Supplementary Information

Long-Term assessment of nutrient dynamics in the Danube River (1996-2021) using flow-normalized indicators: Decoupling flow from management

SM.1: Danube River Basin

The Danube River Basin (DRB) is Europe's second-largest drainage basin, covering approximately 800,000 km² (roughly 10% of continental Europe) flowing through 10 countries and draining a basin shared by 19 countries. The river flows 2,857 km from its source in Germany to the Black Sea, discharging an average of approximately 6,500 m³/s (ICPDR, 2021). The basin, home to about 82 million people (additional material table AM_DA1), exhibits significant climatic and topographical diversity, ranging from alpine headwaters (>3000 m a.s.l.) influenced by Atlantic weather systems to extensive lowlands in the east with a more continental climate. Mean annual precipitation varies considerably across this gradient (Karabulut et al., 2016).

Land cover within the DRB is dominated by agriculture (42%) and forests (35%), with smaller proportions of grasslands (16%) and urban areas (5%) (Karabulut et al., 2016; EEA, 2013). The river system has been significantly altered by human activities, including intensive land use and the construction of numerous reservoirs, dams, and hydropower plants, particularly since the mid-20th century. These modifications regulate flow regimes and influence sediment and nutrient transport throughout the basin (Habersack et al., 2016; Cozzi et al., 2019).

The Danube receives inflow from numerous tributaries, with eight major ones (Table SM_CP2 in Supplementary Information) draining distinct regions and significantly contributing to the main channel's hydrology and water quality characteristics. For analytical purposes and reflecting broad hydro-morphological characteristics, the river is commonly divided into the Upper, Middle, and Lower Danube sections (ICPDR, 2015, 2017, 2021 for TNMN). The locations of the monitoring stations utilized in this study along these sections are depicted in Figure 1.

TABLE SM_CP1: TERRITORIAL DATA ON THE COUNTRIES OF THE DANUBE RIVER BASIN (ICPDR)

Country	Share of the DRB (%)	Territory in the DRB (km²)	Percentage of Territory within DRB (%)	Population in the DRB (millions)
Austria	10.03	80,593	96.1	8.40
Bosnia and Herzegovina	4.77	38,289	74.9	3.20
Bulgaria	5.88	47,235	42.6	3.57
Croatia	4.37	35,111	62.1	2.90
Czech Republic	2.7	21,681	27.5	2.70
Germany	7.00	56,250	15.7	10.07
Hungary	11.58	93,000	100.0	9.80
Moldova	1.56	12,505	36.9	1.10
Montenegro	0.90	7,260	52.5	0.18
Romania	28.91	232,193	97.4	19.50
Serbia	10.21	81,974	92.6	7.00
Slovakia	5.86	47,084	96.0	5.20
Slovenia	2.04	16,420	81.0	1.80
Ukraine	3.81	30,626	5.1	3.03

SOURCE: DANUBE RIVER BASIN MANAGEMENT PLAN 2021 (ICPDR)

TABLE SM_CP2: MAIN TRIBUTARIES OF THE DANUBE RIVER

Tributary	Length (km)	Average Discharge (m³/s)	Danube rkm of the confluence	Major Countries in Basin
Inn	515	732	2225	Switzerland, Germany
Morava	354	110	1880	Czech Republic, Slovakia
Drava	749	541	1379	Italy, Austria, Slovenia, Croatia
Tisza	965	792	1215	Ukraine, Romania, Slovakia, Hungary, Serbia
Sava	940	1572	1170	Slovenia, Croatia, Bosnia, Serbia
Iskar	368	54	637	Bulgaria
Siret	599	240	82	Ukraine, Romania
Prut	953	67	1	Ukraine, Moldova, Romania

SM.2: List of Nutrients Stations

TABLE SM_ NS1: LIST OF NUTRIENTS MONITORING LOCATIONS IN THE DANUBE MAIN CHANNEL. GEOGRAPHICALLY, THE MONITORING STATIONS ARE WELL-DISTRIBUTED ALONG THE RIVER'S COURSE, WITH 9 STATIONS LOCATED IN THE UPPER DANUBE (UPSTREAM OF RKM 1870, DEVIN GATE), 21 IN THE MIDDLE DANUBE (RKM 1870–930, IRON GATE), AND 19 IN THE LOWER DANUBE AND DELTA (DOWNSTREAM OF RKM 930).

Location	id	Latitude (d. m. s.)	Longitude (d. m. s.)	Distance (km)	Drain area (km2)
Neu-Ulm	DE1	48.42528	10.02750	2581	8148.66
Dillingen	DE5	48.56819	10.49875	2538	11325.64
Jochenstein	AT1	48.52129	13.70308	2204	77065.01
Jochenstein	DE2	48.52023	13.70288	2204	77065.01
Abwinden-Asten	AT2	48.25583	14.42194	2120	83934.49
Enghagen	AT5	48.24042	14.51204	2113	84743.25
Wien-Nussdorf	AT3	48.26177	16.37105	1935	101739.9
Hainburg	AT6	48.16435	16.99260	1879	131390.4
Wolfsthal	AT4	48.14167	17.05361	1874	131425
Bratislava	SK1	48.13833	17.10719	**1869**	131552.3
Medvedovo	HU1	47.79243	17.65161	**1806**	131778.2
MedveŽ	SK2	47.79354	17.65199	**1806**	131778.2
Komarno	SK3	47.75117	18.1203	**1768**	150939.5
Komarom	HU2	47.7507	18.12098	**1768**	150939.5
Szob	HU3	47.81083	18.86005	**1708**	183221.5
Szob	SK5	47.8134	18.8532	**1708**	183221.5
Dunafoldvar	HU4	46.81118	18.93377	**1560**	187866
Hercegszanto	HU5	45.90876	18.81422	**1435**	209399.4
Batina	HR1	45.87471	18.82924	**1429**	209399.4
Bezdan	RS1	45.85419	18.85996	**1426**	211103.3
Bogojevo	RS2	45.53015	19.07903	**1367**	253186.1
Borovo	HR2	45.38269	18.96957	**1337**	253293.2
Ilok	HR11	45.23307	19.40855	**1301**	255757.3
Backa Palanka	RS9	45.23430	19.38152	**1299**	255734.4
NoviSad	RS3	45.25506	19.85749	**1255**	256379.6
Zemun	RS4	44.8538	20.40723	**1173**	407325.2
Pancevo	RS5	44.8536	20.63682	**1155**	16649.08
Banatska Palanka	RS6	44.82313	21.35485	**1077**	569422.3
Bazias	RO1	44.8161	21.38397	**1071**	569422.3
Tekija	RS7	44.7123	22.43717	**954**	574809.4
Radujevac	RS8	44.26277	22.68036	851	577371.7
Gruia	RO18	44.27018	22.68355	851	577371.7
NovoSelo Harbour	BG1	45.23307	22.77174	834	19.64
Pristol/Novo Selo	RO2	45.23307	22.77174	834	19.64
Lom	BG9	43.84586	23.33003	741	587060.2
Orjahovo	BG10	43.74081	23.96272	679	606059.4
us. Iskar-Bajkal	BG2	43.71715	24.40407	641	606267

Nikopol	BG11	43.70561	24.89122	598	646816
Downst. Svishtov	BG3	43.6244	25.36434	554	649342.1
us. Russe	BG4	43.8209	25.91537	503	664096.9
Dunare-upst. Arges	RO3	44.05605	26.61905	432	682560.1
Chiciu/Silistra	RO4	44.12345	27.25795	375	685300.2
Silistra/Chiciu	BG5	44.12497	27.26750	375	685300.2
ReniChilia/Kilia arm	RO5	45.46324	29.55336	132	979.14
Reni	UA1	45.43690	28.28780	132	789779.4
Vilkova-Chilia arm	RO6	45.40635	28.2319	18	402.34
Vylkove	UA2	45.39390	29.59190	18	802032.1
Sulina -Sulina arm	RO7	45.18338	29.52966	0	420.55
Sf. Gheorghe arm	RO8	44.88462	29.60945	0	144.67

TABLE SM_NS2: LIST OF NUTRIENTS MONITORING LOCATIONS IN THE TRIBUTARIES OF THE DANUBE

River	Location	id	Latitude (d. m. s.)	Longitude (d. m. s.)	Distance (km)	Drain area (km2)
Sava	Jesenice	HR6	45.86054	15.6922	729	10632
Sava	Jesenice na Dolen.	SI2	45.86092	15.692	729	10632
Sava	Drenje	HR10	45.862	15.69	728.8	10632
Sava	Upst. Una Jasenovac	HR7	45.26881	16.9155	525	9747
Sava	Jasenovac	BA1	45.26667	16.91	500	14979
Sava	Gradiška	BA5	45.14103	17.2551	457	108
Sava	Downstream Zupanja	HR8	45.04049	18.6959	254	66383
Sava	Račinovci	HR12	44.851	18.96	218	67764
Sava	Jamena	RS13	44.87828	19.0836	205	68555
Sava	Raca	BA11	44.89065	19.3346	190	113
Sava	Sremska Mitrovica	RS14	44.96704	19.6021	135	91935
Sava	Šabac	RS15	44.76952	19.699	106	93352
Sava	Ostružnica	RS16	44.73165	20.3118	17	99665
Drava	Ormož Most	SI1	46.40314	16.1554	300	15369
Drava	Ormož	HR9	46.40281	16.1549	300	15369
Drava	Varazdin	HR3	46.3225	16.3628	288	15529
Drava	Botovo	HR4	46.24131	16.9383	227	31111
Drava	D. Miholjac	HR5	45.78311	18.2006	78	37360
Drava	Dravaszabolcs	HU7	45.78443	18.2005	78	37360
Tisza	Tiszabecs	HU10	48.10445	22.8308	757	9243
Tisza	Chop	UA4	48.416	22.184	342	33754
Tisza	Tiszasziget	HU9	46.18552	20.1047	163	138733
Tisza/Sajo	Sajópüspöki	HU8	48.28284	20.3397	124	3184
Prut	Lipcani	MD1	48.1516	26.4831	658	98
Prut	Valea Mare	MD7	47.0754	27.5149	525	46
Prut	Leuseni	MD2	46.8	28.15	292	22507

Prut	Tarasivtsi	UA6	48.1834	26.3364	262	8098
Prut	Costesti Reservoir	MD5	47.5127	27.1446	254	9.3
Prut	Braniste	MD6	47.4745	27.1447	254	3.46
Prut	Leova	MD4	46.29	28.14	216	25424
Prut	Conf. Dan-Giurgiulesti	RO11	45.469	28.2029	0	28500
Prut	Conf. Dan-Giurgiulesti	MD3	45.469	28.203	0	242
Tisa	Martonoš	RS10	45.285	28.1243	152	139325
Tisa	Novi Bečej	RS11	46.11424	20.0814	65	143991
Tisa	Titel	RS12	45.58625	20.1346	8.7	149567
Morava	Lanzhot	CZ1	45.19804	20.3117	79	9884
Morava/Dyje	Pohansko	CZ2	48.68721	16.9893	17	12550
Morava	Bratislava	SK6	48.72349	16.8853	1	26627
Siret	Tcherepkivtsi	UA7	48.18768	16.976	100	1615
Siret	Conf. Dan (Sendreni)	RO10	47.981	26.03	0	68.2
Inn	Kirchdorf	DE3	45.41474	28.0094	195	10008
Inn/Salzach	Laufen	DE4	47.78189	12.1261	47	6093
Sio	Szekszard-Palank	HU6	47.93968	12.9328	13	14702
Iskar	Orechovitza	BG6	46.38004	18.7201	28	8321
Iskar	Gigen mouth	BG12	43.58946	24.3584	4	8581
Russenski Lom	Basarbovo	BG8	43.7064	24.4562	13	2970
Russenski Lom	Mouth	BG15	43.7864	25.9132	1	2986.7
Jantra	Karantzi	BG7	43.8129	25.936	12	6888.4
Jantra	Novgrad mouth	BG14	43.3887	25.6691	4	7442.3
Arges	Conf. Danube-Clatesti	RO9	43.60935	25.579	0	12513
Velika Morava	Ljubicevski Most	RS17	44.145	26.599	21.8	36395
Vah	KomÃ¡rno	SK4	44.58558	21.1325	1.5	19976

SM.3 Streamflow

TABLE SM_SF1: LIST OF DISCHARGE MONITORING STATIONS IN THE DANUBE MAIN CHANNEL. THE NUMBER OF OVERLAPPING DAYS USED FOR COMPARISON (# DAYS), PERFORMANCE METRICS (KGE, NSE, PBIAS) COMPARING MODELED (EFAS) VS. OBSERVED DISCHARGE FOR DANUBE RIVER STATIONS, INCLUDING SPECIFIC BIAS ESTIMATES FOR LOW (<25TH PERCENTILE) AND HIGH (>75TH PERCENTILE) FLOW REGIMES.

Location	id	# days	KGE	NSE	PBIAS	PBIAS-L	PBIAS-H
Neu-Ulm	DE1	4017	NA	NA	NA	NA	NA
Dillingen	DE5	5844	NA	NA	NA	NA	NA
Jochenstein	AT1	9131	0.89	0.77	0.6	1.2	-9.7
Jochenstein	DE2	9800	NA	NA	NA	NA	NA
Abwinden-Asten	AT2	2922	0.81	0.62	3.4	7.6	-17
Enghagen	AT5	5844	0.87	0.77	-0.3	-1.7	-9.3
Wien-Nussdorf	AT3	9131	0.87	0.75	0.3	1.7	-19.4
Hainburg	AT6	6209	0.86	0.77	-5.5	-6.3	-17.7
Wolfsthal	AT4	2922	NA	NA	NA	NA	NA
Bratislava	SK1	12480	NA	NA	NA	NA	NA
Medvedovo	HU1	9123	0.86	0.72	5.4	9.9	-10.2
MedveŽ	SK2	9859	NA	NA	NA	NA	NA
Komarno	SK3	6207	NA	NA	NA	NA	NA
Komarom	HU2	9123	0.88	0.76	4.4	6.7	-4.4
Szob	HU3	9855	0.85	0.72	4.7	6.3	-7.1
Szob	SK5	NA	NA	NA	NA	NA	NA
Dunafoldvar	HU4	8999	0.84	0.7	3.5	5.2	-8.3
Hercegszanto	HU5	8761	0.82	0.66	5.1	9	-6.6
Batina	HR1	2557	NA	NA	NA	NA	NA
Bezdan	RS1	23	0.62	0.47	9.3	5.7	23.2
Bogojevo	RS2	11	NA	NA	NA	NA	NA
Borovo	HR2	1461	0.53	0.18	6.2	7.5	7.3
Ilok	HR11	NA	NA	NA	NA	NA	NA
Backa Palanka	RS9	NA	NA	NA	NA	NA	NA
NoviSad	RS3	NA	NA	NA	NA	NA	NA
Zemun	RS4	NA	NA	NA	NA	NA	NA
Pancevo	RS5	NA	NA	NA	NA	NA	NA
Banatska Palanka	RS6	NA	NA	NA	NA	NA	NA
Bazias	RO1	20075	0.76	0.5	8.3	26.2	-2
Tekija	RS7	NA	NA	NA	NA	NA	NA
Radujevac	RS8	NA	NA	NA	NA	NA	NA
Gruia	RO18	NA	NA	NA	NA	NA	NA
NovoSelo Harbour	BG1	12	NA	NA	NA	NA	NA
Pristol/Novo Selo	RO2	27746	0.77	0.52	13.1	33.8	-4.9
Lom	BG9	NA	NA	NA	NA	NA	NA
Orjahovo	BG10	NA	NA	NA	NA	NA	NA
us. Iskar-Bajkal	BG2	NA	NA	NA	NA	NA	NA
Nikopol	BG11	NA	NA	NA	NA	NA	NA

Downst. Svishtov	BG3	NA	NA	NA	NA	NA	NA
us. Russe	BG4	NA	NA	NA	NA	NA	NA
Dunare-upst. Arges	RO3	11308	0.81	0.6	8.7	22.7	-5.2
Chiciu/Silistra	RO4	27739	0.78	0.55	9.1	27.4	-5.5
Silistra/Chiciu	BG5	12	NA	NA	NA	NA	NA
ReniChilia/Kilia arm	RO5	27757	0.77	0.53	6	24.3	-7.3
Reni	UA1	5844	NA	NA	NA	NA	NA
Vilkova-Chilia arm	RO6	12229	-0.46	-8	105.4	141.2	80.1
Vylkove	UA2	6575	NA	NA	NA	NA	NA
Sulina -Sulina arm	RO7	12266	NA	NA	NA	NA	NA
Sf. Gheorghe arm	RO8	11138	NA	NA	NA	NA	NA

Table SM_ SF2: LIST OF DISCHARGE MONITORING STATIONS in the Danube major tributaries. The number of overlapping days used for comparison (# days), performance metrics (KGE, NSE, PBIAS) comparing modeled (EFAS) vs. observed discharge for Danube River stations, including specific bias estimates for low (<25th percentile) and high (>75th percentile) flow regimes.

River	Location	id	# days	KGE	NSE	PBIAS	PBIAS-L	PBIAS-H
Sava	Jesenice	HR6	4	NA	NA	NA	NA	NA
Sava	Jesenice na Dolen.	SI2	24	0.77	0.57	-0.3	26.7	997
Sava	Drenje	HR10	4	NA	NA	NA	NA	NA
Sava	Upst. Una Jasenovac	HR7	3	0.61	0.59	-15.6	51.2	2196
Sava	Jasenovac	BA1	NA	NA	NA	NA	NA	NA
Sava	Gradiška	BA5	NA	NA	NA	NA	NA	NA
Sava	Downstream Zupanja	HR8	12	NA	NA	NA	NA	NA
Sava	Račinovci	HR12	6	NA	NA	NA	NA	NA
Sava	Jamena	RS13	NA	NA	NA	NA	NA	NA
Sava	Raca	BA11	NA	NA	NA	NA	NA	NA
Sava	Sremska Mitrovica	RS14	0	NA	NA	NA	NA	NA
Sava	Šabac	RS15	NA	NA	NA	NA	NA	NA
Sava	Ostružnica	RS16	NA	NA	NA	NA	NA	NA
Drava	Ormož Most	SI1	24	0.77	0.54	4.3	11.3	727.04
Drava	Ormož	HR9	3	NA	NA	NA	NA	NA
Drava	Varazdin	HR3	NA	NA	NA	NA	NA	NA
Drava	Botovo	HR4	6	0.78	0.61	6.5	17.2	989.76
Drava	D. Miholjac	HR5	6	0.73	0.52	15.1	27.7	1010.28
Drava	Dravaszabolcs	HU7	21	0.72	0.53	13.9	22.9	1140
Tisza	Tiszabecs	HU10	15	NA	NA	NA	NA	NA
Tisza	Chop	UA4	NA	NA	NA	NA	NA	NA
Tisza	Tiszasziget	HU9	21	0.72	0.47	12.3	66.2	2500
Tisza/Sajo	Sajópüspöki	HU8	21	0.7	0.65	-16.2	-14.4	93.05
Prut	Lipcani	MD1	NA	NA	NA	NA	NA	NA
Prut	Valea Mare	MD7	NA	NA	NA	NA	NA	NA
Prut	Leuseni	MD2	NA	NA	NA	NA	NA	NA
Prut	Tarasivtsi	UA6	NA	NA	NA	NA	NA	NA

Prut	Costesti Reservoir	MD5	NA	NA	NA	NA	NA	NA
Prut	Braniste	MD6	NA	NA	NA	NA	NA	NA
Prut	Leova	MD4	NA	NA	NA	NA	NA	NA
Prut	Conf. Dan-Giurgiulesti	RO11	24	-0.08	0.02	-12.5	108.7	1350
Prut	Conf. Dan-Giurgiulesti	MD3	NA	NA	NA	NA	NA	NA
Tisa	Martonoš	RS10	0	0.57	0.09	12.8	60.3	2282.8
Tisa	Novi Bečej	RS11	NA	NA	NA	NA	NA	NA
Tisa	Titel	RS12	NA	NA	NA	NA	NA	NA
Morava	Lanzhot	CZ1	24	0.76	0.54	7.6	82.1	233
Morava/Dyje	Pohansko	CZ2	24	0.43	0.24	6.4	107.7	145
Morava	Bratislava	SK6	12	NA	NA	NA	NA	NA
Siret	Tcherepkivtsi	UA7	NA	NA	NA	NA	NA	NA
Siret	Conf. Dan (Sendreni)	RO10	24	-0.68	-1.01	-100	-100	767
Inn	Kirchdorf	DE3	25	0.8	0.74	-11.9	-10.1	751.60
Inn/Salzach	Laufen	DE4	25	0.71	0.6	-16.6	-20.4	637.078
Sio	Szekszard-Palank	HU6	21	-0.53	-0.6	-99	-95.7	67.4
Iskar	Orechovitza	BG6	NA	NA	NA	NA	NA	NA
Iskar	Gigen mouth	BG12	NA	NA	NA	NA	NA	NA
Russenski Lom	Basarbovo	BG8	NA	NA	NA	NA	NA	NA
Russenski Lom	Mouth	BG15	NA	NA	NA	NA	NA	NA
Jantra	Karantzi	BG7	NA	NA	NA	NA	NA	NA
Jantra	Novgrad mouth	BG14	NA	NA	NA	NA	NA	NA
Arges	Conf. Danube-Clatesti	RO9	4	-0.64	-0.3	-99.7	-99	500
Velika Morava	Ljubicevski Most	RS17	0	-0.49	-0.6	-47.2	47.3	791.94
Vah	KomÃ¡rno	SK4	12	-13.4	-445	1189.	2273.2	499.3

Table SM_SF3: Theill-Sen Slope Estimates (% per year) and Mann-Kendall p-values for Streamflow Trends at Nutrient Monitoring Stations along the Danube River. Trends are evaluated across four key flow metrics: 7-day minimum, daily median, daily mean, and 7-day maximum.

	7- Day Minimum		Median Daily		Mean Daily		7- Day Maximum	
station	Slope	p-value	Slope	p-value	Slope	p-value	Slope	p-value
2560-DE51	-0.77	0.069	-1.20	0.001	-1.19	0.005	-0.15	0.778
2204-AT1	-0.46	0.017	-0.66	0.007	-0.47	0.034	-0.25	0.464
2204-DE2	-0.46	0.017	-0.66	0.007	-0.47	0.034	-0.25	0.464
2113-AT52	-0.43	0.016	-0.60	0.011	-0.47	0.049	-0.24	0.488
1935-AT3	-0.31	0.034	-0.48	0.016	-0.31	0.088	-0.11	0.778
1877-AT46	-0.31	0.034	-0.48	0.016	-0.31	0.088	-0.11	0.778
1869-SK1	-0.46	0.017	-0.66	0.007	-0.47	0.034	-0.25	0.464
1806-HU1	-0.25	0.095	-0.44	0.014	-0.36	0.111	-0.28	0.750
1806-SK2	-0.25	0.095	-0.44	0.014	-0.36	0.111	-0.28	0.750
1768-HU2	-0.18	0.138	-0.34	0.058	-0.32	0.149	-0.23	0.694
1708-HU3	-0.13	0.171	-0.19	0.320	-0.19	0.464	-0.21	0.511
1560-HU4	-0.10	0.302	-0.23	0.268	-0.17	0.488	-0.31	0.561
1435-HU5	-0.21	0.095	-0.28	0.129	-0.19	0.339	-0.24	0.613

1337-HR2	-0.19	0.183	-0.17	0.399	-0.09	0.511	-0.08	0.639
1300-HRRS	-0.19	0.268	-0.16	0.302	-0.08	0.536	-0.08	0.694
1255-RS3	-0.20	0.268	-0.16	0.302	-0.08	0.536	-0.07	0.694
1173-RS4	-0.12	0.807	-0.01	1.000	-0.03	0.896	0.31	0.302
1077-RS6	-0.12	0.807	-0.01	1.000	-0.03	0.896	0.31	0.302
1071-RO1	-0.12	0.807	-0.01	1.000	-0.03	0.896	0.31	0.302
954-RS7	-0.09	0.807	0.01	0.955	-0.02	0.925	0.26	0.285
834-RO2	-0.11	0.866	0.03	0.955	0.01	0.955	0.20	0.586
834-RO2	-0.11	0.866	0.03	0.955	0.01	0.955	0.20	0.586
641-BG2	-0.09	0.866	0.06	0.807	0.03	0.896	0.28	0.536
554-BG3	-0.10	0.896	0.16	0.639	0.14	0.694	0.36	0.358
503-BG4	-0.10	0.896	0.16	0.639	0.14	0.694	0.36	0.358
432-RO3	-0.16	0.837	0.18	0.694	0.21	0.536	0.36	0.399
375-RO4	-0.15	0.807	0.21	0.694	0.23	0.536	0.38	0.358
375-BG5	-0.15	0.807	0.21	0.694	0.23	0.536	0.38	0.358
132-RO5	-0.21	0.613	0.25	0.613	0.23	0.399	0.37	0.358
18-RO6	-0.24	0.613	0.25	0.666	0.24	0.420	0.37	0.358
0-RO8	-0.24	0.613	0.25	0.666	0.24	0.420	0.37	0.358
0-RO7	-0.24	0.613	0.25	0.666	0.24	0.420	0.37	0.358

Table SM_SF4: Thiel-Sen Slope Estimates (% per year) and Mann-Kendall p-values for Streamflow Trends at Nutrient Monitoring Stations along the Danube River. Trends are evaluated across four key flow metrics: 7-day minimum, daily median, daily mean, and 7-day maximum.

		7- Day Minimum		Median Daily		Mean Daily		7- Day Maximum	
station	River	Slope	p-value	Slope	p-value	Slope	p-value	Slope	p-value
729-SI2	Sava	-0.09	0.212	-0.61	0.212	-0.42	0.318	-0.52	0.301
729-HR2	Sava	-0.09	0.212	-0.61	0.212	-0.42	0.318	-0.52	0.301
729-HR106	Sava	-0.09	0.212	-0.61	0.212	-0.42	0.318	-0.52	0.301
525-HR7	Sava	-0.27	0.080	-0.63	0.301	-0.55	0.269	0.02	0.830
235-HR128	Sava	-0.24	0.318	-0.95	0.116	-0.82	0.054	-0.43	0.239
205-RS13	Sava	-0.21	0.254	-0.90	0.164	-0.82	0.069	-0.49	0.225
106-RS15	Sava	-0.24	0.412	-0.55	0.239	-0.67	0.254	-0.27	0.475
17-RS16	Sava	-0.31	0.521	-0.50	0.269	-0.67	0.372	-0.20	0.568
300-SI1	Drava	0.08	0.164	0.18	0.803	0.21	0.643	0.18	0.669
290-HR39	Drava	0.08	0.164	0.18	0.803	0.21	0.643	0.18	0.669
227-HR4	Drava	0.06	0.669	0.00	1.000	0.04	0.775	0.12	0.803
78-HR5	Drava	-0.07	0.592	-0.12	0.748	-0.08	0.830	0.14	0.915
78-HU7	Drava	-0.07	0.592	-0.12	0.748	-0.08	0.830	0.14	0.915
21.8-RS17	Velik	1.49	0.019	3.25	0.001	3.04	0.003	2.06	0.014
1.5-SK4	Vah	-0.76	0.069	0.46	0.520	0.59	0.372	0.63	0.186
152-RS10	Tisza	0.33	0.475	0.09	0.887	-0.10	0.830	-0.08	0.775
65-RS11	Tisza	0.29	0.498	0.05	0.915	-0.12	0.775	-0.03	0.830

8.7-RS12	Tisza	0.23	0.568	0.02	0.972	-0.17	0.721	0.11	0.803
195-DE3	Inn	0.17	0.175	0.02	0.943	-0.14	0.775	-0.01	0.972
47-DE4	Inn	0.28	0.134	-0.08	0.830	0.05	0.775	0.29	0.592
163-HU9	Tisza	0.30	0.454	0.06	0.915	-0.10	0.830	-0.09	0.887
124-HU8	Sajo	7.78	0.001	4.02	0.002	2.44	0.032	1.10	0.239
79-CZ1	Morav	-1.28	0.035	-1.79	0.014	-1.95	0.020	-2.03	0.069
17-CZ2	Morav	0.06	0.830	-0.54	0.432	-0.45	0.617	-0.09	0.830
658-MD1	Prut	-1.33	0.000	0.54	0.475	-0.05	1.000	0.14	0.943
0-RO11	Prut	-0.23	0.335	-0.62	0.372	-0.41	0.643	-0.12	0.915
0-MD3	Prut	-0.23	0.335	-0.62	0.372	-0.41	0.643	-0.12	0.915
0-RO10	Siret	-0.69	0.000	0.53	0.521	0.88	0.254	-0.31	0.748
28-BG6	Iskar	0.29	0.199	1.47	0.042	1.53	0.022	2.25	0.005
4-BG12	Iskar	0.30	0.199	1.56	0.038	1.58	0.022	2.32	0.006
12-BG7	Jantra	0.09	0.521	-0.18	0.915	-0.18	0.858	-0.59	0.617
4-BG14	Jantra	0.13	0.432	-0.13	0.943	-0.18	0.830	-0.39	0.721
13-BG8	Russenk	2.51	0.027	1.11	0.544	0.44	0.592	-0.09	1.000
1-BG15	Russenk	2.51	0.027	1.11	0.544	0.44	0.592	-0.09	1.000
13-HU6	Sio	-1.09	0.000	-1.09	0.000	-1.15	0.000	-1.55	0.042
0-RO9	Argest	-1.09	0.000	-1.09	0.000	-1.15	0.000	-1.55	0.042

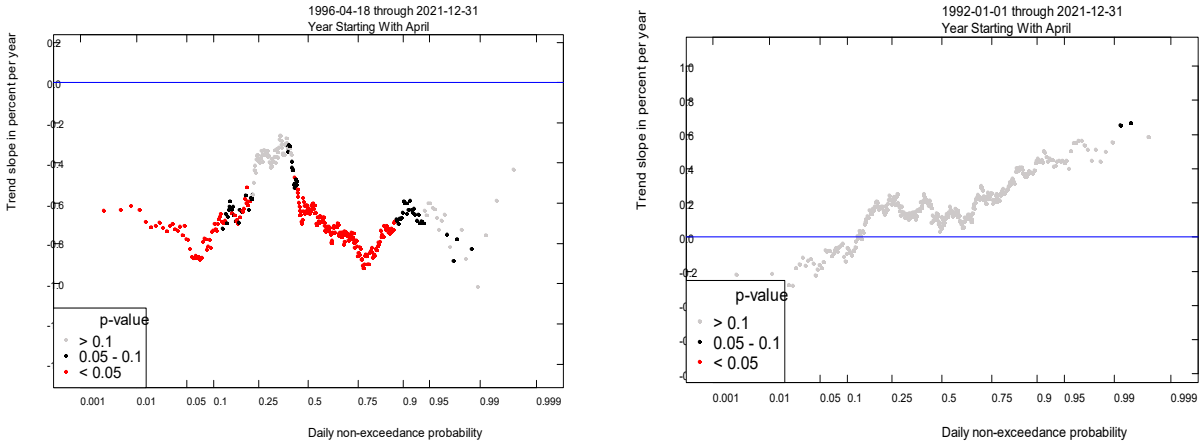


Figure SM_SF1: QUANTILE-KENDALL PLOTS SHOWING THE DAILY STREAMFLOW TRENDS AT DANUBE STATIONS 2113-AT5 (LEFT) AND 554-BG3 (RIGHT). THE PLOTS SHOW NON-EXCEEDANCE PROBABILITY LEVELS OF DAILY FLOW (X-AXIS) AGAINST THE TREND SLOPE (Y-AXIS). Y-AXIS VALUES <0 (HORIZONTAL BLUE LINE) INDICATES DECREASE OF DISCHARGE FOR THAT PROBABILITY LEVEL, >0 INDICATES AN INCREASE. THE MARKER COLOR INDICATES IF THE TREND IS STATISTICALLY SIGNIFICANT (E.G., RED FOR SIGNIFICANT AT P < 0.05).

