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Assessing ecological habitat structure from local to landscape scales using synthetic aperture radar

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ABSTRACT

Ecological studies need accurate environmental data such as vegetation characterization, landscape structure and organization, to predict and explain the spatial distribution of biodiversity. Few ecological studies use remote sensing data to assess the biophysical or structural properties of vegetation to understand species distribution. To date, synthetic aperture radar (SAR) data have seldom been used for ecological applications. However, these sensors provide data allowing access to the inner structure of vegetation which is a key information in ecology. The objective of this article is to compare the predictive power of ecological habitat structure variables derived from a TerraSAR-X image, an aerial photograph and a SPOT-5 image for species distribution. The test was run with a hedgerow network in Brittany and assessed the spatial distribution of the forest ground carabid beetles which inhabit these hedgerows. The results confirmed that radar and optical images can be indifferently used to extract hedgerow network and derived landscape metrics (hedgerow density, network grain) useful to explain the spatial distribution of forest carabid beetles. In comparison with passive optical remotely sensed data, VHSR SAR images provide new data to characterize vegetation structure and more particularly hedgerow canopy cover, a variable known to explain the spatial distribution of carabid beetles in an agricultural landscape, but not yet quantified at a fine scale. The hedgerow canopy cover derived from the SAR image is a strong predictor of the abundance of forest carabid beetles at two scales i.e., a local scale and a landscape scale.

1. Introduction

Ecological studies aiming to explain and predict species distribution or spatial variability of species richness over landscapes need accurate data for quantifying the structure and organization of habitats (St-Louis et al., 2009). Understanding spatial species distribution is directly linked to the ability to characterize the environmental conditions that drive species distribution. Remotely sensed data offer a unique opportunity to provide environmental information with complete coverage, at different spatial and temporal resolutions and extents, such as land cover classification (Kerr and Ostrovsky, 2003) and vegetation biophysical properties (Turner et al., 2003; Jacquemoud et al., 2009) or structural properties (Lee and Pottier, 2009; Imhoff et al., 1997).

The use of remotely sensed data for ecological applications has increased in recent years, for instance to predict species richness (Kerr and Ostrovsky, 2003; Levanoni et al., 2011), or map plant assemblages (Betbeder et al., 2014a; Pu, 2009; Clark et al., 2005). Most of the time, the imagery used in ecology is optical remotely sensed imagery (Kerr and Ostrovsky, 2003), for instance the normalized difference vegetation index (NDVI) is used for many ecological applications (Pettorelli et al., 2014). NDVI provides information on vegetation distribution and dynamics and can be used to predict animal distribution, abundance etc. (Pettorelli et al., 2005). Other remote sensing data, such as SAR (synthetic aperture radar) and LIDAR (light detection and ranging) images, offer new opportunities to characterize vegetation structure over a whole landscape. Indeed, LIDAR remote sensing has the ability to acquire three dimensional measurements of the landscape surface of a study site at a fine spatial resolution, which is useful for estimating a variety of vegetation features (such as tree height, volume,

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biomass) (Heinzel and Koch, 2011; Müller and Brandl, 2009). However, LIDAR is costly meaning that regular time-series monitoring is operationally constrained. Synthetic Aperture Radar (SAR) data are easier to acquire and provide a reliable alternative to optical images, because they are not sensitive to visibility conditions and they can be acquired by day or night (Ulaby, 1990). As radar sensors with very high spatial resolution (VHSR) are all weather instruments, they increase the possibility of frequent data collection allowing inter and intra annual monitoring at fine scales. Moreover, they allow access to the inner structure of vegetation (Betbeder et al., 2014b). Images acquired by these sensors should allow an increase in the amount and accuracy of ecological information extracted from remote sensing data (Kasischke et al., 1997) and improve their utility in ecological studies.

The objective of this article is to test the information provided by SAR imagery as compared to aerial photographs and SPOT-5 imagery for ecological applications and more specifically to explain species abundance. We ran the test with a hedgerow network in Brittany, France. Hedgerows fulfill ecological, social and economic functions such as control of soil erosion, landscape beautification, wood production, microclimatic effects, water quality and conservation of biodiversity (Baudry et al., 2000a). Hedgerow networks play a key role in habitat connectivity for some species and thus influence the degree of fragmentation of the landscape (Petit and Burel, 1998). Furthermore, hedgerow structure (tree and shrub cover, width) is a major variable to determine habitat quality for plants and animals (Le Cœur et al., 2002). A recurrent question in landscape ecology is to determine the "forest" character of such hedgerow network landscapes (Forman and Baudry, 1984). Hedgerows where shade and humidity are permanent because of the vegetation density can be forest-like habitats for small, less mobile species. This can be reinforced by the landscape structure as in fine grain landscapes wind speed is lower, therefore evapotranspiration is also lower. This fosters the ability of hedgerows to harbor species thriving in shady, cool habitats (Burel, 1989). Most studies therefore use maps of networks and a qualification of hedgerow structure. Hedgerow structure is mostly described for small areas from field measurements. Because this process is too time-consuming, hedgerow structure is estimated over landscapes in a semi-quantitative manner (e.g., Defra, 2007). The estimation of tree density, cover, shrub cover in the field is subject to the observers' bias. Furthermore, it is performed on segments of hedgerow networks corresponding to a "hedgerow" defined as either the segment between two connections or the segment along a field defined by its land cover (Baudry et al., 2000a). So these segments are of different sizes and the parameters used to describe them are estimated at a scale that is not always relevant to the study species that inhabit them. Therefore the internal homogeneity or heterogeneity of hedgerows

