land

Article

Influence of Anthropogenic Load in River Basins on River Water Status: A Case Study in Lithuania

Laima Česonienė [1,*], Daiva Šileikienė [1] and Midona Dapkienė [2]

[1] Department of Environment and Ecology, Faculty of Forest Science and Ecology, Vytautas Magnus University, Agriculture Academy, Studentų Str. 11, LT–53361 Akademija, Lithuania; daiva.sileikiene@vdu.lt
[2] Department of Water Engineering, Faculty of Engineering, Vytautas Magnus University, Agriculture Academy, Universiteto Str., 10, LT–53361 Akademija, Lithuania; midona.dapkiene@vdu.lt
* Correspondence: laima.cesoniene1@vdu.lt; Tel.: +370-37-752224

Abstract: Twenty-four rivers in different parts of Lithuania were selected for the study. The aim of the research was to evaluate the impact of anthropogenic load on the ecological status of rivers. Anthropogenic loads were assessed according to the pollution sources in individual river catchment basins. The total nitrogen (TN) values did not correspond to the "good" and "very good" ecological status classes in 51% of the tested water bodies; 19% had a "bad" to "moderate" BOD_7, 50% had "bad" to "moderate" NH_4-N, 37% had "bad" to "moderate" NO_3-N, and 4% had "bad" to "moderate" PO_4-P. The total phosphorus (TP) values did not correspond to the "good" and "very good" ecological status classes in 4% of the tested water bodies. The largest amounts of pollution in river basins were generated from the following sources: transit pollution, with 87,599 t/year of total nitrogen and 5020 t/year of total phosphorus; agricultural pollution, with 56,031 t/year of total nitrogen and 2474 t/year of total phosphorus. The highest total nitrogen load in river basins per year, on average, was from transit pollution, accounting for 53.89%, and agricultural pollution, accounting for 34.47%. The highest total phosphorus load was also from transit pollution, totaling 58.78%, and agricultural pollution, totaling 28.97%. Multiple regression analysis showed the agricultural activity had the biggest negative influence on the ecological status of rivers according to all studied indicators.

Keywords: pollution; ecological status indicators; water quality

check for updates

Citation: Česonienė, L.; Šileikienė, D.; Dapkienė, M. Influence of Anthropogenic Load in River Basins on River Water Status: A Case Study in Lithuania. *Land* **2021**, *10*, 1312. https://doi.org/10.3390/land10121312

Academic Editors: Wiktor Halecki, Dawid Bedla, Marek Ryczek and Artur Radecki-Pawlik

Received: 25 October 2021
Accepted: 26 November 2021
Published: 28 November 2021

1. Introduction

Lithuania is committed to achieving the objectives of the EU Water Framework Directive by 2027 and to achieving good water status in inland waters. There are approximately 30 thousand rivers and creeks in Lithuania, with a longer than 200 m, reaching an overall sum of 63,700 km. Although the ecological condition of Lithuanian rivers has been mostly improving over the last few years, it has been determined that only 49% of them correspond to a good ecological state [1], in the period of 2010–2013.

Human activities change the hydromorphological, physicochemical, and biological parameters of surface water bodies, affecting their biodiversity and ecological functioning [2–9]. Pollution caused by anthropogenic activity sufficiently worsens the state of water ecosystems, resulting in water quality degradation, reducing the potential for water use in various fields and endangering people health [10–14].

Sources of pollution are divided as follows: background pollution (forests), diffuse (non-point) pollution from agricultural lands, surface sewage that is not treated in wastewater treatment plants (WWTPs), and concentrated (point) pollution caused by households, urban, municipal, industrial wastewater (wastewater treatment plants), and others. Human activities affect the condition of water bodies differently in rural areas (agricultural activities, livestock) and urban areas (industrial, municipal, domestic wastewater discharges). Changes of land use also have a negative effect on water condition of rivers [15–21]. Landscape changes caused by anthropogenic activities and land cover make a significant influence on the state of surface waters [22–24], are closely related to water chemical parameters [25], the diversity of fish and macroinvertebrate species [24,26], and sediment metal concentrations [27]. Fragmented urban land use, with many impermeable surfaces, tends to increase river flows and adversely affects water quality [28–30].

Many research have been conducted to evaluate the ecological status of surface waters [31–36]. The multiple anthropogenic pressures (pollution, hydrological, and hydromorphological alterations) on the ecological status of the European rivers were assessed. In one third of the territory of the European Union, the ecological status of rivers has been found to be good, which is linked to the existence of natural areas, and urbanization is leading to poorer ecological status [37].

A concentrated source of pollution is wastewater from factories and households, and it is insufficiently treated and controlled [38–40]. Joshua et al. (2017) have pointed out that substandard practices of wastewater treatment are utilized in developing countries. In these countries, the major causes for this include the insufficient number of wastewater treatment plants, overloading and ineffective operation of existing WWTPs, and others [41].

Diffuse pollution is one of the main problems in irrigated areas. Intensive irrigation and fertilization of arable land and pastures have the greatest negative impact [42,43].

The sewage from residents and their house-holds' lack of connection to the wastewater collection networks also forms diffuse pollution that enters rivers [44]. Diffuse pollution covers large areas, and all such areas are polluted quite equally [45]. Very important diffuse pollution source affecting the condition of rivers is inadequate farming [46–49]. The riverbanks are a suitable place for agriculture, as they are particularly productive. Diffuse pollution is caused not only by farming on riverbanks, but also by agricultural activities in all the river basin. The use of chemical fertilizers and pesticides is an essential part of diffuse pollution entering surface water bodies [50]. Both organic and mineral fertilizers are used to fertilize crops; however, due to erosion, soil leaching, and runoff, they enter surface water bodies and contaminate them with nutrients [51]. Agriculture was the cause of 48% of the deterioration in water quality of surface water bodies of USA [52]. Approximately 30–35% of nitrogen and 10–15% of phosphorus, which pollute surface waters, have been found to come from agricultural activities [53].

Generally, Lithuanian surface water bodies are impacted by both diffuse and concentrated source pollution. In Lithuania, the effect of pollution on the condition of Venta and Mūša-Lielupė river basins was evaluated [38,54,55]. According to the biochemical oxygen demand (BOD_7), human activity accounted for 56% of the influence of pollution on water quality, and 90% of the annual borne total nitrogen (TN) and 78% of the total phosphorus (TP) content in the Merkys River [56]. Of the bodies of water, 46% did not achieve a "good" status in terms of nitrate nitrogen in 2017 [57]. Export coefficients and the retention of biogenic nutrients in Lithuanian river basins were assessed using the MESAW statistical model. The export coefficients of TN and TP showed much higher values from arable land in comparison to forest area, pastures, and meadows from the studied Merkys, Mūša, Žeimena, and Nevėžis river basins, and retained from 67% to 78% of the total nitrogen and from 24% to 63% of the total phosphorus [58].

We performed a study of the effectiveness of diffuse pollution abatement measures in reducing the nutrient pollution of surface water bodies in Lithuania in the context of climate change. The SWAT model was used for this purpose. The results show that climate change is a significant factor in changing the effectiveness of measures to reduce diffuse pollution. The most effective measures to reduce nutrients inputs to water bodies were identified, including pasture/meadow expansion, stubble abandonment for winter, and catch crop cultivation; arable farming was the least efficient method [59].

The aim of this research is to evaluate the impact of anthropogenic load on indicators of the ecological status of rivers.

2. Materials and Methods

2.1. Study Area

To determine the risk of water bodies that do not comply with the water quality standards, the physicochemical quality indicators at 94 locations of 24 rivers were studied. Water samples were taken between January and March, April and June, July and September, and October and December in 2014–2020. The investigated river's water sampling areas and their hydrological data are presented in Figure 1 and Table 1.

