

Testing the response of lichen diversity within the Italian NEC Directive Network of forest sites: the results of the LIFE Modern(NEC) project

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TerraData
environmetrics

The NEC Directive

The National Emission Ceilings (NEC) Directive sets out national emission reduction commitments by EU member states for five important air pollutants:

- Nitrogen oxides
- Non-methane volatile organic compounds
- Sulphur dioxide
- Ammonia
- Fine particulate matter



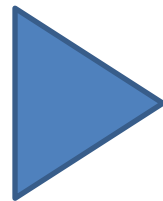
The LIFE MODERn (NEC) Project

New Monitoring System to detect the effects of the reduction of pollutant emissions deriving from the adoption of the NEC Directive

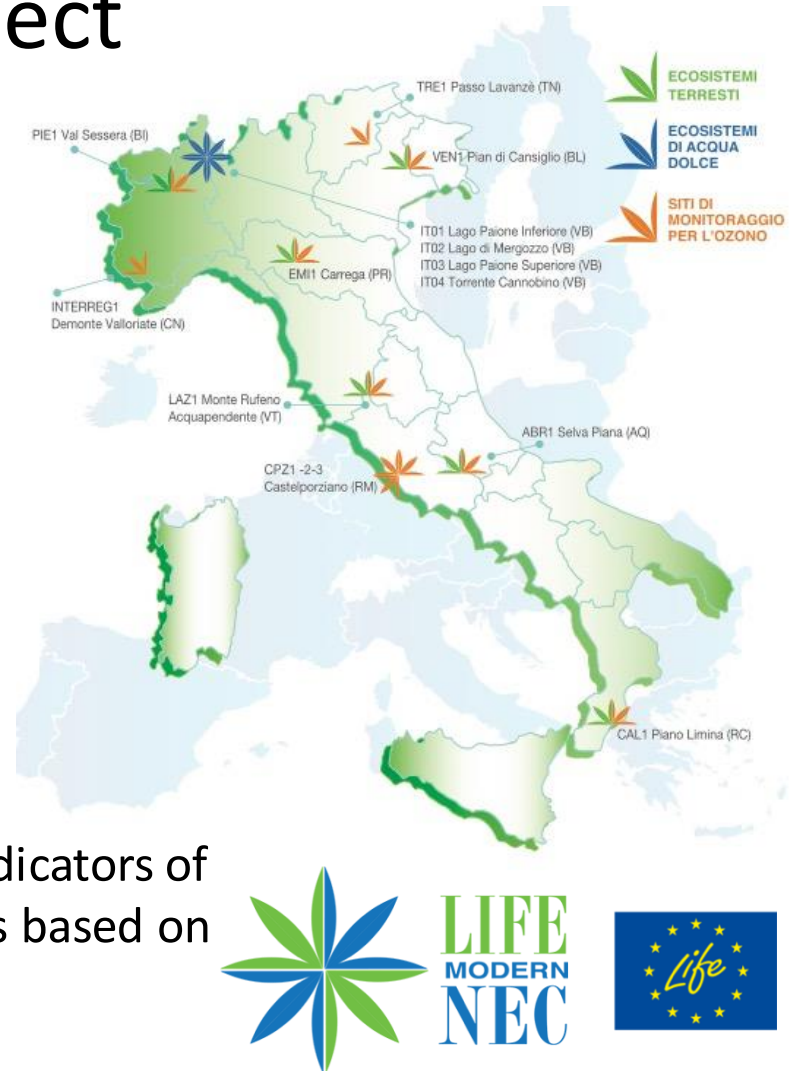
Objective: to improve the system for assessing the impacts of air pollution and climate change on forest and freshwater ecosystems in Italy.

6 to 10 forest sites

Lichens are among the indicators used in the project



New quantitative indicators of air pollution impacts based on **functional diversity**



