Is it possible to monitor multi-taxon biodiversity through Sentinel-2 time series analysis?

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Ecological indicators
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Introduction

- Biodiversity monitoring represents a major challenge in forest ecosystems and where conservation strategies have shifted from single-species protection toward a multi-taxon approach.
- Multitaxonomic studies linking biodiversity to forest structural variables are quite rare due to the effort required for field surveys.
- In this context, remote sensing is a powerful tool, continuously providing broad-scale, consistent, and free information.
- The Sentinel-2 (S2) mission - with 10m spatial resolution and five days of revisitation time - has great potential to produce reliable proxies for biological diversity and support the identification of biodiversity hotspots and consequently guide the selection of areas where to concentrate field analysis.

Study area

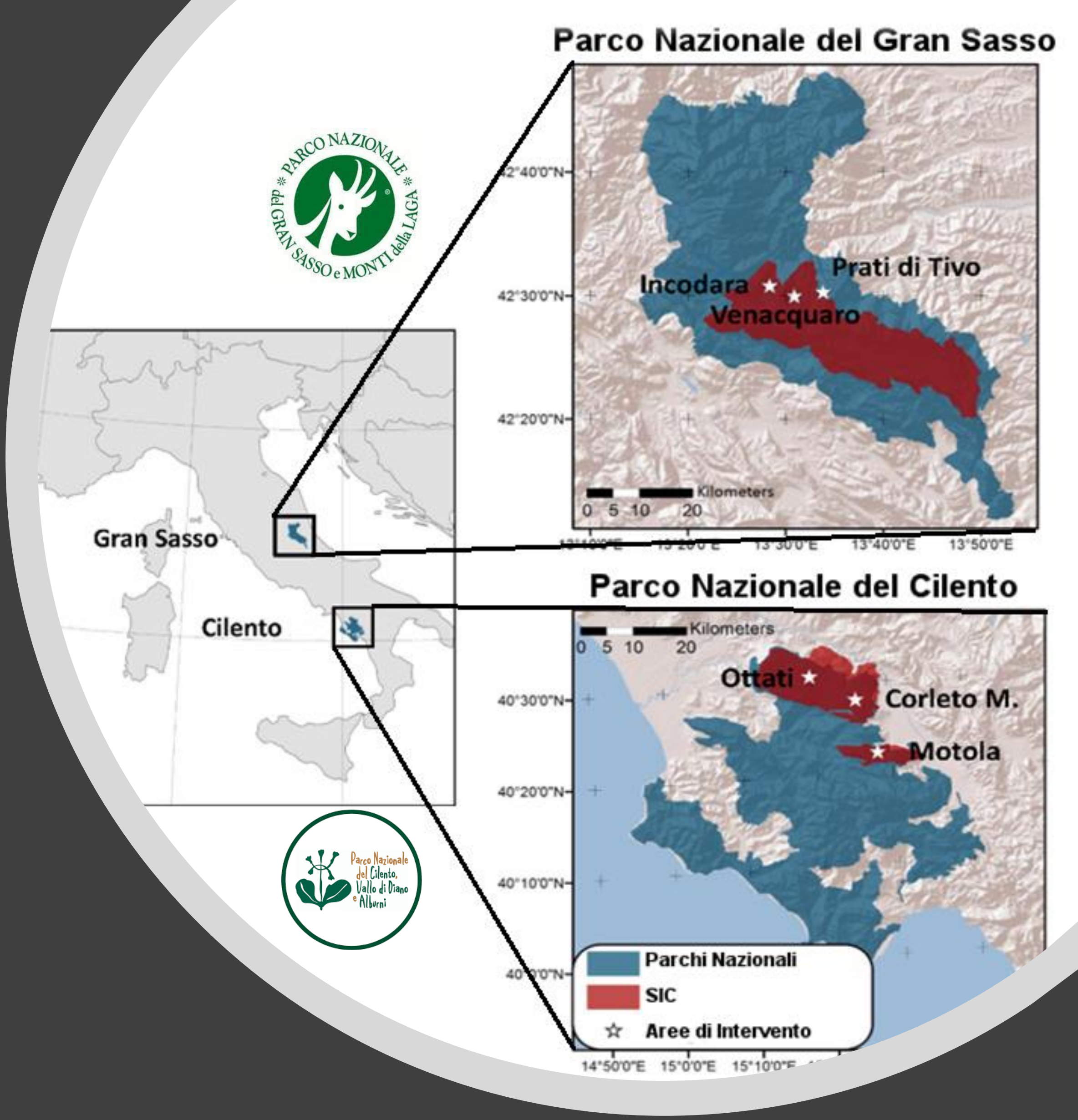
Two areas in beech forest in two National Parks in the central and southern Apennine