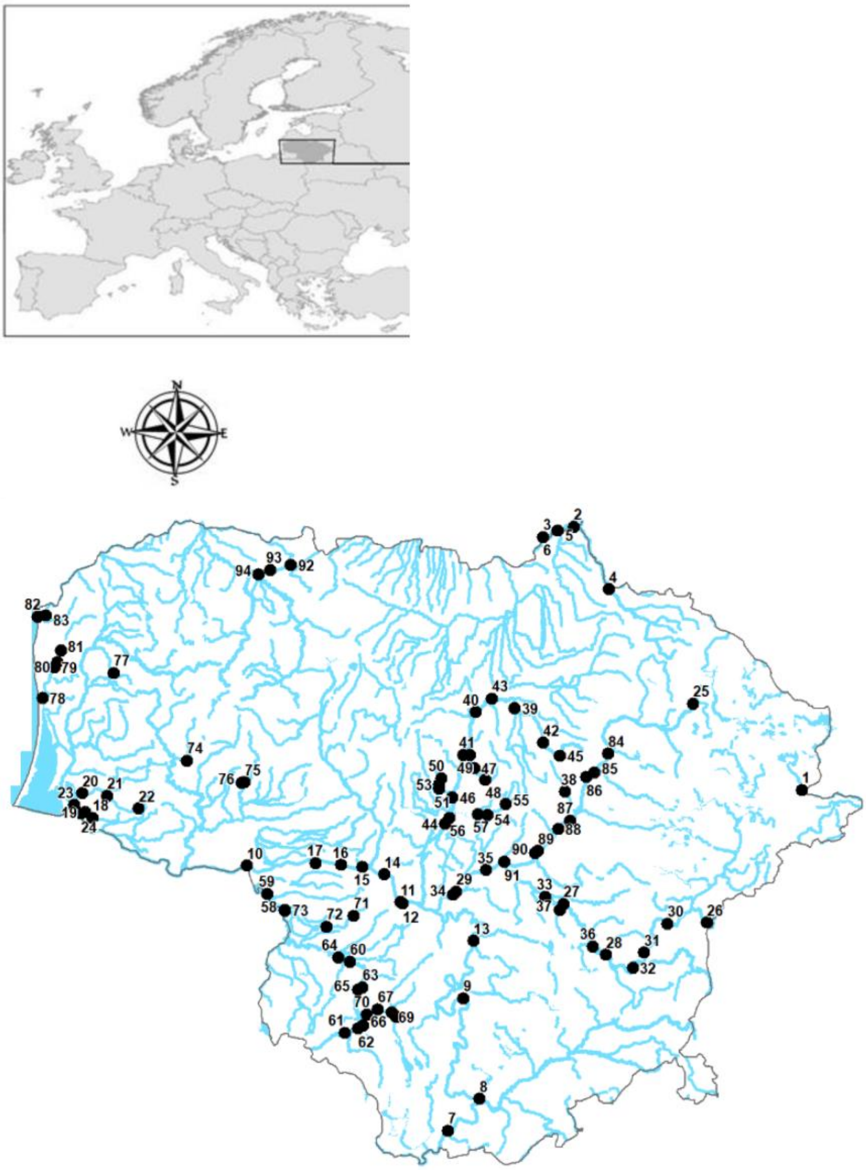

Figure 1. River's water sampling areas.

Table 1. Hydrological data of rivers.

River	Length, km	Length in Lithuania, km	Basin Area, km^2	Basin Area in Lithuania, km^2	Average Flow Rate, m^3/s	Number of Sampling Points	Number on the Map (Figure 1)
Dysna	176	77	8193	726	3.59	1	1
Nemunėlis	191	151	4048	3770	95	5	2–6
Nemunas	937.4	359	98,200	46,600	540	11	7–17
Leitė	26.2	26.2	143	143	1.5	2	18–19
Šyša	61	61	410	410	1.88	3	20–22
Skirvytė	9					2	23–24
Šventoji	246	246	6888.8	6800.7	55.1	11	25; 82–91
Neris	510	237.8	24,942.3	1392	181	10	26–35
Bražuolė	22.7	22.7	109.4	109.4	0.71	1	36
Žiežmara	24	24	65	65	0.49	1	37
Mušia	29	29	227.3	227.3	1.69	1	38
Nevėžis	209	209	6140	6140	33.2	8	39–46
Linkava	36.8	36.8	163.4	163.4	0.82	3	47–49
Kruostas	28.9	28.9	99.7	99.7	0.5	4	50–53
Obelis	53.3	53.3	673.8	673.8	2.7	4	54–57
Šešupė	297.6	297.6	6104.8	4899	34.2	9	58–66
Dovinė	65	65	588.7	588.7	3.4	4	67–70
Nova	69	69	403	403	1.24	3	71–73
Lokysta	46.3	46.3	173	173	2.12	1	74
Ančia	66.4	66.4	278.6	278.6	2.82	1	75
Agluona	22	22	76	76	0.98	1	76
Alantas	43	43	146	146	181	1	77
Akmena—Danė	62.5	62.5	595	595	6.9	4	78–81
Dabikinė	37.2		387.6		2.39	3	92–94

2.2. Water Quality Assessment Standards

The ecological statuses of water bodies at risk were assessed in accordance with the Procedure for Rating the Ecological Status of Surface Water Basin [60]. Research on the physical and chemical quality of elemental indicators have been identified in a laboratory at Vytautas Magnus University. Water samples were collected according to the EN ISO requirement standards: LST EN ISO 5667-14:2016—Water Quality—Sampling—Part 14. The total nitrogen (TN) was tested according to the method of LST EN 13342—2002. The total nitrogen (TN) following determination of nitrogen—determination of bound nitrogen (TNb), following oxidation to nitrogen oxides LST EN 12260:2004. Total phosphorus (TP) analyses were assessed according to LST EN ISO 6878:2004; BOD_7—according to ISO 5815-1:2003 ammonium nitrogen (NH_4^+-N) LST ISO 7150-1:1998, LST EN ISO 13395:2000 nitrate nitrogen (NO_3-N), and LST EN ISO 6878:2004 phosphate phosphorus (PO_4-P).

2.3. Presentation of Pollution Sources

The assessment of contamination sources considered the nature of land use, the nature of cities and settlements, the location of potential sources of concentrated source pollution, the nature and intensity of economic activities in the basin and their potential impact on water bodies, recreational activities, and other economic activities that may not be in good condition according to condition requirements, and so forth.

Diffuse agricultural pollution, consisting of manure and mineral fertilizer loads resulting from agricultural activities and from the load on the population whose households are not connected to sewage collection systems.

The main sources of concentrated pollution are wastewater from cities, settlements, industrial enterprises and rain and surface water, wastewater from urban areas.

High potential for concentrated pollution to enter water bodies directly or through river tributaries.

For the quantification of pollution indicators, the following factors have been assessed:

- Domestic and industrial wastewater disposal facilities in the study areas, the extent of their pollution loads, the impact on the status of the water body and the average TN and TP value of wastewater in the period 2015–2020. Data from the Environmental Protection Agency (EPA) on wastewater dischargers, identified pollutant concentrations, and annual wastewater volumes were estimated by dividing their statistical values by water body feeding basins;
- The number of people connected to the sewage collection systems and sewage management (i.e., central, individual, or no management (statistics)). The contamination loads in the environment released by the residents whose wastewater was not collected were assessed according to the HELCOM recommendations, which specify that one resident generates 25.6 kg of waste according to the BOD_7, 4.4 kg of TN, and 0.9 kg of TP;
- To determine the nutrient loads from residential and commercial areas, data from the SWAT (small watershed to river basin-scale model used to simulate the quality and quantity of surface and ground water) model were used to calculate and evaluate pollution loads. SWAT model is a basin-scale continuous-time model that operates on a continuous basis and assesses the impact of management practices on water, sediment, and agrochemicals in non-monitored basins [61]. SWAT is widely used in assessing soil erosion prevention and control, diffuse source pollution control and regional management in watersheds;
- To assess the impact of the transformation of biogenic nutrients in soil and water body pollution, a SWAT model was used to calculate the average of total nitrogen (TN) and total phosphorus (TP) leaching.

