Trends of inorganic nitrogen deposition in European forests during the period 2000-2020

Arne Verstraeten[1], Andreas Schmitz[2], Aldo Marchetto[3], Nicholas Clarke[4], Anne Thimonier[5], Char Hilgers[6], Anne-Katrin Prescher[6], Till Kirchner[6], Karin Hansen[7], Tamara Jakovljević[8], Carmen Iacoban[9], Wim de Vries[10], Bernd Ahrends[11], Henning Meesenburg[11], Gunilla Pihl Karlsson[12], Per Erik Karlsson[12], and **Peter Waldner**[5]

[1]Research Institute for Nature and Forest (INBO), Brussel, Belgium (arne.verstraeten@inbo.be)
[2]State Agency for Nature, Environment and Consumer Protection of North Rhine-Westphalia, Germany
[3]National Research Council, Water Research Institute, Verbania Pallanza, Italy
[4]Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway
[5]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Switzerland
[6]Thünen Institute of Forest Ecosystems, Eberswalde, Germany
[7]Swedish Environmental Protection Agency, Stockholm, Sweden
[8]Croatian Forest Research Institute, Jastrebarsko, Croatia
[9]National Research and Development Institute in Forestry "Marin Dracea", Romania
[10]Earth Systems and Global Change Group, Wageningen University, The Netherlands
[11]Northwest German Forest Research Institute (NW-FVA), Göttingen, Germany
[12]Swedish Environmental Research Institute (IVL), Gothenburg, Sweden

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1. The ICP Forests deposition monitoring network

1970 – Acid rain and signs of forest dieback
(see e.g. Fig., Ulrich et al. 1979).

1979 – UNECE Convention on Long-range Transboundary Air Pollution
(**Air Convention, 1979**)

1985 – **International Co-operative Programme on Monitoring and Assessment of Air Pollution Effects on Forests (ICP Forests)**
Level I plot network: Tree health state monitoring.

1994 – ICP Forests Agreement and EU Council Regulation 1091/94:
Level II plot network: Intensive Monitoring,
atmospheric deposition, *meteorology, etc., etc*.
co-financing for EU Members ForestFocus -2007, Life+. 2009-'11..

2016 – EU National Emission Ceiling Directive (NEC Directive).

Photo: Thünen Institute for World Forestry

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Clean Air 40 YEARS

UNECE Convention (Geneva, 1979)

1. Methods: Sampler types and examples.

Open field (F)

Wet-only (WD)

3

Photo: A. Verstraeten

Bulk Deposition (BD)

2

Photo: A. Verstraeten

Photo: M. Leimer

Forest stand (S)

Throughfall (TF)

1

Photo: P. Waldner

Photo: D. Zlindra

Photo: O. Schramm

Stemflow (SF)

4

Photo: P. Waldner

Requirements: min. total area, min. replications, continuous sampling, weekly to monthly intervalls.

2. Methods: chemical analyses

- Quantity
- pH
- conductivity
- alkalinity
- K^+; Ca^{2+}; Mg^{2+}
- Na^+; Cl^-
- **NH_4^+-N**; **NO_3^--N**; NO_2^--N; Total N;
- SO_4^{2-}-S
- PO_4^{3-}-P
- DOC
- Al; Mn; Fe; Cu; Zn; Hg; Pb; Co; Mo; Ni; Cd; Total S; Total C; Total P; Cr; HCO3