Three study sites in each National Park.

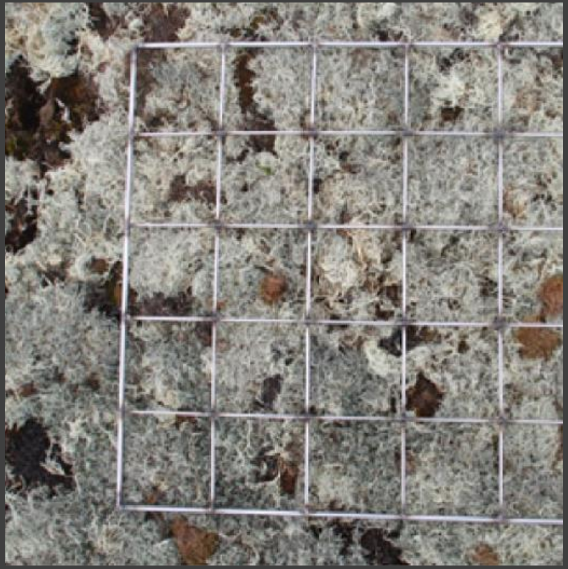
33 field plots (530 m^2), 19 in Gran Sasso (GSML) and 14 in Cilento (CVDA)

Field protocol:

- DBH ≥ 10 cm;
- Height;
- Species;
- Canopy cover;
- Deadwood (dead downed trees, snags, coarse woody debris, stumps);
- 23 tree-related microhabitats types (Winter and Möller, 2008)



Biodiversity sample



- **Saproxylic and non-saproxylic beetles (June to October)**

window flight traps for flying beetles and emergence traps for beetles moving on dead trunks.

Traps were checked approximately every 30 days for a total of four surveys in 2016.

- **Breeding birds (May to June)**

bird breeding season, birdsong production are intensified. Four consecutive days of 10-minute count point.