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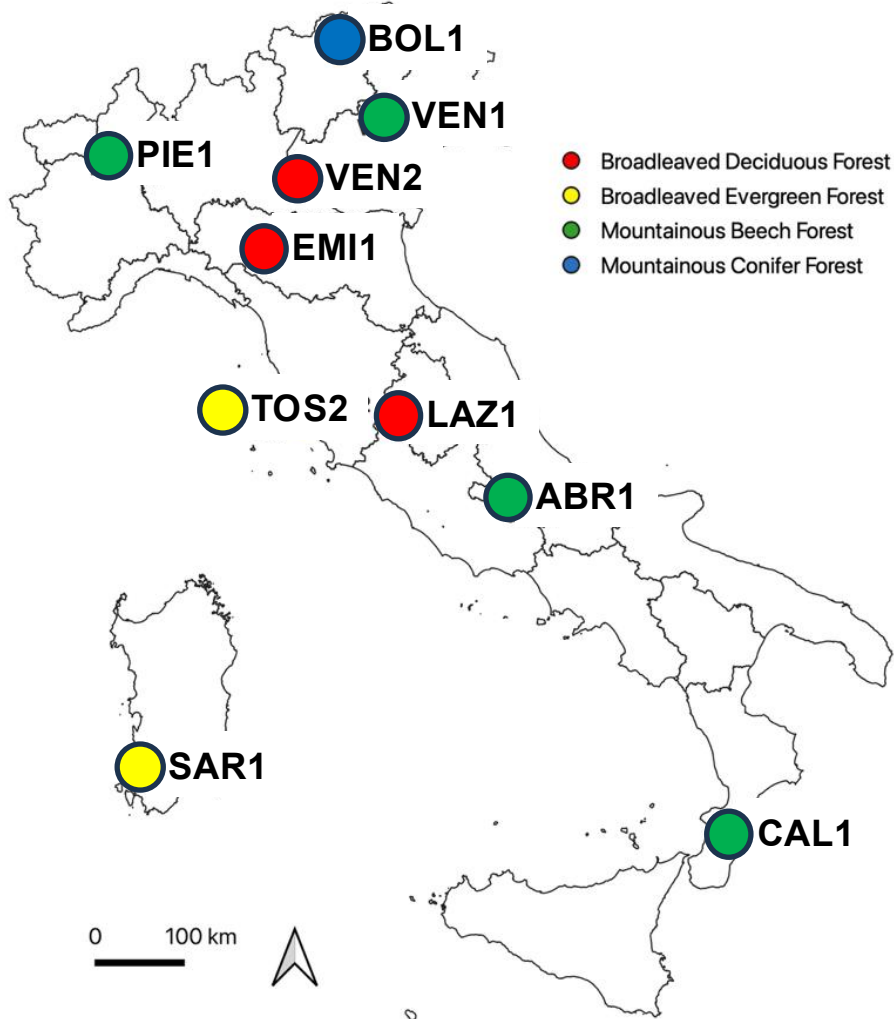


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The Italian NEC Directive Network

10 Forest sites



4

Mountainous Beech Forests (MBF)

Selva Piana (ABR1), Piano Limina (CAL1), Val Sessera (PIE1), Pian del Cansiglio (VEN1). Dominated by *Fagus sylvatica*. Elevations 1100-1500 m.

3

Broadleaved Deciduous Forests (BDF)

Carrega (EMI1), Monte Rufeno (LAZ1), Bosco Fontana (VEN2). Elevations 60-690 m.

2

Broadleaved Evergreen Forests (BEF)

Marganai (SAR1), Cala Violina (TOS2). Dominated by *Quercus ilex*. Elevations 30-700 m.

1

Mountainous Conifer Forest (MCF)

Renon (BOL1). Dominated by *Picea abies* (1740 m).

3 methods adopted in the Project

Epiphytic lichen
diversity and
functional
diversity



Number and
abundance of
fruticose lichen
species on the
ground



Viability of the
indicator
species *Lobaria
pulmonaria*



Epiphytic lichen diversity and functional diversity

Lichen Diversity Value (LDV)

abundance of lichen species within the grid

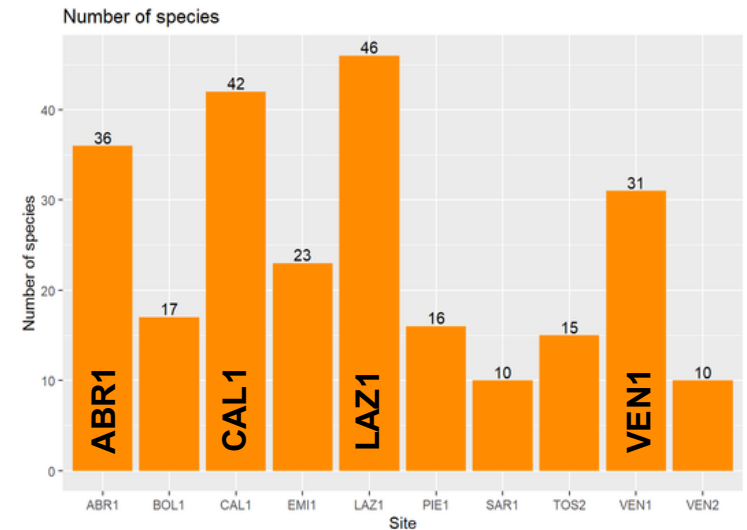
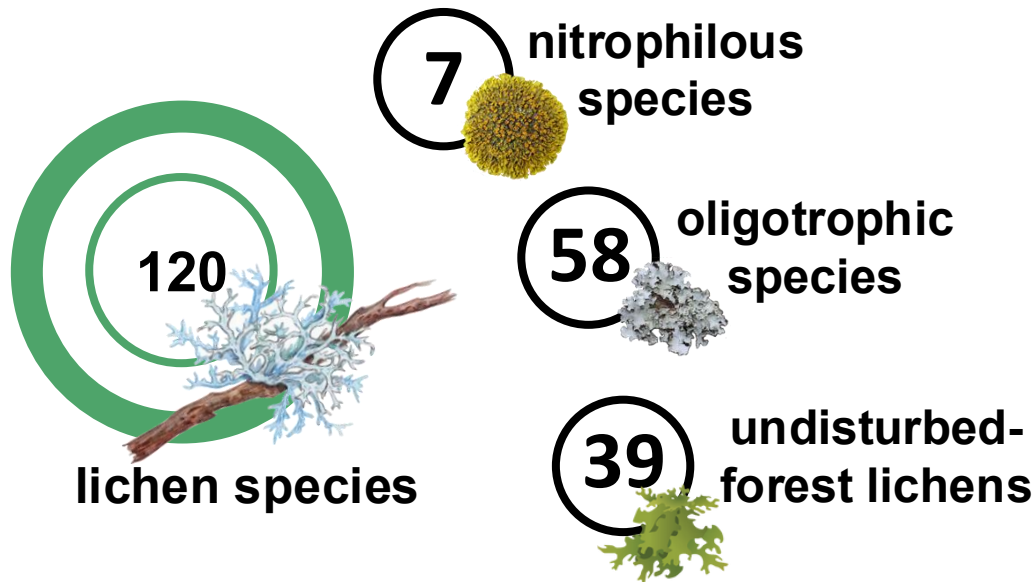
Functional diversity

