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Epiphytic lichen response to air pollution and other stress

Paolo Giordani, Vicent Calatayud,
Silvia Stofer, Oliver Granke

a Life+ co-financed project for the "Further Development and Implementation of an EU-level Forest Monitoring System".

The project coordination centre is situated at the Institute for World Forestry, Hamburg, Germany.

Outline of the presentation

- Aims of the work
- Brief theoretical frame work
- Methods
- Results: the effects of pollution on lichens in European forests
- Conclusions

Aims of the work

- **Detecting N deposition thresholds** causing a shift of epiphytic lichen communities in European forests, **in relation to forest type, precipitations.**

- **Identifying lichen functional groups** responding to pollution-related stresses (e.g. N deposition).

- Overview of **geographic patterns of thresholds exceedance** at the monitored plots.

- **Political**: improving the knowledge on the effects of N on lichens for contributing to CLEs, CLOs, CLs in different forest ecosystems throughout Europe.

- **Scientific**: understanding the interactions between lichen diversity, pollutants , climate and forest structural parameters.

Because of their close dependence on the atmosphere for their metabolic processes epiphytic lichens are among the most sensitive organisms to air pollution.

Nevertheless, they are also strongly influenced by both macro- and microenvironmental variables, which affect their richness, abundance, and distribution on different spatial scales.

- **Epiphytic lichen sampling** at 83 Level II intensive monitoring plots.

- **Yearly average throughfall deposition** data (nitrogen and sulphur compounds) from intensive forest monitoring.

- **Forest type and precipitations** data at the same plots.

A minimum of 12 trees per plot

A monitoring grid (4 independent quadrat segments of five 10 x 10 cm squares each attached vertically to the trunk)

The four quadrats placed to correspond with the 4 aspects (NSEW) of the tree trunk.

Methods

Selection of lichen functional groups

- For each sampled species, **ecological indices from the literature were assigned**, based on Nimis & Martellos (2008) and in Wirth (2005).
- Species were assigned to three groups in relation to nitrogen tolerance: **oligotrophic, mesotrophic, and nitrophytic**.
- A **further grouping was performed based on growth form** (macro vs. microlichens).

Methods

Selection of functional groups: oligotrophic macrolichens

Methods

N Critical Loads and threshold for lichen community composition

L.H. Geiser et al. / Environmental Pollution 158 (2010) 2412–2421 2419

Table 7

Comparison of lichen community based CLs for the US and Europe. Application of the regression model developed for western Oregon and Washington (Table 3 Eq. (1)) to datasets from California and Scotland using appropriate precipitation ranges and comparable thresholds for lichen community composition yielded CLs comparable to published CLs. Applying a more protective lichen response threshold to the Scotland data yielded lower CLs (italics) than published CLs.

Study area	Threshold lichen community composition	Matching OR/WA air score	Ann precip (cm)	CL using OR/WA model (kg N ha^{-1} y^{-1})	Previously published CL (kg N ha^{-1} y^{-1})	Reference	N Deposition measure
Wet coniferous forest, western	30–41% Oligotrophs	0.21	44	2.7		This paper	CMAQ
OR & WA, US	30–41% Oligotrophs	0.21	186	5		This paper	CMAQ
	30–41% Oligotrophs	0.21	451	9.2		This paper	CMAQ
Mesic coniferous forest, California	40% Oligotrophs	0.02–0.21	111	2.5–3.8	3.1	Fenn et al., 2008	Throughfall
Sierras, US	25% Oligotrophs	0.33–0.49	111	4.6–5.7	5.2	Fenn et al., 2008	Throughfall
	0% Oligotrophs	1.0–2.0	111	9.1–15.8	10.2	Fenn et al., 2008	Throughfall
Mediterranean mixed hw-conifer forest,	50% Eutrophs	0.33–0.49	17	3.1–4.2	5.5	Fenn et al., in press	CMAQ
Greater Central Valley, California, US	50% Eutrophs	0.33–0.49	156	5.3–6.4	5.5	Fenn et al., in press	CMAQ
Wet Atlantic oakwoods, Scotland, UK	0% Oligotrophs	1.0–2.0	221	10.8–17.5	11–18	Mitchell et al., 2005	Stem flow
	25% Oligotrophs	0.33–0.49	221	*6.4–7.4*		This paper	
Boreal Sweden	↓Diversity & cover	n.a.	n.a.	n.a.	5–10	Nordin et al., 2005	N additions
The Netherlands	↓Diversity & cover	n.a.	n.a.	n.a.	8–9	Van Dobben et al., 2006	Simulated