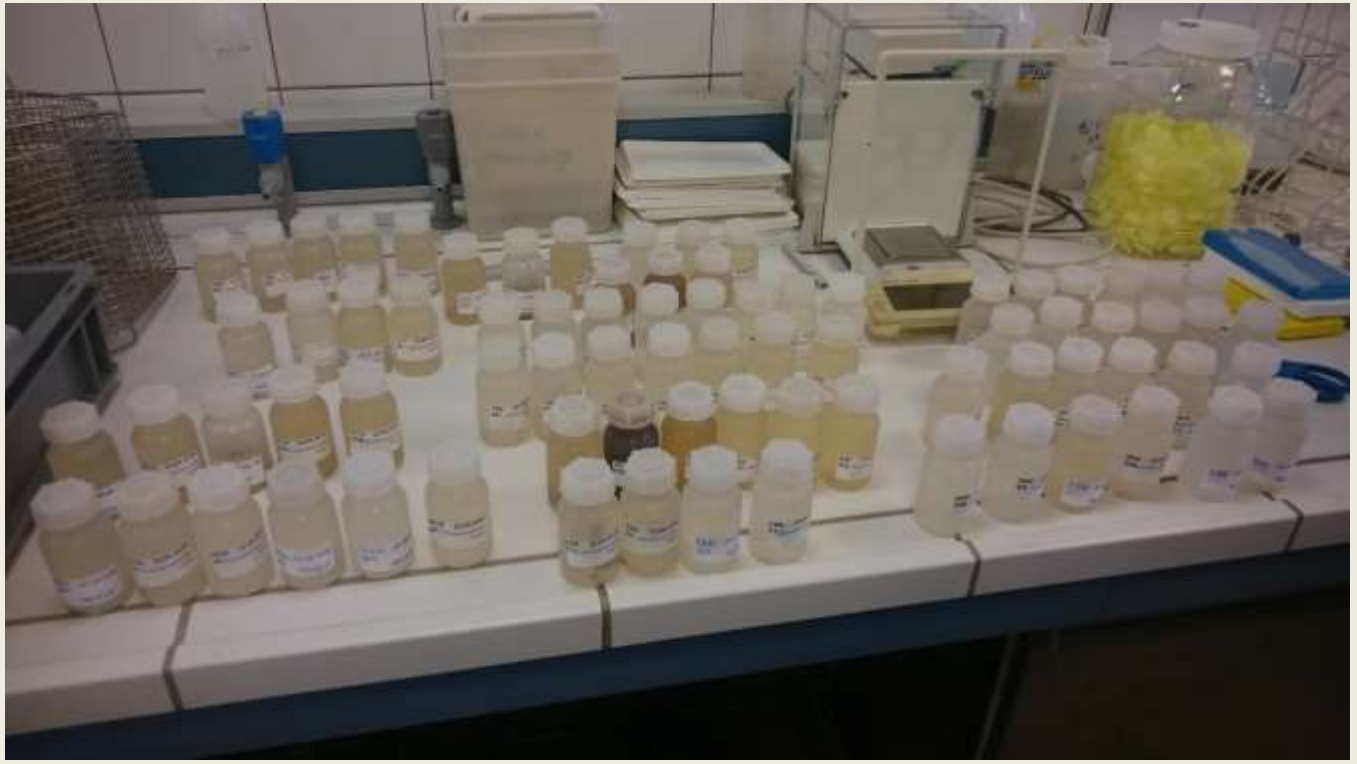
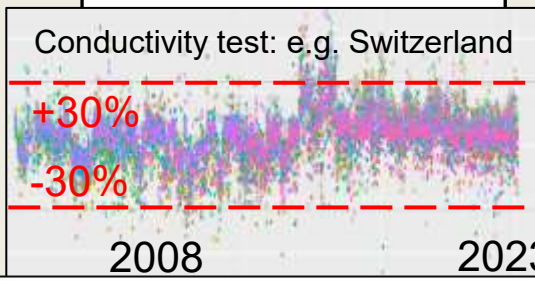
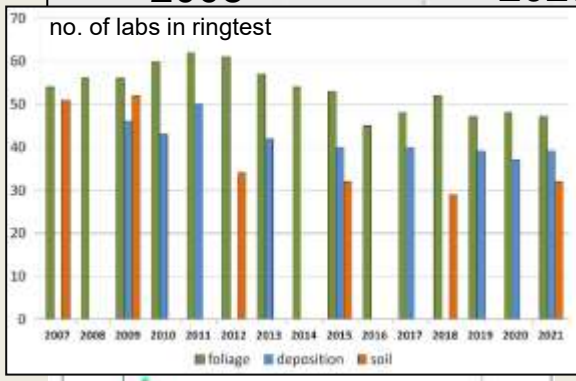