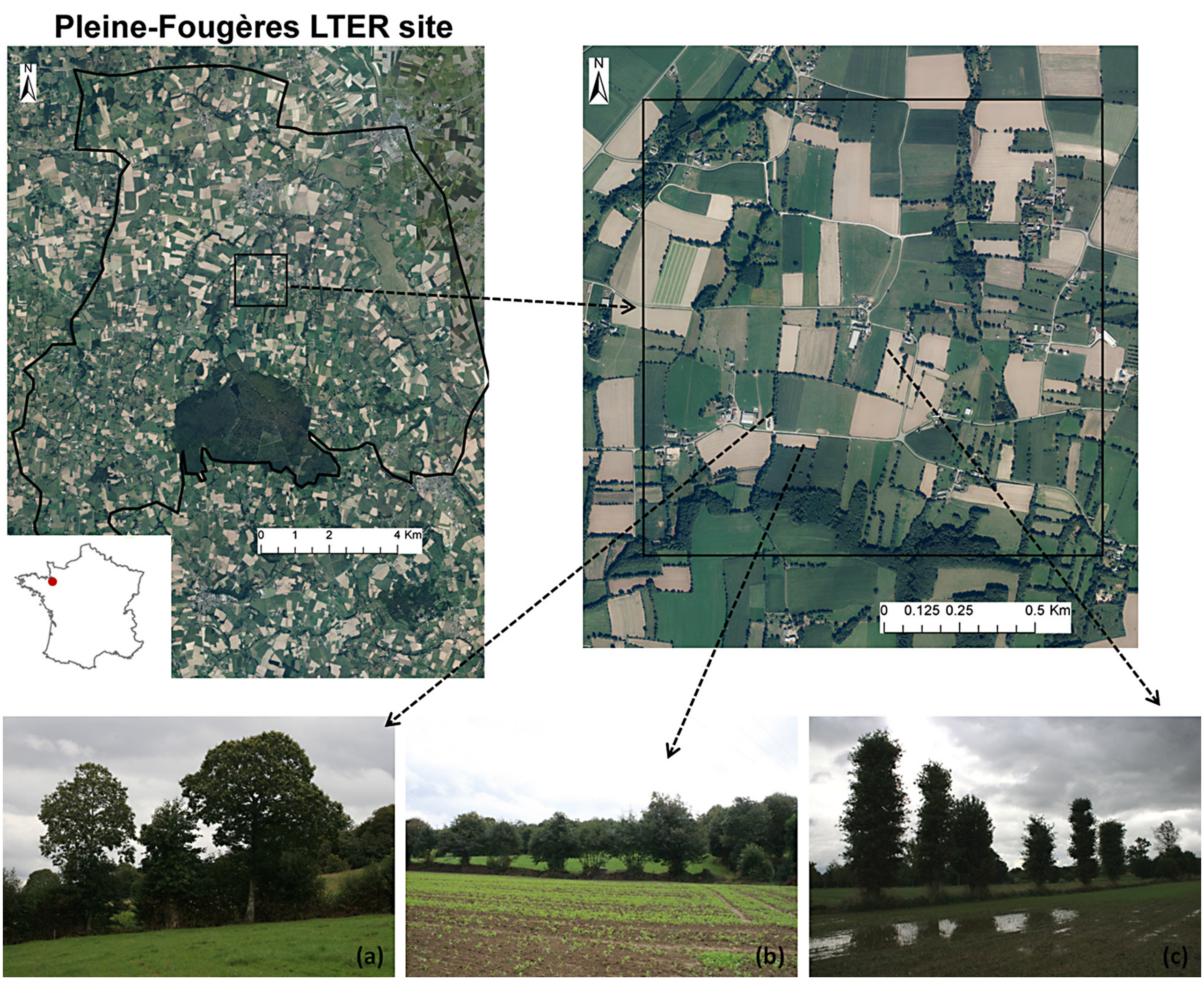

Fig. 1. Location of the study site focusing on a sub-network where biological data sampling has been performed. This sub-network presents different canopy structures (a) (c), with (a) or without (b) (c) underlying shrubs and pruned trees.