PROJECT INFORMATION

Project title: Remote sensing upscaling biodiversity from ICP-Forests Lv. II using ESA's Sentinels

Project ID:

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PROJECT DESCRIPTION

Research Background

Recently, there were several novel spaceborne sensors launched by the European Space Agency (ESA) offering an unprecedented opportunity for mapping several important aspects of biodiversity, including taxonomic, structural and functional diversity, to regional or even global scale and at very high spatial resolution. Specifically, the ESA's Sentinel-2 (hereafter S2) spaceborne spectroradiometer, which was launched in 2015, equipped with 13 spectral bands and provides global coverage of up to 10 m spatial resolution observations suitable for resolving fine details of variations in vegetation dynamics. The C-band SAR (synthetic aperture radar) instrument onboard ESA's Sentinel-1 satellite (hereafter S1), which was launched in 2014, on the other hand, provides important information about landscape topography and canopy structure which is complementary to S2 optical measurements. So far the potential of these novel Earth observations for mapping forest biodiversity remains to be fully understood. A precursor study by the PI of this proposal & colleagues has demonstrated that ESA's Sentinels provide valuable information related to ground vegetation at very detailed spatial scale, such as phenology and photosynthesis (Ma et al. 2017). It is urgent to further explore the full potential for estimating biodiversity with joint-use of ESA's Sentinels and field biodiversity data such as those from ICP-Forests.

Aims and Objectives

The aim of this project is to develop statistical methods for upscaling biodiversity derived from ICP-Forests data using ESA's S1 and S2. To be specific, we plan to:

1. derive taxonomic, structural, and functional diversity measures from ICP-Forests Lv. II plot data across European forests;
2. explore the link between canopy structure, species composition, and functional traits with RS proxies (e.g., spectral heterogeneity, landscape texture, phenology);
3. develop robust statistical algorithms, including feature selection and nonlinear dimensionality reduction approaches, for estimating biodiversity using Sentinels.

Significance and Innovation

1. This project will for the first time explore the joint use of ESA's S1 radar and S2 multispectral optical observations for upscaling several important aspects of forest biodiversity, including functional diversity;
2. The derived models can be applied across space (and potentially across time) to understand spatial-temporal variations in forest biodiversity across Europe;
3. With derived biodiversity maps we could further explore the mechanic links between biodiversity (taxonomic, structural, and functional) and ecosystem functioning.

Methodology Description

The overall workflow can be described in following four major steps:

- **Deriving several biodiversity measures from ICP-Forests Lv. II plot data.** The biodiversity measures we plan to derive from Lv. II plot data include taxonomic diversity (species richness, Shannon index), structural diversity (diversity in canopy height, DBH, and LAI), and functional diversity (diversity in functional traits such as leaf nitrogen and specific leaf area). We will test several methods for computing functional diversity including a distance-based method using multiple traits weighted by species abundance (Laliberte & Legendre, 2010). For traits that are not available from the Lv. II data, we will obtain them from the TRY database (Kattge et al. 2015);

- **Preprocessing satellite observations.** We will process high-resolution S1 C-band radar backscatter and S2 multispectral reflectance measurements for selected ICP-Forests Lv. II plots. These data will be preprocessed, including atmospheric correction, and we will perform quality filtering to remove undesired observation (e..g., the cloud covered). For S1, we will also apply multi-temporal filtering to remove spikes in the data due to instrument noises;
- **Deriving remote sensing biodiversity proxies.** We will then compute several remote sensing biodiversity proxies, including 1) spectral heterogeneity indices computed from S2 (Rocchini et al. 2010; Lausch et al. 2016); 2) texture-related indices from S1 and S2: 3) landscape topography such as Digital Elevation Model (DEM) from S1; 4) multi-temporal indices such as phenology from S1 and S2.
- **Developing robust statistical models for predicting biodiversity using remote sensing proxies.** We will start with the simple multiple-regression model. To account for multicollinearity among predictive variables, we will test advanced statistical methods such as PCA regression or partial-least square regression. To further consider potential nonlinearity between remote sensing proxies and biodiversity, we will test novel statistical methods such as nonlinear PCA regression.

Justifications for requesting Lv. II plot data

To develop statistical models for predicting biodiversity using ESA's Sentinels, we would like to request the Lv. II intensive plot data from ICP-Forests for following reasons:

1. the ICP-Forests is a comprehensive forest monitoring network with several hundreds of high-quality field plots distributed across latitudes and forest types. The representativeness of ICP-Forests Lv. II plot network satisfy our need for developing models for mapping biodiversity across forest types;

2. the size of the Lv. II plot (minimum 0.25 ha homogeneous forest area) is ideal for comparing to Sentinels (the size of a single pixel ranging from 10m to 60m);
3. the intensive Lv. II plot data is needed because we require not only ground vegetation data (species composition/abundance) but also canopy structure (tree height, DBH, LAI) and functional traits (specific leaf area, leaf nitrogen content);
4. Lastly, the latest available Lv. II plot data (2015/2016/2017) is desired for comparing to Sentinels which were launched in 2014 and 2015 respectively.

Expected outcomes

- Taxonomic, structural, and functional diversity derived from ICP-Forests Lv. II field plot data across a wide range of European forests;
- Improved understanding of the link between remote sensing optical and radar measurements with different aspects of biodiversity over different forest types;
- Robust statistical models for mapping forest biodiversity at very high spatial resolution using novel spaceborne measurements.

Research background of the PI and other supports to this project

The PI Dr. Ma has rigorous and well-balanced training in ecosystem ecology and remote sensing and equipped with extensive experiences in using Earth observation data for detecting and quantifying spatial-temporal variations in vegetation phenology (Ma et al. 2013), ecosystem functioning (Ma et al. 2014), and their relationships to climate variability (Ma et al. 2015, 2016). Besides, the PI is currently carrying on a project of the German Centre for Integrative Biodiversity Research (iDiv), inviting close collaborations with several leading scientists in ecosystem ecology and Earth system science, such as Prof. Dr. C. Wirth, R. Richter (iDiv), Drs. A. Huth, F. Bohn, and S. Lehmann (Helmholtz Centre for Environmental Research, Germany), Prof. Dr. M. Reichstein, Drs. J. Kattge, M. Mahecha, and M. Migliavacca, T. Musavi from Max-Planck Institute for Biogeochemistry (Germany). These will ensure Xuanlong &

colleagues to achieve the proposed objectives and deliver expected outcomes within the timeframe of this project.

Timeline (beginning and end of the project): Feb 2018 - May 2019

Year	**Months**	**Activity**
2018	Feb	Starting exploring the ICP-Forests Lv. II plot data, focusing on variable / site selection
	May-May	Deriving taxonomic/structural/functional diversity from selected Lv. II plot data and preprocessing S1 & S2 measurements
	May	(if possible) Presenting the very first results during the 7th ICP-Forests Scientific Conference in Riga, Latvia
	Jun-Aug	Deriving remote sensing biodiversity proxies from preprocessed S1 and S2 data and linking them to field biodiversity measures
	Sep-Nov	Developing statistical models for predicting biodiversity using S1 and S2 measurements
2019	Jan-Mar	Finalising analyses and preparing manuscripts
	April-May	Submitting papers to peer-reviewed journal & project concluded

References

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