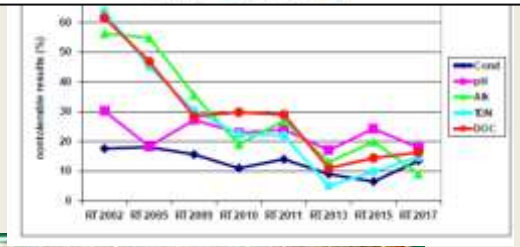
Photo: Arne Verstraeten

2. Methods: Quality assurance and quality checks

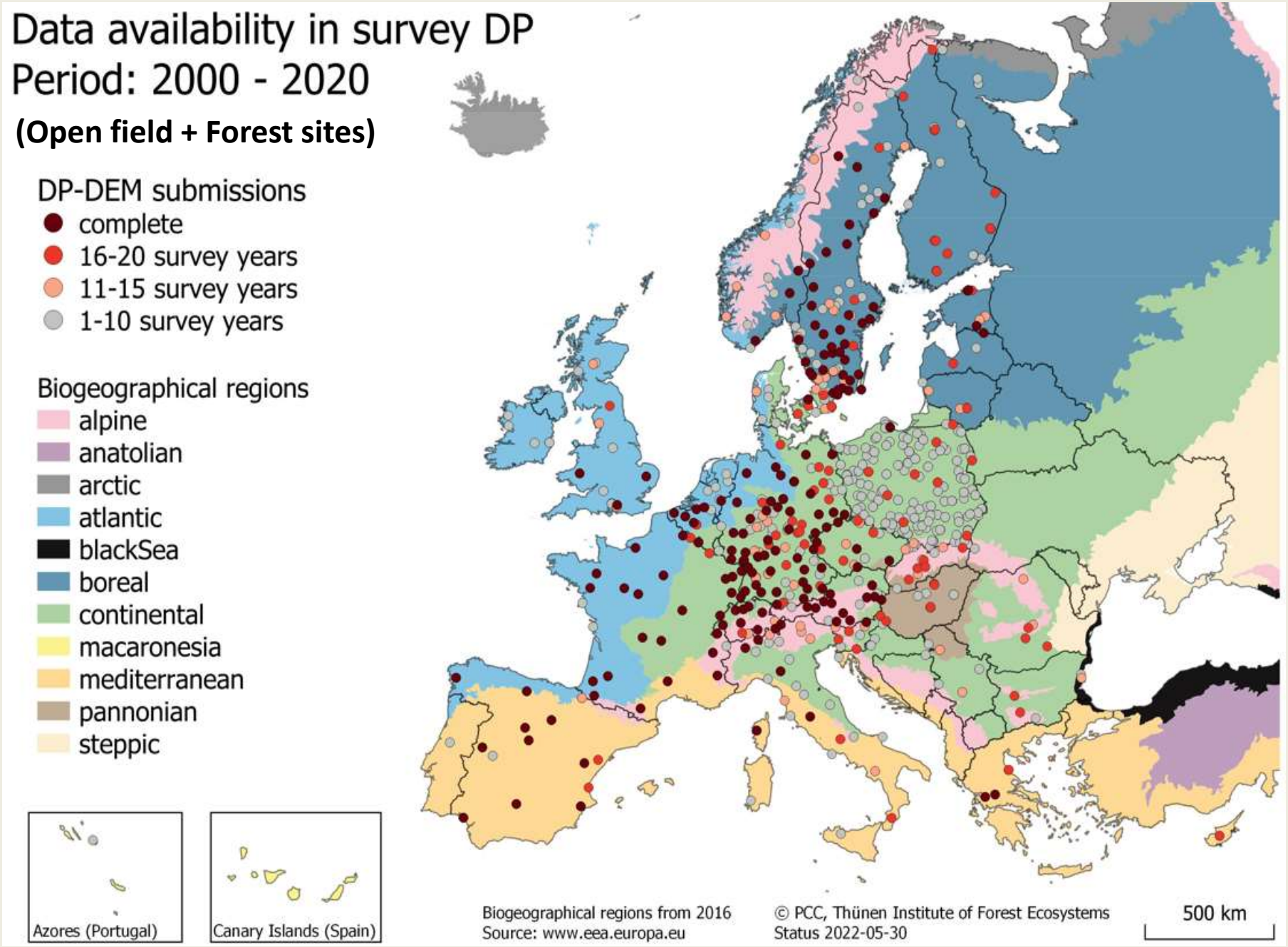
- **Harmonized methods**: ICP Forests Manual (Part XIV) continuously elaborated by an Expert Panel
  ***DQO**: detect changes of +/-30% in 10 years and between sites*
- **Field test and intercomparison:**
  (1) number of samplers to cover within plot variability tested
  (2) all samplers compared at 1 site Netherlands,
  (3) compare national and 1 harmonized sampler : many sites
- **Transportation and storage:** several tests were done
- **Analytical methods**: list of recommended methods
- **QC in labs** : consistency cond., ion balance, N comp., Na/Cl ratio
- **Control chards**: Local Reference Material (LRM) to test temporal stability
- **Ringtests**: mandatory since 2009 to test comparability.
- **Automated checks**:
  implemented in Data Portal of the Central Database
- *Further checking by PCC and EP members during evaluations*.







