Monitoring Global Climate Change with Lichens

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The recently published VDI standard 3957 Part 20 (VDI 2017) specifies 45 so-called "climate change indicators“ (CCI), all of which epiphytic lichens with temperate-Mediterranean and sub Atlantic-Mediterranean distribution in Europe. CCI enable assessment of temporal alterations due to global climate change. Spatial variability of CCI abundance may be influenced by local conditions. Therefore, temporal studies are preferable to spatial comparisons.

- In North Rhine-Westphalia (NRW), the federal state with the highest mean temperature in Germany [1], the authors have, until now, recorded 25 of these indicator species (Tab. 1).
- In NRW, since about 2000 (Fig. 1), CCI-Index (= average number of climate change indicators per standard tree in a particular time in the study area or parts thereof) has significantly increased from around 1 to up to 4,5 at the warmest sites along the Rhine valley close to Düsseldorf and Cologne [2, 3].
- In NRW, CCI-Index significantly declines with altitude and/or longitude. Most CCI are gathering in the Western part of the state.
- In the Mettmann District, since 2001 [3], a steep increase in the CCI-Index has been observed (Fig. 2). The spatial variability, however, is only in part due to different altitude of the sampling stations.
- Climate change indicators are the lichens showing the highest frequency increase (Fig. 3). In contrast, acidophytic lichen species are becoming increasingly rare.
- Besides CCI, several warmth adapted and +/- nitrophytic lichens have recently been (re)recorded for the first time in NRW, e.g. *Physcia clementei*, *P. tribacia*, or *Physciella chloantha*.
- A monitoring program in Düsseldorf [4] reveals a continuous increase in the CCI index since 2003 (Fig. 4). On standard trees which have been repeatedly examined, the differences are statistically significant from year to year.
- In Düsseldorf, CCI are preferentially observed at the suburban sampling stations. Some species, however, are also common at overheated locations, e.g. *Punctelia borreri* or *P. subrudecta* (results not shown).

The observations are interpreted as both a success of improved environmental techniques which have resulted in lower emission loads, and as a result of local impacts of global climate change.

Fig. 1: Change in the climate change indicator index (CCI-Index) in North Rhine-Westphalia between 2000 and 2017.
Data basis: Lichens recorded on 1815 and 751 standard trees in the years 2000 to 2002 and 2014 to 2017, respectively. Class widths of CCI-Index were calculated via the mean standard deviation of each individual project. Non-adjoining classes differ significantly. Grid: 25k topographic maps or NW quadrants thereof. Background: bright grey, lowlands; dark grey, area above 200 m height.

