

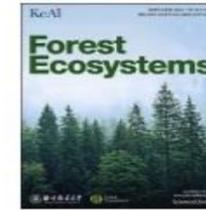


# Biodiversity in primary vs. managed forests: Biological legacies of old living and large dead trees drive lichen diversity

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## BACKGROUND

- **Primary forests** in Europe are scarce and fragmented
  - Biodiversity hotspots
- **Managed forests** dominate the landscape.
  - Often simpler structure
- **Lichens** = indicators of forest naturalness

# STUDY AIMS

- Quantify differences in **total and red-listed lichen species richness** between forest types.
- Identify which **structural and environmental attributes** drive lichen diversity.
- Identify structural attributes that promote lichen diversity in **managed forests** and provide practical insights for **conservation planning**.



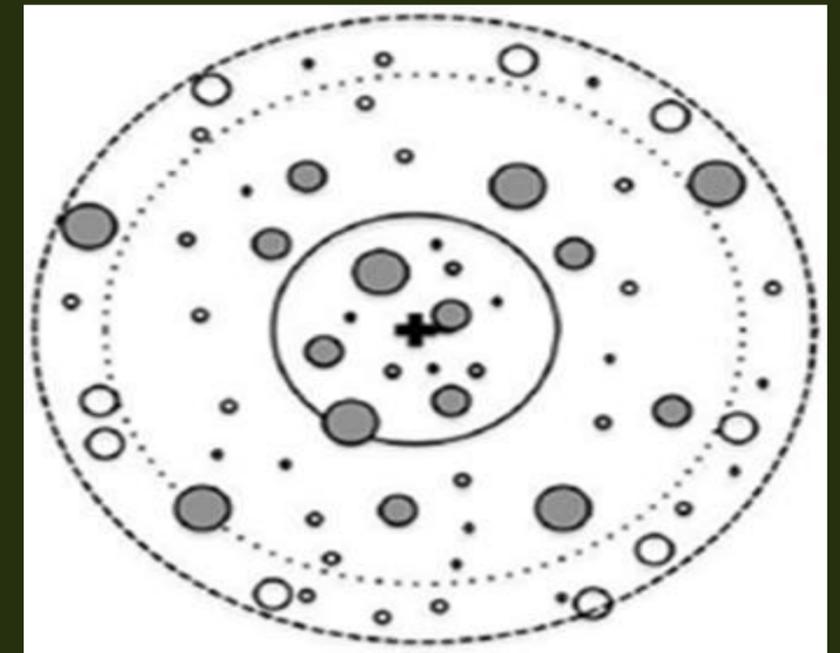
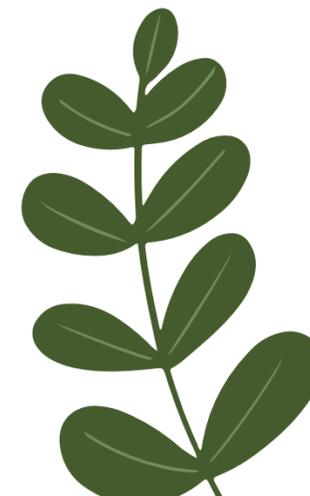
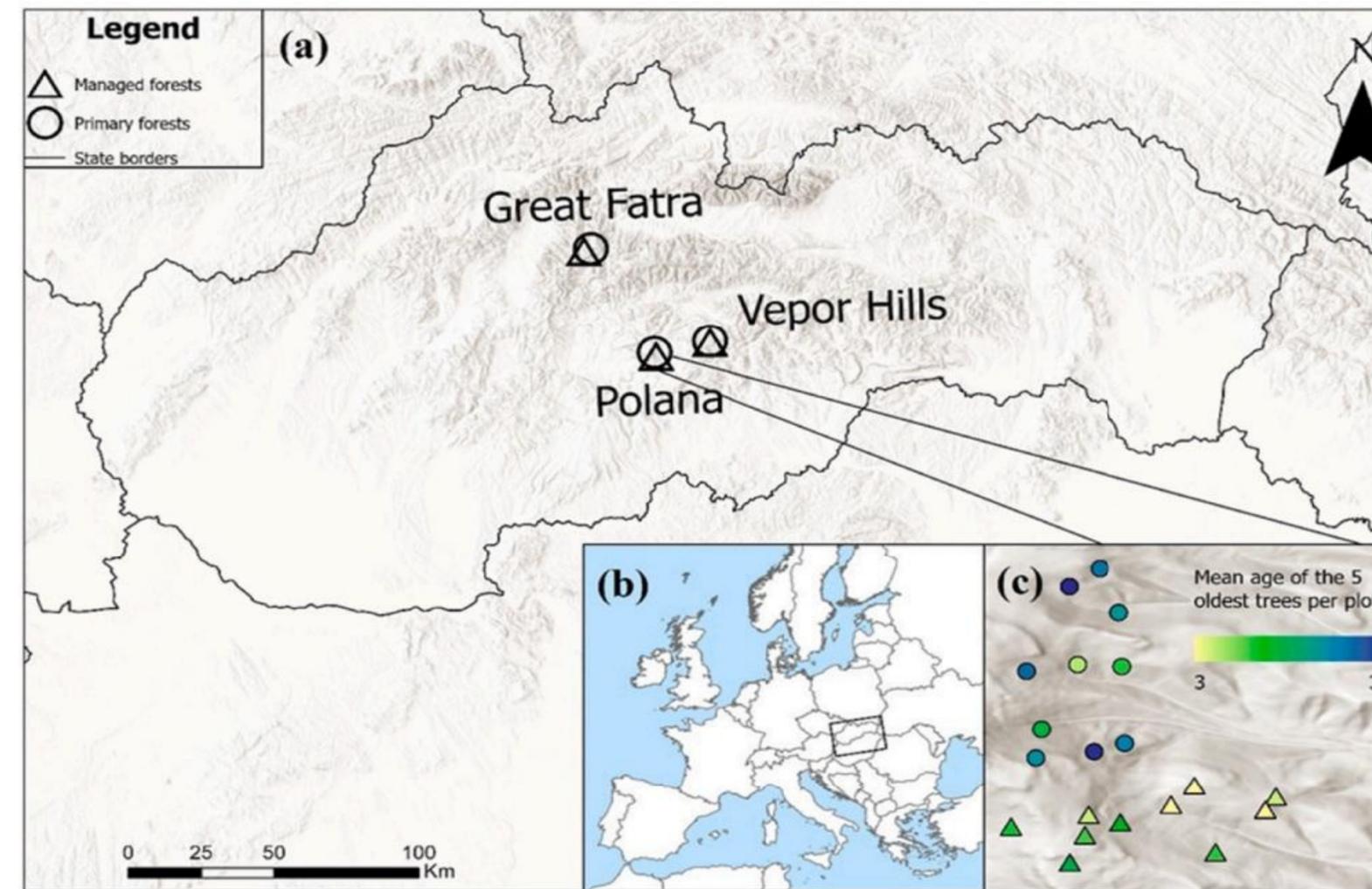
# STUDY DESIGN

