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Soil occupation efficiency and landscape conservation in four Mediterranean urban regions

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ABSTRACT

This study investigates the relationship between soil sealing and landscape conservation in four Mediterranean regions (Athens, Barcelona, Lisbon, Rome) characterized by different patterns of urban expansion. Per-capita sealed land, a landscape conservation index and selected territorial variables were considered into a multivariate exploratory framework aimed at assessing the correlation between land-use efficiency (based on the degree of soil sealing per-capita) and the quality of suburban landscape. A population density gradient with intensity of sealed land decreasing with the distance from the central city was observed in compact urban regions such as Athens and Barcelona. A mixed urban gradient was observed in Rome and Lisbon. In all the considered cities the spatial distribution of per-capita sealed land was not correlated with the urban gradient indicating that land consumption follows place-specific patterns irrespective of landscape quality. These findings suggest that urban containment and landscape conservation are policy targets requiring environmental measures irrespective of the prevailing morphology of the urban region (compact vs dispersed). In this context, green infrastructure planning is a promising tool for landscape conservation and the containment of soil sealing within fragile and dynamic contexts such as the wildland-urban interface.

1. Introduction

Soil sealing is a typical expression of land take in both developed and emerging countries, and determines loss of soil resources due to the covering of land for housing, roads or other construction work. A soil can be considered as sealed when irreversible changes in its permeability have occurred (Panagos et al., 2012). Impervious surfaces are mainly pavement structures (roads, sidewalks, driveways and parking lots) that are covered by impenetrable materials such as asphalt, concrete, brick, stone and rooftops (European Environment Agency, 2006). Thus, soil sealing results in a loss of fertile soils for agriculture (Gardi et al., 2015; He et al., 2013) and causes changes in the hydrological cycle at the local scale (He et al., 2013) and carbon storage (Sallustio et al., 2015), meanwhile determining habitat fragmentation and a reduced efficiency in the use of land (Ramos et al., 2000). Besides, impacts on the well-being and health of urban dwellers have been recognized (Tzoulas et al., 2007; Lafortezza et al., 2009).

In some European countries effective policies aimed at steering soil sealing were recently enforced in law. For example, in Germany, a law was introduced since 1998 setting a national target for soil consumption below 11,000 ha per year, though the effectiveness of such a policy is actually hampered by a lack of legal obligation and institutional commitment (Artmann, 2014a). Since 1999, United Kingdom set a planning target to realize 60% of new urban housing in already urbanized areas (Champion, 2002). In France, a buffer zone of 15 km between two urban municipalities was required to allow development of green field (Roux and Vanier, 2006). In countries with mostly unregulated urban growth, such as in southern Europe (King et al., 1997), the uncontrolled consumption of land

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is an increasingly relevant phenomenon characterized by lack of attention to the quality of the soil developed.

Although previous studies evaluated quantity and quality of land taken by urbanization in Mediterranean areas (Munafò et al., 2010; Frondoni et al., 2011; Salvati and Sabbi, 2011; Salvati, 2013; Salvati et al., 2013; Quatrini et al., 2015), few attempts have been deserved to link urban form and the type of urban diffusion with the conservation of suburban landscapes. In this context, an active role is played by high value agricultural areas (i.e. open habitats shaped by traditional farming systems) and peri-urban forests. In particular, Barbati et al. (2013) underline how forest expansion is the only natural process that may counteract the consumption of the natural capital and ecosystems services of peri-urban land due to uncontrolled urban sprawl. Planning and management of peri-urban areas are still not effective as far as soil sealing control and landscape conservation are concerned, because these areas are principally affected by multiple and rapidly changing urban demands (Konijnendijk et al., 2006; Miller, 1997). Besides, differentiated planning strategies are increasingly required for urban development models characterized by compact and dispersed urban forms. For this reason, monitoring soil sealing and efficiency in the use of urban land in relation to landscape conservation is important in terms of supporting a sustainable spatial planning of peri-urban land (Elia et al., 2014). Areas where infrastructures and other man-made systems interact with undeveloped areas (wildland–urban interface, WUI) are vulnerable to land cover conversion and man-induced biotic processes, including exotic species introduction, wildlife subsidization, disease transfer, wildfires, fragmentation and habitat loss (Bar-Massada et al., 2014).