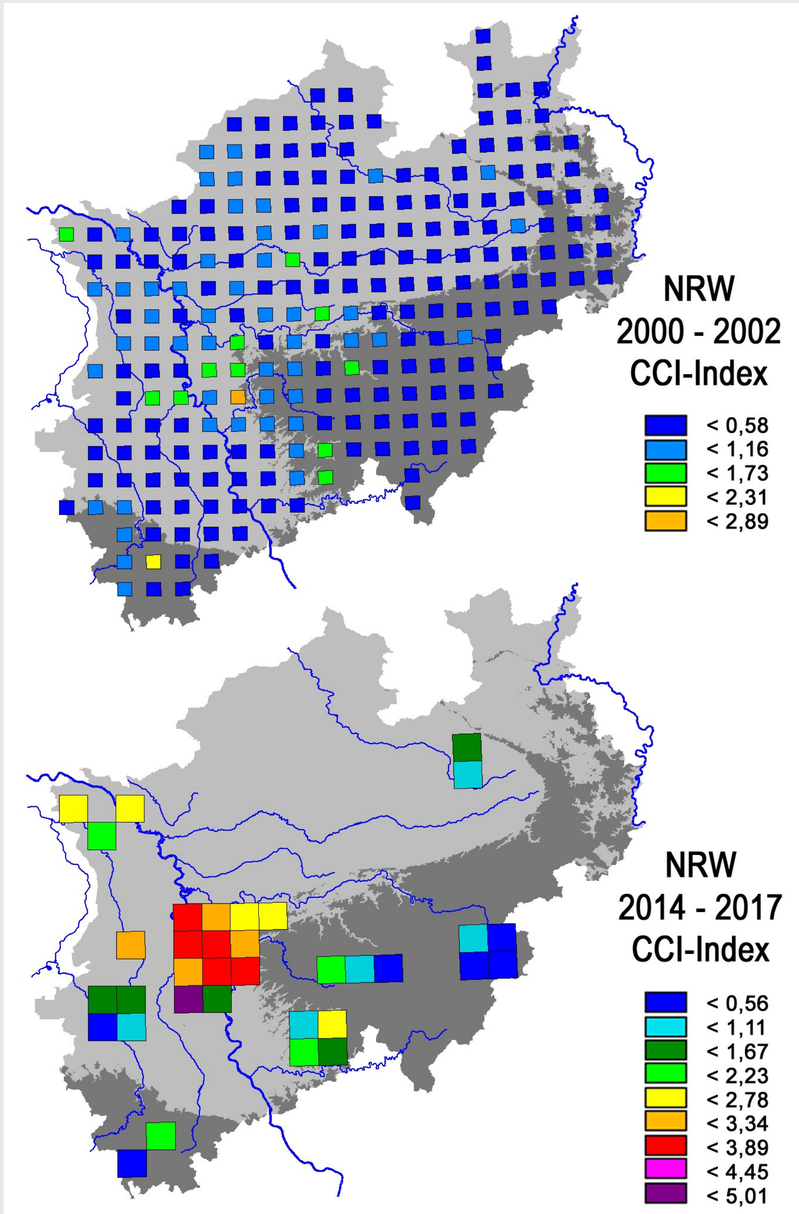
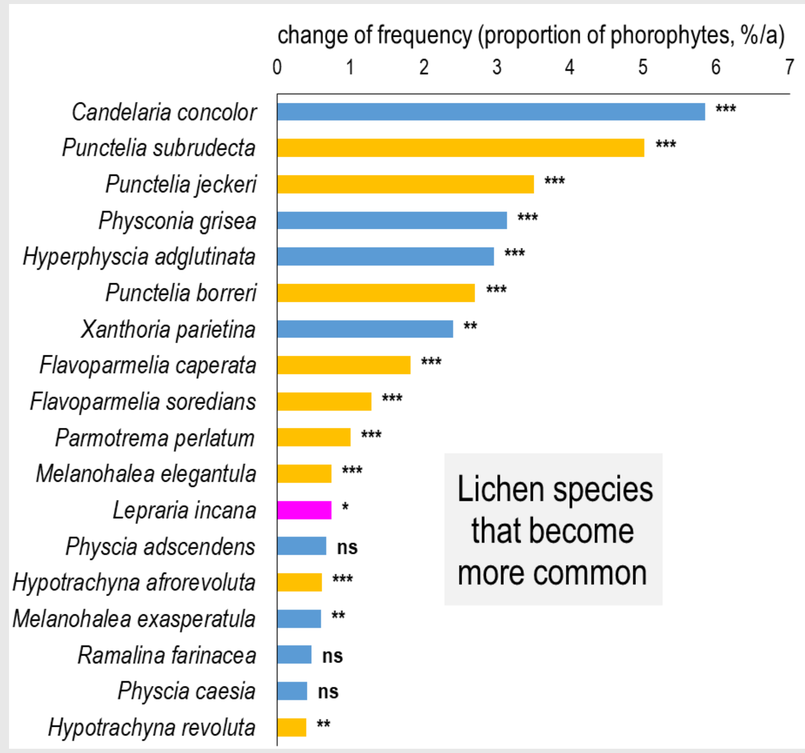
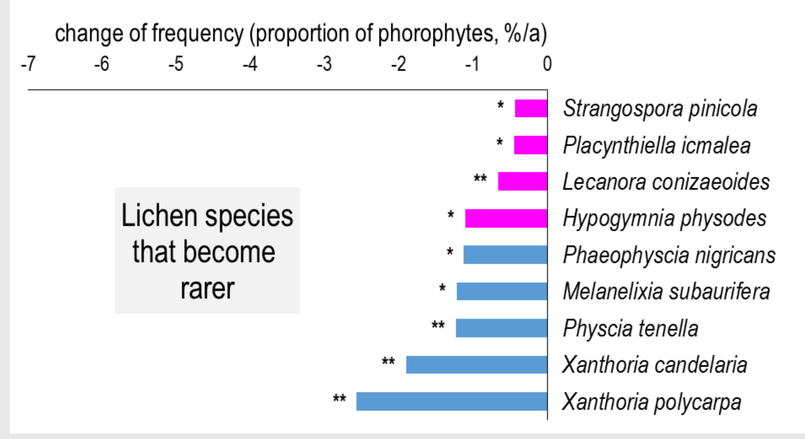


Fig. 3: Changes in the frequencies of climate change indicators and other lichens in Düsseldorf 2003 to 2017.
Data basis: lichens on up to 208 standard trees at four sampling sites in the municipal area of Düsseldorf; 11 surveys 2003 to 2017 [4]. Lichen frequency is given as the proportion of trees with at least one thallus of the respective species. **Orange bars**: climate change indicators. **Blue bars**: neutrophytes or nitrophytes. **Purple bars**: acidophytes. Alteration was analysed with the Mann-Kendall trend test (* p<0,05; ** p<0,01; *** p<0,001; ns, no significant alteration). Only data of lichens with more than ± 0,4 % annual alteration are shown.