SM.4: Nutrient Concentration Distribution via Boxplots

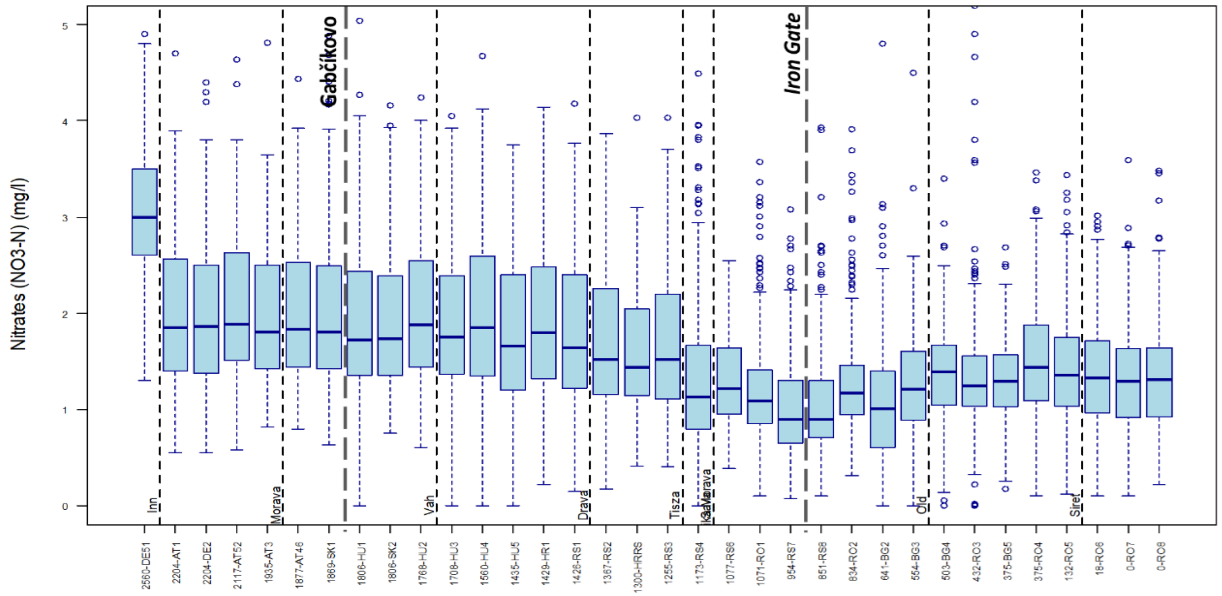


FIGURE SM_BP1: BOXPLOT ILLUSTRATING THE CONCENTRATION DISTRIBUTIONS OF **NO3-N** FOR THE MONITORING STATIONS ALONG THE MAIN COURSE OF THE DANUBE RIVER, AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY A COUNTRY IDENTIFIER. ADDITIONAL CONTEXT IS PROVIDED REGARDING ITS RELATIVE POSITION TO THE CONFLUENCES OF MAJOR TRIBUTARIES AND THE TWO PRIMARY RESERVOIRS: GABČÍKOVO AND IRON GATE.

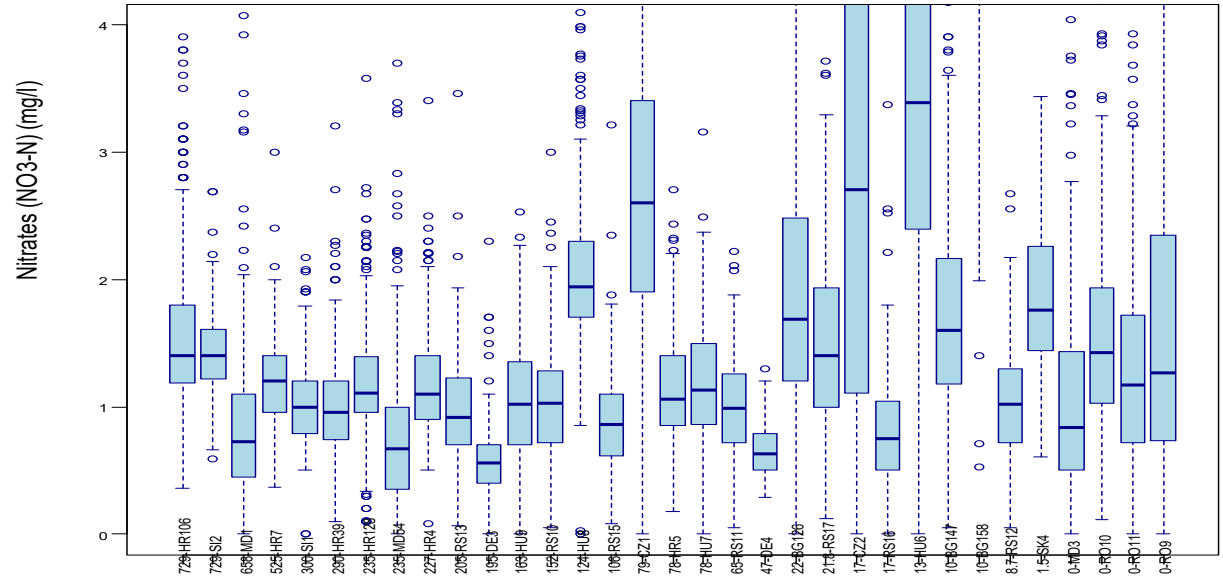


FIGURE SM_BP2: BOXPLOT REPRESENTING THE CONCENTRATION DISTRIBUTION OF **NO3-N** AT MONITORING STATIONS IN THE TRIBUTARIES OF THE DANUBE RIVER. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL

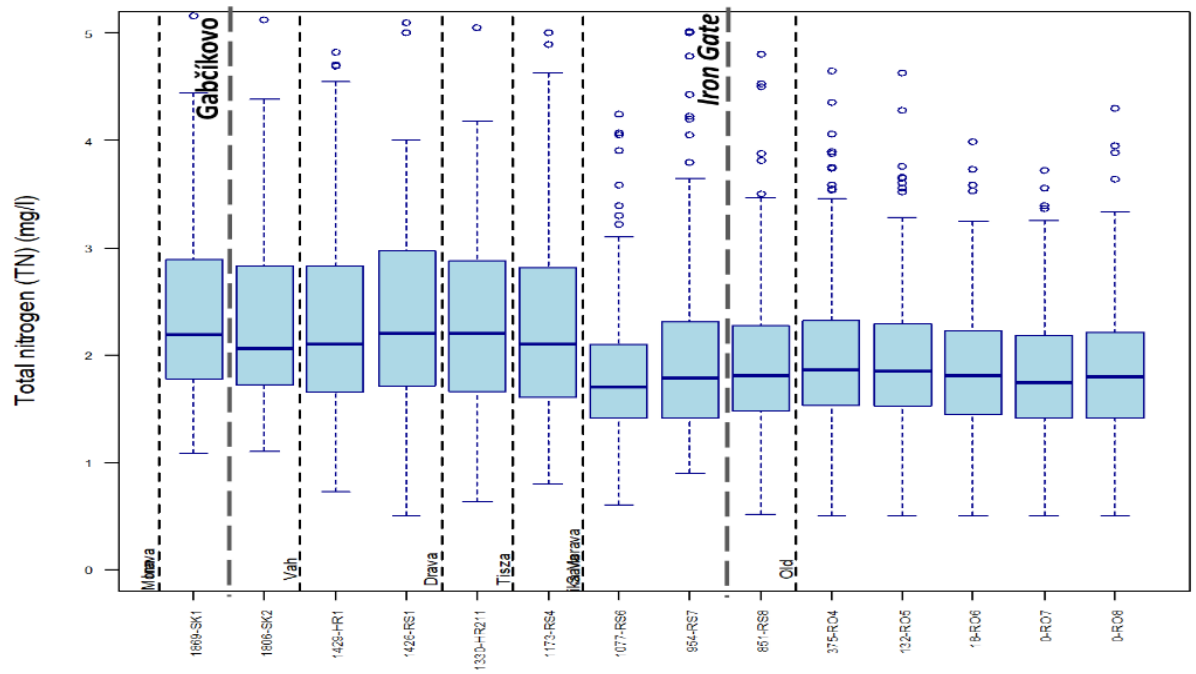


FIGURE SM_BP3: BOXPLOT ILLUSTRATING THE CONCENTRATION DISTRIBUTIONS OF **TN** FOR THE MONITORING STATIONS ALONG THE MAIN COURSE OF THE DANUBE RIVER, AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY A COUNTRY IDENTIFIER. ADDITIONAL CONTEXT IS PROVIDED REGARDING ITS RELATIVE POSITION TO THE CONFLUENCES OF MAJOR TRIBUTARIES AND THE TWO PRIMARY RESERVOIRS: GABČÍKOVO AND IRON GATE.

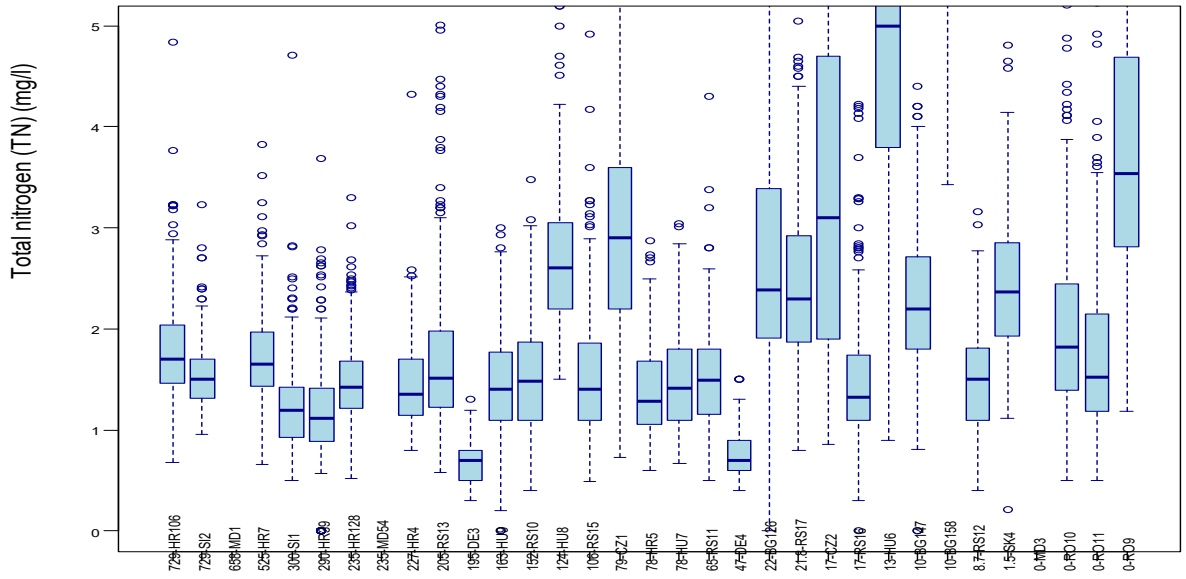


FIGURE SM_BP4: BOXPLOT REPRESENTING THE CONCENTRATION DISTRIBUTION OF **TN** AT MONITORING STATIONS IN THE TRIBUTARIES OF THE DANUBE RIVER. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL

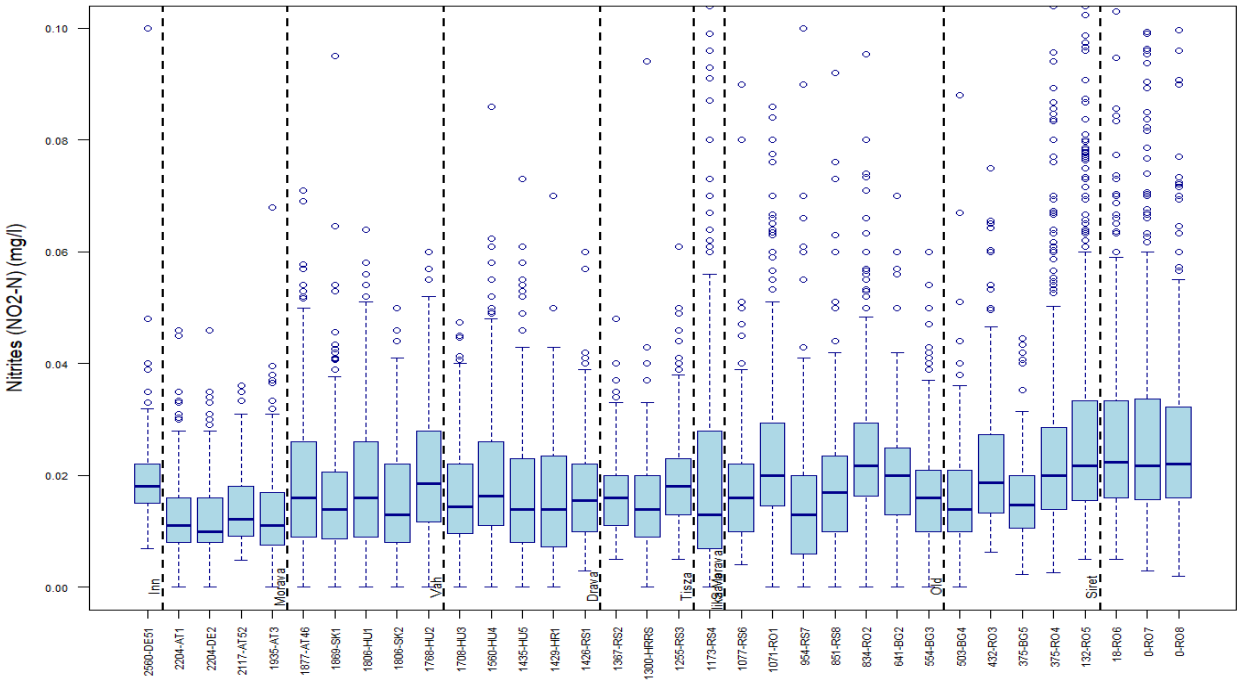


FIGURE SM_BP5: BOXPLOT ILLUSTRATING THE CONCENTRATION DISTRIBUTIONS OF **NO2-N** FOR THE MONITORING STATIONS ALONG THE MAIN COURSE OF THE DANUBE RIVER, AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY A COUNTRY IDENTIFIER. ADDITIONAL CONTEXT IS PROVIDED REGARDING ITS RELATIVE POSITION TO THE CONFLUENCES OF MAJOR TRIBUTARIES AND THE TWO PRIMARY RESERVOIRS: GABČÍKOVO AND IRON GATE

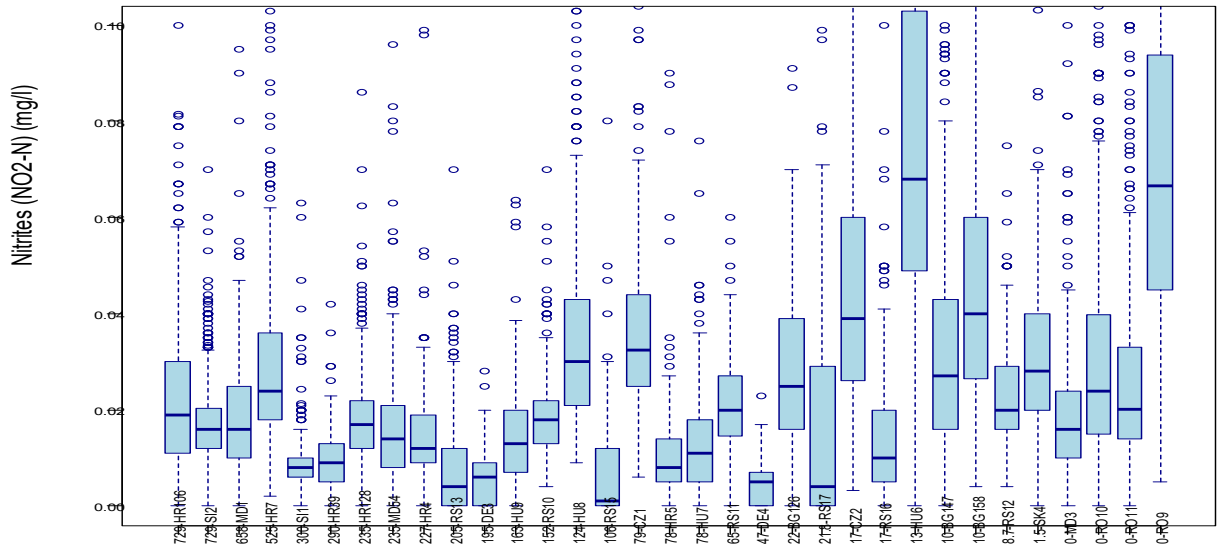


FIGURE SM_BP6: BOXPLOT REPRESENTING THE CONCENTRATION DISTRIBUTION OF **NO2-N** AT MONITORING STATIONS IN THE TRIBUTARIES OF THE DANUBE RIVER. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL

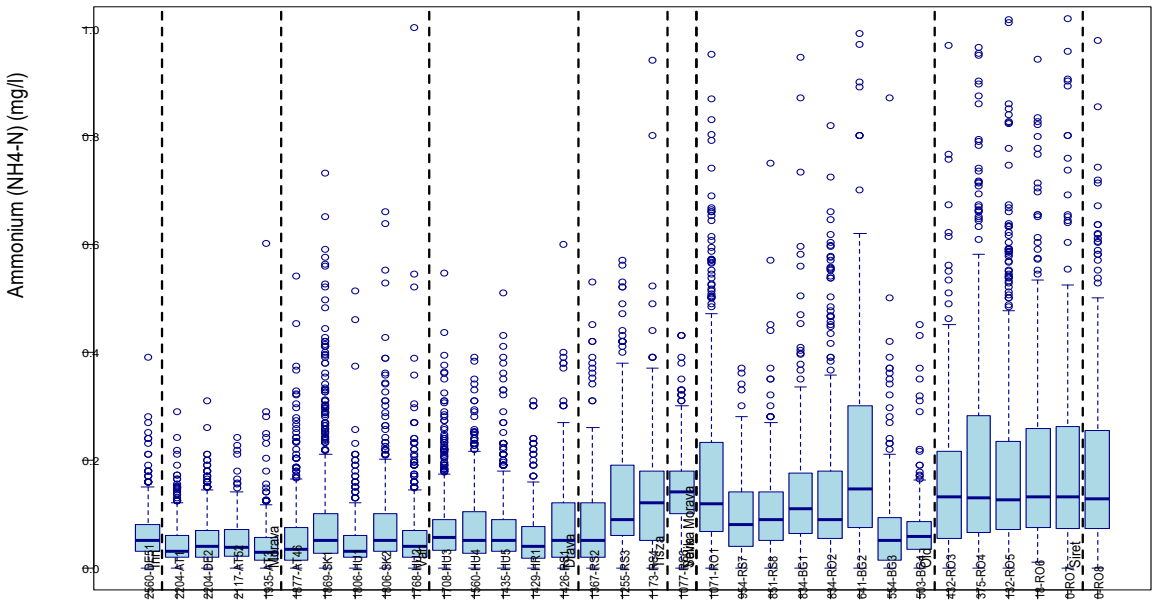


FIGURE SM_BP7: BOXPLOT ILLUSTRATING THE CONCENTRATION DISTRIBUTIONS OF **NH4-N** FOR THE MONITORING STATIONS ALONG THE MAIN COURSE OF THE DANUBE RIVER, AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY A COUNTRY IDENTIFIER. ADDITIONAL CONTEXT IS PROVIDED REGARDING ITS RELATIVE POSITION TO THE CONFLUENCES OF MAJOR TRIBUTARIES AND THE TWO PRIMARY RESERVOIRS: GABČÍKOVO AND IRON GATE

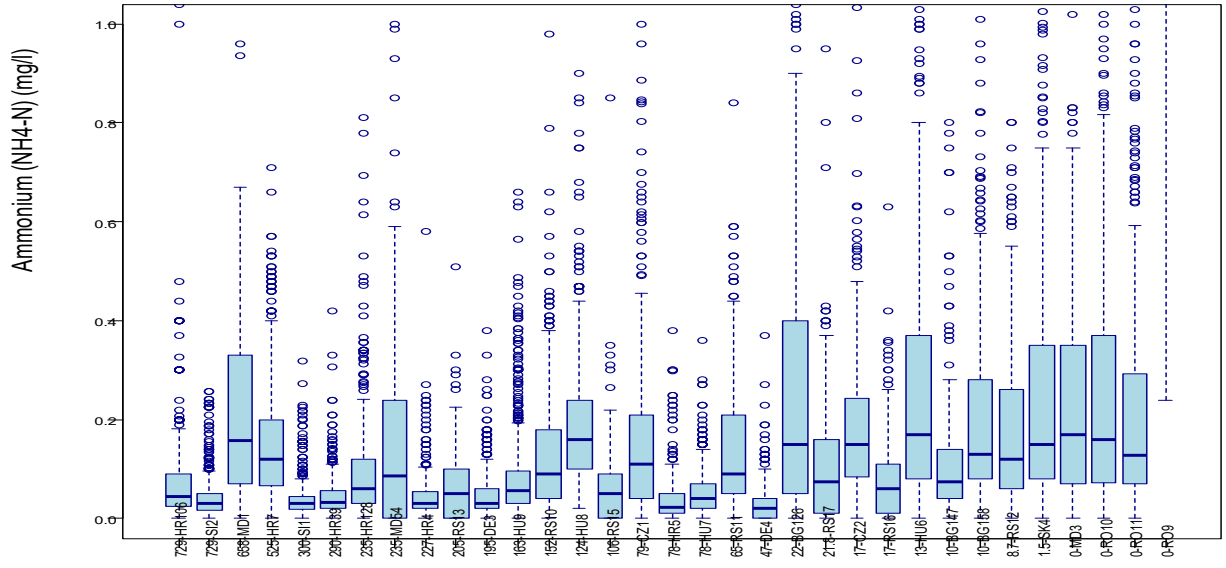


FIGURE SM_BP8: BOXPLOT REPRESENTING THE CONCENTRATION DISTRIBUTION OF **NH4-N** AT MONITORING STATIONS IN THE *TRIBUTARIES* OF THE DANUBE RIVER. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL

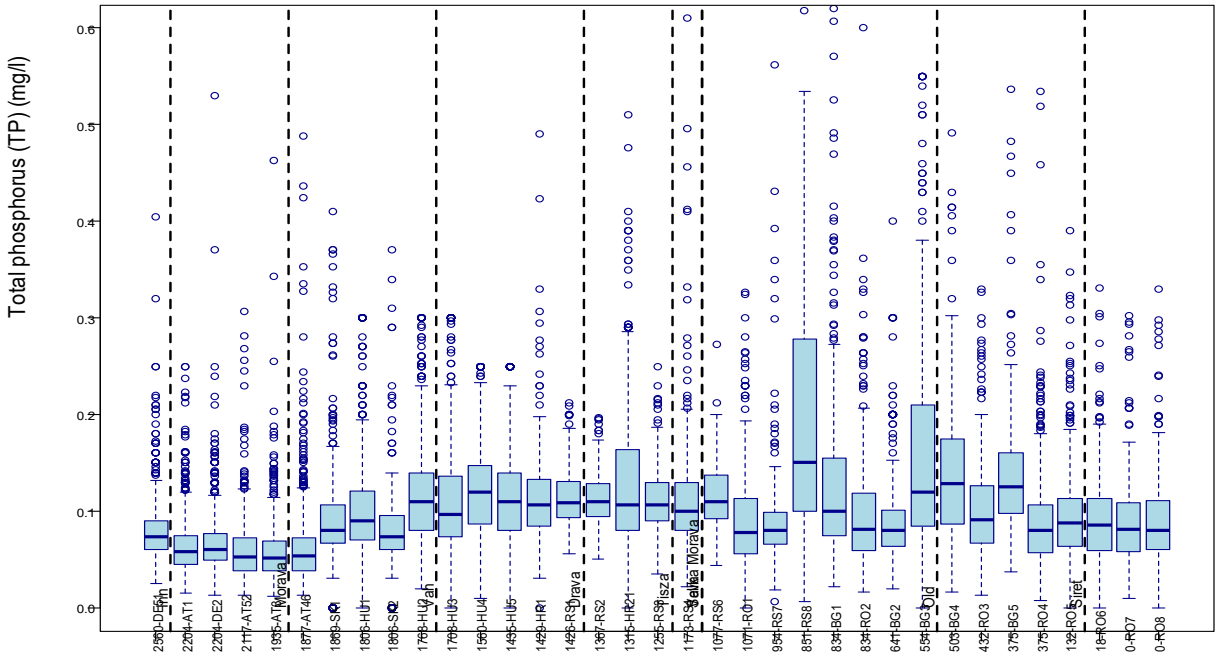


FIGURE SM_BP9: BOXPLOT ILLUSTRATING THE CONCENTRATION DISTRIBUTIONS OF **TP** FOR THE MONITORING STATIONS ALONG THE MAIN COURSE OF THE DANUBE RIVER, AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY A COUNTRY IDENTIFIER. ADDITIONAL CONTEXT IS PROVIDE REGARDING ITS RELATIVE POSITION TO THE CONFLUENCES OF MAJOR TRIBUTARIES AND THE TWO PRIMARY RESERVOIRS: GABČÍKOVO AND IRON GATE

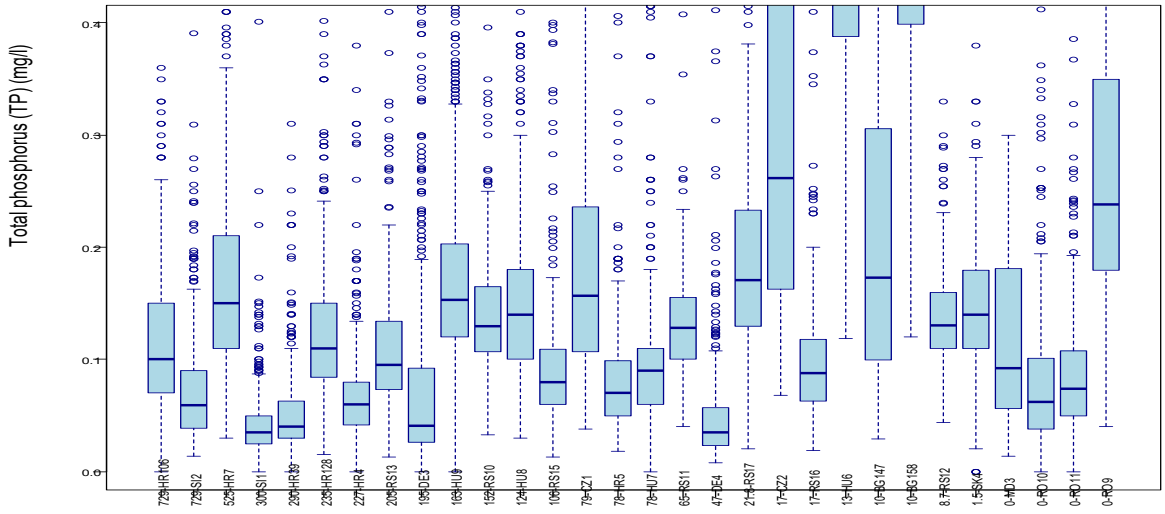


FIGURE SM_BP10: BOXPLOT REPRESENTING THE CONCENTRATION DISTRIBUTION OF **TP** AT MONITORING STATIONS IN THE *TRIBUTARIES* OF THE DANUBE RIVER. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL

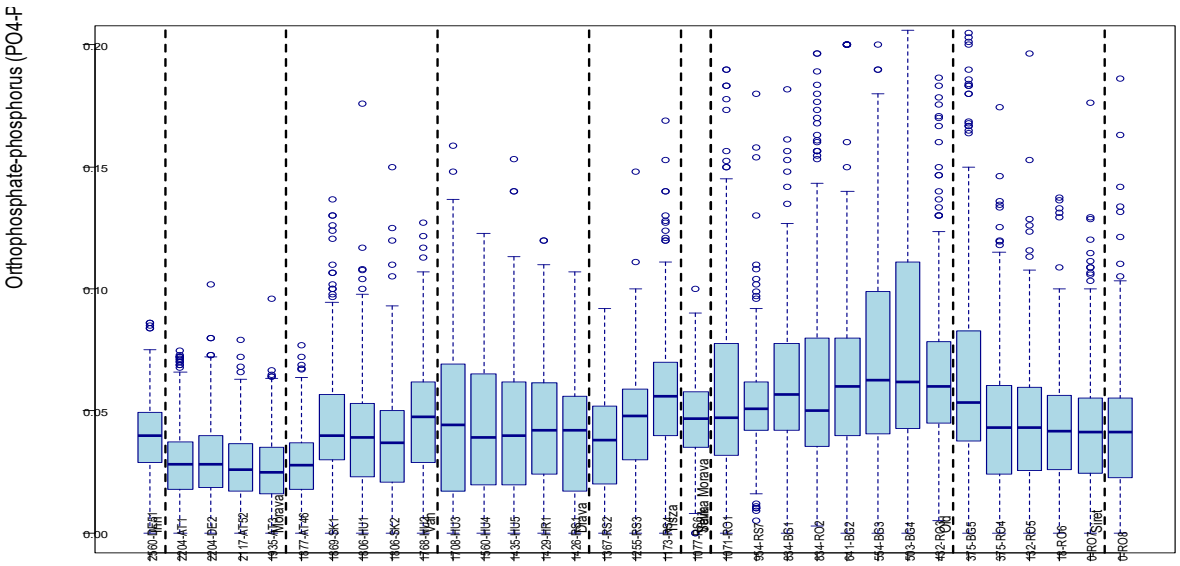


FIGURE SM_BP11: BOXPLOT ILLUSTRATING THE CONCENTRATION DISTRIBUTIONS OF **PO4-P** FOR THE MONITORING STATIONS ALONG THE MAIN COURSE OF THE DANUBE RIVER, AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY A COUNTRY IDENTIFIER. ADDITIONAL CONTEXT IS PROVIDE REGARDING ITS RELATIVE POSITION TO THE CONFLUENCES OF MAJOR TRIBUTARIES AND THE TWO PRIMARY RESERVOIRS: GABČÍKOVO AND IRON GATE.

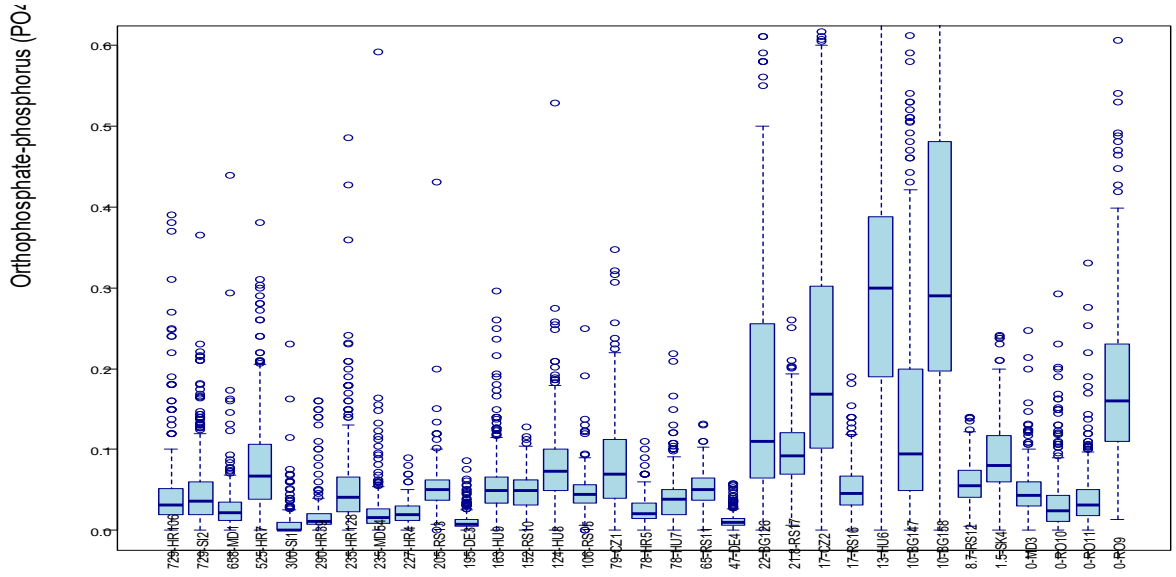


FIGURE SM_BP12: BOXPLOT REPRESENTING THE CONCENTRATION DISTRIBUTION OF **PO4-P** AT MONITORING STATIONS IN THE TRIBUTARIES OF THE DANUBE RIVER. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE *TRIBUTARIES*, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL.