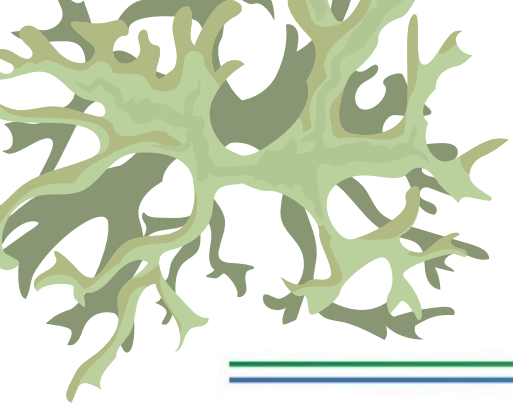
- Proportion of macrolichens (foliose and fruticose species)
- Proportion of nitrophytic lichens
- Proportion of oligotrophic lichens



Lichen Diversity Values (LDV)

Sampling period: 2019, 2020 and 2023-2024





Relationship between lichens and atmospheric depositions

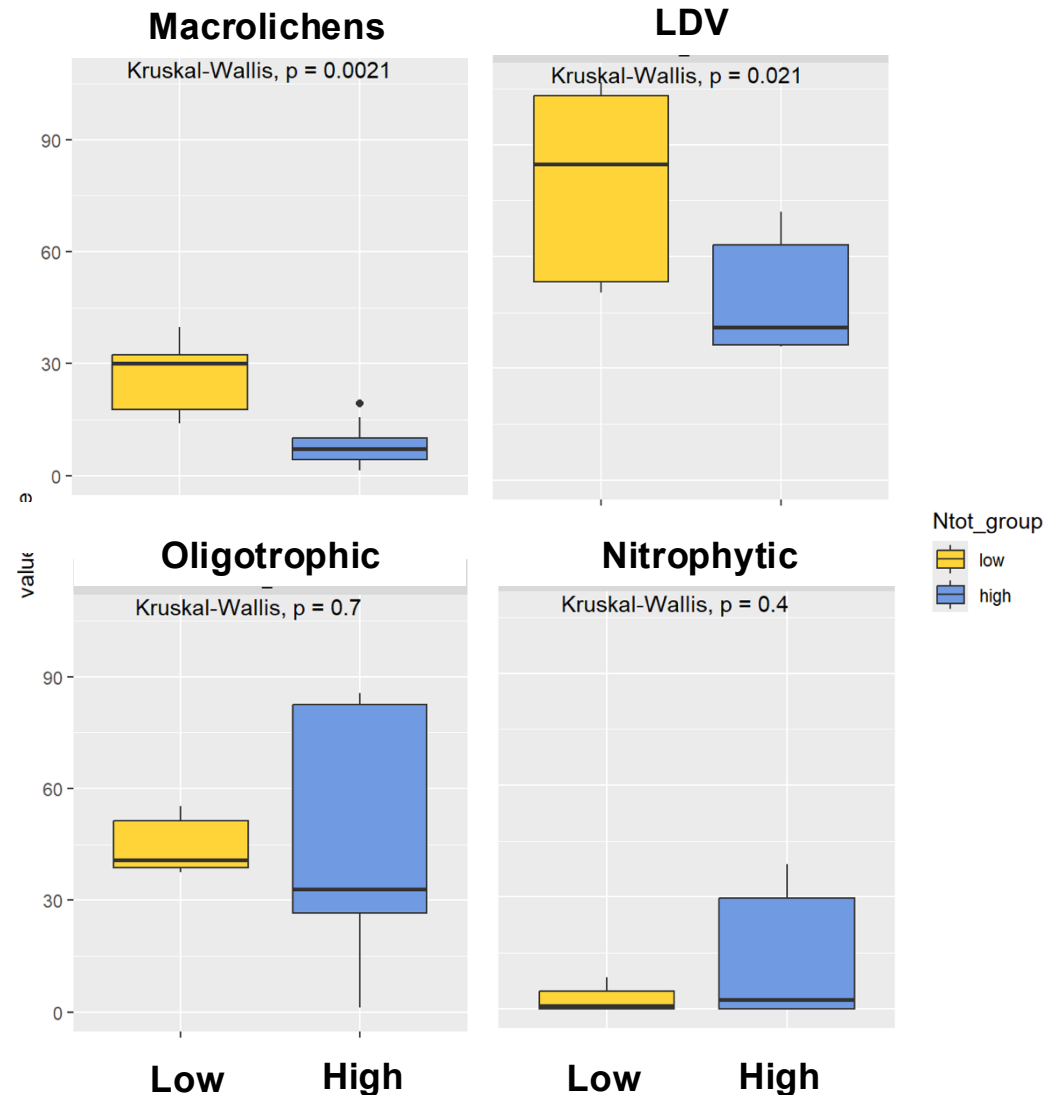
- Forest sites were grouped into two groups (high and low nitrogen deposition) based on the median value of total nitrogen deposition.
- Responses of lichen functional diversity was tested (Kruskal Wallis test).