2. Methods: Sites descriptions



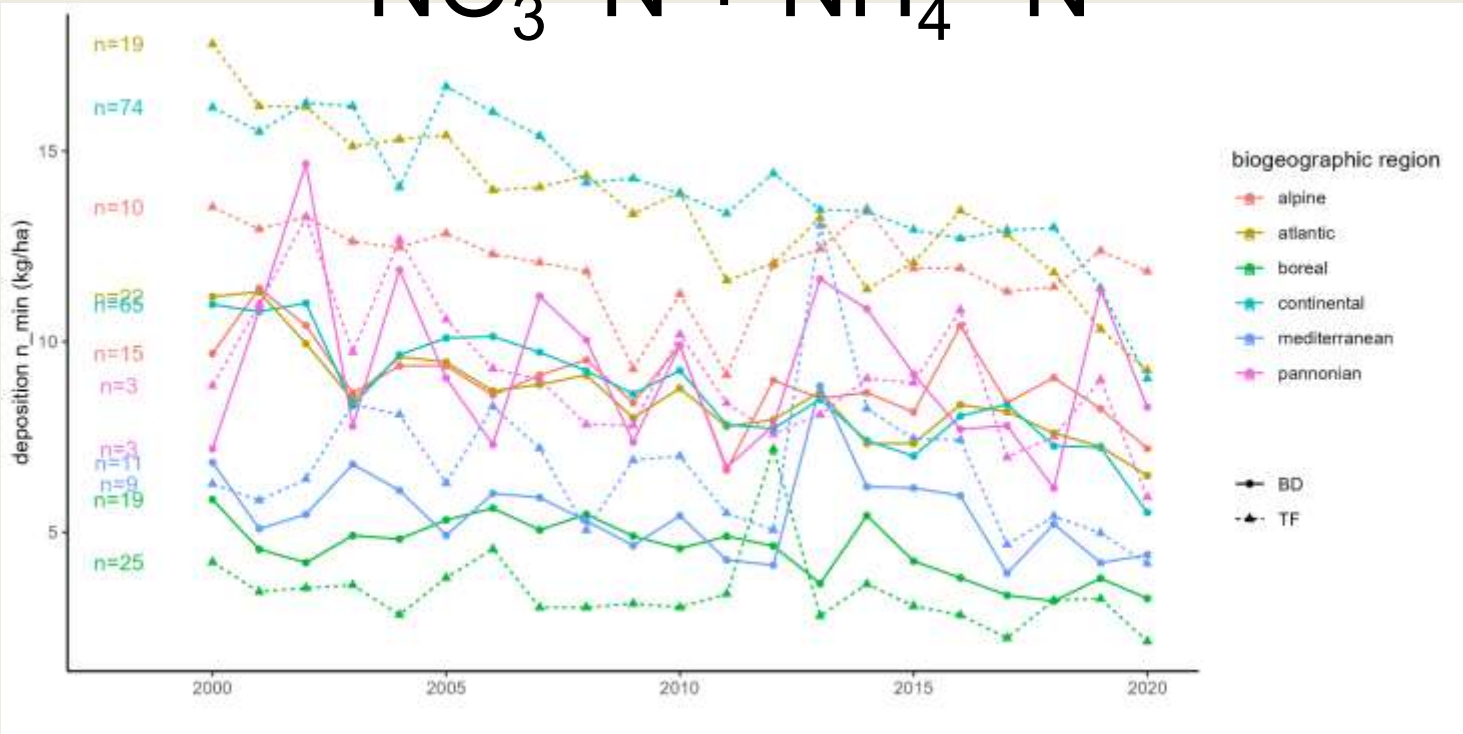
3. Trends in throughfall and bulk deposition

- Throughfall (TF) and Bulk Deposition (BD) sampling periods were aggregated to monthly data.
- Analysis plot-wise and grouped (6 biogeographical regions).
- Calculation of Sen's slope for linear trends (Sen 1978). Seasonal Partial Mann-Kendall Test for significance (Libiseller & Grimvall 2002). R-package ‘rkt’ (Marchetto 2021).
- Trends were evaluated for the whole 2000-2020 as well as for the first (2000-2010) and second decade (2010-2020), seperately.
- Only plots with complete time series, allowing for 1 missing year included.