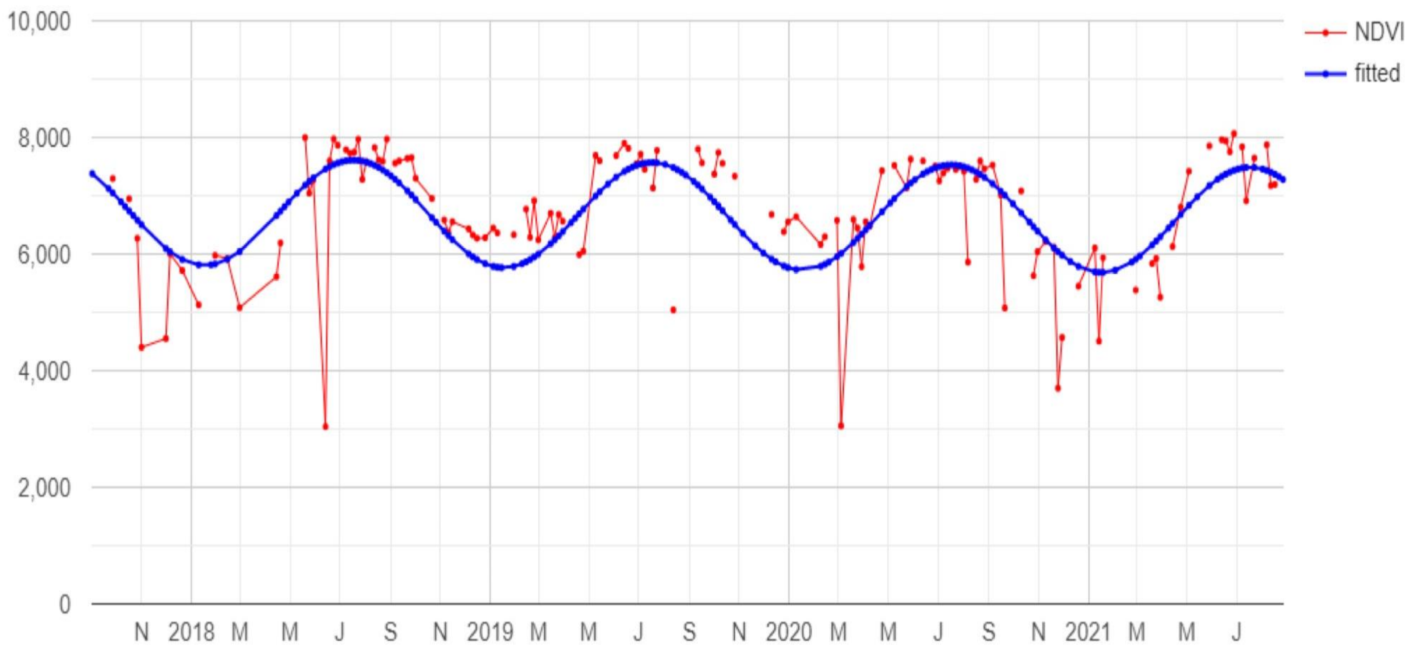
recorded every species detected both visually and by hearing.

- **Epiphytic lichens (June)**

sampled on the three beech trees nearest each plot's center having a DBH equal to or greater than 16 cm. Portable 10 × 50 cm frame composed of five 10 × 10 cm quadrats; facing all cardinal directions at the height of 100 cm from the ground. All lichen species inside the frames were considered;

Sentinel-2 data

Harmonic trend



- S2 imagery acquired over the study area between 2017-09-01 and 2021-08-31, cloud cover <70%. Clouds and cirrus masked out with the cloud probability dataset.
- Different spectral indices (NDVI, NBR, EVI, TCW, TCG, TCB, TCA)
- Four harmonic function coefficients were calculated to identify the pixel harmonic trend. Each pixel harmonic trend function was further used to calculate the amplitude, the phase, and the root means square error.
- **A total of 91 harmonic metrics**