In this sense, regional planning, when framed in a broader context – for example in a Green Infrastructure (GI) perspective – may be a challenging opportunity to harmonize urban growth and landscape conservation (Lafortezza et al., 2013), because it considers ecological and social values in combination with other land-use developments (Aegisdóttir et al., 2009). GI is, in fact, defined as an interconnected network of green spaces that preserve natural ecosystem functions and values and provide associated benefits to human populations (Benedict and McMahon, 2002). The GI concept is the connecting element to many fields such as urban forestry, landscape planning, ecosystem services, human well-being and health. At the same time, GI can be the reference framework for an effective landscape management that takes into account the real territorial complexity to obtain greater resilience systems and a more sustainable development (Lafortezza, 2013).

Based on these premises, our study aims to (i) evaluate how the efficiency in the use of land (in terms of per-capita sealed land), land fragmentation (in terms of spatial distribution of unsealed land) and landscape conservation (in terms of degree of conservation) are affected by different urban forms, and (ii) provide mitigation, compensation and planning indications targeting soil sealing negative impacts in peri-urban environments, in the framework of recent European guidelines (European Environment Agency, 2006).

2. Materials and methods

2.1. Study area

Four urban regions in southern Europe are considered in this paper: Lisbon in Portugal, Barcelona in Spain, Rome in Italy, and Athens in Greece. The four study areas (three of them are capital cities) were selected as exemplificative cases of traditionally compact (or dense) cities undergoing spatial restructuring towards urban diffusion (Salvati, 2013). European Environment Agency (2011) classified Mediterranean cities as the most compact and land-saving in Europe. However, a number of these cities are evolving towards settlement scattering and uneven land consumption with moderate population growth or, in some cases, with demographic decline. Among the selected cities, Athens and Lisbon have respectively a hyper-compact morphology and a semi-dense mono-centric urban form, Barcelona is a compact polycentric city and Rome is a semi-dense city evolving towards a dispersed and chaotic urban form (Salvati, 2013).

For each city, the investigated area corresponds to the NUTs-3 (Nomenclature of Territorial Units for statistics) region administered by that city. Each selected area encompasses (or is a little larger than) the boundaries of the related 'Urban Atlas' region (European Environment Agency, 2010). In order to collect comparable data among the considered regions, we defined local municipalities as the elementary spatial domain (Salvati, 2013). Local administrative boundaries, in fact, have been largely used as the denominator for demographic and land-use change analysis (Garcia and Riera, 2003; Tsai, 2005; Munafò et al., 2010; Salvati and Zitti, 2011). In the present study, the municipal boundaries allowed for reliable comparisons with external sources, including official data from statistical sources (e.g. population density). They represent the minimum mapping unit of most statistical surveys and are also easily interpretable by non-technical users. Main morphological and demographic characteristics are reported in Figs. 1 and 2.

2.2. Map dataset

A raster dataset of built-up and non-built-up areas, including continuous degree of soil sealing ranging from 0% to 100% in 100×100 m spatial resolution with European coverage, was used in this study to derive soil sealing data (European Environment Agency, 2011). This dataset (freely available in GeoTiff format and referring to the year 2006) was realized in 2009 by multi-sensor and bi-temporal, ortho-rectified satellite imagery (IMAGE 2006) and covers 38 European countries. Very high resolution Google Earth imageries were used as Supplementary datasets to validate the soil sealing map. Reference sealing percentages were obtained using a 10×10 m grid positioned around sampling points. To evaluate classification accuracy omission error, commission error and overall accuracy were estimated. Classification accuracy of built-up and non-built-up areas is higher than 85% per hectare, and both omission and commission errors are below 15% (European Environment Agency, 2011). According to the descriptive statistics derived from the map, 6.5% of the European territory was covered by 1 ha cells including sealing in 2006 (any percentage between 1% and 100%), and the total sealed surface area was 1.8%, with Greece and Spain ranking below average (respectively 1.3% and 1.4%), Italy and Portugal above average (respectively 2.8% and 3.1%). Freely available Corine Land Cover (CLC) vector maps for the 4 urban regions were used as supplementary land cover data (http://www.eea.europa.eu/data-and-maps/data/clc-2006-vector-data-version). The available 2006 CLC maps for Barcelona, Lisbon and Rome were considered in this study while the 2000 CLC map was used for Athens because the lack of more recent CLC cartography.

2.3. Spatial analysis

The composition of sealed land in each spatial unit was estimated as the percent surface of 22 classes of imperviousness (0%, 1–5%, 6–10%, ..., 91–95%, 96–99%, 100%) of the total municipal surface area by using a tool provided with ArcGIS software (see Section 2.4). Simultaneously, a value of the landscape conservation coefficient that expresses vegetation quality was assigned to each CLC class (third-level nomenclature). In particular, an increasing value in terms of the state of conservation of the landscape was