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Research paper

Testing the applicability of ecosystem services mapping methods for peri-urban contexts: A case study for Paris

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ABSTRACT

Through their semi-natural and agricultural areas, peri-urban regions are pivotal in providing ecosystem services (ES) to city dwellers. To quantify the ES provided by these areas, it is possible to use ES mapping methods: many ES mapping methods rely on land cover maps, but most maps are coarse compared to the peri-urban scale. Nevertheless, readily-available land use data and methods are often used to map ES at such scales, without contextualisation. As a result, such methods may not be able to capture the diversity that is present in the peri-urban vegetation, which could have consequences for their accuracy and furthermore for urban planning policies.

To increase our understanding of the applicability of ES mapping methods in peri-urban regions, we assessed to what degree sites with similar plant composition in the green belt of Paris, France, were also projected to have similar ES bundles. We considered two commonly used ES model types: proxy-based models (here: look-up tables) and phenomenological models. We used 252 sites for which botanical survey data were available and applied the ES models to seven ES relevant in the peri-urban context. A cluster analysis was used to group sites, hence facilitating analyse of the spatial congruence between types of vegetation and bundles of ES.

Clustering sites based on plant composition revealed six distinct clusters. Clustering sites based on ES bundles as estimated by phenomenological models and proxy-based models, resulted in four and two clusters, respectively. The proxy-based clustering only highlighted broad-leaved forests as an important ES supply source. The phenomenological model estimates of ES allowed a more nuanced clustering of sites into four different groups. The level of congruence between the different sets of clusters based on plant composition and estimated ES bundles was low. Except for forests, the commonly used ES models tested here were not able to represent the same level of heterogeneity in the peri-urban landscape as was found in the vegetation. Our results demonstrate the need to integrate finer scale approaches and primary data in ES assessments of peri-urban areas.

1. Introduction

Ecosystem services (ES) mapping and assessment is increasingly common, in line with science-policy initiatives globally, like IPBES (http://www.ipbes.net/), and regionally, like MAES for the European Union (http://biodiversity.europa.eu/maes). Land cover data are a common data source for ES assessments (e.g. Andrew et al., 2015; Crossman et al., 2013; Egoh et al., 2012; Malinga et al., 2015; Martínez-Harms and Balvanera, 2012; Harms and Balvanera, 2012). However, such data are coarse representations of the actual vegetation composition and often do not represent the intensity of land use or land management. Indeed, Eigenbrod et al. (2010); for England) and Schulp et al. (2014a; for Europe) revealed that estimates by ES mapping methods based on land cover data exhibited relatively large uncertainty and variability. Another source of uncertainty and error originates from the coarse resolution of land cover data typically used to map ES. Such data do not represent fine scale heterogeneity in land cover, resulting in potential errors in ES estimates in heterogeneous areas, such as peri-urban regions (Van der Biest et al., 2015).

Other approaches assess ES based on the functional relationship between the traits of plant communities and the provision of ES (Díaz et al., 2007), hence overcoming some of the uncertainties of methods primarily using land cover. However, studies linking plant functional traits and ES are mostly local, given the data-intensity and complexity of such models. This challenges the transposition of trait-based methods to more complex landscapes, and to larger spatial scales (Lavorel et al., 2011). Some studies have been conducted at landscape scales (Crouzat et al., 2015; Homolová et al., 2014) but mostly in areas valuable from a

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biodiversity conservation perspective, which are often remote, such as alpine grasslands.

The limitations of both types of approaches to map ES are especially important in peri-urban areas. While often less relevant from a biodiversity conservation perspective, peri-urban regions are pivotal in the provision of ES to people, given that over half of global population lives in cities (United Nations, 2015). Peri-urban areas still represent considerable amounts of non-built up land that provide ES (Huang et al., 2011; McGregor and Simon, 2012) although some need to be more closely delivered to beneficiaries (e.g. recreation and air quality regulation), than others (e.g. carbon sequestration) (Casado-Arzuaga et al., 2013; Vejre et al., 2010; Verhagen et al., 2017). Here, the relations between vegetation and ES are little studied, although ES have received much attention in an urban context (e.g. Alam et al., 2016; Haase et al., 2014; La Rosa et al., 2016). Studies that map ES in urban areas have mostly used general vegetation covers (Larondelle and Haase, 2013; Tratalos et al., 2007), with some using more detailed vegetation types in ES assessment (Derkzen et al., 2015; Holt et al., 2015; Lehmann et al., 2014). Given that peri-urban landscapes, at least in Europe, are typically heterogeneous in land cover (Couch et al., 2007; Hoggart, 2016), mapping approaches using coarse resolution data may have relatively large errors in ES estimates (Van der Biest et al., 2015). Indeed, Malinga et al. (2015) conclude that while most ES mapping studies concern the municipal scale and fine grain size (1 ha), most of these studies used generic data and models for calculating ES generation at these finer grain sizes. Therefore, it is important to improve the understanding of the relations between actual vegetation composition, land cover classification and ES assessments in the peri-urban context, at fine grain size. Even though vegetation composition alone cannot be considered an optimal proxy for ES provision either, it is a relevant indicator of degree to which ES mapping methods based on land cover data capture actual variation in vegetation at the local scale.