Biodiversity indices

- Shannon entropy index $H' = -\sum_{i=1}^{S} p_i \log p_i$

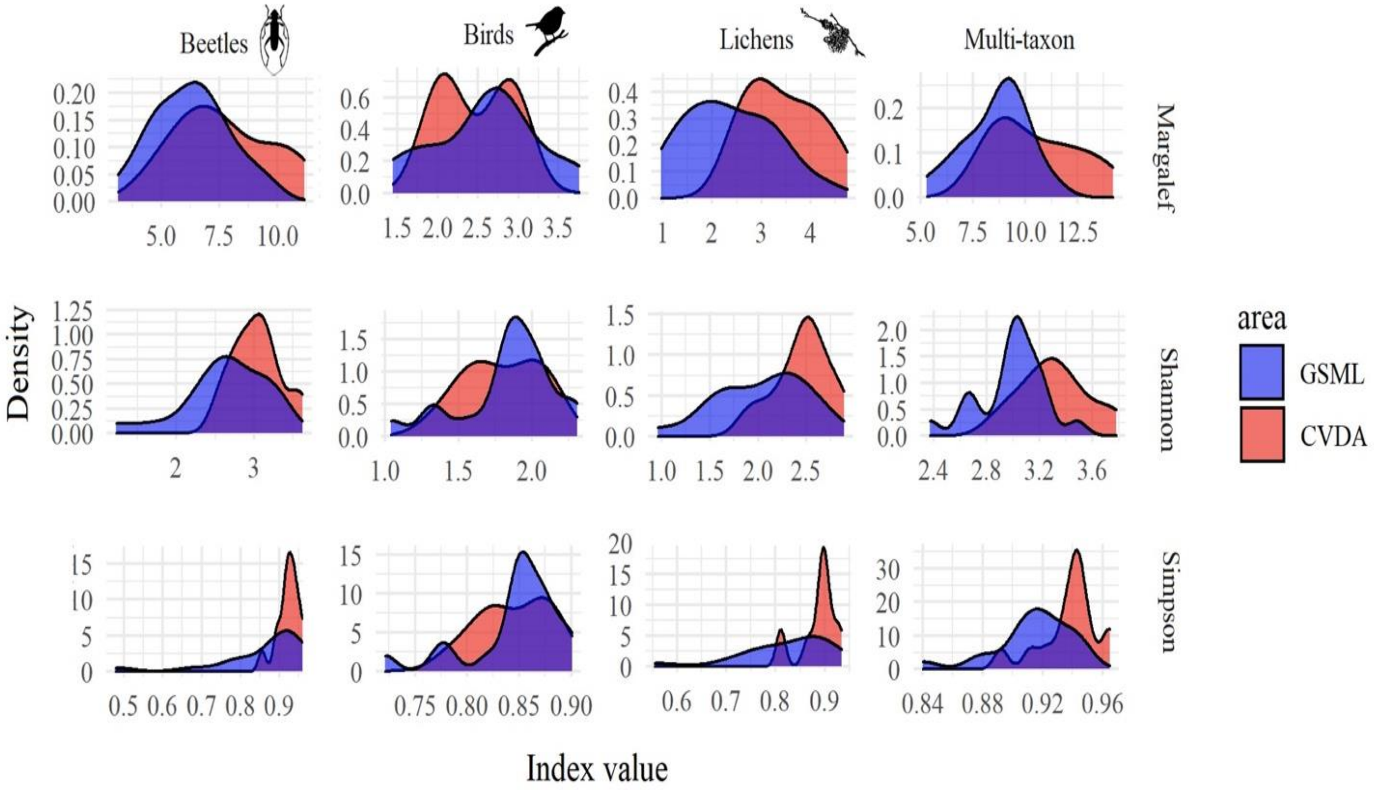
- Simpson diversity index $D = \sum_{i=1}^{S} {p_i}^2$

- Margalef's richness index $d = \frac{\mathrm{S}-1}{\ln(\mathrm{N})}$

- The two study sites were compared in terms of species diversity, microhabitats, and forest structural variables.
- independent T-test And Wilcoxon-Mann-Whitney test.
- Extrapolation curves
- Pearson's product-moment correlation (r) matrix between each *harmonic metric*, species diversity, and structural variables was calculated separately for each study site.

Results

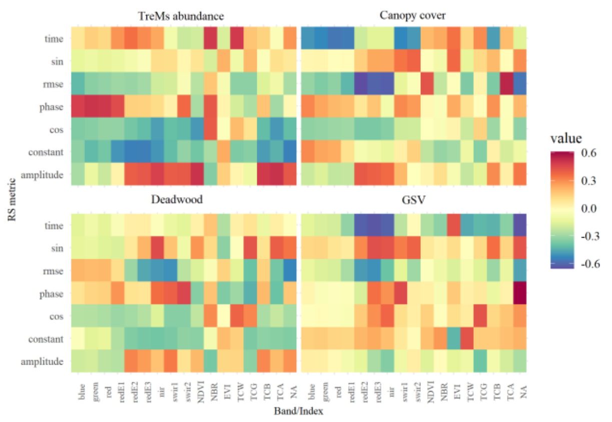
Variable	Test	Statistic	p	p.signif
N° Species lichens	Wilcoxon-Mann-Whitney	206.500	0.00674	**
Shannon index beetles	Wilcoxon-Mann-Whitney	196.000	0.02130	*
Simpson index lichens	Wilcoxon-Mann-Whitney	202.000	0.01110	*
Simpson index Multi-taxon	Wilcoxon-Mann-Whitney	208.000	0.00545	**
Margalef index Multi-taxon	T-test	3.527	0.00133	**
Shannon index Multi-taxon	T-test	3.123	0.00387	**
Margalef index beetles	T-test	2.218	0.03405	*
Shannon index lichens	T-test	3.023	0.00498	**
Margalef index lichens	T-test	3.586	0.00114	**
GSV	T-test	-4.932	0.00003	***