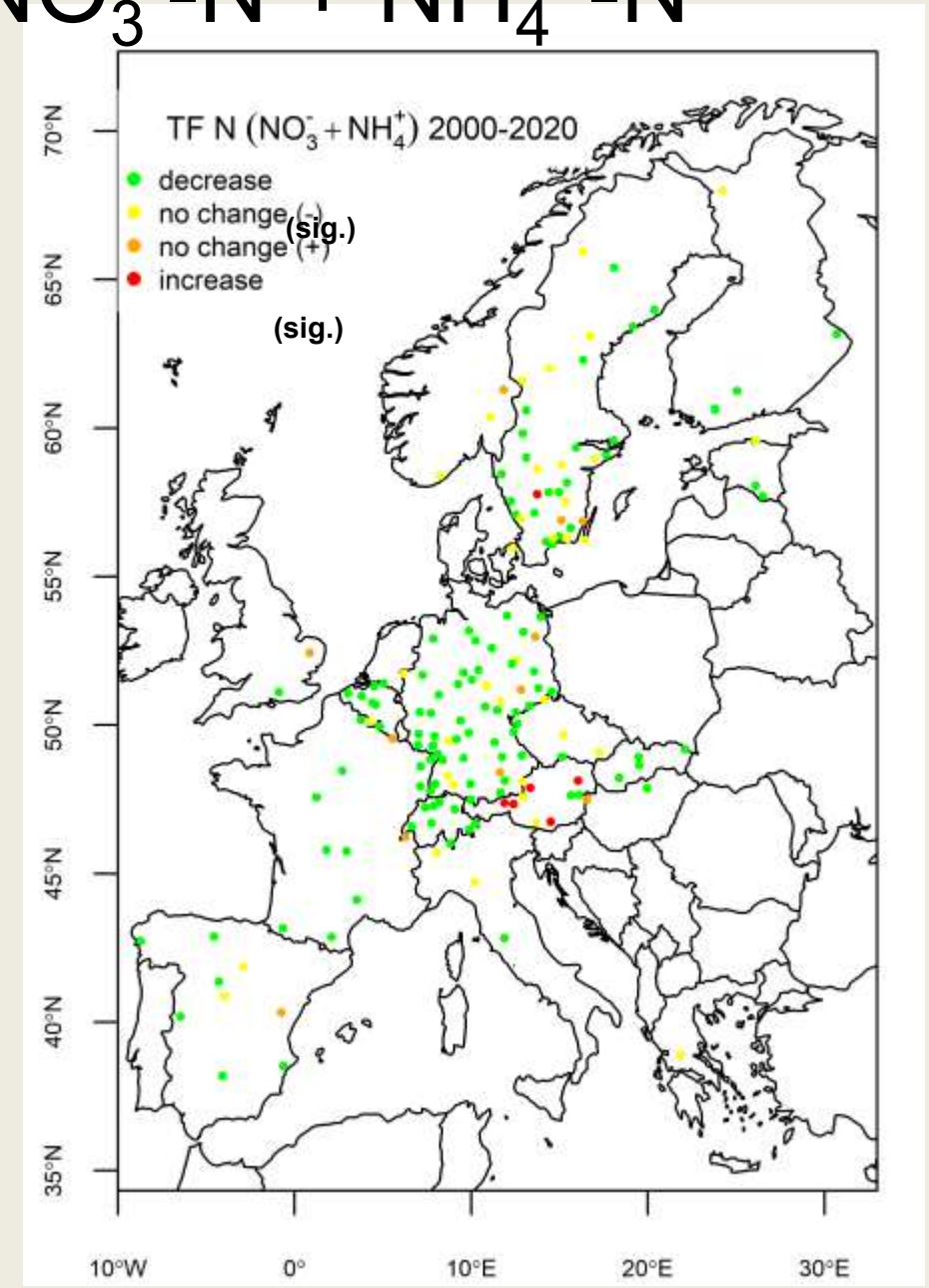
TF NO_3^--N + NH_4^+-N deposition

- Steady but slow decline.
- Increasing at a limited number of sites.