2.4. Statistical Analyses

To statistically assess the significant impacts on quality factors related to the ecological status of water bodies, the impacts of anthropogenic load indicators TP and TN from municipal wastewater, surface wastewater, households not connected to sewage networks, agricultural land, background, and transit pollution (t/year); agricultural land, forests, wetlands, meadows, arable, infertile land, and green land (ha) on water quality indicators (Y) for the water in rivers were determined. A multiple linear regression model was applied:

$$Y = a + b_1x_1 + b_2x_2 + \ldots + b_kx_k. \quad (1)$$

The coefficient b_j shows how much the value of Y increases (or decreases) by one unit, as x_j increases when the remaining x_k are fixed. *t* is Student's criterion, according to which we determined whether the b_j coefficients differed statistically significantly from zero, and according to this, we decided whether the predicted values depended upon x_j. The standardized coefficient beta was used to determine the relative influence of independent variables on the predicted Y. In absolute terms, a higher beta coefficient indicates greater dependence of Y on x_j.

The regression model is appropriate due to the following:

- The Levene test was applied as an endogeneity test; the R code was applied to generate the analyses in this area, $R^2 \geq 0.20$;
- ANOVA was performed with a *p*-value of <0.05;
- *t*-tests were performed, showing significance at $p < 0.05$;
- All SWFs (Dispersion reduction factor) were ≤ 4 (no diversity problems);
- All Cook measure values were ≤ 1.

3. Results

3.1. Ecological Status Classes of the Stretches of Rivers According to the Physicochemical Values of Elemental Indicators

Studies on the physicochemical quality of element indicators were performed for NO_3-N (mg/L), NH_4-N (mg/L), TN (mg/L), PO_4-P (mg/L), TP (mg/L), and the BOD_7 (mg/L). The results are shown in Figure 2.

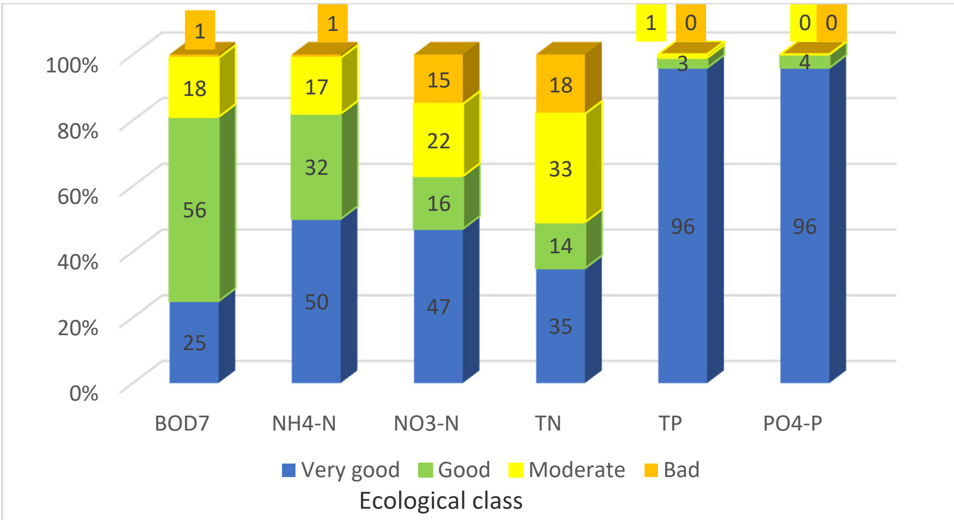

Figure 2. Ecological status classes of rivers according to the values of indicators of the physicochemical quality of elements%.

The results presented in Figure 2 show that, according to the TN, 51% of the studied rivers did not meet the requirements of the "good" ecological class; 19% of the rivers had a "bad" to "moderate" BOD_7, 50% had ''bad" to ''moderate" NH_4-N, 37% had ''bad" to ''moderate" NO_3-N, 4% had ''bad" to ''moderate" TP, and 4% had ''bad" to ''moderate" PO_4-P.

3.2. Assessment of Nutrient Loads in River Basins

Nutrient loads in the river basins were calculated by collected the SWAT model data. Calculations were performed in tons per year for the inflows into the rivers for the total nitrogen and total phosphorus. The TN and TP loads in river basins (t/year) are presented in Figure 3.

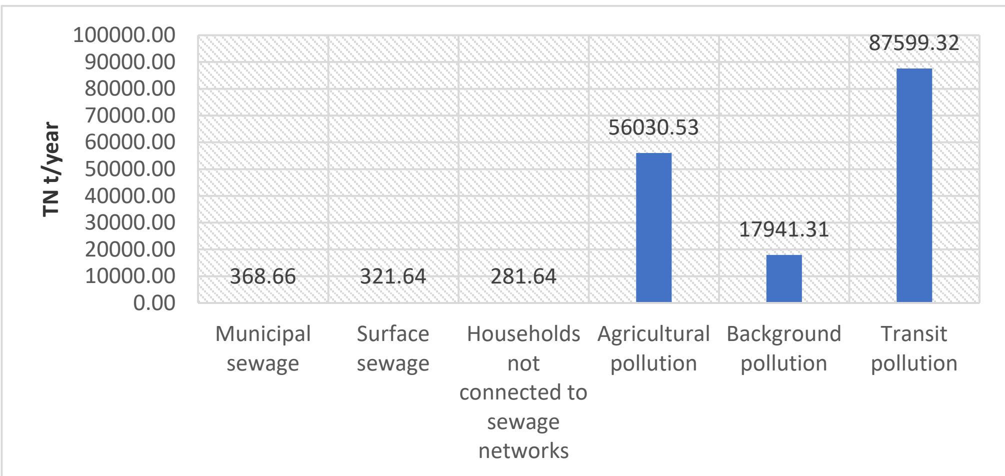

Figure 3. *Cont.*

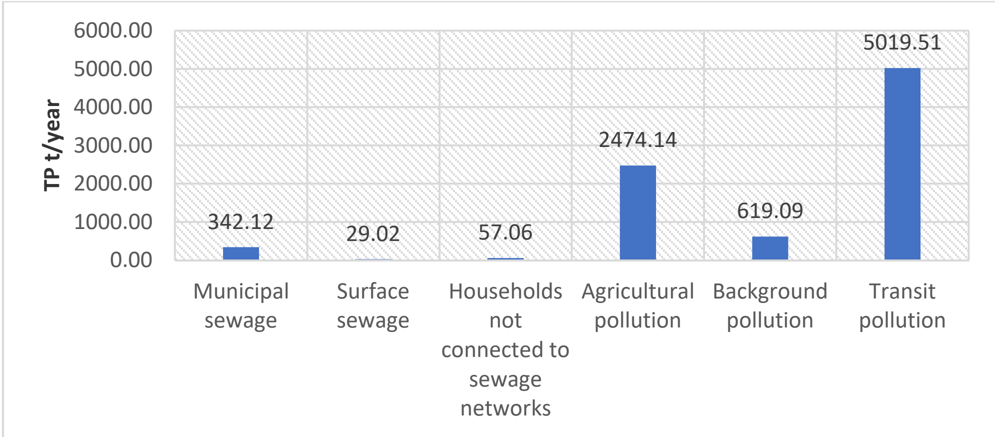

Figure 3. Amounts of total nitrogen and total phosphorus load in river basins (t/year).

The river basins get the largest amounts of pollution from transit loads located above the research locations, with the total nitrogen equaling 87,599.32 t/year and total phosphorus amounting to 5019.51 t/year. From agricultural activities, the total nitrogen reached 56,030.53 t/year and the total phosphorus was 2474.14 t/year. The amounts from background pollution (urban areas and forests) were 17,941.31 t/year of total nitrogen and 619.09 t/year of phosphorus. The amounts from municipal sewage were 368.66 t/year of total nitrogen and 342.12 t/year of phosphorus. The amounts from surface sewage were 321.64 t/year of total nitrogen and 29.02 t/year of phosphorus. Residents whose sewage was not discharged into sewage treatment systems generated 281.64 t/year of total nitrogen and 57.06 t/year of phosphorus.

Figure 4 shows the percentage distribution of total nitrogen and total phosphorus loads in the studied river basins.

The highest annual total nitrogen load for river basins per year, on average, came from transit pollution, accounting for 53.89%. A total of 34.47% came from agricultural pollution, 11.04% came from background pollution (urban areas and forests), 0.17% came from pollution from residents who were not connected to sewage systems, 0.20% came from surface sewage, and 0.23% came from municipal wastewater.