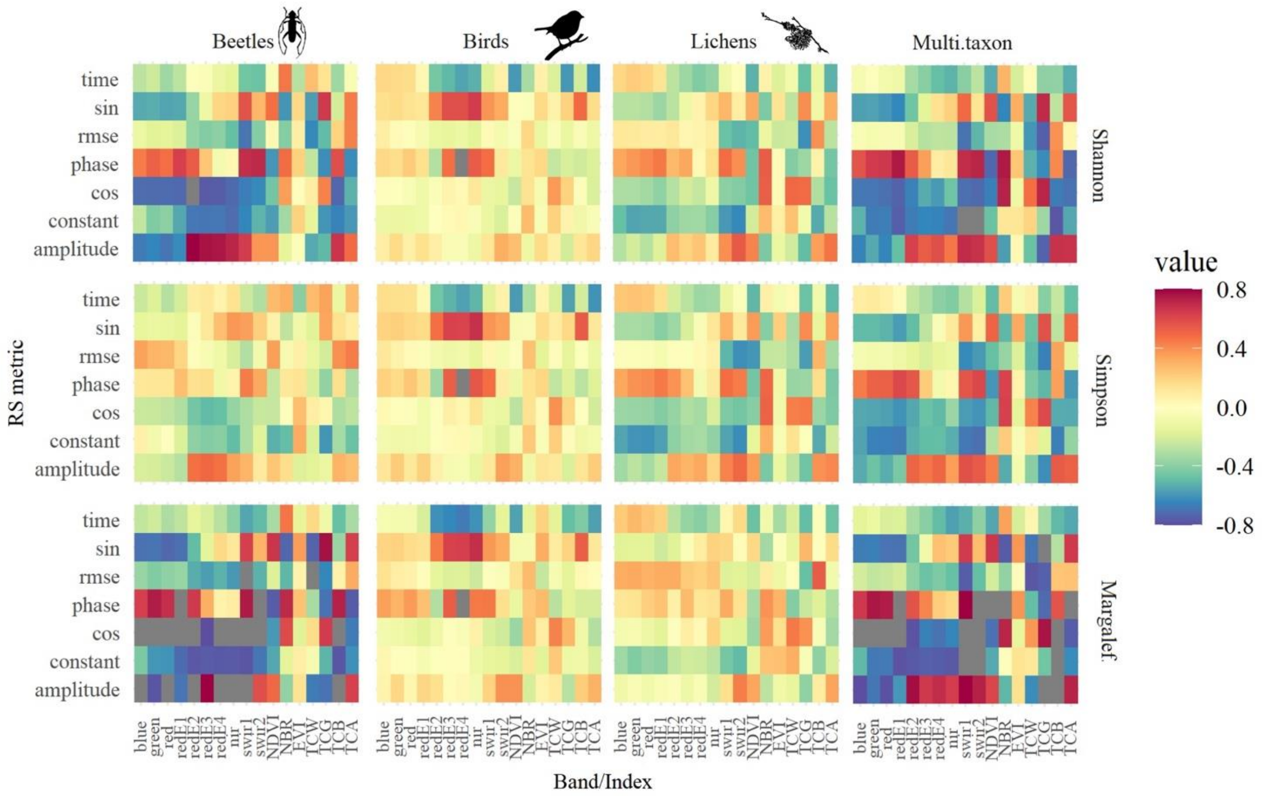
Results

Site	Index	Taxon	S2 metrics	r
CVDA	Margalef	beetles	Amplitude red edge-2	0.88
CVDA	Margalef	beetles	Sine green	-0.91
GSML	Margalef	lichens	Phase TCG	0.81
GSML	Simpson	lichens	Sine TCG	-0.81