- **WESTERN CARPATHIANS:** Poľana, Vepor Hills and Great Fatra.

- **50 PERMANENT PLOTS:** paired *primary* vs. *managed* beech forests.

- **STRUCTURAL DATA** + dendrochronology.

- **LICHEN SURVEY:** 5,156 specimens

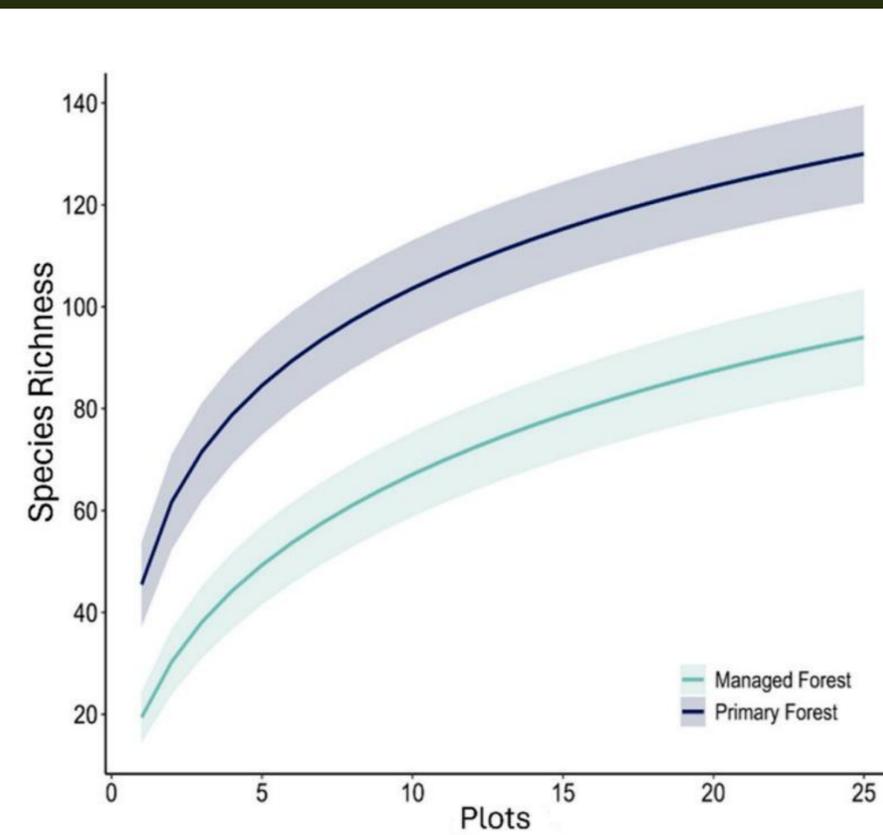