The highest annual load of total phosphorus in river basins was from transit pollution, accounting for 58.78%. A total of 28.97% came from agricultural pollution, 7.25% came from background pollution (urban areas and forests), 0.67% came from pollution from inhabitants who were not connected to sewage systems, 0.34% came from surface sewage, and 4.01% came from municipal wastewater.

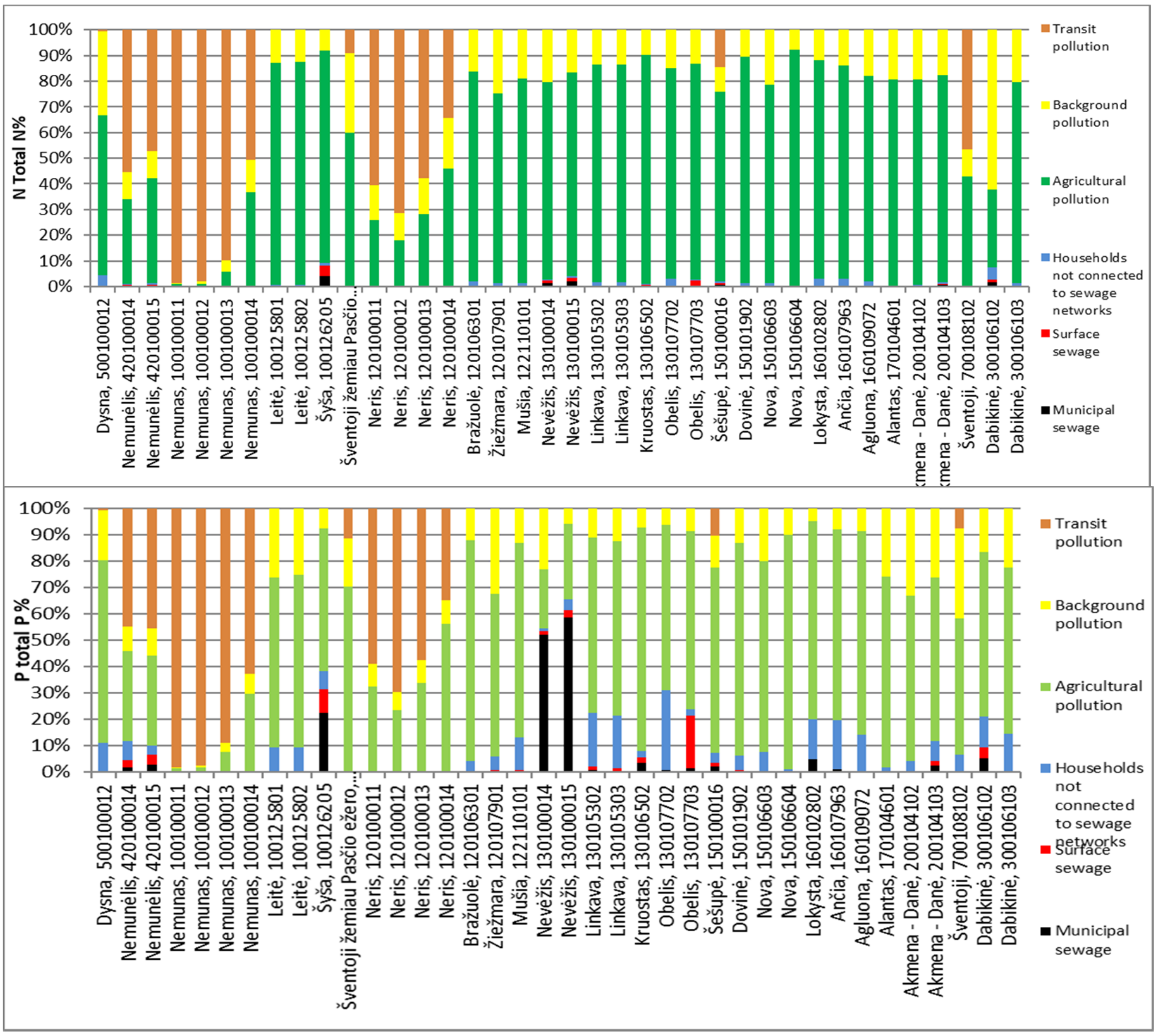

Figure 4. Percentage distribution of total nitrogen and total phosphorus loads in studied river basins (names of rivers and water body code).

3.3. Influence of Anthropogenic Loading on Total Nitrogen, Ammonium Nitrogen, Nitrate Nitrogen, Total Phosphorus, and Phosphate Phosphorus

The influence of anthropogenic loading on total nitrogen concentration (TN is dependent variable Y) was calculated by multiple regression analysis and results are presented in Table 2.

Multiple regression analysis of the influence of anthropogenic loads on the total nitrogen concentration in the water showed that the total nitrogen value was affected by N from agricultural land, and the total nitrogen amount was generated from agricultural land and arable land ($p < 0.05$). The higher the concentrations of TN were from arable land and agricultural land, the higher the value of TN was in the water (positive function).

The effect of anthropogenic loads on the ammonium nitrogen concentration (NH_4-N is dependent variable Y) was calculated by multiple regression analysis. The results are presented in Table 3.

Table 2. The influence of anthropogenic loads in rivers basins on the total nitrogen concentration in the water.

Environmental Factor	Unstandardized Coefficients		Standardized Coefficients	t	Significance Level $p < 0.05$
	B	Std. Error	Beta		
Constant	3.853	0.587		6.566	0.000
N from municipal wastewater, t/year	−0.128	0.132	−1.912	−0.969	0.349
N from surface wastewater, t/year	−0.015	0.137	−0.174	−0.108	0.915
N from households not connected to sewage networks, t/year	−0.208	0.239	−1.827	−0.870	0.399
* N from agricultural land, t/year	0.005	0.003	4.745	1.544	0.045
N from background, t/year	−0.011	0.015	−1.736	−0.720	0.484
N from transit pollution, t/year	−0.001	0.001	−0.161	−0.374	0.714
* Agricultural land, ha	0.027	0.017	13.642	1.557	0.042
Forests, ha	0.009	0.017	1.938	0.519	0.612
Wetlands, ha	0.025	0.029	0.268	0.854	0.407
Meadows, ha	0.043	0.047	2.390	0.923	0.372
* Arable land, ha	0.036	0.013	9.809	2.732	0.016
Infertile land, ha	−0.083	0.078	−1.726	−1.063	0.306
Green land, ha	3.010	2.489	2.725	1.210	0.246

Dependent variable: TN; * significance factor, $p < 0.05$.

Table 3. The influence of anthropogenic loads in river basins on the ammonium ion concentration in the water.

Environmental Factor	Unstandardized Coefficients		Standardized Coefficients	t	Significance Level $p < 0.05$
	B	Std. Error	Beta		
Constant	0.033	0.022		1.508	0.154
N from municipal wastewater, t/year	0.006	0.005	1.800	1.203	0.249
N from surface wastewater, t/year	0.005	0.005	1.122	0.921	0.373
* N from households not connected to sewage networks, t/year	0.012	0.009	2.187	1.374	0.049
* N from agricultural land, t/year	0.000	0.000	3.309	1.421	0.047
N from background, t/year	2.408×10^{-5}	0.001	0.080	0.044	0.966
* N from transit pollution, t/year	0.000	0.000	0.852	2.606	0.021
Agricultural land, ha	−0.001	0.001	−5.301	−0.798	0.438
* Forests, ha	−0.002	0.001	−9.231	−3.263	0.006
* Wetlands, ha	0.002	0.001	0.533	2.241	0.042
* Meadows, ha	0.003	0.002	3.674	1.871	0.048
* Arable land, ha	0.001	0.001	5.630	2.069	0.049
* Infertile land, ha	−0.010	0.003	−4.026	−3.271	0.006
* Green land, ha	−0.411	0.093	−7.511	−4.398	0.001

Dependent variable: NH_4-N; * significance factor, $p < 0.05$.