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Results

Spearman correlations between functional groups and N

Spearman Rank Order Correlations	
Functional group	**Total dry N**
Macro meso	-0,25
Macro nitro	-0,20
Macro meso+nitro	-0,28
Macro oligo	-0,70
Micro meso	0,03
Micro nitro	-0,18
Micro meso+nitro	0,04
Micro oligo	0,12
All Species Richness	-0,39
%macro meso	-0,26
%macro nitro	-0,18
%MACRO meso+nitro	-0,27
%macro oligo	-0,65
%micro meso	0,28
%micro nitro	-0,15
%micro meso+nitro	0,26
%micro oligo	0,55

A **Non Parametric Multiplicative Regression** was performed on the functional group **%oligotrophic macrolichen species**

Total Cross R^2= 0.49; $p<0.01$

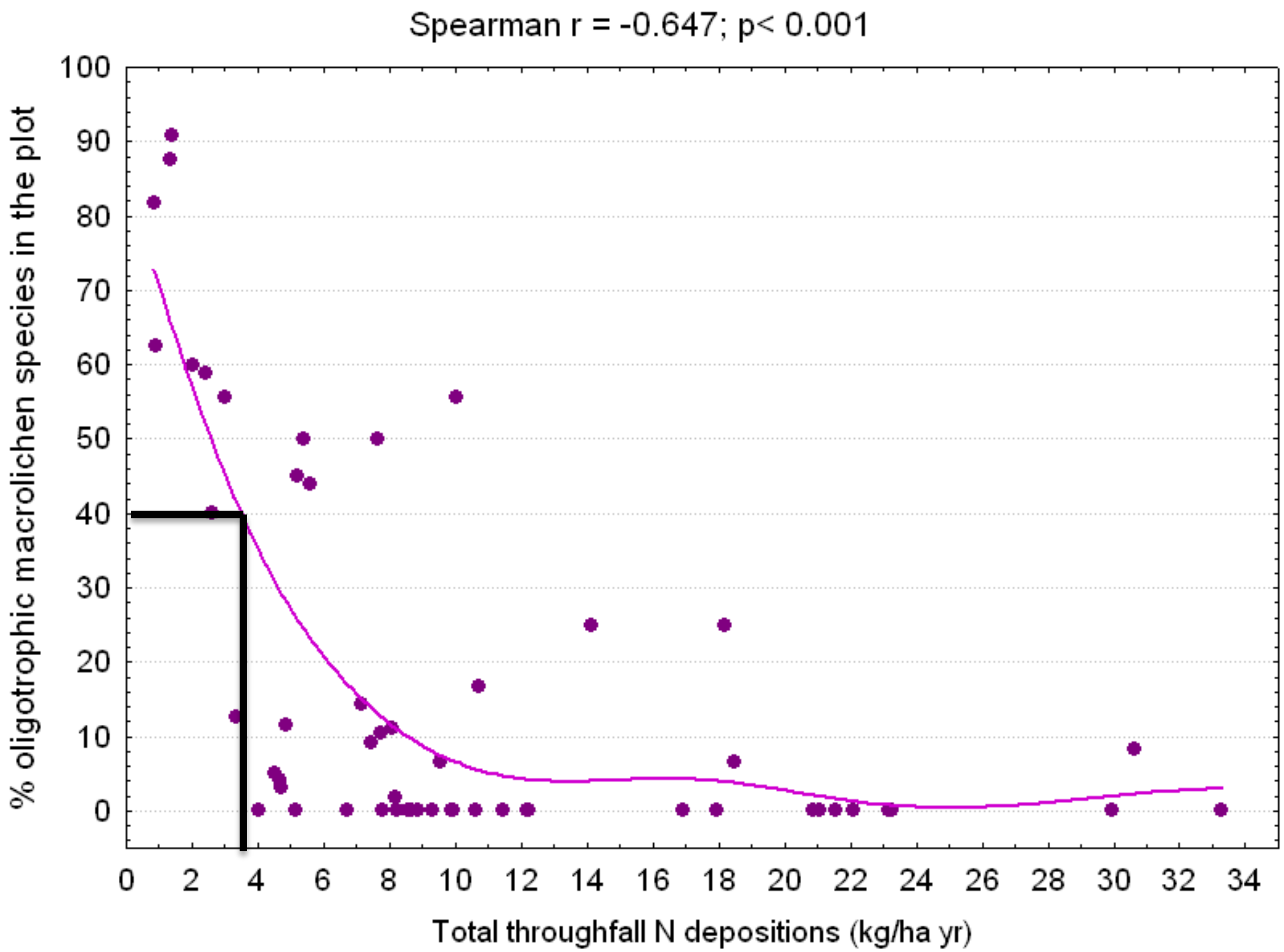
Order of inclusion of the predictors in the model (cumulative Cross R^2):

