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Baltic Marine Environment Protection Commission

Input of nutrients by the eleven selected rivers in the Baltic Sea region in 1995–2021 (PLC-8)

Nutrients

Baltic Sea Environment Proceedings n°204

Published by:

Helsinki Commission – HELCOM
Katajanokanlaituri 6 B
00160 Helsinki, Finland

www.helcom.fi

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For bibliographic purposes this document should be cited as:
"Inputs of nutrients by eleven selected rivers in the Baltic Sea region in 1995 to 2021. Baltic Sea Environment Proceedings n°204. HELCOM (2025)"

This publication is part of the Eighth Baltic Sea Pollution Load Compilation (PLC-8) project.

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ISSN: 0357-2994

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Summary

The eleven selected rivers cover over half (52%) of the Baltic Sea catchment area and over 55 million people inhabit their catchment areas, meaning that anthropogenic pressure is high. The pressure is higher in the southern catchments, where population is densest and agricultural activity is intense. Consequently, the nutrient loads are higher in the south: For example, in 2021 the area specific total nitrogen (TN) load of the Lielupe River was 2125 kg km^{-2}, whereas it was 125 kg km^{-2} for the Kemi River (in the north). The variation in the area specific total phosphorus (TP) loads also was high: The Göta River 6.0 kg km^{-2} and the Pregolya River 34 kg km^{-2}. The 11 rivers exported 349,000 t of total nitrogen and 13,800 t of total phosphorus into the Baltic Sea in 2021, which was 54% of the waterborne TN load and 58% of the respective TP load of the Baltic Sea. The Neva River contributed over 39% of the total flow into the Baltic Sea, but the Vistula River had the highest TN and TP loads in 2021 with 25% and 34% respectively. TP load showed a statistically significant decrease from 1995 to 2021, with TP being decreased by 6,000 t (30%), but the trends for individual rivers varied greatly. The decreasing tendency in the TN load found previously had levelled off. On the contrary, in some rivers a remarkable increase in TN loads was observed during the last decade.

Figure 1. The monitored catchment areas of the eleven selected rivers of the Baltic Sea catchment.

Introduction

The 11 rivers of this report (Figure 1) include the seven biggest rivers draining into the Baltic Sea and all nine Baltic transboundary rivers having Nutrient Input Ceilings (NICs). NICs are established for rivers with significant contributions from several countries. Each river NIC is further divided between the contributing countries, including also the non-Contracting Countries Belarus, Czechia and Ukraine, according to their share of nutrient inputs in the reference period (1997-2003). The NICs for individual country contributions included in the countries net NICs are presented in the BSAP (HELCOM, 2021a). The river NICs and all calculations are described in detail in HELCOM (2021b).

Over 55 million people live in these rivers' catchments and their proportion is over half of the total nutrient loads of the Baltic Sea. The human pressure is highest in southern parts of the catchment, where population is the densest and agriculture the most intensive (Table 1, Figure 2). Around one third of the total catchment area is cultivated, but it varies widely: Over half of the catchment areas of the Nemunas, Barta, Lielupe, Vistula and Oder rivers are covered by agricultural areas, whereas forests dominate the catchments of the Göta, Kemi, Neva and Daugava rivers. The proportion of inland lakes is high (>15%) in the Göta River and the Neva River catchments, which substantially reduces pollution load exported by those rivers into the Baltic Sea. The order of individual rivers presented in this report is based on the average flow (small rivers first).

Table 1. Catchment characteristics of the 11 selected rivers and the entire Baltic Sea.

River	Area (km^2)	Length (km)	Population	Population density (people per km^2)	Cultivated	Urban	Forest	Inland waters	Other
Barta	1697	103*	21 600	13	65.3	2.1	31.3	0.5	0.8
Daugava	82183	1020	2 393 100	29	26.0	1.3	67.4	2.2	3.1
Göta	50133	756	1 701 600	34	10.9	1.4	56.5	18.0	13.2
Kemi	51121	500	104 000	2	0.5	0.3	76.2	3.5	19.4
Lielupe	16702	119*	481 700	29	60.2	2.8	35.3	0.6	1.2
Nemunas	95536	937	5 151 800	54	50.6	2.7	42.3	1.3	3.0
Neva	279455	74	6 108 000	22	3.6	0.7	75.2	16.4	4.0
Oder	114650	854	16 000 000	140	57.2	6.8	34.3	1.2	0.6
Pregolya	13144	123*	1067300	81	46.7	2.1	31.6	2.6	17.0
Venta	11098	346*	250 500	23	51.1	2.2	44.7	1.0	1.1
Vistula	192246	1047	22 000 000	114	58.2	6.0	33.3	1.0	1.6
Sum of the 11 rivers	907964		55 279 600	61	31.5	3.0	54.2	7.0	4.4
Whole Baltic sea	1729500		84 000 000	49	24.8	2.6	58.4	6.6	7.6

* Wikipedia
Land use information from Copernicus Corine land cover for all except global land cover for Russia, Ukraine and Belarus
Catchment areas are from spatial data and covers the monitored part of rivers, land use values are also covering the monitored part of the river

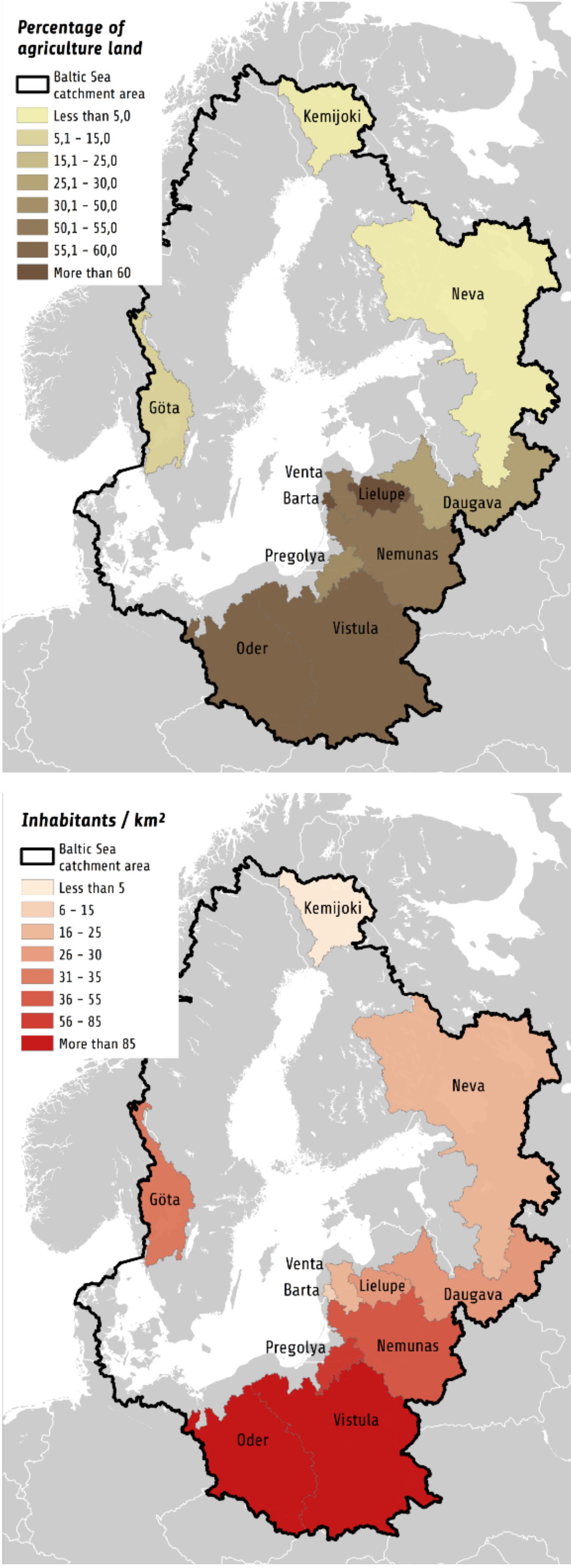


Figure 2. Distribution of agricultural land and population density in the catchments of the 11 selected rivers in 2021 (Russian data is partly from 2005).

1. All the eleven rivers: loads in 2021 and trends between 1995–2021

Total annual nutrient loads from rivers depend greatly on annual average precipitation in the river basin and consequently the river flow. Therefore, flow normalized values for total nitrogen (TN) and total phosphorus (TP) loads were used for inter-annual comparison of the loads and for analyzing long-term trends. In 2021 the non-normalized TN load by the 11 selected rivers was 352 000 tonnes (t) and TP load 13,800 t. The proportion of flow from the 11 rivers to the Baltic Sea was 40% and the respective proportions of waterborne TN load was 54% and TP load 58% of the total flow and load to the Baltic Sea. The Neva River contributed with 39% of the total flow of the 11 rivers, but the Vistula River had the highest TN (25%) and TP loads (34%) (Figure 3).

The area specific TN and TP loads of the 11 selected rivers varied widely, with a general increasing trend from north to south (Figure 4), as population density and the proportion of cultivated area increases (Table 2). On the contrary, runoff values were highest in the northernmost basin (the Kemi and Göta rivers), where evaporation is lower. The highest area specific TN were detected in the Lielupe, the Venta and the Barta river basins (Table 2). The area specific TP loads were the highest in the Pregolya, the Vistula and the Oder river basins, and the lowest area specific TP loads were reported for the Göta and Kemi river basins (Figure 4). In contrast, nutrient loads per capita are low in the densely populated Vistula and Oder catchments indicating that nowadays municipal wastewaters are efficiently treated.

Trends in the flow-normalized TN loads were variable in individual rivers: both downward and upward trends were observed. As a sum of the 11 selected rivers no statistically significant trend could be detected between 1995 and 2021 (Figure 5). In contrast to the TN inputs, the flow-normalized TP loads decreased statistically significantly: The total decrease in TP load was substantial: 6000 t (32%) (Figure 6).

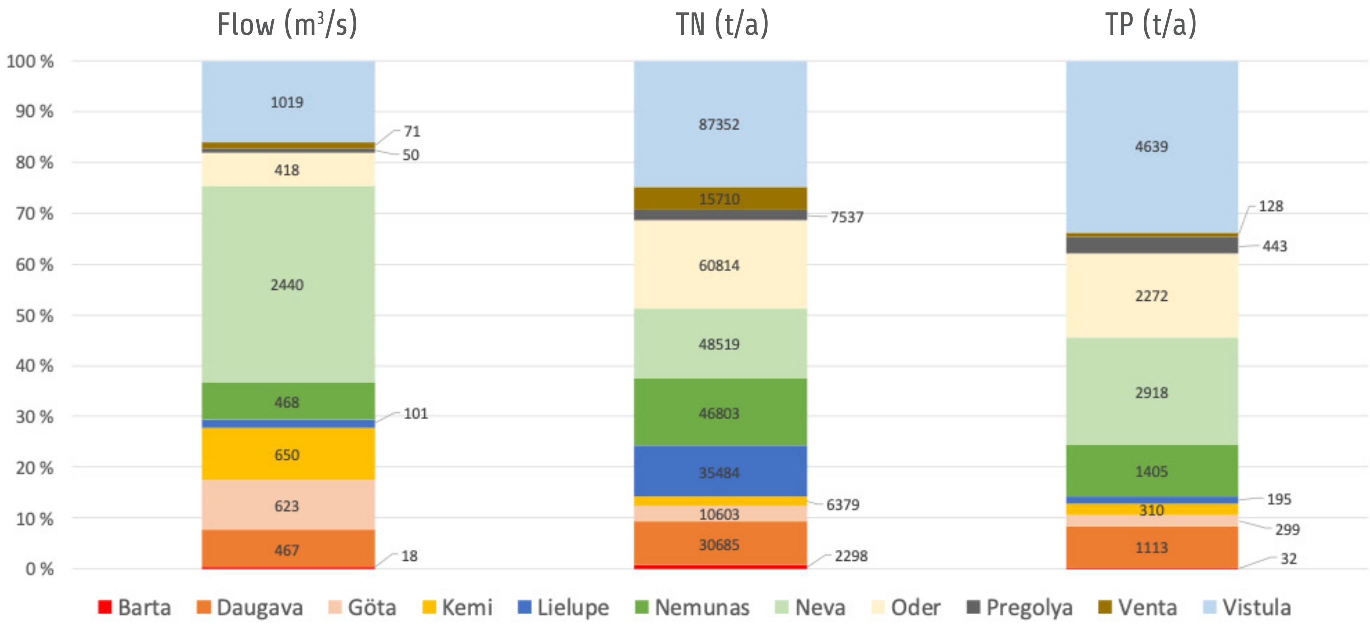


Figure 3. Proportions of flow, flow-normalized TN load and flow-normalized TP load for the 11 selected rivers of the Baltic Sea catchment area in 2021.

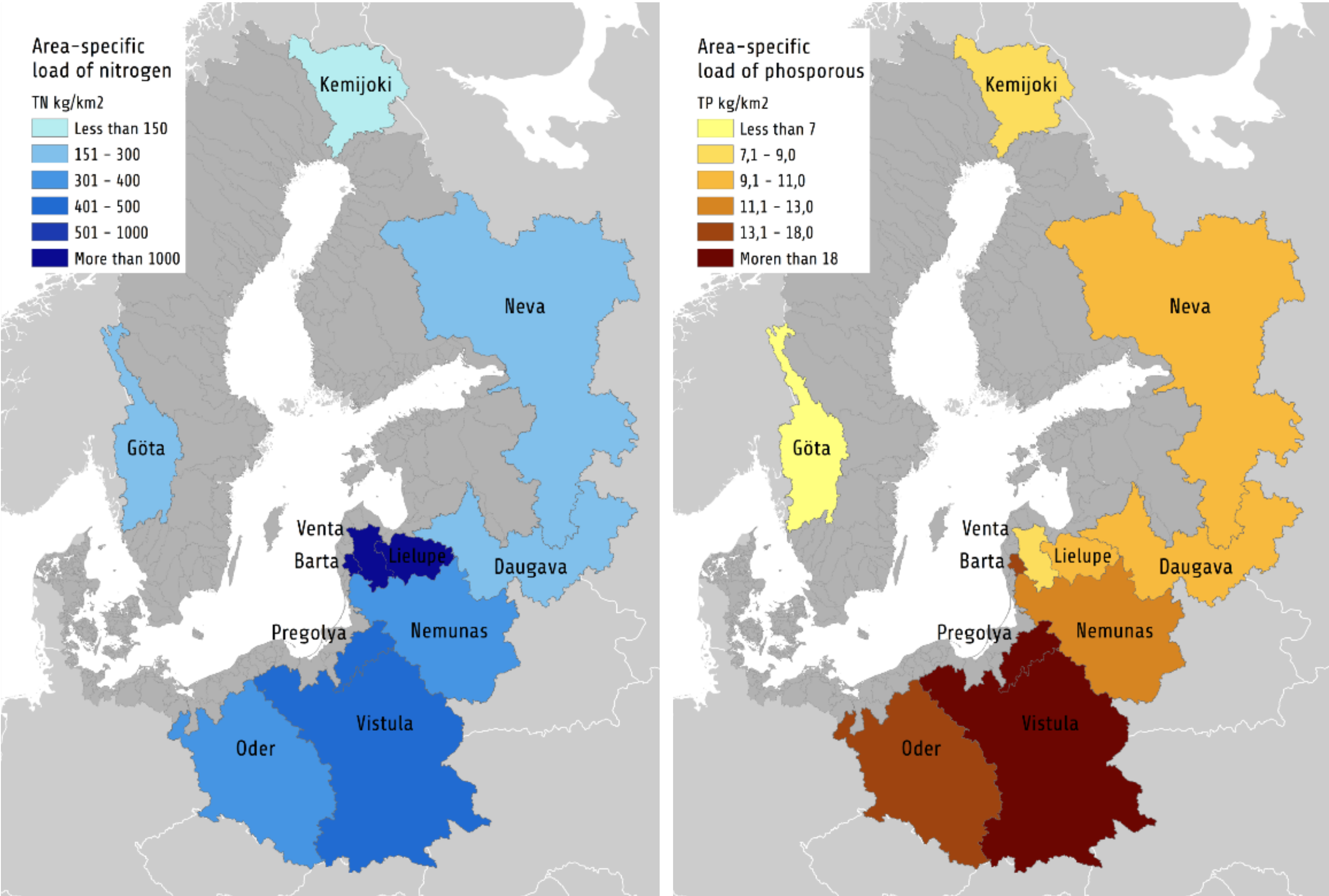


Figure 4. Area specific loads kg km-2 (load/area) of TN and TP from the catchments or sub-catchments of the eleven selected rivers in 2021.

Table 2. Runoff, area specific TN and TP loads (load/area), TN and TP concentrations in 2021 and average concentrations 1995-2020. Concentrations were calculated from annual load and flow values.

	Runoff	Total nitrogen				Total phosphorus			
River	Runoff (l/s/km^2) in 2021	Flow-normlised area specific TN load (kg/km^2) in 2021	Flow-normalised TN load per capita (kg/inhabitant) in 2021	Flow-normalised TN concentration (mg/l) in 2021	Flow-normalised average TN concentration (mg/l) 1995-2020	Flow-normlised area specific TP load (kg/km^2) in 2021	Flow-normalised TP load per capita (kg/inhabitant) in 2021	Flow-normalised TP concentration (mg/l) in 2021	Flow-normalised average TP concentration (mg/l) 1995-2020
Barta	10.7	1350	69.0	4.0	2.4	18.8	2.42	0.056	0.083
Daugava	5.7	373	14.5	2.1	1.8	13.5	0.55	0.076	0.068
Göta	12.4	211	8.1	0.5	0.7	6.0	0.20	0.015	0.019
Kemi	12.7	125	64.8	0.3	0.4	6.1	3.37	0.015	0.019
Lielupe	6.0	2120	40.5	11.2	5.6	11.7	0.73	0.062	0.102
Nemunas	4.9	490	8.1	3.2	2.2	14.7	0.36	0.095	0.098
Neva	8.7	174	9.0	0.6	0.7	10.4	0.50	0.038	0.041
Oder	3.6	530	3.8	4.6	3.7	19.8	0.21	0.172	0.204
Pregolya	3.8	573	6.7	4.8	3.0	33.7	0.39	0.281	0.174
Venta	6.4	1420	35.1	7.0	3.0	11.6	0.93	0.057	0.079
Vistula	5.3	454	4.2	2.7	2.8	24.1	0.26	0.144	0.174

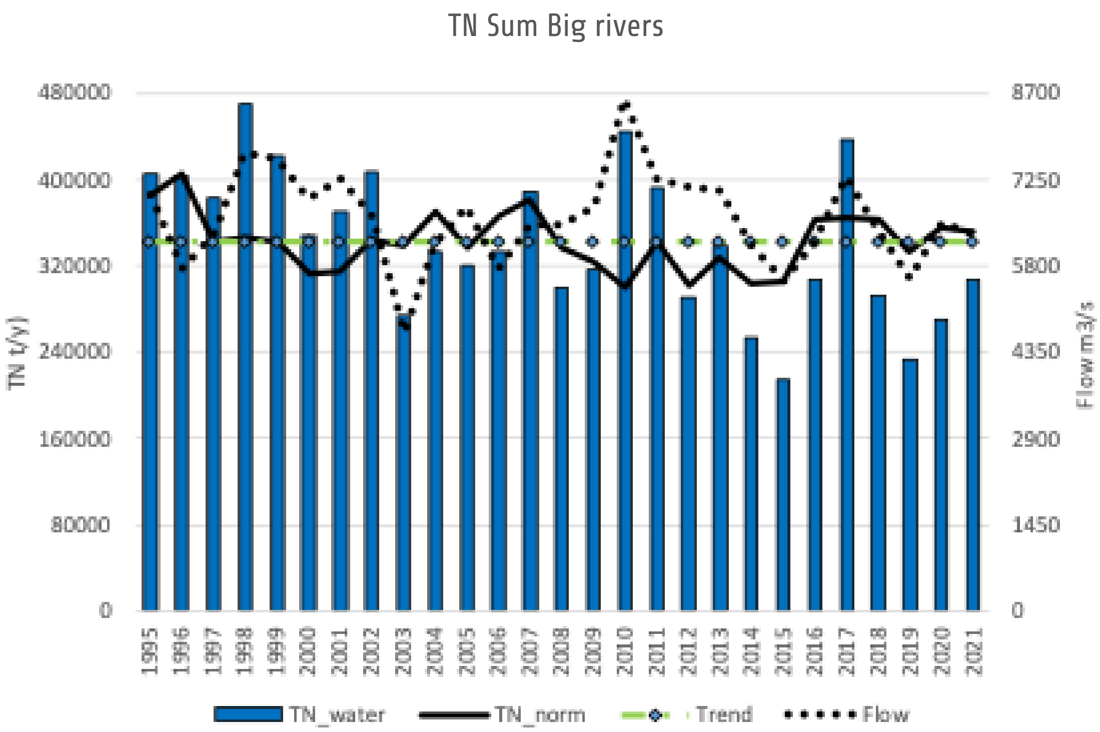


Figure 5. Total nitrogen (TN) load (blue bars) of the 11 selected rivers between 1995 and 2021. The dashed black line shows flow, the black line flow-normalized nutrient load and the green lines linear statistically non-significant trend.

