

Update on Steady state Critical Loads of the Czech Republic

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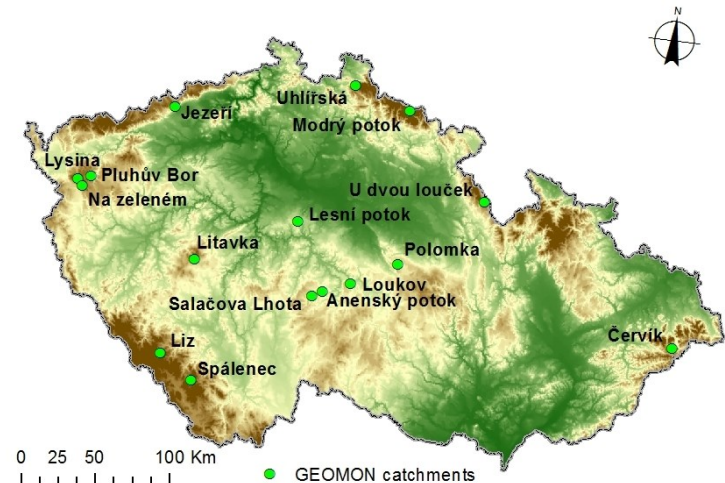
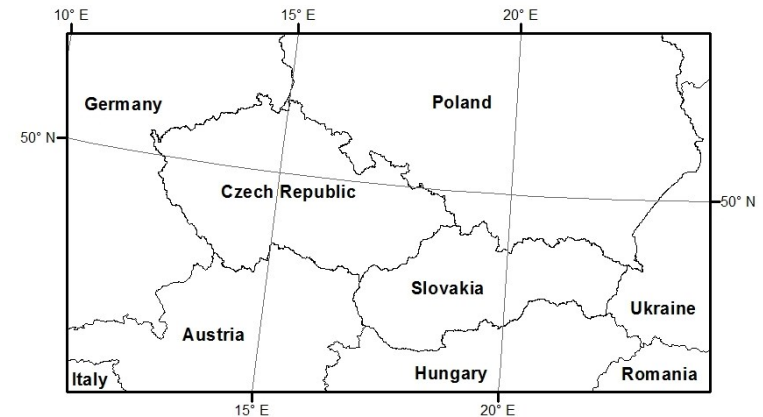
Collaborating experts:

Filip Oulehle

Jakub Hruška

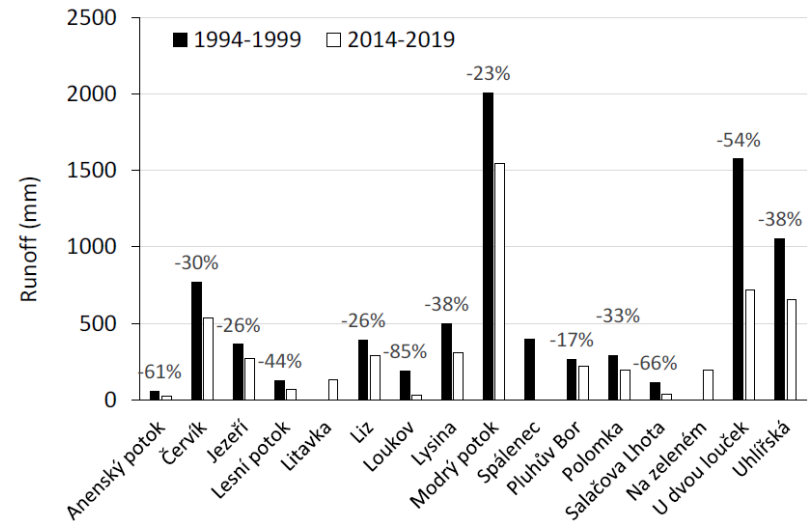


- new generalizable evidence from GEOMON network on changes in:
 - precipitation
 - temperature
 - evapotranspiration
 - runoff
- new evidence on denitrification rates (Oulehle et al. 2021 – under review)



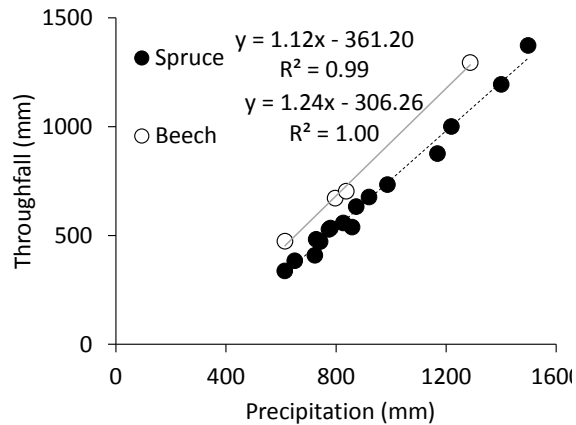
Changes in water balance and temperature