SM.5: Temporal Trends in Nutrient Concentrations via Heatmaps

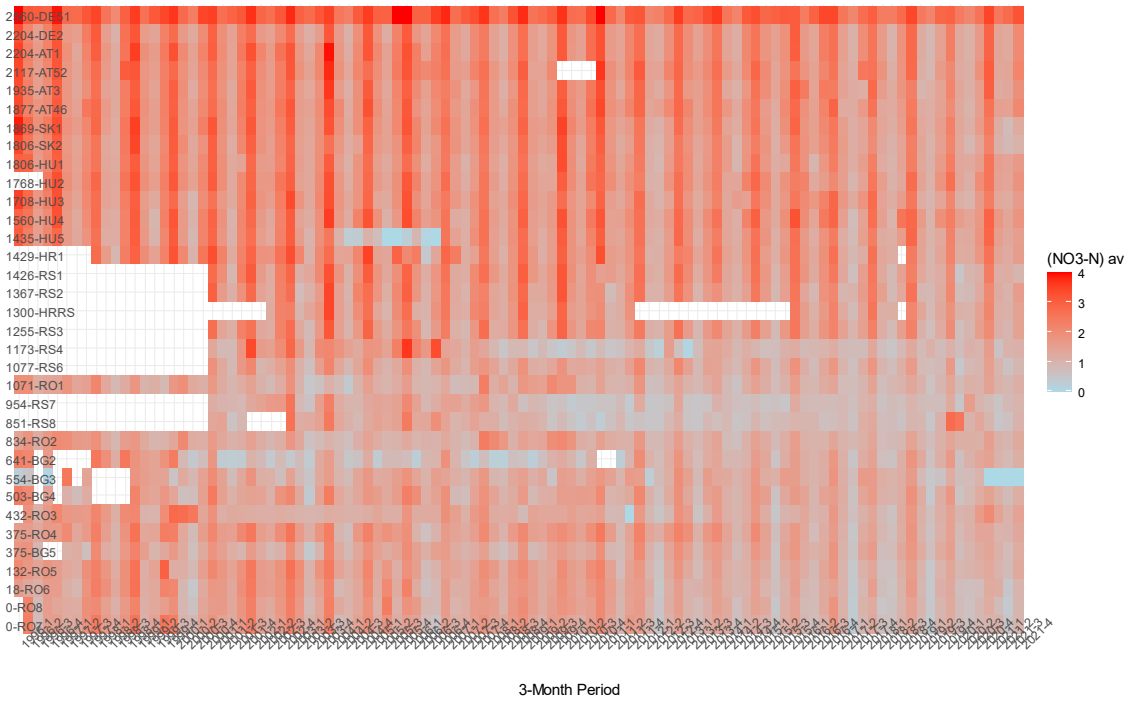


FIGURE SM_HM 1: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **NO3-N** FROM 1996 TO 2021 IN MONITORING STATIONS ALONG THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR A DETAILED LIST AND DESCRIPTION OF ALL MONITORING STATIONS IN THE MAIN CHANNEL, REFER TO TABLE SM_NS1 IN THE SUPPLEMENTARY MATERIAL

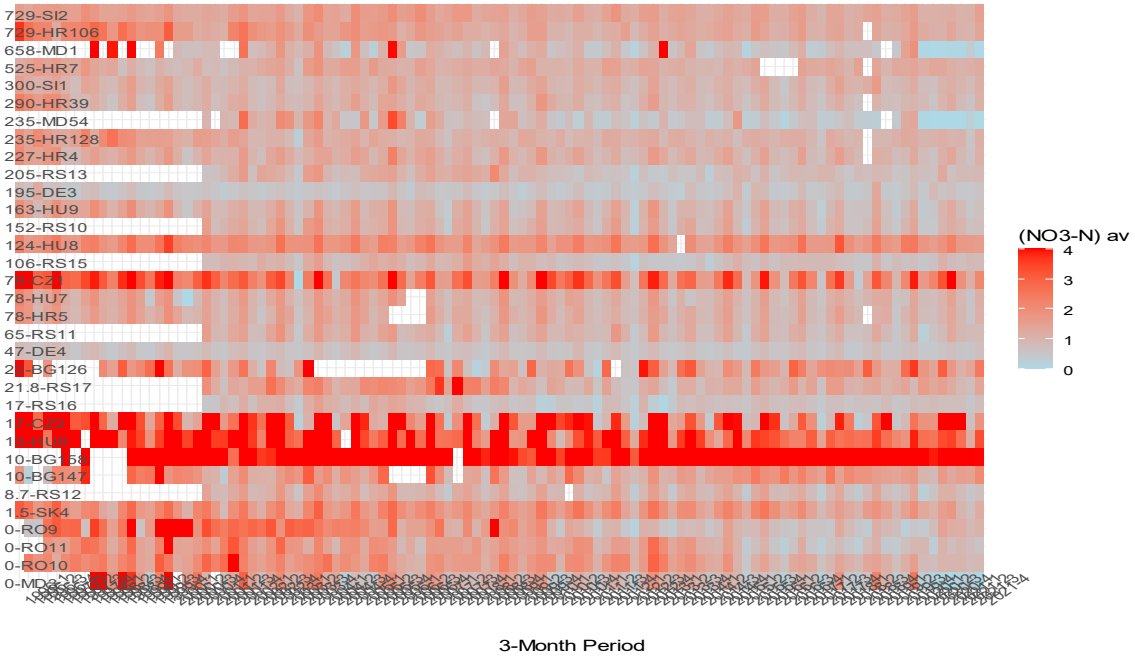


FIGURE SM_HM2: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **NO3-N** FROM 1996 TO 2021 IN MONITORING STATIONS LOCATED IN THE ***TRIBUTARIES*** OF THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL.

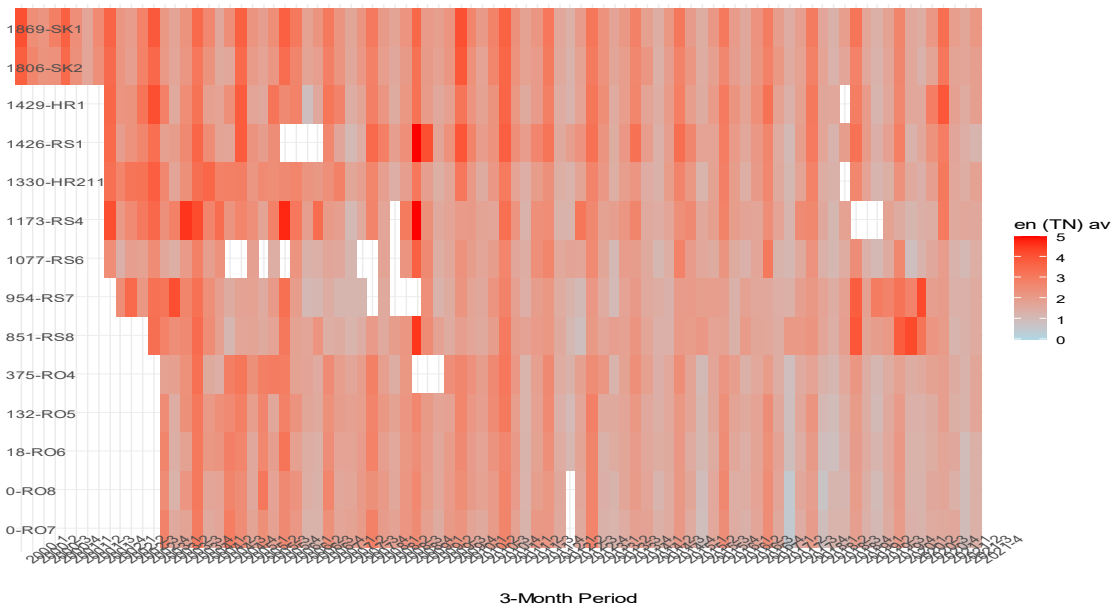


FIGURE SM_HM 3: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **TN** FROM 1996 TO 2021 IN MONITORING STATIONS ALONG THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR A DETAILED LIST AND DESCRIPTION OF ALL MONITORING STATIONS IN THE MAIN CHANNEL, REFER TO TABLE SM_NS1 IN THE SUPPLEMENTARY MATERIAL

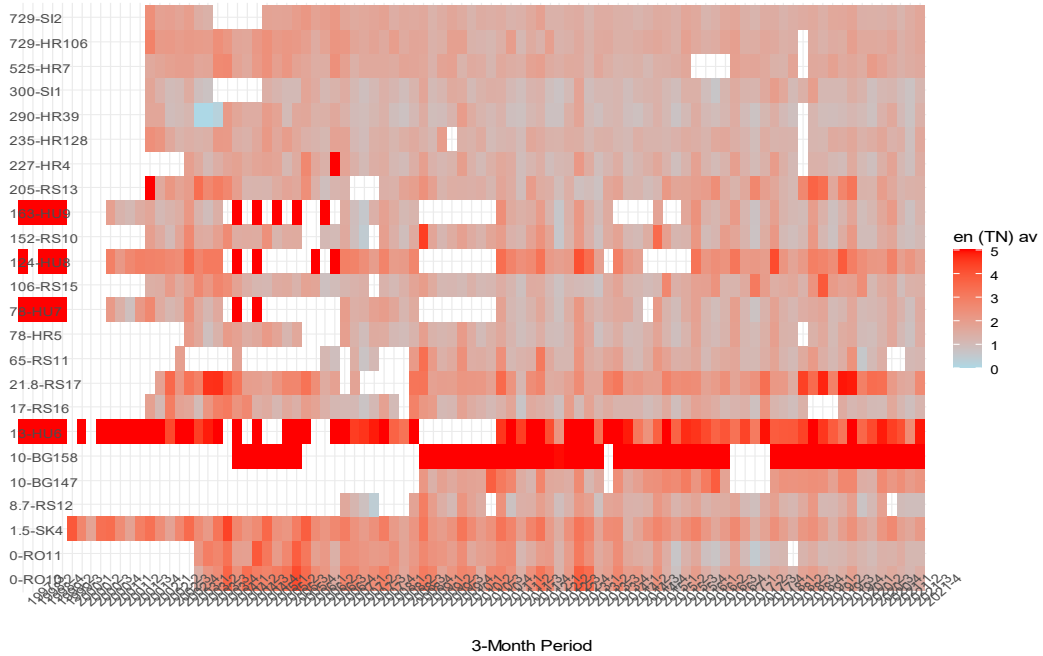


FIGURE SM_HM 4: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **TN** FROM 1996 TO 2021 IN MONITORING STATIONS LOCATED IN THE ***TRIBUTARIES*** OF THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL.

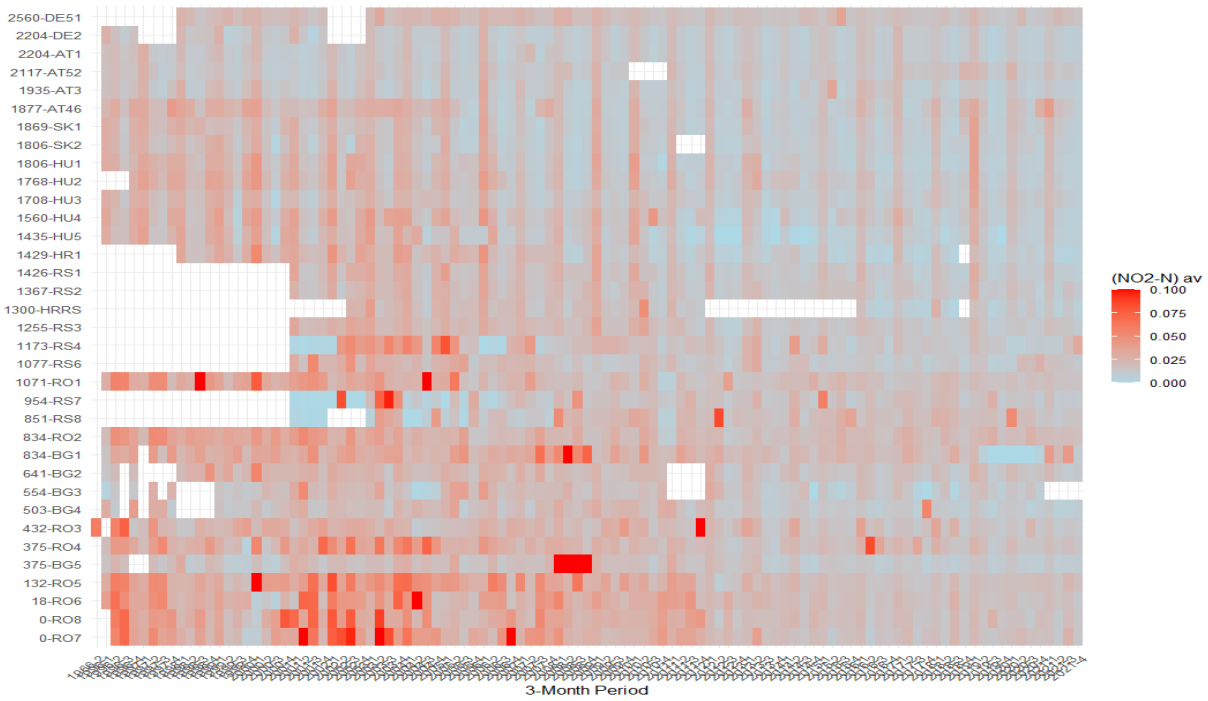


FIGURE SM_HM 5: HEATMAP SHOWING THE 3 MONTH AVERAGE CONCENTRATION OF **NO2-N** FROM 1996 TO 2021 IN MONITORING STATIONS ALONG THE DANUBE AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY AN IDENTIFIER CORRESPONDING TO THE COUNTRY IN WHICH IT IS LOCATED (REFER TO TABLE AM1).

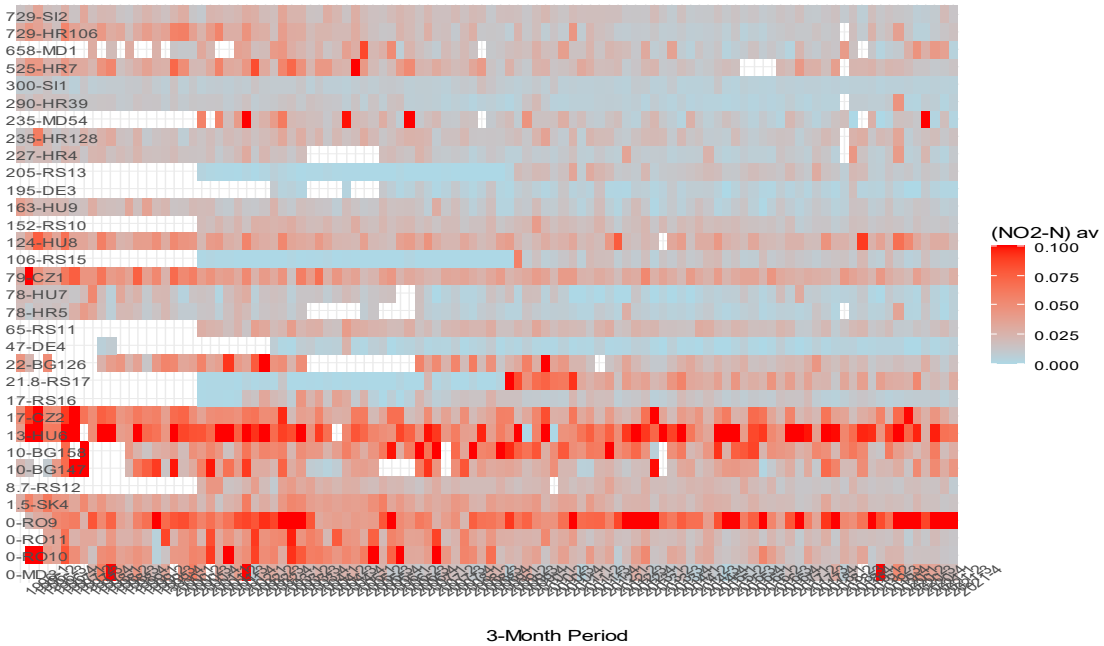


FIGURE SM_HM 6: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **NO2-N** FROM 1996 TO 2021 IN MONITORING STATIONS LOCATED IN THE ***TRIBUTARIES*** OF THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL.

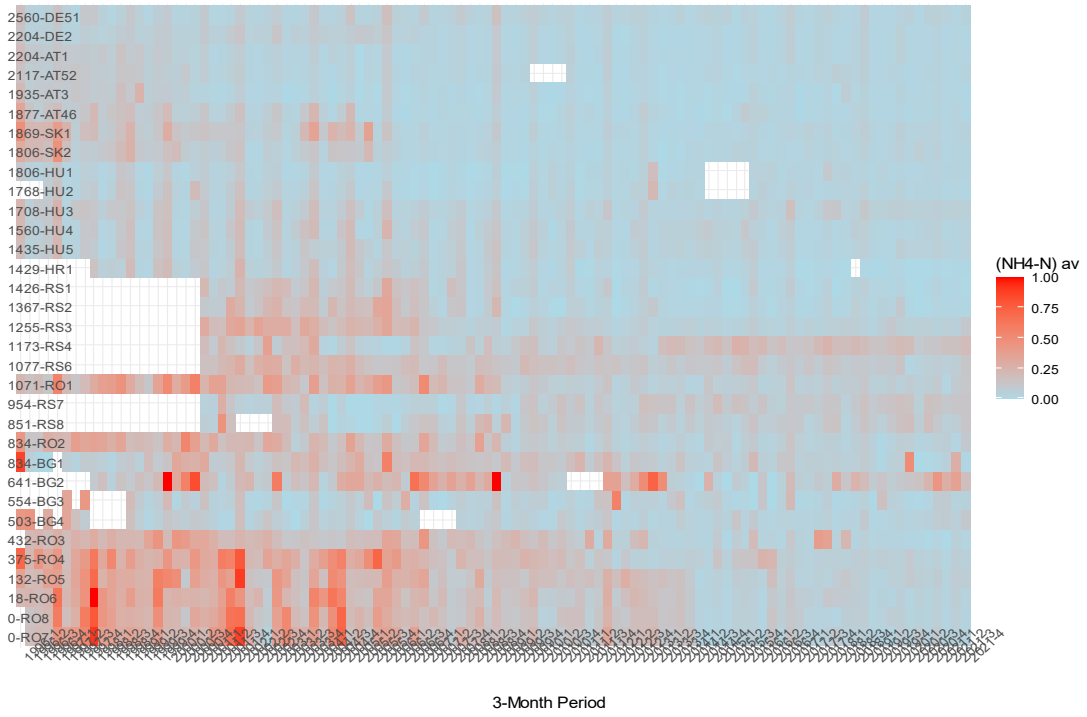


FIGURE SM_HM 7: HEATMAP SHOWING THE 3 MONTH AVERAGE CONCENTRATION OF **NH4-N** FROM 1996 TO 2021 IN MONITORING STATIONS ALONG THE DANUBE AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY AN IDENTIFIER CORRESPONDING TO THE COUNTRY IN WHICH IT IS LOCATED (REFER TO TABLE AM1).

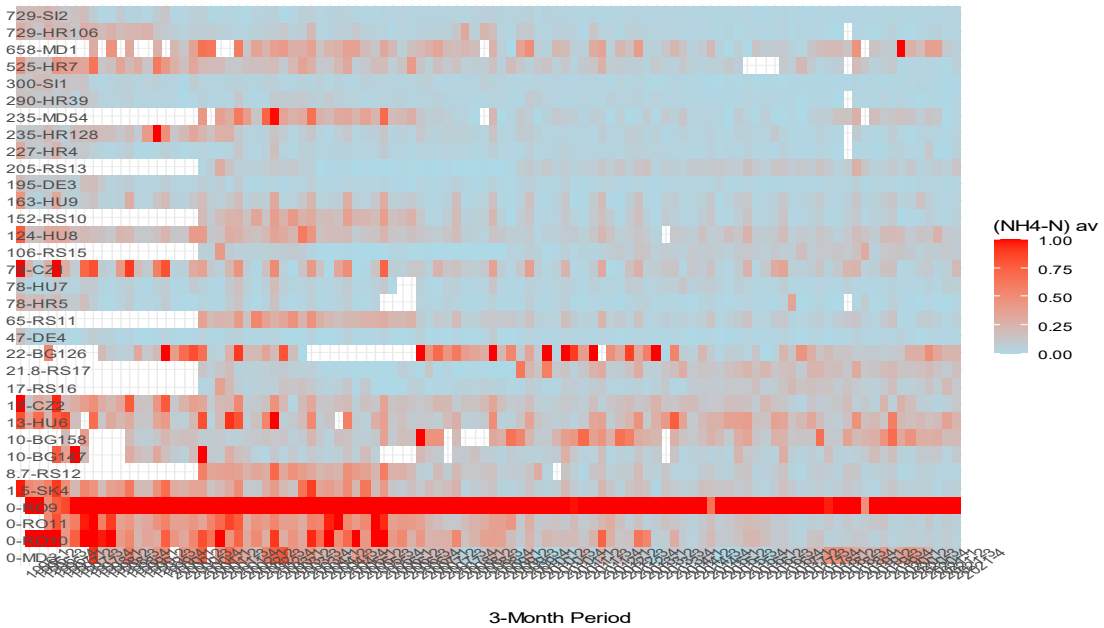


FIGURE SM_HM8: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **NH4-N** FROM 1996 TO 2021 IN MONITORING STATIONS LOCATED IN THE ***TRIBUTARIES*** OF THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL.

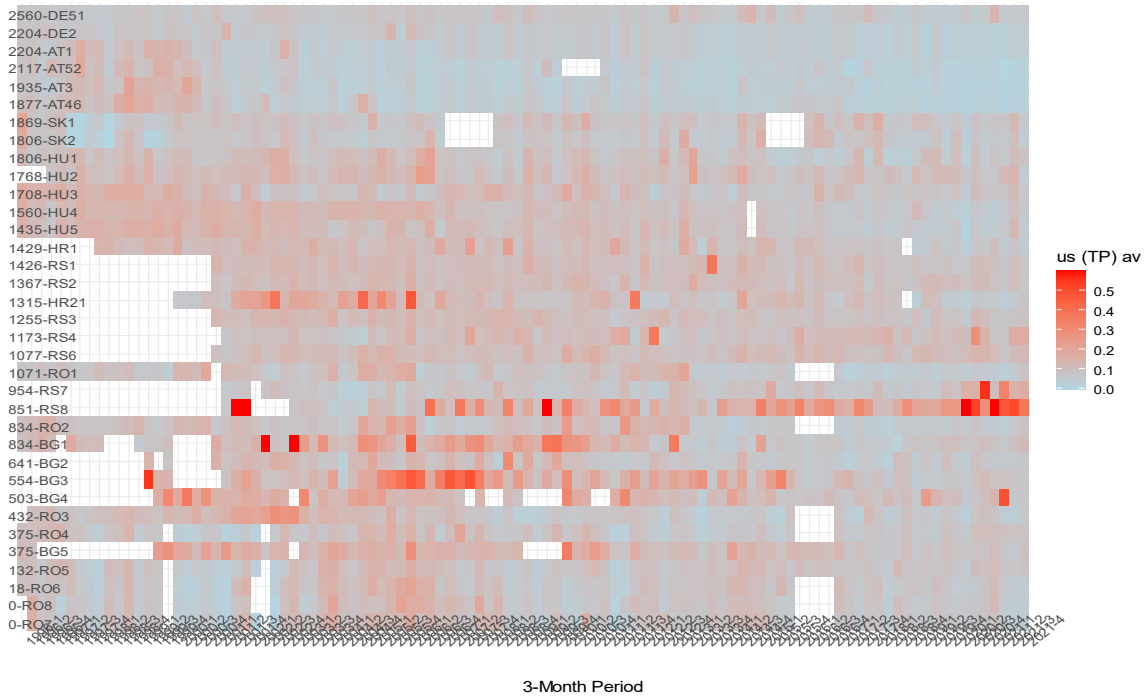


FIGURE SM_HM 9: HEATMAP SHOWING THE 3 MONTH AVERAGE CONCENTRATION OF **TP** FROM 1996 TO 2021 IN MONITORING STATIONS ALONG THE DANUBE AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY AN IDENTIFIER CORRESPONDING TO THE COUNTRY IN WHICH IT IS LOCATED (REFER TO TABLE AM1).

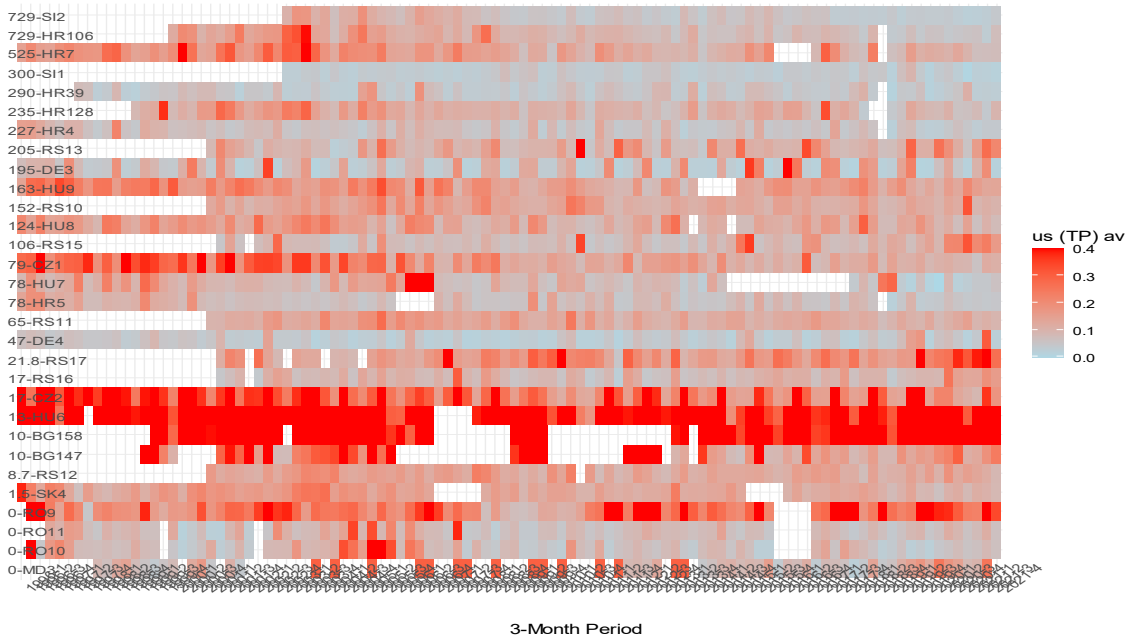


FIGURE SM_HM10: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **TP** FROM 1996 TO 2021 IN MONITORING STATIONS LOCATED IN THE ***TRIBUTARIES*** OF THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL.

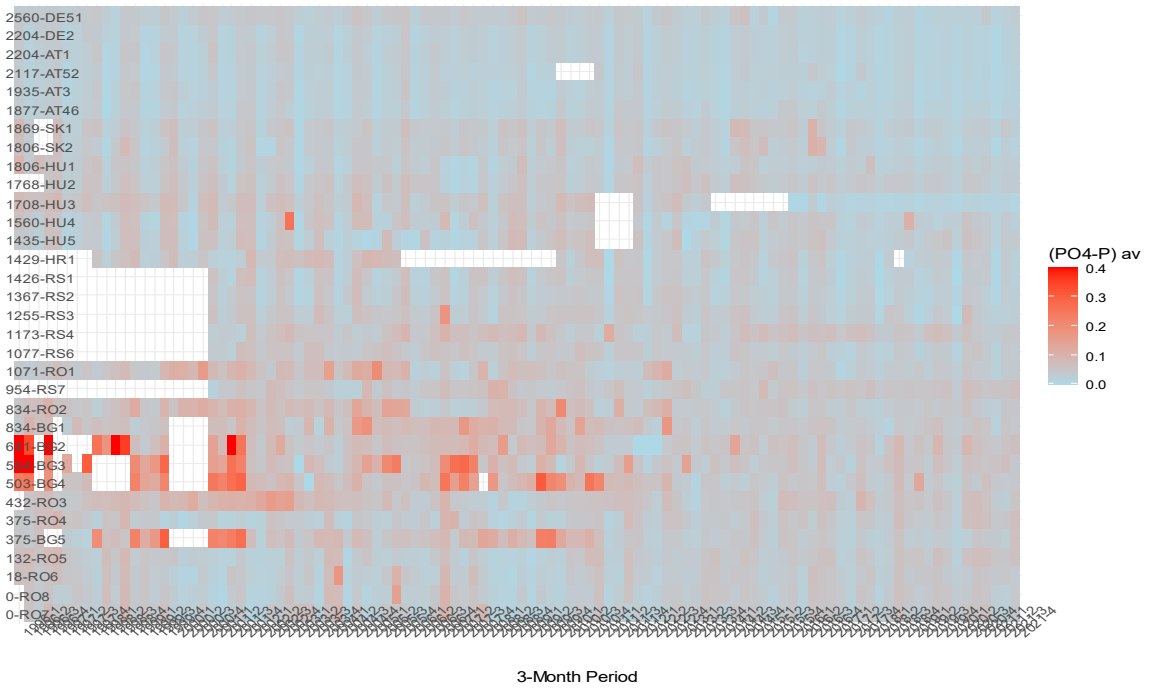


FIGURE SM_HM 11: HEATMAP SHOWING THE 3 MONTH AVERAGE CONCENTRATION OF **PO4-P** FROM 1996 TO 2021 IN MONITORING STATIONS ALONG THE DANUBE AFTER DATA PREPROCESS. EACH STATION IS IDENTIFIED BY A NUMBER INDICATING ITS KILOMETER POINT ALONG THE RIVER, FOLLOWED BY AN IDENTIFIER CORRESPONDING TO THE COUNTRY IN WHICH IT IS LOCATED (REFER TO TABLE AM1).

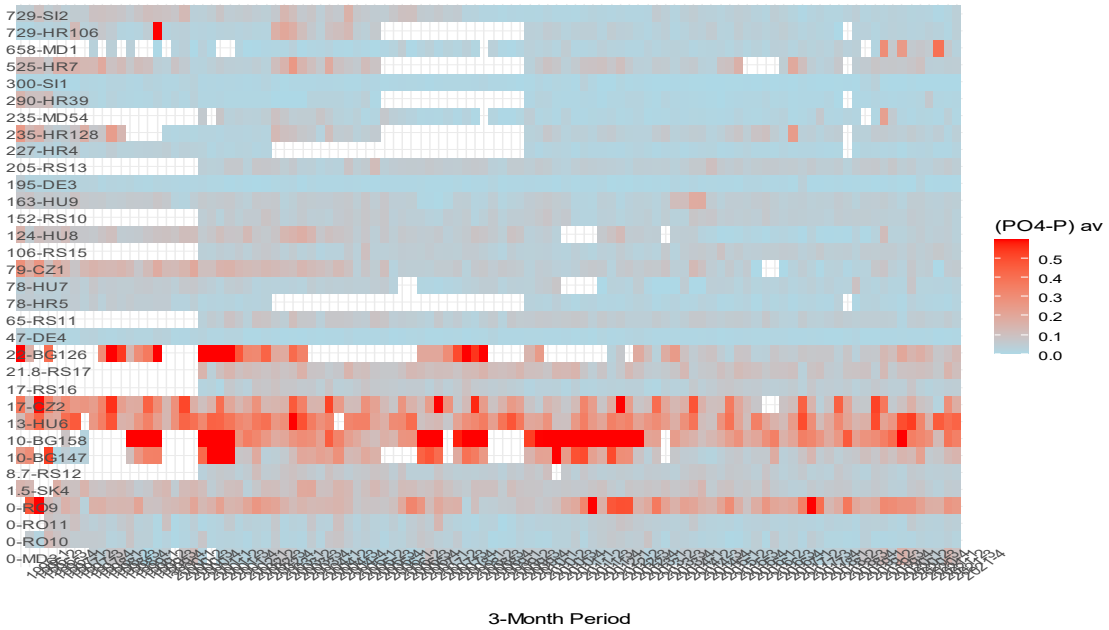


FIGURE SM_HM12: HEATMAP DEPICTING THE THREE-MONTH AVERAGE CONCENTRATION OF **PO4-P** FROM 1996 TO 2021 IN MONITORING STATIONS LOCATED IN THE ***TRIBUTARIES*** OF THE DANUBE RIVER, FOLLOWING DATA PREPROCESSING. FOR DETAILED INFORMATION ON THE LOCATIONS OF NUTRIENT MONITORING STATIONS IN THESE TRIBUTARIES, REFER TO TABLE SM_NS2 IN THE SUPPLEMENTARY MATERIAL

SM.6: WRTDS Model. Theoretical Formulation and Performance Assessment

The Weighted Regressions on Time, Discharge, and Season (WRTDS, Hirsch et al., 2010) method is particularly well-suited for analyzing discrete, long-term water quality monitoring datasets, such as those available for the Danube basin.
The core of WRTDS is a flexible regression model relating the natural logarithm of the nutrient concentration (ln(c)) to decimal time (t), the natural logarithm of daily mean discharge (ln(Q)), and seasonal cyclic components:

$$\ln(c) = \beta_0 + \beta_1 t + \beta_2 \ln(Q) + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t) + \epsilon \qquad \textit{eq 1}$$

where β_0-β_4 are locally estimated coefficients and ϵ represents the residual error. A key feature of WRTDS is that the coefficients β_0-β_4 are not fixed over the entire period of record but are estimated uniquely for each day for which an estimate is required. This estimation uses a weighted regression approach, where observations in the historical dataset are weighted based on their proximity in time, discharge magnitude, and season to the conditions of the specific day being estimated (Hirsch et al., 2010). This allows the model to adapt to potential changes in concentration-discharge relationships and seasonal patterns over time. The model generates daily estimates of concentration, which are then multiplied by the corresponding daily discharge to estimate daily load.

A crucial output for trend assessment is the flow-normalized (FN) concentration and flux. FN estimates are calculated by averaging the model predictions derived using the actual distribution of historical flows observed for each specific calendar day across the entire period of record (Hirsch & De Cicco, 2015). This procedure effectively removes the influence of year-to-year variations in discharge, providing a clearer measure of underlying changes in water quality potentially related to shifts in sources, management practices, or long-term climatic influences (Choquette et al., 2019).

In this study, WRTDS was applied to the time series of NO3-N, NH4-N, TN, TP, and PO4-P at stations with sufficient data coverage (see Section 2.2.1). Daily FN concentrations and FN fluxes were computed for the entire study period (1996-2021) and subsequently aggregated to annually to evaluate long-term trends and seasonal patterns. The statistical significance of trends was assessed using bootstrap methods (Hirsch et al., 2015). All WRTDS analyses were performed using the R statistical computing environment (R Core Team, 2014) and the EGRET package (Hirsch & De Cicco, 2015).
Quantitative assessment of the WRTDS model performance (Tables SM_Perf1 and SM_Perf2 in Supplementary Material) reveals distinct patterns depending on the constituent and river section. For Nitrate (NO3-N), the model generally captured the seasonal dynamics well, with concentration R^2 (R^2LogC) values typically ranging between 0.50 and 0.80 in the upper and middle Danube, though decreasing to 0.30–0.45 in the lower reaches. Flux estimates for nitrogen remained consistently robust (R^2LogF frequently > 0.80).