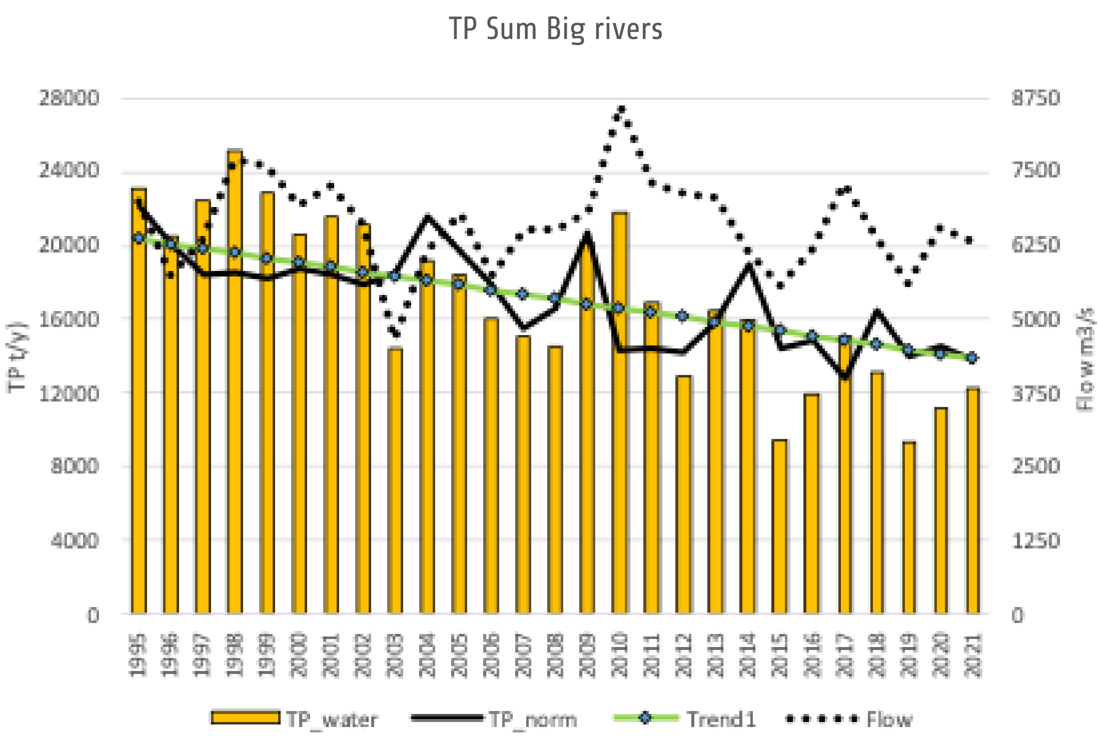


Figure 6. Total phosphorus (TP) load (yellow bars) of the 11 selected rivers between 1995 and 2021. The dashed black line shows flow, the black line flow-normalized nutrient load and the green line statistically significant linear trend.

2. The Venta River

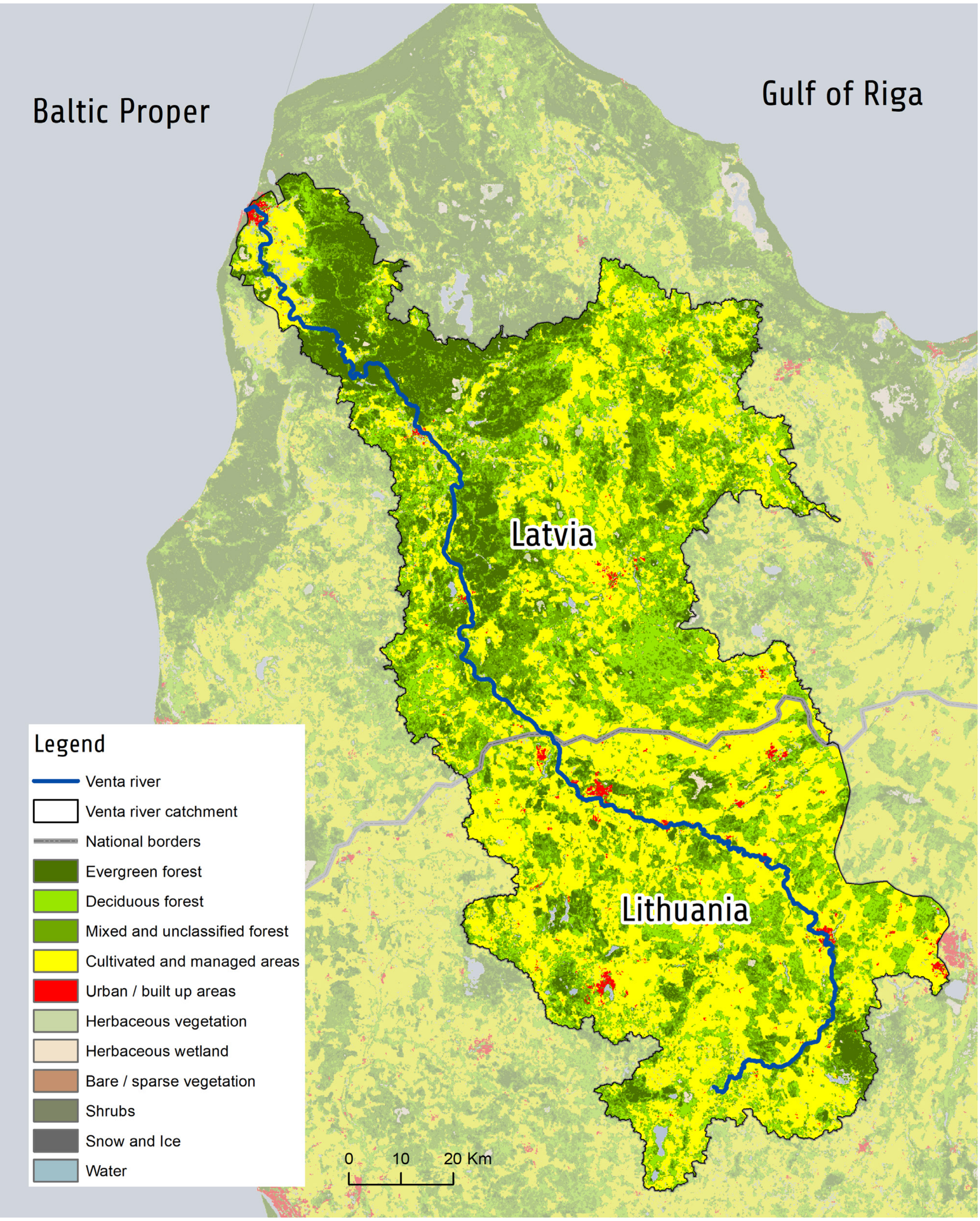


Figure 7. The drainage area (black line) of the Venta River, country borders (grey line) and land cover classes based on Corine 2018.

2.1. Basic information

The Venta River is located in north-western part of Lithuania and in western part of Latvia (Figure 7). The area of the river catchment is 11 795 km^2, out of which about 55% belongs to Latvia and 45% to Lithuania. Dominating land-cover types are agricultural land and forests covering 51% and 44% of the catchment, respectively. A major part of nutrient loads originates from diffuse sources and inputs from agriculture are important in the Venta basin. The whole Venta catchment in Lithuania and part of the catchment in Latvia has been designated as a nitrate vulnerable zone according to the EU Nitrates Directive. There are six small hydroelectric power plants on the Venta River in Lithuania and in addition many small plants exist on tributaries of the Venta in both countries. The largest towns on the banks of the Venta are Mazeikiai (33 000 inhabitants) in Lithuania, and Kuldiga (10 000 inhab.) and Ventspils (33 000 inhab.) in Latvia.

Over 80% of the TN loads and 53% of the TP loads of the Venta River originated from diffuse sources in 2021 (Figure 8). The proportion of TN inputs from point sources was only 1%, whereas point sources contributed with 18% of the TP loads.

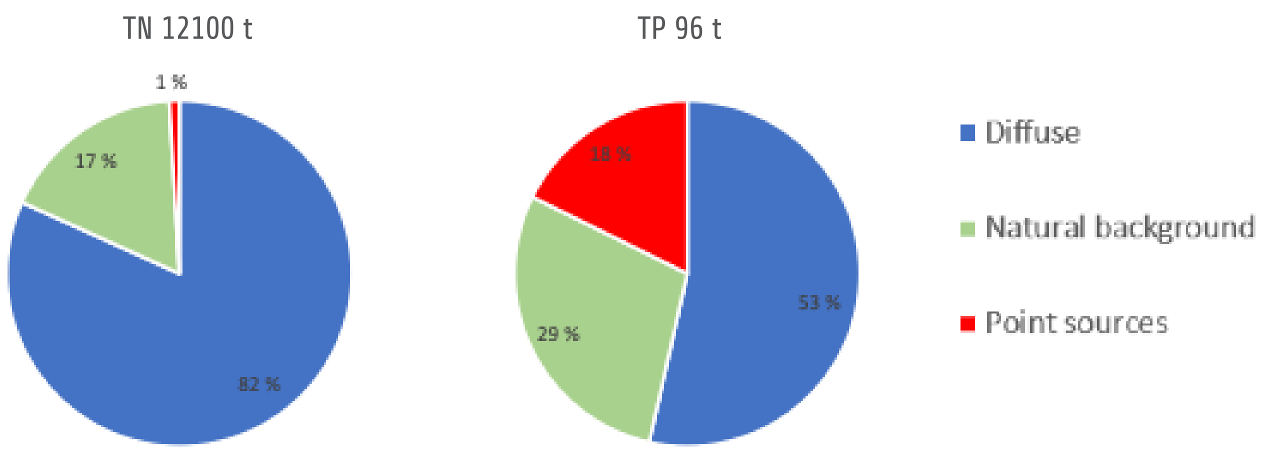


Figure 8. Total nitrogen (TN) and total phosphorus (TP) loads in tonnes (t) exported by the Venta River in 2021 divided into load sources.

2.2. Trends in the export: the Venta River

In 2021 the Venta flow was around 75% of the long-term average flow (1995-2021), which was reflected in exceptionally low total phosphorus (TP) export (96 t, 41% of the average) (Figure 8). However, the total nitrogen (TN) export of was 46% higher than the long-term average. In 2021 the area specific TN load was 1420 kg km^{-2} and the mean TN concentration was 7030 µg l^{-1} (Table 2). The respective TP load was 11.6 kg km^{-2} and the mean concentration was 57 µg l^{-1}. In 2000 an upward trend started in TN export by the Venta River, and from 2000 to 2021 the TN load has doubled (Figure 9). There was a stepwise reduction in TP export in 2007 and since then the TP load has stayed at a lower level. Both the TN and TP loads of the Venta are above the nutrient input ceilings (NICs).

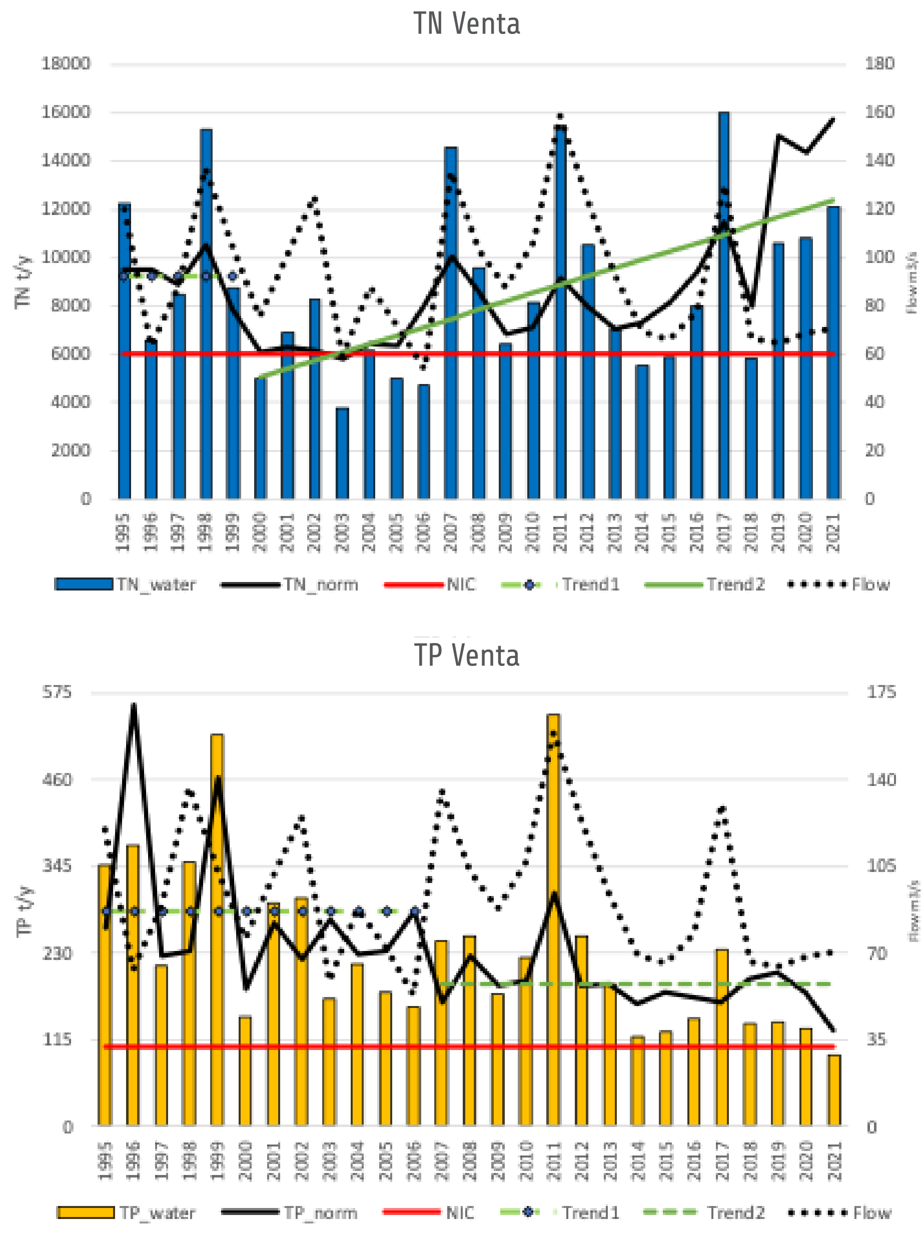


Figure 9. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Venta River from 1995 to 2021. The dashed black lines show flow, the black lines flow-normalized nutrient export and the green lines the trend in the flow-normalized export. Solid green lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input ceilings (NIC).

2.3. Mitigation measures

In Latvia the basic measures (required by the national and EU legislation) include a sufficient treatment of municipal and industrial wastewaters, prevention of untreated wastewater discharges into environment, building centralized sewage systems in towns with population equivalent (PE) ≥2000, use of fertilizers and manure according to regulations to prevent nutrient leakages from cultivated lands, crop diversification and maintenance of permanent grassland and ecological landscape elements and many other measures to protect water resources and biodiversity. Supplementary measures for reduction of nitrogen (N) and phosphorus (P) load are planned in waterbodies that are not in a good ecological status due to increased nutrient concentrations. Improvement of waste water treatment plant (WWTP) efficiency is foreseen to reduce the point source load. Measures to reduce diffuse nutrient loads from agriculture include the creation of sedimentation ponds, introduction of conservative or minimum tillage practices as well as establishment of long-term plantations in arable lands, establishment of buffer strips along watercourses and other measures. Additionally, to control nitrogen loads, the use of N fertilizer should be reduced by 20% and controlled drainage installed in those waterbodies where nitrogen concentrations exceed the target value for good ecological quality.

In the Lithuanian part of the Venta River basin the agricultural pollution reduction measures foreseen and being implemented are in line with nationwide agricultural pollution reduction measures. The national common agricultural policy (CAP) is one of the most important instruments, which takes form of financially supported relevant eco-schemes and obligatory environmental requirements, related to introduction of winter catch crops, low-till agriculture, leaving stubble fields, special regimes in risk water bodies basins etc. Moreover, better regulation of the use of fertilizing products is foreseen in order to prevent over-fertilization of soils and leaching of nutrients into water bodies by preparing a methodology for the preparation of fertilization plans, based on which it would be possible to calculate the optimal amount of fertilizers for different crops. This information on fertilization plans and actual usage will have to be provided into newly established database which is now under development. This information should help better monitor fertilizer use, detect potential problems and/or their root-causes. It is also planned to undertake more forceful information campaigns and trainings to farmers on mutually environmentally and economically beneficial measures, on financial support schemes and rules in the National CAP, the importance of pollution reduction measures and ways to implement them (manure handling, fertilization plans preparation etc.).

In terms of pollution reduction from point sources, it is planned to continue increasing the efficiency of wastewater treatment where it is needed, as well as undertake inventories of the sewage outlets into lakes with a view to detect and control possible undocumented sewage outlets. It is planned to install better surface wastewater treatment infrastructure if pollution is discharged into lakes. Overall, more obstacles will be introduced to establish new wastewater discharge outlets to standing waters. Aquaculture is planned to be more thoroughly controlled with a view to ensure fishponds do not have significant adverse impact of downstream water bodies. Furthermore, pollution from scattered dwellings will be further curbed to a certain degree by ongoing connection of residents' homes to the central wastewater collection infrastructure.

3. The Barta River

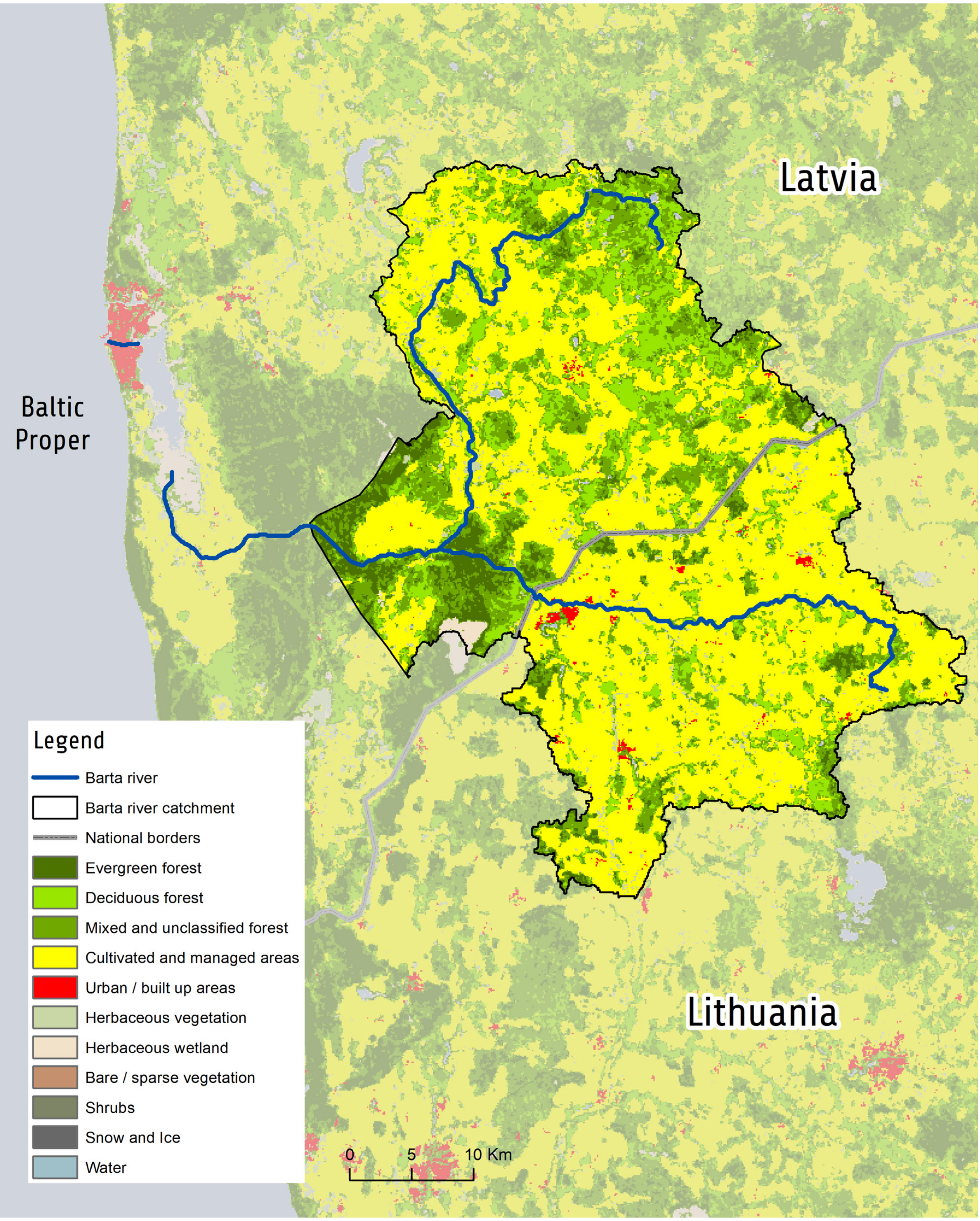


Figure 10. The drainage area (black line) of the monitored part of the Barta River, country borders (grey line) and land cover classes based on Corine 2018.