Tab. 1: Climate change indicators (CCI) which have already been recorded in NRW.
Red List NRW: red list categories (Bültmann et al. 2011), (not spec.), not specified; (0) extinct, (1) critically endangered, (2) endangered, (3) vulnerable, (D) data deficient, (*) least concern. **Black squares** indicate records by the authors in the Western Part of the federal state or in its capital Düsseldorf and the surrounding Mettmann District. **First Record:** Year of the first record by the authors; (-) not observed so far or no recent records published; (*) observations 1980 to 1995 (Heibel 1995) or generally common lichen species; (?) probably overlooked.

Species Name	Red List NRW	Western NRW	Düsseldorf Mettmann	First Record
Arthonia pruinata	0			-
Arthonia ruana	3	■		*
Bacidina neosquamulosa	*	■	■	1999
Bactrospora dryina	0			-
Collema fasciculare	0			-
Coniocarpon cinnabarimum	0			-
Degelia plumbea	not spec.			-
Diploicia canescens	3	■	■	2003
Fellhanera bouteillei	1	■		2006
Flavoparmelia caperata	*	■	■	*
Flavoparmelia soredians	3	■	■	*
Fuscidea lightfootii	0			-
Graphis elegans	1	■		2001
Halecania viridescens	*	■	■	*
Hypotrachyna afrorevoluta	not spec.	■	■	2003
Hypotrachyna laevigata	not spec.			-
Hypotrachyna revoluta	3	■	■	*
Lecanographa amylacea	0			-
Lecanora hybocarpa	not spec.			?
Melanohalea elegantula	*	■	■	*
Melanohalea laciniatula	2	■	■	*
Micarea adnata	D			*
Micarea viridileprosa	D	■	■	2001
Nephroma laevigatum	0			-
Opegrapha ochrocheila	2	■		2003
Opegrapha vermicellifera	3	■		*
Parmelia submontana	2	■		2017
Parmelina quercina	0			-
Parmotrema perlatum	*	■	■	*
Parmotrema pseudoreticulatum	D	■		2001
Parmotrema reticulatum	D	■	■	2008
Pertusaria hymenea	1			-
Pertusaria trachythallina	0			-
Phaeographis inusta	0			-
Physcia tribacioides	D	■	■	2003
Porina leptalea	*	■	■	2005
Punctelia borreri	D	■	■	2002
Punctelia jeckeri	*	■	■	(1999)
Punctelia subrudecta	*	■	■	*
Pyrenula nitida	2			*
Pyrenula nitidella	1			-
Ropalospora viridis	*			*
Schismatomma decolorans	D	■	■	2011
Thelotrema lepadinum	1			*
Usnea florida	1			-

Fig. 2: Temporal change in the climate change indicator index (CCI-Index) in the Mettmann District between 2001 and 2017.
Data basis: Lichens recorded on 73, 151, 150, 144, and 165 standard trees in 2001, 2009, 2010, 2013, and 2017, respectively. Class width is chosen arbitrarily. Digital map: © OpenStreetMap.org (CC-BY-SA). M4606 etc.: 25k ordnance survey map number.

