

Can biodiversity be seen from space?

Multiscale complexity in remote-sensing images to predict ecosystem trends and functional structure beyond conventional spectral indices

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Project at a Glance

A biodiverse landscape may not simply be greener or more heterogeneous. It may possess a distinctive organisation across scales: habitat mosaics, edges, corridors, characteristic patch sizes, lacunarity and long-range correlations. Aerial and satellite images preserve much of this geometry, yet standard ecological products often compress it into pixel classes or a few averages. The challenge is to determine whether multiscale observables carry robust ecological information and, as a possible extension, whether they reveal spatial reorganisation before visible degradation.



Figure 1: Illustrative remote-sensing image of a forested landscape. Image generated by ChatGPT.

Project Description

The project builds on our work on structural complexity in images [1] and multiscale relevance [2], which characterises image organisation through coarse-graining and information-theoretic measures. We will investigate whether these approaches can reveal meaningful relationships between landscape structure and biodiversity. Previous research has established spectral heterogeneity as a potential proxy for species diversity [3] and demonstrated the value of image texture for modelling biodiversity patterns [4]. The question is therefore not simply whether heterogeneous landscapes support more species, but whether their organisation across scales provides additional, interpretable ecological information.

The internship will begin with openly available data from the National Ecological Observatory Network (NEON), combining high-resolution airborne imagery, laser measurements of vegetation structure and ecological field observations at the same sites. After matching images to ecological plots, we will measure multiscale complexity, spatial correlations and habitat geometry, and compare these quantities with plant species richness and vegetation structure. Comparisons with standard spectral and texture measures, spatial randomisations and validation on previously unseen sites will help establish whether the relationships are robust to seasonality, sampling effort and spatial resolution. The objective is not black-box prediction, but an interpretable understanding of what landscape patterns reveal about living communities. If convincing relationships emerge, we will investigate their evolution during drought, fire or fragmentation, without assuming that structural changes necessarily anticipate ecological collapse.

A complementary extension could focus on farmland biodiversity: can the spatial organisation of fields, hedgerows and semi-natural habitats help explain the ecological communities they support? Building on our modelling work on predatory arthropods and natural pest control [5], we could investigate whether multiscale image descriptors capture ecologically relevant features of agricultural landscapes beyond the total amount of habitat. Where suitable field observations are available, this would connect landscape complexity to mechanisms such as dispersal and access to refuges, while distinguishing effects on species diversity from those on arthropod abundance.

References

- [1] S. Lakhal, A. Darmon, J.-P. Bouchaud, and M. Benzaquen, “Beauty and structural complexity,” *Physical Review Research* **2**, 022058(R) (2020).
- [2] S. Lakhal, A. Darmon, I. Mastromatteo, M. Marsili, and M. Benzaquen, “Multiscale relevance of natural images,” *Scientific Reports* **13**, 14879 (2023).
- [3] D. Rocchini *et al.*, “Remotely sensed spectral heterogeneity as a proxy of species diversity: Recent advances and open challenges,” *Ecological Informatics* **5**, 318–329 (2010).
- [4] M.-N. Tuanmu and W. Jetz, “A global, remote sensing-based characterization of terrestrial habitat heterogeneity for biodiversity and ecosystem modelling,” *Global Ecology and Biogeography* **24**, 1329–1339 (2015).
- [5] E. Moretti, M. Loreau, and M. Benzaquen, “A spatially explicit ecological-economic framework for biodiversity and pest management,” *Journal of Environmental Management* **396**, 128111 (2025).