3.1. Basic information

The Barta River is located in north-western part of Lithuania and in western part of Latvia (Figure 10). The area of the river catchment is 2016 km^2, out of which about 51% belongs to Latvia and 49% to Lithuania. The river starts in Lithuania, in Žemaičiu Upland in the Plunge district. In Latvia, the Barta River flows into the Liepajas Lake, which is connected to the Baltic Proper. The lowest reach of the river was channelized during Soviet times. Agricultural lands and forests cover 65% and 31% of the total river catchment, respectively. Although main part of the Barta catchment in Latvia is covered by forests and wetlands, nutrient runoff from agricultural sources is recognized as an important pressure for the Barta catchment in the 3rd River Basin Management Plan in Latvia. In Lithuania, the catchment is designated as a nitrate vulnerable zone according to the EU Nitrates Directive. Major settlements on the banks of the Barta are Skuodas (5 500 inhabitants) and Mosedis (900 inhab.) in Lithuania, as well as Nica (980 inhab.) in Latvia.

In 2021 90% of the total nitrogen (TN) loads and 75% of the total phosphorus (TP) loads of the Barta River originated from diffuse sources (Figure 11). Natural background leaching was the second largest source of nutrients. TN inputs from point sources were negligible, whereas the share TP inputs from point sources was 8% of the total TP inputs.

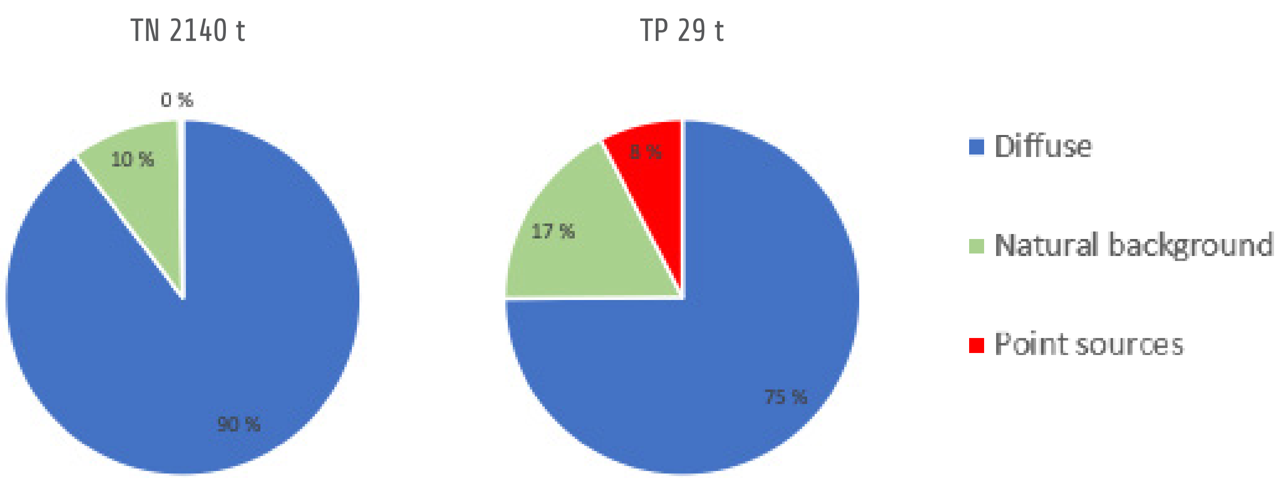


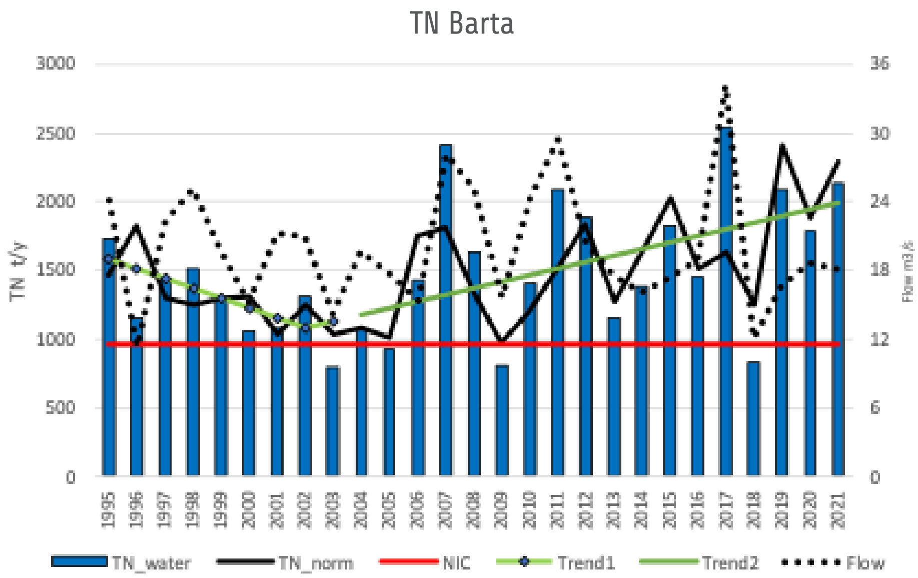
Figure 11. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Barta River in 2021 divided into load sources.

3.2. Trends in the export: the Barta River

In 2021 the flow was 91% of the long-term average flow (1995-2021), which was reflected in low total phosphorus (TP) export (29 t, 55% of the average) (Figure 11). However, the total nitrogen (TN) export of was 46% higher than the long-term average. In 2021 the area specific TN load was 1350 kg km^{-2} and the mean TN concentration was 4010 µg l^{-1} (Table 2). The respective TP load was 18.8 kg km^{-2} and the mean concentration was 56 µg l^{-1}. Similarly to the Venta River an upward trend in TN export by the Barta River started in early 2000s, and from 2003 to 2021 the TN load has nearly doubled (Figure 12). There was a remarkable stepwise reduction in TP export in 2002 and TP load has stayed at a lower level. Both the TN and TP loads of the Barta are above the nutrient input ceilings (NICs).

3.3. Mitigation measures

See mitigation measures in the chapter of the Venta River.



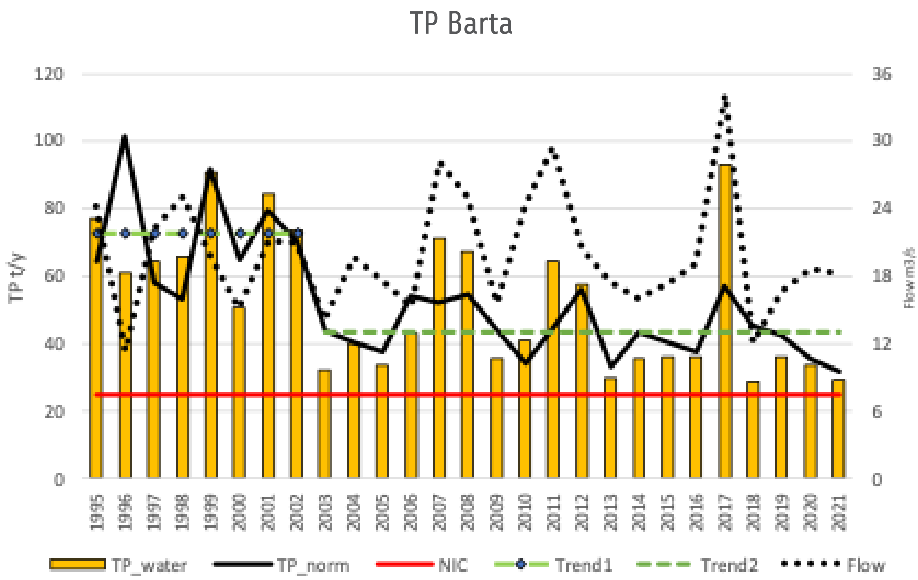


Figure 12. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Barta river from 1995 to 2021. The dashed black lines show flow, the black lines flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid green lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input ceilings (NIC).

4. The Lielupe River

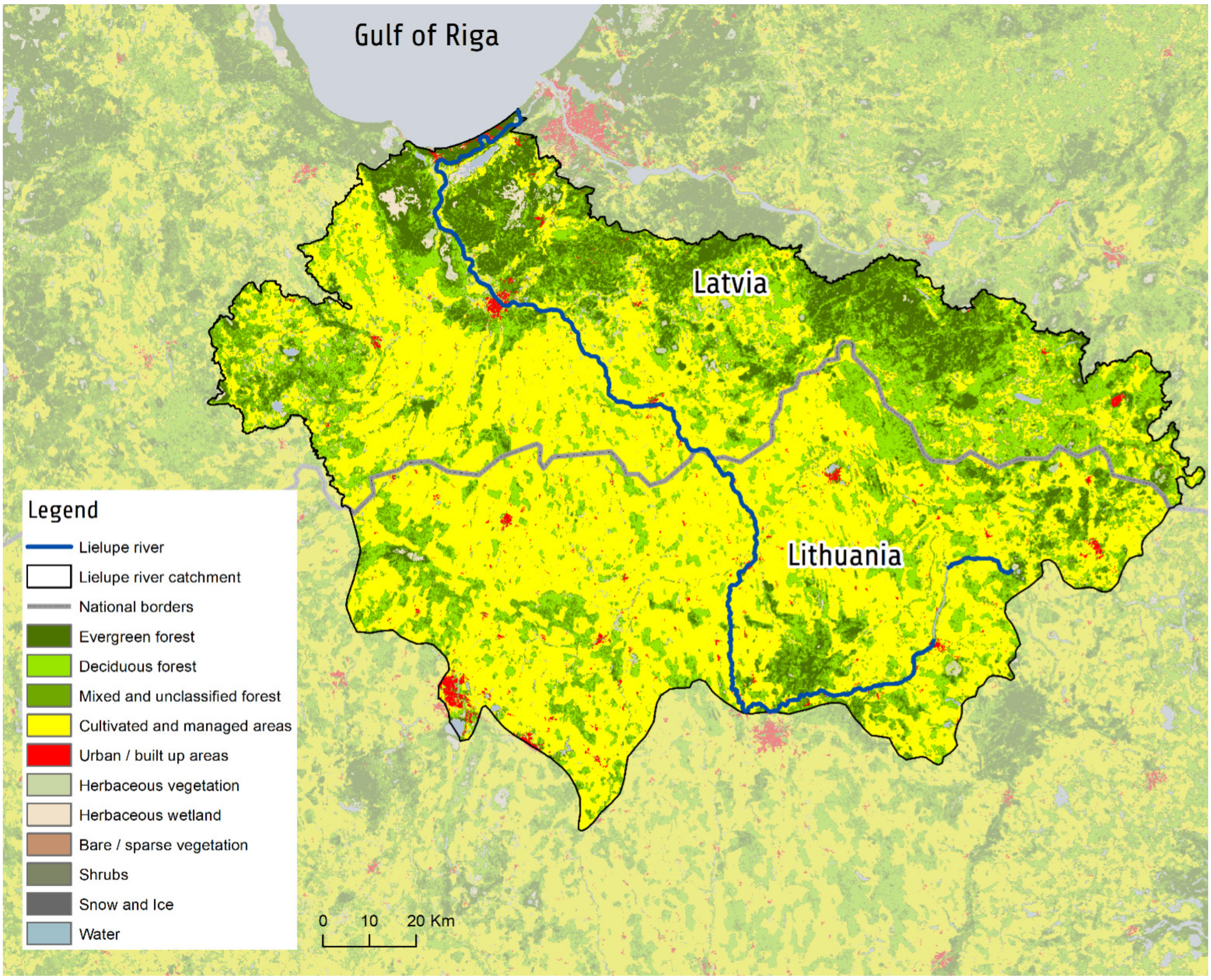


Figure 13. The drainage area (black line) of the Lielupe River, country borders (grey line) and land cover classes based on Corine 2018.

4.1. Basic information

The Lielupe River starts in Latvia at the confluence of the Musa and the Memele/Nemunelis rivers near Bauska Town (Figure 13). The river catchment is located in central Latvia and northern part of Lithuania. It has an area of 17 600 km² which is about equally distributed between Latvia and Lithuania. The Lielupe River and most of its tributaries are potamal lowland rivers. Downstream from Jelgava Town in Latvia, the slope of the Lielupe river is only 5–10 cm/km. The riverbed is much lower than the average Baltic Sea level over a length of 100 km upstream from the river mouth. As a result, water flows upstream in autumn and winter. In the highest flooding events, brackish water from the Gulf of Riga flows up the river mouth and sometimes reaches the Kalnciems region where monitoring station of water quality is located (Koltsova and Belakova, 2009). The Lielupe catchment is characterised by intense agricultural activities. Agricultural land occupies 60% of the river basin. Large territories in both countries have been drained and many rivers have been channelized during Soviet times. 58-81% of catchment of the Lielupe tributaries in Lithuania are drained (Stankeviciene and Stankevicius, 2014). Catchment in Lithuania and part of the Latvian catchment is designed as a nitrate vulnerable zone according to the EU Nitrates Directive. Average density of population in Latvian part of the catchment is 25 inhabitants/km². The largest towns in Latvian part of the catchment are Jelgava (54 800 inhabitants), Jurmala (51 000 inhab.) and Bauska (9 700 inhab.). In Lithuanian part, the largest towns are Birzai (10 400 inhab.), Joniskis (8 500 inhab.), and Pasvalys (6 400 inhab).

Nearly 90% of the total nitrogen (TN) loads and 76% of the total phosphorus (TP) loads of the Lielupe River originated from diffuse sources (Figure 14). Natural background leaching was the second largest nutrient source. TN inputs from point sources were negligible, whereas the share TP inputs from point sources was 10% of the total TP inputs.

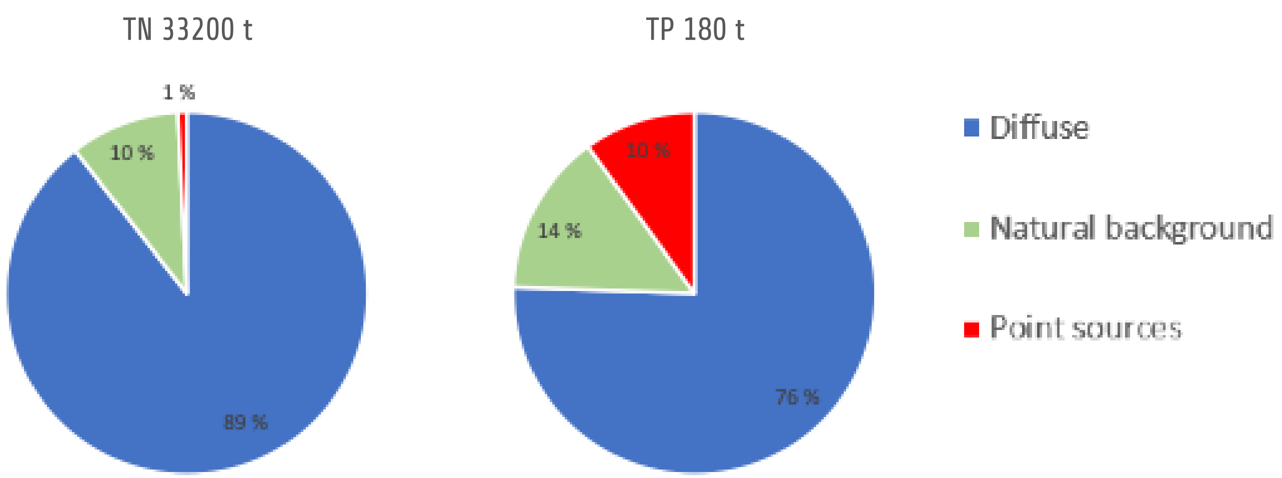


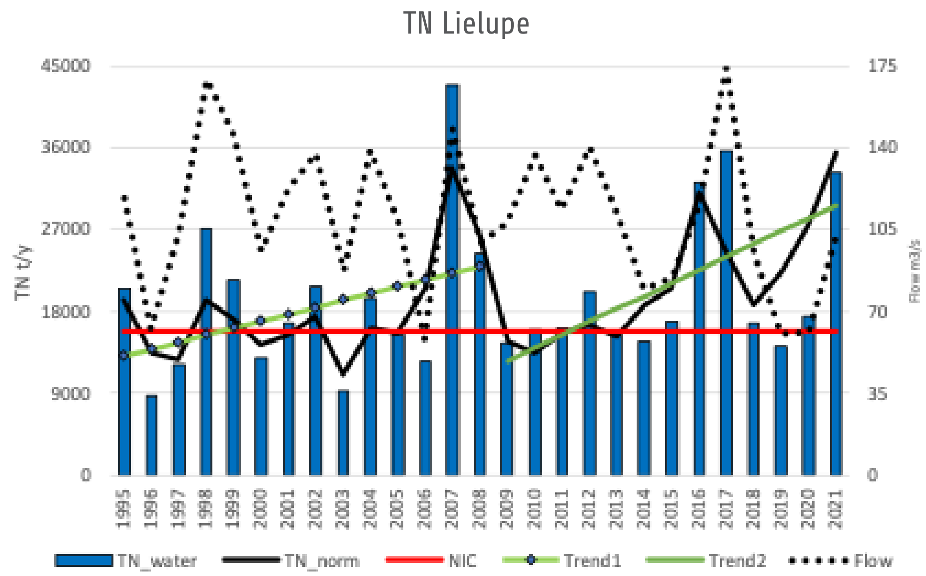
Figure 14. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Lielupe River in 2021 divided into load sources.

4.2. Trends in the export: the Lielupe River

In 2021 the flow was slightly (9%) lower than then long-term average flow, which was reflected in low total phosphorus (TP) export (180 t) (Figure 15). However, the total nitrogen (TN) export (over 33 000 t) was 79% higher than the long-term average. In 2021 the area specific TN load was 2120 kg km^{-2} and the mean TN concentration was exceptionally high: 11 200 µg l^{-1} (Table 2). The respective TP load was 11.7 kg km^{-2} and the mean concentration was 62 µg l^{-1}. The upward trend in TN export of the Lielupe River could be divided into two parts: the first one started in 1995 and ended in 2008 (Figure 15). From 2009 onwards there has been a continuous upward trend and presently the TN export by the Lielupe is substantially higher than it was in the mid-1990s. The TP export decreased remarkably between 1995 and 2001 and has stayed at a lower level since then.

4.3. Mitigation measures

See mitigation measures in the chapter of the Venta River.



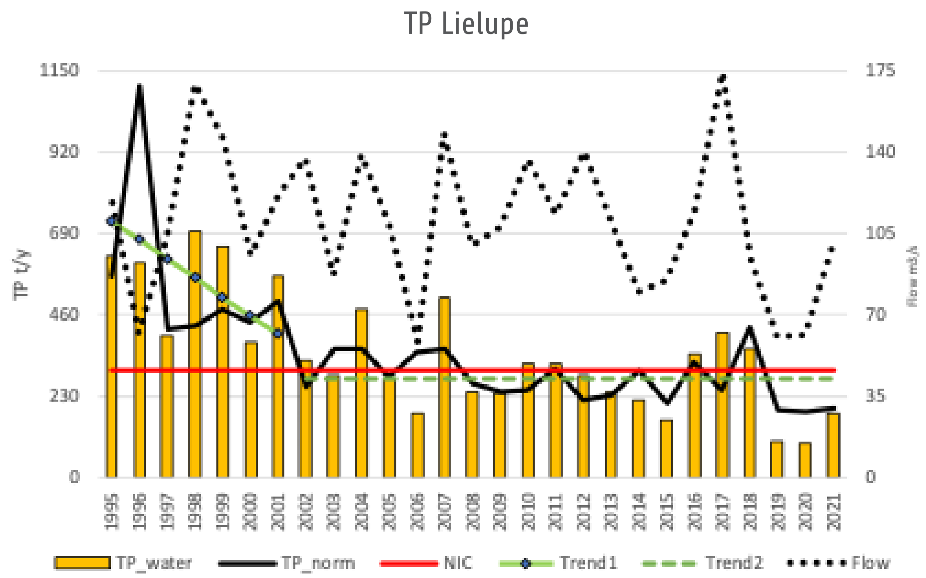


Figure 15. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Lielupe river from 1995 to 2021. The dashed black lines show flow, the black lines flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid green lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input cceilings (NIC).