1. Forest type (0.21)
2. Precipitations (0.33)
3. Total N depositions (0.48)
4. Sulphate depositions (0.49)

Results

Total throughfall N depositions on % oligotrophic macrolichens

A throughfall nitrogen deposition **≈ 3.8 kg/ ha yr** was related to the threshold of 40% oligotrophs.



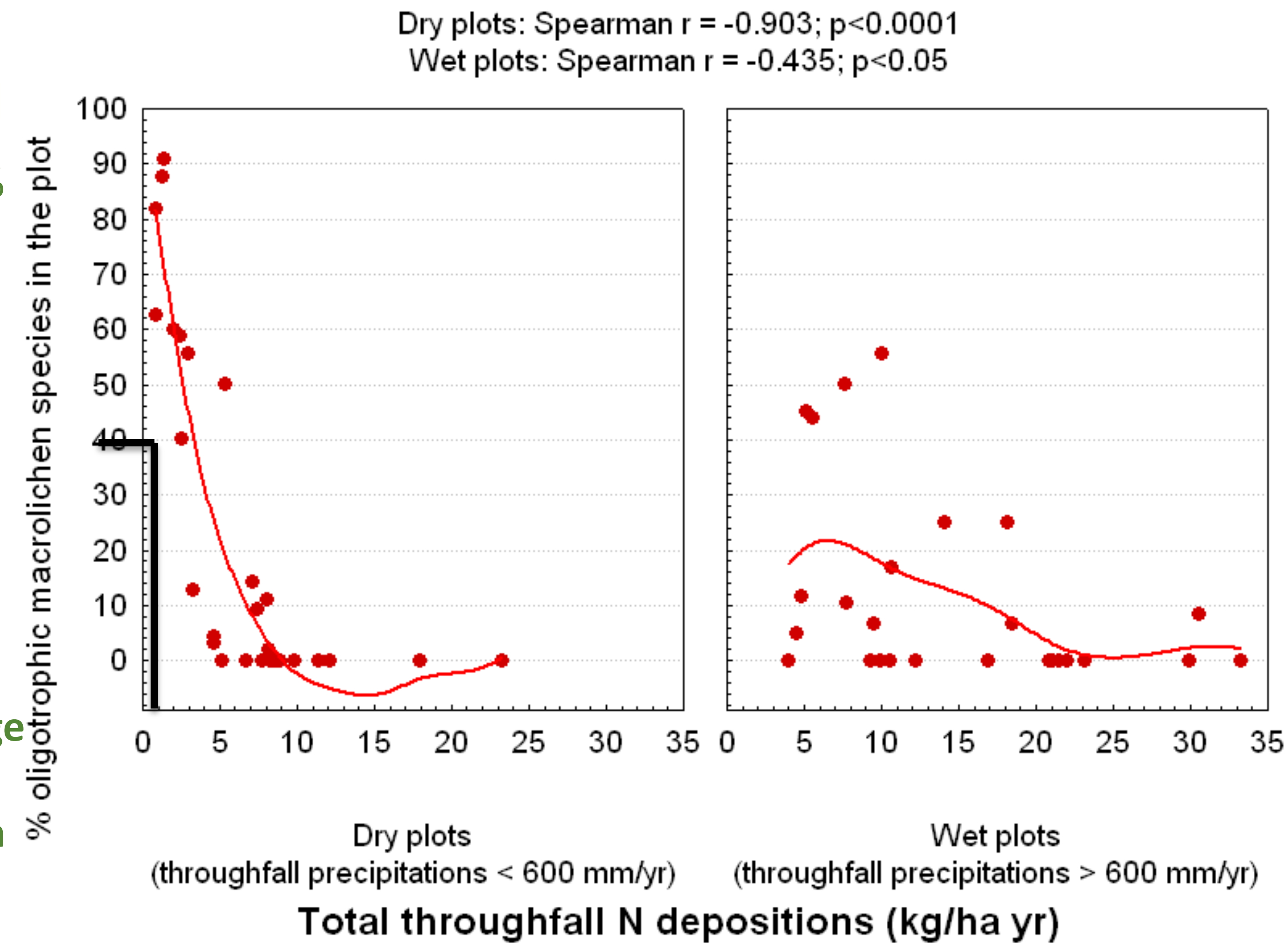
Results

The interaction with precipitations

3.5 kg/ha yr
N depositions were associated to the 40% oligo threshold in plots with low precipitations

>9 kg/ha yr
lead to a complete disappearance of oligotrophic species

A **modeled percentage of 20% oligotrophic species is expected in plots with higher annual precipitation.**