- annual precipitation - no significant overall trend
 - at four (Červík, Modrý důl, Polomka and U dvou louček) out of 16 catchments, linear trend analysis indicated significant ($p < 0.05$) precipitation reduction since 1994
- mean annual temperature increased by 1.27°C over the last two decades
- statistically significant ETo increase was observed at 14 out of 16 catchments
 - Average increase accounted for 45 mm per 1°C increase of air temperature



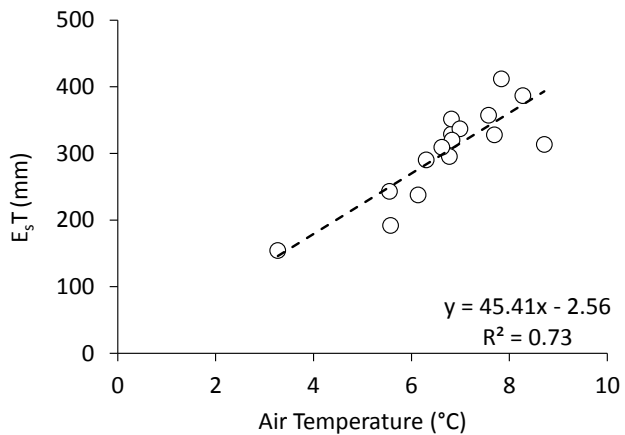
Name	Area (ha)	Latitude	Longitude	Elevation (m a.s.l.)			Air temperature ($^{\circ}\text{C}$)	
				max	mean	min	1962-2019	1994-2019
Anenský potok	26	49°33'N	15°05'E	546	520	486	7.0	8.3
Červík	181	49°27'N	18°23'E	961	802	637	5.8	6.8
Jezeří	260	50°33'N	13°28'E	906	758	479	5.7	6.8
Lesní potok	63	49°58'N	14°46'E	501	471	412	7.6	8.7
Litavka	179	49°39'N	13°51'E	844	774	694	5.9	7.0
Liz	94	49°03'N	13°40'E	1070	942	827	5.5	6.1
Loukov	54	49°38'N	15°19'E	702	577	472	6.6	7.8
Lysina	25	50°01'N	12°39'E	943	881	828	5.4	6.3
Modrý potok	254	50°43'N	15°41'E	1555	1301	1008	2.5	3.3
Na zeleném	60	50°00'N	12°43'E	802	786	733	6.0	6.8
Pluhův Bor	21	50°03'N	12°46'E	796	764	690	5.9	6.8
Polomka	66	49°47'N	15°45'E	650	614	554	6.6	7.7
Salačova Lhota	200	49°32'N	14°59'E	745	640	560	6.4	7.6
Spálenec	53	48°55'N	13°59'E	859	826	791	5.7	6.6
U dvou louček	30	50°13'N	16°29'E	955	922	878	4.4	5.6
Uhlířská	180	50°50'N	15°09'E	885	818	776	4.5	5.6

We extrapolated the derived relationships



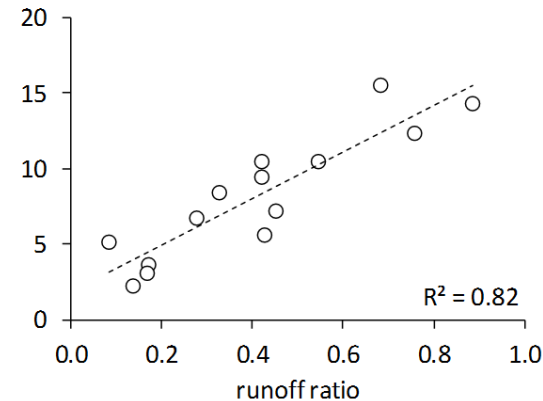
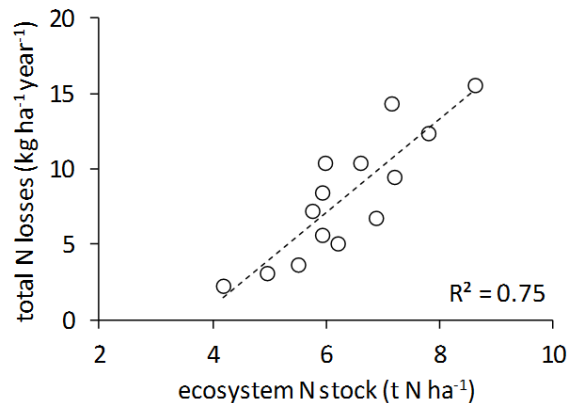
$$Q = \text{Precip.} - \text{Inter.} - \text{EsT}$$