5. The Pregolya River

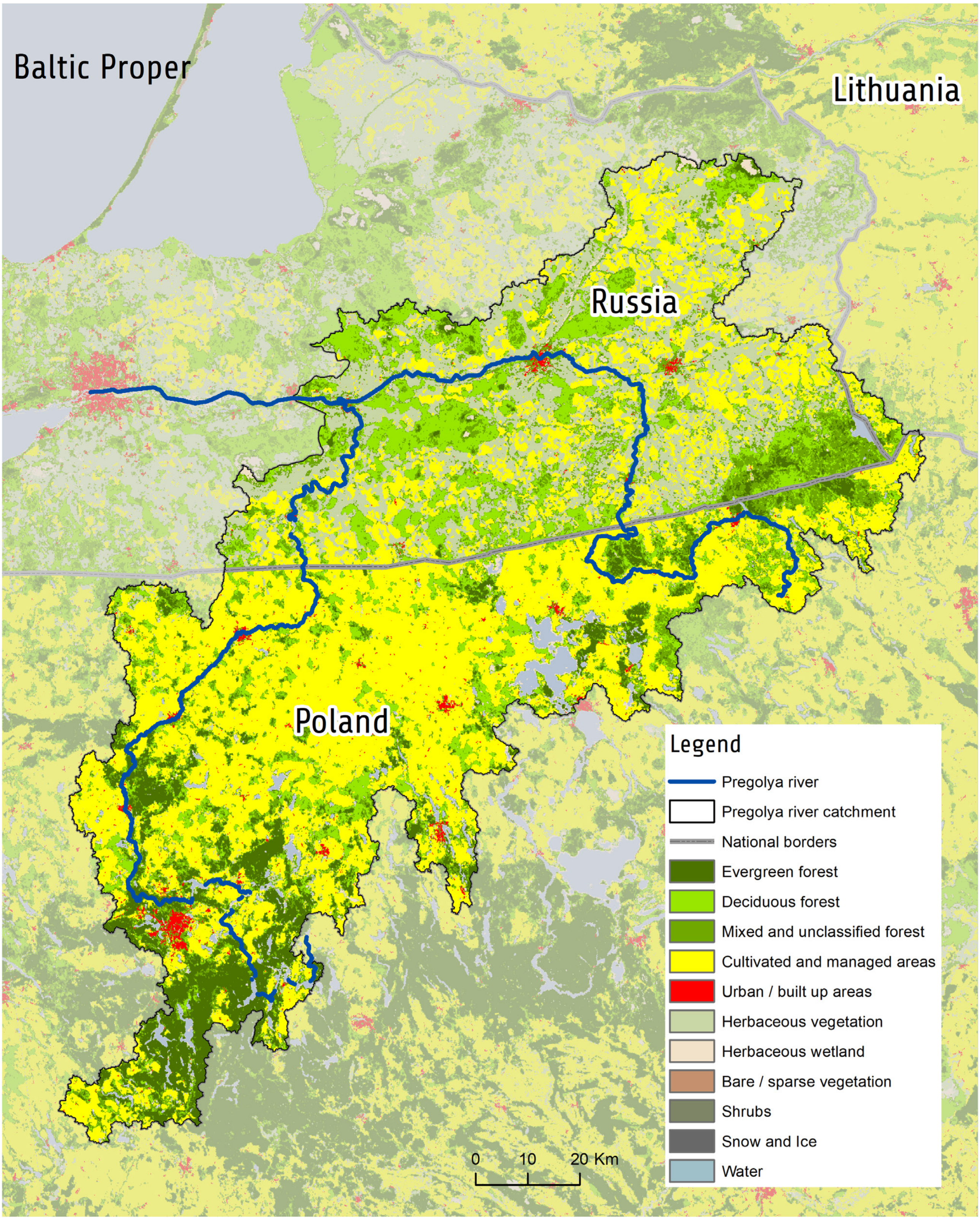


Figure 16. The monitored part of the drainage area (black line) of the Pregolya River, country borders (grey line) and land cover classes based on Corine 2018.

5.1. Basic information

The Pregolya River has a length of 123 km and the river is bifurcates in two branches in the city of Gvardeysk: The main branch, the Pregolya, flows through the city of Kaliningrad into the Vistula Lagoon and the other branch, the Deyma, flows into Curonian Lagoon. Its catchment area is 15,500 km^2 and it is occupied by Russia and Poland in approximately equal proportions 49% and 51% respectively (Domin et al. 2017). Agricultural areas are concentrated in the Polish side and of the whole catchment nearly half (47%) is cultivated (Table 1). Forest cover 32% of the catchment and urban areas 2%, respectively. Kaliningrad with 475 000 inhabitants is the biggest city in the Pergolya catchment, whereas on the Polish side the biggest city is Olszyn with 172 000 inhabitants.

The major part (79-84%) of the nutrient loads in the Pregolya River originates from diffuse sources, mainly agriculture in the Polish part of the catchment (Figure 17). The proportion of point source loads was clearly higher for the total phosphorus (TP) loads compared to the respective total nitrogen (TN) loads: TN 6% vs TP 14%.

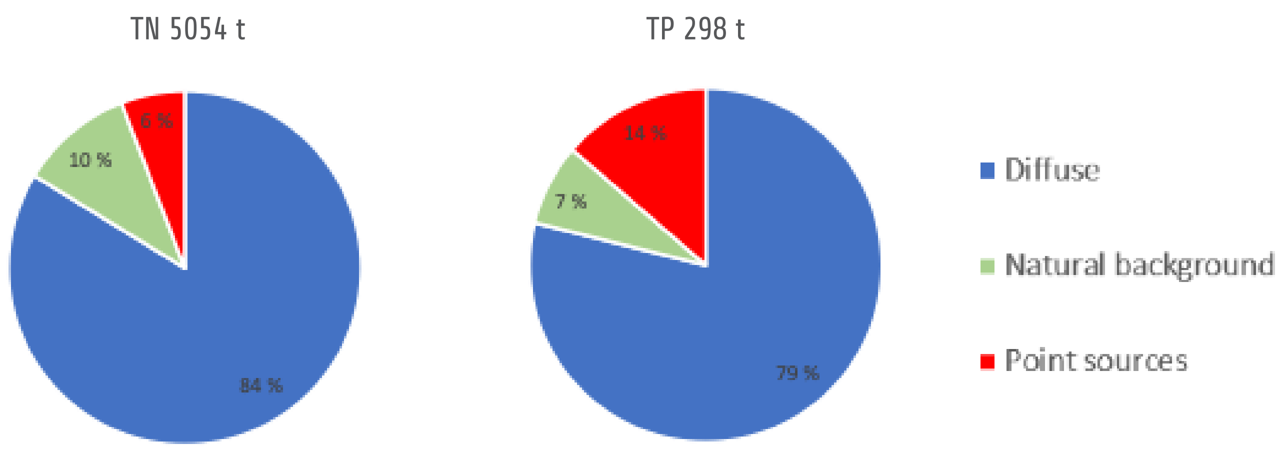
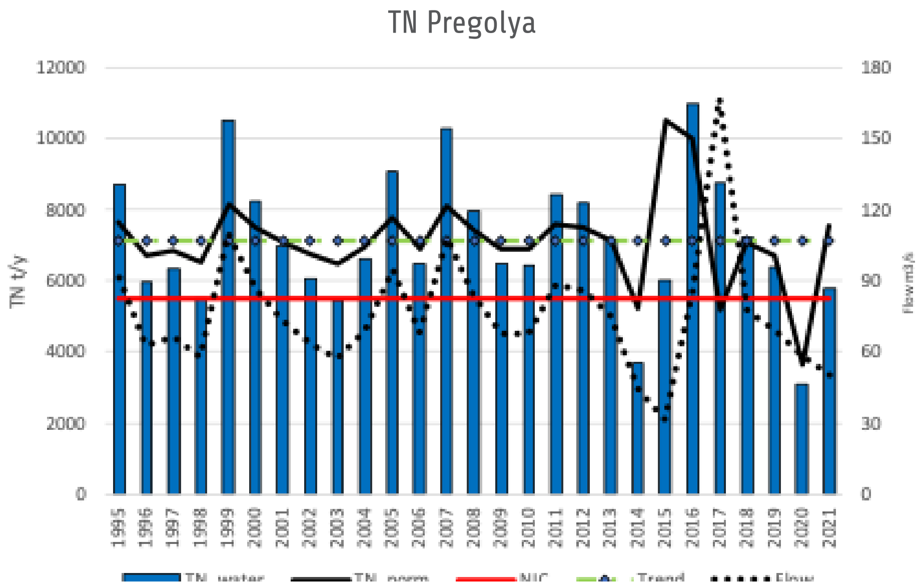


Figure 17. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Pregolya River in 2021 divided into load sources.

5.2. Trends in the export: the Pregolya River

In 2021 the flow was remarkably (35%) lower than the long-term average (77 m^3/s), which was reflected in lower total nitrogen (TN) and total phosphorus (TP) exports (around 80% of the long-term average). In 2021 the area specific TN load was 573 kg km^{-2} and the mean TN concentration was 4770 µg l^{-1} (Table 2). The respective TP load was 33.7 kg km^{-2} and the mean concentration was 281 µg l^{-1}. No trends could be detected in TN or TP export (Figure 18).



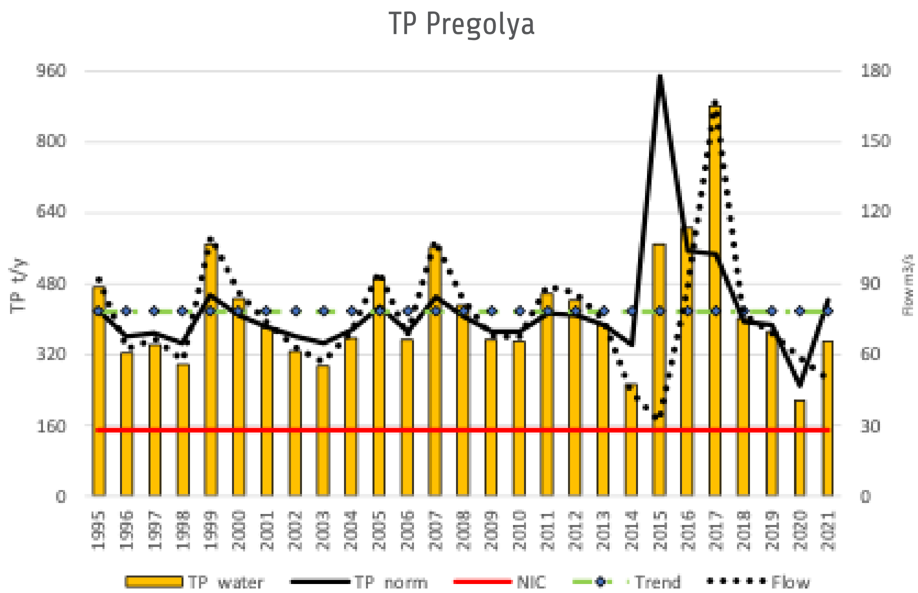


Figure 18. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Pregolya River from 1995 to 2021. The dashed black lines show flow, the black lines flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid green lines significant trend and dashed green lines indicate statistically non-significant trend. Red straight line shows the nutrient input ceiling NIC.

6. The Göta River

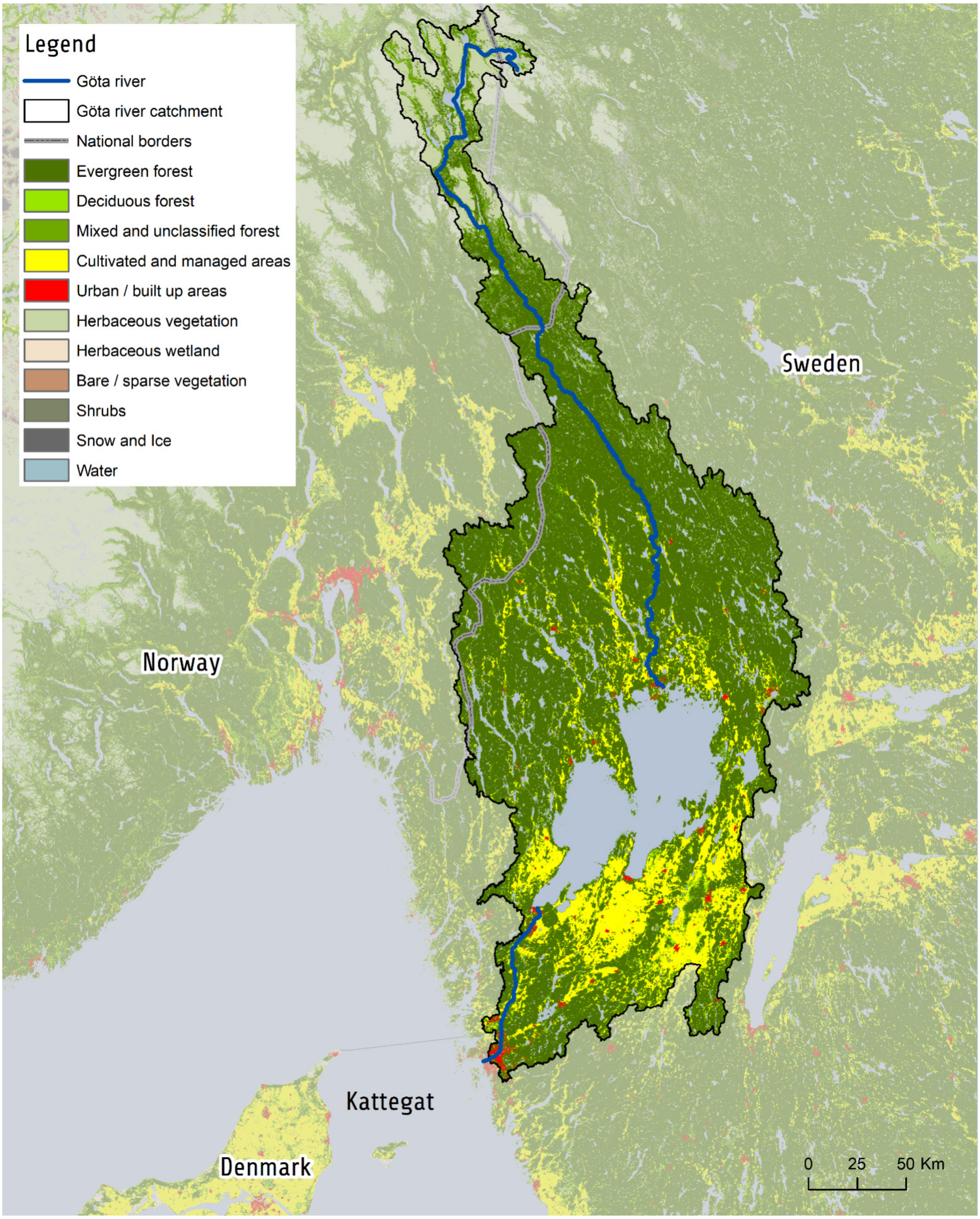


Figure 19. The drainage area (black line) of the Göta River, country borders (grey line) and land cover classes based on Corine 2018.

6.1. Basic information

The area of the Göta River's drainage basin is 50,200 km^2. Most of the catchment belongs to Sweden (85%) and represents about 10% of total Swedish land area. However, the northernmost part of the river system is located in Norway (Figure 19). The northern parts are pristine, whereas the human impact is most evident in the southern parts of the catchment. More than 50% of land use is forested areas, especially in the northern part (Sonesten 2004). Arable land is mainly found in the south-eastern part, as well as in the lower reaches of the catchment areas running into Lake Vänern (Figure 19). Also, the areas beyond the outlet of Lake Vänern have a notable amount of arable land. Lake Vänern, the largest lake in Sweden and the third largest in Europe, has an import role in the nutrient transport in the

catchment as it efficiently retains nutrients originating from the upstream areas of the catchment. The river divides into two river branches near the estuary leading into the North Sea. At least two thirds of the river volume runs through the northern branch: Nordre älv (Göta älvs vattenvårdsförbund 2015). The southern branch passes through the city of Gothenburg providing more than 700 000 people with drinking water. The Göta River is utilized as a shipping channel and it allows for transport of goods both in the upstream and downstream direction. The total fall in height between lake Vänern and the sea is 44 meters. This is used for producing hydropower through a highly regulated water flow in several hydroelectric power plants, corresponding to a total capacity of approximately 300 MW. The Göta River is a recipient for inputs originating from various industries, sewage treatment plants and individual sewers as well as storm water from urban areas and inputs from agriculture in the catchment area. Population density is 34 inhabitants per km^2 and Karlstad, Trollhättan and Gothenburg are the largest cities in the catchment.

Natural background leaching was the main source of the total nitrogen (TN) inputs (38%), whereas agriculture was the largest source of the total phosphorus (TP) load (31 %) of the Göta River in 2021. Agriculture was the second biggest source for TN (23%) and natural background leaching for TP (26%) (Figure 20). Beside agriculture and other diffuse sources, atmospheric deposition was an important contributor to the nutrient loads. Point sources contributed with 11% of TN load and 13% of the TP load respectively. Compared to the nutrient sources in the previous big rivers report (HELCOM 2021c) the percentual proportion of atmospheric TP deposition has remarkably increased. The reason behind it is, that the deposition of TP for 2021 is an average value for 2019-2021 based on monitoring data and differ geographically, with the highest deposition in the southern parts of Sweden. Data from 2017 is based on an older and lower value (4 kg/km2/year) applied for the whole of Sweden.

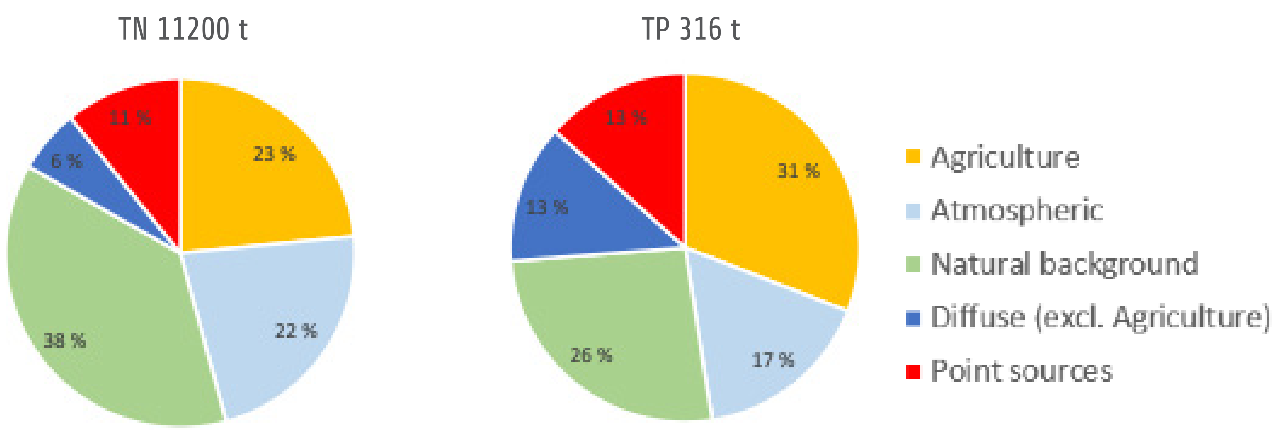
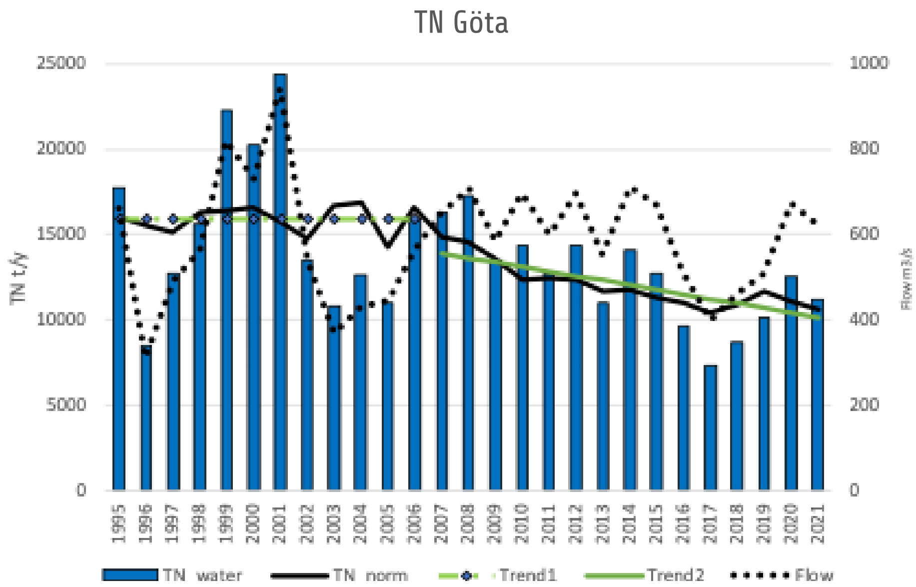


Figure 20. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Göta River in 2021 divided into load sources.

6.2. Trends in the export: the Göta River

In 2021 the flow was around 106% of the long-term average flow (1995-2021), which was reflected in the total nitrogen (TN) export (11,200 t) and total phosphorus (TP) export (316 t) (Figure 20). Nonetheless, the export of both nitrogen and phosphorus were lower than the long-term average. The TN export was only around 81% of the long-term average export and the TP export 91%, respectively. In 2021 the area specific TN load was 211 kg km^{-2} and the mean TN concentration was 540 µg l^{-1} (Table 2). The respective TP load was 6,0 kg km^{-2} and the mean concentration was 15 µg l^{-1}. A statistically significant decrease in TN export has been observed since 2007 (Figure 21). In fact, the TN load has been decreasing since the mid 1980's. This is a general tendency for nitrogen transport in different parts of the river system as well as for the nitrogen levels in Lake Vänern. The reduced nitrogen levels in the system are due to reduced inputs of nitrogen from point sources (Christensen et al. 2002) including nitrogen removal from wastewater treatment plants, and also from diffuse nitrogen sources. A slight, step-wise reduction in TP export could be detected in 2007, and since then the TP export has stayed at a lower level (Figure 21).