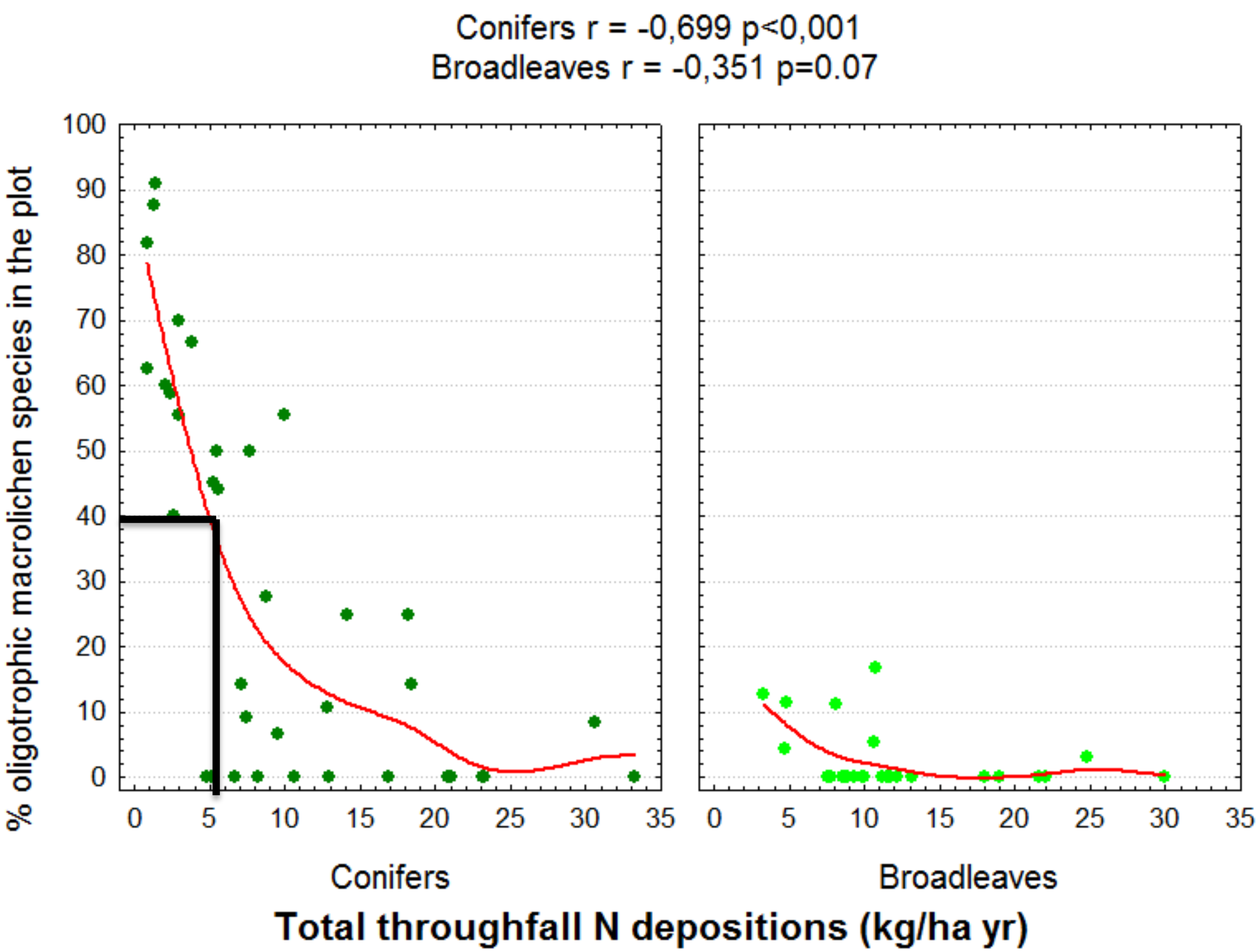


Results

