Supplementary material

S1. Volatilization results

Simulated N volatilization for one field in Aurajoki catchment was 13 kg ha^{-1} a^{-1}, which was 67% of the surface applied $NH4^+$ in manure (Figure S1a). At the Aurajoki catchment scale (9618 field plots), mean N volatilization was 7.7 kg ha^{-1} a^{-1} (including also N volatilization from mineral N fertilizer), and surface applied N in manure was 18 kg ha^{-1} a^{-1} (Figure S1b).

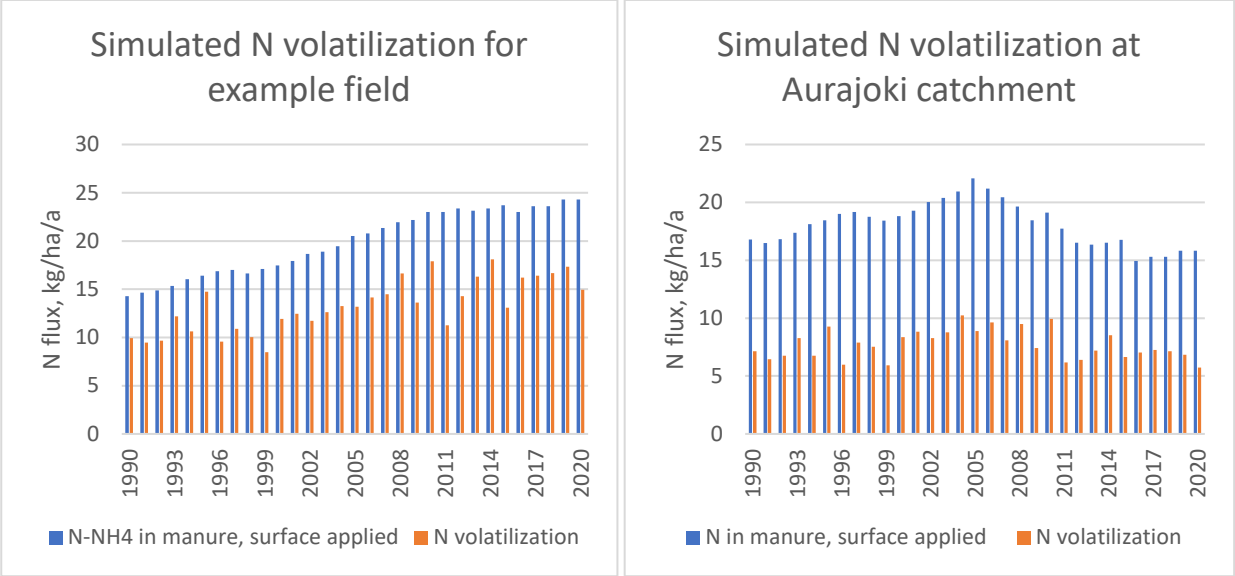


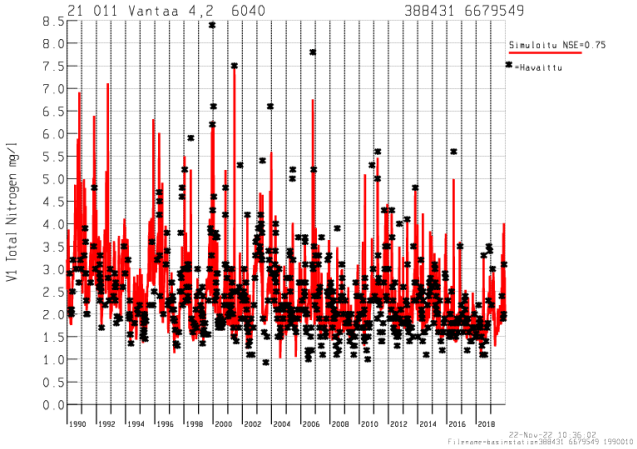
Figure S1. a) **N-NH4 in manure**, surface applied and N volatilization for one example field (Aurajoki catchment), b) **N in manure** surface applied and N volatilization, mean for Aurajoki catchment fields.