$$\text{Inter.} = \text{Precip.} - \text{Thf}$$



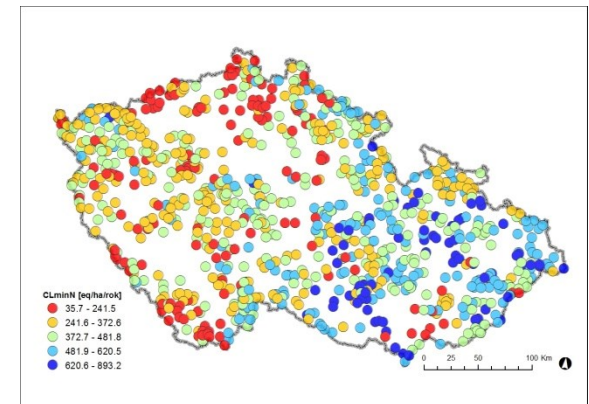
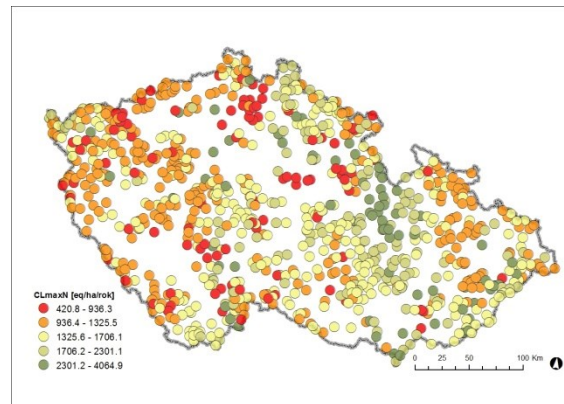
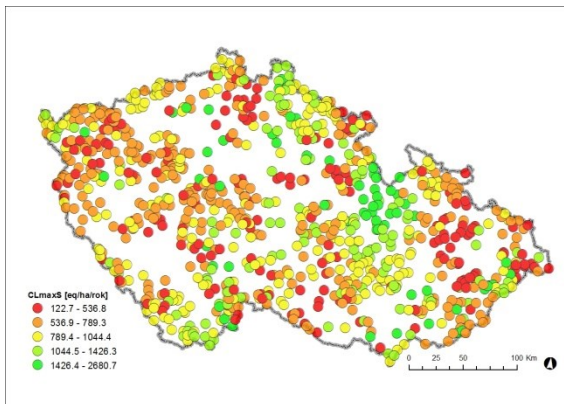
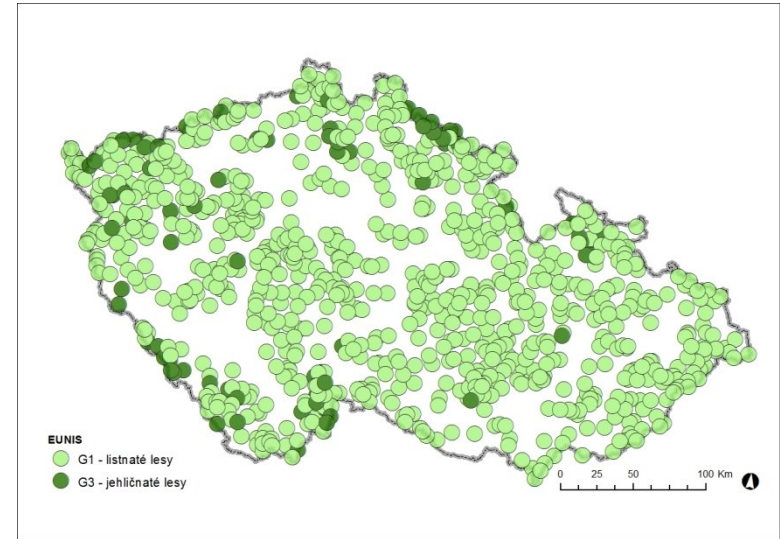
We updated data

- on BC depositions and Cl deposition
- on precipitation and temperature
- on denitrification (Oulehle et al. 2021)
 - measured dissolved N fluxes complemented by a detailed inventory of N stock and N isotope data in plant biomass and forest soil
 - an average denitrification flux of $2.6 \text{ kg N ha}^{-1} \text{ year}^{-1}$ (range = $0.1 - 7.0 \text{ kg N ha}^{-1} \text{ year}^{-1}$)