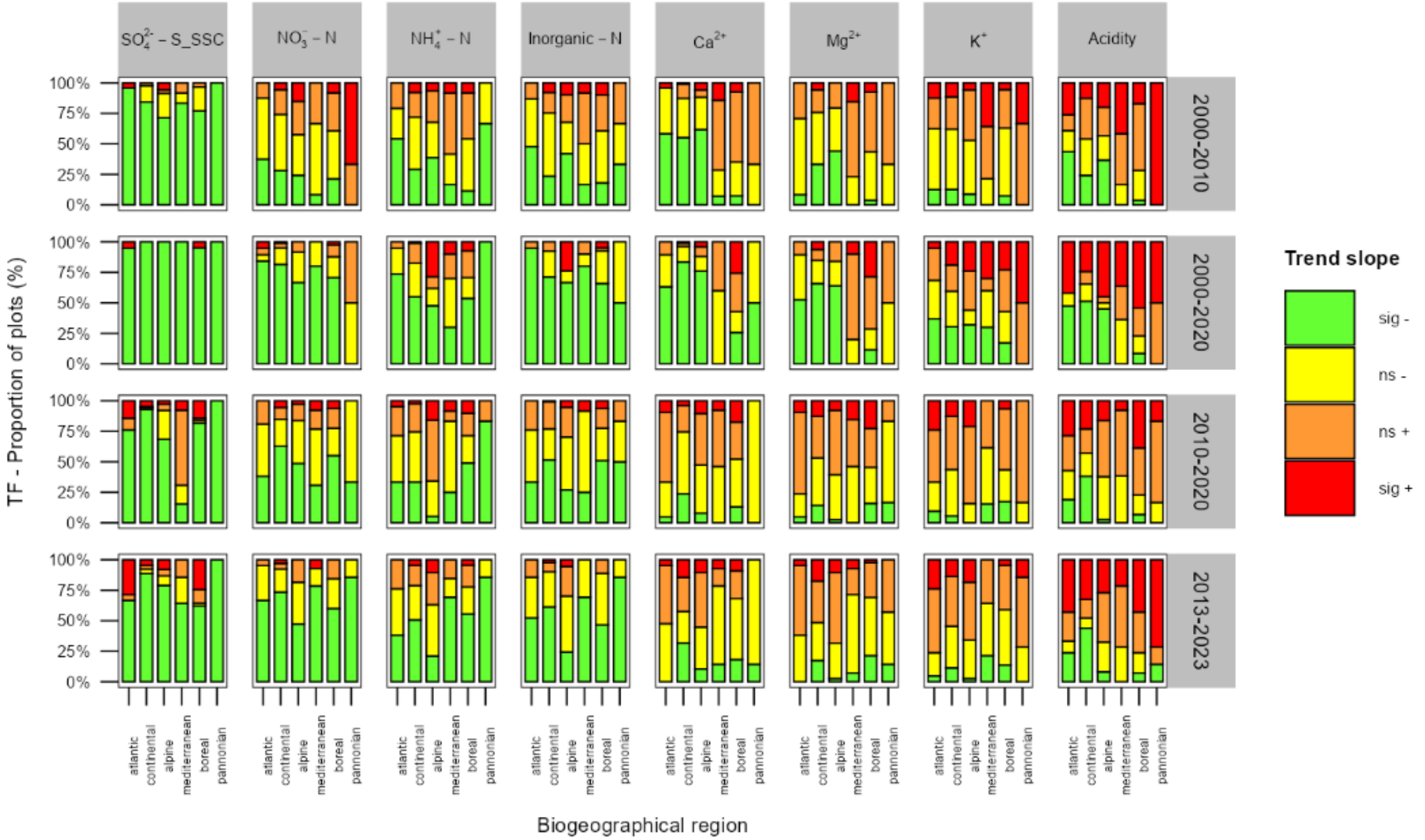
NO_3^--N + NH_4^+-N