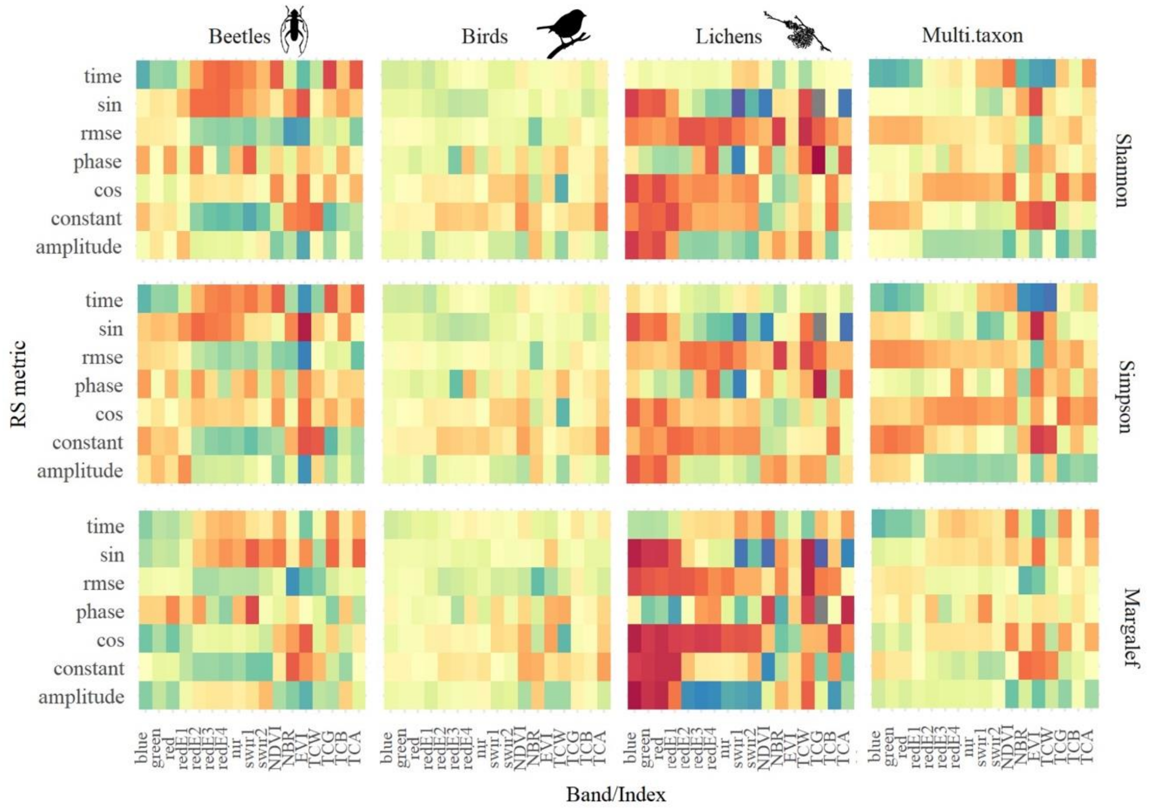
Structural variables



CVDA



GSML



Discussion

Alpha diversity analysis showed higher values for beetles and lichens in CVDA.