This research aims at assessing the congruence between two commonly used ES mapping methods based on land use data, and plant composition for a peri-urban context. We considered (1) proxy-based models (*sensu* Lavorel et al., 2017: "*models that relate ES indicators to land or marine cover, abiotic and possibly biotic variables by way of calibrated empirical relationships or expert knowledge* ") − namely the ES assessment matrix by Burkhard et al. (2012) − and (2) phenomenological models (*sensu* Lavorel et al., 2017: "*based on an understanding of biological mechanisms underpinning ES supply* […] *They assume, but do not represent explicitly, a mechanistic relationship between elements of the landscape, considered as ES* [Providers] *units, and the provisioning of ES* ") for seven ES: air quality regulation, global climate regulation, flood protection, pollination, wild food provision, erosion regulation, and recreation. We used Paris, France, as a case study. The peri-urban green space of this large metropolis serves a large population and is heterogeneous in landscape character and therefore likely to have spatial variation in ES provision. For 252 sites, we assessed the plant composition from botanical surveys. For these sites ES were quantified using both types of ES modelling approaches. Next, sites were clustered three times, based on either their plant composition or their ES bundle, as estimated by the two model types, and the degree of congruence among the three sets of clusters was determined. By doing so, our study aims at indicating the degree to which land use and vegetation heterogeneity are reflected in the ES bundles estimated by different modelling approaches. Note that this focus on ES bundles is different from earlier studies, which compared individual ES models to each other (Schulp et al., 2014a) and to primary data (Eigenbrod et al., 2010). The ES bundle approach is relevant because policies often aim at protecting the overall level of ecosystem service provision rather than or additional to the provision of individual services (Schulp et al., 2014a). Moreover, Eigenbrod et al. and Schulp et al. focussed on national to continental scales using 1–10 km resolution. Here we focus on the smaller-scale peri-urban context, using data as fine-grained as possible (0.1–1 km resolution). This is valuable because correct assessment of ES in peri-urban regions is important for designing effective green infrastructure networks to support human well-being − a key objective under the EU Strategy on Green Infrastructure (European commission, 2013), and which can also support Sustainable Development Goal 11: sustainable cities and communities (United Nations, 2015).

2. Materials & methods

This section comprises four parts: we first explain the Parisian peri-urban context and the selected study areas (2.1.). Second, we describe the plant data and the survey methods used to collect them (2.2.). Third, we specify the ES mapping models (2.3.), and last, we present how cluster analysis is used to evaluate the congruence between ES bundles and plant data (2.4.).

2.1. Study area

We focus our research on the peri-urban interface of Paris, France, which forms the intermediate between rural and urban land. It is designated as a "green belt" by the Île-de-France Regional Council. This so-called green belt is approximately 20 km wide and covers 2662 km^2 around the urban core of Paris (Fig. 1). Contrary to other green belts in Europe such as London or Berlin (Alexandre, 2013; Amati, 2008), the concept of the Île-de-France green belt has never been strictly embedded or enforced in land cover management and spatial planning. As it has been discussed elsewhere (Allen, 2003; Simon, 2008), drawing limits to peri-urban areas is not an easy task as land use is characterised by hybridization and heterogeneity. Here, the area consists of a patchwork of land cover types where woodland, cropland, semi-natural land and urban land coexist and where almost four million people live (Roussel, 2016). For these people, as well as for inhabitants of the city of Paris itself, the region provides important benefits for well-being through ES provision. The pressure on non-built-up areas has recently risen again with the Grand Paris project for which an extended transportation network is planned (Belkind, 2013) as well as new economic and housing developments (Gallez, 2014). In this context, which is applicable to many cities worldwide, it is even more relevant to understand the distribution and composition of peri-urban vegetation and the ES it supplies.

In order to apprehend the spatial complexity of the green belt area, three study areas were selected to represent the landscape diversity of the area (see squares in Fig. 1, detailed in Fig. 2).

The first area (Fig. 2A Pierrelaye) is situated in the north-west of Paris urban area and includes the isolated agricultural land around the small city of Pierrelaye, the state forest of Montmorency and the valley of the Oise river. The area presents a combination of the different land cover/land use types in a peri-urban context. Vegetation patches vary in size, form and are scattered throughout the area. The eastern extension intends to catch forests, which are a recurrent land cover in the context of Paris (see Fig. 1).

The second area (Fig. 2B Plaine de France) lays in the north-east part of the Paris urban area around the city of Goussainville, on an agricultural plateau called "Plaine de France", in proximity of the International Airport Charles de Gaulle. The area represents intensive agricultural lands under urban pressure. Most of the plateau is used for crop production, with semi-natural vegetation being scarce. The Paris metropolis has been extending here for the last forty years. Some grassland and woodland remain on the narrow and gentle slopes of a few small brook valleys.

The last area (Fig. 2C Vallée de Chevreuse) is centred on the valley of the river Yvette, in the south-west of Paris urban area, also known as "Vallée de Chevreuse". The topography and related land cover and land use is typical of the Île-de-France valleys: slopes can be steep and are mostly covered by trees, while the valley bottom is occupied by built-up area with some riparian habitat along the river. The valley is notably known for nature protection measures, such as a nature reserve on the western part of the area, hence, the extension in this direction.