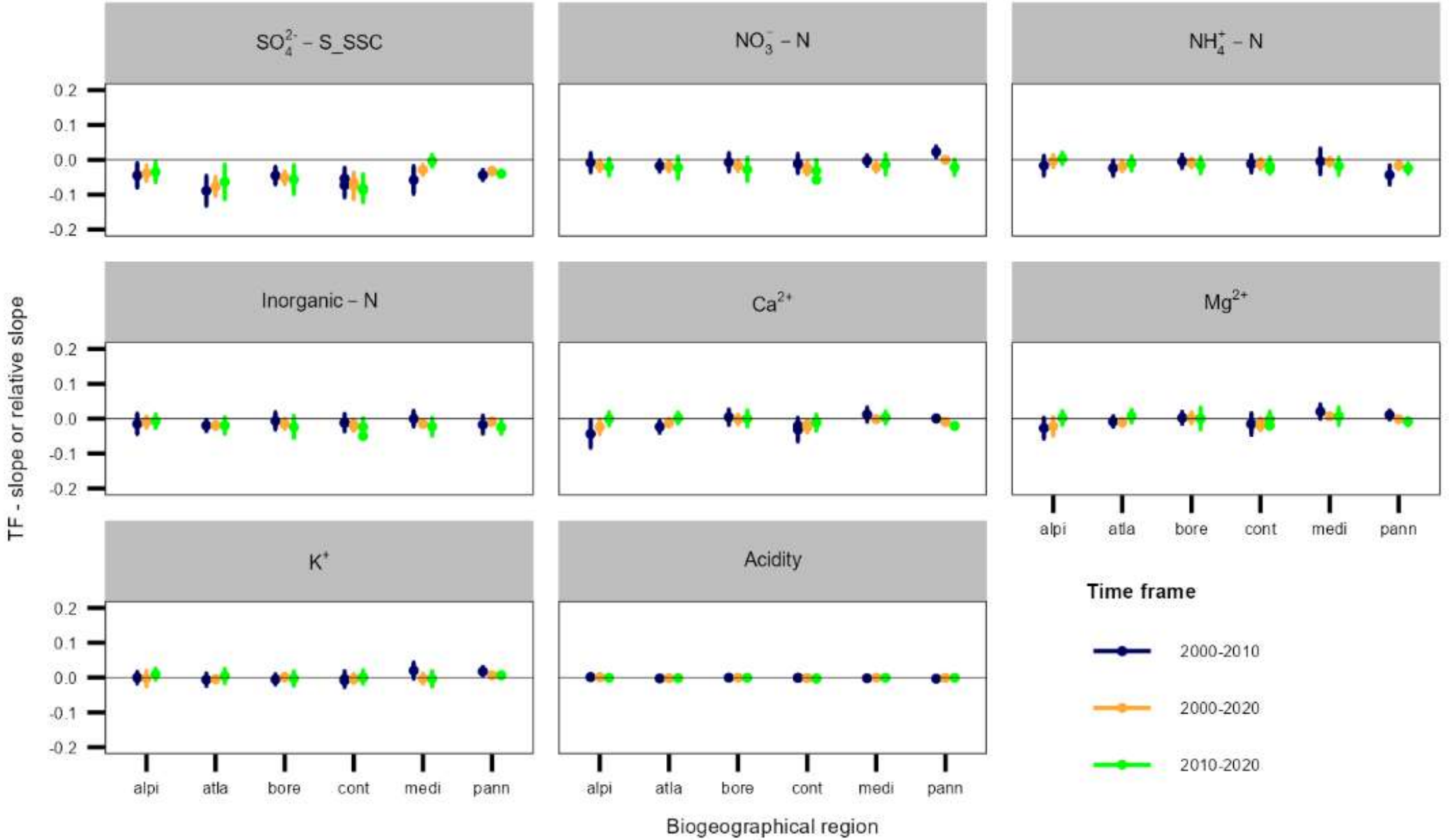
NO_3^--N + NH_4^+-N



Verstraeten et al. (in prep.)