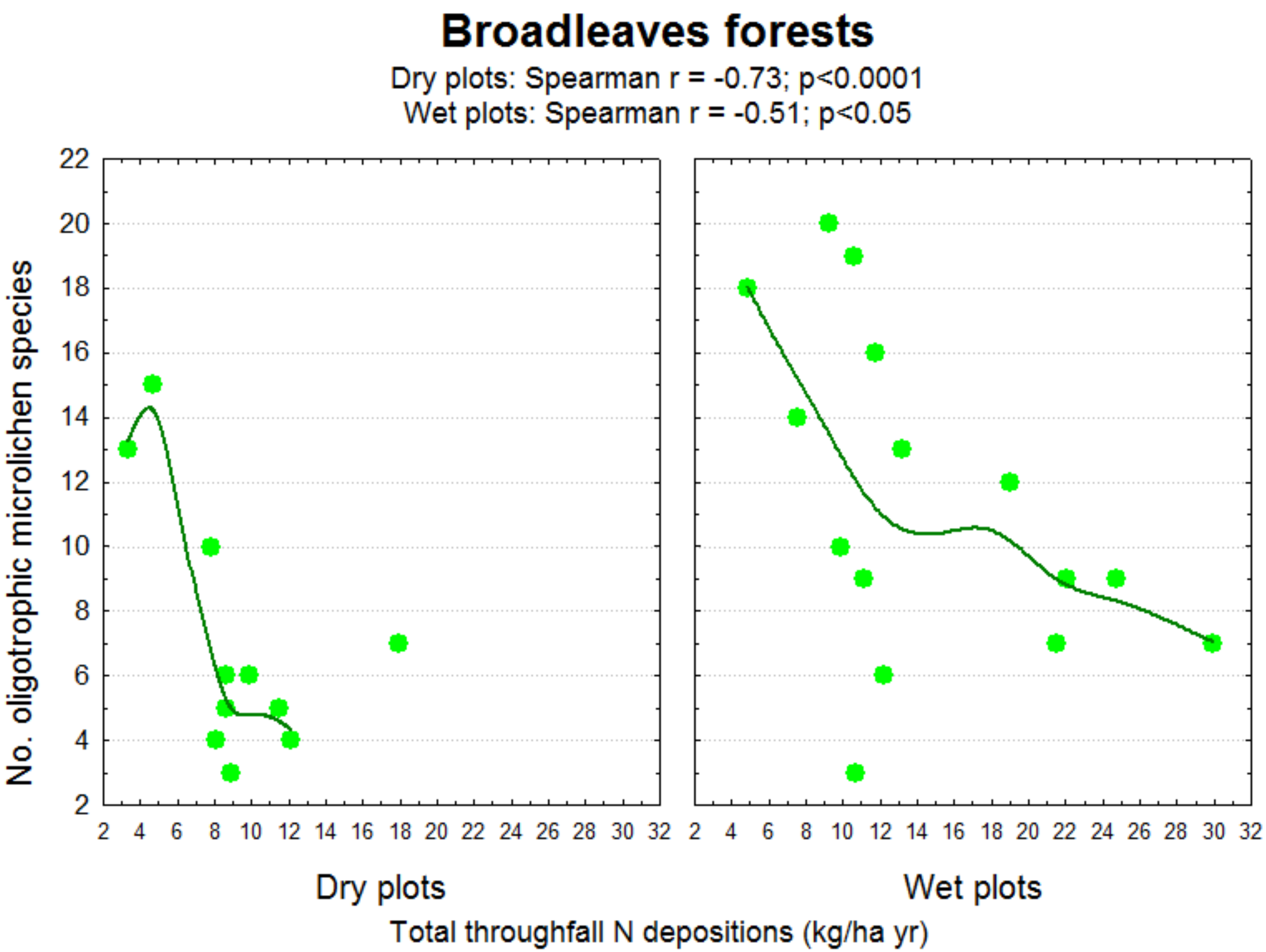
Differences depending on the forest type