Multiple regression analysis of the influence of anthropogenic loads on the ammonium nitrogen concentration in the water showed that the total NH_4-N value was affected by the TN from households not connected to sewage networks, the TN from agricultural land and transit pollution, and the NH_4-N amount generated from forests, wetlands, meadows, arable land, infertile land, and green land ($p < 0.05$). The higher the concentrations of NH_4-N were from households not connected to the sewage networks, agricultural land, transit pollution, wetlands, meadows, and arable land, the higher the value of the NH_4-N was in the water (positive function). The higher the NH_4-N concentrations were from forests, infertile land, and green land, the lower the NH_4-N concentration was in the water (negative function).

The effect of anthropogenic loads on the nitrate nitrogen concentration (NO_3-N is dependent variable Y) was calculated by multiple regression analysis. The results are presented in Table 4.

Table 4. The influence of anthropogenic loads in basins on the total nitrogen concentration in the water.

Environmental Factor	Unstandardized Coefficients		Standardized Coefficients	t	Significance Level $p < 0.05$
	B	Std. Error	Beta		
Constant	2.358	0.514		4.584	0.000
N from municipal wastewater, t/year	−0.060	0.116	−1.289	−0.515	0.614
N from surface wastewater t/year	0.006	0.120	0.106	0.052	0.959
N from households not connected to sewage networks, t/year	0.185	0.209	2.348	0.882	0.393
N from agricultural land, t/year	0.001	0.003	1.921	0.493	0.629
N from background; t/year	−0.002	0.013	−0.395	−0.129	0.899
N from transit pollution, t/year	0.000	0.001	0.051	0.094	0.926
Agricultural land, ha	0.013	0.015	9.911	0.893	0.387
Forests, ha	0.005	0.015	1.523	0.322	0.752
Wetlands, ha	0.018	0.026	0.277	0.698	0.497
Meadows, ha	0.023	0.041	1.800	0.549	0.592
* Arable land, ha	0.021	0.012	8.031	1.766	0.049
Infertile land, ha	−0.013	0.068	−0.388	−0.188	0.853
Green land, ha	0.505	2.182	0.661	0.231	0.820

Dependent variable: NO_3-N; * significance factor, $p < 0.05$.

Multiple regression analysis of the influence of anthropogenic loads on the nitrate nitrogen concentration in the water showed that the NO_3-N value was affected only by arable land ($p < 0.05$). The higher the concentration of NO_3-N was from arable land, the higher the value of NO_3-N was in the water (positive function).

The effect of anthropogenic loads on the total phosphorus concentration (TP is dependent variable Y) was calculated by multiple regression analysis. The results are presented in Table 5.

Multiple regression analysis of the influence of anthropogenic loads in basins on the concentration of total phosphorus in the water showed that the total phosphorus value was influenced by the discharge of surface wastewater from households not connected to sewage networks, agricultural land, arable land, infertile land, and green land ($p < 0.05$). The higher the TP concentration was in the surface wastewater from households not connected to sewage networks, agricultural land, arable land, the higher the TP value was in the water (positive function). The larger the infertile and green areas were in the river basins, the lower the total phosphorus concentration was in the water (negative function).

The effect of anthropogenic loads on the phosphate phosphorus concentration, (PO_4-P is dependent variable Y), was calculated by multiple regression analysis. The results are presented in Table 6.

Table 5. The influence of anthropogenic loads in river basins on the total phosphorus concentration in the water.

Environmental Factor	Unstandardized Coefficients		Standardized Coefficients	t	Significance Level $p < 0.05$
	B	Std. Error	Beta		
Constant	0.038	0.007		5.166	0.000
P from municipal wastewater, t/year	0.000	0.001	0.176	0.116	0.910
* P from surface wastewater, t/year	0.013	0.008	1.014	1.688	0.043
* P from households not connected to sewage networks, t/year	0.026	0.011	3.846	2.345	0.034
* P from agricultural land, t/year	0.001	0.001	3.038	1.597	0.043
P from background, t/year	0.000	0.002	0.082	0.072	0.944
P from transit pollution, t/year	−0.002	0.002	−1.034	−1.392	0.186
Agricultural land, ha	9.643×10^{-5}	0.000	4.004	0.453	0.657
Forests, ha	0.000	0.000	3.511	1369	0.192
Wetlands, ha	0.000	0.000	−0.098	−0.298	0.770
Meadows, ha	0.000	0.001	2.101	0.849	0.410
* Arable land, ha	0.000	0.000	9.569	1.963	0.049
* Infertile land, ha	−0.003	0.001	−4.328	−2.552	0.023
* Green land, ha	−0.085	0.038	−6.274	−2.217	0.044

Dependent variable: TP, * significance factor, $p < 0.05$.

Table 6. The influence of anthropogenic loads in river basins on the total phosphorus concentration in the water.

Environmental Factor	Unstandardized Coefficients		Standardized Coefficients	t	Significance Level $p < 0.05$
	B	Std. Error	Beta		
Constant	0.009	0.009		0.981	0.343
* P from municipal wastewater, t/year	0.004	0.001	0.321	3.192	0.007
P from surface wastewater, t/year	0.005	0.010	0.021	0.531	0.604
P from households not connected to sewage networks, t/year	0.006	0.014	0.047	0.429	0.675
P from agricultural land, t/year	0.000	0.001	−0.021	−0.165	0.871
* P from background, t/year	0.004	0.002	0.138	1.827	0.049
* P from transit pollution, t/year	−0.008	0.002	−0.200	−4.061	0.001
* Agricultural land, ha	0.001	0.000	1.732	2.957	0.010
* Forests, ha	−0.000	0.000	−0.350	−2.060	0.049
Wetlands, ha	0.000	0.000	0.006	0.271	0.790
* Meadows, ha	0.002	0.001	0.394	2.402	0.031
* Arable land, ha	0.001	0.000	0.802	2.482	0.026
* Infertile land, ha	−0.006	0.001	−0.550	−4.896	0.000
* Green land, ha	−0.133	0.049	0.514	−2.741	0.016

Dependent variable: PO_4-P, * significance factor, $p < 0.05$.

Multiple regression analysis of the influence of anthropogenic loads in basins on the concentration of phosphate phosphorus in the water showed that the PO_4-P value was influenced by the discharge of municipal wastewater from background and transit pollution, agricultural land, forests, meadows, arable land, infertile land, and green land ($p < 0.05$). The higher the PO_4-P concentration was in the municipal wastewater from background pollution, agricultural land, meadows, arable land, the higher the PO_4-P value was in the water (positive function). The higher the transit pollution, and the larger the forests, infertile, and green areas were in the river basins, the lower the PO_4-P concentration was in the water (negative function).

4. Discussion

Agricultural activity has strict negative impact on condition of surface water bodies, their ecosystems, the degradation of vegetation, and the quantitative and qualitative changes in fish populations in the Mediterranean basin [62]. The main factor affecting the Baltic Sea region environment is the increased amount of nutrients in rivers, mainly from diffuse agricultural sources [63]. The diffused nitrogen of anthropogenic origin account for about 70% of the total load deposited into rivers and lakes of the Baltic Sea basin area. Of the total diffuse load of nitrogen deposited into the Baltic Sea, 80% is from agriculture [64,65]. In Estonia, Latvia, and Lithuania, agriculture was intensified, and the amount of nitrogen fertilizers was increased after the 1990s [66].

Ikauniece and Lagzdinš assessed the status of two rivers, the Slocene and the Age, in Latvia. It was found that the ecological and chemical status of these rivers depended on the following factors: climatic conditions, types of soil and land-use, and human activities. The impact of land-use types and concentrations of total nitrogen, NO_3 -N, NH_4-N, total phosphorus, and PO_4^--P on the water of rivers was established. The highest concentrations of these substances were determined in the spring. It can be stated that snow melt during the spring period increases losses of biogenic compounds from concentrated sources [36].

An increase in sensitivity was found in basins with more agricultural land and more fertilizer. A change in the use of chemical fertilizers by $\pm$20% affected the NO_3-N loads in the water body between zero effect and an increase of $\pm$13%, while a change in manure use by $\pm$20% affected the NO_3-N loads in the water body from zero effect to a change of $-$6% to +7% [63]. Ferrier [67] pointed out that nitrate concentrations in water of the rivers depend on the area of arable land, and there is a relationship between orthophosphate-P, suspended solids concentrations and meadow cover. Studies conducted in the Liswarta basin (Poland) have showed that high concentrations of nutrients in the Liswarta River and its tributaries are closely linked to the agriculture activities in this basin. However, urban wastewater effluents effected the highest concentrations of nutrients set in the Biała Oksza River [34]. Other Polish researchers assessed the influence of land use on the condition of the Dunajec, Czarny Dunajec, Biały Dunajec, and Białka rivers in the Podhale region (southern Poland). The results of their study showed that the concentrated pollution sources, such as effluents from WWTPs or untreated sewage from households, were more important than diffuse sources but agricultural activities significantly affect water quality of rivers [39].