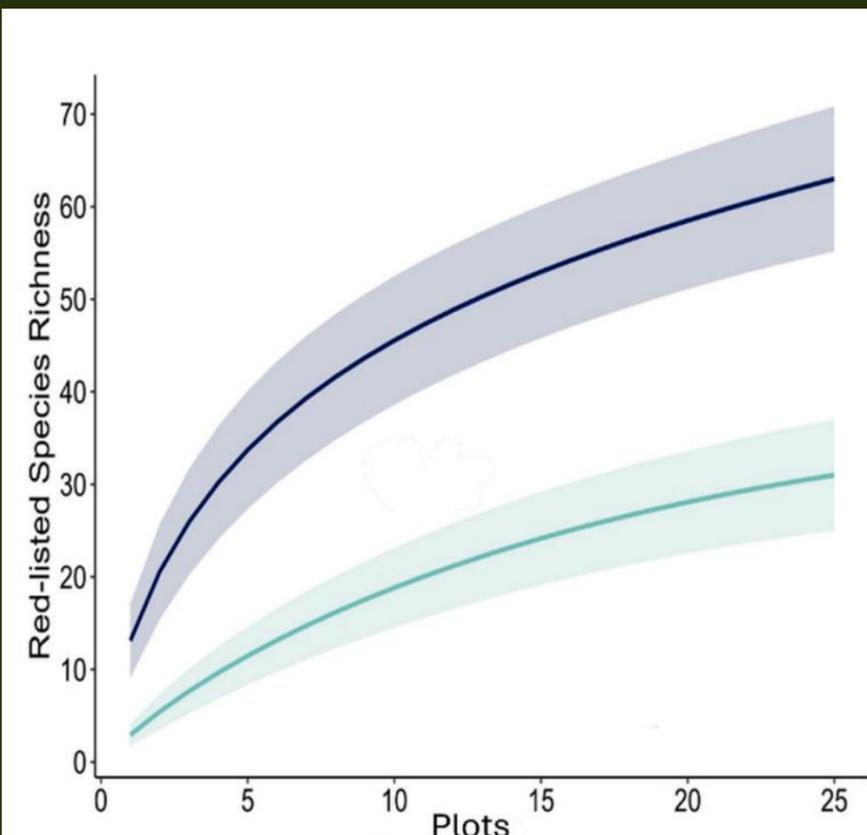
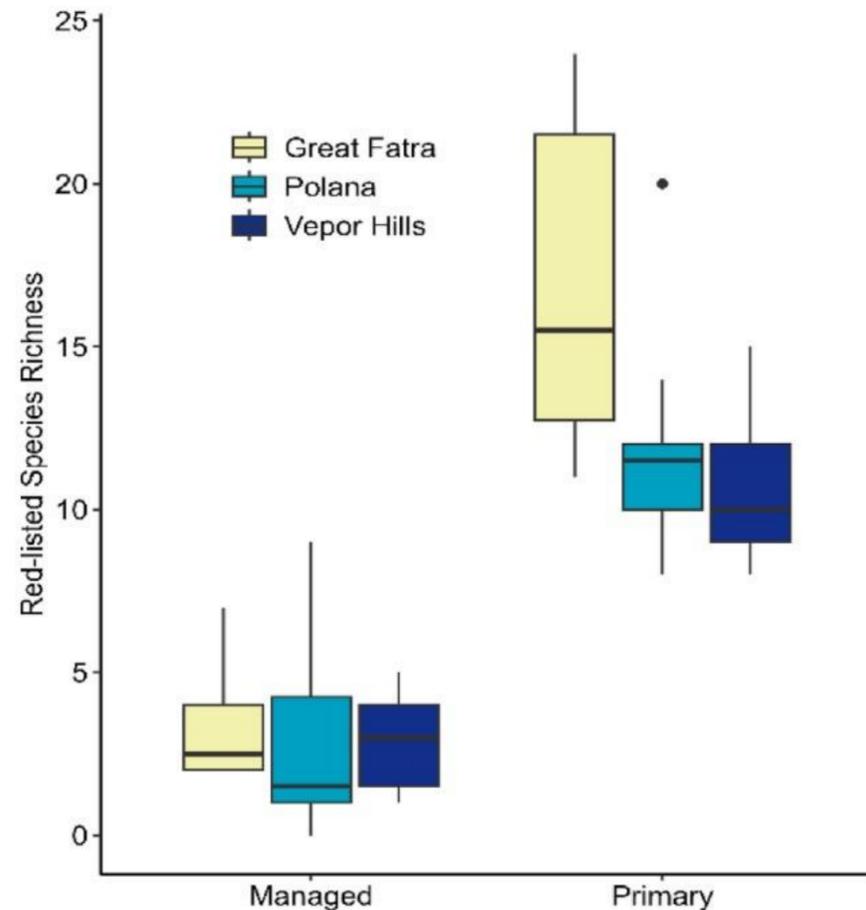
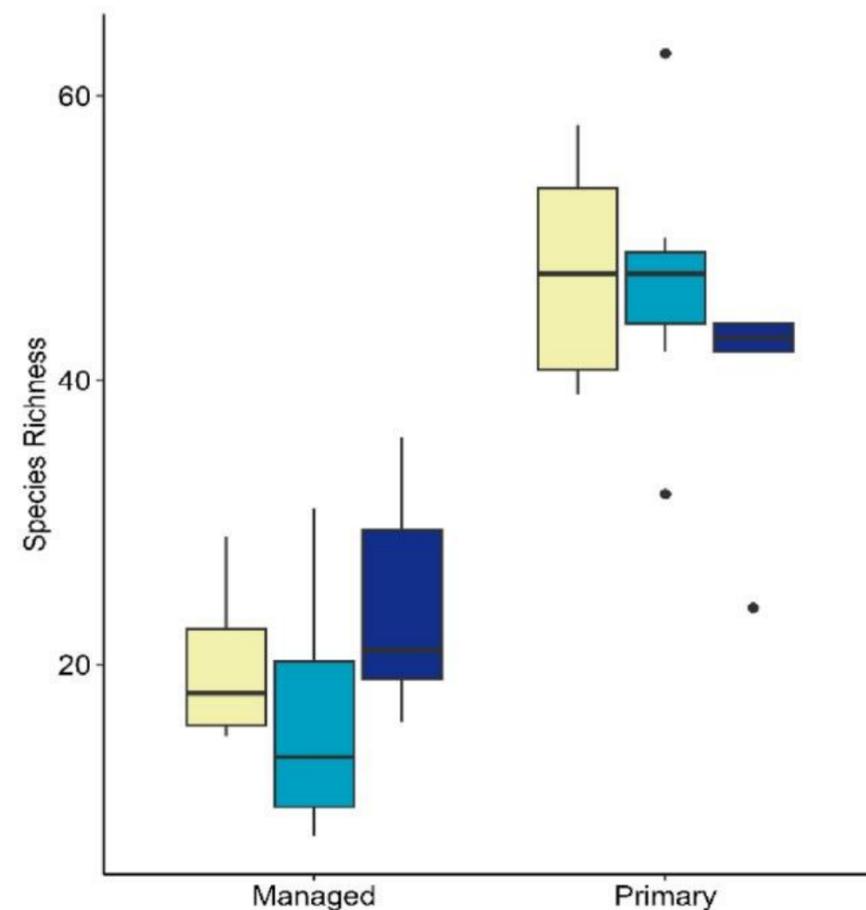