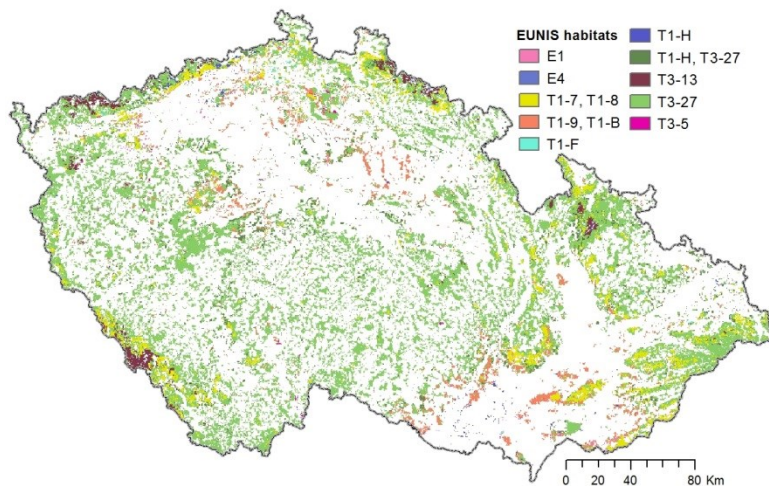
Former database

- 957 sites
- only forest
- reported area 6396.25 km²
- 8.2% of the national territory

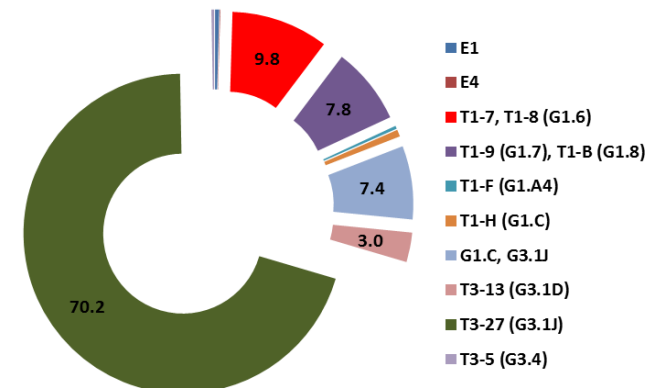


Updated database

- **area 23 831.25 km²**
- 30.2% of the national territory
- Forests
- Dry grasslands
- Alpine and subalpine grasslands

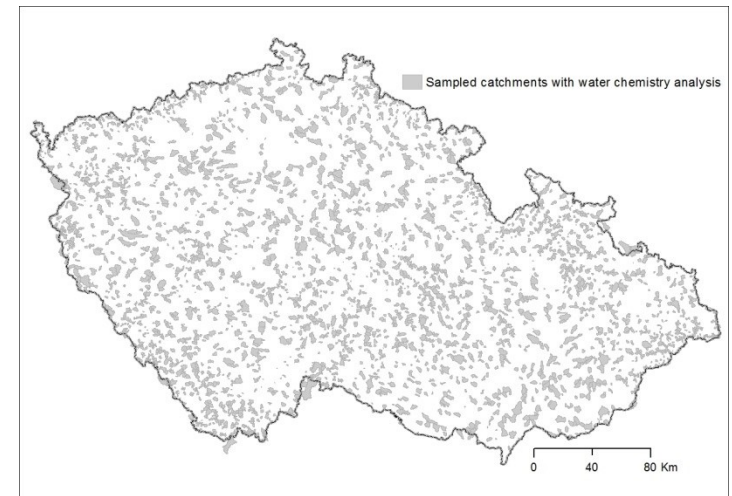


Habitat	EUNIS	Area considered [km2]	Area considered in [%] of the national territory
Dry grasslands	E1	98.5	0.1
Alpine and subalpine grasslands	E4	14	0.0
Fagus forest on non-acid soils/ Fagus forest on acid soils (Beech woodland)	T1-7, T1-8 (G1.6)	2345.75	3.0
Temperate and submediterranean thermophilous deciduous forest, Acidophilous Quercus forest (Thermophilous deciduous woodland, Acidophilous oak-dominated woodland)	T1-9 (G1.7), T1-B (G1.8)	1857.75	2.4
Ravine forest (Ravine and slope woodland)	T1-F (G1.A4)	72.25	0.1
Broadleaved deciduous planted forests of non site-native trees (Highly artificial broadleaved deciduous forestry plantations)	T1-H (G1.C)	168.5	0.2
Mixed forests (Highly artificial broadleaved deciduous forestry plantations and Norway spruce reforestation)	G1.C, G3.1J	1772.25	2.2
Hercynian subalpine Picea forests (Hercynian subalpine spruce forests)	T3-13 (G3.1D)	713.5	0.9
Picea abies reforestation (Norway spruce reforestation)	T3-27 (G3.1J)	16721.5	21.2
Temperate continental Pinus sylvestris forest (Scots pine woodland south of the taiga)	T3-5 (G3.4)	67.25	0.1
	Total	23831.25	30.2



Maximum critical load of sulphur $CL_{max}(S)$:

- $$CL_{max}S = BC_{dep} - Cl_{dep} + BC_w - BC_u - ANC_{lecrit}$$
- Weathering rates of base cations BC_w were derived from texture and parent material classes
 - computed using so-called weathering rate classes W_{class} and average annual soil temperature (equation V.44, CLRTAP, 2017).
- The parent material class was derived from detailed map of the Geochemical reactivity of rocks of the Czech Republic
- The BC_w was divided into respective cations, for individual rocks, based on their proportions in freshwater streams draining monolithological catchments with no settlement and intensive agriculture, sampled throughout the Czech Republic



	Na_share	Ca_share	Mg_share	K_share
mean	0.21	0.52	0.23	0.04
max	0.39	0.88	0.50	0.17
min	0.04	0.36	0.05	0.00

Maximum critical load of sulphur $CL_{max}(S)$

- Precipitation surplus (in mm)
 - equations derived from empirical data from the GEOMON catchments
- $Q_{br} = Thf_{br} - EsT$
- $Q_{con} = Thf_{con} - EsT$
 - Q_{br} - broadleaved forest precipitation surplus (in mm)
 - Q_{con} - coniferous forest precipitation surplus (in mm)
- Thf - throughfall precipitation
 - $Thf_{br} = 1,24 \cdot Precip - 306,26$
 - $Thf_{con} = 1,12 \cdot Precip - 361,20$
 - Thf_{br} – broadleaved forest throughfall precipitation
 - Thf_{con} – coniferous forest throughfall precipitation
 - Precip – mean annual precipitation (mm)
- EsT - Evapotranspiration
 - $EsT = 45,41 \cdot Temp - 2,56$
- Outside the range of environmental conditions covered by GEOMON, the precipitation surplus was computed according to equation V.96b in the Mapping Manual (CLRTAP, 2017)

Maximum critical load of nitrogen $CL_{\max}(N)$

- $CL_{\max}(N) = CL_{\min}(N) + CL_{\max}(S)/(1-f_{de})$
 - f_{de} denitrification fraction ($0 \leq f_{de} < 1$)
- Previously we used the f_{de} based on soil type and the clay fraction in the soil

Table CZ-5. Denitrification values used for various soil classes.

Clay %	f_{de}
0	0.0
5	0.1
15	0.1
25	0.3
32.5	0.7
52.5	0.7
peat	0.8

- the f_{de} was newly computed from the nitrogen denitrification and nitrogen deposition

$$f_{de_con} = N_{de_con} / N_{dep}$$

$$f_{de_br} = N_{de_br} / N_{dep}$$

-
- $N_{de_con} = 7.95 \cdot (Q_{con}/Precip) - 0,47$
-

- $N_{de_br} = 7.95 \cdot (Q_{br}/Precip) - 0,47$
-

- f_{de_con} – denitrification fraction for Coniferous forests
- f_{de_br} – denitrification fraction for Broadleaved forest
- N_{de_con} – denitrification in Coniferous forests (in $kg \cdot ha^{-1} \cdot yr^{-1}$)
- N_{de_br} – denitrification in Broadleaved forests (in $kg \cdot ha^{-1} \cdot yr^{-1}$)
- N_{dep} – nitrogen deposition (in $kg \cdot ha^{-1} \cdot yr^{-1}$)
- Q_{con} – coniferous forest precipitation surplus (in mm)
- Q_{br} – broadleaved forest precipitation surplus (in mm)

Outside the range of environmental conditions covered by GEOMON we adopted the denitrification fraction as a function of soil drainage from the Table V.7 in the Mapping Manual (CLRTAP, 2017). Sites covered by Histosols were excluded from the calculation.

Critical load of eutrophication CLeut

CLeutN reported values - the minimum values between CLnutN (computed by the SMB method) and CLempN