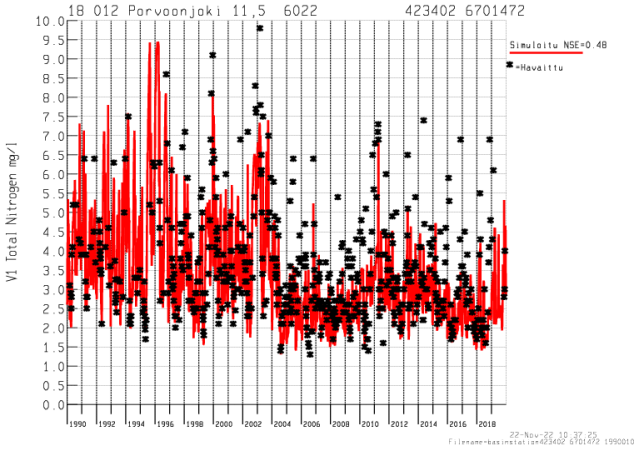
S2. Simulated and observed mean TN concentration, Nash and Sutcliffe efficiency (NSE) criteria and source apportionment (as % of total loading) (2013-2020) for selected river points

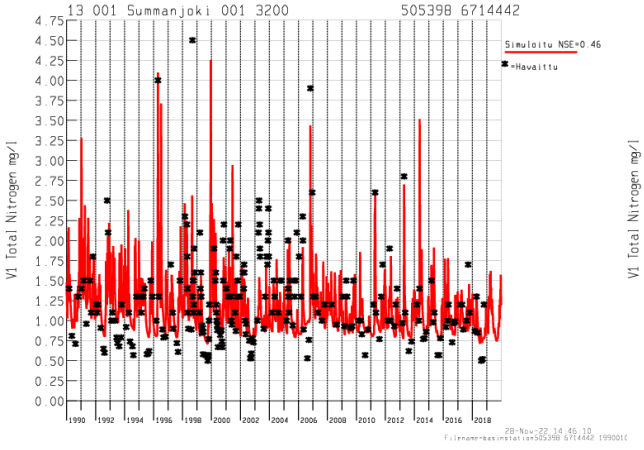
Observation point	ELY centre	Number of observations	Observed concentration, mg/l	Simulated concentration, mg/l	Difference, mg/l	NSE	Agricultural loading	Forestry loading	Natural background loading	Scattered settlements	Loading with urban runoff	Deposition to water bodies	Point load
28_001 Aurajoki outlet	South west Finaln d	233	2.66	2.54	0.11	0.59	73.8	1.9	17.8	1.6	3.1	0.3	1.5
21_011 Vantaanjoki outlet	Uusi maa	147	2.06	2.06	0	0.75	43.2	1.9	28.6	2.7	9.2	1.1	13.2
18_012 Porvoonjoki outlet	Uusi maa	146	3.14	2.64	0.5	0.48	52.6	1.2	19.2	1.8	3.5	0.6	21.2
13_001 Summanjoki outlet	South east Finlan d	41	1.02	1.06	-0.04	0.46	34.8	5.4	53.0	1.4	2.4	1.6	1.4
34_011 Eurajoki outlet	Satak unta	138	1.9	1.66	0.24	0.65	67.7	1.9	15.9	1.9	2.8	2.9	6.9
44_011 Lapuanjoki outlet	South Ostro bothn ia	100	1.81	1.7	0.11	0.73	57.7	5.9	24.7	1.7	2.6	1.4	6.1