Primary forests host ~25 % more lichens and 2x more red-listed species

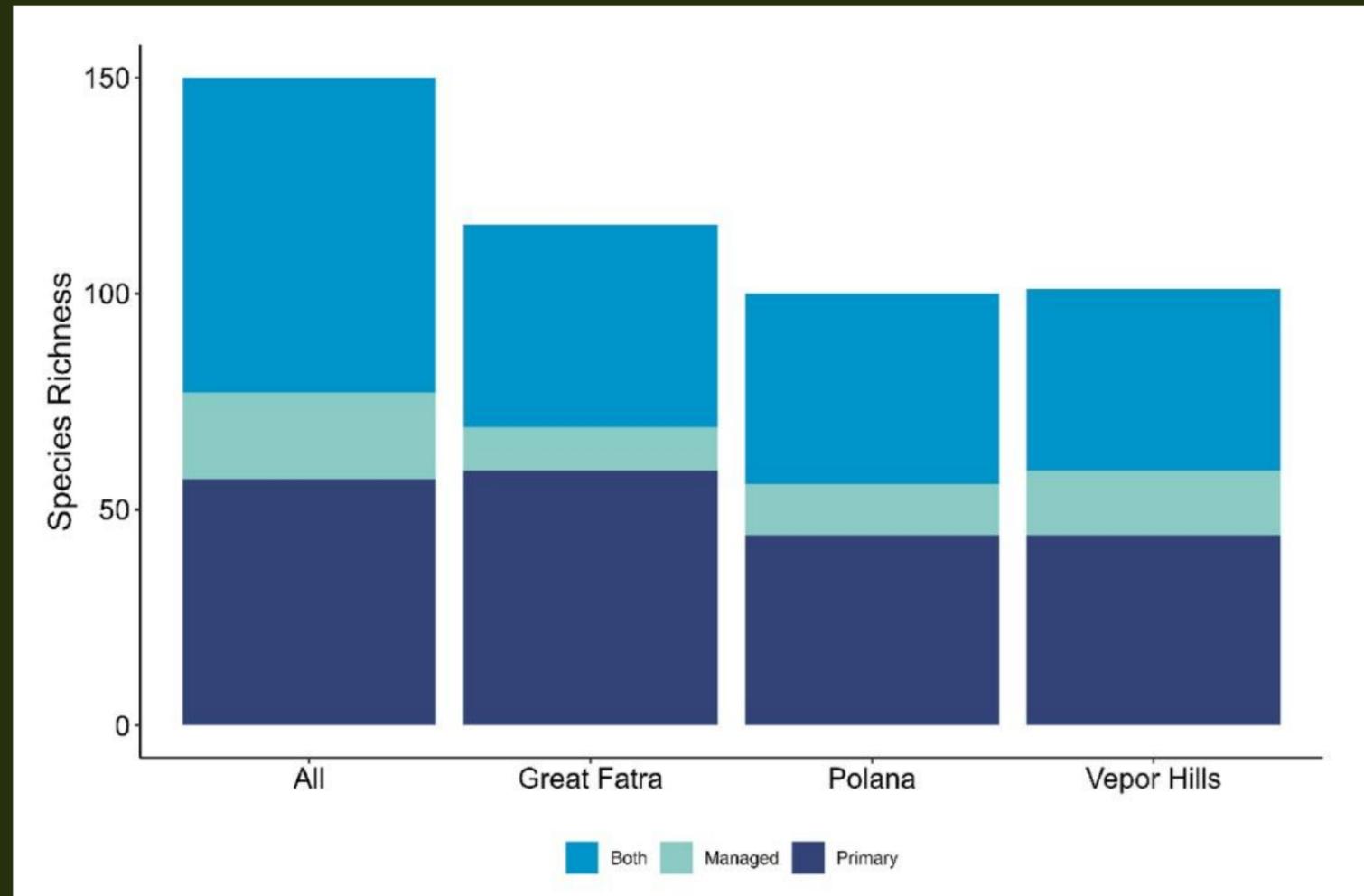
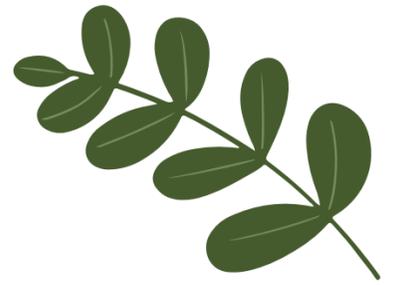
Primary forests: 126 species (62 red-listed)