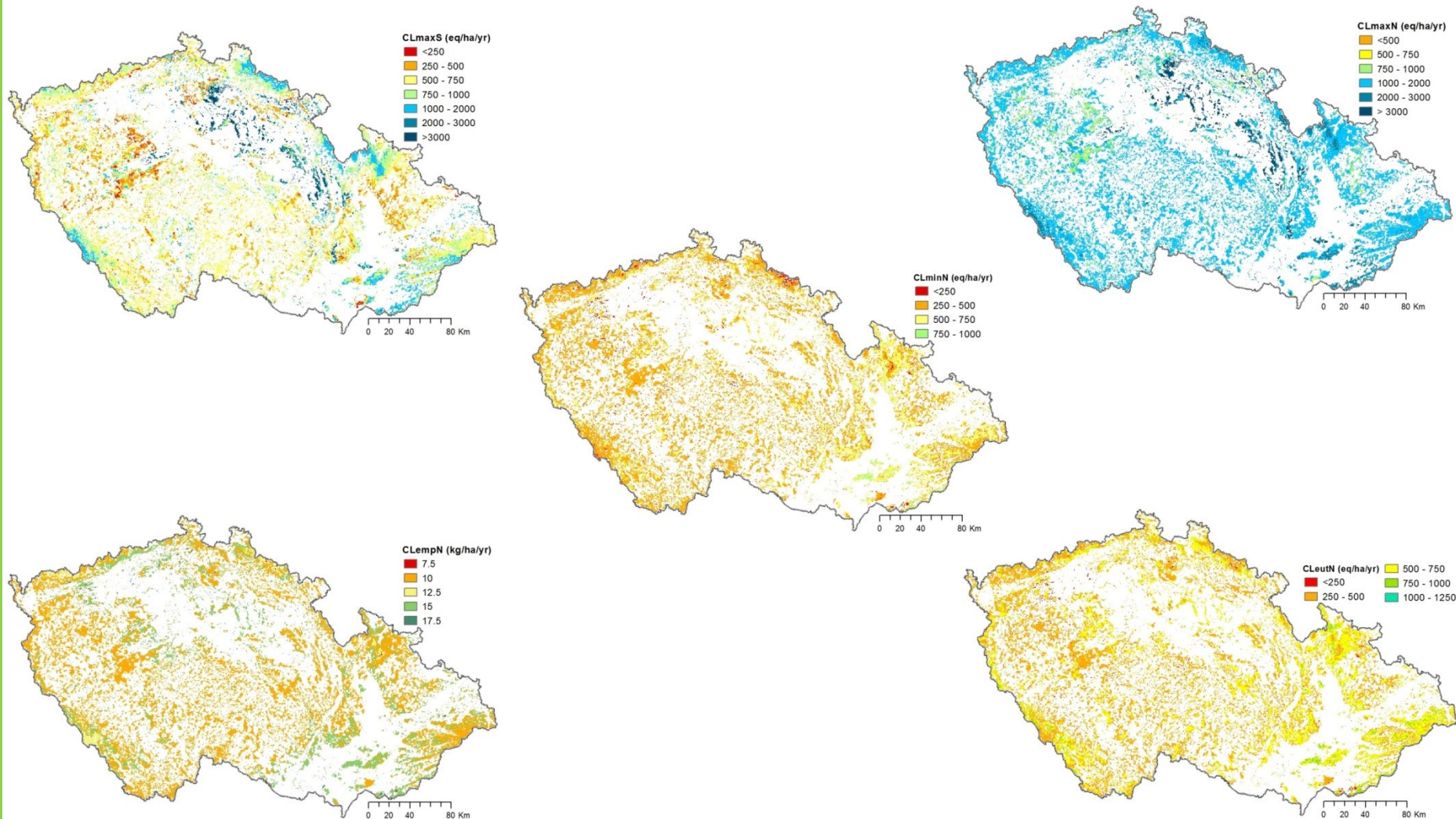
CLnutN:

- $CLnutN = N_{upt} + N_{imacc} + N_{leacc} / (1 - f_{de})$
 - f_{de} denitrification fraction
- $N_{le(acc)}$ acceptable leaching of nitrogen (in $eq \cdot ha^{-1} \cdot yr^{-1}$)
 - $N_{le(acc)} = [N]_{acc} \cdot Q$.
 - Acceptable N concentration was set according to the Mapping Manual (CLRTAP, 2017)
 - 1 ($mg \cdot l^{-1}$) for Coniferous forest and
 - 2 ($mg \cdot l^{-1}$) broadleaved forest and other ecosystems

