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Prediction of plant diversity in grasslands using Sentinel-1 and -2 satellite image time series

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ABSTRACT

The prediction of grasslands plant diversity using satellite image time series is considered in this article. Fifteen months of freely available Sentinel optical and radar data were used to predict taxonomic and functional diversity at the pixel scale (10 m × 10 m) over a large geographical extent (40,000 km^2). 415 field measurements were collected in 83 grasslands to train and validate several statistical learning methods. The objective was to link the satellite spectro-temporal data to the plant diversity indices. Among the several diversity indices tested, Simpson and Shannon indices were best predicted with a coefficient of determination around 0.4 using a Random Forest predictor and Sentinel-2 data. The use of Sentinel-1 data was not found to improve significantly the prediction accuracy. Using the Random Forest algorithm and the Sentinel-2 time series, the prediction of the Simpson index was performed. The resulting map highlights the intra-parcel variability and demonstrates the capacity of satellite image time series to monitor grasslands plant taxonomic diversity from an ecological viewpoint.

1. Introduction

Natural and semi-natural grasslands cover 22% of the European agricultural land surface (Bengtsson et al., 2019). Grasslands are today one of the most endangered ecosystems due to land use change, agricultural intensification, and abandonment (Pärtel et al., 2005). Grasslands host a unique biodiversity, which support the provision of key ecosystem services such as carbon storage, food production crop pollination, pest regulation and contribute to landscape scale amenities such as landscape scenic view. Permanent grasslands are crucial to maintain biodiversity in many agricultural landscape (Watkinson and Ormerod, 2001; Habel et al., 2013), and particularly insect diversity: they provide host plants, nectar, pollen (Ockinger and Smith, 2007) as well as nest sites (Carrié et al., 2018; Potts and Willmer, 1997).

Yet, despite recent regulation in favor of grasslands, agriculture intensification, abandonment and urbanization generate a decrease of both grasslands surface area and plant diversity (O'Mara, 2012; Newbold et al., 2016) leading to a loss of biodiversity (plants, insects, birds) and its related ecosystem services. Therefore, there is an urgent need to monitor grasslands over large extents in order to assess their current state in terms of area covered but also to estimate their plant diversity and their carrying capacity for insect populations. While the area information can be extracted from land cover databases (e.g. CORINE Land Cover (Heymann, 1994)) diversity and carrying capacity data are scarcely available. Though, spatial location, extent and quality of grasslands are crucial for their conservation per se but also to produce maps of related ecosystem services in agricultural areas. For instance, *mobile agents based ecosystem services* (Kremen et al., 2007) such as pollination and pest regulation rely on the presence of a mosaic of crops and semi-natural elements among which grasslands are crucial and represent the largest surface area.

Plant diversity is usually assessed by botanical surveys of the grasslands and indices related to the diversity in species of a community are commonly computed (richness, Shannon and Simpson diversity (Magurran, 2004)). Functional diversity can also be derived from the botanical survey through *functional types*, i.e., set of species exhibiting similar attributes having similar effect on ecosystems (Diaz and Cabido, 2001). Field surveys, sometimes called ground-truth in the remote

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