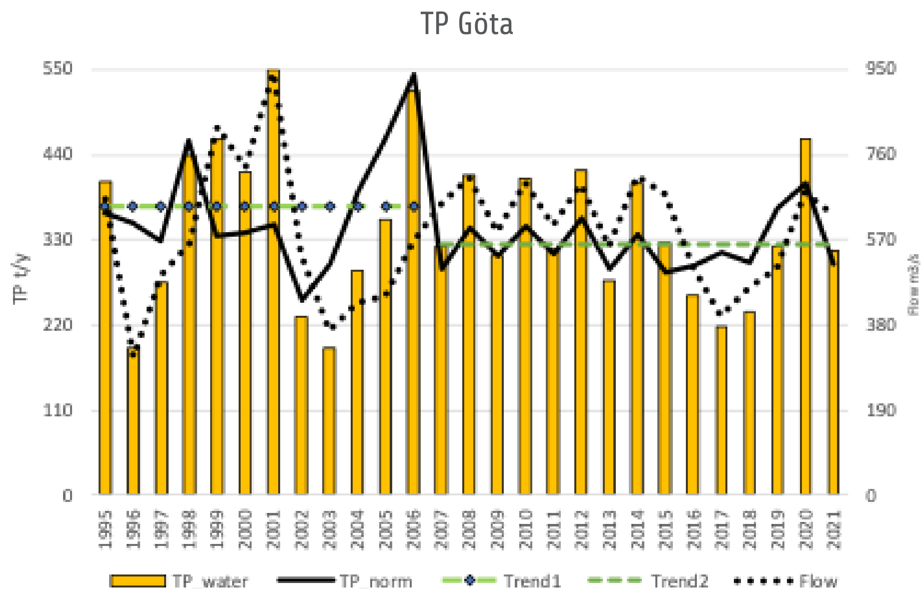


Figure 21. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Göta River from 1995 to 2021. The dashed black lines show flow, the black lines flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid green lines indicate statistically significant trend and dashed lines non-significant trend.

6.3. Mitigation measures

Within the catchment of the Göta River there are several authorities planning and implementing all kind of different measures aiming at mitigating the negative impact humans have on the ecology of the catchment. Planning and implementing of those measures is done in collaboration with local stakeholder, farmers and NGOs.

The absolute bulk of the measures (several thousands) aim at the reduction of inputs of nutrients and hazardous substances. Not surprisingly, the majority of measures planned are ones coping with the input of nutrients such as liming, the upgrading of major point sources such as wastewater treatment plants (WWTPs), the upgrading of treatment solutions for scattered dwellings (alternatively connecting them to the central WWTP) and solutions to cope with inputs resulting from stormwaters.

Additionally, different types of measures are identified, planned or implemented within forestry and agriculture. Besides the measures more on managing side in agriculture (as in precision application of fertilizers, Buffer zones, winter catch crops, etc.) there are also ones considering the beneficial effects of changing land use from crop land to less intensive types of usage. This comes also with the benefits of reducing the erosion of topsoil, influencing sediment balance and riverbed colmation. In combination with several hundred measures aiming at recreating natural hydraulic conditions, with closer to natural discharges, timing and durations, and numerous efforts to reconnect tributaries and removing obstacles for the migration of aquatic life in all directions should ensure an improvement of the Göta River, its habitats and the species depending on it.

7. The Kemi River

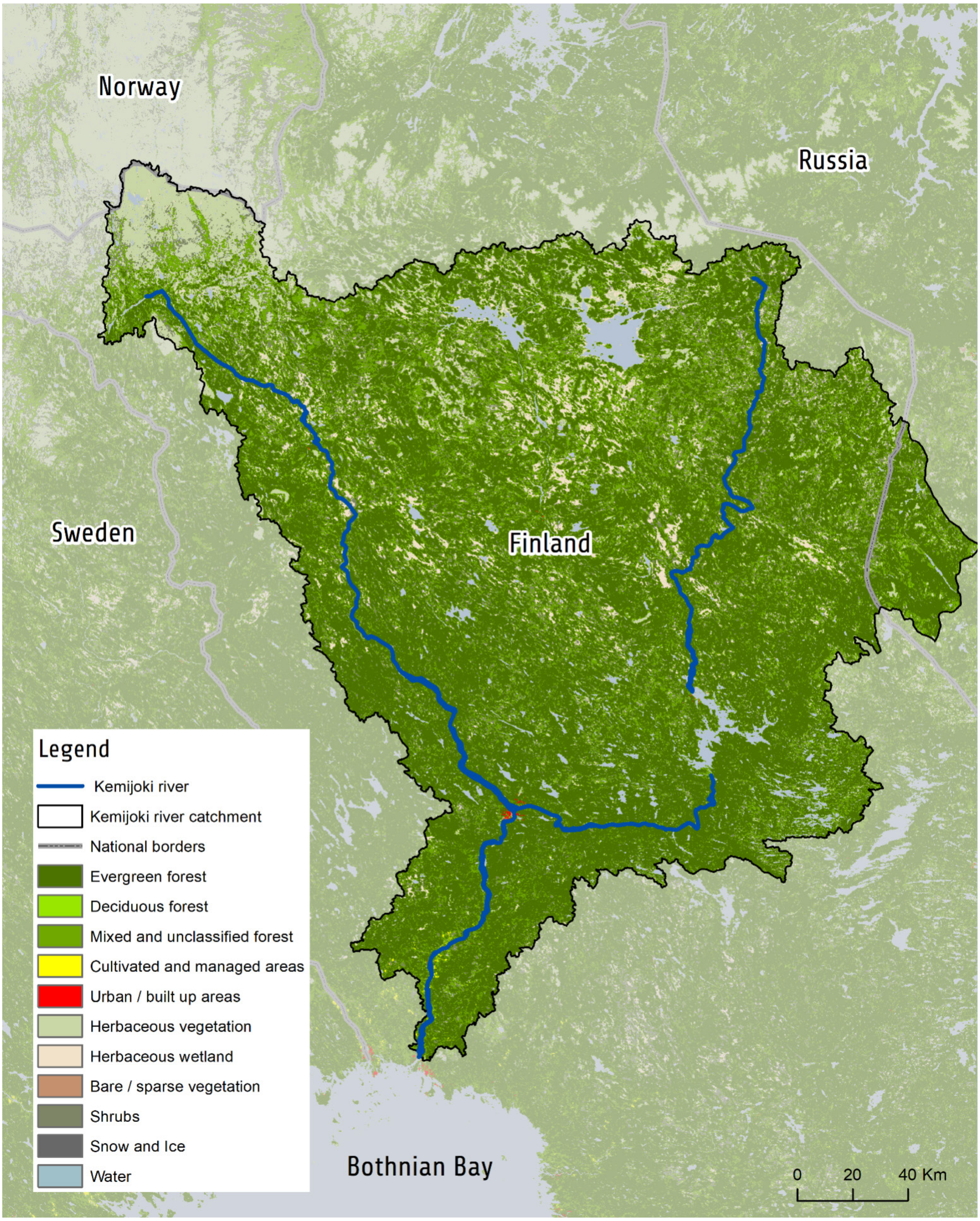


Figure 22. The drainage area (black line) of the Kemi River, country borders (grey line) and land cover classes based on Corine 2018.

7.1. Basic information

The Kemi River stretches for 550 km, making it the longest river in Finland. It flows into the Bothnian Bay. It drains the northern parts of Finland and a small part of its catchment is in Russian territory (Figure 22). The river has been intensively used for hydroelectric production and the first dam was built in 1946. Today the total number of hydroelectric plants is 21. In addition to dams, two large reservoirs were built in the late 1960s in the northern parts of the catchment for hydroelectric purposes. Forests cover over half and peatlands one quarter of the catchment area. The northernmost parts of the catchment area are in particularly pristine condition. Human impact, beside hydroelectric production, is mainly due to forestry activities. In addition, there are about 20 peat production areas and three mines. The only other industrial activity contributing to the pollution load was the pulp factory in Kemijärvi, but this was closed in 2008. Most of the cultivated areas and the majority of settlements are located in the lower parts of the catchment. Agricultural land areas and urban areas cover together less than 1% of the total catchment area and the population density is only 2 people per km^2. The largest city in the area is Rovaniemi with 62 000 inhabitants.

The major share (>65%) of nutrients exported to the Baltic Sea from the River Kemi in 2021 originated from natural leaching (Figure23). Agriculture's share of the total nitrogen (TN) load was 4% and 6% of the total phosphorus (TP) load. Forestry was more important source of nutrient loads than agriculture contributing with 13% of and 26% of the TN and TP inputs, respectively. Compared to the nutrient sources in the previous big rivers report (HELCOM 2021c) the percentual proportion of forestry has remarkably increased. This is mainly due to new and more accurate estimates of nutrient inputs originating from forestry practices (Finér et al. 2020).

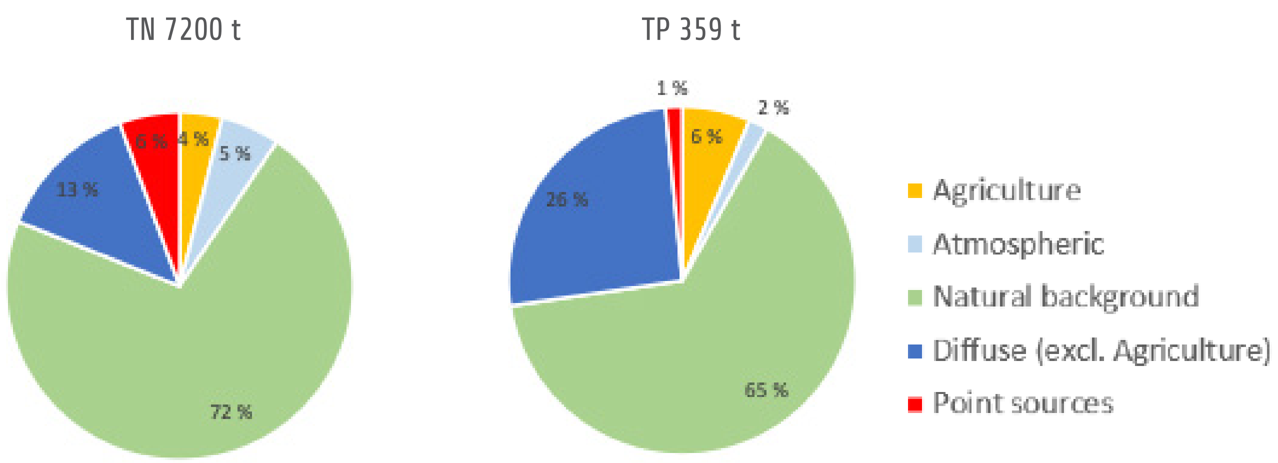
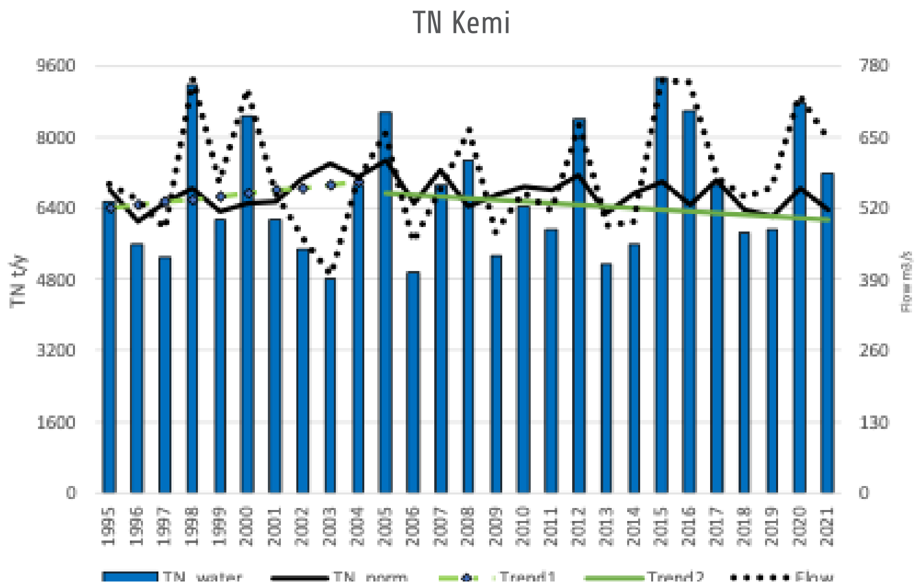


Figure 23. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Kemi River divided into load sources.

7.2. Trends in the export: the Kemi River

In 2021 the flow was slightly higher (12%) compared to the long-term average flow and both total nitrogen (TN) and total phosphorus (TP) export were slightly higher compared to the long-term average export. In 2021 the area specific TN load was 125 kg km^{-2} and the mean total nitrogen concentration was 311 µg l^{-1}. The respective TP load was 6.1 kg km^{-2} and the concentration was 15 µg l^{-1}. In 2004 a downward trend in the TN export begun (Figure 24). In the TP export a stepwise reduction was detected in 2006. Climate change is projected to increase precipitation and runoff especially in the northern parts of the Baltic Sea over the next century (Graham 2004) and there are signs that the flow is increasing in northernmost Finland (Räike et al. 2014), which will most likely lead to an increase in nutrient transport to the sea. Approximately half of the annual nutrients in the River Kemi are exported to the sea during spring floods in May to early June. However, the timing of floods is changing and the spring thaw is expected to start earlier in future (Blöschl et al. 2017).



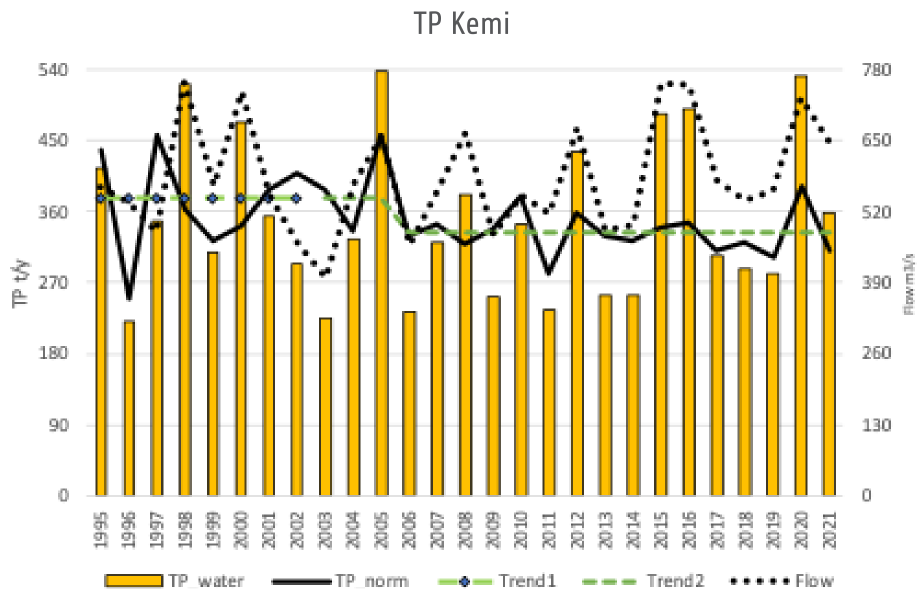


Figure 24. Total nitrogen (TN) (blue bars) and total phophorus (TP) (yellow bars) export by the Kemi River from 1995 to 2021. The dashed black lines show flow, the black lines flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid green lines indicate statistically significant trend and dashed lines non-significant trend.

7.3. Mitigation measures

Compared to most of the other rivers in Finland the Kemi River is quite pristine, but anyhow many of its waterbodies are not in good ecological status. Generally, the human pressure increases downstream towards the river mouth. The mitigation measures in the Kemi River basin are especially targeted in reducing loads of nutrients and suspended solids.

Forestry has been estimated to be the most remarkable pressure in many of the waterbodies not in ecologically good status. Therefore, many mitigation measures are targeted in reducing loads originating from forestry. These measures include more strict regulation of forest fertilization, wider buffer strips in logging areas and better planning how maintenance ditching is implemented. Also the mitigation measures to reduce inputs originating from agricultural activities include many variable actions, like wider buffer strips, more strict regulation of P fertilization, and winter-time plant cover.

In addition, there also are remarkable investments targeted in reducing nutrient inputs both from scattered dwellings and municipal point sources. In northern Finland, the focus in MWWTPs has been in reducing phosphorus loads and in many plants the nitrogen reduction is low, which is partly due to low winter-time temperatures. The forthcoming action plans aim at further improvements of wastewater treatment mainly with maintenance works.

Even if there are quite precise plans of the mitigation measures and their costs for the period 2022 to 2027, there are no estimates of their effectiveness, i.e. no estimates how much nutrient loads will be reduced. Especially there is a big gap in knowledge how the planned mitigation measures in forestry will affect loads.

8. The Daugava River

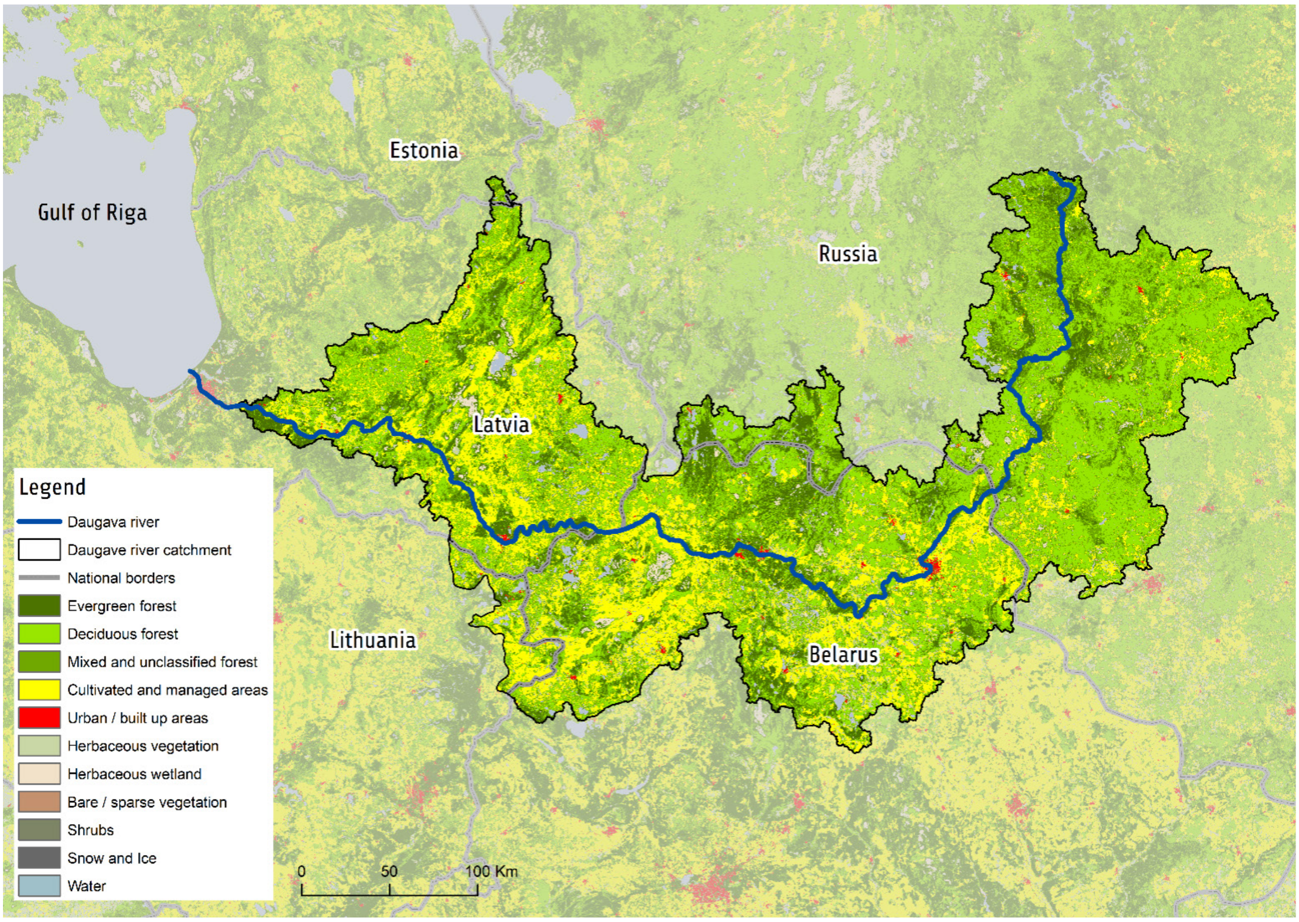


Figure 25. The monitored part of the drainage area (black line) of the Daugava River, country borders (grey line) and land cover classes based on Corine 2018.