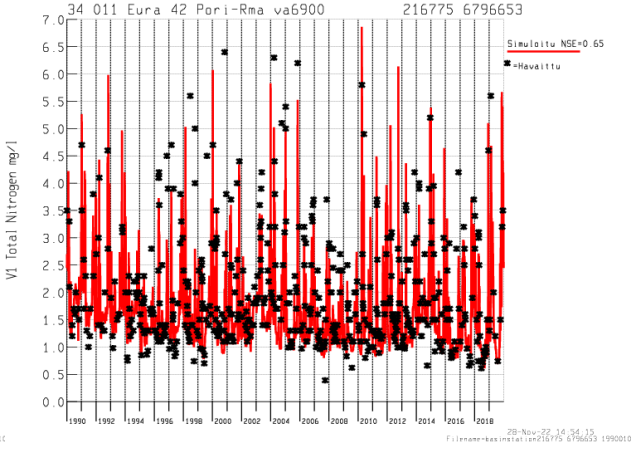
49_011 Perhonjoki outlet	Ostro bothnia	102	1.16	1.28	-0.12	0.54	40.4	10.6	38.4	1.5	1.7	2.1	5.4
53_011 Kalajoki outlet	North Ostro bothnia	93	1.57	1.55	0.02	0.68	52.2	9.1	28.9	1.7	2.0	1.1	5.0
57_012 Siikajoki outlet	North Ostro bothnia	96	1.04	1.06	-0.02	0.74	33.8	16.0	43.3	0.7	1.5	1.7	2.9

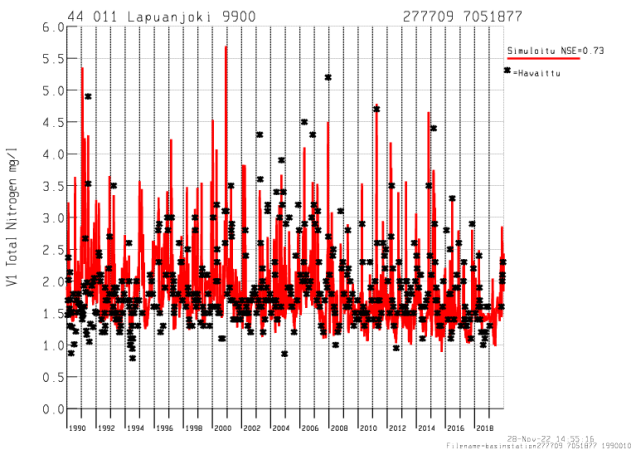
S3. Observed and simulated daily TN concentrations for selected test observation points.