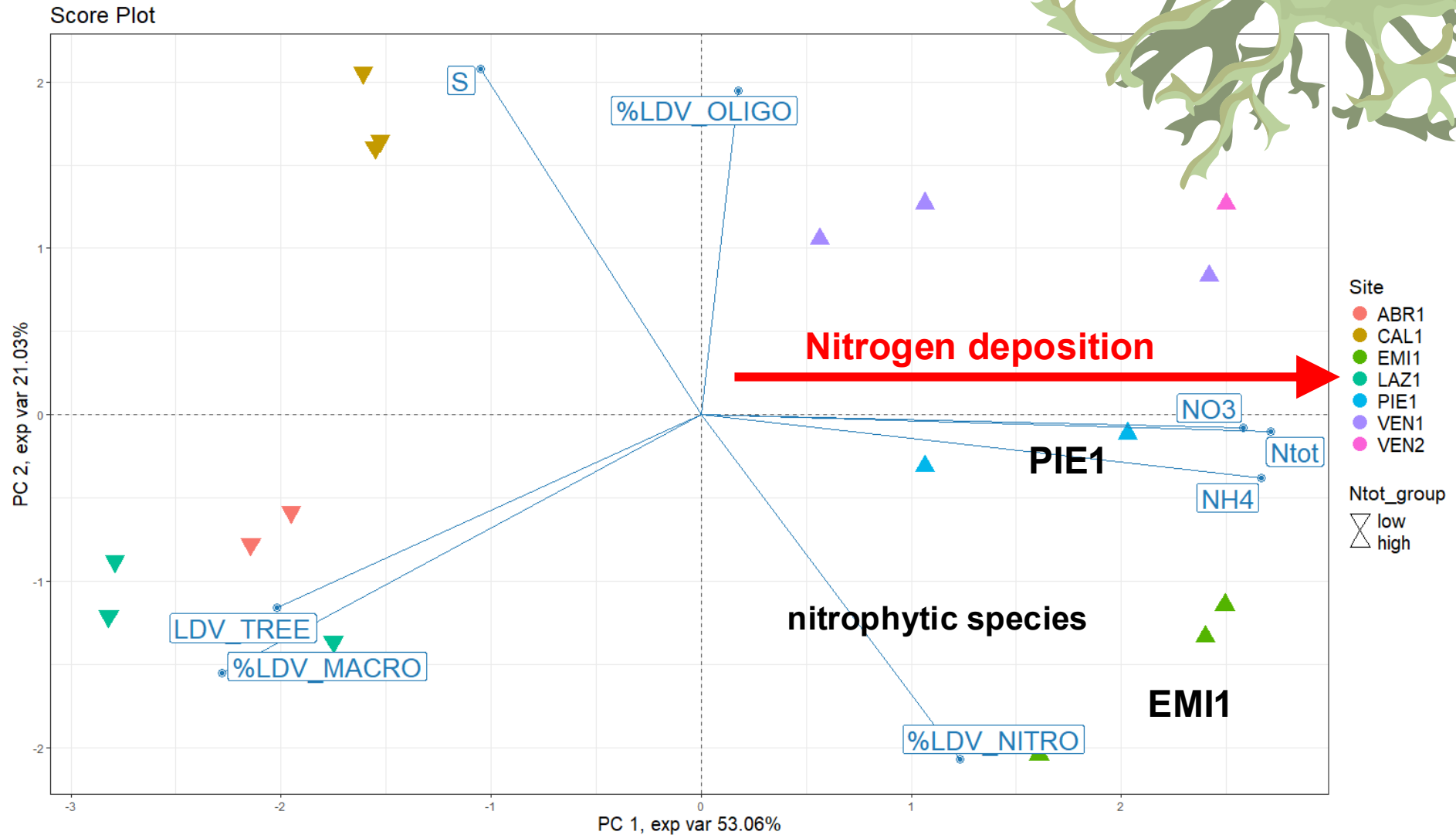
Lichens and atmospheric depositions

Sites with lower nitrogen deposition show significantly higher **LDV** ($p < 0.05$) and **macrolichens** ($p < 0.01$) than sites with higher nitrogen deposition.