8.1. Basic information

The area of the Daugava River's drainage basin is 87 900 km^2 and it is 1020 km long (Figure 25). The Daugava River begins in western Russia, in the Valdai Hills, and crosses the territories of Belarus and Latvia where it flows into the Gulf of Riga. 38% of the catchment belongs to Belarus, 31% to Russia and 28% to Latvia. The rest of the Daugava catchment belongs to Lithuania and Estonia.

Forests cover about 67% of the Daugava catchment, and cultivated areas occupy around 26%. Population density varies greatly, being the highest in the area around Riga. Several large towns in Latvia and Belarus are located on the banks of Daugava River: Riga (615 000 inhabitants), Ogre (23 000), Daugavpils (81 000), Navapolatsk (96 000), Polatsk (80 000) and Vitebsk (359 000). Deterioration of water quality of the Daugava River started during the Soviet era, when large factories and new residential areas were built without the necessary sewage treatment plants.Navapolatsk town is one of the major sources of pollution to the Daugava River due to its oil processing, refinery plants and developed chemical industry. Municipal wastewater treatment plants and agricultural activities are also considerable sources of pollution.

The ecosystem of the lower reaches of the Daugava is strongly influenced by the dams and reservoirs of three hydroelectric power plants: Plavinas, Kegums and Rīga. In Belarus two hydroelectric power plants (Vitebsk and Polatsk) have been in operation since 2017. There are plans to build two more hydroelectric power plants in Beshenkovichi and Verkhnedvinsk.

The largest proportion of the Daugava's nutrient inputs are transboundary, originating from countries upstream from Latvia (Figure 26). The Latvian part in 2021 (28% of total nitrogen TN and 18% of total phosphorus TP) came mainly from diffuse sources, but there is no data available of more detailed division (e.g. agriculture, scattered dwellings). Natural background inputs and point source loads were of minor importance in Latvian inputs into the Daugava River. Compared to the nutrient sources in the previous big rivers report (HELCOM 2021c) the percentual proportion of transboundary loads have increased indicating that a larger share of nutrient inputs originated in Belarus and Russia.

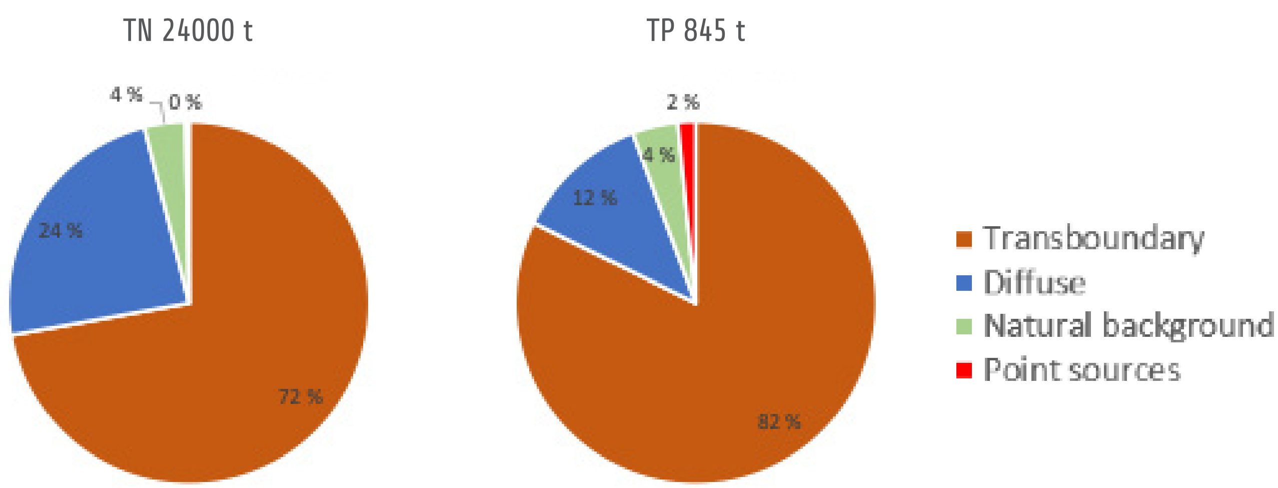


Figure 26. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Daugava River in 2021 divided into load sources.

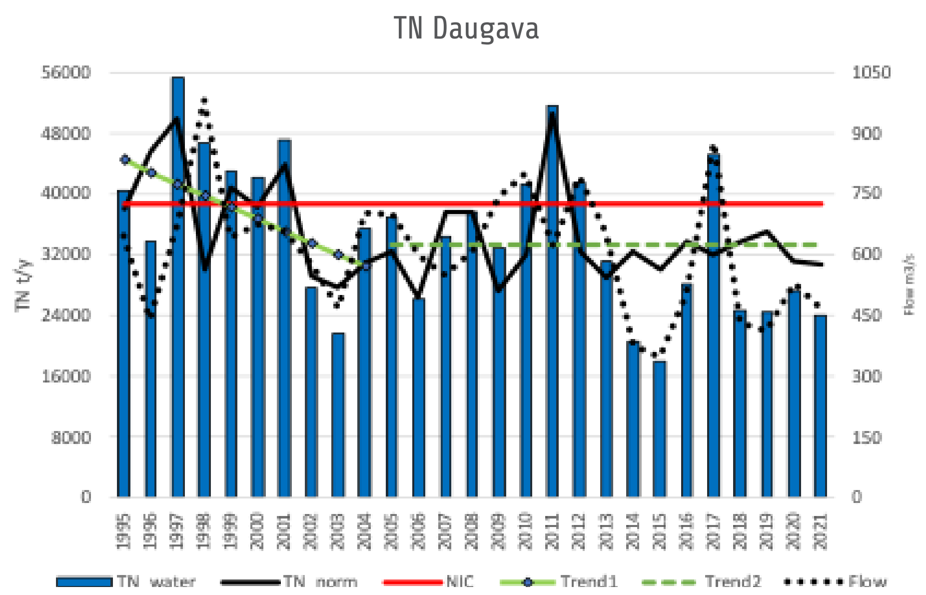
8.2. Trends in the export: the Daugava River

In 2021 the flow was nearly 24% lower than the long term mean flow and nutrient loads were also 32–36% below the long-term mean. The area specific total nitrogen (TN) load was 373 kg km^{-2} and the mean TN concentration was 2080 µg l^{-1}. The respective total phosphorus (TP) load was 13.5 kg km^{-2} and the TP concentration was 76 µg l^{-1}.

Major reduction in anthropogenic loading in Latvia occurred between 1987 and 1996 when consumption of fertilizers and number of livestock drastically decreased (Stålnacke et al. 2003). The TN export decreased from 1995 to 2005, but after that no changes could be detected (Figure 27). There was no statistically significant trend in TP export between 1995 and 2021. Changes in analytical methods have hampered the estimation of changes in load, as nutrient load calculation up until 2003-2004 were based on filtered samples, thus underestimating the total loads. This is supported by abrupt changes in DIP/TP (dissolved inorganic phosphorus/total phosphorus) ratio, which occurred at that time (Savchuck et al. 2012). Highest nutrient concentrations in Latvian rivers are observed in spring when nutrients are flushed out from the catchment soils (Klavins et al. 2003). Around 40 % of the annual flow occurs in spring (Apsite et al. 2009), but future projections predict substantial reduction of spring flow and increase of winter flow (Latkovska et al. 2012).

8.3. Mitigation measures

See mitigation measures in the chapter of the Venta River.



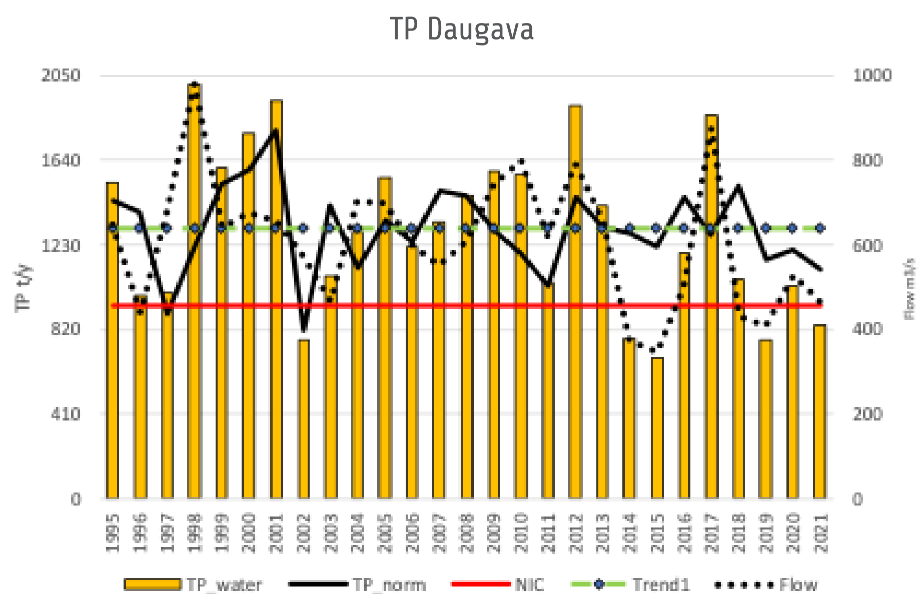


Figure 27. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Daugava River from 1995 to 2021. The dashed black lines are showing flow, the black lines flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid green lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input ceilings (NIC).

9. The Nemunas River

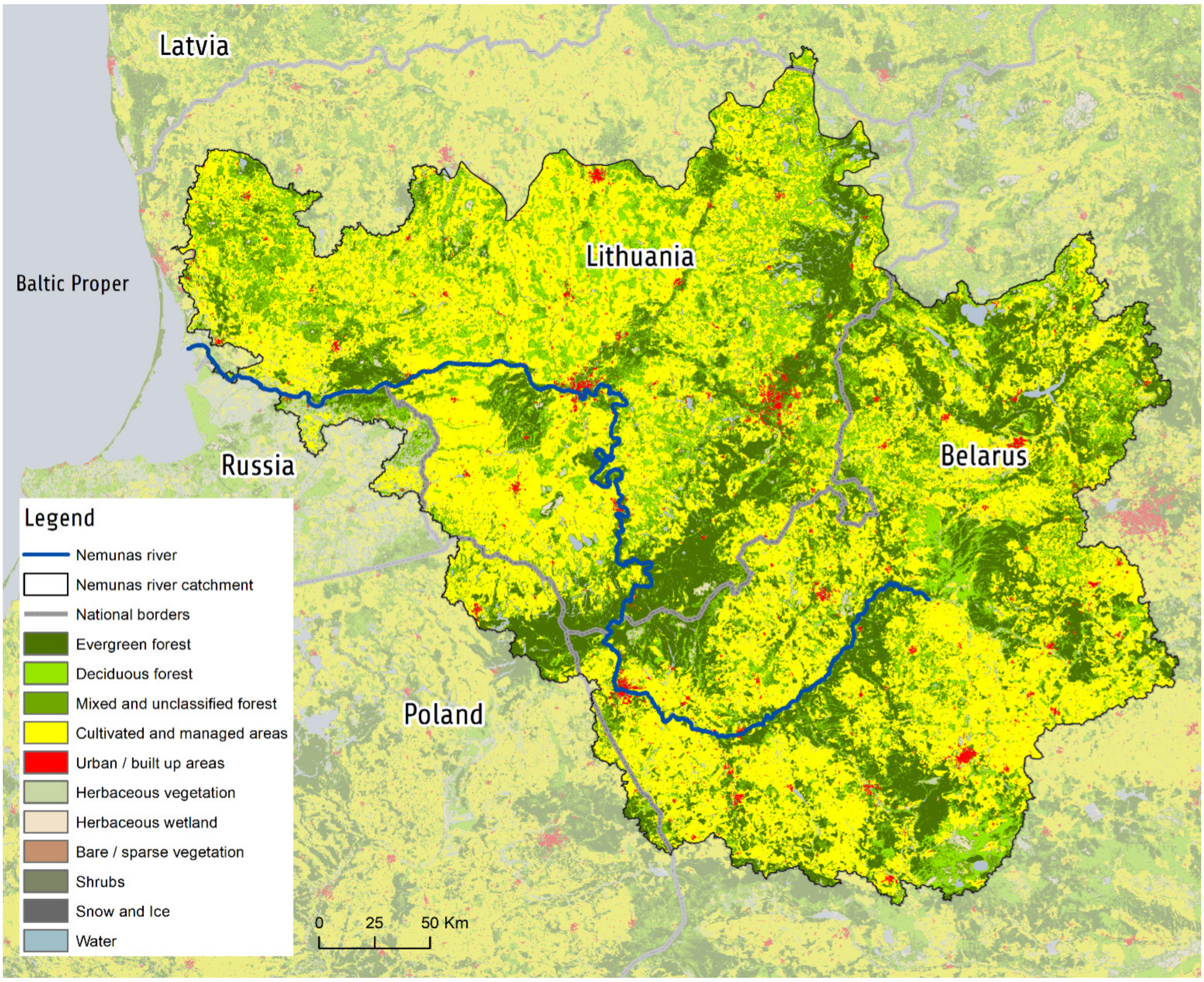


Figure 28. The drainage area (black line) of the Nemunas River, country borders (grey line) and land cover classes based on Corine 2018.

9.1. Basic information

The area of the Nemunas River's drainage basin is 97 900 km^2 (Figure 26), which is shared between five countries making it a good example of complicated transboundary issues. The largest, and nearly equal parts, of the catchment belongs to Lithuania (46 700 km^2) and Belarus (45 463 km^2). The rest is shared between Russia (3125 km^2), Poland (2515 km^2) and Latvia (88 km^2). Additional complication arises because the mouth of the river and a significant part of downstream water is shared between two countries: Lithuania and Russia, making it at the same time a transboundary and border river, which is a unique combination in the Baltic Sea drainage basin. Moreover, it all gets even more complex because of the Matrosovka channel, which at 50 km from the river mouth diverts one quarter of all Nemunas river volume into Russian territory.

The total length of the Nemunas River is 937 km. It is the fourth longest river in the Baltic Sea basin. 436 km of it flows in Belarus, 359 km in Lithuania and the remaining 116 km stretch is the border between Lithuania and Russia's Kaliningrad oblast. Land cover in the Nemunas River basin is dominated by agricultural land, which occupy more than half of the basin area in Lithuania. Forest and natural areas make up around one-third, while surface water bodies and urban areas cover 2% of the basin each (Table 1). Total population in the basin is estimated at around 5,4 million people and the biggest city is Vilnius with around 543 000 inhabitants. There is only one major reservoir in the Nemunas River, which was built for hydroelectric power generation in 1960, close to Kaunas (Lithuania). Another hydroelectric power generation station was built close to Grodno city (Belarus) in 2012. However, it was built using run-of-the-river hydroelectricity, meaning that no reservoir was needed.

Over 40% of the total nitrogen (TN) load and 54% of the total phosphorus (TP) load was transboundary in 2021 i.e. transported into Lithuania from the upstream countries, mainly Belarus (Figure 29). The Lithuanian inputs came mostly from agriculture (63% of TN and 47% of TP).

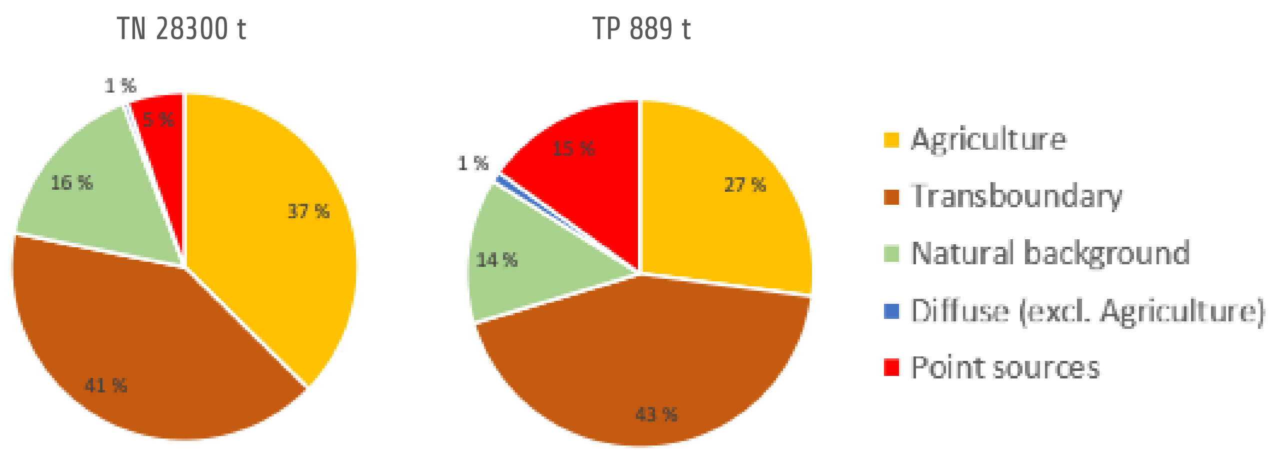


Figure 29. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Nemunas River in 2021 divided into load sources.

9.2. Trends in the export: the Nemunas River

In 2021 the flow was 22% lower than the long-term average flow. Respectively also nutrient export decreased: the total nitrogen (TN) export was 17% below the average level and the total phosphorus (TP) export 41% respectively. In 2021 the area specific TN load was 490 kg km^{-2} and the mean total nitrogen concentration was 3170 µg l^{-1}. The respective total phosphorus load was 14.7 kg km^{-2} and total phosphorus concentration 95 µg l^{-1}.

Since 2000 an upward trend in TN export has been evident (Figure 30), which was due to an increase in the intensity of agricultural activities: From 2001 onwards the area under cultivation and fertilizer usage gradually increased. A distinct drop in TP load happened during 2004-2005, around the time when Lithuania joined the European Union. This was due to large investments in the upgrading and building of new waste water treatment facilities, largely financed by the European Union.

9.3. Mitigation measures

See mitigation measures in the chapter of the Venta River.

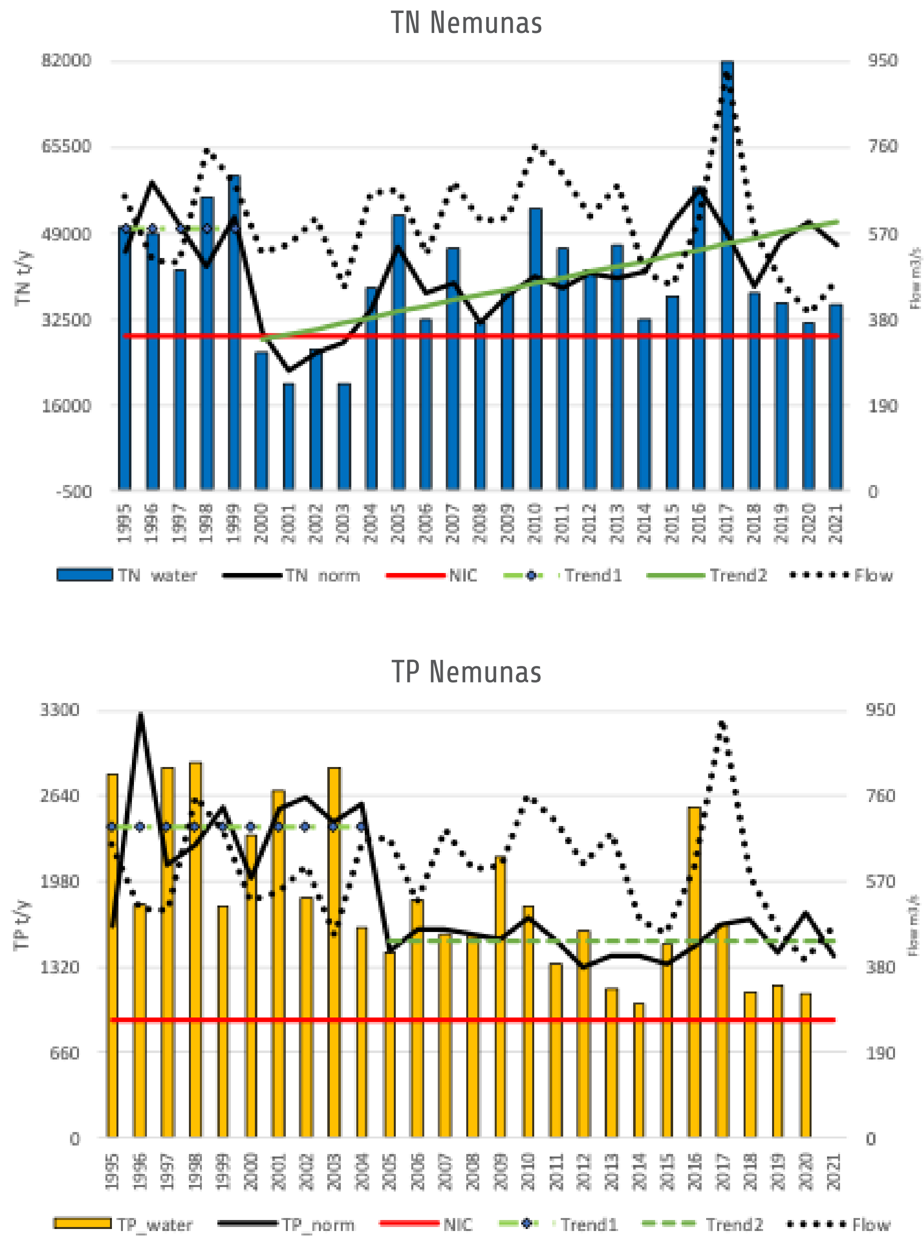


Figure 30. Total nitrogen (TN) (blue bars) and total phosphorus (TP) export (yellow bars) by the Nemunas River from 1995 to 2021. The black lines are showing flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input ceilings (NIC).