Watershed modelling was used to discover the critical areas of water quality of rivers, as well as to define impacts and identify the most significant pollution sources in the river basins in Lithuania. Regional diffuse pollution leaching patterns were estimated using this model. The largest leaching rates total phosphorus were assessed in the southeastern and western parts of Lithuania. The largest leaching of total nitrogen was determined to occur in the center of the country. It can be seen from the modelling results that agriculture is the dominant pollution source in all Lithuanian river basins. The organic loads from diffuse pollution sources accounted for 60–90% of the annual loads in all of the river basins, excluding the urban catchments of the Neris and Nemunas rivers. The total phosphorus loads from agricultural sources accounted for 50–93% of the annual TP load. The pollution from concentrated sources and non-sewered households had almost no influence on the nitrate loads, and agriculture was the only dominant source of pollution, contributing

90–99% of the annual nitrate load [68]. It was determined that, satisfactorily, 90% of all nitrogen entered the Mūša sub-catchment from the diffuse pollution sources, including 87% from the arable land and just a little more than 3% from the forest territory and pastures. A total of 10% of all nitrogen in the basin came from the concentrated pollution sources. The largest amounts of total phosphorus in the Mūša sub-catchment entered the basin from the concentrated pollution sources (about 49%), arable land (36%) and about 15% from the forest area and pastures [69].

Various sources indicate measures for protection against diffuse pollution. In Poland, the recommendations for the protection of river valleys from biogenic pollution include the activities such as preserving natural vegetation on the banks of rivers, reducing of intensive agriculture activities and others [34]. Scholz [70] introduced diffuse pollution control strategies involving draining the natural wetlands by ditches in Germany.

In Lithuania, the main measures that should be applied to reduce the input of pollution from agricultural activities into rivers and other inland waters are as follows [71]:

- ✓ The application of fertilization plans and targeted/precision farming. Balanced fertilization reduces the need for fertilizers and pesticides and saves water resources. This results in less nitrogen and phosphorus leaching and less eutrophication in surface water bodies;
- ✓ Additional protection strips for surface water bodies. The protective strips of natural vegetation left along the water bodies help to absorb excess nutrients and control water pollution;
- ✓ Stubble fields left during the winter help conserve water resources and prevent nutrient leaching;
- ✓ The installation of controlled drainage. An intelligent drainage system increases yields by reducing the need for fertilizer and stopping the leaching of nutrients into surface water bodies.

5. Conclusions

1. The total nitrogen values did not comply with the requirements of to the ''good'' and ''very good'' ecological status classes in 51% of the tested water bodies; 19% had a ''bad'' to ''moderate'' BOD_7, 50% had ''bad'' to ''moderate'' NH_4-N, 37% had ''bad'' to ''moderate'' NO_3-N, 4 % had ''bad'' to ''moderate'' PO_4-P, and the total phosphorus values did not correspond to the ''good'' or ''very good'' ecological status classes in 4% of the tested water bodies;
2. River basins accumulate the biggest quantities from the following sources: transit pollution, contributing 87,599 t/year of total nitrogen and 5020 t/year of phosphorus; agricultural pollution, contributing 56,031 t/year of total nitrogen and 2474 t/year of total phosphorus;
3. The biggest total nitrogen load in river basins per year is from transit pollution, accounting for 53.89%; agricultural pollution accounts for 34.47%. The highest total phosphorus load is also from transit pollution, accounting for 58.78%; agricultural pollution accounts for 28.97%;
4. The multiple regression analysis showed that the agricultural activity had the biggest negative influence on the ecological status of rivers according to all studied indicators.

Author Contributions: L.Č. designed the study and performed the experiments; L.Č., D.Š. and M.D. performed the experiments, analyzed the data, and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are available in a publicly accessible repository.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Aplinkos apsaugos agentūra. Upių, ežerų ir tvenkinių ekologinė būklė/Environmental Protection Agency. Ecological Status of Rivers, Lakes and Ponds. 2017. Available online: https://www.akoalicija.lt/veikla/2019-06-26-d%C4%97l-upi%C5%B3-ekologin%C4%97s-b%C5%ABkl%C4%97s-gerinimo (accessed on 29 August 2021). (In Lithuanian).
2. Tejerina-Garro, F.L.; Maldonado, M.; Ibañez, C.; Pont, D.; Roset, N.; Oberdorff, T. Effects of natural and anthropogenic environmental changes on riverine fish assemblages: A framework for ecological assessment of rivers. *Biol. Appl. Sci. Braz. Arch. Biol. Technol.* **2005**, *48*, 91–108. [CrossRef]
3. Hu, W.; Wang, G.; Deng, W.; Li, S. The influence of dams on ecohydrological conditions in the Huaihe River basin, China. *Ecol. Eng.* **2008**, *33*, 233–241. [CrossRef]
4. Żelazny, M.; Siwek, J.P. Determinants of seasonal changes in streamwater chemistry in small catchments with different land uses: Case study from Poland's Carpathian foothills. *Pol. J. Environ. Stud.* **2012**, *21*, 791–804.
5. Lenart-Boroń, A.; Wolanin, A.; Jelonkiewicz, Ł.; Chmielewska-Błotnicka, D.; Żelazny, M. Spatiotemporal variability in microbiological water quality of the Białka river and its relation to the selected physicochemical parameters of water. *Water Air Soil Pollut.* **2016**, *227*, 22. [CrossRef]
6. Bojarczuk, A.; Jelonkiewicz, L.; Lenart-Boroń, A. The effect of anthropogenic and natural factors on the prevalence of physicochemical parameters of water and bacterial water quality indicators along the river Białka, southern Poland. *Environ. Sci. Pollut. Res.* **2018**, *25*, 10102–10114. [CrossRef]
7. Álvarez, X.; Valero, E.; Torre-Rodríguez, N.; Acuña-Alonso, C. Influence of Small Hydroelectric Power Stations on River Water Quality. *Water* **2020**, *12*, 312. [CrossRef]
8. Zhao, K.; Wu, H.; Chen, W.; Sun, W.; Zhang, H.; Duan, W.; Chen, W.; He, B. Impacts of Landscapes on Water Quality in A Typical Headwater Catchment, Southeastern China. *Sustainability* **2020**, *12*, 721. [CrossRef]
9. Hughes, R.M.; Vadas, R.L., Jr. Agricultural Effects on Streams and Rivers: A Western USA Focus. *Water* **2021**, *13*, 1901. [CrossRef]
10. Burkholder, J.; Libra, B.; Weyer, P.; Heathcote, S.; Kolpin, D.; Thorne, P.S.; Wichman, M. Impacts of waste from concentrated animal feeding operations on water quality. *Environ. Health Perspect.* **2007**, *115*, 308–312. [CrossRef] [PubMed]
11. Páll, E.; Niculae, M.; Kiss, T.; Şandru, C.D.; Spînu, M. Human impact on the microbiological water quality of the rivers. *J. Med. Microbiol.* **2013**, *62*, 1635–1640. [CrossRef]
12. Kroll, S.A.; Oakland, H.C. A review of studies documenting the effects of agricultural best management practices on physiochemical and biological measures of stream ecosystem integrity. *Nat. Areas J.* **2019**, *39*, 58–77. [CrossRef]
13. Liu, J.; Han, G.; Liu, X.; Liu, M.; Song, C.; Zhang, Q.; Yang, K.; Li, X. Impacts of Anthropogenic Changes on the Mun River Water: Insight from Spatio-Distributions and Relationship of C and N Species in Northeast Thailand. *Int. J. Environ. Res. Public Health* **2019**, *16*, 659. [CrossRef]
14. Liu, Y.; Li, H.; Cui, G.; Cao, Y. Water quality attribution and simulation of non-point source pollution load flux in the Hulan River basin. *Sci. Rep.* **2020**, *10*, 3012. [CrossRef] [PubMed]
15. Castillo, M.M.; Allan, J.D.; Brunzell, S. Nutrient concentrations and discharges in a Midwestern agricultural catchment. *J. Env. Qual.* **2000**, *29*, 1142–1151. [CrossRef]
16. Valiela, I.; Bowen, J.L. Nitrogen sources to watersheds and estuaries: Role of land cover mosaics and losses within watersheds. *Environ. Pollut.* **2002**, *118*, 239–248. [CrossRef]
17. Buck, O.; Niyogi, D.K.; Townsend, C.R. Scale-dependence of land use effects on water quality of streams in agricultural catchments. *Environ. Pollut.* **2004**, *130*, 287–299. [CrossRef] [PubMed]
18. Alam, M.N.; Elahi, F.; Alam, D.U. Risk and water quality assessment overview of River Sitalakhya in Bangladesh. *Acad. Open Internet J.* **2006**, *19*, 112–202.
19. Zhang, Q.L.; Shi, X.Z.; Huang, B.; Yu, D.S.; Öbornc, I.; Blombäckc, K.; Wang, H.J.; Pagella, T.F.; Sinclair, F.L. Surface water quality of factory-based and vegetable-based peri-urban areas in the Yangtze River delta region, China. *Catena* **2007**, *69*, 57–64. [CrossRef]
20. Hussain, M.; Ahmed, S.M.; Abderrahman, W. Cluster analysis and quality assessment of logged water at an irrigation project, eastern Saudi Arabia. *J. Environ. Manag.* **2008**, *86*, 297–307. [CrossRef]
21. Khatri, N.; Tyagi, S. Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Front. Life Sci.* **2015**, *8*, 23–39. [CrossRef]
22. Allan, J.D. Landscapes and riverscapes: The influence of land use on stream ecosystems. *Annu. Rev. Ecol. Evol. Syst.* **2004**, *35*, 257–284. [CrossRef]
23. Bhat, S.; Jacobs, J.M.; Hatfield, K.; Prenger, J. Relationships between stream water chemistry and military land use in forested watersheds in Fort Benning. *Georgia. Ecol. Ind.* **2006**, *6*, 458–466. [CrossRef]
24. Hopkins, R.L. Use of landscape pattern metrics and multiscale data in aquatic species distribution models: A case study of a freshwater mussel. *Landsc. Ecol.* **2009**, *24*, 943–955. [CrossRef]
25. Tran, C.P.; Bode, R.W.; Smith, A.J.; Kleppel, G.S. Land-use proximity as a basis for assessing stream water quality in New York State (USA). *Ecol. Indic.* **2010**, *10*, 727–733. [CrossRef]
26. Weijters, M.J.; Janse, J.H.; Alkemade, R.; Verhoeven, J.T.A. Quantifying the effect of catchment land use and water nutrient concentrations on freshwater river and stream biodiversity. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2009**, *19*, 104–112. [CrossRef]