The response of **nitrophytic** and **oligotrophic** species is not significant.

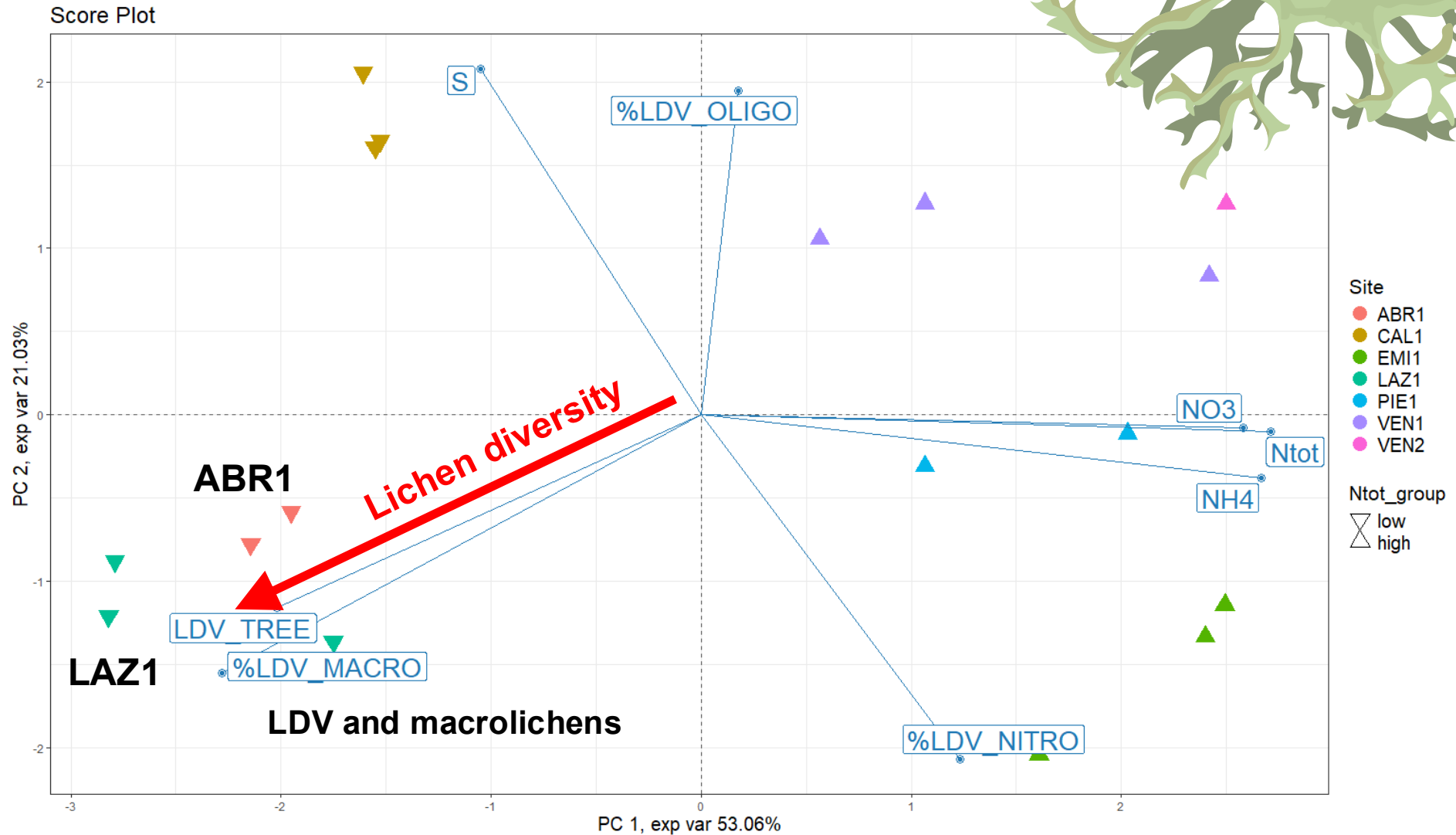


PCA



PC1 reflects a **gradient of nitrogen deposition**, separating **PIE1** and **EMI1** as the sites with the greatest abundance of **nitrophytic species**.

PCA

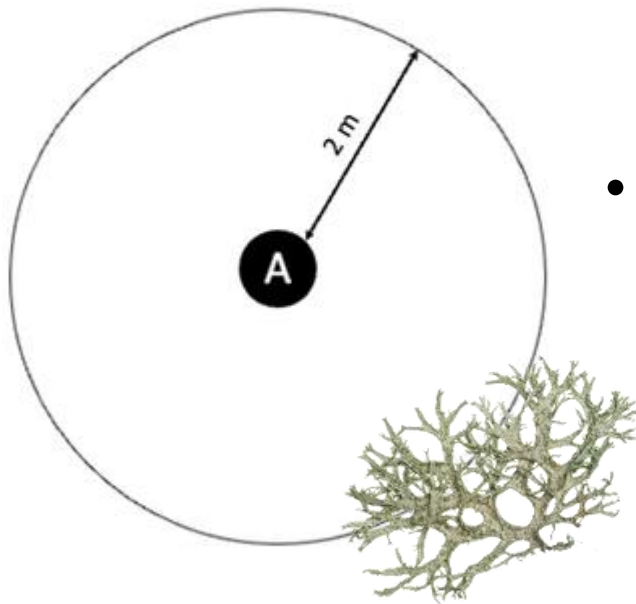


Negative PC1 and PC2 scores are associated with **ABR1** and **LAZ1**, which have the highest **macrolichen** abundance and the highest **Lichen Diversity Values (LDV)**.



