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Analysis

Soil Matters? A Multivariate Analysis of Socioeconomic Constraints to Urban Expansion in Mediterranean Europe

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ABSTRACT

Urban expansion and socioeconomic transformations of metropolitan regions may negatively impact environmental quality and functions of peri-urban landscapes. In the present study, the role of continuous and discontinuous urban expansion as a driver of high-quality soil consumption has been investigated in 66 southern European metropolitan regions. Landscape metrics and socioeconomic indicators were considered together in a multivariate exploratory analysis with the aim to assess the intensity of recent urban expansion (2000 – 2010) and the consequent depletion of different soil types in Portuguese, Spanish, French, Italian and Greek cities. Overall, urban expansion involved preferentially high-quality soils in the study area. A Principal Component Analysis identified diverging city profiles as far as spatial patterns of soil consumption are concerned. Per-capita declared income, income growth rate, population density and landscape diversity were highest in metropolitan regions where urban expansion consumed soils with lower quality than non-urban soils. Urban expansion consumed high-quality soils in metropolitan regions with low per-capita built-up area, low soil quality index and peri-urban landscapes dominated by forests. Results of our study inform policies for urban containment. Design of effective measures mitigating loss of high-quality peri-urban soils requires a comprehensive understanding of multiple impacts of local socioeconomic contexts on land consumption processes.

1. Introduction

Representing a vital, limited and non-renewable natural resource, Soil supports ecosystem functions such as biological productivity, water purification and carbon cycling, demonstrating ability to recovery even in contexts where land-use mosaics have determined spatially-heterogeneous human disturbance (Verburg et al., 2008). Soils play a key role in ecosystem services' provision, depending on their physical, chemical and biological attributes which are shaped by a mix of natural and anthropogenic factors (Karlen et al., 2003). However, if anthropogenic pressure exceeds a given limit, soils would be unable to perform pivotal tasks and become ecologically vulnerable (Lorent et al., 2008). Humans are among the most influential agents and directly or indirectly impact the performance characteristics of soil, thus limiting or enhancing its productive capacity (Amundson et al., 2003). Preserving soil quality is considered a primary target of any environmental protection strategy at various spatial scale, from local to continental (*e.g.* Salvati et al., 2012); soil health management and conservation was recently recognized as a relevant issue in the United Nation Sustainable Development Goals (see http://www.un.org/sustainabledevelopment/sustainable-development-goals/), contributing directly to four goals ('no poverty', 'zero hunger', 'clean water and sanitation' and 'life on land') and indirectly to most of the remaining goals.

With soils being inherently variable over space and susceptible to multiple uses for the benefit of human beings, soil and land capitals assume a fundamental role in local development (Robinson and Lebron, 2010; Roseta-Palma et al., 2010; Ferrara et al., 2016). For centuries, fertile soils have ensured the maintenance of a viable agriculture and rural settlements, promoting industrial growth in suitable areas (Hubacek and van den Bergh, 2006). In recent decades, urbanization processes, including urban sprawl and city shrinkage, have caused an increased consumption of soil resources with negative environmental impacts (Paul and Tonts, 2005; Aguilera et al., 2011; Inostroza et al., 2013; Salvati et al., 2015). Historically-produced and place-specific processes have traditionally shaped landscape transformations, often resulting in divergent socioeconomic outcomes (McCauley et al., 2015).

At the global scale, urban dispersion is a key socioeconomic issue (Couch et al., 2007) and a serious concern for sustainable development (Longhi and Musolesi, 2007). Being primarily driven by urban sprawl (Scalenghe and Ajmone Marsan, 2009), sealing of high-quality soils is

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considered a relevant threat for European environments (European Environment Agency, 2012). Soil degradation in the Mediterranean basin outlines the intrinsic fragility of rural ecosystems, with multiple socioeconomic factors determining (a more or less intense) conversion of natural and agricultural land to urban use (Ferrara et al., 2014; Zitti et al., 2015). Although it was demonstrated that soil sealing might influence patterns and composition of socio-ecological systems (Salvati and Carlucci, 2013), impacts on economic structures and performances have occasionally been investigated (Verburg et al., 2013). A diachronic study reconstructing land consumption trends over the last 50 years in Italy (Salvati, 2013), reported that urbanization-driven land-use has involved soils with different economic value, depending on the observed pattern of urban expansion (*e.g.* compact *vs* dispersed). Compact urban expansion has been demonstrated to consume low-quality soils in degraded fringe landscapes (Salvati et al., 2012). Conversely, an increased proportion of high-quality rural land converted into dispersed settlements was observed in Mediterranean Europe (Salvati et al., 2014a). Selective land take by urban expansion was frequently observed in Southern Europe (Garcia, 2010; Serra et al., 2014; Salvati and Ferrara, 2013). In northern Italy, Ceccarelli et al. (2014) identified land with high suitability to agriculture as the most threatened by dispersed urbanization. Ferrara et al. (2014) observed a mismatch in the spatial distribution of intensive cropland and high-quality soils, possibly determined by urban expansion.

