 (r = –0.786, p = 0.036). A statistically strong negative correlation was found between average lake depth and BDS_7 values of N (r = –0.858, p = 0.014), P) (r = –0.899, p = 0.006), PO_4-P (r = –0.779, p = 0.039) (r = –0.858, p = 0.014). A statistically strong positive correlation was found between the shoreline length and N (r = 0.750, p = 0.042). p = 0.047).

3. The larger the area of organic farms from the total basin area, the lower the values of biochemical oxygen consumption, total phosphorus, phosphate phosphorus, nitrate nitrogen and total nitrogen concentrations. A statistically strong negative correlation was found between the area of organic farms from the total basin area and total nitrogen concentration (N) (r = –0.862, p = 0.013), total phosphorus concentration (P) (r = –0.739, p = 0.042), phosphate phosphorus concentration (PO_4-P) (r = –0.744, p = 0.020), nitrate nitrogen concentration (NO_3-N) (r = –0.755, p = 0.049) and biochemical oxygen consumption values (BOD_7) (r = –0.676, p = 0.045).

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Rasa Žolynaitė, Skirmantas Pocius, Laima Česonienė

EKOLOGINĖS ŽEMĖS ŪKIO GAMYBOS POVEIKIS PAVIRŠINIO VANDENS BŪKLEI

Santrauka

Žemės ūkis, jo veiklos būdai nuolat turi įtakos paviršinių vandens telkinių vandens kokybei. Nustatyta, kad Lietuvoje 63 % upių ir 64 % ežerų vandens telkinių priskirti rizikos grupei ir neatitinka geros būklės kriterijų. Pagrindiniai veiksniai, lėmę pablogėjusią vandens telkinių būklę, yra besitęsianti ir didėjanti pasklidoji tarša – daugiausiai dėl žemės ūkio veiklos, kai kurių vandens telkinių būklei turėjo įtakos ir sutelktoji tarša, ilgalaikiai hidromorfinių paviršinių vandens telkinių pokyčiai, gamtiniai procesai ir kintančios klimatinės sąlygos. Šiuo tyrimu siekta nustatyti ekologinės žemės ūkio gamybos poveikį šalia esantiems paviršiniams vandens telkiniams. Gauti rezultatai rodo, kad kuo didesnis ekologinių ūkių plotas viso ežero mitybos baseino plote, tuo biocheminio deguonies sunaudojimo vertės, bendrojo fosforo, fosfatų fosforo, nitratų azoto ir bendrojo azoto koncentracijos mažesnės. Ekologinė žemės ūkio gamyba daro teigiamą poveikį paviršinių vandens telkinių būklei.

Raktažodžiai: vandens telkinys, būklės klasė, ekologinis ūkis