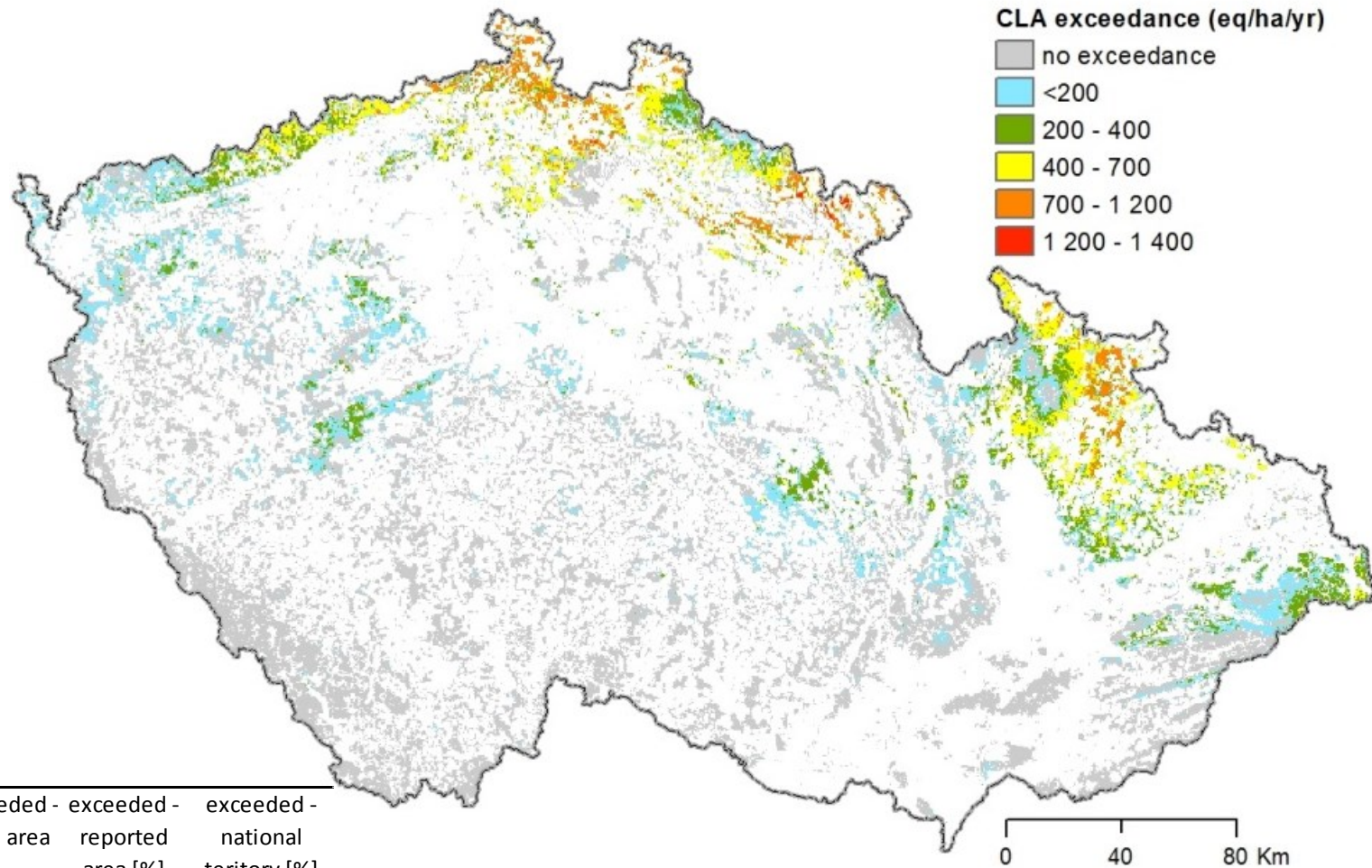
Empirical critical load of nitrogen CLempN

- For the selected EUNIS habitats we set an average value of the range listed for these habitats in the „Review and revision of empirical critical loads“ (Bobbink and Hettelingh, 2011)