Epiphytic fruticose lichens on the ground

- Particularly sensitive to pollution and climate change



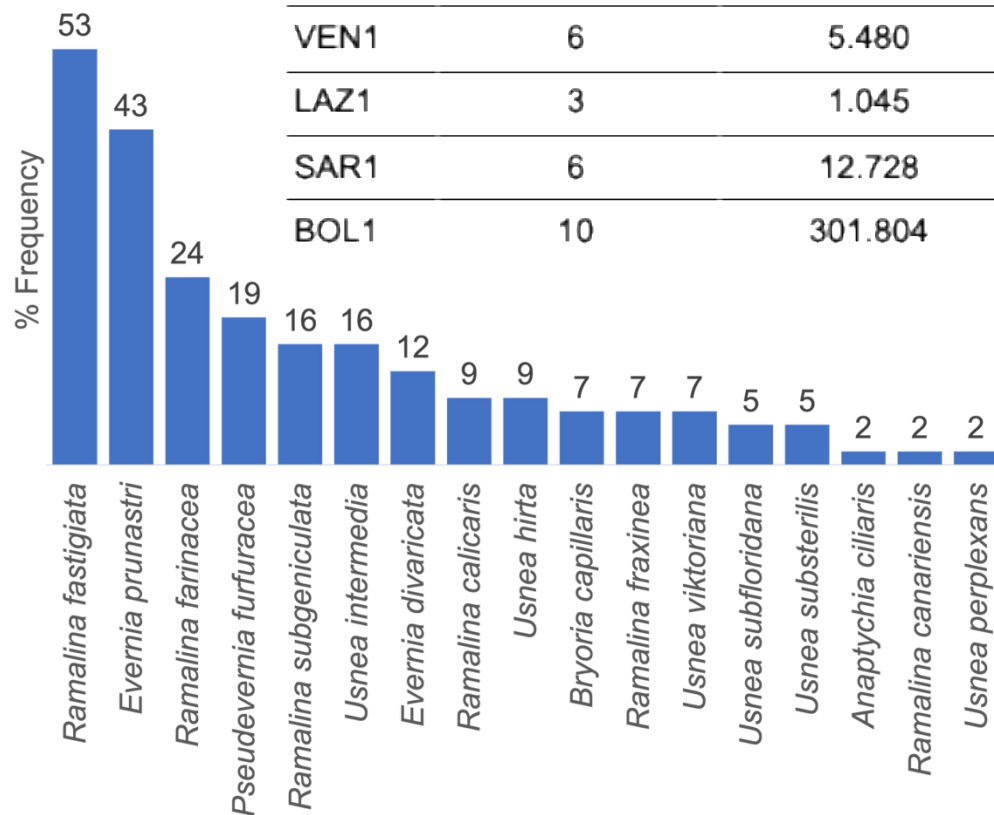
- Clearly visible, identifiable by the naked eye, in the field as a distinct morphological guild

Variables: number of species, relative abundance and biomass



Epiphytic fruticose lichens on the ground

- Detected in 5 out of the 10 sites
- 17 species



Site	N species	Cumulative weight (g)
ABR1	3	1.650
VEN1	6	5.480
LAZ1	3	1.045
SAR1	6	12.728
BOL1	10	301.804

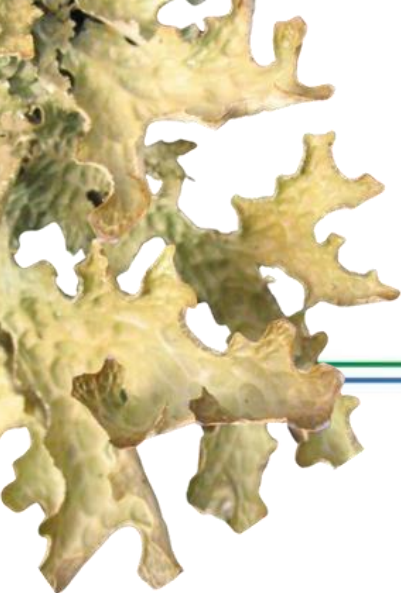
Lobaria pulmonaria

Very sensitive to air pollution
and in large decline in Europe

Flagship species: easy to
identify

Umbrella species: associated
with many other rare or
endangered forest dwelling
organisms