For Total Phosphorus (TP) and Ammonium, models showed lower explanatory power for daily concentrations, with R^2LogC values often below 0.40, particularly in the lower Danube and specific tributaries (e.g., Table SM_Perf2). This lower performance reflects the high stochasticity of particulate transport and point-source pulses that are not fully captured by discharge-based regressions. However, crucially for the objectives of this study, the flux estimates remained reliable, with R^2LogF values generally exceeding 0.70–0.80 across most stations. Furthermore, the WRTDS Flow-Normalization technique is specifically designed to handle such high-frequency noise, effectively filtering residual variability to extract the underlying multi-year trend signal (Hirsch et al., 2010; Chanat et al., 2016).

TABLE SM_PERF1: QUANTITATIVE PERFORMANCE EVALUATION OF WRTDS MODELS FOR MONITORING STATIONS ALONG THE DANUBE RIVER MAIN CHANNEL. THE TABLE PRESENTS THE COEFFICIENT OF DETERMINATION FOR THE NATURAL LOGARITHM OF CONCENTRATION (R^2LOGC) AND FLUX (R^2LOGF) FOR ALL ANALYZED NITROGEN (NO3-N, TN, NH4-N, NO2-N) AND PHOSPHORUS (TP, PO4-P) SPECIES. STATIONS ARE ORDERED GEOGRAPHICALLY FROM UPSTREAM (GERMANY) TO DOWNSTREAM (ROMANIA/UKRAINE). CELLS MARKED AS 'NA' INDICATE STATIONS WHERE INSUFFICIENT DATA PREVENTED VALID MODEL CALIBRATION FOR THAT SPECIFIC CONSTITUENT

	NO3		TN		NH4		NO2		TP		PO4	
Stations	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F
2560-DE51	0.57	0.92	--	--	0.57	0.78	0.35	0.86	0.51	0.90	0.49	0.83
2204-AT1	0.77	0.82	--	--	0.54	0.61	0.59	0.72	0.45	0.76	0.43	0.61
2204-DE2	0.77	0.81	--	--	0.49	0.62	0.62	0.75	0.45	0.78	0.42	0.60
2117-AT52	0.76	0.82	--	--	0.50	0.59	0.42	0.62	0.49	0.71	0.36	0.53
1935-AT3	0.75	0.83	--	--	0.51	0.60	0.58	0.72	0.51	0.72	0.34	0.51
1877-AT46	0.76	0.85	--	--	0.51	0.60	0.54	0.64	0.49	0.71	0.36	0.52
1869-SK1	0.79	0.87	0.79	0.90	0.60	0.66	0.63	0.72	0.34	0.78	0.37	0.62
1806-SK2	0.80	0.88	0.78	0.90	0.59	0.68	0.60	0.71	0.22	0.72	0.30	0.58
1806-HU1	0.77	0.88	--	--	0.52	0.66	0.62	0.72	0.37	0.78	0.41	0.63
1768-HU2	0.77	0.87	--	--	0.51	0.60	0.62	0.74	0.36	0.79	0.41	0.60
1708-HU3	0.71	0.83	--	--	0.42	0.48	0.57	0.71	0.25	0.53	0.56	0.66
1560-HU4	0.75	0.83	--	--	0.52	0.50	0.52	0.62	0.46	0.78	0.45	0.55
1435-HU5	0.53	0.66	--	--	0.46	0.47	0.54	0.68	0.45	0.76	0.41	0.53
1426-RS1	0.66	077	0.62	0.76	0.46	0.51	--	--	--	--	--	--
1367-RS2	0.74	0.80			0.53	0.54	0.45	0.64	0.20	0.79	0.51	0.61
1300-HRRS	0.76	0.80	0.59	0.77	--	--	0.47	0.58	--	--	--	--
1255-RS3	0.80	0.85	--	--	0.63	0.68	0.53	0.74	0.29	0.81	0.32	0.50
1173-RS4	--	--	0.40	0.69	0.14	0.15	0.04	0.20	0.07	0.49	0.06	0.37
1077-RS6	0.69	0.84	0.48	0.78	0.35	0.54	0.34	0.62	0.05	0.72	0.32	0.54
1071-RO1	0.33	0.61			0.52	0.57	0.31	0.56	0.19	0.44	0.24	0.42
954-RS7	0.14	0.35	0.15	0.55	0.04	0.23	0.00	0.13	0.01	0.41	0.00	0.43
851-RS8	0.14	0.33	0.08	0.46	-0.01	0.16	0.07	0.20	0.16	0.30	--	--
834-RO2	0.32	0.67	--	--	0.54	0.62	0.27	0.59	0.18	0.42	0.22	0.41
641-BG2	0.25	0.35	--	--	-0.03	0.09	0.33	0.64	0.18	0.50	0.28	0.47
554-BG3	0.19	0.51	--	--	0.14	0.22	-0.02	0.33	0.23	0.46	0.31	0.44
503-BG4	0.41	0.65	--	--	0.42	0.45	0.24	0.49	0.14	0.44	0.32	0.42

432-RO3	0.29	0.55	--	--	0.52	0.59	0.21	0.43	0.51	0.65	0.34	0.51
375-RO4	0.52	0.72	0.54	0.80	0.45	0.51	0.19	0.45	0.11	0.40	0.20	0.36
375-BG5	0.57	0.78	--	--	--	--	0.27	0.51	0.31	0.64	0.32	0.45
132-RO5	0.56	0.76	0.57	0.83	0.38	0.49	0.22	0.46	0.10	0.48	0.23	0.37
18-RO6	0.45	0.66	0.55	0.81	0.38	0.45	0.11	0.39	0.09	0.45	0.04	0.25
0-RO8	0.54	0.73	0.52	0.77	0.47	0.54	0.14	0.36	0.04	0.40	0.03	0.19
0-RO7	0.54	0.71	0.50	0.77	0.47	0.53	0.23	0.39	0.07	0.43	0.07	0.25

TABLE SM_PERF3: QUANTITATIVE PERFORMANCE EVALUATION OF WRTDS MODELS FOR MONITORING STATIONS ALONG THE MAJOR TRIBUTARIES OF THE DANUBE RIVER. THE TABLE PRESENTS THE COEFFICIENT OF DETERMINATION FOR THE NATURAL LOGARITHM OF CONCENTRATION (R2LOGC) AND FLUX (R2LOGF) FOR ALL ANALYZED NITROGEN (NO3-N, TN, NH4-N, NO2-N) AND PHOSPHORUS (TP, PO4-P) SPECIES. STATIONS ARE ORDERED GEOGRAPHICALLY FROM UPSTREAM (GERMANY) TO DOWNSTREAM (ROMANIA/UKRAINE). CELLS MARKED AS 'NA' INDICATE STATIONS WHERE INSUFFICIENT DATA PREVENTED VALID MODEL CALIBRATION FOR THAT SPECIFIC CONSTITUENT

	NO3		TN		NH4		NO2		TP		PO4	
Stations	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F	R^2C	R^2F
729-SI2	0.46	0.95	0.42	0.95	0.36	0.71	0.30	0.75	0.49	0.75	0.48	0.63
729-HR106	0.40	0.87	0.35	0.92	0.35	0.62	0.50	0.75	0.29	0.66	0.17	0.36
525-HR7	0.25	0.84	0.34	0.89	0.38	0.47	0.38	0.49	0.41	0.59	0.31	0.32
235-HR128	0.37	0.83	0.32	0.89	0.41	0.55	0.19	0.61	0.12	0.59	0.16	0.40
205-RS13	0.13	0.65	0.06	0.70	0.17	0.43	0.44	0.67	-0.04	0.51	0.00	0.58
106-RS15	0.16	0.68	0.07	0.74	0.24	0.46	0.42	0.69	0.05	0.60	0.02	0.61
17-RS16	0.17	0.58	0.12	0.74	0.16	0.30	0.11	0.52	0.07	0.62	0.09	0.54
300-SI1	0.56	0.82	0.33	0.68	0.36	0.60	0.35	0.76	0.10	0.59	0.28	0.64
290-HR39	0.46	0.71	0.21	0.25	0.20	0.44	0.39	0.66	0.06	0.57	0.25	0.57
227-HR4	0.53	0.74	0.59	0.85	0.30	0.36	0.38	0.60	0.17	0.63	0.34	0.62
78-HR5	0.65	0.76	0.59	0.79	0.40	0.31	0.48	0.50	0.19	0.57	0.43	0.62
78-HU7	0.74	0.83	0.50	0.74	0.40	0.39	0.49	0.64	0.15	0.53	0.19	0.54
21.8-RS17	0.21	0.65	0.16	0.80	0.27	0.48	0.51	0.66	0.08	0.60	0.02	0.63
1.5-SK4	0.76	0.89	0.53	0.82	0.64	0.66	0.33	0.56	0.30	0.62	0.41	0.61
163-HU9	0.66	0.88	0.50	0.88	0.56	0.60	0.32	0.72	0.38	0.85	0.20	0.63
152-RS10	0.59	0.84	0.55	0.87	0.46	0.58	0.13	0.74	0.15	0.83	0.18	0.66
65-RS11	0.54	0.83	0.48	0.87	0.48	0.59	0.16	0.70	0.17	0.83	0.20	0.63
8.7-RS12	0.54	0.85	0.38	0.86	0.54	0.68	0.20	0.74	0.09	0.85	0.28	0.75
195-DE3	0.46	0.69	--	--	0.49	0.60	--	--	0.55	0.80	0.41	0.67
47-DE4	0.72	0.92			0.21	0.45	0.22	0.68	0.44	0.78	0.49	0.62
124-HU8	0.29	0.98	0.18	0.97	0.36	0.86	0.29	0.95	0.24	0.94	0.43	0.90
79-CZ1	0.65	0.90	--	--	0.62	0.78	0.38	0.88	0.47	0.86	0.48	0.79
17-CZ2	0.81	0.86	--	--	0.38	0.50	0.38	0.71	0.65	0.79	0.71	0.78
658-MD1	0.31	0.73	--	--	0.17	0.65	0.00	0.69	--	--	0.21	0.71
0-RO11	0.49	0.68	0.47	0.78	0.48	0.63	0.21	0.57	0.03	0.48	0.03	0.34
0-MD3	0.49	0.65	--	--	0.21	0.45	0.33	0.65	0.28	0.44	--	--
0-RO10	0.43	0.97	0.50	0.98	0.56	0.90	0.20	0.89	-0.01	0.84	-0.1	0.83
13-HU6	0.31	0.87	0.37	0.89	0.37	0.69	--	--	0.29	0.89	0.33	0.39
0-RO9	0.39	0.46	--	--	0.09	0.14	--	--	0.12	0.12	0.27	0.79

SM.7 Flow-Normalized NO3-N Fluxes and Concentrations in Danube Tributaries

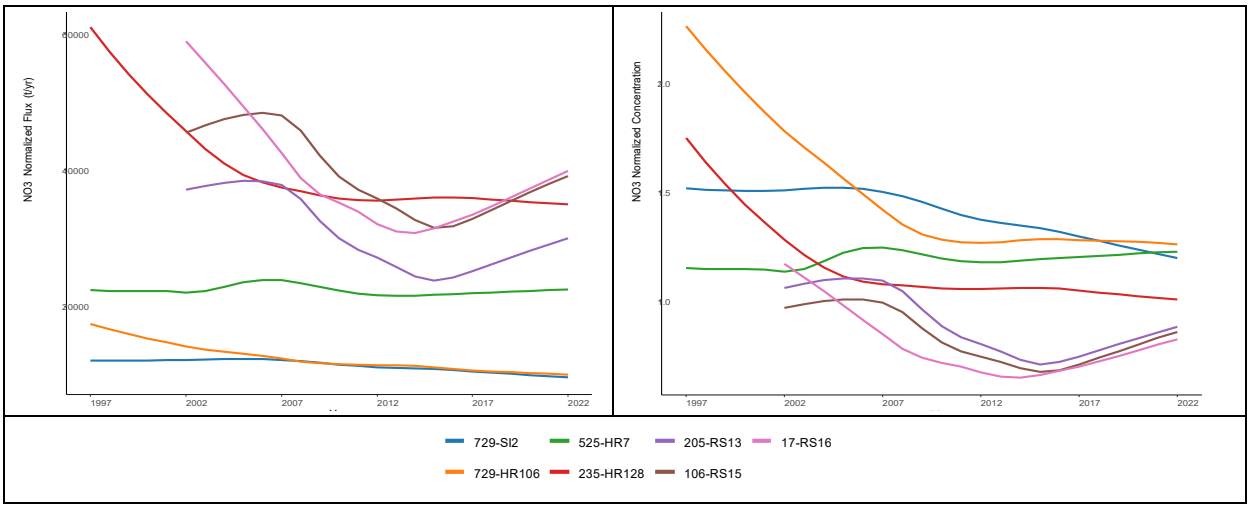


FIGURE SM_FN 1: TEMPORAL EVOLUTION OF NORMALIZED **NO3-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **SAVA** RIVER FROM 1996 TO 2021.

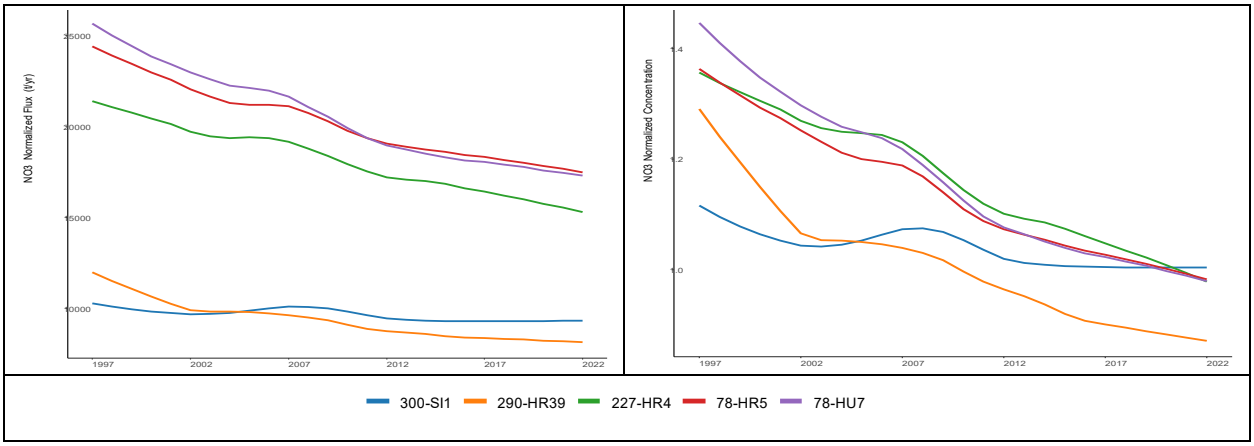


FIGURE SM_FN 2: TEMPORAL EVOLUTION OF NORMALIZED **NO3-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **DRAVA** RIVER FROM 1996 TO 2021.

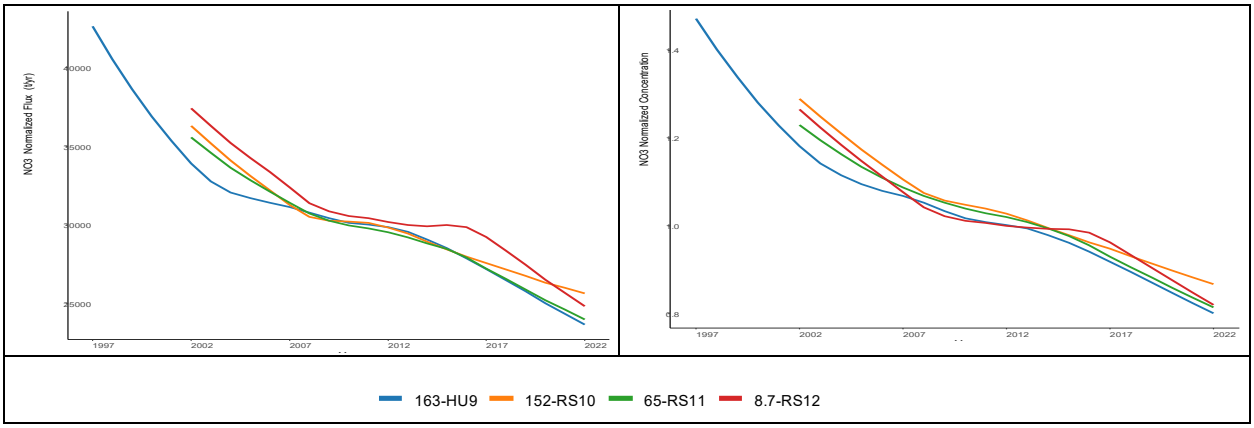


FIGURE SM_FN 3: TEMPORAL EVOLUTION OF NORMALIZED **NO3-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **TISZA** RIVER FROM 1996 TO 2021.

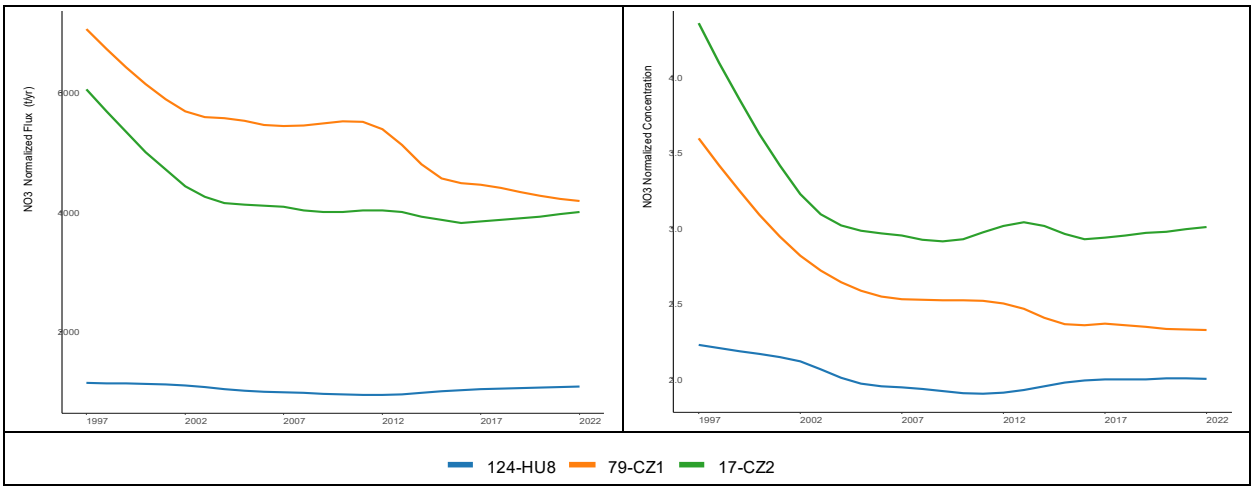


FIGURE SM_FN 4: TEMPORAL EVOLUTION OF NORMALIZED **NO3-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **MORAVA** RIVER FROM 1996 TO 2021.

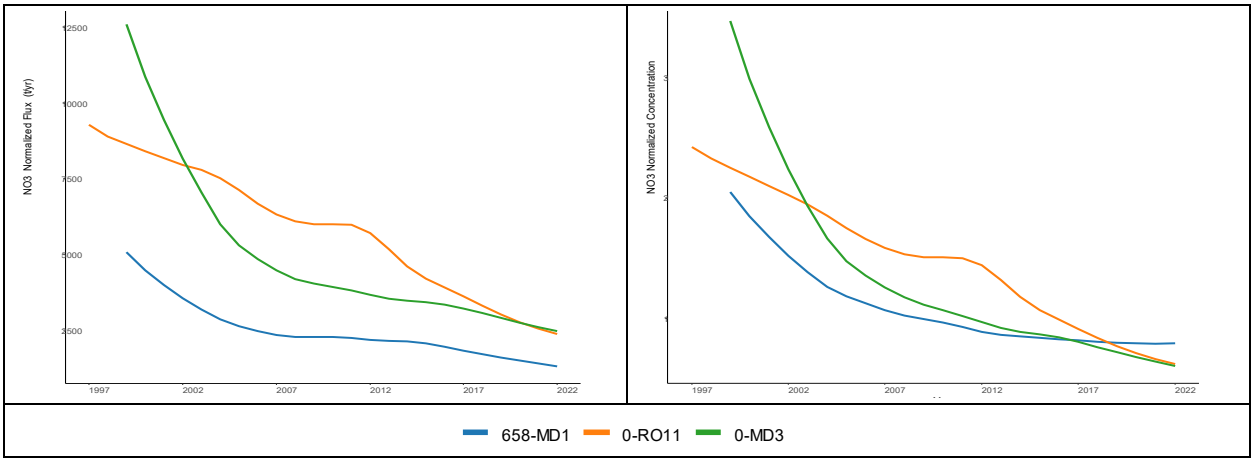


FIGURE SM_FN 5: TEMPORAL EVOLUTION OF NORMALIZED **NO3-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **PRUT** RIVER FROM 1996 TO 2021.

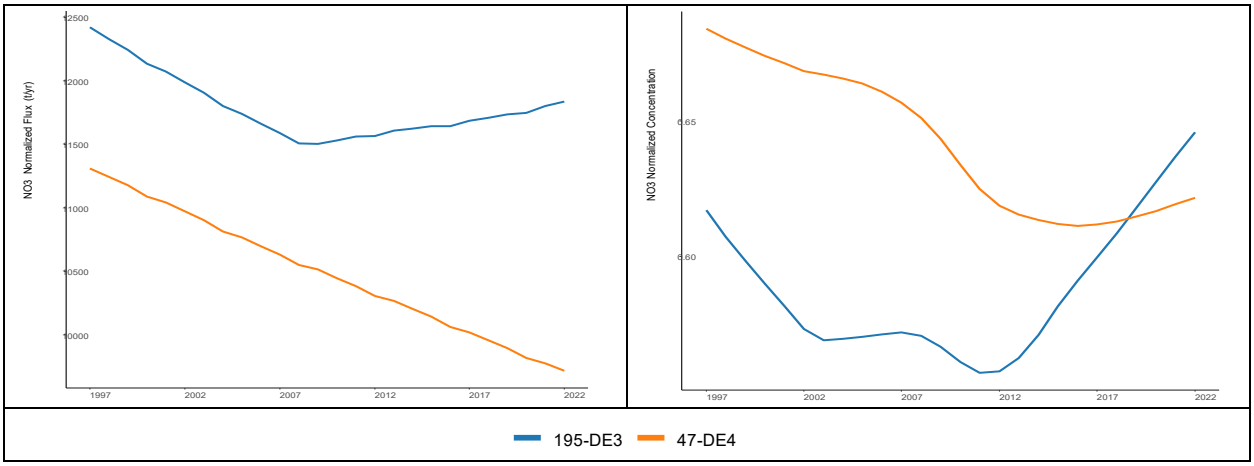


FIGURE SM_FN 6: TEMPORAL EVOLUTION OF NORMALIZED **NO3-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **INN** RIVER FROM 1996 TO 2021.

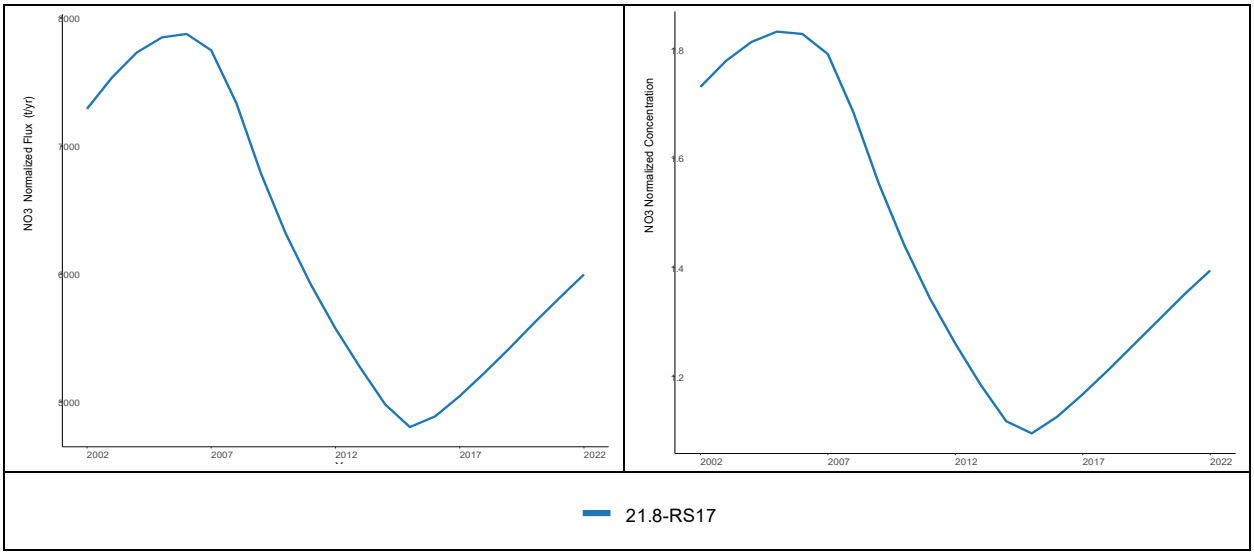


FIGURE SM_FN 7: TEMPORAL EVOLUTION OF NORMALIZED **NO3-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS AT THE **LJUBICEWSKI** STATION ON THE **VELIKA** MORAVA RIVER FROM 1996 TO 2021.

SM.8 Flow-Normalized NH4-N Fluxes and Concentrations in Danube Tributaries

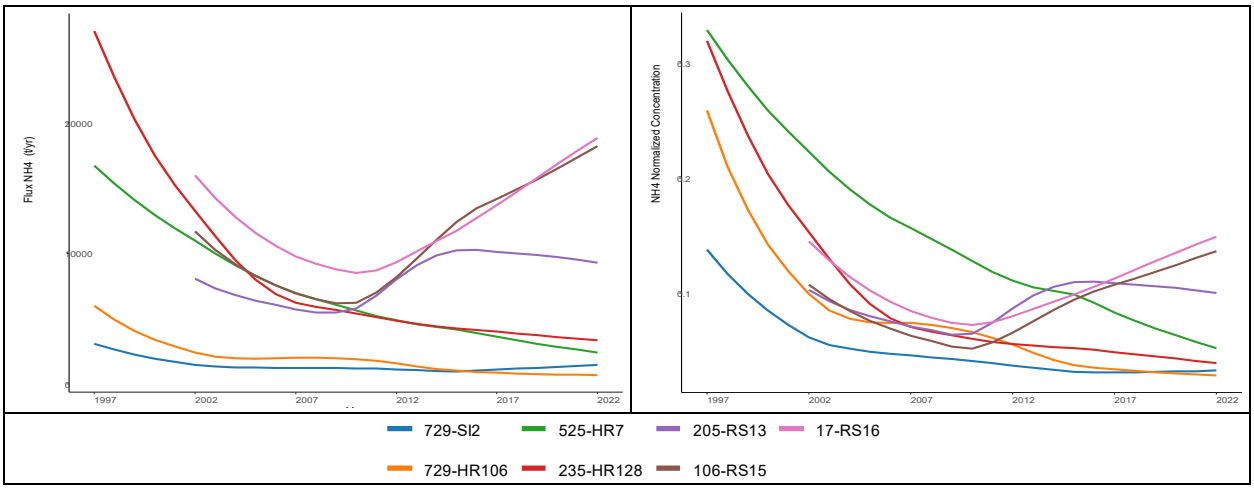


FIGURE SM_FN 8: TEMPORAL EVOLUTION OF NORMALIZED **NH4-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **SAVA** RIVER FROM 1996 TO 2021.

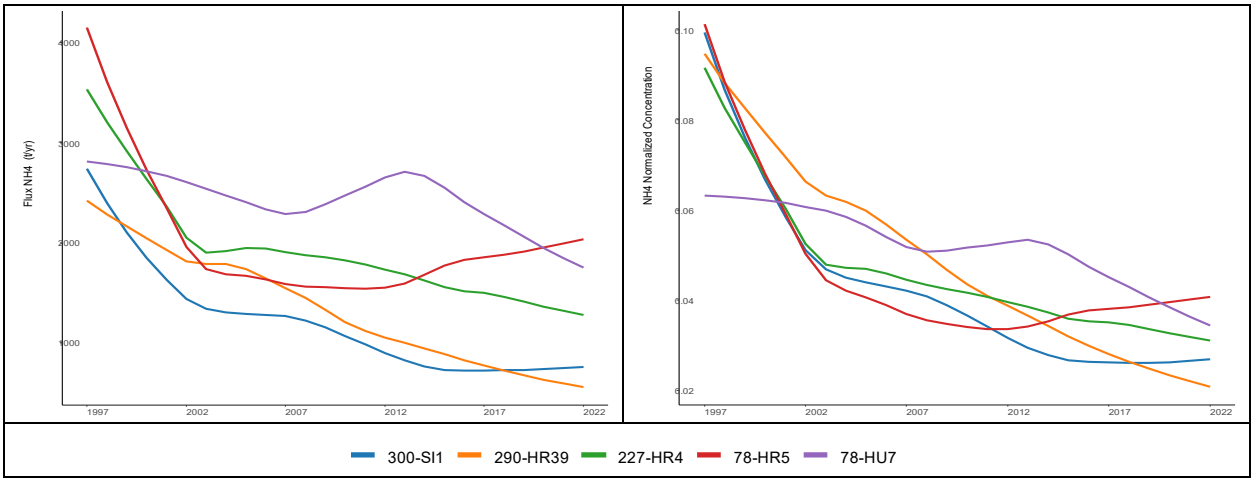


FIGURE SM_FN 9: TEMPORAL EVOLUTION OF NORMALIZED **NH4-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **DRAVA** RIVER FROM 1996 TO 2021.

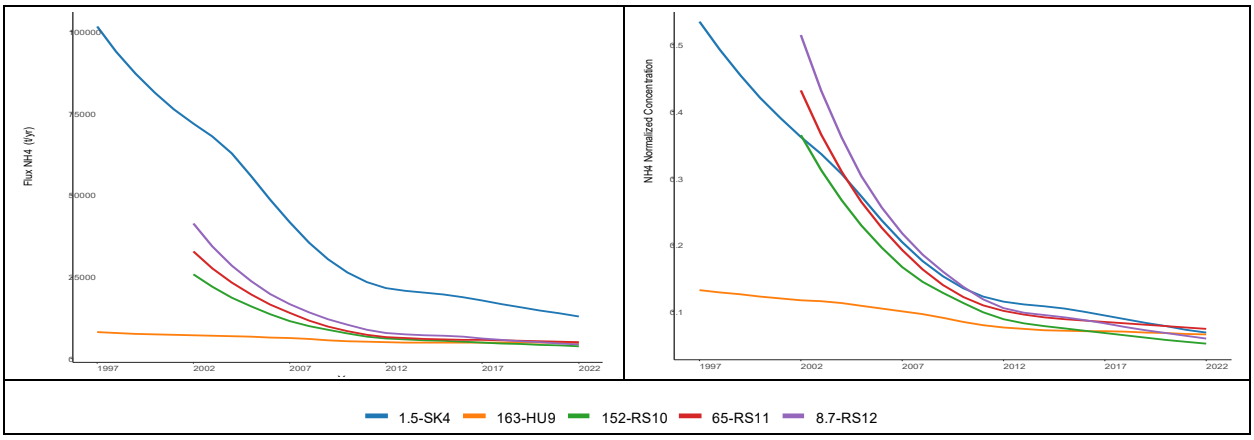


FIGURE SM_FN 10: TEMPORAL EVOLUTION OF NORMALIZED **NH4-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **TISZA** RIVER FROM 1996 TO 2021.

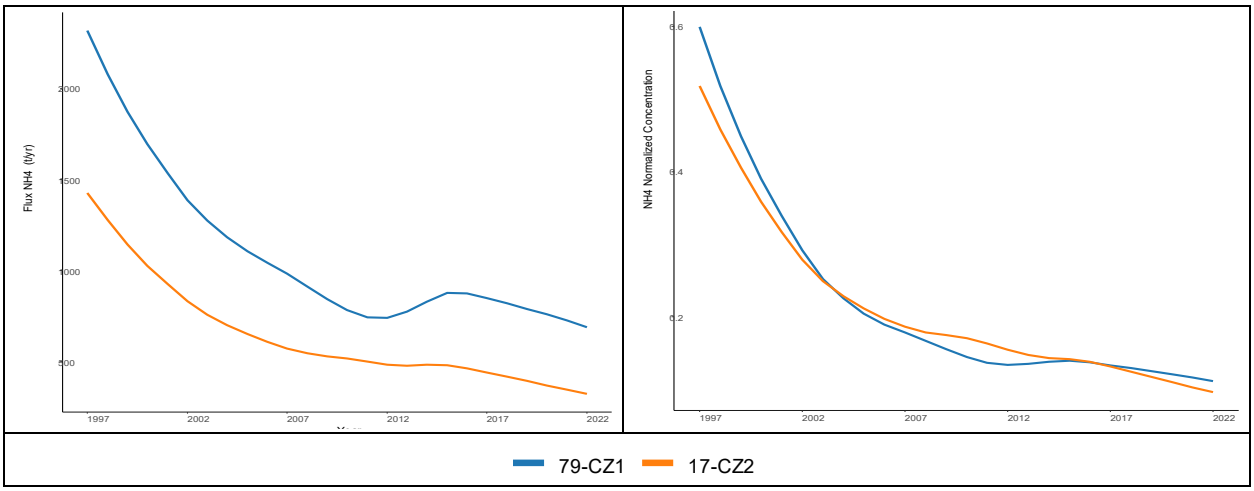


FIGURE SM_FN 11: TEMPORAL EVOLUTION OF NORMALIZED **NH4-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **MORAVA** RIVER FROM 1996 TO 2021.