5 kg/ha yr
N depositions were associated to the 40% oligo threshold in Conifer forests

The correlation is not statistically significant for broadleaves

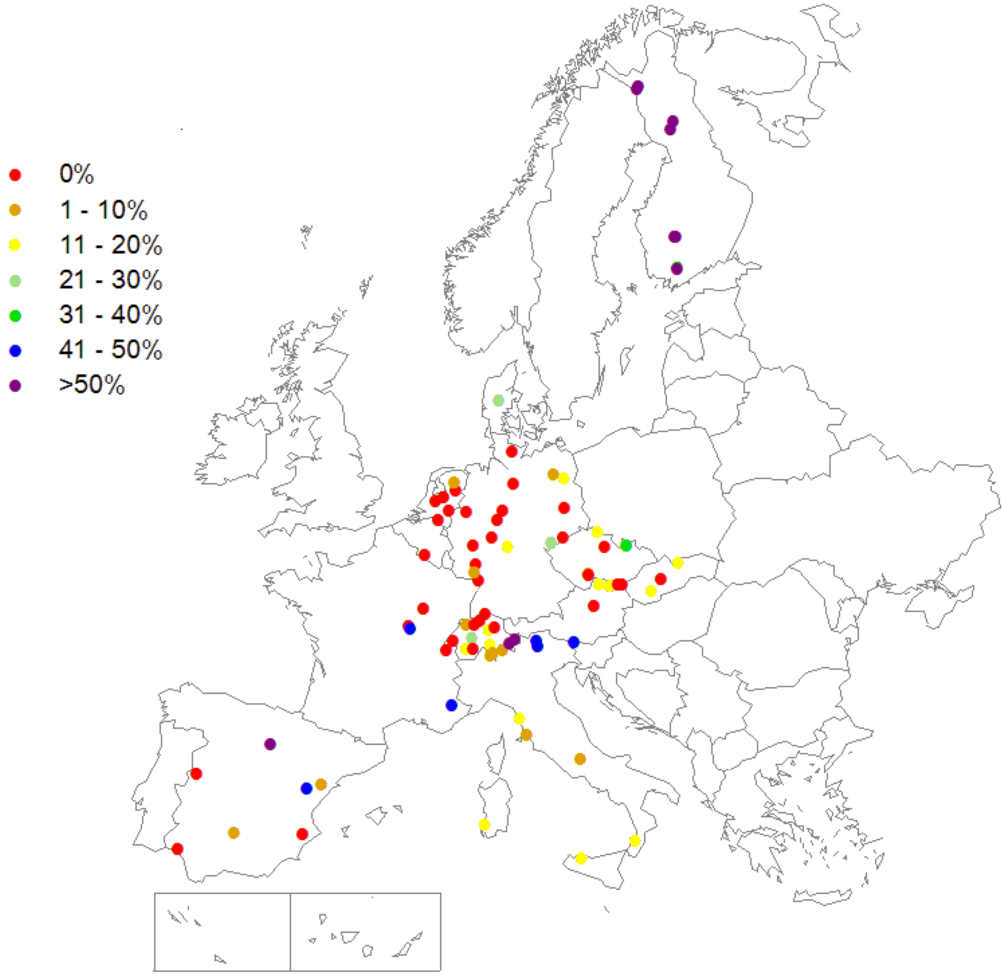


The **absolute number of oligo microlichens** showed negative trends in broadleaves plots with both high and low precipitations



Results

Geographic pattern in European forests



Conclusions 1/2

Main scientific output

- In European forests epiphytic **lichens are sensitive to interactive effects between precipitations, forest type and pollution**.
- The number of species and percentage of **oligotrophic species of epiphytic lichens is affected by throughfall nitrogen deposition** in a considerable number of Level II plots.
- Critical **throughfall nitrogen deposition,** based on lichen diversity can be set for different forest type and precipitation regimes (ranging from 3.5 to 5 kg N/ha yr).

Conclusions 2/2

Politically relevant issue

- **About half of the plots**, mainly located in Germany and other Central European Countries, **showed a low occurrence of oligotrophs, in relation with high throughfall N depositions.**

- Thanks to their high sensitiveness to pollution, epiphytic lichens may provide **more conservative attention levels** (e.g. CLEs and CLs) **for the entire forest ecosystems**.