27. Hollister, J.W.; August, P.V.; Paul, J.F. Effects of spatial extent on landscape structure and sediment metal concentration relationships in small estuarine systems of the United States' Mid-Atlantic Coast. *Landsc. Ecol.* **2008**, *23*, 91–106. [CrossRef]
28. Sliva, L.; Williams, D.D. Buffer zone versus whole catchment approaches to studying land use impact on river water quality. *Water Res.* **2001**, *35*, 3462–3472. [CrossRef]
29. Brabec, E.A. Imperviousness and land-use policy: Toward an effective approach to watershed planning. *J. Hydrol. Eng.* **2009**, *14*, 425–433. [CrossRef]
30. Lee, S.W.; Hwang, S.J.; Lee, S.B.; Hwang, H.S.; Sung, H.C. Landscape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics. *Landsc. Urban Plan.* **2009**, *92*, 80–89. [CrossRef]
31. Kelly, M.; Bennion, H.; Burgess, A.; Ellis, J.; Juggins, S.; Guthrie, R.; Jamieson, J.; Adriaenssens, V.; Yallop, M. Uncertainty in ecological status assessments of lakes and rivers using diatoms. *Hydrobiologia* **2009**, *633*, 5–15. [CrossRef]
32. Nõges, P.; Van de Bund, W.; Cardoso, A.K.; Solimini, A.G.; Heiskanen, A.S. Assessment of the ecological status of European surface waters: A work in progress. *Hydrobiologia* **2009**, *633*, 197–211. [CrossRef]
33. Ayobahan, S.U.; Ezenwa, I.M.; Orogun, E.E.; Uriri, J.E.; Wemimo, I.J. Assessment of Anthropogenic Activities on Water Quality of Benin River. *J. Appl. Sci. Environ. Manag.* **2014**, *18*, 629–636. [CrossRef]
34. Matysik, M.; Atsalon, D.; Ruman, M. Surface Water Quality in Relation to Land Cover in Agricultural Catchments (Liswarta River Basin Case Study). *Pol. J. Environ. Stud.* **2015**, *24*, 175–184. [CrossRef]
35. Česonienė, L.; Šileikienė, D.; Dapkienė, M.; Radzevičius, A.; Räsänen, K. Assessment of chemical and microbiological parameters on the Leite River Lithuania. *Environ. Sci. Pollut. Res.* **2019**, *26*, 18752–18765. [CrossRef] [PubMed]
36. Ikauniece, K.; Lagzdiņš, A. The assessment of chemical and ecological status in the water bodies of Slocene and Age. *Water Manag. Res. Rural Dev.* **2020**, *35*, 241–247. [CrossRef]
37. Grizzetti, B.; Pistocchi, A.; Liquete, C.; Udias, A.; Bouraoui, F.; van de Bund, W. Human pressures and ecological status of European rivers. *Sci. Rep.* **2017**, *7*, 205. [CrossRef] [PubMed]
38. Ruminaitė, R. Research and Evaluation of the Anthropogenic Activity Impact on the River Runoff and Water Quality. Ph.D. Thesis, Vilnius Gediminas Technical University, Vilnius, Lithuania, 2010. Available online: http://vddb.laba.lt/fedora/get/LT-eLABa-0001:E.02~{}2010~{}D_20101222_130641-59851/DS.005.0.01.ETD (accessed on 5 May 2021). (In Lithuanian).
39. Lenart-Boroń, A.; Wolanin, A.; Jelonkiewicz, E.; Żelazny, M. The effect of anthropogenic pressure shown by microbiological and chemical water quality indicators on the main rivers of Podhale, southern Poland. *Env. Sci. Pollut. Res. Int.* **2017**, *24*, 12938–12948. [CrossRef] [PubMed]
40. Cesoniene, L.; Dapkiene, M.; Sileikiene, D.; Rekasiene, V. Impact of Wastewater Treatment Plant on Water Quality of the River Mazoji Sruoja, Plunge District. *J. Environ. Res. Eng. Manag.* **2017**, *73*, 33–44.
41. Joshua, N.; Edokpayi, J.N.; Odiyo, J.O.; Durowoju, O.S. Impact of Wastewater on Surface Water Quality in Developing Countries: A Case Study of South Africa. In *Water Quality*; IntechOpen: London, UK, 2017; pp. 401–416. Available online: https://www.intechopen.com/chapters/53194 (accessed on 5 May 2021). [CrossRef]
42. Alcon, F.; de-Miguel, M.D.; Martínez-Paz, J.M. Assessment of real and perceived cost-effectiveness to inform agricultural diffuse pollution mitigation policies. *Land Use Policy* **2021**, *107*, 104561. [CrossRef]
43. Matono, P.; Batista, T.; Sampaio, E.; Ilhéu, M. Effects of Agricultural Land Use on the Ecohydrology of Small-Medium Mediterranean River Basins: Insights from a Case Study in the South of Portugal. In *Land Use—Assessing the Past, Envisioning the Future*; IntechOpen: London, UK, 2019; pp. 29–51.
44. Liu, J.; Shen, Z.; Chen, L. Assessing how spatial variations of land use pattern affect water quality across a typical urbanized watershed in Beijing, China. *Landsc. Urban Plan.* **2018**, *176*, 51–63. [CrossRef]
45. Sveikauskaite, I. Lithuanian River Pollution and Water Quality Trends in 1992–2009. Master's Thesis, Vytautas Magnus University, Kaunas, Lithuania, 2011.
46. Fogelberg, S. Modelling nitrogen retention at the catchment scale.Report UPTEC W 03 019. Uppsala: Uppsala University. P. 1-51.French urban catchment. *Water Res.* **2003**, *85*, 432–442.
47. Organisation for Economic Co-operation and Development. *Environmental Performance of Agriculture in OECD Countries Since1990*; OECD: Paris, France, 2008; ISBN 9789264040922.
48. Kyllmar, K.; Bechmann, M.; Deelstra, J.; Iital, A.; Blicher-Mathiesen, G.; Jansons, V.; Koskiaho, J.; Povilaitis, A. Long-term monitoringof nutrient losses from agricultural catchments in the Nordic-Baltic region-A discussion of methods, uncertainties. *Agric. Ecosyst. Environ.* **2014**, *198*, 4–12. [CrossRef]
49. Povilaitis, A.; Šileika, A.; Deelstra, J.; Gaigalis, K.; Baigys, G. Nitrogen losses from small agricultural catchments in Lithuania. *Agric. Ecosyst. Environ.* **2014**, *198*, 54–64. [CrossRef]
50. Xiao, L.; Liu, J.; Ge, J. Dynamic game in agriculture and industry cross-sectoral water pollution governance in developing countries. *Agric. Water Manag.* **2021**, *243*, 106417. [CrossRef]
51. Waller, D.M.; Meyer, A.G.; Raff, Z.; Apfelbaum, S.I. Shifts in precipitation and agricultural intensity increase phosphorus concentrations and loads in an agricultural watershed. *J. Environ. Manag.* **2021**, *284*, 112019. [CrossRef] [PubMed]
52. USEPA (U.S. Environmental Protection Agency). National Water Quality Inventory Report. EPA-841-F-02-003. 2002. Available online: https://www.epa.gov/sites/production/files/2015-09/documents/2007_10_15_305b_2002report_report2002305b.pdf. (accessed on 30 August 2021).

