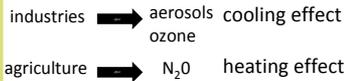


1 nitrogen and climate?

anthropogenic N emissions can both cool or warm the climate system...

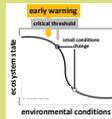
but on the future the cooling effects of combustion emissions will be offset by the warming effects of agricultural emissions : higher efficiency of fertilizers use is critical (EPA).



How can we tell if too much nitrogen is escaping from agriculture activities?

nitrogen deposits on ecosystems, causing changes on its functioning and biodiversity...

but the changes are not always linear: on "critical thresholds points" for a small change on environmental conditions the ecosystem can experience a major change on its state

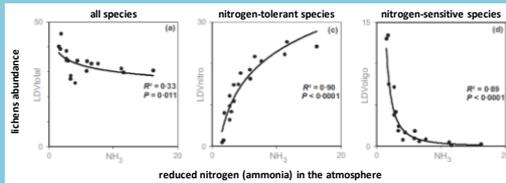


We need an early warning signal, alerting us if ecosystems have passed their safety boundary for nitrogen.

2 lichens are extremely sensitive to N

lichen diversity responds to increasing amounts of nitrogen in the atmosphere, even to very low concentrations...

but not all species respond in the same way, some increase in abundance, while other decrease; those are lichen functional response groups, i.e., groups of species with a similar response to an environmental driver

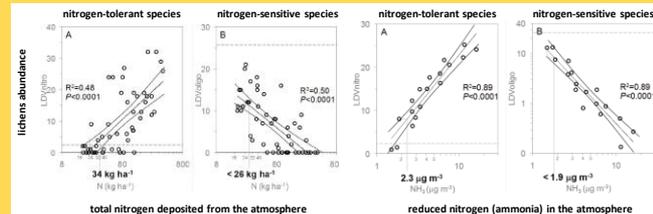


Lichen functional groups, not all species diversity, can be used to study the firsts effects of nitrogen

3 setting critical thresholds for excessive N

critical thresholds are concentrations in the atmosphere (critical levels) or deposition in the ecosystem (critical loads) that are known to cause an effect

lichens have been used at the European level to set the critical loads and levels for N; the values obtained with lichens (and bryophytes) were lower than the values obtained for plants or other organisms

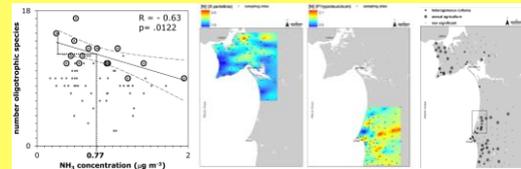


Changes in lichen diversity are early-warning tools, showing the minimum amount of excessive nitrogen changing the ecosystem

4 implications for climate change mitigation

lichen can be used under a wide range of real-world situation, at both local and regional scale, and provide spatial explicit outputs

lichens can be used to set critical thresholds even under the influence of multiples pollutants (left), map regionally the amount of nitrogen in the atmosphere (center) and separate the effects of multiple nitrogen sources such as annual and permanent agriculture (right)



Lichens were shown to be ecological indicators for nitrogen excess, early-warning us for N exceedances and possibly related increases of the climate system