Results



Results – CLacid

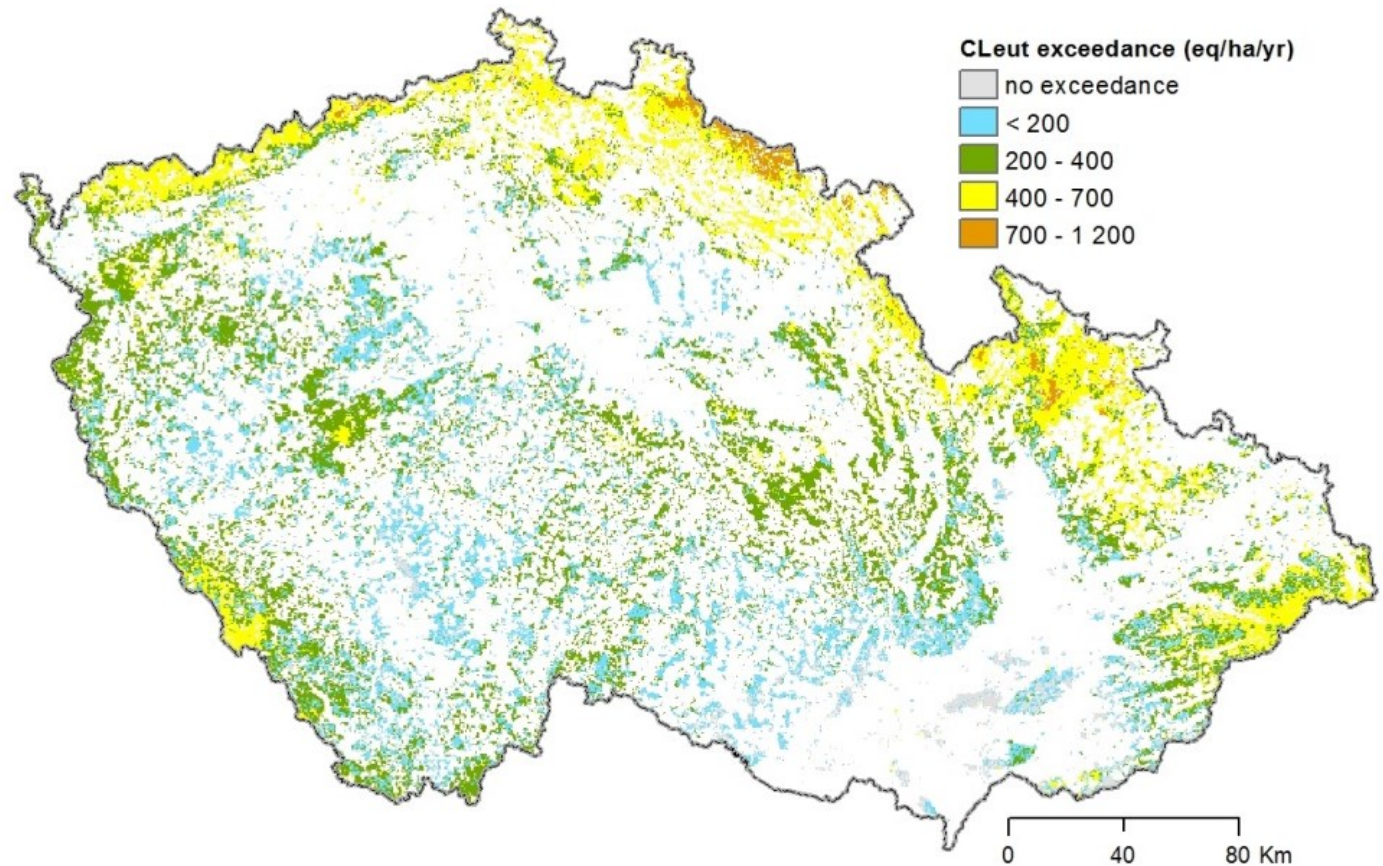
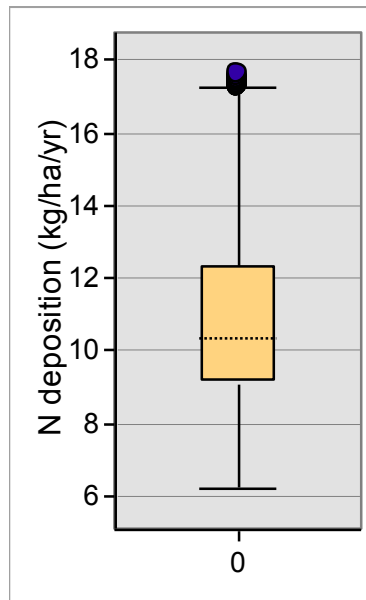


	not exceeded - reported area [%]	exceeded - reported area [%]	exceeded - national territory [%]
new database	64.6	35.4	10.7
former database	64.5	35.5	2.9

Results

Habitat	EUNIS	CLacid		
		not exceeded - reported habitat area [%]	exceeded - reported habitat area [%]	exceeded - national territory [%]
Dry grasslands	E1	94	6	0.0
Alpine and subalpine grasslands	E4	91	9	0.0
Fagus forest on non-acid soils/ Fagus forest on acid soils (Beech woodland)	T1-7, T1-8 (G1.6)	56	44	1.3
Temperate and submediterranean thermophilous deciduous forest, Acidophilous Quercus forest (Thermophilous deciduous woodland, Acidophilous oak-dominated woodland)	T1-9 (G1.7), T1-B (G1.8)	79	21	0.5
Ravine forest (Ravine and slope woodland)	T1-F (G1.A4)	50	50	0.0
Broadleaved deciduous planted forests of non site-native trees (Highly artificial broadleaved deciduous forestry plantations)	T1-H (G1.C)	64	36	0.1
Mixed forest (Highly artificial broadleaved deciduous forestry plantations and Norway spruce reforestation)	G1.C, G3.1J	63	37	0.8
Hercynian subalpine Picea forests (Hercynian subalpine spruce forests)	T3-13 (G3.1D)	55	45	0.4
Picea abies reforestation (Norway spruce reforestation)	T3-27 (G3.1J)	65	35	7.5
Temperate continental Pinus sylvestris forest (Scots pine woodland south of the taiga)	T3-5 (G3.4)	70	30	0.0
TOTAL		64.6	35.4	10.7

Results – CLeut



CLeut is exceeded on 94% of the reported area!

THANK YOU FOR YOUR ATTENTION