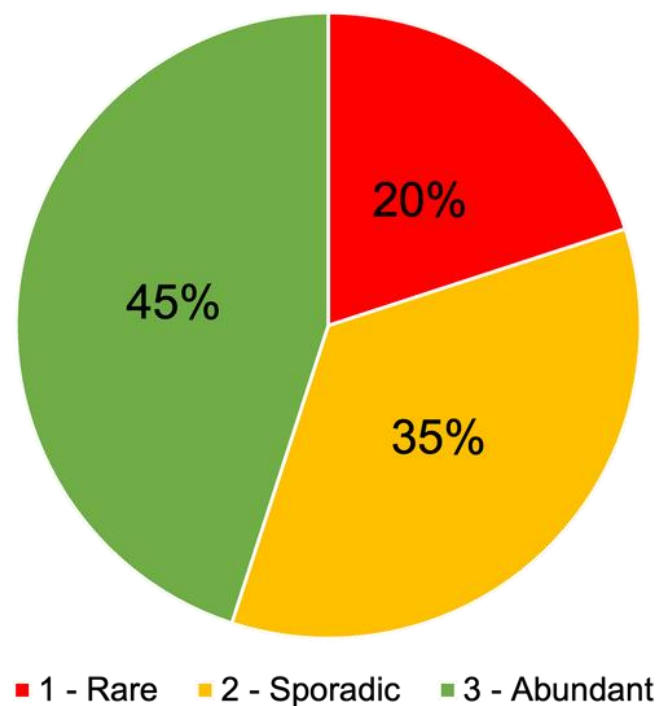
Detected in 2 out of the 10 plots.

- **VEN 1:** rare (1 tree)
- **CAL1:** abundant (19 trees; 37%)

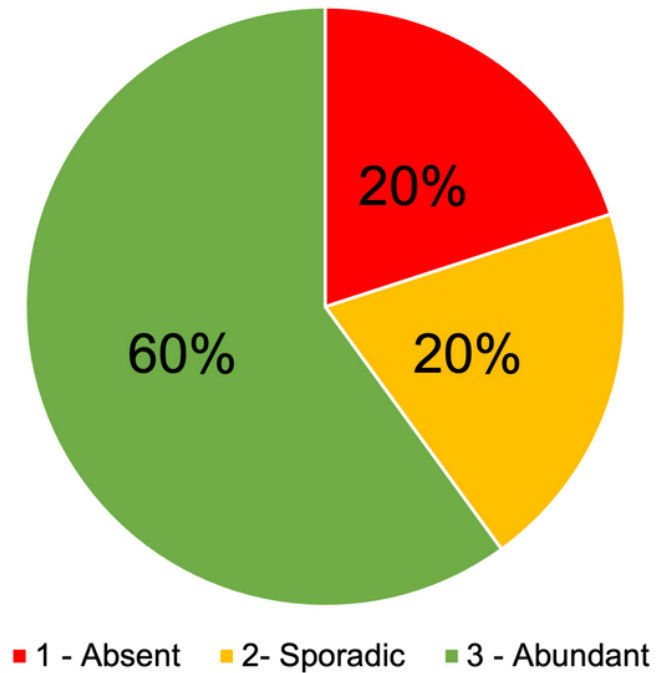
At the site CAL1 *Lobaria* is abundant on 45% of the trees (> 10 thalli per tree)

Most specimens showed good vitality and conservation, as indicated by their large size