10. The Oder River

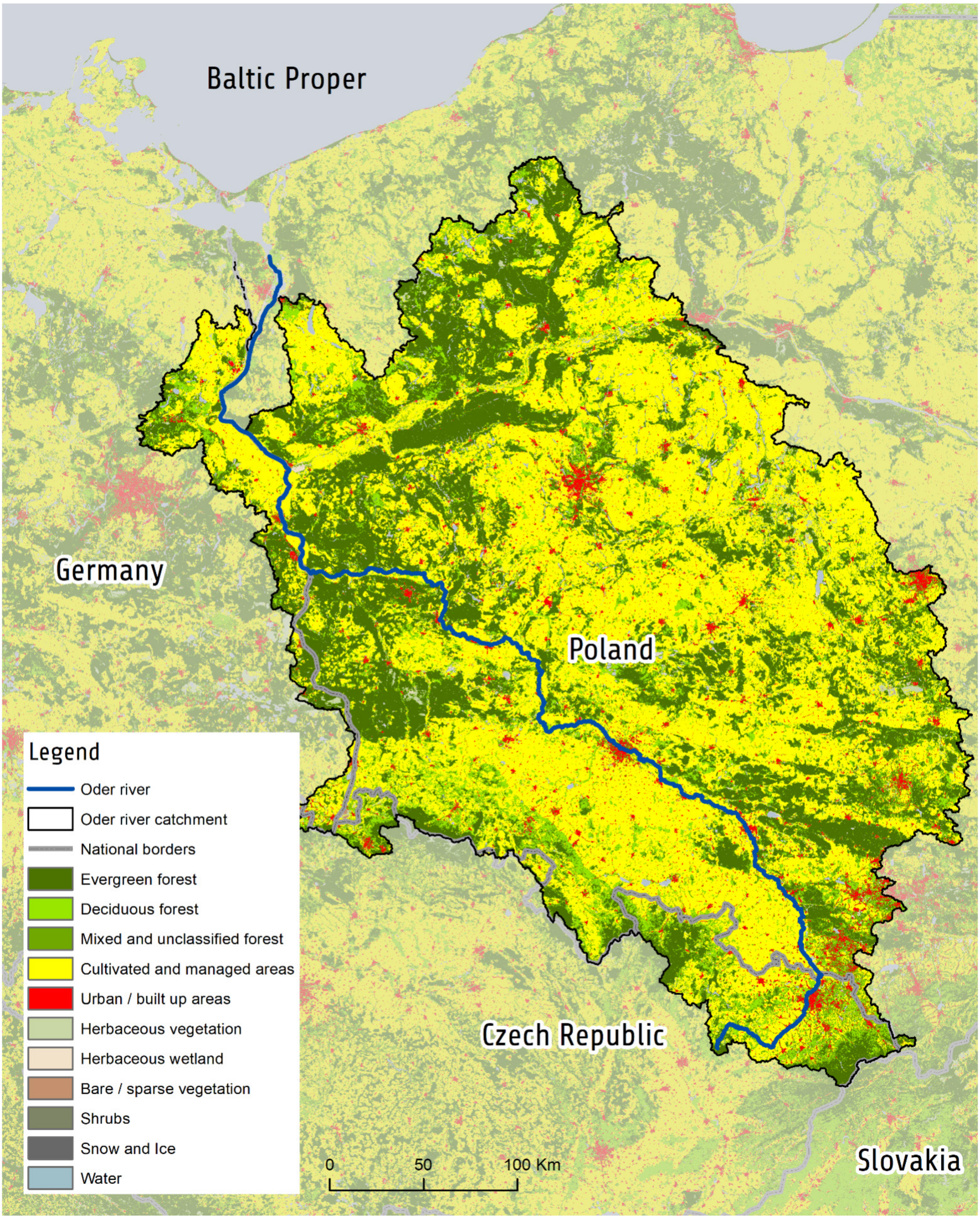


Figure 31. The drainage area (black line) of the Oder River, country borders (grey line) and land cover classes based on Corine 2018.

10.1. Basic information

The Oder or Odra River basin is the second biggest river basin in Poland. Its total drainage area is 118 000 km^2 of which 106 000 km^2 is located in Poland, 7000 in Czech Republic and 5000 in Germany. Monitored part of the river basin constitutes 98% of total area. The Odra River is 841 km long and its lower section is the border between Poland and Germany (467 km). The source of the Oder River is located in Czechia approximately 634 m above sea level. Oder has a mountainous character in the source section, while in the lower course it changes into a lowland river. Oder is navigable almost along its entire section within the borders of Poland. Oder flows into the Baltic Sea through the Szczecin Lagoon.

The main pressures identified in Oder River basin is mainly: agriculture, municipal management, mining and hydrological transformations. Approximately 58% of its area is developed by agricultural land use. Oder River is also direct receiver of wastewater from large cities like Wrocław, Szczecin, Opole and Frankfurt. In total, 16 million inhabitants live within the river basin.

In 2021 61% of the Oder total nitrogen (TN) load originated from agriculture and 44% of the total phosphorus (TP) load respectively (Figure 32). Point sources were a remarkable TP load source with a proportion of 38%. Transboundary inputs comprised 9-14% of the nutrient loads. Compared to the nutrient sources in the previous big rivers report (HELCOM 2021c) the percentual proportion of transboundary TP inputs has decreased and the share of TP inputs increased. Sources of TN inputs have remained approximately the same.

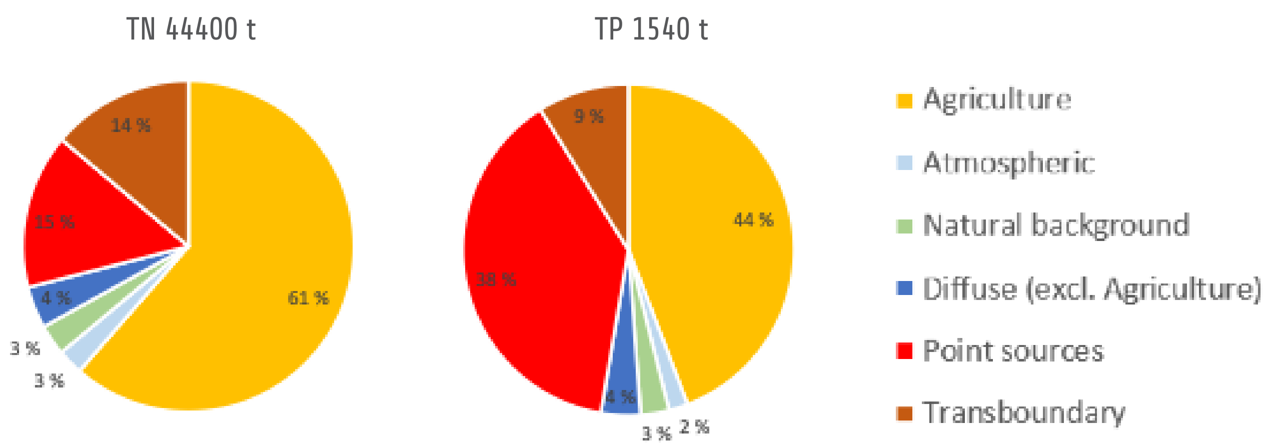
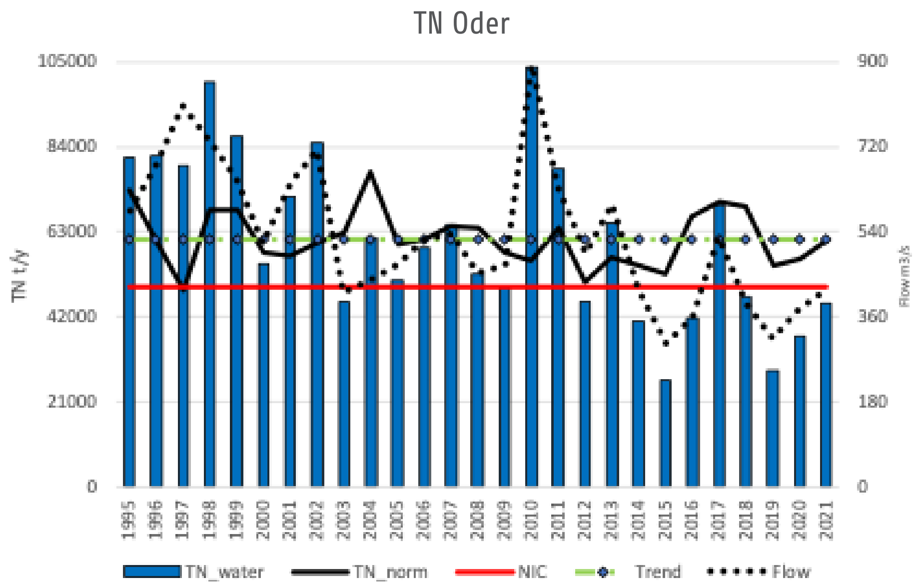


Figure 32. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Oder River in 2021 divided into load sources.

10.2. Trends in the export: the Oder River

In 2021 the flow was 22% lower than the long-term average flow. This was clearly reflected in nutrient export: total nitrogen (TN) export was 44 000 t and total phosphorus (TP) export 1540 t. The TN export was around 82% of the long-term average export and the TP export only 46%, respectively. The area specific total nitrogen load was in 530 kg km^{-2} and the mean total nitrogen concentration was 4610 µg l^{-1}. The respective total phosphorus load was 19,8 kg km^{-2} and total phosphorus concentration was 172 µg l^{-1}.

There was no trend in TN export from 1995 to 2021. In contrast, a stepwise decrease in TP export could be observed in 2006 and since then the P export has stayed at a lower level, (Figure 33). In 2021 TP load was 29% lower compared to the respective load in the reference period (1997–2003). To some extent, the changes in nutrient inputs from the Oder to the Baltic Sea may be explained by developments in wastewater management and in agriculture. In Poland the 1990s were a period of stagnation in agriculture and of major investments in wastewater treatment plants, prompted by the adoption in 1991 of regulations requiring nitrogen and phosphorus removal in all wastewater treatment plants. From the early 2000s onwards, and particularly since Poland's accession to the European Union, there has been a pronounced increase in the intensity of agriculture, including a growth in the use of mineral fertilizers, to some degree offset by the implementation of more environment-friendly agricultural practices concerning natural and mineral fertilizer use. The net effect of the changes in wastewater treatment and agriculture was a slow reduction in nutrient inputs to the Baltic. There is little doubt that in the past decade nutrient loads (particularly nitrogen) from large wastewater treatment plants continued to decline. However, the apparent recent surge in phosphorus inputs, if confirmed by future monitoring, could be associated with the fact that in 2006 regulations concerning effluent quality were relaxed, allowing smaller wastewater treatment plants not to remove phosphorus upon expiry of their pre-2006 permits. This rather complex picture is further altered by the irregularity of flows, including the 2010 flood which resulted in a strong spike in actual nitrogen and phosphorus inputs.



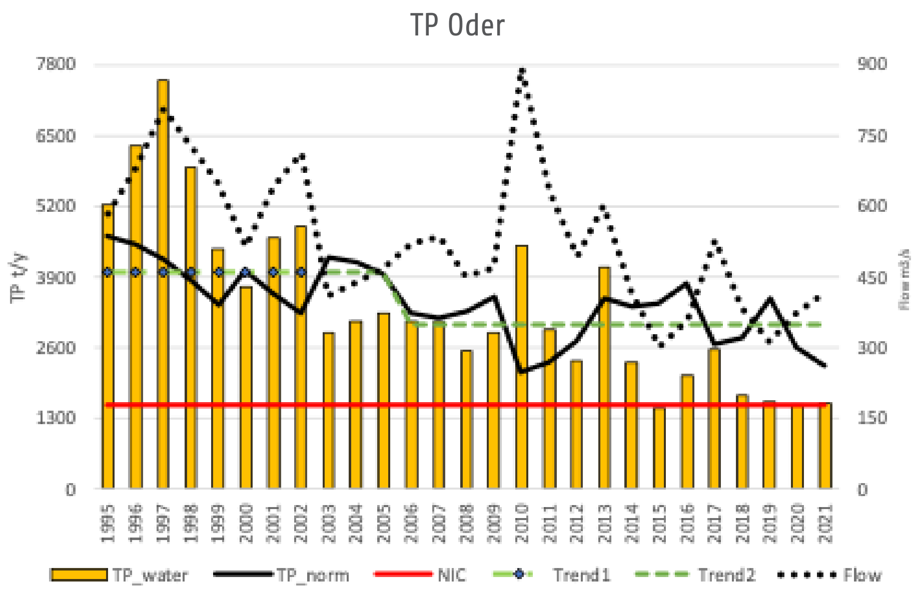


Figure 33. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Oder River from 1995 to 2021. The black lines show flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input ceilings (NIC).

10.3. Mitigation measures

Germany

In Germany nutrient loads into the Oder River have decreased mainly due to the construction of wastewater treatment plants with efficient nutrient elimination and the reduction of nitrogen surpluses on agricultural land. From a trans-regional perspective of coastal waters and inland waters, a further reduction in nutrient inputs is necessary in order to achieve the nutrient concentration target in coastal waters and the Baltic Sea, which are endangered by eutrophication. For this reason, activities to reduce nutrients have been pushed forward at an international level together with the Republic of Poland and Czechia as part of the cooperation within the International Commission for the Protection of the Oder River (ICPO).

New reduction targets were derived on a scientifically sound basis, taking into account the requirements of the marine strategy framework directive (MSFD), the BSAP and the nutrient inputs/reduction requirements for the German part of the Baltic Sea catchment area. In addition, an international agreement was made within the ICPO for trans-national target concentration values for total nitrogen (TN) and total phosphorus (TP) at the limnic-marine transition point in Krajnik Dolny (PL). Based on the results of a nutrient input model scenario carried out in 2014 for the Oder River basin community, target concentrations for nitrogen and phosphorus have now been set. These are 0,1 mg/l for total phosphorus and 2,6 mg/l for total nitrogen at the transition point from the limnic to the marine area in Kajnik Dolny. Further measures for the German area of the Oder River basin community are covered by the Urban Waste Water Directive (91/271/EEC) which aims to prevent water pollution due to inadequate waste water treatment. To this end, municipalities with a population equivalent of 2000 or more must be equipped with a connection to a wastewater treatment plant and soon the stricter requirements of the revised UWWTD will apply.

In order to comply with the implementation of the EU Nitrates Directive, the national measures - in particular the Fertilizer Ordinance (DüV) - were revised in 2020 to improve their effectiveness in reducing water pollution and the risk of eutrophication. It is assumed that the implementation of the revised Fertilizer Ordinance, complemented by agri-environmental measures and voluntary agreements with the agricultural sector, will have an important contribution to further nutrient reductions in the German area of the Oder River. Specific actions include e.g. the extended periods during which fertilizers may not be applied. The distance from the nearest surface water when applying fertilizers has been increased (buffer stripes) and the application of fertilizers on sloping land has been regulated. Fertilization on water-saturated, frozen and snow-covered soils was restricted. A precise fertilizer requirement calculation was stipulated prior to each fertilization. Application methods, incorporation times and maximum quantities were specified within the revised Ordinance. The effect on the nitrogen reduction of the revised Fertilizer Ordinance of May 2020, which is to be classified as the most fundamental measure, is estimated be around 25 % in an initial forecast scenario for the German part of the Oder River basin community.

Poland

In Poland among the planned pro-environmental mitigation measures to reduce nutrient loads in the Vistula and Oder river basins (resulting from 3rd riber basin management plans (RBMPs)) are:

- River surface water bodies – control measures aimed at reducing diffuse pollution from agriculture.
- Lake surface water bodies – educational and advisory measures aimed at reducing lake pollution with biogenic compounds from agriculture and measures related to the active shaping of buffer zones.

Measures resulting from the Polish MSFD programmes:

- Differentiation of environmental fees for nutrients (source: Municipalities)
- Changing the principles of natural fertilizers management (source: Agriculture)
- The use of selected water reclamation devices to reduce the load of nutrients from agricultural areas (source: Agriculture)
- Limitation of felling of forests in the vicinity of waters (source: Forestry)
- Ensuring conditions for safe storage of natural fertilizers (source: Agriculture)
- Increasing the area of agricultural land covered by fertilization plans (source: Agriculture)
- Analysis of the possibility of increasing the degree of phosphorus removal in sewage treatment plants (source: Municipalities)

In June 2022, the International Commission for the Protection of the Oder River against Pollution (ICPO) adopted the Nutrient Reduction Strategy for the International Oder River Basin District, containing a catalogue of actions recommended for implementation at the local, national and international level to ensure sustainable management of nutrients in the river basin and limit the phenomenon of eutrophication. Actions were proposed in the areas of urban wastewater treatment, agriculture, nutrients retention, nutrients recycling and interdisciplinary activities. The Strategy specifies target values for TN and TP concentrations for the monitoring point at the junction of inland and marine waters (Krajnik Dolny), which should allow achieving the Maximum Allowable Input (MAI) adopted in the Baltic Sea Action Plan.

11. The Vistula River

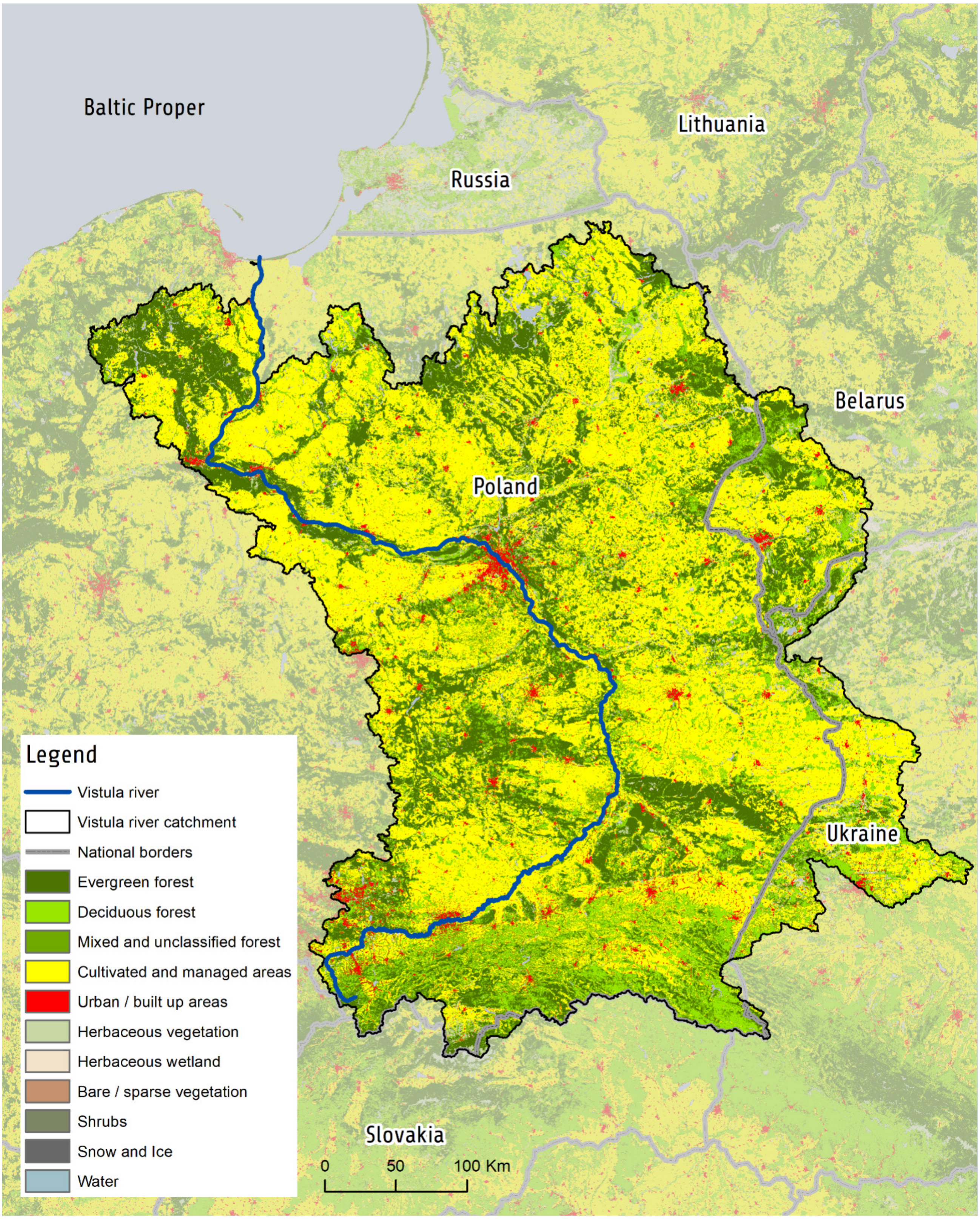


Figure 34. The monitored part of the drainage area (black line) of the Vistula River, country borders (grey line) and land cover classes based on Corine 2018.