Among the great number of studies in land-use science, only few have investigated the relationship between local communities and soil quality (Raymond et al., 2009; Dominati et al., 2010). Land-use changes and soil depletion may have unpredictable consequences on fragile landscapes, determining (or consolidating) disparities in the access to high-quality soils among competing actors (Ferrara et al., 2014). Consequently, urbanization-driven soil consumption could be considered an issue of spatial justice when it alters the distribution of high-quality soils along the urban gradient (Briassoulis, 2011). In fact, depletion of soil resources was demonstrated to be associated with territorial disparities, economic backwardness, poverty and increased human pressure on fragile rural districts (Salvati and Ferrara, 2014). Social inequalities and economic polarization have influenced soil quality along urban-rural and elevation gradients in the Mediterranean region (Corbelle-Rico et al., 2012; Niedertscheider and Erb, 2014; Zitti et al., 2015). In addition to deregulated urban expansion (especially evident in the Italian and Greek contexts), land mismanagement has sometimes determined a spatial divergence in natural resources' quality, possibly influencing the local socio-ecological background (Salvati and Carlucci, 2014; Salvati et al., 2014b, 2015).

In this regard, environmental and social concerns are particularly relevant in case of urban sprawl (Camagni et al., 2002). In the quest for space, dispersed settlements have exerted a great pressure on the environment in terms of soil consumption. In many instances, affluent households' desire for place amenities coupled with economic advantages for developers have led to loss of high-quality forest land and ecosystem fragmentation. The inequality mechanisms for which weaker subjects experiencing the consequences of environmental degradation produced by the stronger ones (Kashwan, 2017) are particularly important in case of land consumption, where 'the combined effect of economic, social and institutional/political factors determines a boost in the housing sector to the detriment of social interest' (Bimonte and Stabile, 2017).

Original frameworks approaching socio-environmental phenomena along urban-rural gradients are fundamental to identify metropolitan districts affected by urban sprawl (Safriel and Adeel, 2008; Raymond et al., 2009). Local communities in the northern Mediterranean region are representative examples of heterogeneous environmental conditions determined by a mix of demographic, cultural, economic and political factors, negatively affecting soil quality (Salvati and Carlucci, 2011). Preserving high-quality soils should be recognized as a policy target, especially where agriculture is an essential component of district value-added. However, this goal has rarely been considered in peri-urban land sustainable management (Ferrara et al., 2014).

This study provides an original analysis of the impact socio-economic contexts have on environmentally-fragile peri-urban areas in Mediterranean Europe, investigating soil quality and urban expansion in 66 metropolitan regions from 5 southern European countries (Portugal, Spain, France, Italy and Greece). We evaluated land take and the characteristics of recently developed soils distinguishing among compact, dispersed and mixed urbanization patterns, with the use of high-resolution land-use maps. A comprehensive analysis of soil quality was based on a composite index integrating different soil attributes with the aim to assess the overall depletion in soil resources due to urbanization (Salvati et al., 2014a). The methodology here proposed can be part of a geographic system informing decisions for sustainable land management and regional planning.

2. Materials and Methods

2.1. Study Area

The northern Mediterranean region has a complex topography with distinct vegetation, soil and climatic zones that reflect place-specific factors shaping socioeconomic local contexts. The present study focuses on 66 metropolitan regions > 100,000 inhabitants (Fig. 1) at the beginning of the 2000s (see list in Table 1) belonging to 5 Mediterranean European countries (Portugal, Spain, France, Italy and Greece). Portugal is represented by its capital city, Lisbon, and 5 major urban centres (Setubal, Aveiro, Oporto, Faro, Coimbra). Eighteen Spanish metropolitan areas were considered including the capital city, Madrid, northern cities (Santander, Bilbao), southern cities facing the Mediterranean Sea (Alicante, Malaga, Cordoba, Valencia, Murcia, Barcelona, Palma di Mallorca) and internal cities such as Badajoz, Zaragoza, Vitoria Gasteiz, Oviedo, Seville, Valladolid, Toledo and Pamplona Iruna. Nice and Montpellier are representative of the French Mediterranean region. The 31 Italian cities here considered cover homogeneously the latitude range from the north to the south of the country. Finally, Athens and other 8 cities (Volos, Kavala, Kalamata, Patras, Iraklion, Salonika, Ioannina and Larisa) are representative of the Greek territory. The countries considered here are characterized by relevant socio-economic disparities, such as Italy (northern *vs* southern regions) or Spain (more accessible urban regions *vs* less accessible rural districts). Territorial disparities may reflect spatial divides in soil quality, land-use and processes of landscape fragmentation (Salvati et al., 2012).

2.2. Elementary Data

City boundaries were delineated according to the European Urban Areas statistical classification (http://www.urbanaudit.org/) of "Large Urban Zones", described by the Urban Audit program as regions from which a considerable share of the residents' commute into the central city (Eurostat, 2004). The objective of the Urban Audit program is to collect homogeneous data for cities with different socioeconomic and environmental characteristics, allowing for between- and within-countries comparisons (Guerois et al., 2012). We used maps from the Urban Atlas (UA) program providing pan-European comparable land-use data referring to the late 2000s for inner cities ('City') and Large Urban Zones ('Luz') > 100,000 inhabitants as defined by the Urban Audit program. The UA nomenclature identified 20 land-use classes, grouped into 9 categories for the aim of this study (Table 2): dense urban fabric (sealed land > 50%; code 1); mixed urban fabric (30% > sealed land > 50%; code 2); discontinuous urban fabric (sealed land < 30%; code 3); service settlements (code 4); transport network (code 5); open areas with urban use (code 6); green urban spaces, wetlands and water bodies (code 7); cropland (code 8); and forests (code 9).

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