Managed forests: 93 species (31 red-listed)

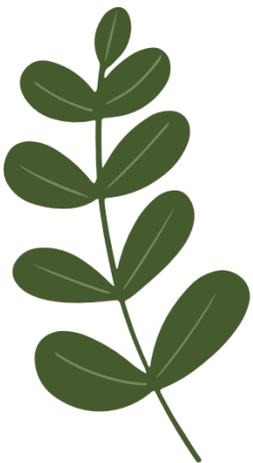
→ Even the most diverse managed plots reached only the lower range of primary forest richness.

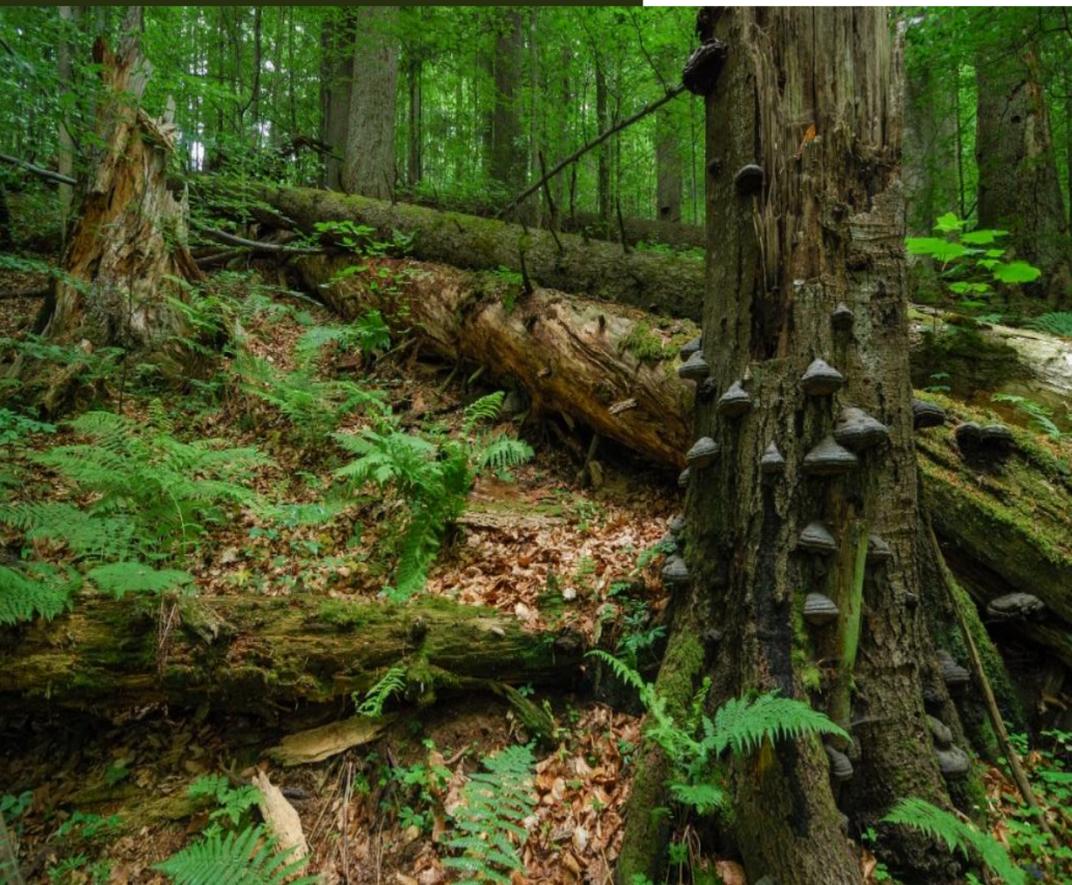


# Unique species within forest types



- **37.5 %** of all recorded species occurred only in **primary forests**.
- **13.9 %** were unique to **managed forests**.
- This highlights the **exceptional biodiversity value** of primary forests.





# Variables and Analysis



## Primary forest vs managed forest

**Table 1**

Summary of structural and lichenological variables measured and observed values, and the results of the Mann–Whitney *U* test assessing differences between forest types.

Variable	Description (unit)	Primary				Managed				Significance level
		Mean	Min.	Max.	SD	Mean	Min.	Max.	SD	
<b>Environmental variables</b>										
Elevation	Elevation of the study plots centres (m a.s.l)	1165.5	1042	1285	66.2	898.4	541	1177	208.1	***
<b>Forest structure</b>										
BA of live trees	Basal area of living trees (DBH $\geq 10$ cm) (m <sup>2</sup> ·ha <sup>-1</sup> )	37.9	15	67	11	35.7	0	77	27.4	ns
Maximum DBH of standing deadwood	DBH of the largest standing DW per plot (DBH $\geq 10$ cm) (cm)	7.2	3.6	10.4	1.6	34.5	0	7.4	2.3	***
Total deadwood	Sum of lying and standing DW (DBH $\geq 10$ cm) (m <sup>3</sup> ·ha <sup>-1</sup> )	198	34	628	141.7	40.7	2	134	33.3	***
Maximum tree age	Age of the oldest tree on study plots (years)	252.6	125	365	61.1	68.1	3	236	67.9	***
<b>Lichen species</b>										
Lichen species richness	Number of lichen species per study plot	45.48	24	63	7.9	19.4	8	36	7.7	***
<b>Red-listed (RL) lichen species</b>										
RL lichen species richness	Number of red-listed lichen species per study plot	13.1	8	24	4.5	3	0	9	2.2	***

Variables: Environmental and structural.

Models: Generalized Least Squares (GLS) per forest type.

# Environmental and structural drivers of lichen species richness

## Model Results: Managed Forests

**Table 2**

Final GLS results of best-fitting models for lichen species richness and red-listed species richness in managed forest plots. The table summarises regression coefficients and their levels of statistical significance and standard error for each variable.