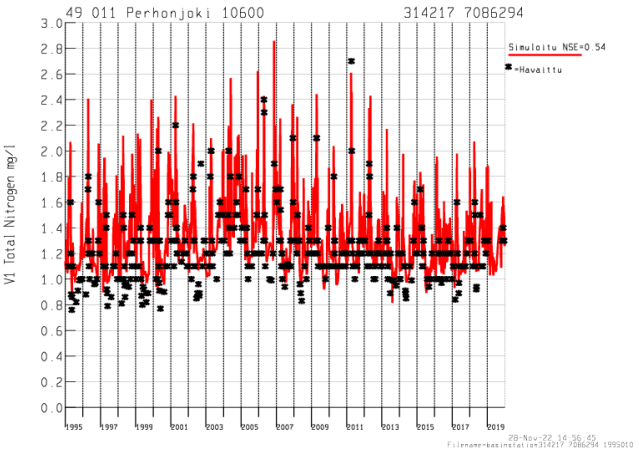


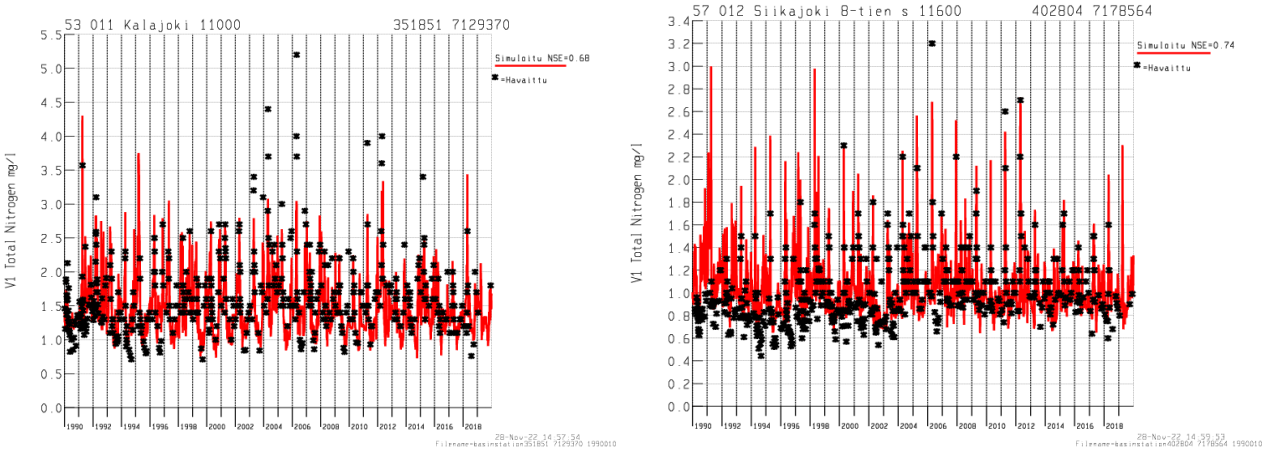




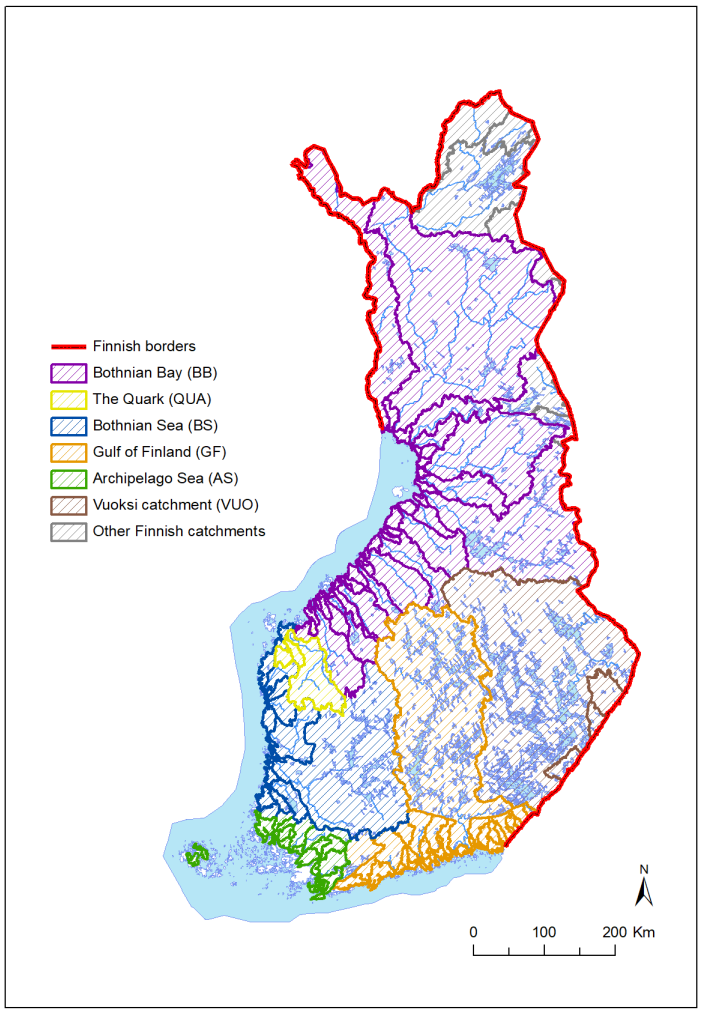




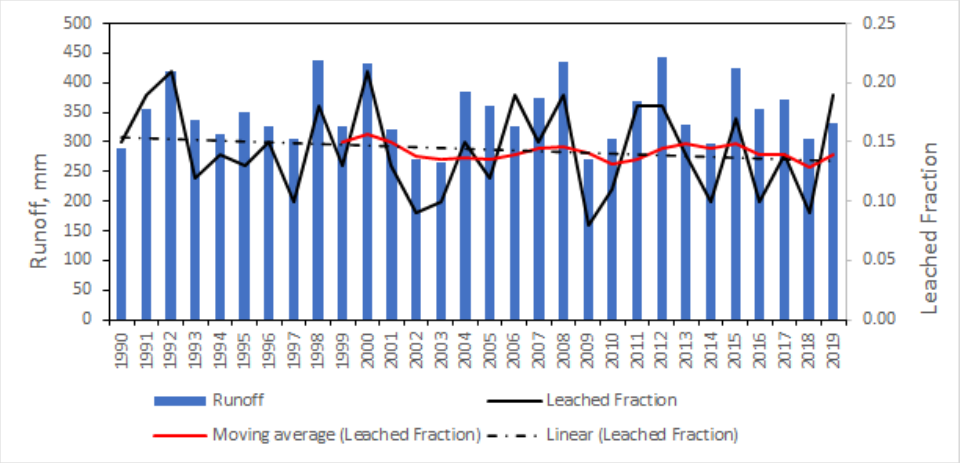


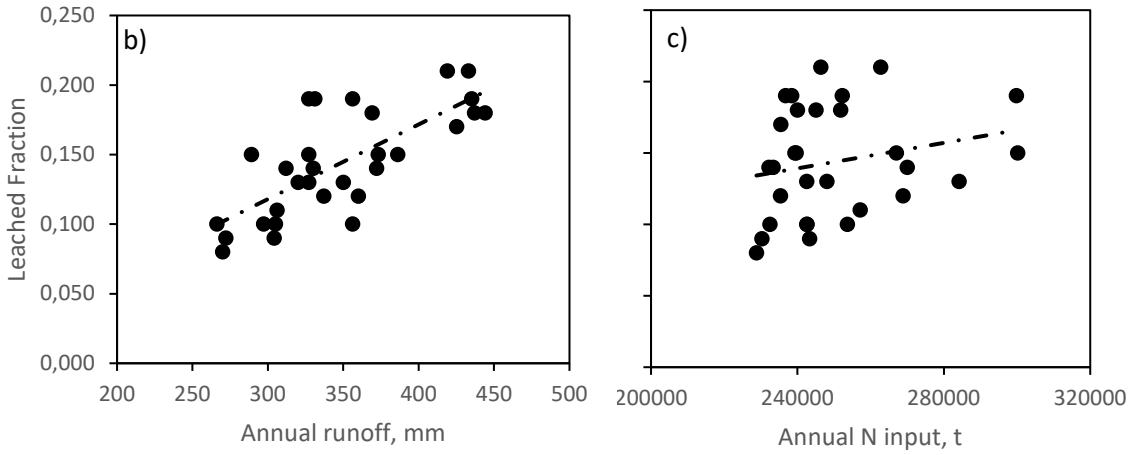


S4. Map of the Baltic Sea sub-basin catchments.



S5. a) Annual mean simulated runoff and leached N fraction for the whole Finland for years 1990-2019, and its relationship to b) annual meanrunoff and c) annual mean N input.





S6. Agricultural TN loading (10^3 t a^{-1}) for the whole Finland for the period 1990-2019

Year	Agricultural TN loading, 10^3 t a^{-1}	Year	Agricultural TN loading, 10^3 t a^{-1}	Year	Agricultural TN loading, 10^3 t a^{-1}
1990	43.8	2000	52.2	2010	27.6
1991	56.8	2001	33.0	2011	44.5
1992	55.7	2002	21.9	2012	44.4
1993	32.4	2003	24.2	2013	31.8
1994	37.3	2004	36.7	2014	24.7
1995	37.5	2005	27.5	2015	40.1
1996	40.1	2006	44.3	2016	23.2
1997	26.4	2007	35.0	2017	32.6
1998	44.8	2008	49.0	2018	21.6
1999	30.9	2009	17.7	2019	46.3
Mean	40.6		34.2		33.7