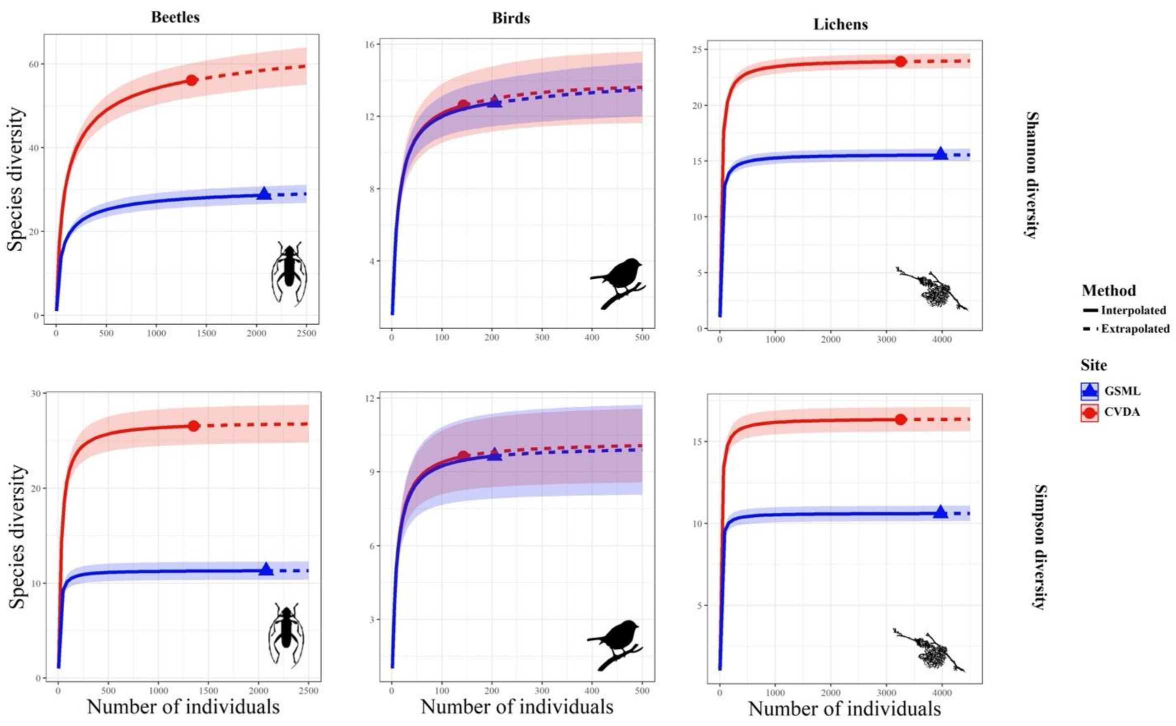
Lack of similarity in the distribution of dominant species in beetles' community (Margalef and Simpson).

Few differences were found between the areas when considering birds (21 in GSML and 20 in CVDA) and lichens (43 in GSML and 51 in CVDA).

The alpha diversity suggested differences in species composition between the two protected areas.

CVDA presents larger trees and more habitat trees. Area in south aspect promote greater diversity.