11.1. Basic information

The Vistula River is the biggest river in Poland with its drainage area of 194 000 km^2 total. The main watercourse is 1020 km and is located within the borders of Poland in its entire section. The source of the Vistula River is located in the southern part of Poland and it flows directly into the Baltic Sea (Bay of Gdansk). The river basin is located mainly in Poland (169 000 km^2), but also in Slovakia (2000 km^2), Ukraine (13 000 km^2) and Belarus (10 000 km^2). Vistula River basin covers over half of the total surface area of Poland.

The Vistula River basin is developed mainly by agricultural land use (60%). It is populated by approximately 22 million of inhabitants with larger cities like: Warsaw, Gdansk, Krakow (Poland), or Lviv (Ukraine). most important factors responsible for diffuse sources of pollution are agriculture, scattered dwellings and atmospheric deposition. As for the point sources, the municipal management is the main source of nutrient inputs. The Vistula River is hydrologically modified in the upper and estuary sections of the river and retains the features of a natural river in the middle section. Its main tributaries (Narew, San, Pilica) also remain not heavily modified in most sections of the watercourse.

Over half of nutrient loads of the Vistula River in 2021 originated from agriculture: 61% of the total nitrogen (TN) load and 52% of the total phosphorus (TP) load, respectively (Figure 35). Point sources were also a remarkable nutrient load source with a proportion of 15% TN and 25% TP. Approximately 6-11% of nutrient loads were transboundary. Compared to the nutrient sources in the previous big rivers report (HELCOM 2021c) the percentual proportion of different nutrient sources had remained approximately the same.

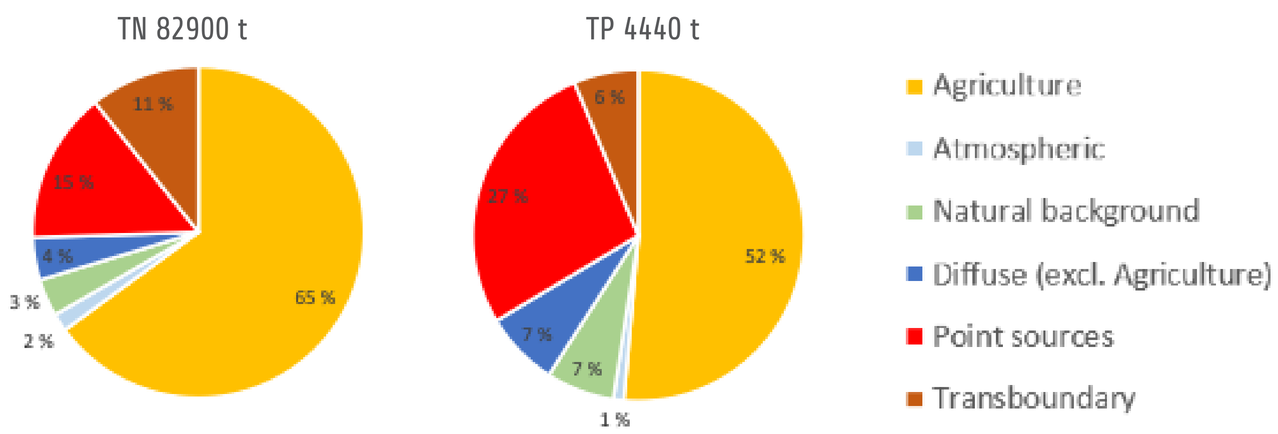
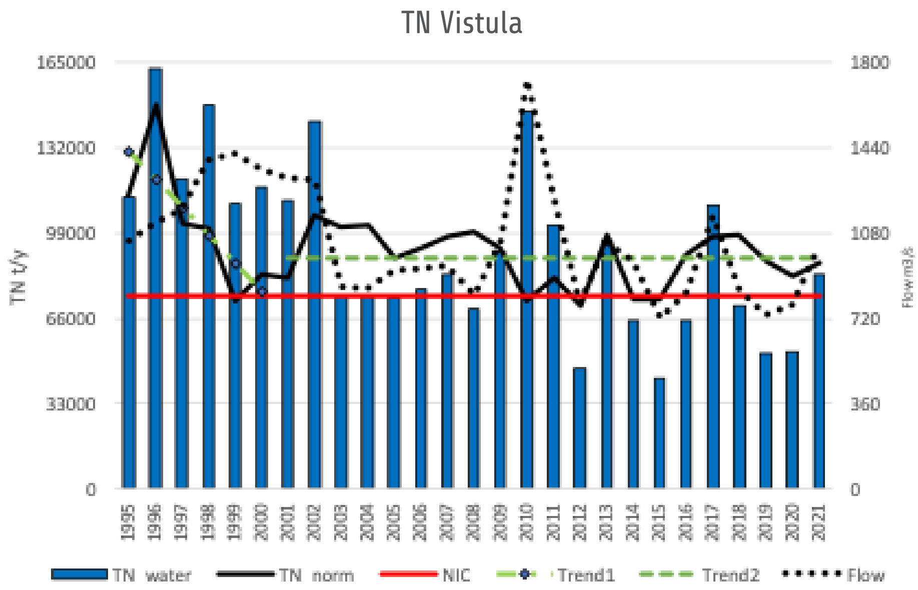


Figure 35. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Vistula River in 2021 divided into load sources.

11.2. Trends in the export: the Vistula River

In 2021 the flow was at the same level as the long-term average flow. The total nutrient loads were slightly lower than the average loads: the TN export was 82 900 t and the TP export 4440 t. The area specific total nitrogen load was 454 kg km^{-2} and the mean total nitrogen concentration was 2720 µg l^{-1}. The respective total phosphorus load was 24.1 kg km^{-2} and mean total phosphorus concentration was 144 µg l^{-1}.

There was a sharp decrease in TN load from 1995 to 1999 and after that no downward trend was observed (Figure 36). In the TP loads a constant decrease could be detected starting in 1995. To a large extent, the changes in nutrient inputs from the Vistula to the Baltic Sea may be explained by developments in wastewater management and in agricultural practices. The 1990s were a period of stagnation in agriculture and of major investments in wastewater treatment plants, prompted by the adoption of regulations requiring nitrogen and phosphorus removal in all wastewater treatment plants in 1991. From the early 2000s onwards, and particularly since Poland's accession to the European Union, there has been a pronounced increase in the intensity of agriculture, including a growth in the use of mineral fertilizers, to some degree offset by the implementation of more environmentally-friendly agricultural practices concerning natural and mineral fertilizer use. The apparent recent surge in phosphorus inputs, if confirmed by future monitoring, could be associated with the fact that in 2006 regulations concerning effluent quality were relaxed, allowing smaller wastewater treatment plants not to remove phosphorus upon expiry of their pre-2006 permits. This rather complex picture is further altered by the irregularity of flows, including the 2010 floods which resulted in a pronounced peak in actual nitrogen and phosphorus inputs.



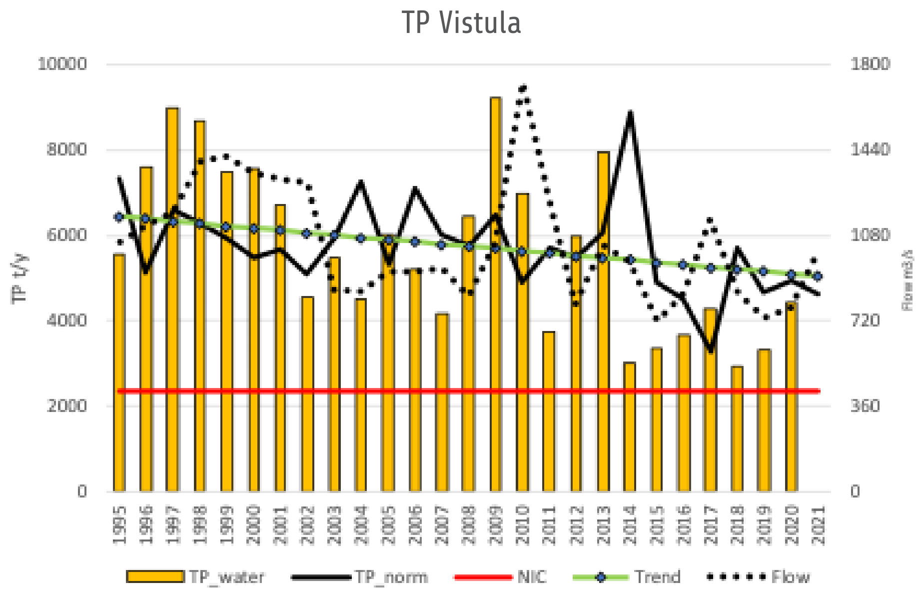


Figure 36. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Vistula River from 1995 to 2021. The black lines show flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input ceilings (NIC).

11.3. Mitigation measures

See Polish mitigation measures of the Oder River.

12. The Neva River

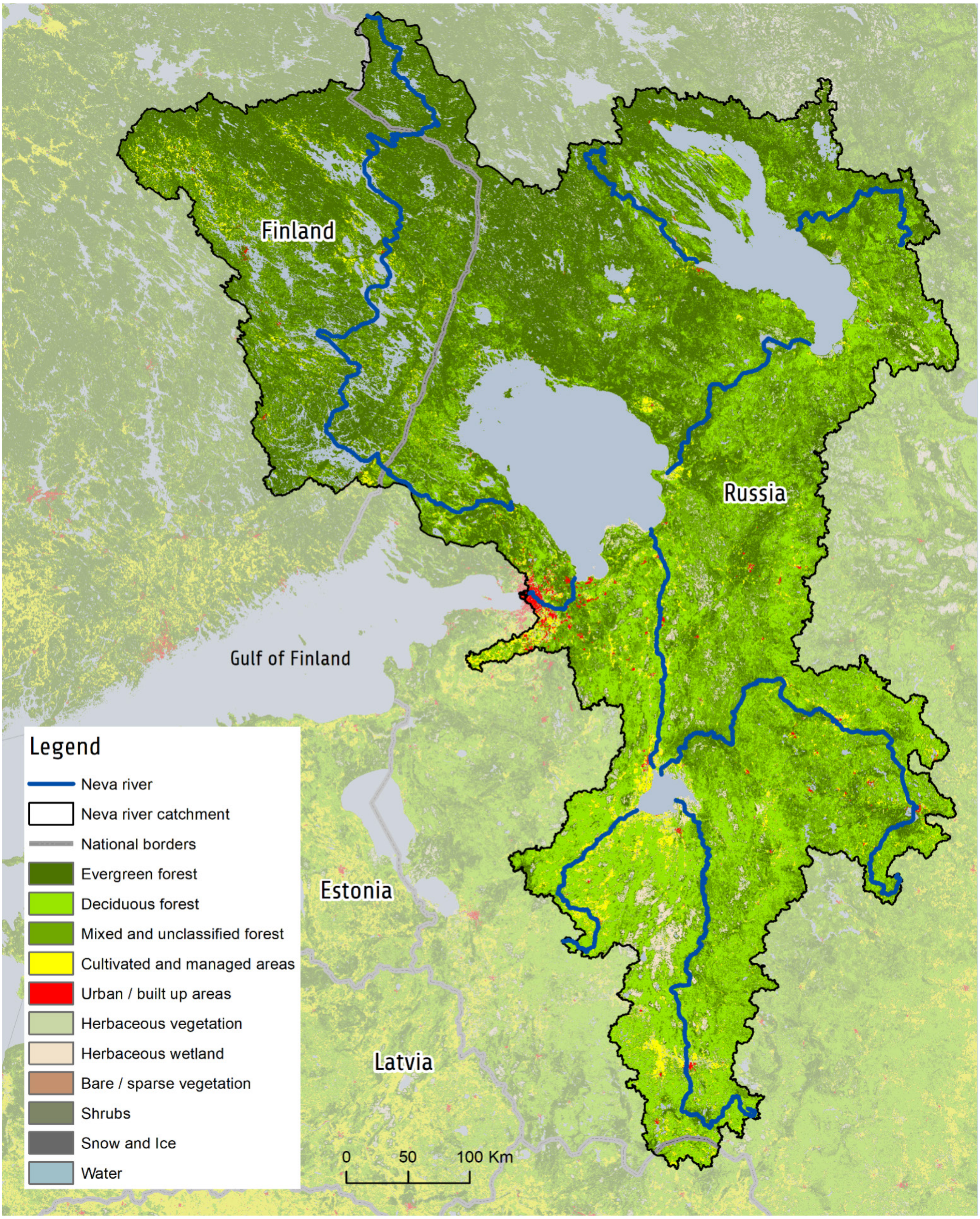


Figure 37. The drainage area (black line) of the Neva River, country borders (grey line) and land cover classes based on Corine 2018.

12.1. Basic information

The Neva River has the largest drainage basin of all Baltic rivers: 281 600 km^2. The biggest part of the catchment belongs to Russia, but also a large area is in Finnish territory (Figure 37). The north-eastern parts are in a pristine state, whereas the areas along the riverside are densely populated. Europe's two largest lakes (Ladoga and Onega) are situated in the catchment area and they retain a large share of the nutrient inputs from their upstream catchment. Forests cover 55% of the catchment area, whereas urban and cultivated areas together cover only approximately 12% (Table 1).

Over 60% Neva's nutrient inputs in 2021 originated from natural background leaching (Figure 38). Compared to the nutrient sources in the previous big rivers report (HELCOM 2021c) the percentual proportions of different nutrient sources have changed: the share of natural background has increased, whereas the share of point sources decreased. Furthermore, the proportion of nutrient inputs originating from diffuse sources other than agriculture has decreased.

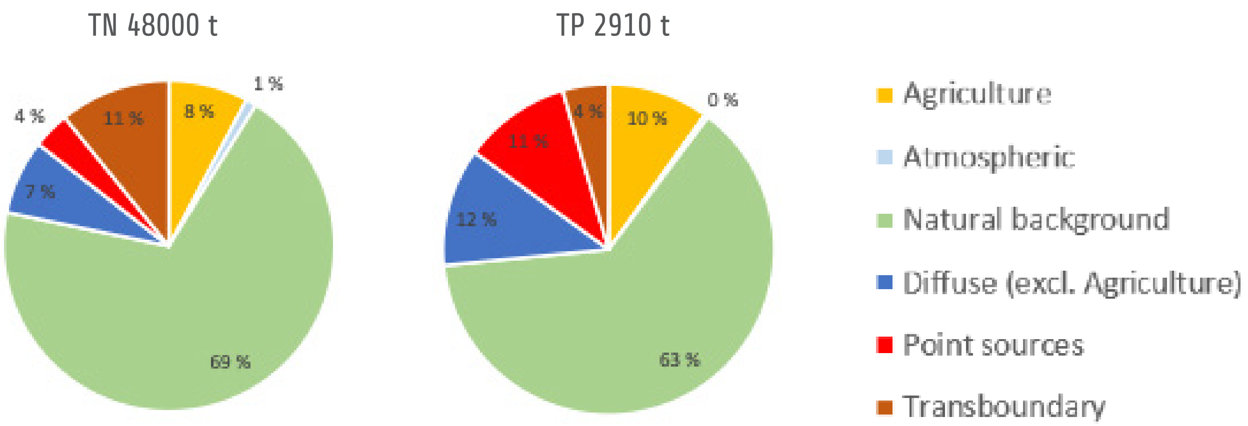


Figure 38. Total nitrogen (TN) and total phosphorus (TP) loads exported by the Neva River in 2021 divided into load sources.

12.2. Trends in the export: the Neva River

In 2021 the flow was at the same level than the long term average. The total nitrogen (TN) export was 48 000 t and the total phosphorus (TP) export was 2910 t. The TN export was around 83% of the long-term average export and the TP export 95%, respectively. The area specific TN load was 174 kg km^{-2} and the mean TN concentration was 631 µg l^{-1}. The TP load was 10,4 kg km^{-2} and the mean TP concentration was 38 µg l^{-1}. The hydrological characteristics of the Neva River between two large water basins means it does not have hydrological regime typical for rivers. Transport of nutrients thus primarily depends on their concentration in Lake Ladoga but not on water flow and that's why flow normalization has no effect on the nutrient loads.

The TN export by the Neva increased between 1995 and 2003, and subsequently decreased in later years (Figure 39). There was a sudden drop in TP export in 2006 and in 2021 TP export has stayed at that level. The main reason behind the decrease in phosphorus load were improvements in treatment of wastewater originating from point sources. One of the most important achievements was the reconstruction of the main sewer collector in the northern part of St. Petersburg, carried out by Vodokanal between 2008 and 2012, which enabled the closure of sixty-seven direct discharges of untreated wastewater to the Neva River. In 2014 99% of wastewater was treated in St. Petersburg and the nitrogen load had decreased by 14 000 t y^{-1} (60%) and the phosphorus load by 3600 t y^{-1} (90%) since 1978 (Vodokanal 2015).

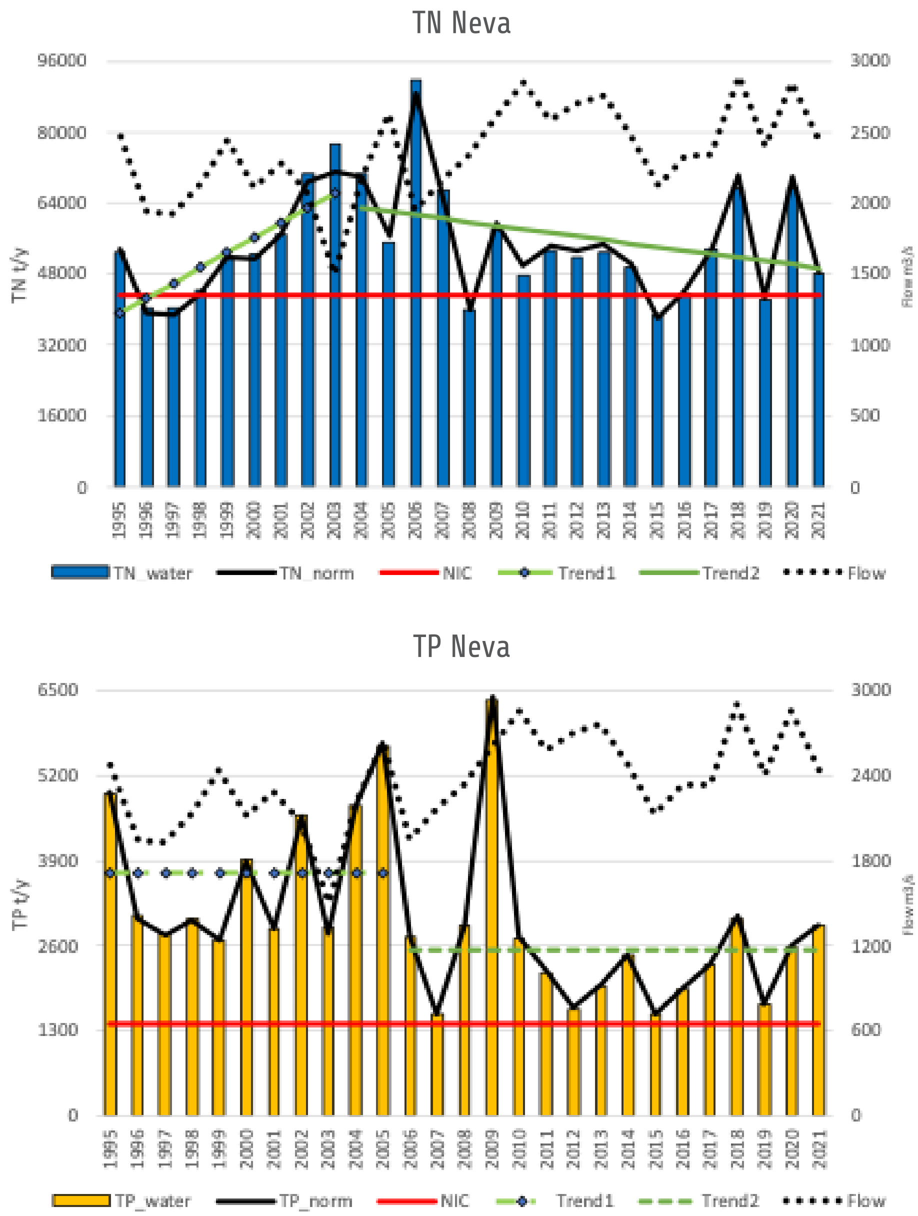


Figure 39. Total nitrogen (TN) (blue bars) and total phosphorus (TP) (yellow bars) export by the Neva River from 1995 to 2021. The black lines show flow-normalised nutrient export and the green lines the trend in the flow-normalised export. Solid lines indicate statistically significant trend and dashed lines non-significant trend. Red straight line shows the nutrient input ceilings (NIC).

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