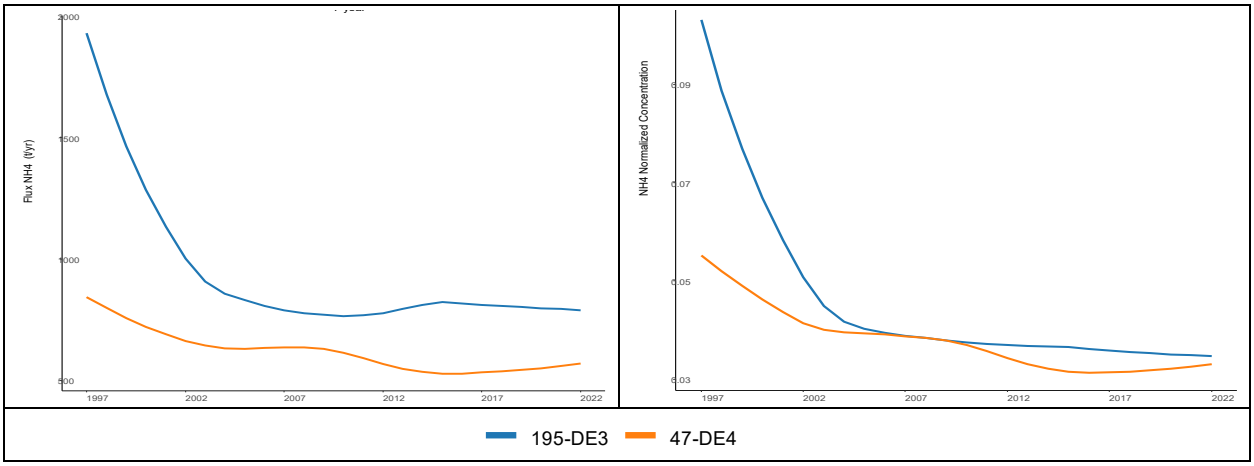


FIGURE SM_FN 12: TEMPORAL EVOLUTION OF NORMALIZED **NH4-N** FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **INN** RIVER FROM 1996 TO 2021.

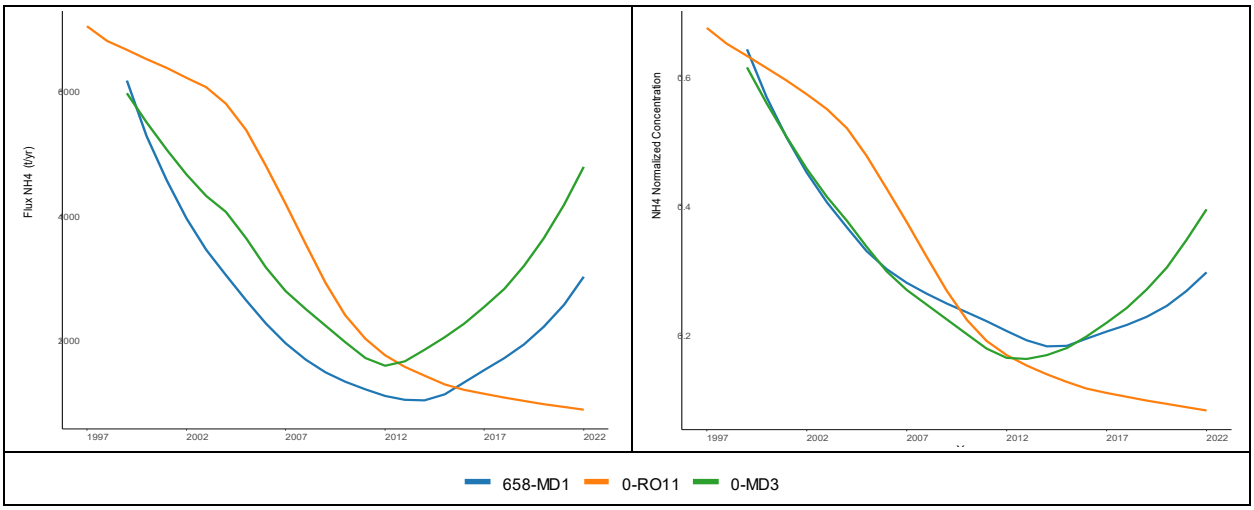


FIGURE SM_FN 13: TEMPORAL EVOLUTION OF NORMALIZED NH4-N FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **PRUT** RIVER FROM 1996 TO 2021.

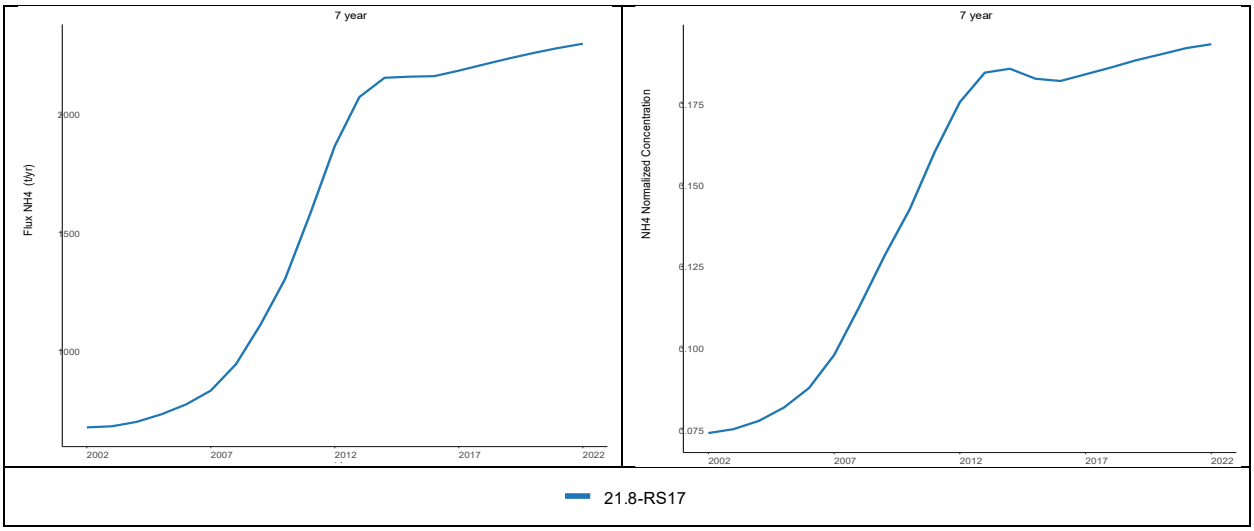


FIGURE SM_FN 14: TEMPORAL EVOLUTION OF NORMALIZED NH4-N FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **LJUBICEWSKI** STATION ON THE **VELIKA MORAVA** RIVER FROM 1996 TO 2021.

SM.9 Flow-Normalized TP Fluxes and Concentrations in Danube Tributaries

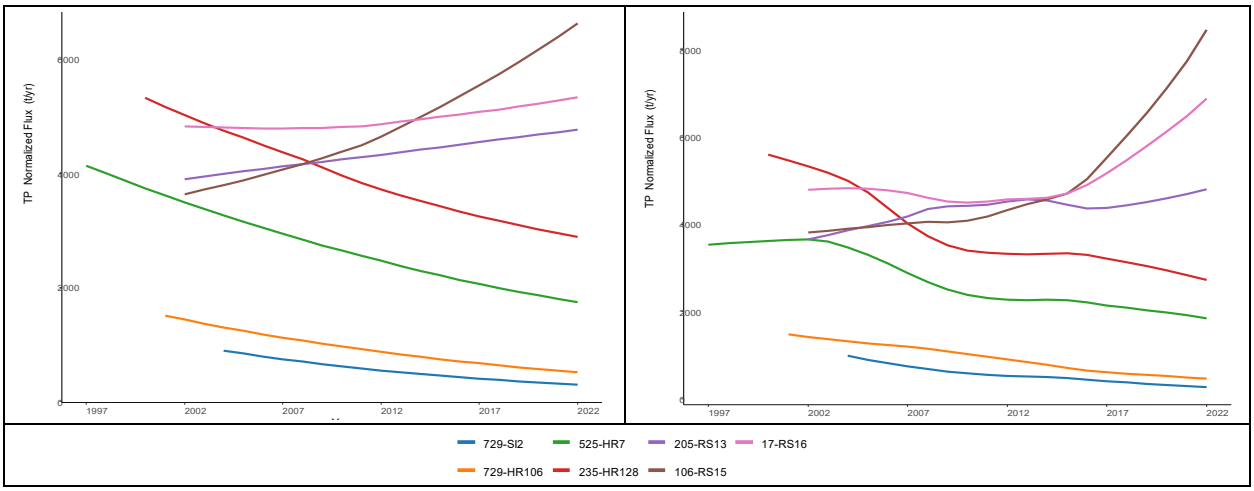


FIGURE SM_FN 15: TEMPORAL EVOLUTION OF NORMALIZED TP FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **SAVA** RIVER FROM 1996 TO 2021.

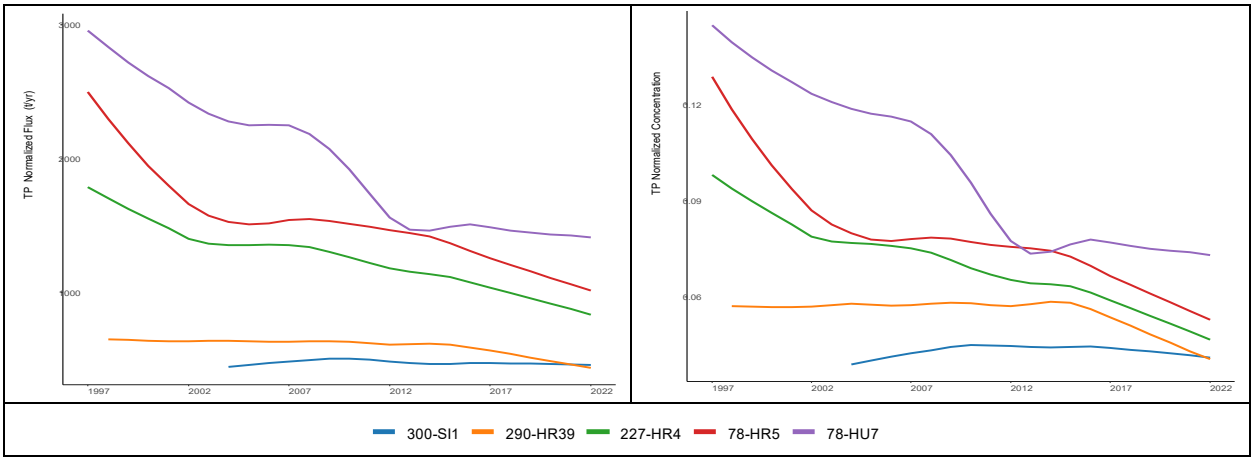


FIGURE SM_FN 16: TEMPORAL EVOLUTION OF NORMALIZED TP FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **DRAVA** RIVER FROM 1996 TO 2021.

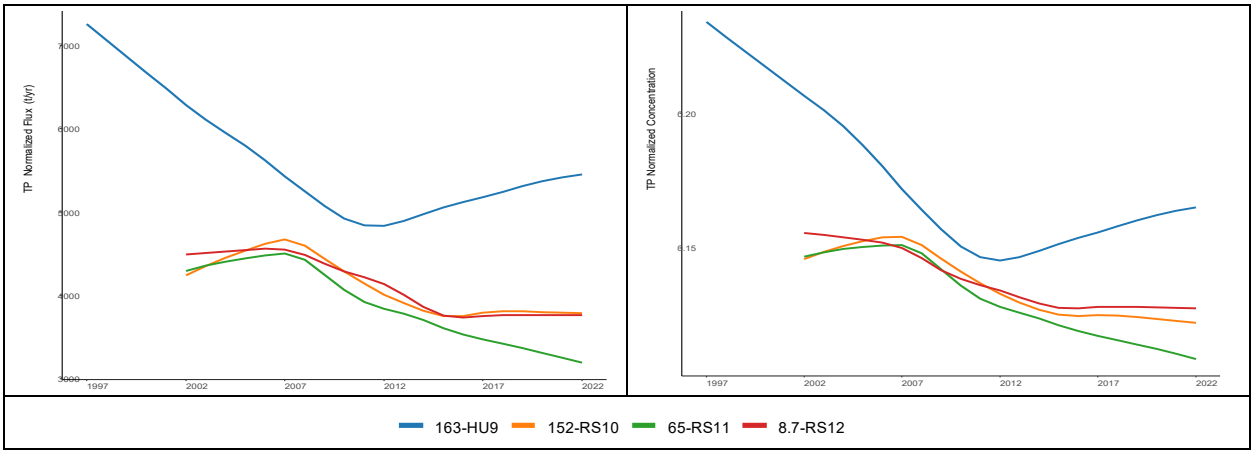


FIGURE SM_FN 17: TEMPORAL EVOLUTION OF NORMALIZED TP FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **TISZA** RIVER FROM 1996 TO 2021.

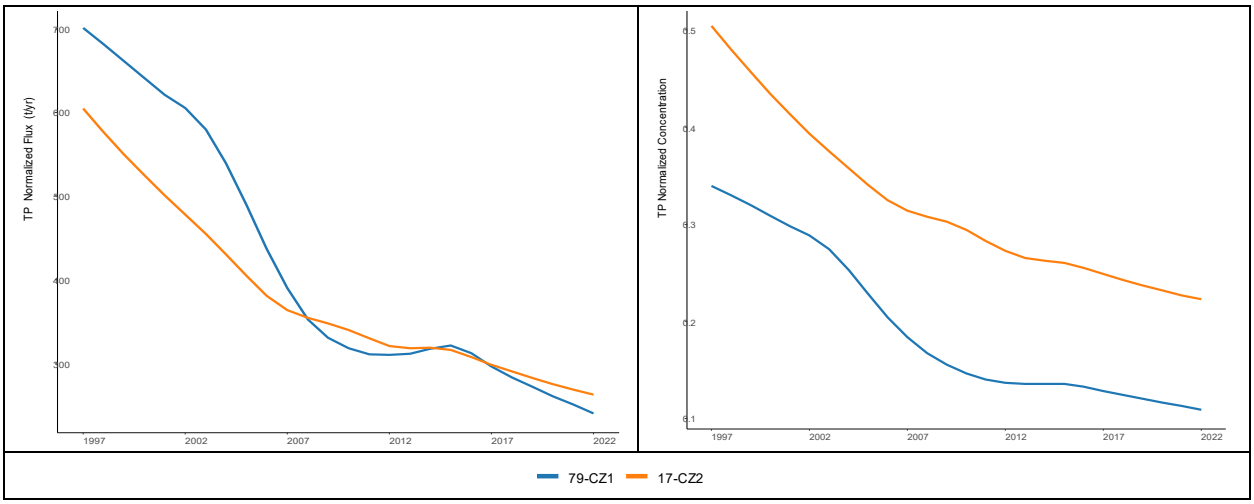


FIGURE SM_FN 18: TEMPORAL EVOLUTION OF NORMALIZED TP FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **MORAVA** RIVER FROM 1996 TO 2021.

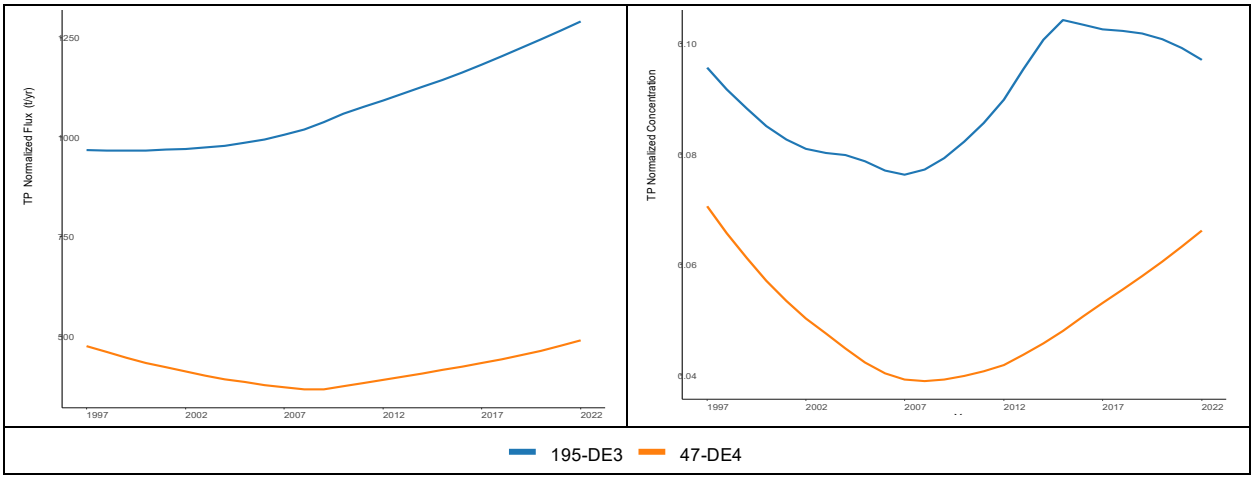


FIGURE SM_FN 19: TEMPORAL EVOLUTION OF NORMALIZED TP FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **INN** RIVER FROM 1996 TO 2021.

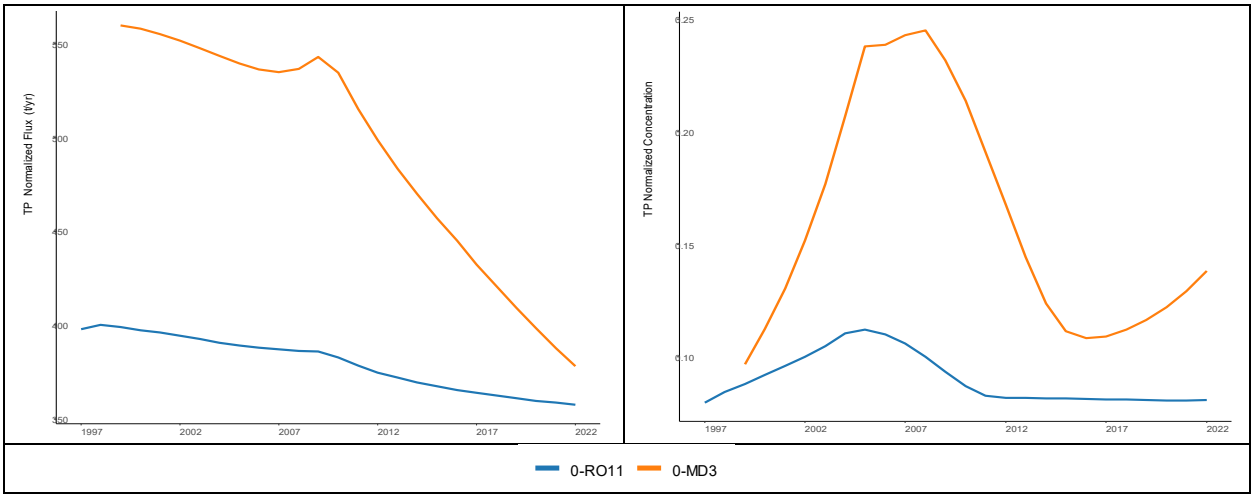


FIGURE SM_FN 20: TEMPORAL EVOLUTION OF NORMALIZED TP FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG THE **PRUT** RIVER FROM 1996 TO 2021.

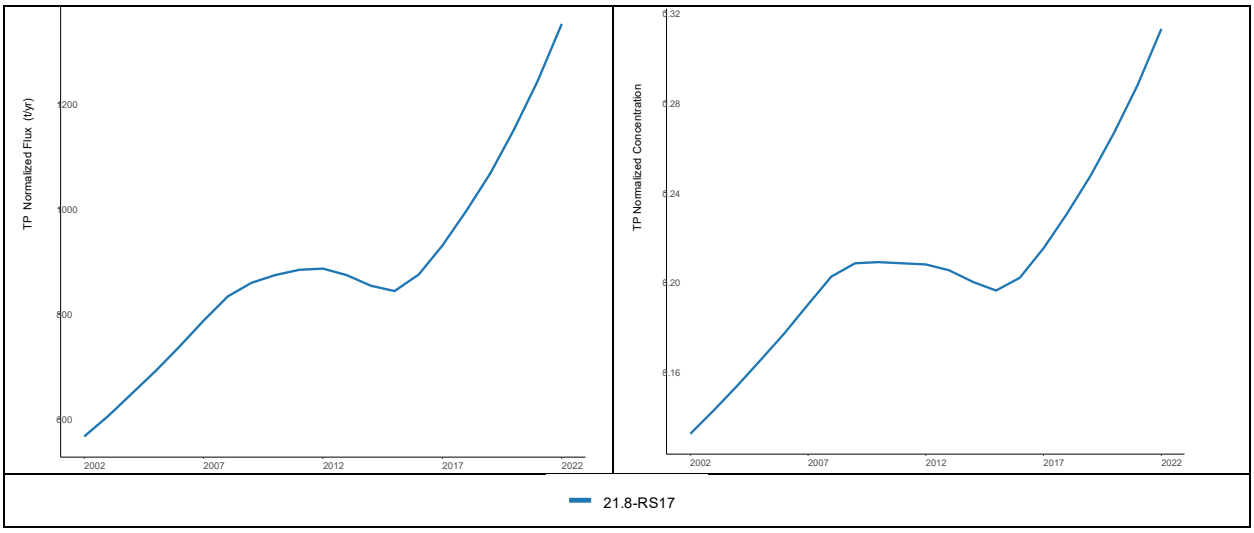


FIGURE SM_FN 21: TEMPORAL EVOLUTION OF NORMALIZED TP FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR SELECTED REPRESENTATIVE STATIONS ALONG **THE LJUBICEWSKI STATION** ON THE **VELIKA MORAVA RIVER** FROM 1996 TO 2021.

SM.10 Flow-Normalized PO4-P Fluxes and Concentrations in Danube

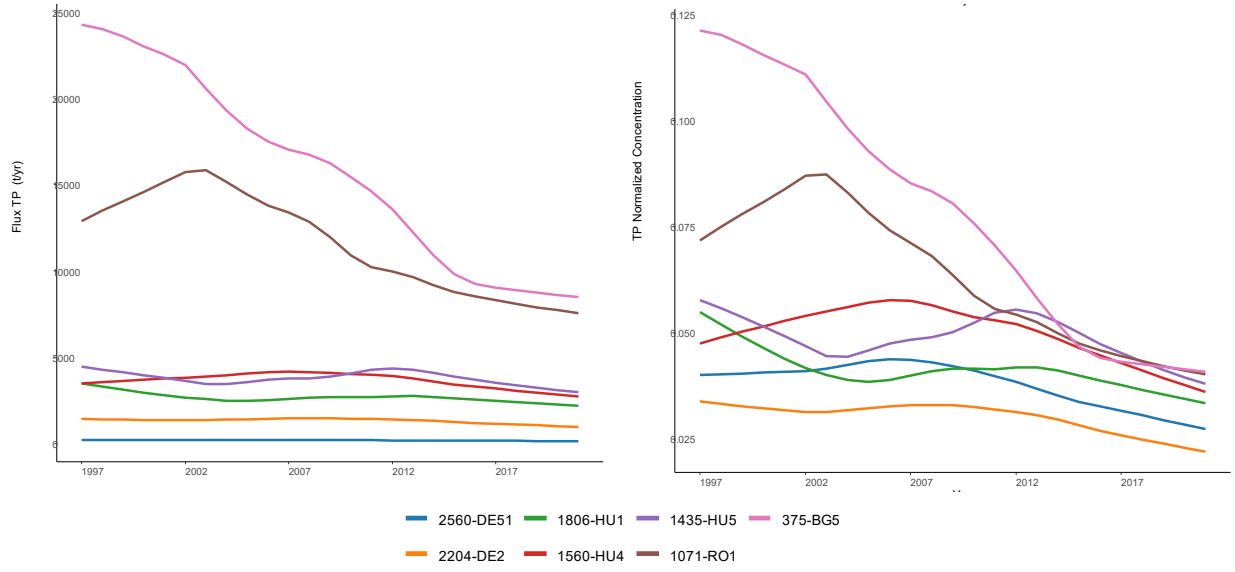


FIGURE SM-PO4: TEMPORAL EVOLUTION OF FLOW-NORMALIZED PO4-P FLUXES (LEFT) AND CONCENTRATIONS (RIGHT) FOR VARIOUS STATIONS ALONG THE DANUBE RIVER FROM 1997 TO 2023.

SM.11 TN & TP monthly average Concentrations

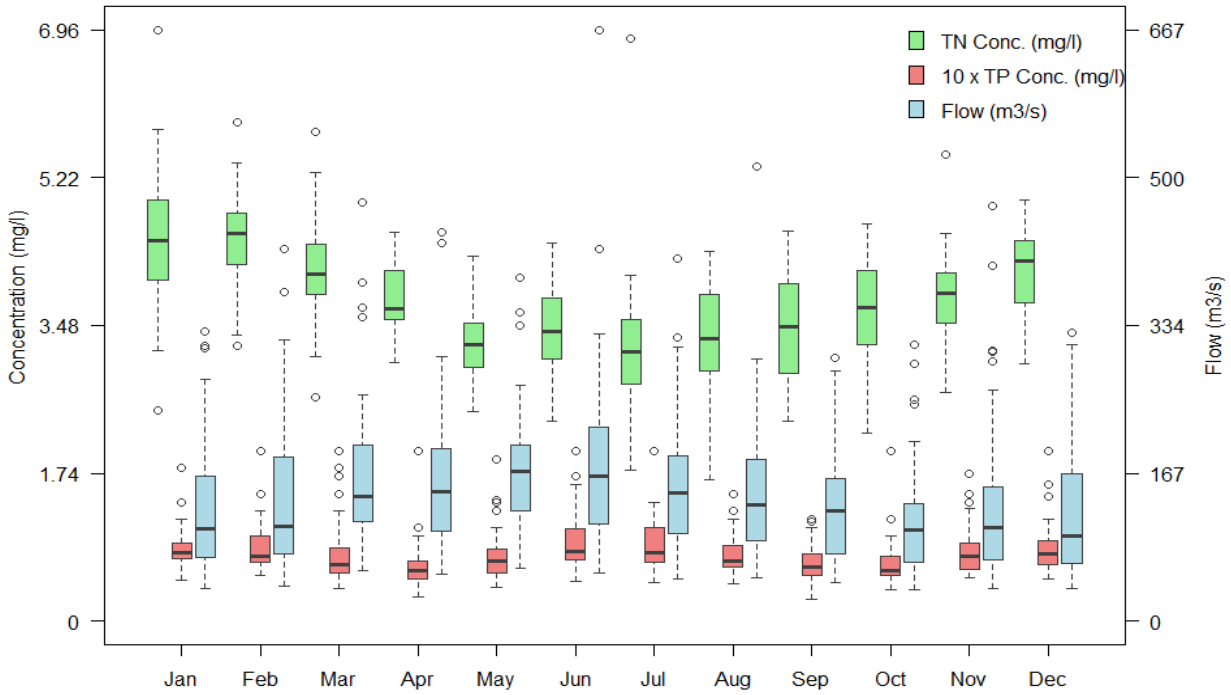


FIGURE SM_TN&TP1: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN) DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED), AND RIVER DISCHARGE (BLUE) AT STATION 2560-DE51 FOR THE PERIOD 1996-2021

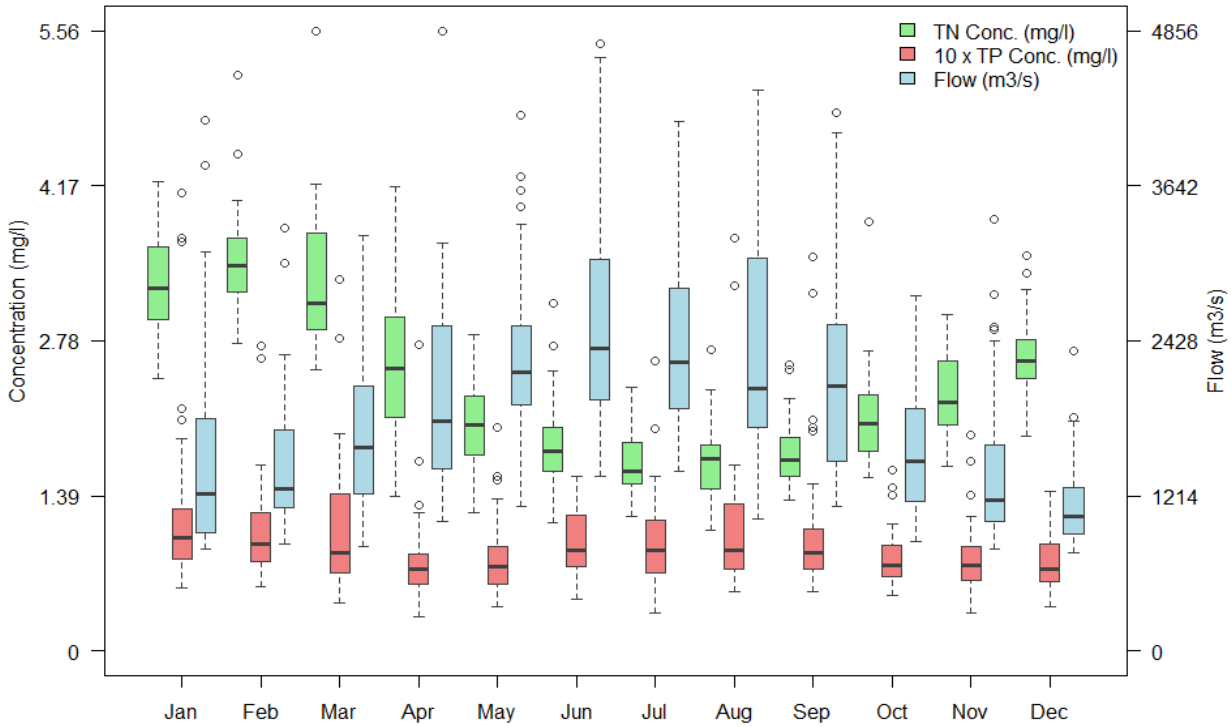


FIGURE SM_TN&TP2: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN), TP CONCENTRATIONS MULTIPLIED BY 10 (RED), AND RIVER DISCHARGE (BLUE) AT STATION 1869SK1 FOR THE PERIOD 1996-2021

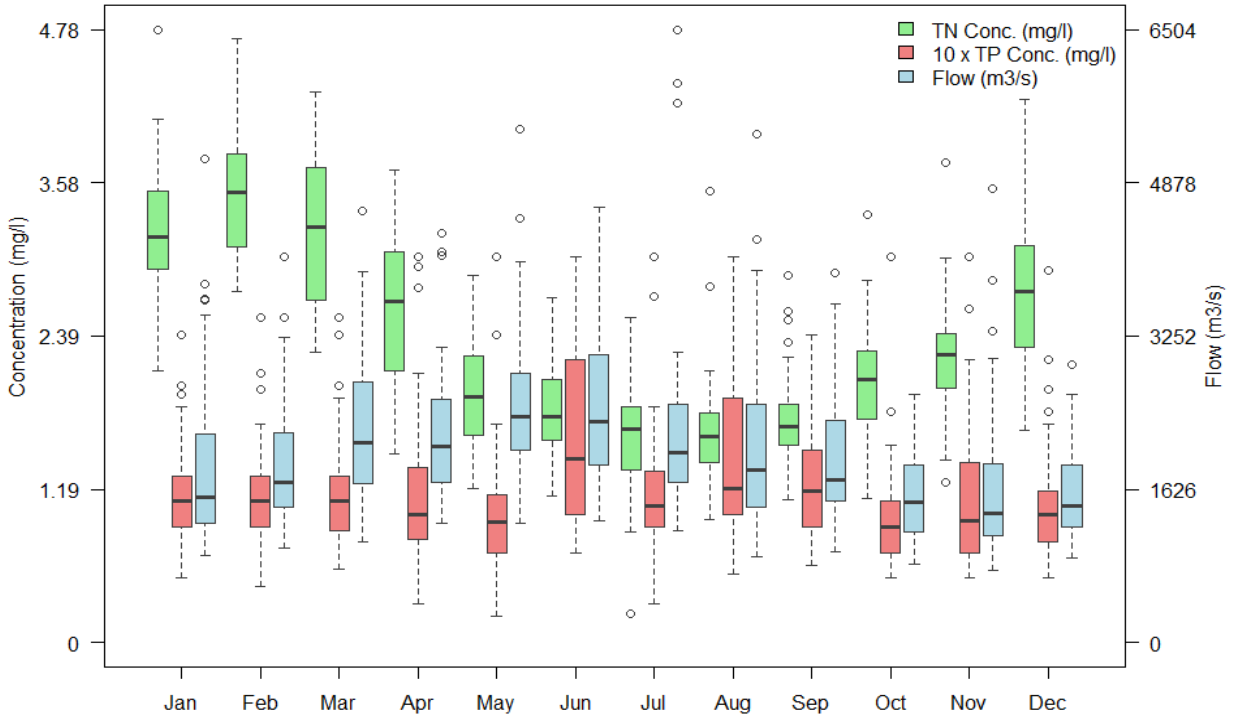


FIGURE SM_TN&TP3: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN) DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED) AND RIVER DISCHARGE (BLUE) AT STATION 1768-HU2 (KOMAROM) FOR THE PERIOD 1996-2021