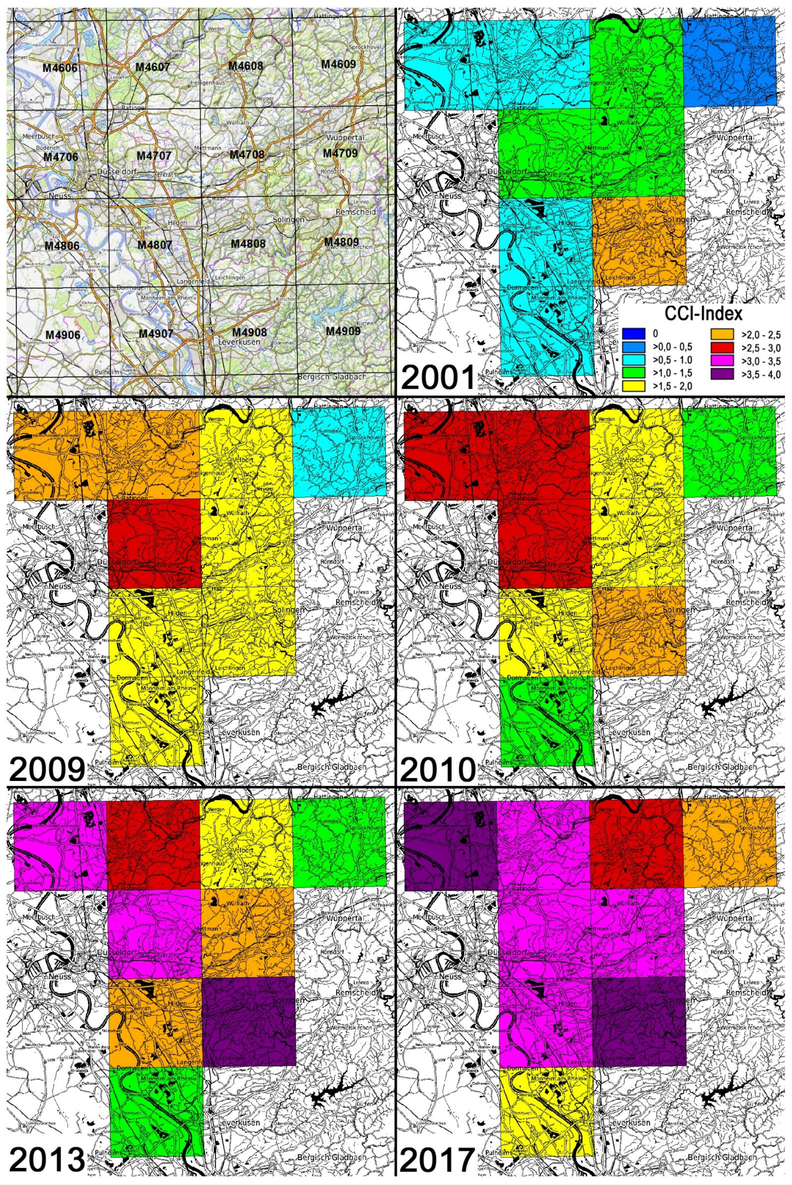
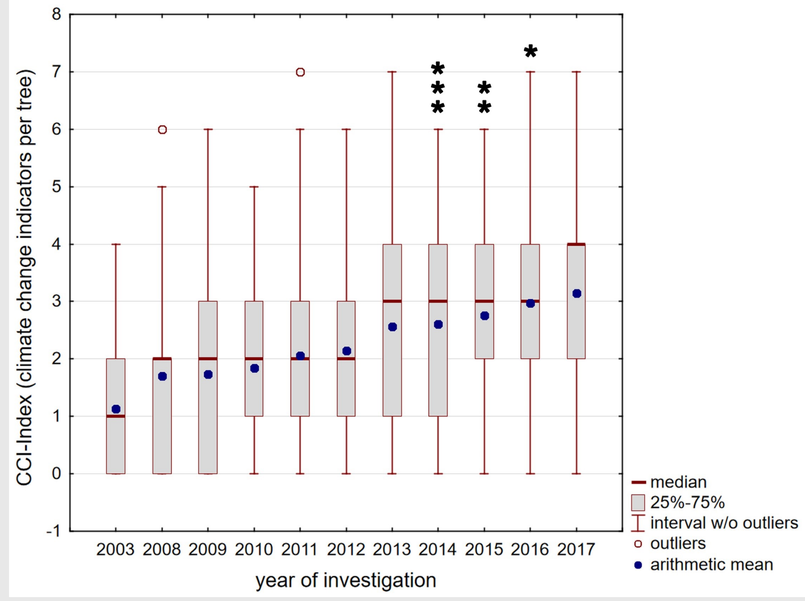


Fig. 4: Temporal change in the CCI-Index in Düsseldorf.
Data basis: Lichens on 87 standard trees which were repeatedly investigated during a monitoring program at four sampling units located in den city center and in the urban fringe. Wilcoxon signed-rank test was applied to compare results of 2017 with those of previous years (* p<0,05; ** p<0,001; *** p<0,00005; 2013 and before: p<0,00001).



Supported by the NRW State Ministry of the Environment, by the Office for the Environment of Düsseldorf and by the Mettmann County administration.

References

[1] Deutscher Wetterdienst, www.dwd.de, Climate Data Center
[2] Franzen, I., Stapper, N.J. & Frahm, J.-P. 2002: Ermittlung der lufthygienischen Situation Nordrhein-Westfalens mit epiphytischen Flechten und Moosen als Bioindikatoren. – Düsseldorf, MUNLV. 41 S.
[3] Schmitz, U., Stapper, N., Pieren, H., Busch, J. 2018: Klimafolgenmonitoring Kreis Mettmann 2017. – www.ulfschmitz.de, Düsseldorf, 92 S.
[4] Schmitz, U., Stapper, N., Stevens, M., Wirooks, L., Busch, J. 2018: Klimafolgenmonitoring Landeshauptstadt Düsseldorf. – www.ulfschmitz.de, Düsseldorf, 205 S.

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