Abundance of *Lobaria*

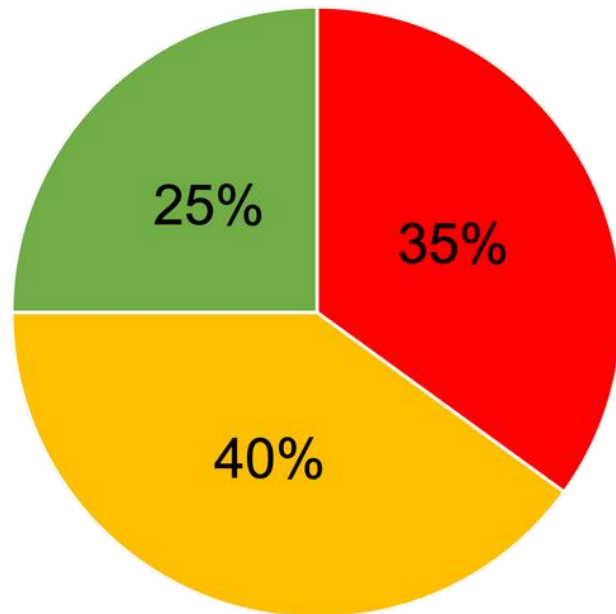


Presence of meristematic lobes



Meristematic lobes are abundant in 60% of the trees

Presence of juvenile thalli

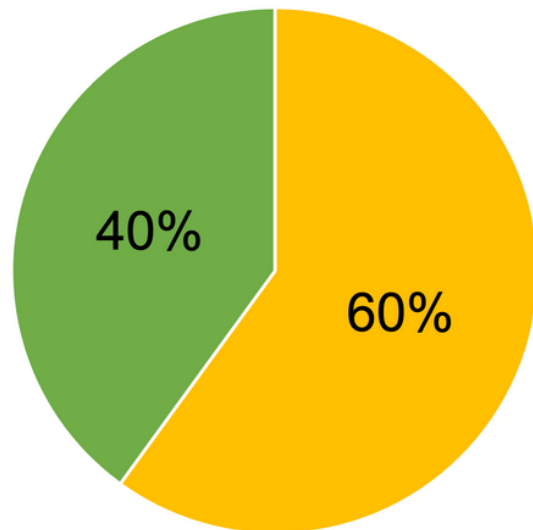


■ 1 - Absent ■ 2- Sporadic ■ 3 - Abundant

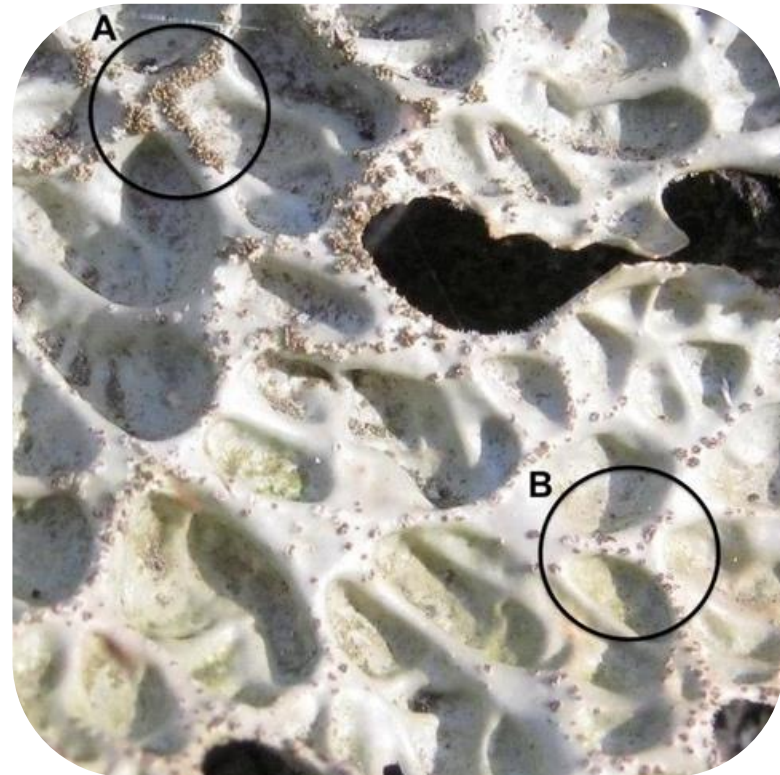


Juvenile thalli (<2 cm) are absent from 35% of the trees, sporadic in 40% and abundant only in 25%

Presence of vegetative propagules



■ 1 - Absent ■ 2- Sporadic ■ 3 - Abundant



Vegetative propagules are sporadic in 60% of the trees and abundant in 40%. Apothecia occur on 10% of the lichen thalli

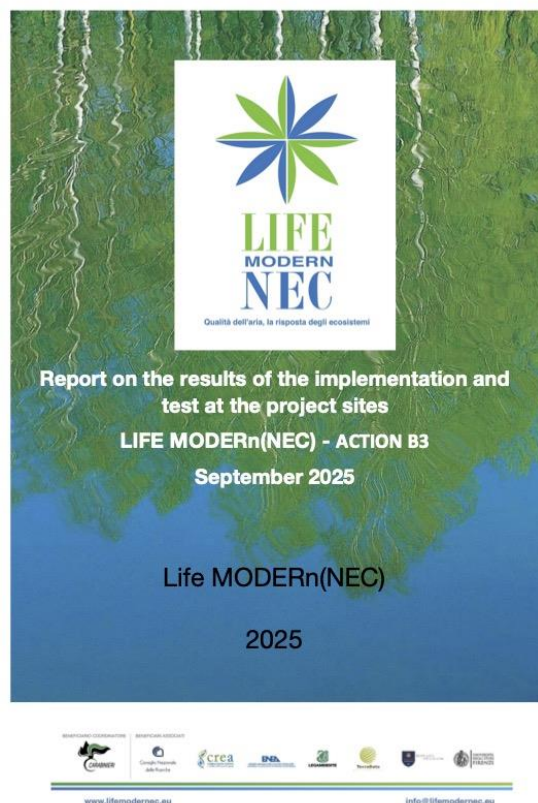
Concluding remarks

- ❖ The tested protocols provide reliable, complementary tools for long-term monitoring across the Italian NEC Directive Network.
- ❖ No single indicator captures forest ecosystem condition alone:
 - LDV and functional diversity track lower-trunk communities and their response to nitrogen deposition.
 - Fallen fruticose lichens give indirect access to canopy assemblages.
 - *Lobaria pulmonaria* signals habitat continuity, stand maturity and ecological integrity.
- ❖ Combined, these approaches strengthen early-warning capacity and improve long-term assessment of forest biodiversity under air pollution and climate change.



Thank you!

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