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Are ecosystem service hotspots located in protected areas? Results from a study in Southern Italy

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ABSTRACT

Ecosystems are essential in providing multiple services to society. However, understanding ecosystem services (ESS) in terms of spatial distribution and trade-offs still remains a challenge for landscape planners and natural resource managers. In this paper, we analyzed the supply of a set of ESS – carbon storage, soil erosion protection, biodiversity, and recreation – within the landscape surrounding the city of Bari in Southern Italy. Through an analysis of this landscape, which includes natural protected areas, such as Natura 2000 Network sites, national and regional parks and nature reserves, and in view of the recent Fitness Check of the Nature Directives, we aimed to provide answers to the following questions: (i) *Where are the areas of high and low supply of individual ecosystem services located?;* (ii) *Where do ecosystem service trade-offs (i.e., 'hotspots' and 'coldspots') occur?*; and (iii) *To what extent are ecosystem service hotspots and coldspots located within or outside of natural protected areas?* Results show that most of the landscape in the study area supplied at least one of the selected ESS and that ESS hotspots were mostly located within forested and/or natural areas. Hotspots occupied 8.0% of the total landscape, with 23.7% located in natural protected areas. Coldspots were scarce and equal to 2.4%; they constituted only 0.1% of natural protected areas. Almost all of the landscape (89.6%) consists of intermediate areas (i.e., between hotspots and coldspots); 76.2% of natural protected areas consists of intermediate areas. This latter finding is relevant because the high intermediate classes are potentially high-performing areas, which lie mainly on the borders of protected spaces; they can positively influence ecological processes and thus enhance a wide-ranging provision of ESS. Our results highlight the importance of analyzing landscapes to facilitate the selection of priority areas where management efforts would yield maximum benefits.

1. Introduction

Over the last decade, the ecosystem services (ESS) concept has received a substantial and perhaps unexpected amount of attention worldwide (Millennium Ecosystem Assessment [MEA], 2005). A growing number of public administrations, environmental agencies and international organizations have begun to employ this concept in their plans for the sustainable management of natural resources and ecosystems, with the goal to foster the long-term supply of ESS (Bunker et al., 2005; Carpenter et al., 2009; Willemen et al., 2013; Spanò et al., 2017). The MEA approach is based on the notion that resource management involves trade-offs – relationships of mutual contrast and/or synergy – among ESS and that the quantitative and scientifically based assessment of trade-offs is essential for sound decision-making (Bennett et al., 2009; García-Nieto et al., 2013; Romano et al., 2015; Lafortezza and Chen, 2016). Consequently, there is now a considerable interest in establishing new approaches to quantify the trade-offs of ESS (Turner et al., 2003; Rodriguez et al., 2006). These approaches must also account for the varying spatial and temporal scales over which management decisions affect ESS (Bagstad et al., 2013; Burkhard et al., 2013). Indeed, ecosystems supply services at different spatial and temporal scales, ranging from the short-term and site level to the long-term and global level (Hein et al., 2006). Moreover, ESS are closely connected with stakeholders, since the scale at which ESS are provided defines the type of stakeholders that can benefit from it (Vermeulen and Koziell, 2002; Lafortezza et al., 2013). Maynard et al. (2010) proposed an ESS framework illustrating the linkages between ecosystems and community wellbeing, which could eventually support decision makers in the application of the ESS concept in planning and management strategies.

Understanding ESS trade-offs across space and time remains a key challenge especially for landscape planners and decision makers, which often require streamlined approaches to map the spatial distribution of ESS in relation to current land-use and land-cover (LULC) and its

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change (Egoh et al., 2008; Grêt-Regamey et al., 2008; de Groot et al., 2010; Petter et al., 2013). In their review of different ESS mapping tools, Crossman et al. (2013) propose an approach to reduce the gap between theory and practice in the application of the ESS concept.

In this perspective, it becomes a priority to analyze ecosystems as part of a broader landscape or system and within this system to identify the main ESS 'hotspots', defined as the spatial locations where most ESS reach the highest level of provision, in contrast with 'coldspots', where ESS provision reaches the minimum (Nelson et al., 2008; Tallis et al., 2008). For example, Qiu and Turner (2013) analyzed the supply, spatial distribution and trade-offs of a series of different ESS and identified hotspots where the synergies among different services were significant.

As a general statement natural protected areas (e.g., Natura 2000 Network sites), established and managed to ensure the conservation of biodiversity and other natural processes in situ, positively affect the capacity of ESS supply (McNeely, 1994; Mulongoy and Chape, 2004). In fact, a number of studies have shown that often ESS hotspots are especially located within the boundaries of natural protected areas (García-Nieto et al., 2013; Palomo et al., 2013). On the other hand, further research has also revealed that a vast majority of ESS hotspots are located outside of protected areas (e.g., Davids et al., 2016; Balvanera et al., 2006). The results of these studies indicate that considerable portions of hotspots lie outside of formally regulated and managed protected areas, remaining vulnerable to human pressures. To shed light on these seemingly contradictory findings, we investigated the spatial provision of ESS by posing the following question: *To what extent are ESS hotspots located within or outside of natural protected areas?* This question is particularly important if we consider that the majority of natural protected areas do not provide cultural or soil protection services, while these services are key components of the ESS paradigm.