53. Staniszewska, M.; Schnug, E. Status of organic agriculture in thecountries of the Baltic Sea region. *Landbauforsch. Volkenrode* **2002**, *52*, 75–80.
54. Vincevičienė, V.; Asadauskaitė, A. Assessment of Point Pollution and Impact to Water Quality of the Transboundary River Basins–the Venta and the Musa–Lielupe. *Environ. Res. Eng. Manag.* **2002**, *1*, 41–51.
55. Ruminaitė, R. Water runoff and pollution peculiarities in Lielupe watershed per 1992–2006-year period. *Water Manag. Eng.* **2010**, *36*, 100–108.
56. Povilaitis, A. Source apportionment and retention of nutrients and organic matter in the merkys river basin in southern Lithuania. *J. Environ. Eng. Landsc. Manag.* **2008**, *16*, 195–204. [CrossRef]
57. Plungė, S.; Gudas, M. Žemės ūkis ir Lietuvos vandenys. Žemės ūkio veiklos poveikis Lietuvos upių būklei ir taršos apkrovoms į Baltijos jūrą/Impact of Agricultural Activities on the Condition of Lithuanian Rivers and Pollution Loads in the Baltic Sea. 2018. Available online: https://www.akoalicija.lt/veikla/2019-06-26-d%C4%97l-upi%C5%B3-ekologin%C4%97s-b%C5%ABkl%C4%97s-gerinimo (accessed on 29 August 2021). (In Lithuanian).
58. Povilaitis, A. Nutrient Retention in Surface Waters of Lithuania. *Pol. J. Environ. Stud.* **2011**, *20*, 1575–1584.
59. Plungė, S.; Gudas, M. Klimato kaitos poveikis vandens telkiniams. Priemonių taršai iš žemės ūkio šaltinių sumažinti galimybių įvertinimas klimato kaitos perspektyvoje/Impact of Climate Change on Water Bodies. Assessment of Measures to Reduce Pollution from Agricultural Sources in the Perspective of Climate Change. 2021. Available online: https://vanduo.old.gamta.lt/files/report1627991771354.html (accessed on 29 August 2021).
60. Approval of the Description of the Procedure for Assessing the Ecological Status of Surface Water Bodies. Order of the Minister of the Environment of the Republic of Lithuania: 12 April 2007 No. D1-210/Lietuvos Respublikos Aplinkos Ministro Įsakymas dėl Paviršinių Vandens Telkinių Būklės Nustatymo Metodikos Patvirtinimo 2007m. Vilnius. Balandzio 12 d. Nr. D1; 2017. Available online: https://portalcris.vdu.lt/cris/bitstream/20.500.12259/115090/1/tomas_kantaravicius_md.pdf (accessed on 5 May 2021).
61. Arnold, J.G.; Srinisvan, R.; Muttiah, R.S.; Williams, J.R. Large area hydrologic modeling and assessment. Part I: Model development. *J. Am. Water Resour.* **1998**, *34*, 73–89. [CrossRef]
62. Hermoso, V.; Clavero, M.; Kennard, M.J. Determinants of fine-scale homogenization and differentiation of native freshwater fish faunas in a Mediterranean Basin: Implications for conservation. *Divers. Distrib.* **2012**, *18*, 236–247. [CrossRef]
63. Thodsen, H.; Farkas, C.; Chormanski, J.; Trolle, D.; Blicher-Mathiesen, G.; Grant, R.; Engebretsen, A.; Kardel, I.; Andersen, H.E. Modelling Nutrient Load Changes from Fertilizer Application Scenarios in Six Catchments around the Baltic Sea. *Agriculture* **2017**, *7*, 41. [CrossRef]
64. HELCOM. Eutrophication in the Baltic Sea—An integrated thematic assessment of the effects of nutrient enrichment and eutrophication in the Baltic Sea region. *Balt. Sea Environ. Proc.* **2009**, *115*, 148.
65. Voss, M.; Dippner, J.W.; Humborg, C.; Hürdler, J.; Korth, F.; Neumann, T.; Schernewski, G.; Venohr, M. History and scenarios of future development of Baltic Sea eutrophication. *Estuar. Coast. Shelf Sci. J.* **2011**, *92*, 307–322. [CrossRef]
66. Andersen, H.E.; Blicher-Mathiesen, G.; Bechmann, M.; Povilaitis, A.; Iital, A.; Lagzdins, A.; Kyllmarf, K. Reprint of “Mitigating diffuse nitrogen losses in the Nordic-Baltic countries”. *Agric. Ecosyst. Environ.* **2014**, *198*, 127–134. [CrossRef]
67. Ferrier, R.C.; Edwards, A.C.; Hirst, D.; Littlewood, I.G.; Watts, C.D.; Morris, R. Water quality of Scottish rivers: Spatial and temporal trends. *Sci. Total Environ.* **2001**, *265*, 327–342. [CrossRef]
68. Vaitiekūnienė, J.; Hansen, F.T. National scale water modelling to assess and predict pollution trends in Lithuanian rivers. *Environ. Res. Eng. Manag.* **2005**, *4*, 30–42.
69. Stankevičienė, R. Research and Evaluation of the Anthropogenic Activity Impact on the River Runoff and Water Quality. Summary of Doctoral Dissertation; Vilnius Gediminas Technical University (VILNIUS TECH); Vilnius Technica. 2010. Available online: https://talpykla.elaba.lt/elaba-fedora/objects/elaba:1862147/datastreams/MAIN/content (accessed on 12 April 2021).
70. Scholz, M. *Wetlands for Water Pollution Control*, 2nd ed.; Elsevier Science: Saldorf, UK, 2016.
71. Rural Development. Official Document on Improving the Ecological Condition of Lithuanian Rivers and Other Water Bodies. 2019. Available online: https://www.akoalicija.lt/veikla/2019-06-26-d%C4%97l-upi%C5%B3-ekologin%C4%97s-b%C5%ABkl%C4%97s-gerinimo (accessed on 29 August 2021).