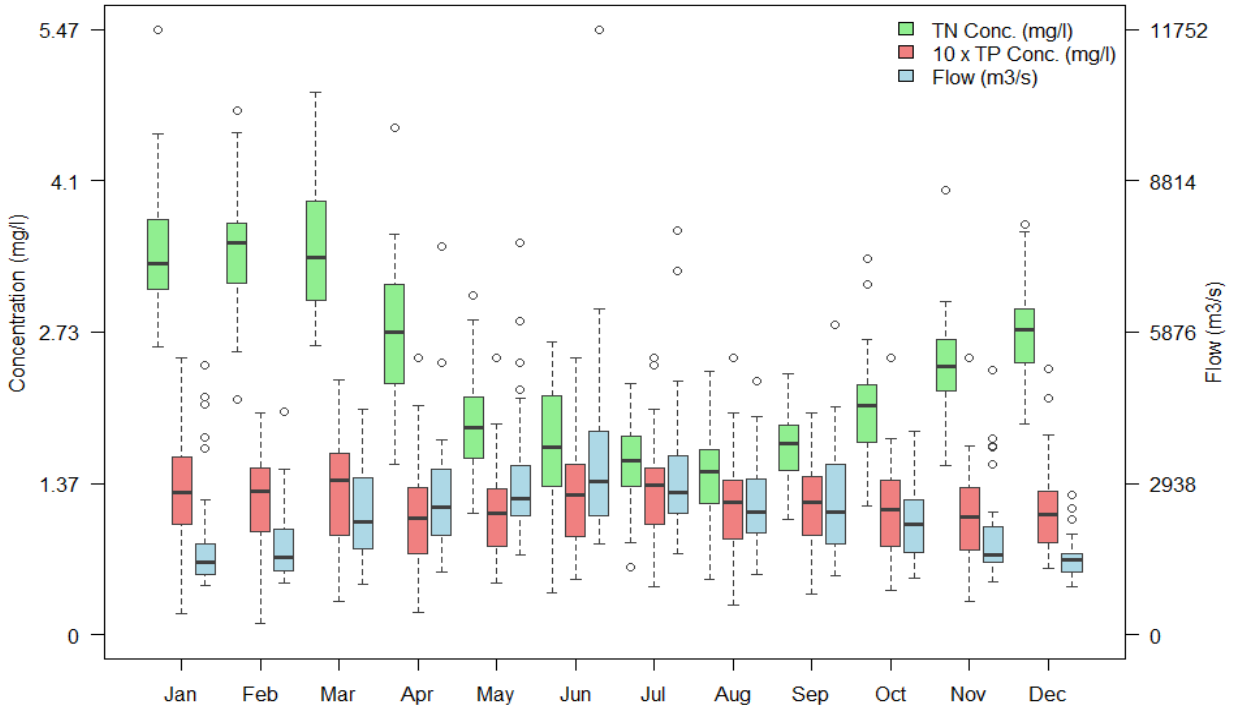


FIGURE SM_TN&TP4: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN) DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED), AND RIVER DISCHARGE (BLUE) AT STATION 1560 (DUNAFOLDDVAR) FOR THE PERIOD 1996-2021

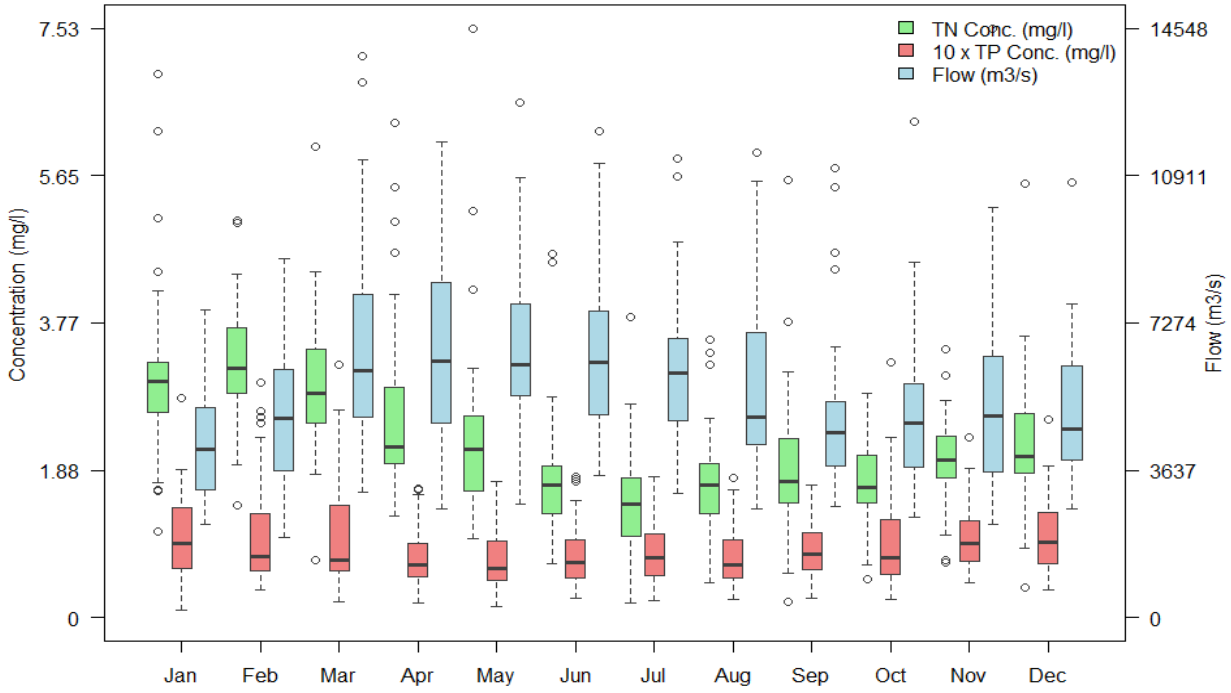


FIGURE SM_TN&TP5: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN), DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED), AND RIVER DISCHARGE (BLUE) AT STATION 1071(BAZIAS) FOR THE PERIOD 1996-2021

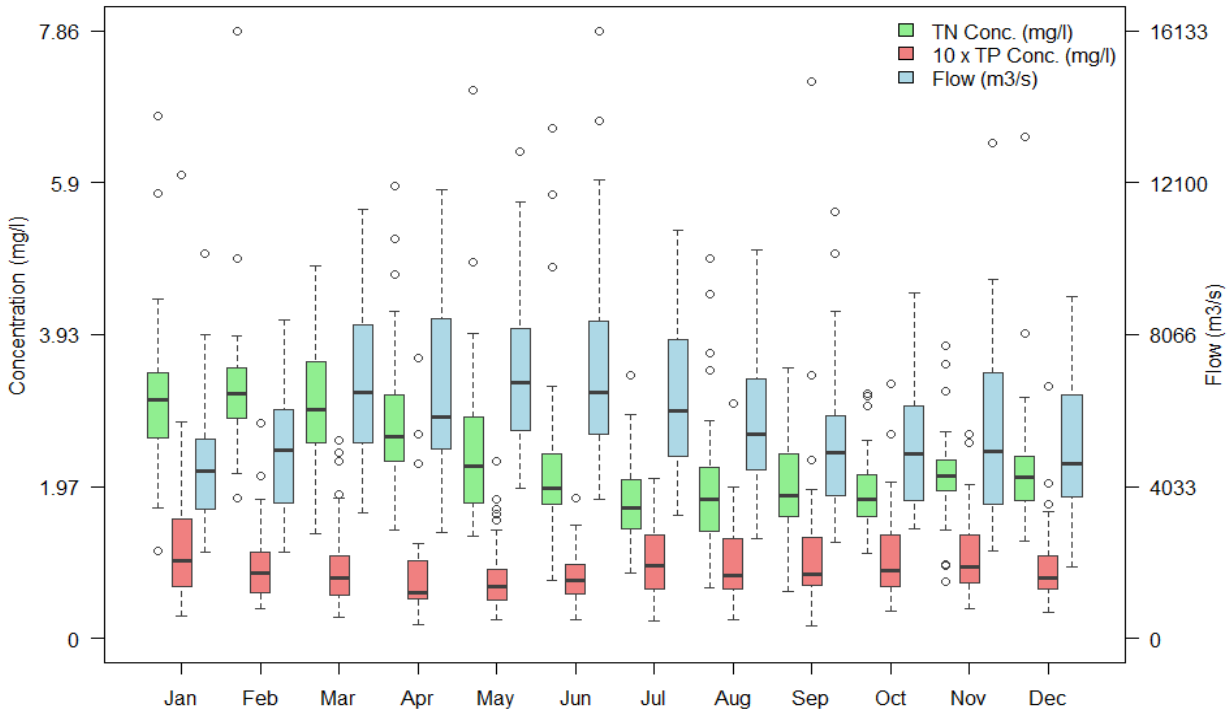


FIGURE SM_TN&TP6: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN), DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED), AND RIVER DISCHARGE (BLUE) AT STATION 834 (PRISTOL) FOR THE PERIOD 1996-2021

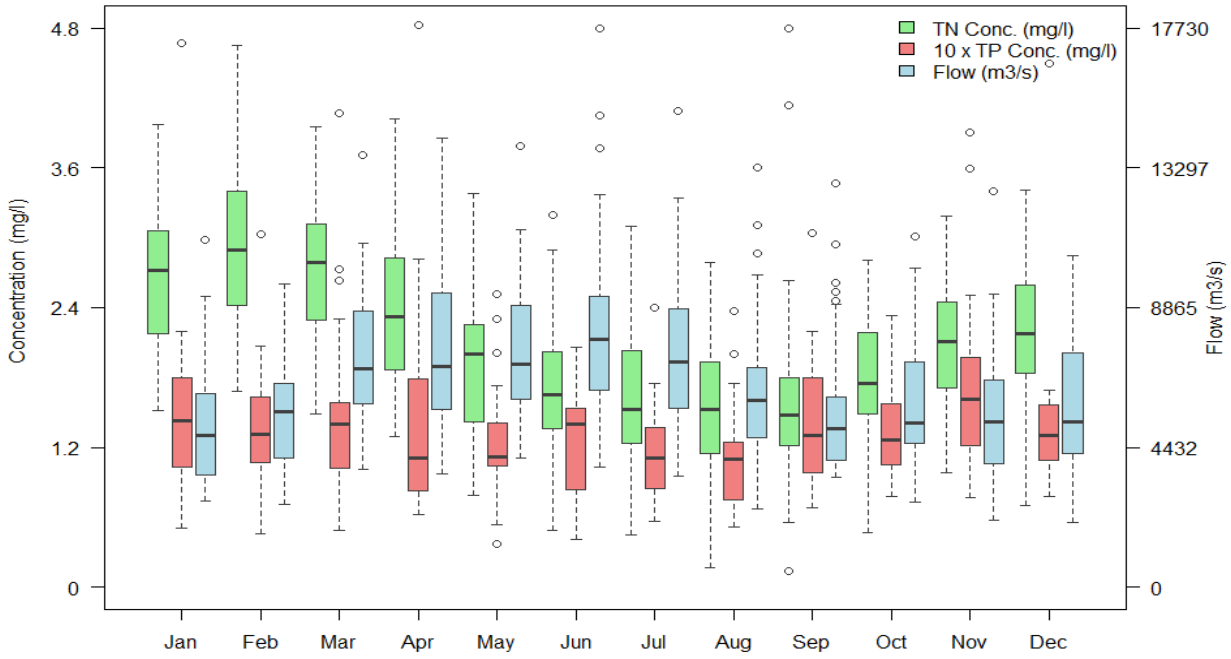


FIGURE SM_TN&TP7: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN) DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED), AND RIVER DISCHARGE (BLUE) AT STATION 375BG5 FOR THE PERIOD 1996-2021

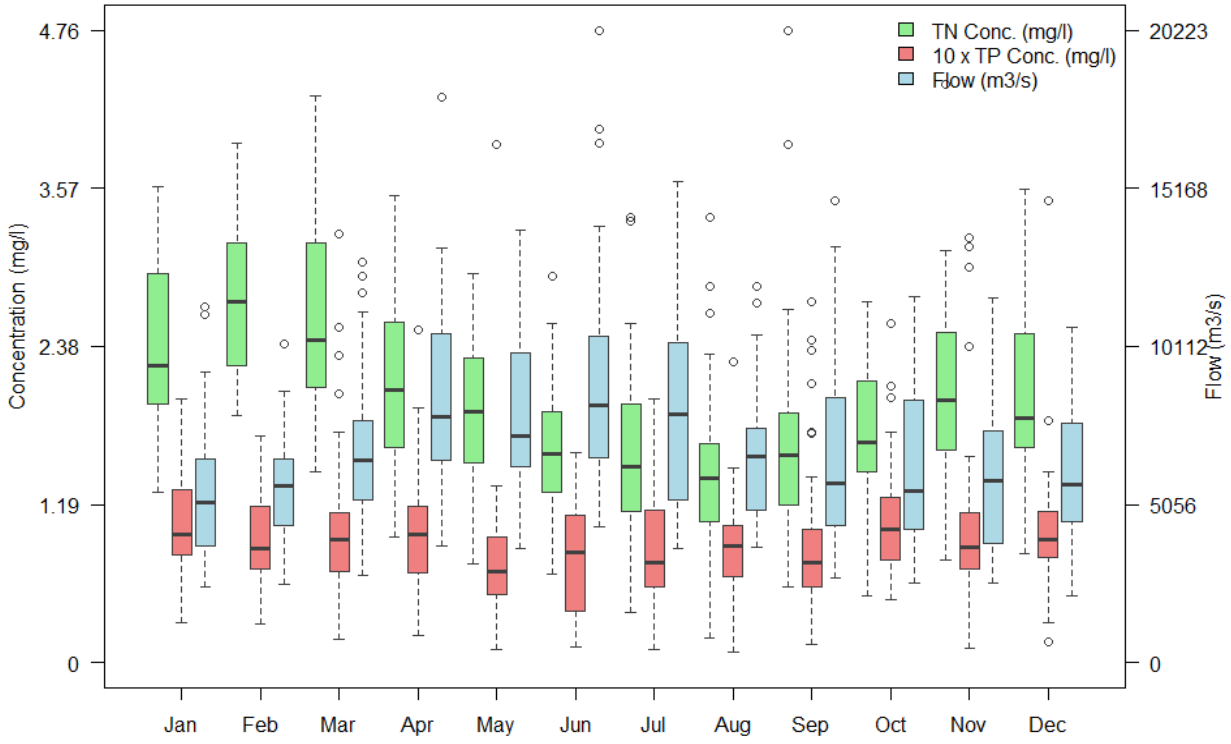


FIGURE SM_TN&TP8: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN) DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED), AND RIVER DISCHARGE (BLUE) AT STATION 132RO5 FOR THE PERIOD 1996-2021

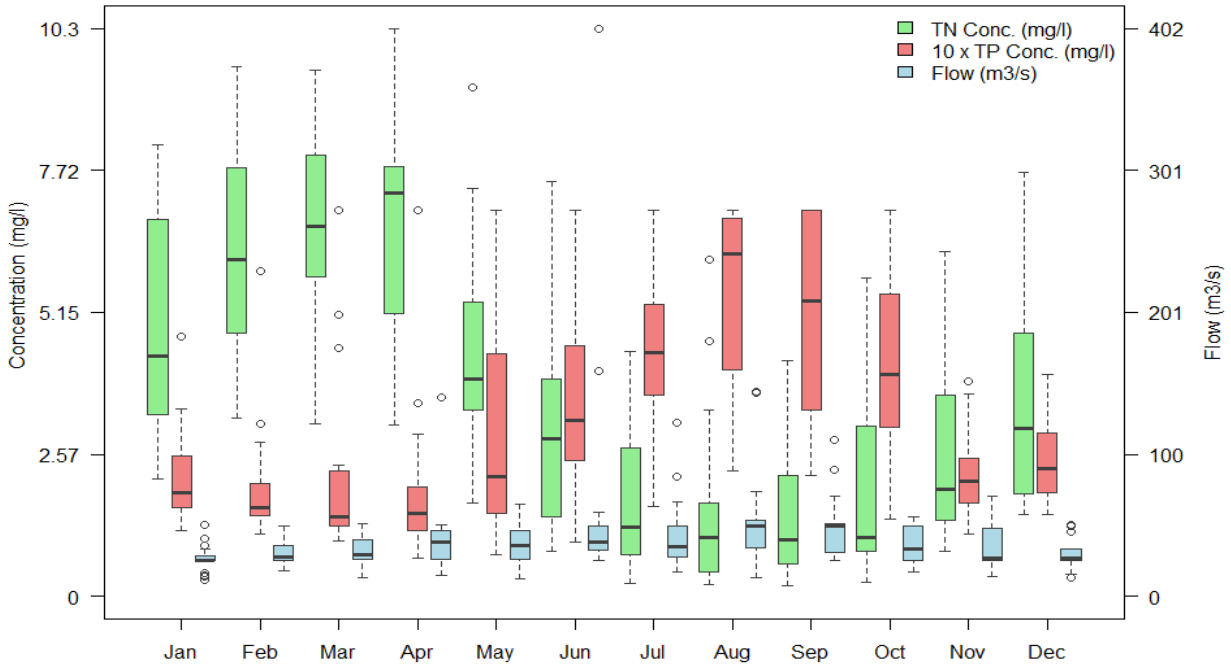


FIGURE SM_TN&TP9: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN) DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED) AND RIVER DISCHARGE (BLUE) AT STATION MORAVA 17-CZ2 FOR THE PERIOD 1996-2021

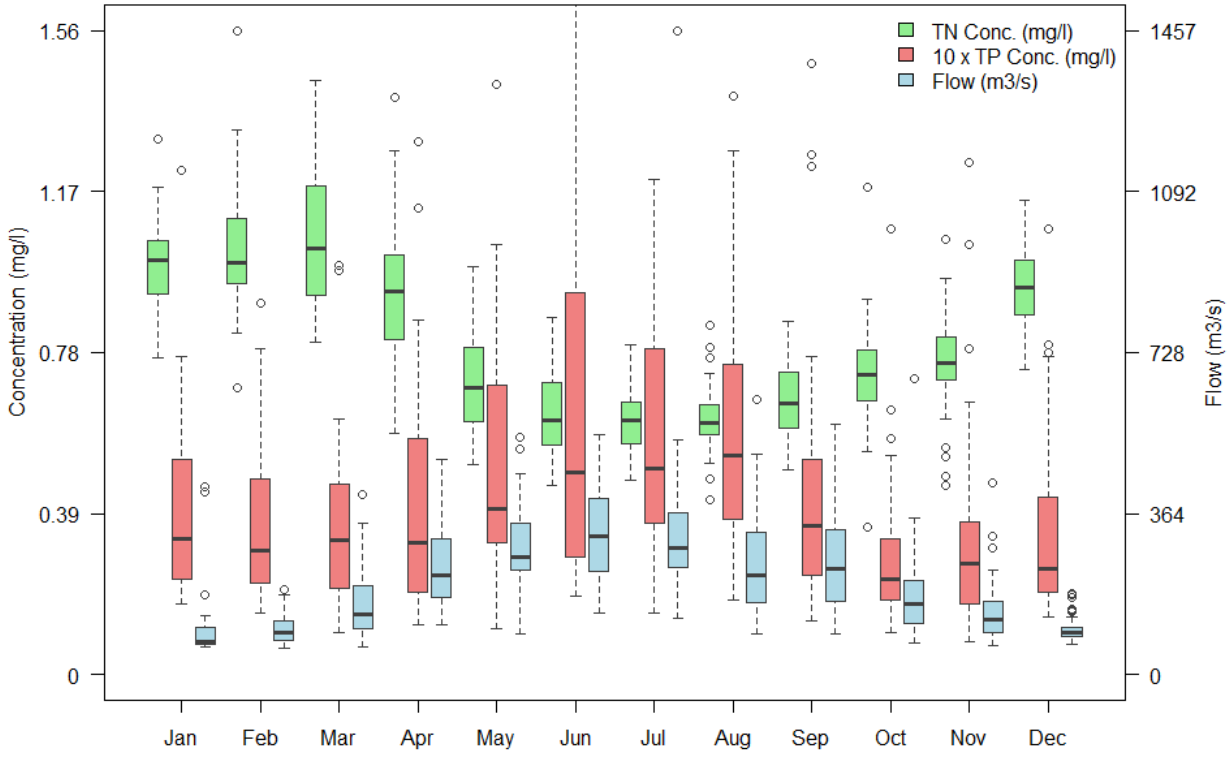


FIGURE SM_TN&TP10: MONTHLY DISTRIBUTION TN CONCENTRATIONS (GREEN) FROM NO3, DERIVED FROM NO3 USING THE CORRECTION FACTOR FROM TABLE SM_TN/NO1, TP CONCENTRATIONS MULTIPLIED BY 10 (RED) AND RIVER DISCHARGE (BLUE) AT STATION INN 47-DE4 FOR THE PERIOD 1996-2021

SM.12 TN/NO3 ratio in Danube

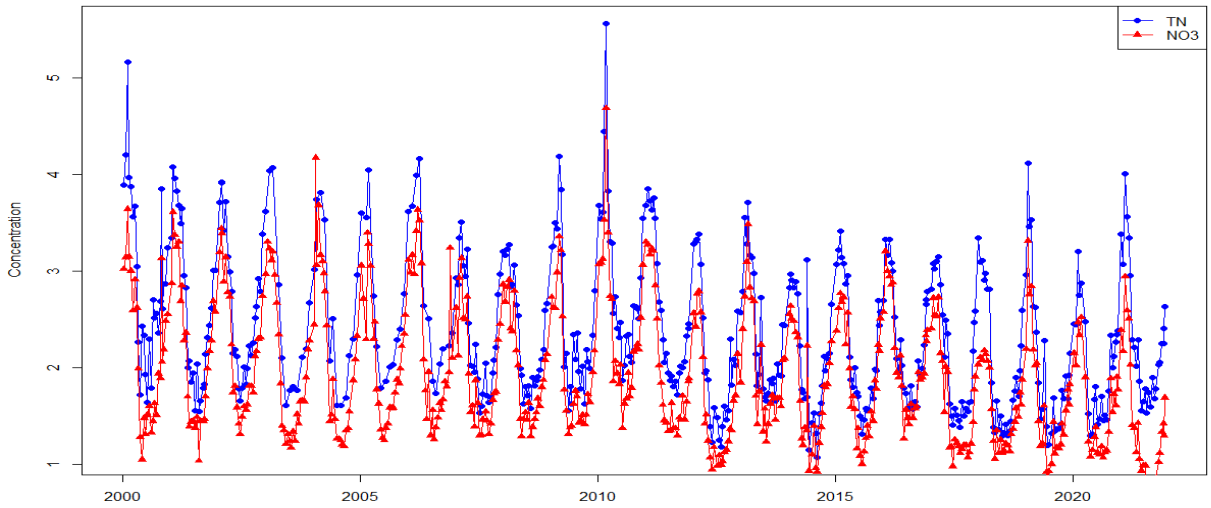


FIGURE SM_TN/NO 1: TEMPORAL EVOLUTION OF TN (BLUE) AND NO3 (RED) CONCENTRATIONS BASED ON RAW DATA AVAILABLE AT STATION **1869-SK1** ON THE DANUBE RIVER FROM 2000 TO 2021

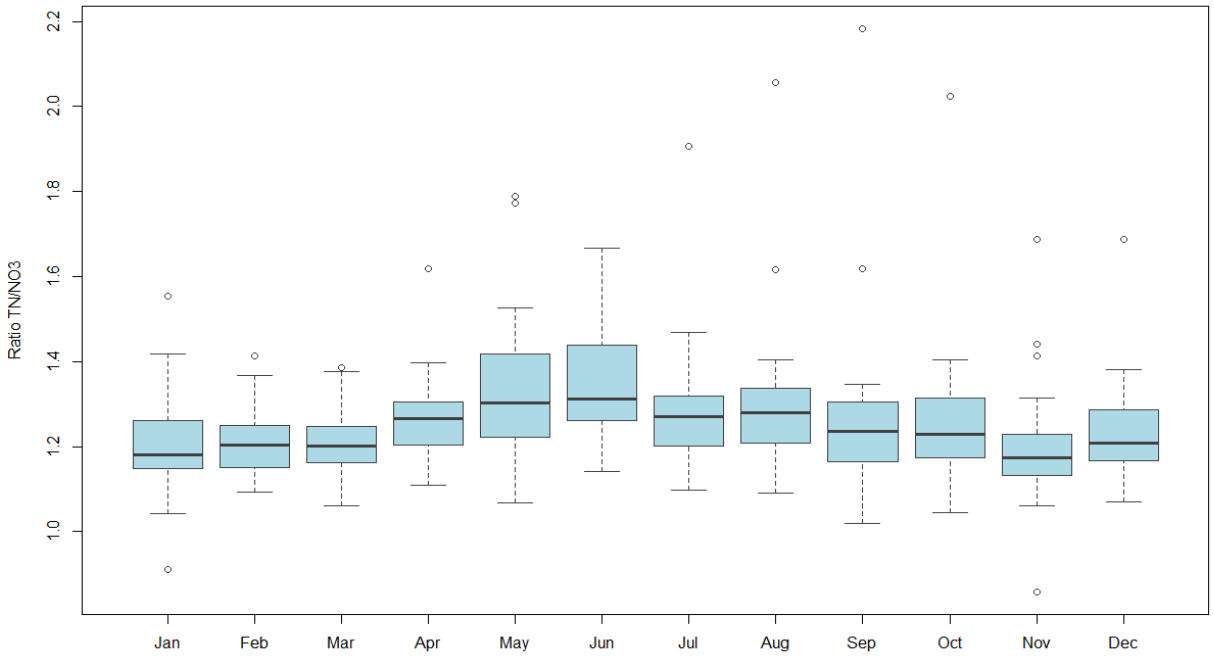


FIGURE SM_ TN/NO 2: MONTHLY DISTRIBUTION OF THE TN/NO3 CONCENTRATION RATIO BASED ON RAW DATA AT STATION **1869-SK1** ON THE DANUBE RIVER FROM 2000 TO 2021

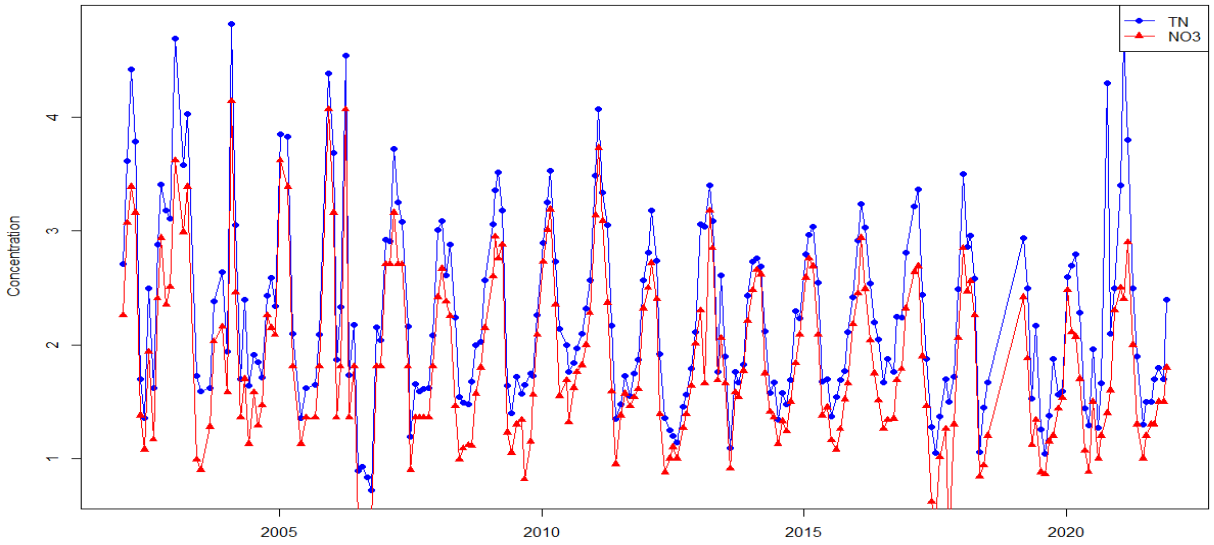


FIGURE SM_TN/NO 3: TEMPORAL EVOLUTION OF TN (BLUE) AND NO3 (RED) CONCENTRATIONS BASED ON RAW DATA AVAILABLE AT STATION 1429-HR1 ON THE DANUBE RIVER FROM 2000 TO 2021

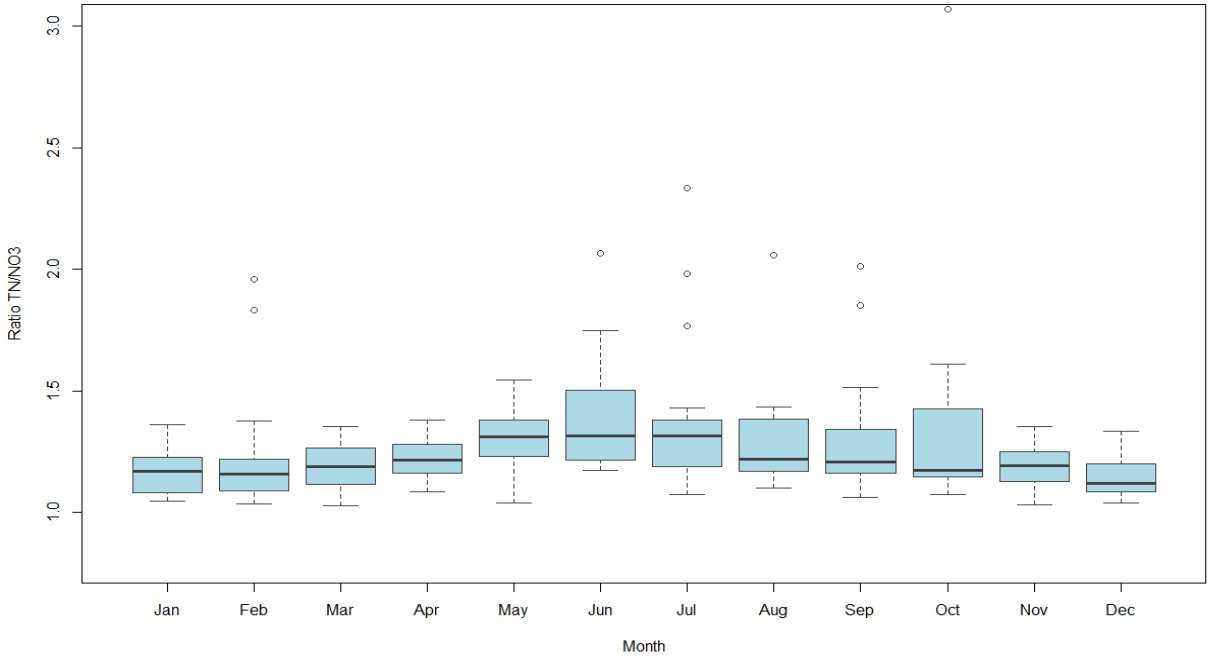


FIGURE SM_TN/NO 4: MONTHLY DISTRIBUTION OF THE TN/NO3 CONCENTRATION RATIO BASED ON RAW DATA AT STATION ***1429-HR1*** ON THE DANUBE RIVER FROM 2000 TO 2021