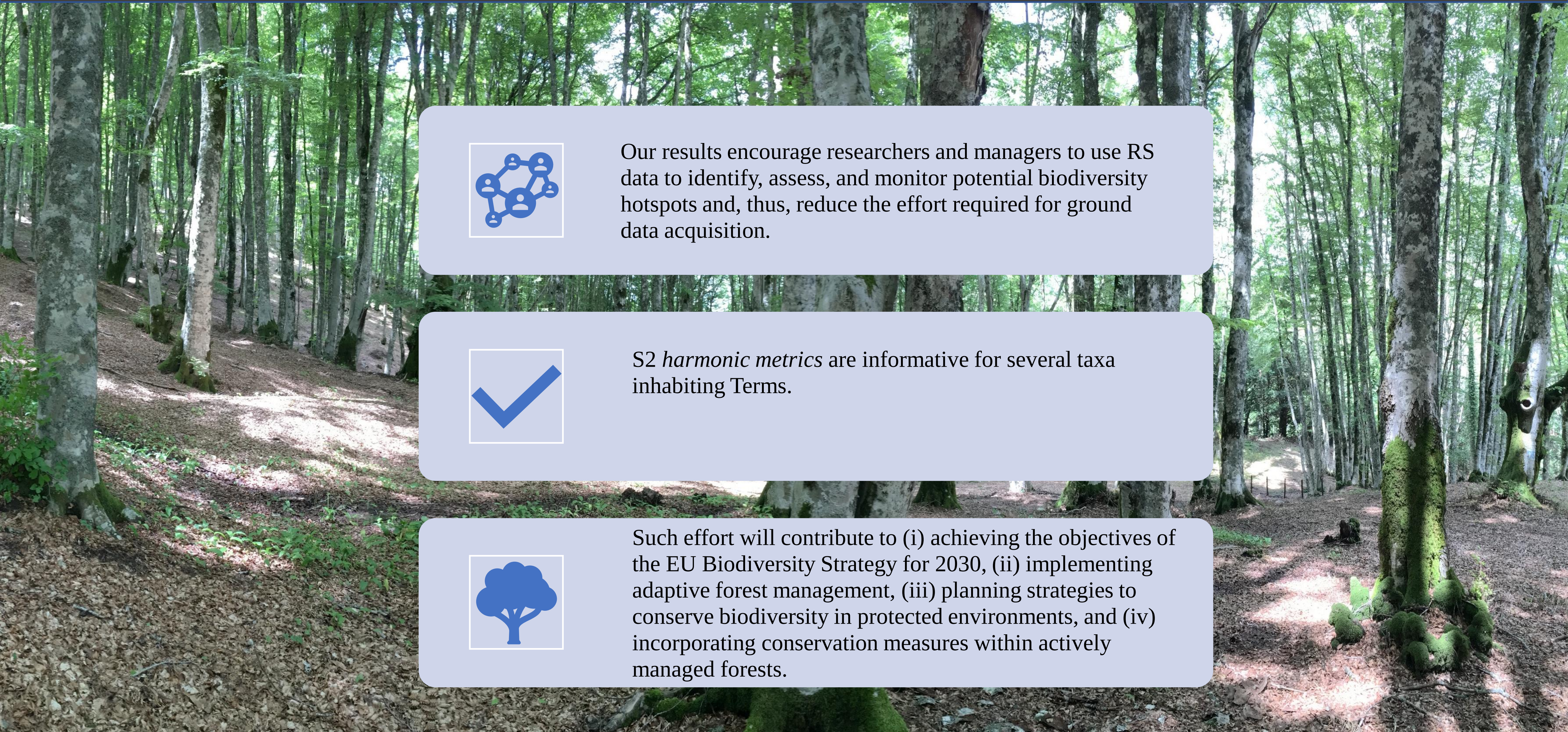
Some families of saproxylic and non-saproxylic beetles need direct solar radiation and low tree cover (low NDVI) to perform their biological functions, so an inverse correlation between RS metrics and species abundance could be expected. The same considerations could be made for epiphytic lichens, whose richness should be higher in forests with higher light penetration.



Each taxon responds relatively differently to a particular set of structural variables.

S2 indices (EVI, NDVI, and NBR) could be linked to the variability of photosynthetic activity, which directly or indirectly affects the diversity and abundance of saproxylic species, by favoring the biological activity of adult beetles and allowing pollination.

Conclusion



Our results encourage researchers and managers to use RS data to identify, assess, and monitor potential biodiversity hotspots and, thus, reduce the effort required for ground data acquisition.

S2 *harmonic metrics* are informative for several taxa inhabiting Terms.

Such effort will contribute to (i) achieving the objectives of the EU Biodiversity Strategy for 2030, (ii) implementing adaptive forest management, (iii) planning strategies to conserve biodiversity in protected environments, and (iv) incorporating conservation measures within actively managed forests.

Thank you for the attention