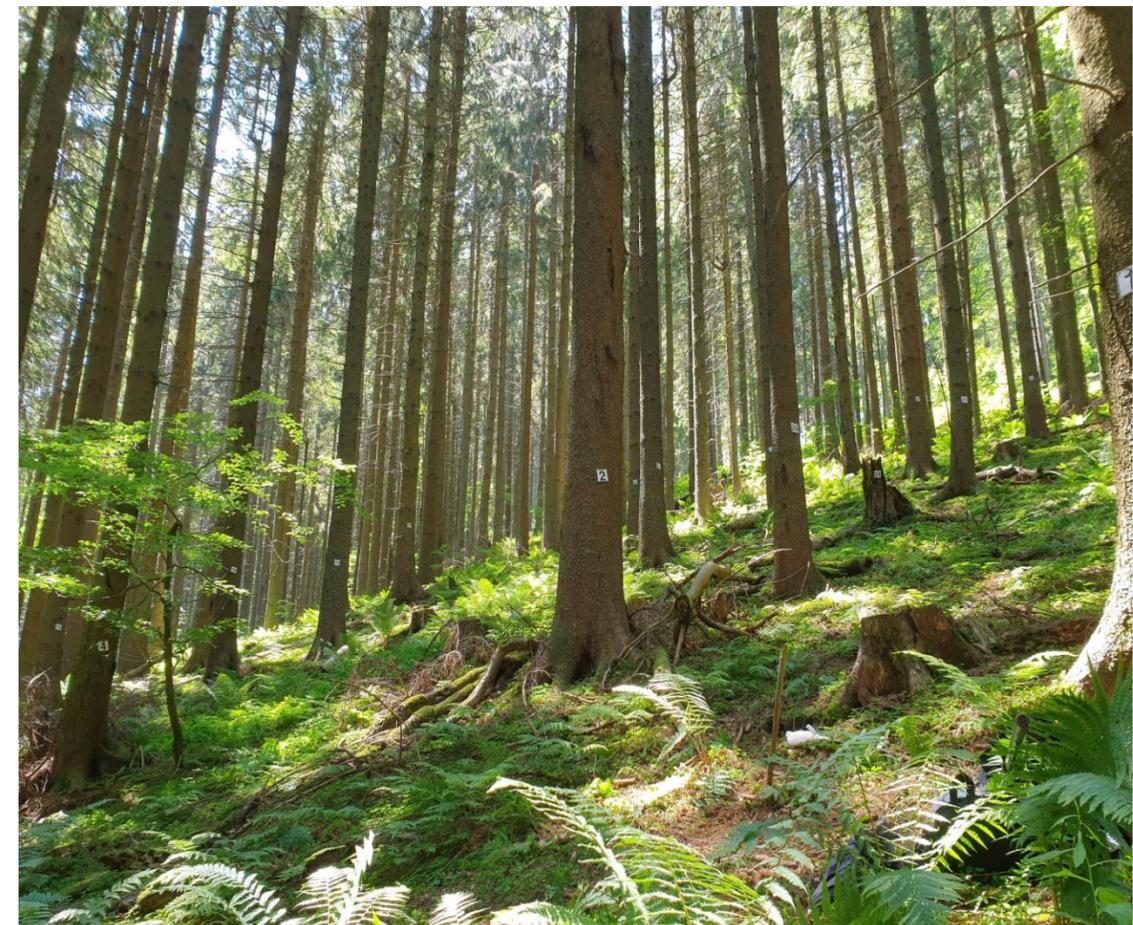
Managed forest						
	Species richness			Red-listed species richness		
	Regression coefficient	Standard error	Significance coefficient	Regression coefficient	Standard error	Significance coefficient
Elevation	-0.0095	0.0062	ns	0.0032	0.0017	.
Max. DBH of standing deadwood	0.0264	0.0046	***	-	-	-
Basal area	-0.1283	0.0418	**	-0.0459	0.0165	*
Tree maximum age	-	-	-	0.0289	0.0063	***

## Model Results: Primary Forests

**Table 3**

Final GLS results of best-fitting models for lichen species richness and red-listed species richness in primary forest plots. The table summarises regression coefficients and their levels of statistical significance and standard error for each variable.

Primary forest						
	Species richness			Red-listed species richness		
	Regression coefficient	Standard error	Significance coefficient	Regression coefficient	Standard error	Significance coefficient
Elevation	0.0405	0.0226	.	0.0292	0.0127	*
Tree maximum age	0.0186	0.0245	ns	0.0165	0.0138	ns
Basal area	-0.2294	0.1340	ns	-0.1368	0.0752	.



# Conservation & management implication



## Primary forests

Serve as **irreplaceable refuges of biodiversity**.

Protection of primary and old-growth forests in Europe should be the highest priority for forest biodiversity conservation, yet remains **incomplete**, with many areas still **unmapped and unprotected**.

Protecting primary and old-growth forests alone is insufficient to maintain biodiversity— effective conservation also depends on **enhancing structural and habitat complexity within managed forests**.



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