SO_4^{2-} – S_SSC
NO_3^- – N
NH_4^+ – N
Inorganic – N
Ca^{2+}
Mg^{2+}
K^+
Acidity
2000-2010
2000-2020
2010-2020
2013-2023
100%
75%
50%
25%
0%
TF - Proportion of plots (%)
atlantic
continental
alpine
mediterranean
boreal
pannonian
Biogeographical region
Trend slope
sig -
ns -
ns +
sig +

4. Temporal trend relative slopes TF



5. Conclusions

- TF NO_3^--N decreased -10 to -30% but is re-increasing at some sites.
- TF NH_4^+-N decreased lesser and is stable or increasing at more sites.
- TF Inorganic N deposition steadily declined, but less than SO_4^{2-}S (that declined ~60% since 2000).
- TD of inorganic N is highest in central Europe (and low e.g. in inner-alpine Valleys). S and BC have slightly different patterns.
- Long-term measurements are required to study deposition trends.

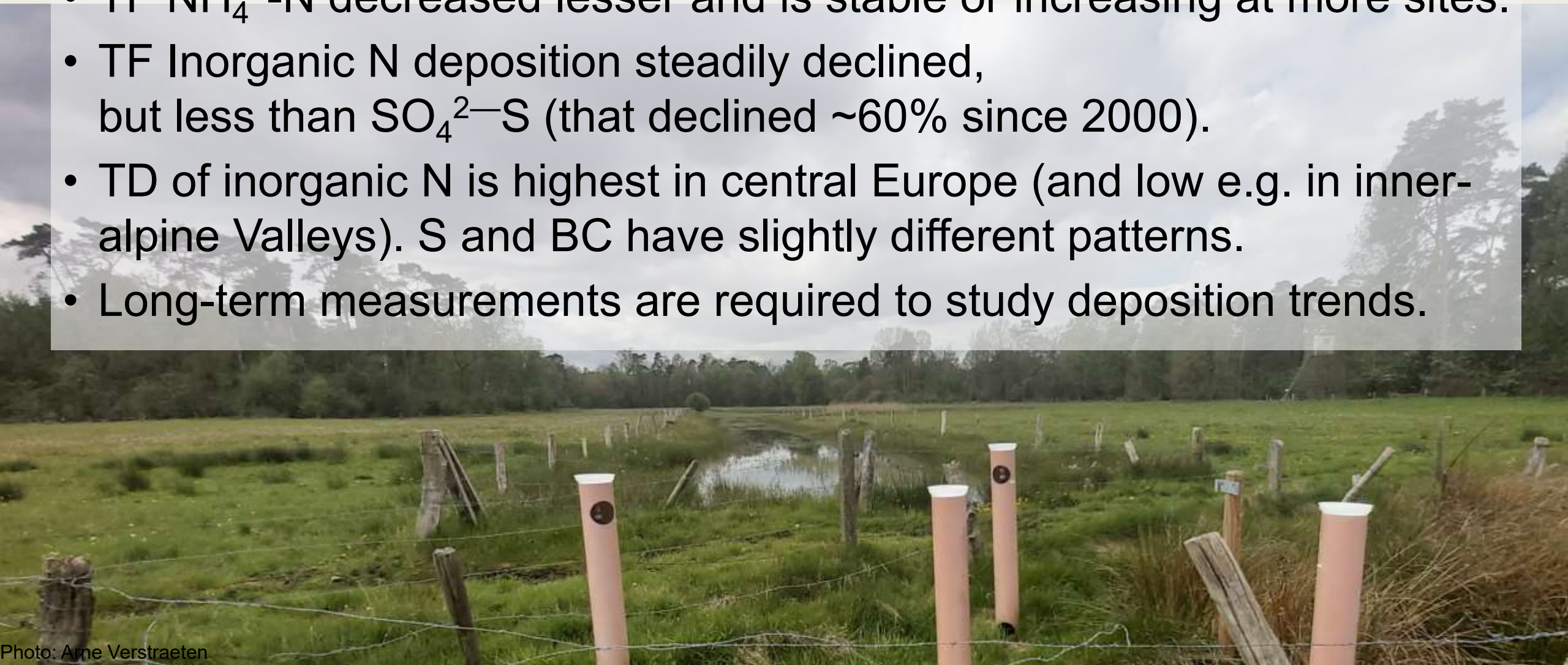


Photo: Arne Verstraeten

Acknowledgements

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We would like to especially thank all the numerous field observers, laboratory staff and scientific experts for the decades of dedicated work that enabling the creation of these unique time series.

Thank you for your attention!

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http://www.icp-forests.org/documentation