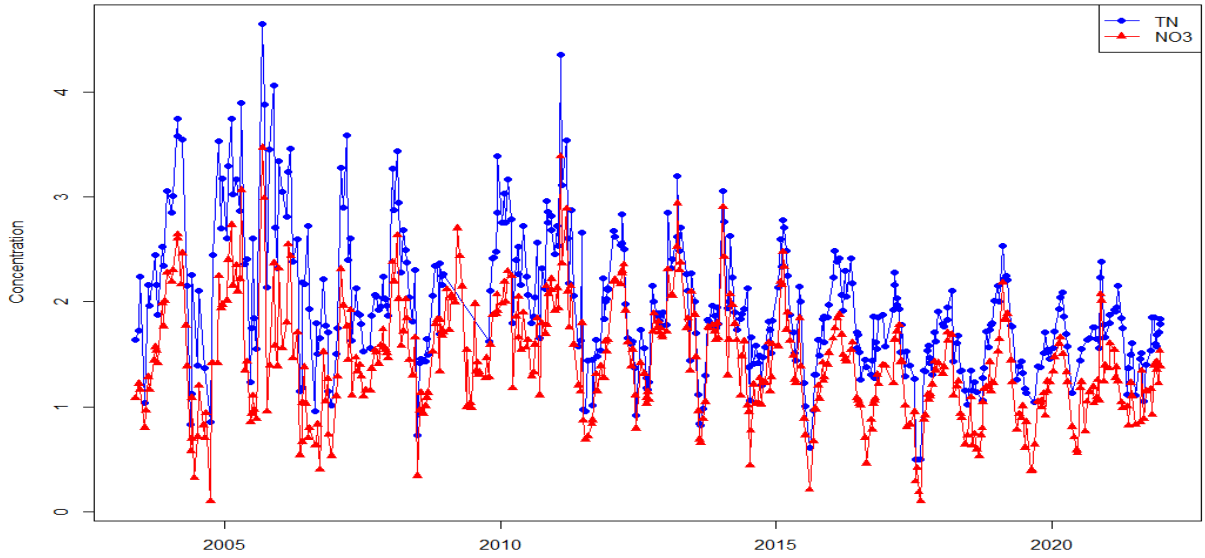


FIGURE SM_TN/NO 5: TEMPORAL EVOLUTION OF TN (BLUE) AND NO3 (RED) CONCENTRATIONS BASED ON RAW DATA AVAILABLE AT STATION ***375-RO4*** ON THE DANUBE RIVER FROM 2000 TO 2021

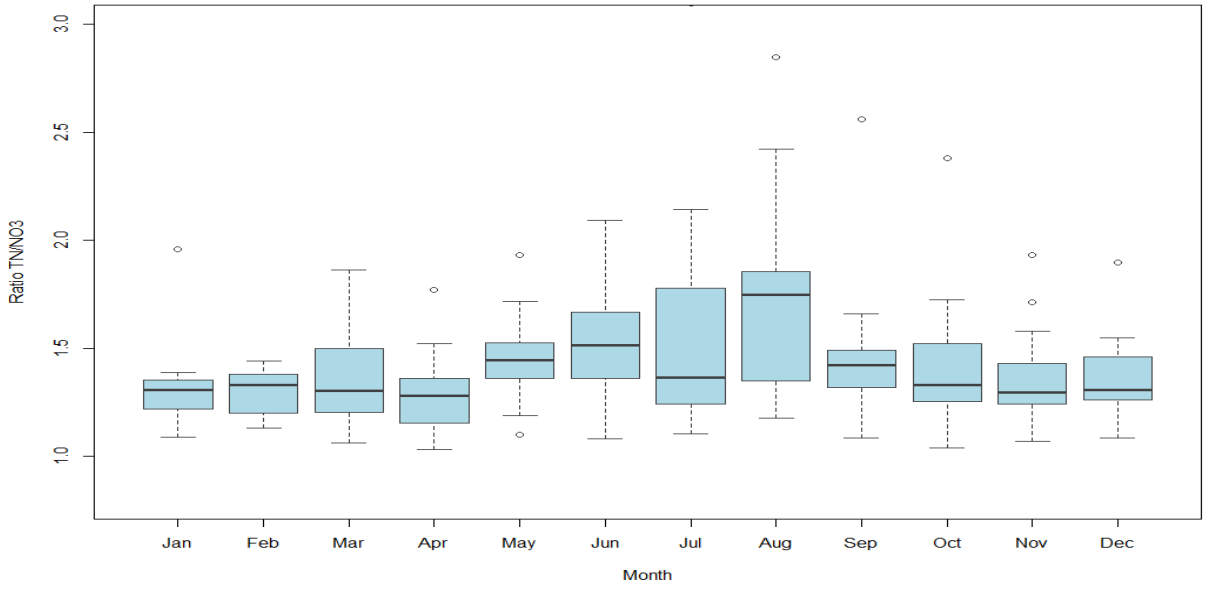


FIGURE SM_TN/NO 6: MONTHLY DISTRIBUTION OF THE TN/NO3 CONCENTRATION RATIO BASED ON RAW DATA AT STATION ***375-RO4*** ON THE DANUBE RIVER FROM 2000 TO 2021

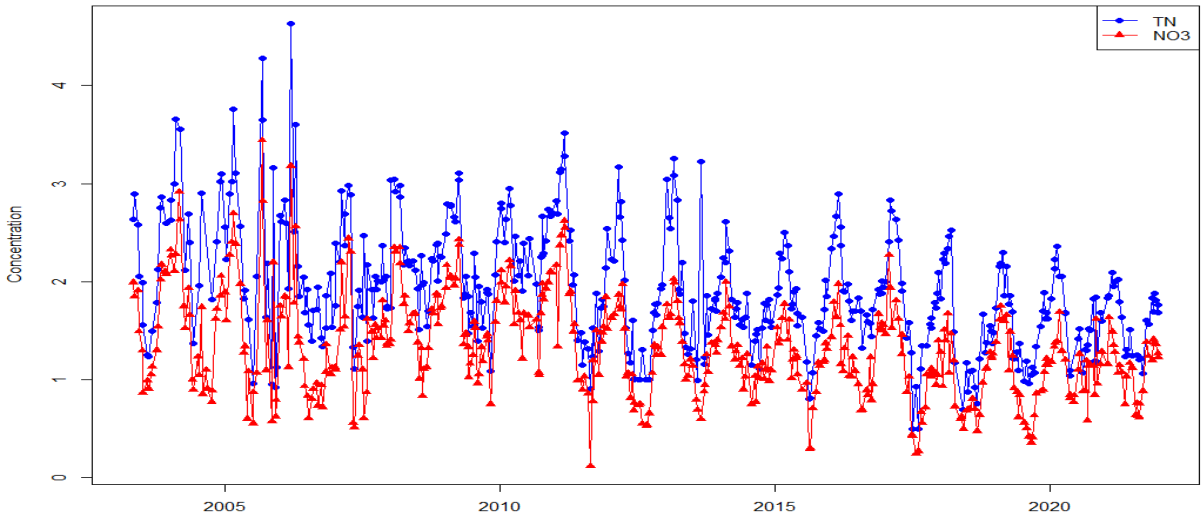


FIGURE SM_TN/NO 7: TEMPORAL EVOLUTION OF TN (BLUE) AND NO3 (RED) CONCENTRATIONS BASED ON RAW DATA AVAILABLE AT STATION **18-RO6** ON THE DANUBE RIVER FROM 2000 TO 2021

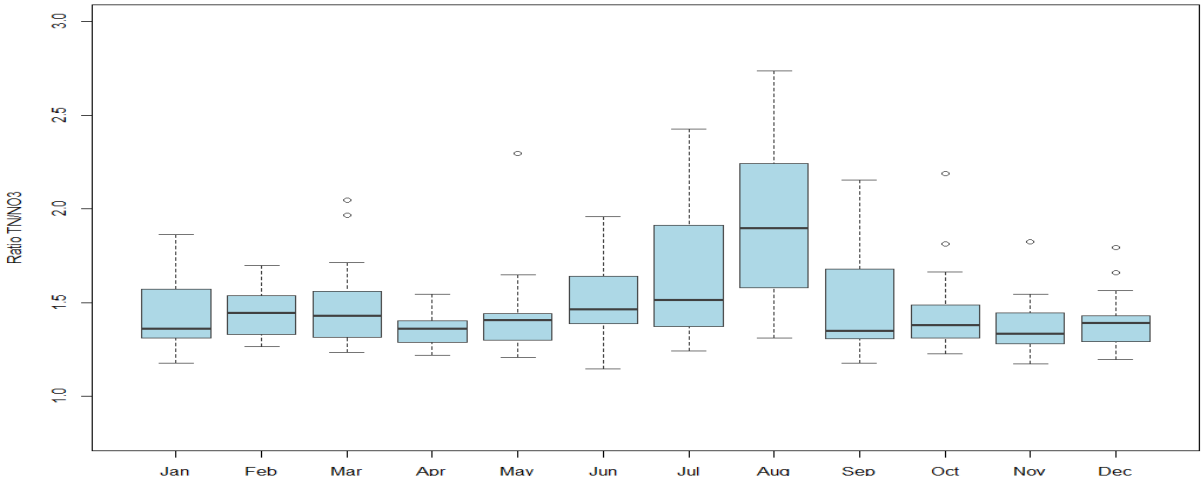
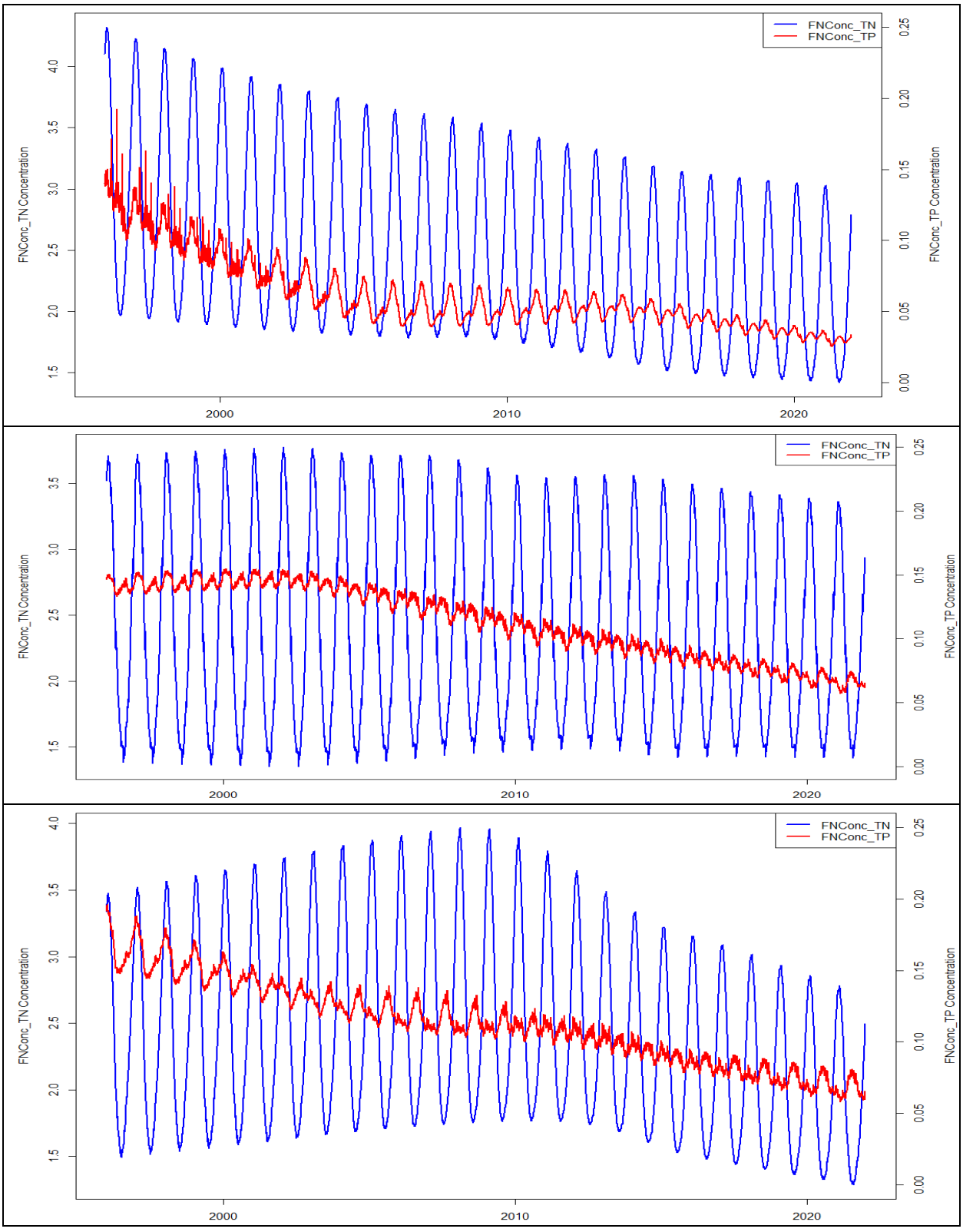


FIGURE SM_TN/NO 8: MONTHLY DISTRIBUTION OF THE TN/NO3 CONCENTRATION RATIO BASED ON RAW DATA AT STATION **18-RO6** ON THE DANUBE RIVER FROM 2000 TO 2021

TABLE SM_TN/NO 1: RELATIONSHIP BETWEEN THE MONTHLY MEDIANS OF FLOW-NORMALIZED CONCENTRATION RATIOS OF TOTAL NITROGEN (TN) TO NITRATE (NO3) FOR FOUR REGIONS ALONG THE DANUBE RIVER, DEFINED BASED ON THEIR DISTANCE FROM THE RIVER'S MOUTH, OVER THE PERIOD 1996-2021. FOR THE UPPER ZONE, DATA FROM STATION 1869-SK1 WERE USED. THE MIDDLE-UPPER ZONE COMPRISES THE AVERAGE DATA FROM STATIONS 1426-RS1 AND 1429-HR1. THE MIDDLE-LOWER ZONE INCLUDES THE AVERAGE DATA FROM STATIONS 1173-RS4, 954-RS7, AND 851-RS8. THE LOWER ZONE INCLUDES THE AVERAGE DATA FROM STATIONS 375-RO AND 18-RO6.

TN/NO3	> km	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upper	1600	1.18	1.2	1.2	1.27	1.3	1.31	1.27	1.28	1.24	1.23	1.17	1.21
Middle-Upper	1200	1.17	1.16	1.19	1.22	1.31	1.32	1.31	1.22	1.21	1.17	1.19	1.12
Middle-Lower	600	2.07	2.01	1.93	1.97	2.11	1.92	1.73	1.92	1.93	1.71	1.85	1.76
lower	0	1.37	1.38	1.35	1.31	1.47	1.53	1.55	1.63	1.39	1.38	1.34	1.32

SM.13 Long-Term Trends in Flow-Normalized Nutrient Concentrations and Stoichiometry



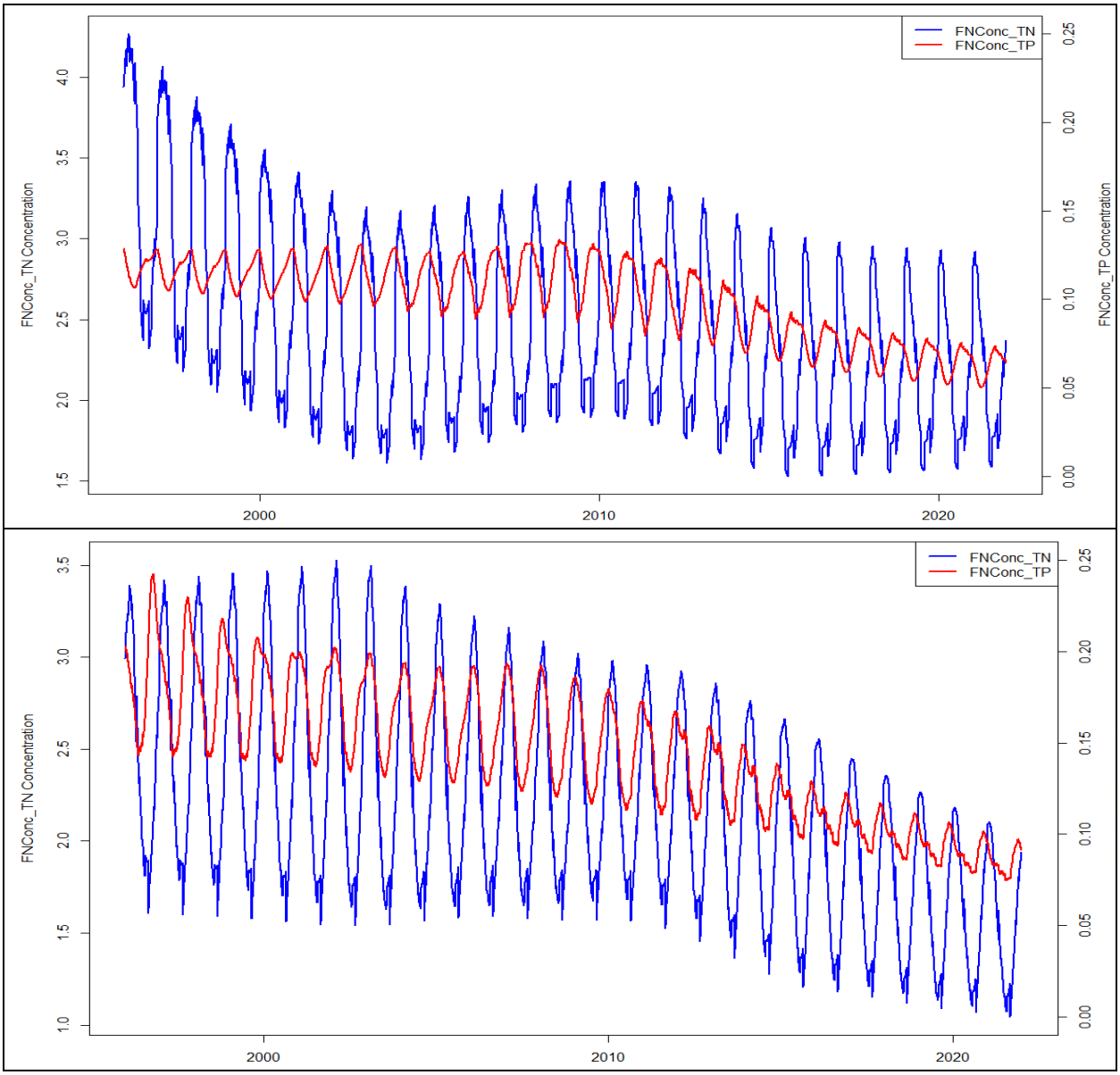
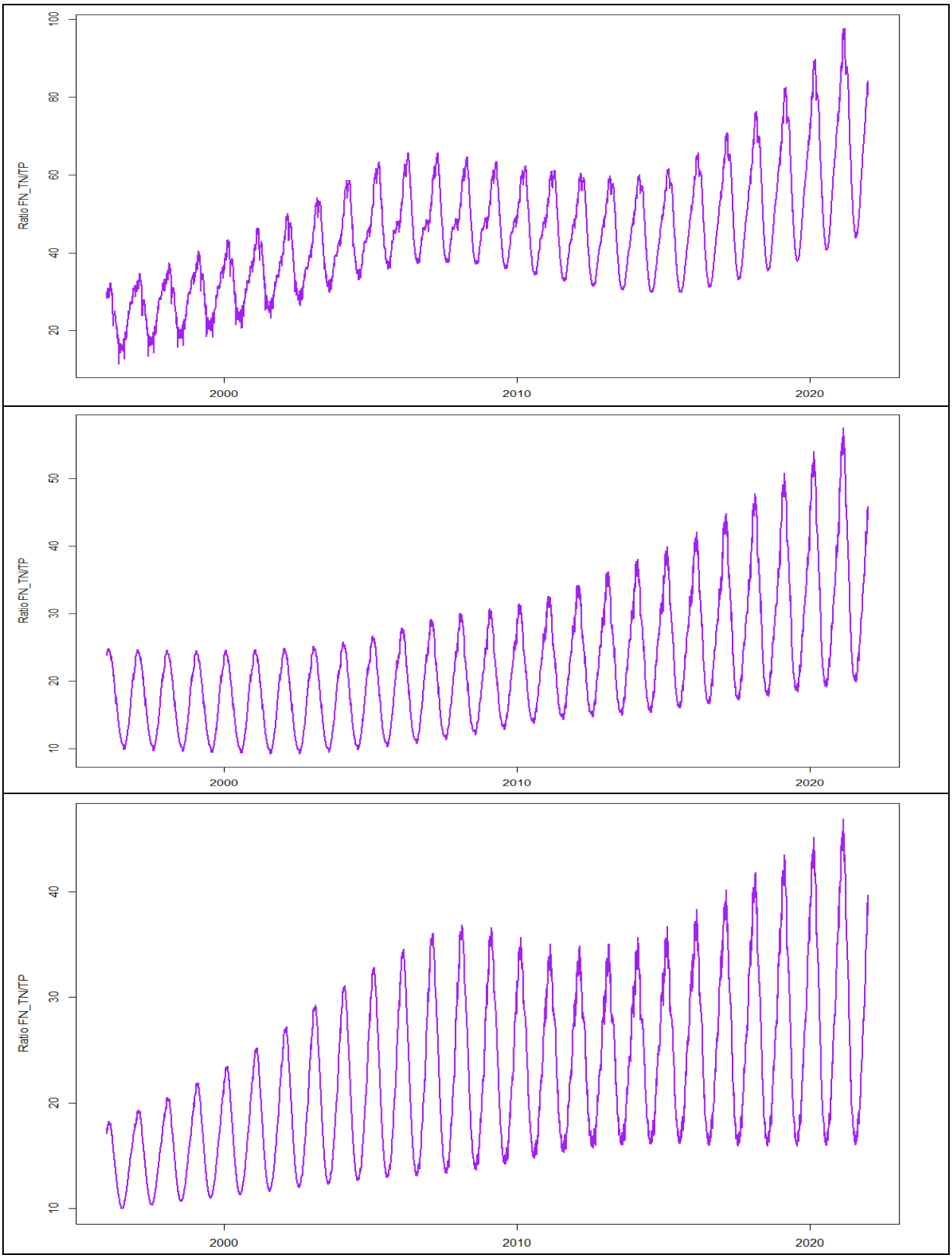


FIGURE SM_TN/TP 1: LONGITUDINAL COMPARISON OF FLOW-NORMALIZED NUTRIENT DYNAMICS AND STOICHIOMETRY. THE FIGURE DISPLAYS THE TEMPORAL EVOLUTION FROM 1996 TO 2021 OF FLOW-NORMALIZED (FN) CONCENTRATIONS FOR NO_3-N (BLUE LINE) AND TP (RED LINE) FOR FIVE KEY STATIONS ALONG THE DANUBE RIVER, ARRANGED SPATIALLY FROM UPSTREAM (TOP ROW) TO DOWNSTREAM (BOTTOM ROW). THE STATIONS ARE: 1935-AT3, 1560-HU4, 1435-HU5, 834-RO2, AND 375-BG5.


Ratio FN_TN/TP
20
40
60
80
100
2000
2010
2020
Ratio FN_TN/TP
10
20
30
40
50
2000
2010
2020
Ratio FN_TN/TP
10
20
30
40
2000
2010
2020

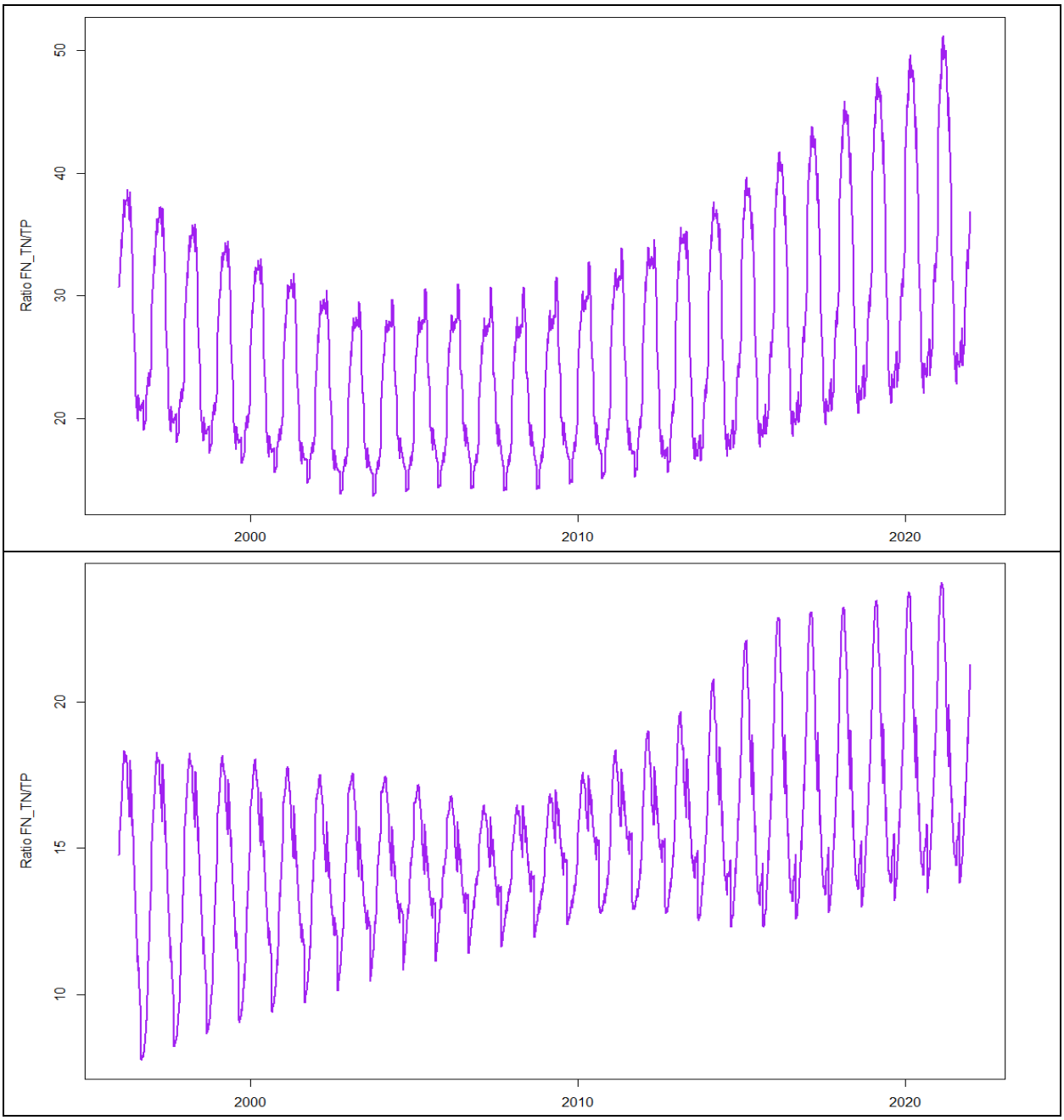
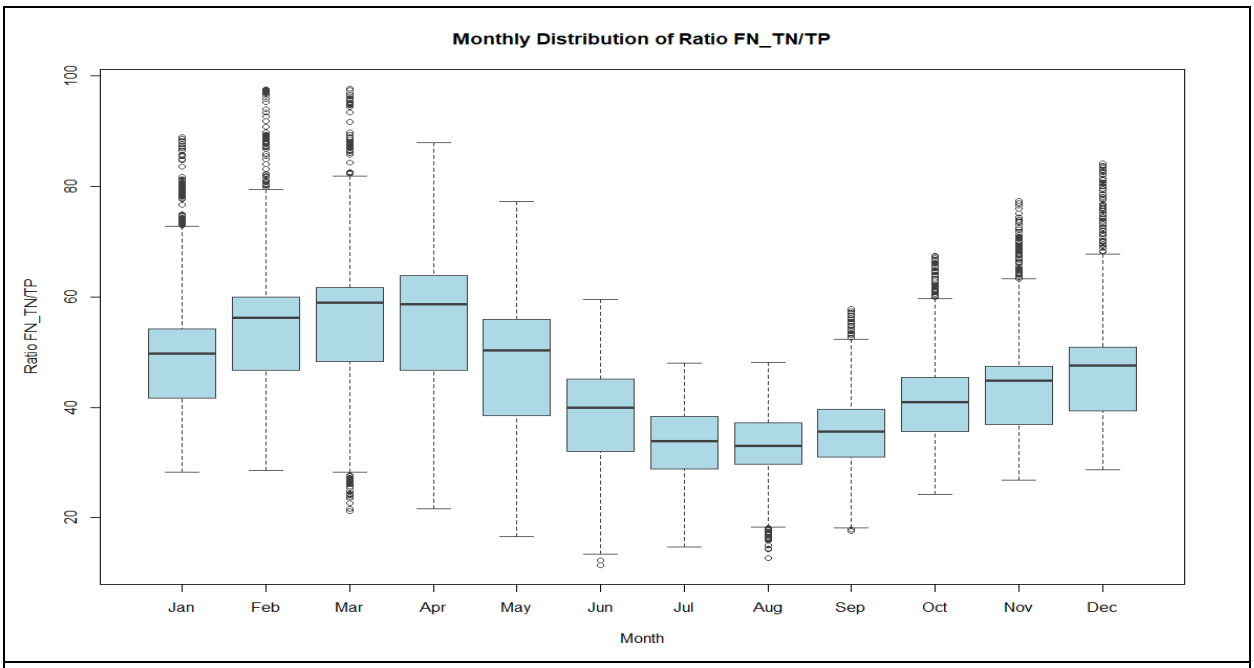
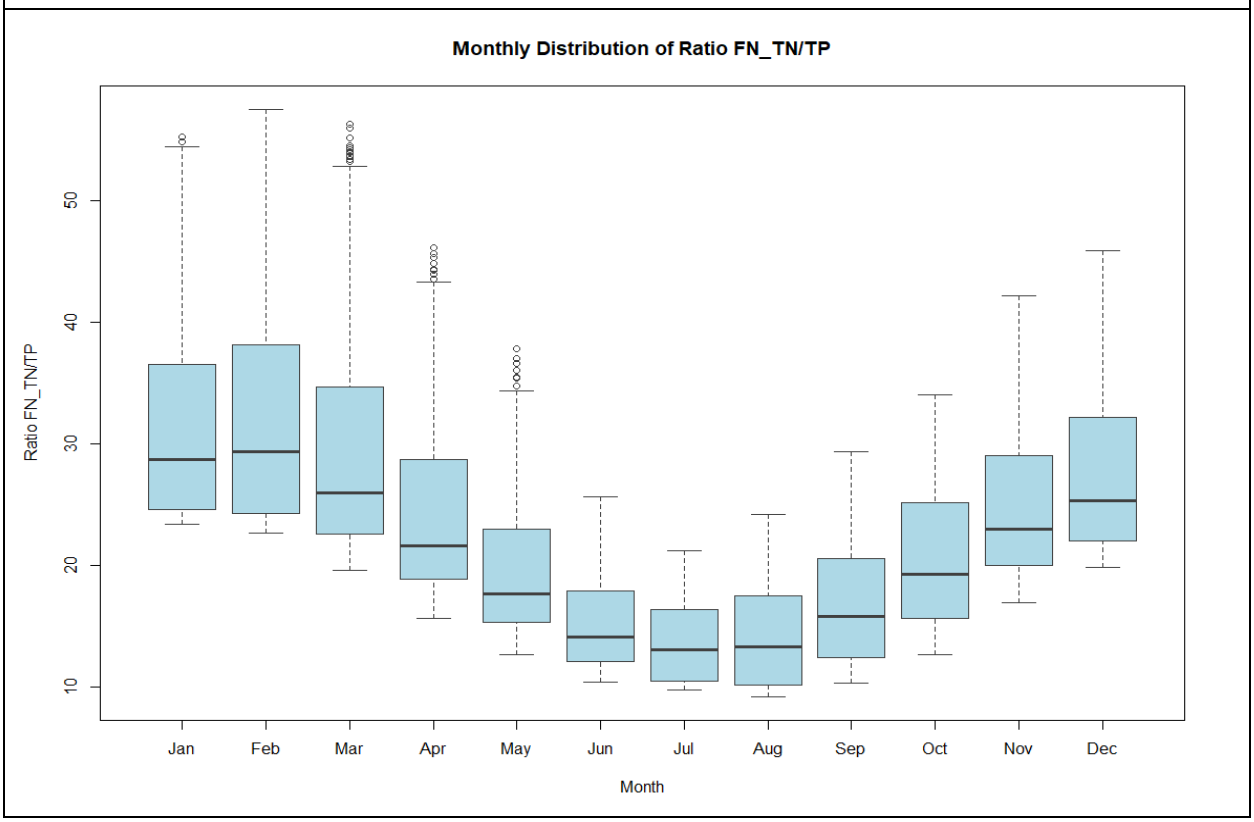
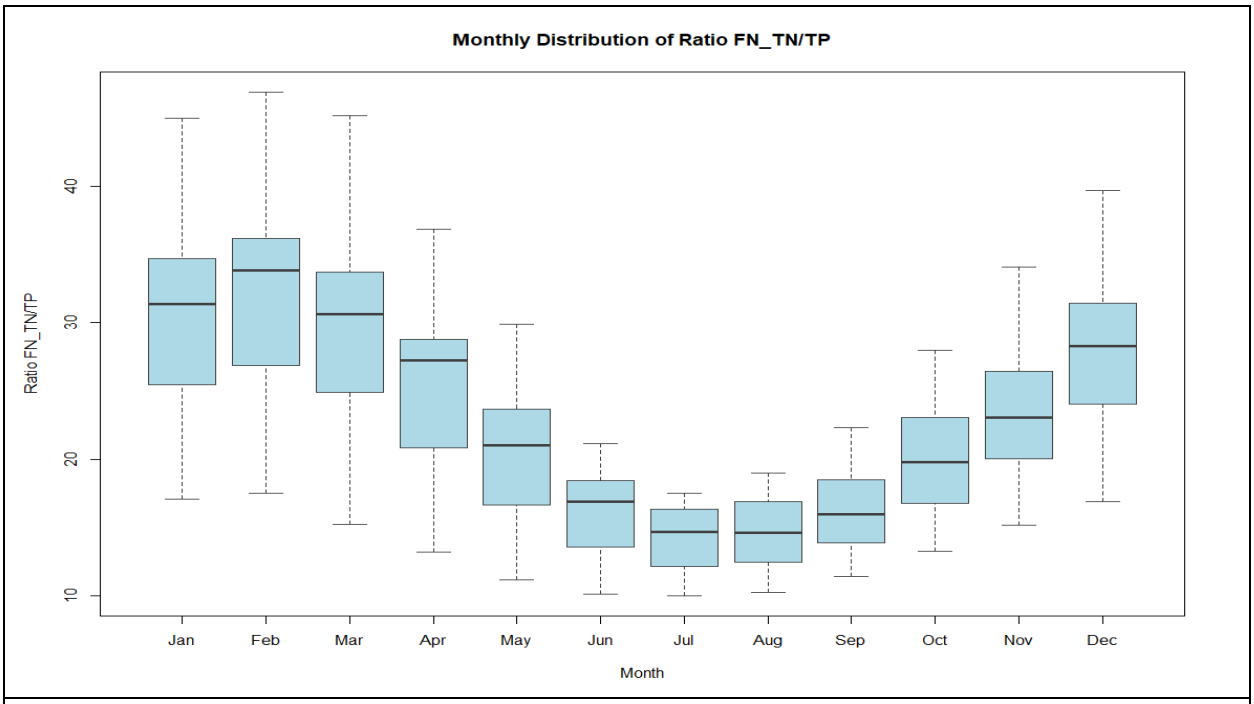