For this purpose, we developed a model exercise using the Metropolitan Area of Bari (MAoB), Southern Italy, as a case example. We analyzed the provision of four selected ESS and devised a method to assess their trade-offs and synergies across the MAoB agroforestry landscape, thus identifying the locations of ESS hotspots *vs.* coldspots. Furthermore, we assessed the relative amount of hotspots falling within or outside of natural protected areas, including Natura 2000 Network sites, national and regional parks and nature reserves in the MAoB. Lastly, we discussed the implication of our findings in relation to the land-use policies and management plans adopted by the local MAoB authorities.

2. Materials and methods

2.1. Study area

The Metropolitan Area of Bari (MAoB), including the Municipality of Bari and 32 towns within its province, is located in the central part of the Apulia region (Southern Italy) (Fig. 1) and the object of our case study. This densely populated urban zone (1,104,530 inhabitants (ISTAT, 2016) covers an extension of 2839.6 km^2 and constitutes a part of the karst plateau commonly known as the 'Murgia'. The morphology of the MAoB is for the most part quite flat with slight sloping (10°–15°). The Murgia gently slopes seaward in a sequence of terraces and scarps that run parallel to the Adriatic coast (Regional Landscape Plan, original title 'Piano Paesaggistico Territoriale Regionale' [PPTR], 2013). Relevant morphological elements found in this context are the ephemeral streams named 'lame', which are flat-bottomed canyons that drain stormwater runoff during intense rainfalls. Given that the lame are normally arid components of the Murgia landscape, they are largely used for agricultural purposes. The agricultural matrix, mostly dominated by cereal crops, olive groves, orchards and vineyards, alternates with natural vegetation species such as Mediterranean steppe grasslands, shrublands, oaks, woodlands, and coniferous plantations. Because of these diverse characteristics, the landscape is considered an agroforestry system (Bisantino et al., 2016).

The MAoB includes natural protected areas (855.44 km^2, equal to 30.1% of the total landscape): one national park, one regional park, one regional nature reserve, five Sites of Community Importance (SCI) and one Special Protection Area (SPA) as part of the Natura 2000 Network; some overlapping occurs for certain areas (Fig. 1). The natural protected areas of the MAoB and their respective sizes are reported in detail in Table 1.

This highly heterogeneous landscape is subject to diverse pressures caused by multiple land uses, which often prevent the conservation of (local) natural resources. For these reasons, the authorities involved in the MAoB government have recently changed legislation to limit resource exploitation and implement principles of sustainable planning. For instance, in 2015, the Apulia Region adopted the new Regional Landscape Plan (Piano Paesaggistico Territoriale Regionale [PPTR]) with the aim of protecting and enhancing natural resources. Similarly, the Watershed Authority of the Apulia Region has included recent provisions for soil erosion protection in the Regional Hydrogeological Management Plan (Piano di Assetto Idrogeologico [PAI]) (Abdelwahab et al., 2016). At local scale, the Municipality of Bari is in the process of drafting the new General Urban Plan (Piano Urbanistico Generale [PUG]) to ensure sustainable urban development. The same objectives are foreseen for the MAoB by the Strategic Plan (Piano Strategico [PS]).

2.2. Ecosystem service estimation and mapping

The main purpose of this study is to answer the following questions: (i) *Where are the areas of high and low supply of individual ecosystem services located?;* (ii) *Where do ecosystem service trade-offs (i.e., 'hotspots' and 'coldspots') occur?*; and (iii) *To what extent are ecosystem service hotspots and coldspots located within or outside of natural protected* areas?.

The analysis started with the selection of relevant ESS for our study area (see Fig. 2) as potential drivers for sustainable planning by regional and local authorities. In particular, we considered a set of four ESS – carbon storage, soil erosion protection, biodiversity, and recreation – provided by the MAoB agroforestry landscape. We complied with the indications and recommendations contained in the official documents and landscape management plans proposed by the authorities (PUG for the Municipality of Bari; PS for the Metropolitan Area of Bari; PPTR of the Apulia Region; and PAI of the Regional Watershed Authority). For each ESS, an indicator representing the relative biophysical process was selected, and for each indicator we compiled or adapted spatially explicit information about its capacity to provide a given ESS. Because the formats and spatial units of each ESS assessment model varied, all input data were transformed into a 20-m spatial resolution grid. The supply of ESS was mapped and to identify relevant trade-offs among ESS, expressed as hot- and coldspots, we proceeded with the overlay of the normalized ESS values (Fig. 2). Lastly, we evaluated to what extent ESS hot- and coldspots are located within or outside of MAoB's natural protected areas. A full description of the ecosystem functions and biophysical models used to estimate and map selected ESS is reported in the following subsections.

2.2.1. Carbon storage

We assumed carbon stock as an indicator of the capacity of ecosystems to contribute to climate regulation because of their potential to influence atmospheric CO_2 concentration (Braswell and Schimel, 1997; Lauterbach, 2007; Luyssaert et al., 2008). We estimated the amount of carbon stored in each 20-m cell in the study area by summing four major carbon pools: aboveground biomass (AGB), belowground biomass (BGB), deadwood/litter (DWB), and topsoil organic carbon (SOC) (Table 2). The carbon storage for each pool was estimated by LULC type, as derived from the regional LC map 'Uso del Suolo (UDS) Puglia – 2011′ (Regione Puglia, 2011), based on carbon estimates from the Intergovernmental Panel on Climate Change (IPCC) tier-I approach (Eggleston et al., 2006) and integrated with published and