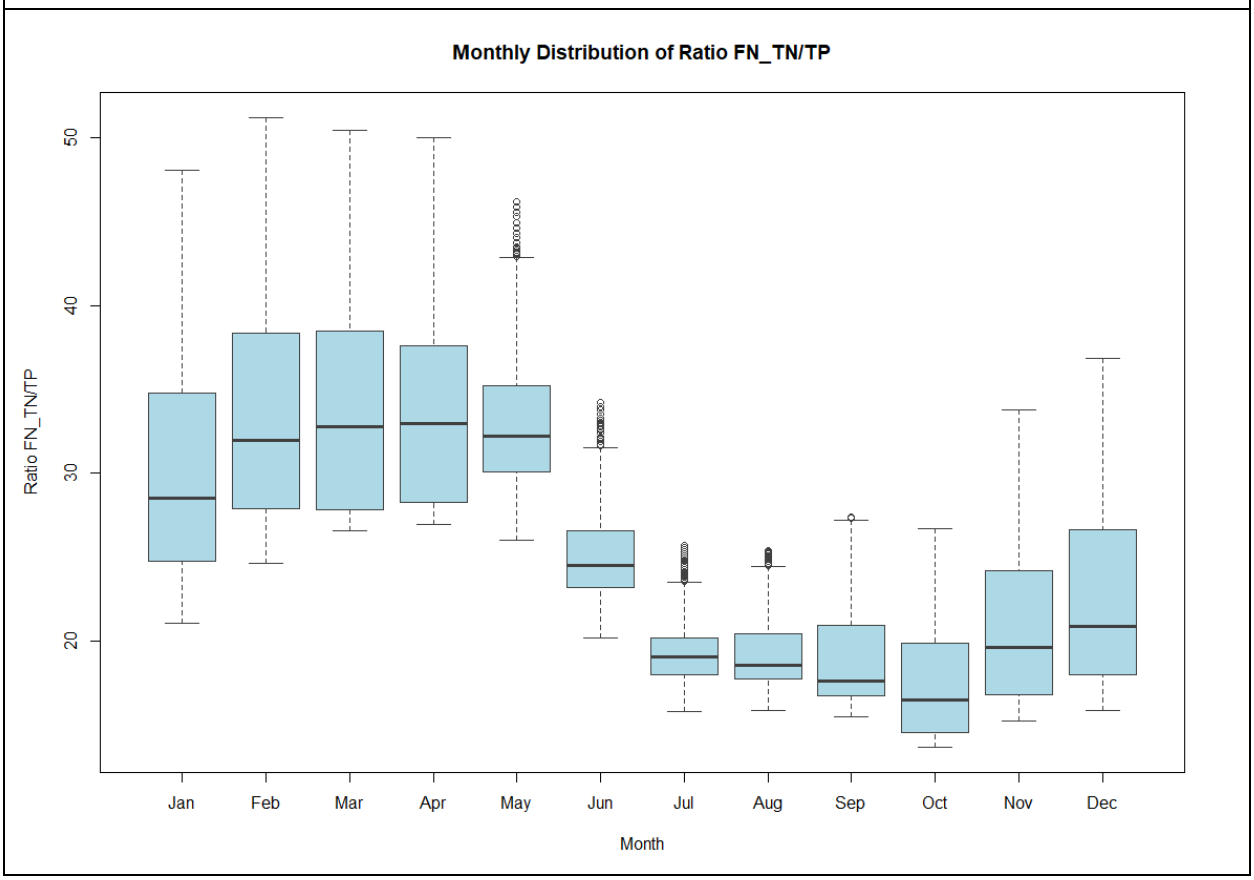
FIGURE SM_TN/TP 2: LONGITUDINAL COMPARISON OF FLOW-NORMALIZED NUTRIENT DYNAMICS AND STOICHIOMETRY. THE FIGURE DISPLAYS THE TEMPORAL EVOLUTION FROM 1996 TO 2021 OF FLOW-NORMALIZED (FN) TN/TP RATIO FOR FIVE KEY STATIONS ALONG THE DANUBE RIVER, ARRANGED SPATIALLY FROM UPSTREAM (TOP ROW) TO DOWNSTREAM (BOTTOM ROW). THE STATIONS ARE: 1935-AT3, 1560-HU4, 1435-HU5, 834-RO2, AND 375-BG5.

SM.14 Drivers of Seasonal Stoichiometry: Opposing Nutrient Cycles






Monthly Distribution of Ratio FN_TN/TP
Ratio FN_TN/TP
10
20
30
40
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Monthly Distribution of Ratio FN_TN/TP
Ratio FN_TN/TP
20
30
40
50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

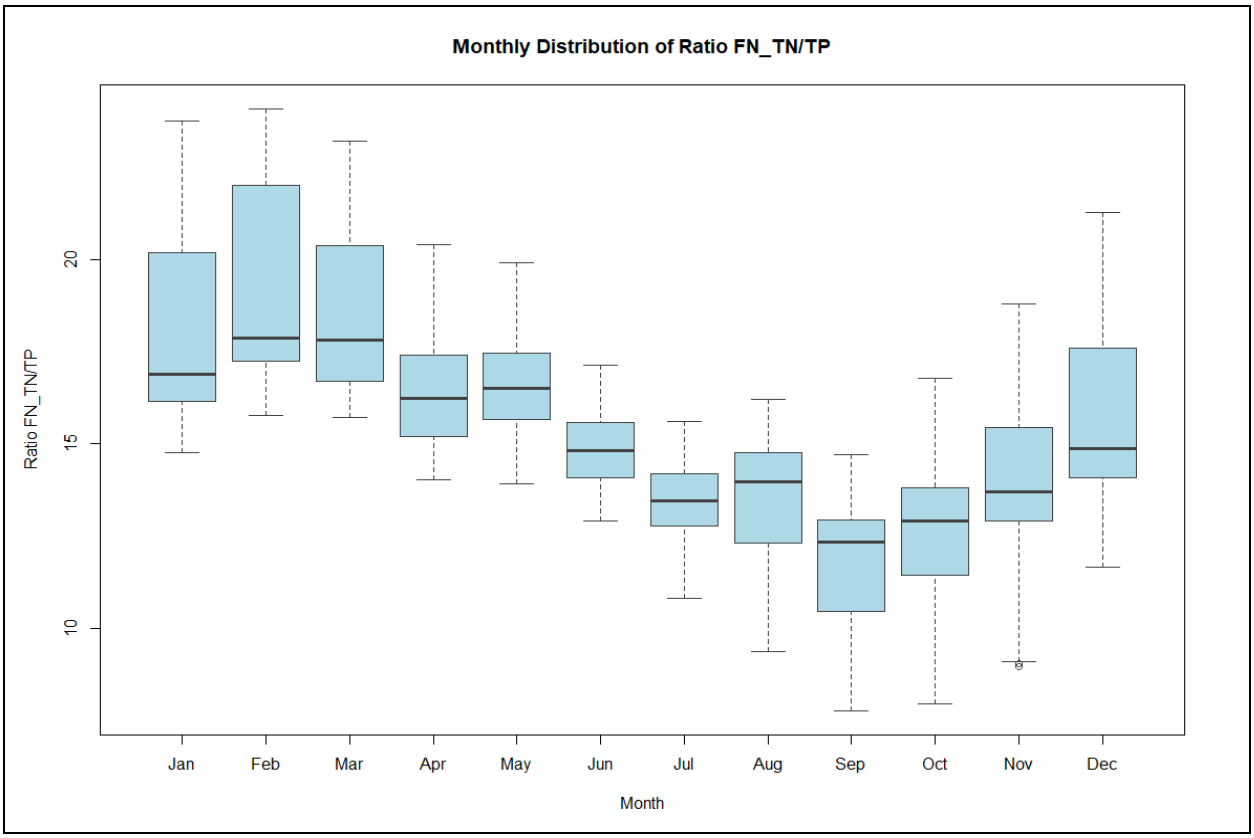
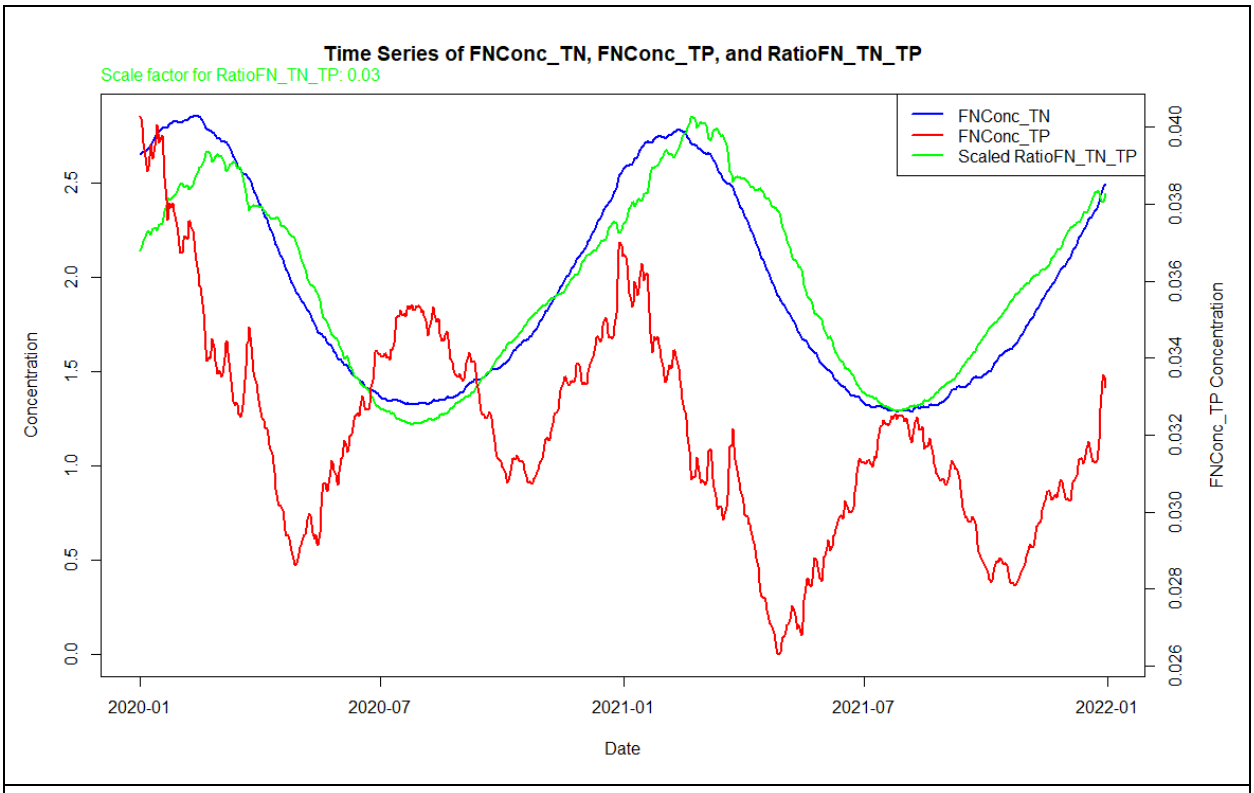
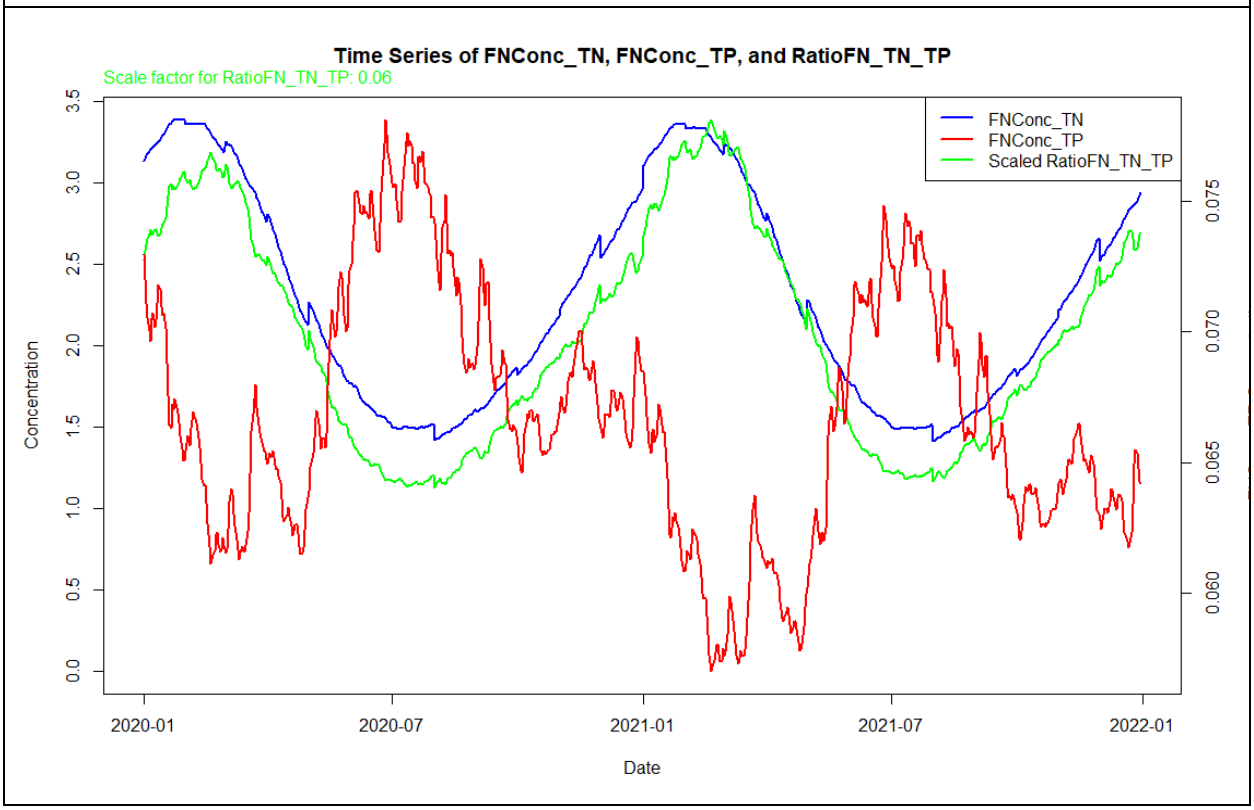
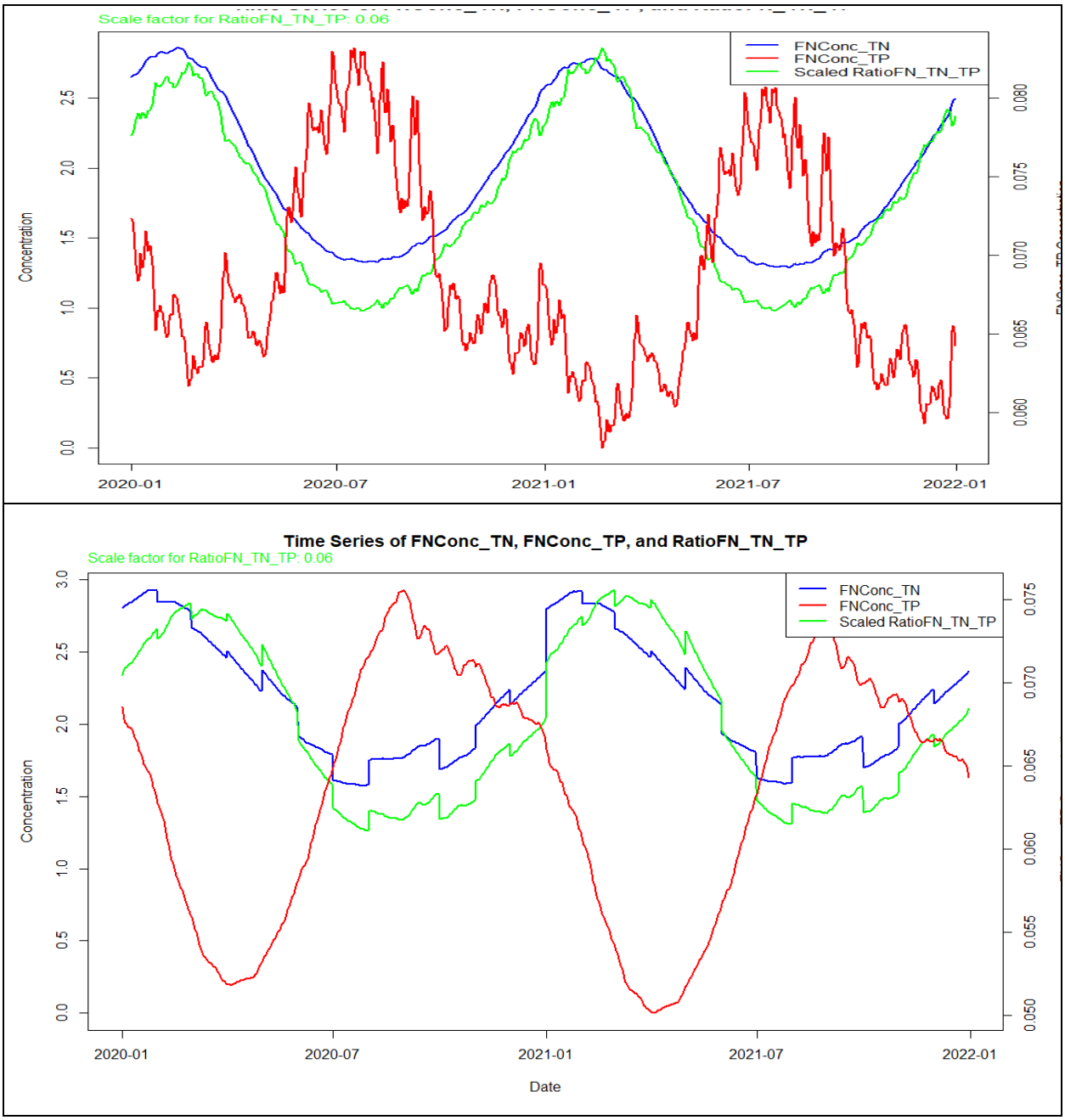


FIGURE SM_ST 1: LONGITUDINAL COMPARISON OF FLOW-NORMALIZED NUTRIENT DYNAMICS AND STOICHIOMETRY. THE FIGURE DISPLAYS THE TEMPORAL EVOLUTION FROM 1996 TO 2021 OF FLOW-NORMALIZED (FN) TN/TP RATIO FOR FIVE KEY STATIONS ALONG THE DANUBE RIVER, ARRANGED SPATIALLY FROM UPSTREAM (TOP ROW) TO DOWNSTREAM (BOTTOM ROW). THE STATIONS ARE: 1935-AT3, 1560-HU4, 1435-HU5, 834-RO2, AND 375-BG5


Time Series of FNConc_TN, FNConc_TP, and RatioFN_TN_TP
Scale factor for RatioFN_TN_TP: 0.03
FNConc_TN
FNConc_TP
Scaled RatioFN_TN_TP
Concentration
FNConc_TP Concentration
Date
2020-01
2020-07
2021-01
2021-07
2022-01


Time Series of FNConc_TN, FNConc_TP, and RatioFN_TN_TP
Scale factor for RatioFN_TN_TP: 0.06
FNConc_TN
FNConc_TP
Scaled RatioFN_TN_TP
Concentration
Date
2020-01
2020-07
2021-01
2021-07
2022-01


Scale factor for RatioFN_TN_TP: 0.06
FNConc_TN
FNConc_TP
Scaled RatioFN_TN_TP
Concentration
0.0
0.5
1.0
1.5
2.0
2.5
0.060
0.065
0.070
0.075
0.080
2020-01
2020-07
2021-01
2021-07
2022-01
Time Series of FNConc_TN, FNConc_TP, and RatioFN_TN_TP
Scale factor for RatioFN_TN_TP: 0.06
FNConc_TN
FNConc_TP
Scaled RatioFN_TN_TP
Concentration
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.050
0.055
0.060
0.065
0.070
0.075
2020-01
2020-07
2021-01
2021-07
2022-01
Date

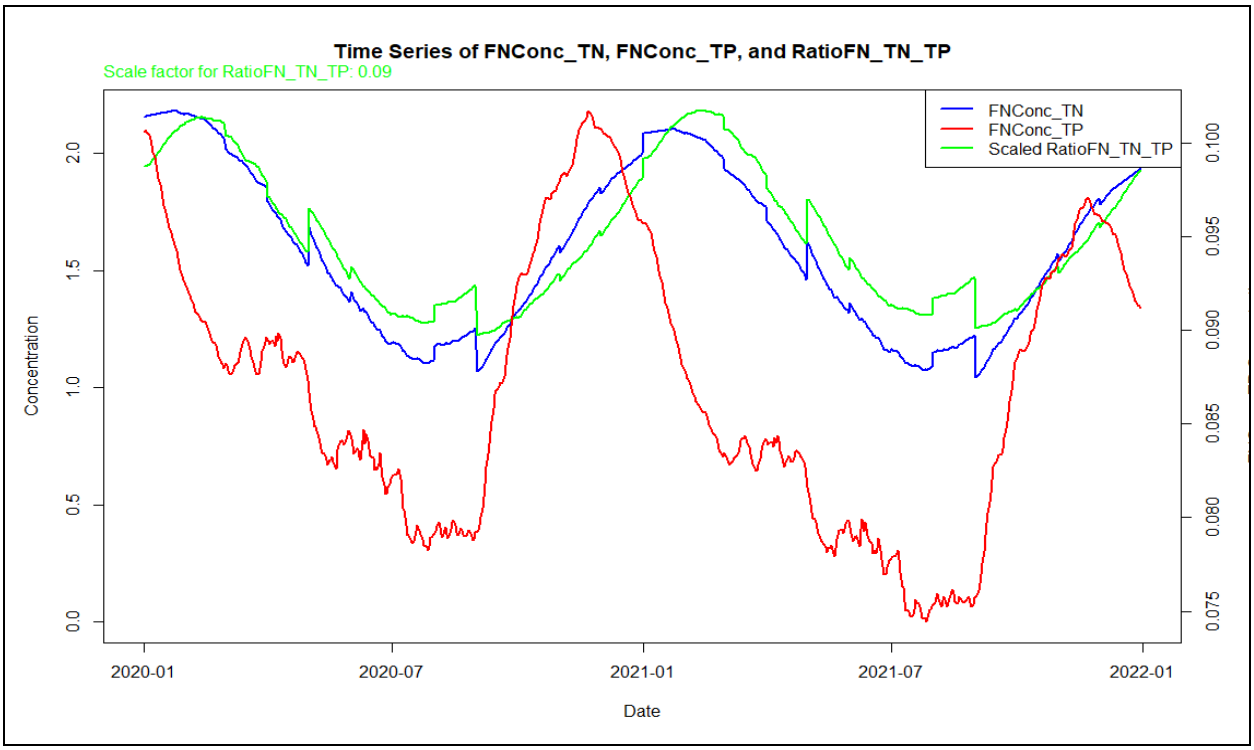


FIGURE SM_ST 2: DETAILED TWO-YEAR TIME SERIES OF FLOW-NORMALIZED NUTRIENT CYCLES IN THE DANUBE. THE FIGURE DISPLAYS THE TEMPORAL EVOLUTION OF FLOW-NORMALIZED (FN) CONCENTRATIONS FOR TN (BLUE LINE) AND TP (RED LINE) FOR THE YEARS 2020 AND 2021), FOR FIVE KEY STATIONS ALONG THE DANUBE RIVER. THE STATIONS ARE ARRANGED SPATIALLY FROM UPSTREAM (TOP ROW) TO DOWNSTREAM (BOTTOM ROW). THE STATIONS ARE: 1935-AT3, 1560-HU4, 1435-HU5, 834-RO2, AND 375-BG5. TO FACILITATE COMPARISON, THE TN/TP RATIO (GREEN LINE) HAS BEEN SCALED AND PLOTTED ON THE SAME PRIMARY Y-AXIS, ILLUSTRATING THE PHASE LAG BETWEEN THE NUTRIENT PEAKS.

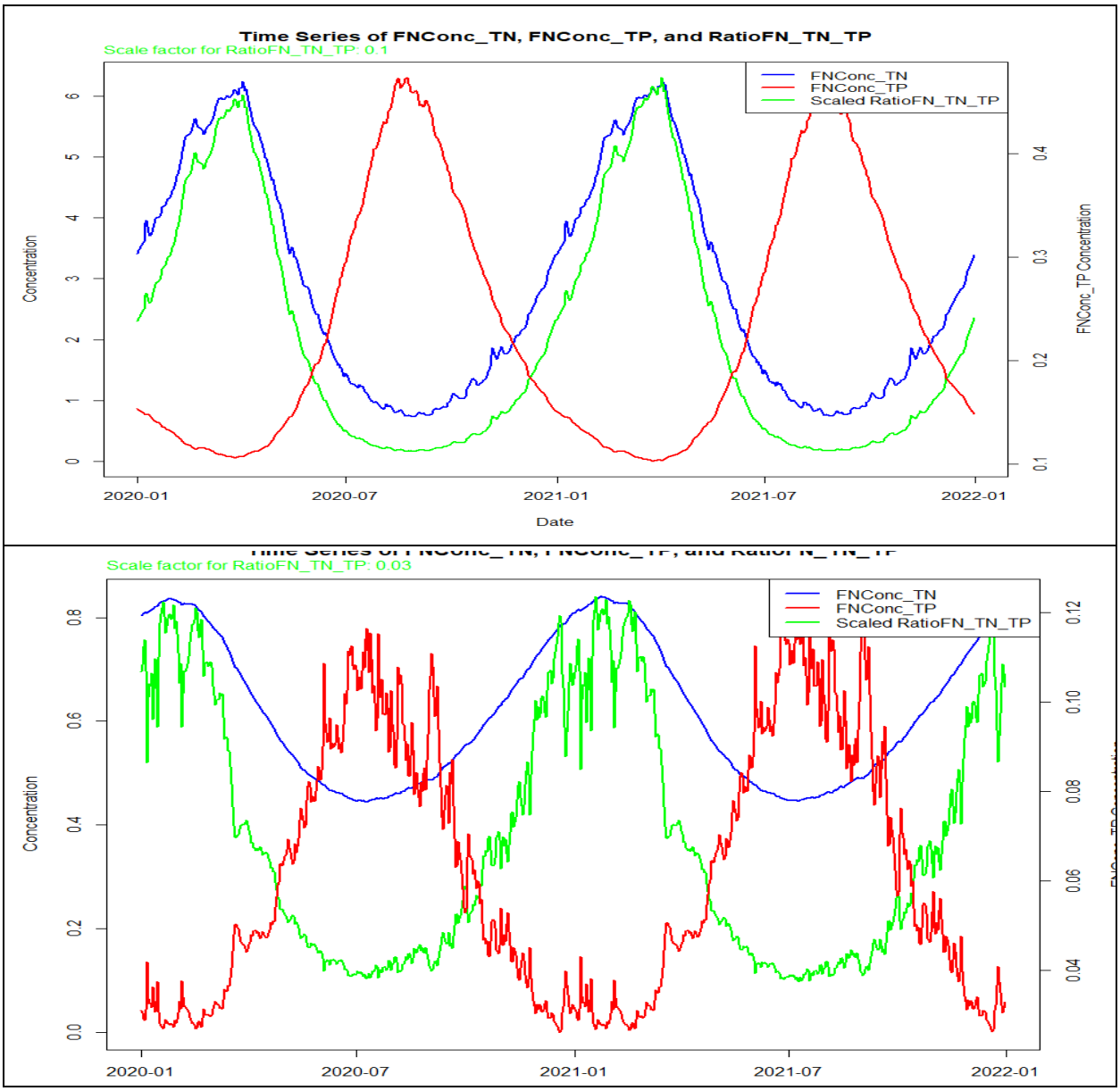


FIGURE SM_ST 3: LONGITUDINAL COMPARISON OF FLOW-NORMALIZED CONCENTRATIONS AND STOICHIOMETRY. THE FIGURE DISPLAYS THE VALUES FOR THE YEARS 2020 AND 2021 OF FLOW-NORMALIZED (FN) CONCENTRATIONS OF (BLUE) AND TP(RED), AS WELL AS THE RATIO (GREEN) BETWEEN BOTH VARIABLES (RESCALED IN RELATION TO THE LEFT AXIS), FOR THE STATIONS MORA17_CZ2 IN THE MORAVA RIVER

SM.15 Nitrogen Inputs

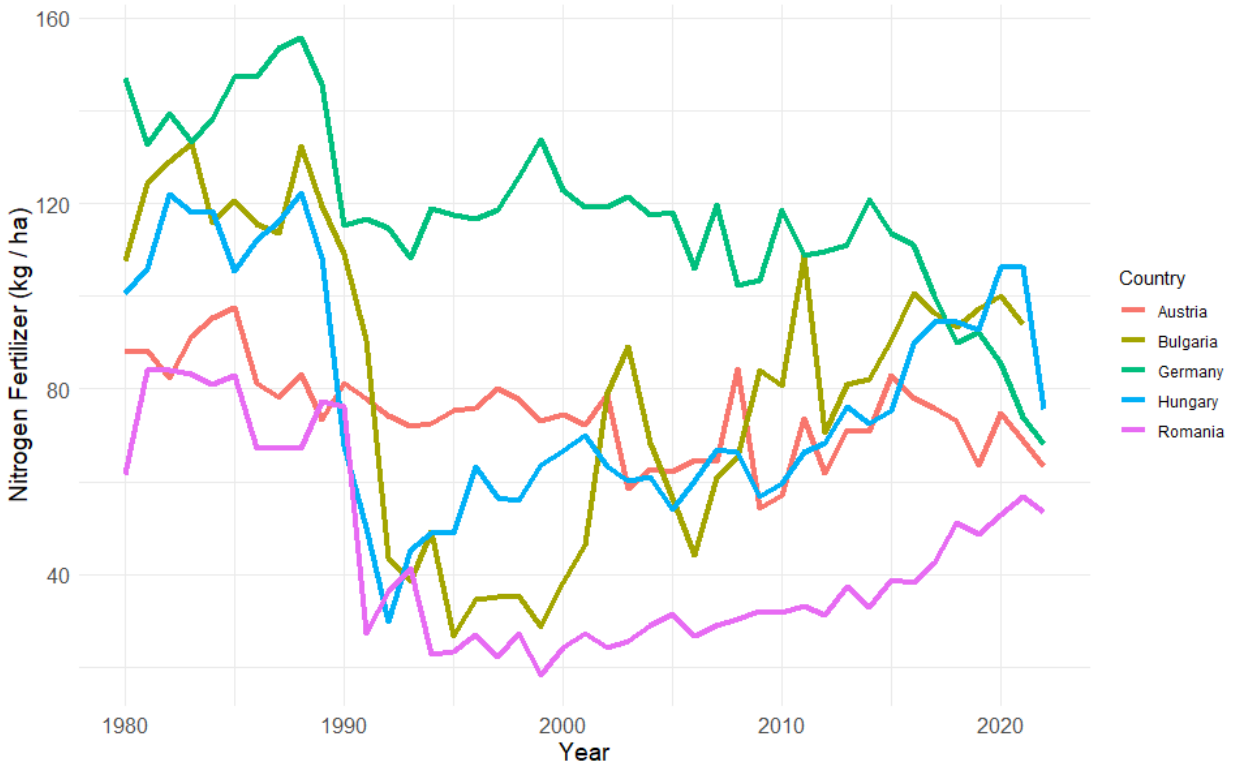


FIGURE SM_I1: EVOLUTION OF NITROGEN APPLICATION FROM 1980 TO 2020 IN FIVE DANUBE COUNTRIES (DATA SOURCE: FAO 2023, HTTPS://WWW.FAO.ORG/FAOSTAT/EN/#DATA/ESB)

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