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Soil resources, land cover changes and rural areas: Towards a spatial mismatch?

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HIGHLIGHTS

- The impact of urban expansion (1945–2001) on soil depletion was studied in northern Italy.
- Non-urbanized land decreased from 11.8% in 1945 to 6.3% in 2001.
- Urbanization between 1945 and 1971 reflects the increase of dense settlements around pre-existing centers.
- Urbanization between 1971 and 2001 consumed soils with progressively higher quality.
- The edification of pervious land is an unreliable indicator of soil quality depletion.

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ABSTRACT

The present study analyzes the impact of long-term urban expansion on soil depletion in Emilia-Romagna, an agricultural-specialized region of northern Italy. Using settlement density maps at three points in time (1945, 1971 and 2001) dense and diffused urbanization trends were assessed and correlated with soil quality. Non-urbanized land decreased from 11.8% in 1945 to 6.3% in 2001. Urbanization dynamics between 1945 and 1971 reflect the increase of dense settlements around pre-existing urban centers. To the contrary, a discontinuous, low- and medium-density urban expansion along the road network and in the most fertile lowland areas was observed between 1971 and 2001. Overall, urbanization consumed soils with progressively higher quality. However, a diverging trend was observed in the two investigated time intervals: soil with high quality was occupied by compact and dense settlements during 1945–1971 and by discontinuous, medium- and low-density settlements during 1971–2001. These findings document the polarization in areas with low and high soil capital and may reflect disparities in agricultural production and increasing environmental degradation. Moreover, the analysis shows a diverging trend between land and soil consumption patterns suggesting that the edification of pervious land is an unreliable indicator of soil quality depletion. Taken together, the results of this study illustrate the (increasing) spatial mismatch between agricultural land and high-quality soils as a consequence of urbanization-driven landscape transformations and may inform measures to contain soil depletion driven by economic growth.

1. Introduction

Land resource management depends on a series of factors of political, economic, social and ecological origins (Hubacek and Van den Bergh, 2006). Within economic structures that encourage land concentration, private land ownership and unrestricted land markets can be damaging for ecosystem stability, environmental quality and landscape integrity. Economic policies can create incentives for 'throw away' patterns of resource exploitation, in which resources are mined for short-term profit (Bruegmann, 2005).

From both the research and policy perspectives, Zuindeau (2007) pointed out the importance of disentangling territorial disparities not only from the social and economic points of view, but also in the light of the environmental quality. In fact, environmental problems related to natural resource imbalances and socioeconomic polarization contribute to determine territorial disparities (Briassoulis, 2004; Portnov and Safriel, 2004; Salvati et al., 2009; Zdruli, 2012). Salvati and Zitti (2011) introduced the concept of 'environmental divide' as a factor contributing to the formation and consolidation of regional disparities at different temporal scales. Understanding the causes of spatial mismatches in

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environmental quality needs a multidisciplinary approach (Polyzos et al., 2008). Intended as an original approach to sustainability science, Salvati et al. (2013) quantified territorial disparities in the level of vulnerability to land degradation according to an evaluation framework integrating biophysical and socioeconomic variables on a country scale. This contributed to the implementation of more effective policies in the direction of a spatially-balanced sustainable development.

Previous studies examining environmental–economic dynamics in the last fifty years indicate that territorial imbalances widen in Europe and socioeconomic disparities consolidated in rural and coastal areas, triggering a mechanism which impacted negatively the environmental quality of entire regions (Zuindeau, 2007). These dynamics reflect an increased environmental 'divide' between northern and southern regions which is probably due to the differential influence of biophysical factors, diverging comparative advantages of neighboring areas compatible with a sustainable development (e.g. resource potentials, imbalances, competitiveness and barriers) and a generally less sustainable and effective land management in southern Europe (Salvati and Zitti, 2011). The effect of these factors could be spatially neutral (stable or increasing impact on the environment throughout the whole area) or asymmetric (increasing impact in areas with low or high soil quality), thus amplifying (or reducing) disparities in the spatial distribution of soil resources (Salvati et al., 2013).

The importance of assessing territorial disparities in ecological processes is also associated with equity matters in resource distribution (Zuindeau, 2007). The potential for natural resource loss might not only remain a problem for the local population, but also could spread to neighboring territories in a process that would accelerate economic polarization and lead to social conflicts e.g. for soil resources appropriation (Scalenghe and Ajmone Marsan, 2008). Such conflicts represent a serious obstacle to sustainable development and require policies to correct imbalances and reduce environmental externalities of the economic growth (Briassoulis, 2004). This is especially important in ecologically fragile areas with structurally-weak economies such as southern Europe (Garcia Latorre et al., 2001).

Soil is an important resource contributing to the stability of the ecosystem and the productivity of human activities. However, soil degradation processes are accelerating in many parts of Europe due to human pressure (European Environment Agency, 2006). In the context of the Soil Thematic Strategy (European Commission, 2012), the European Commission promoted research activities in the field of land-take assessment and soil sealing monitoring (Joint Research Centre and European Environment Agency, 2012). As reported by Montanarella (2007) and Zdruli et al. (2007), changes in the use of land contributed to soil erosion, decline in organic matter, local and diffused soil contamination, sealing, compaction and salinization. All these processes negatively impact soil functions and ecosystem services (see, for instance, Sposito and Zabel, 2003). Increasing concerns for soil consumption at the European and national level justify permanent monitoring and further research informing the sustainable management of peri-urban soils.

Loss in soil quality in Mediterranean Europe is considered a multifaceted process depending on biophysical, socioeconomic, cultural and institutional factors, with negative effects on food security, environmental stability and the resilience of local communities in rural areas (Conacher and Sala, 1998). Due to its spatial complexity, soil quality and degradation were often approached at the 'on-site' scale with a focus on biophysical variables only (Montanarella, 2007).

Salvati (2013a) proposed a logical framework for the assessment of soil consumption due to urban expansion and applied this methodology to a mono-centric city to evaluate if edification consumed soils with the highest quality. Based on previous considerations, there is a definite need to enlarge and adapt this approach to monitor soil consumption in larger regions. The monitoring scheme should evaluate the effect of settlement expansion in rural areas characterized by infrastructural development and restructuring of the economic base which determines settlement dispersion along the road network. In this perspective, an accurate assessment of soil sealing in mixed urban–rural landscapes characterized by imperviousness rates ranging e.g. between 5% and 20% is relevant for large-scale quantification of the possible soil resource loss due to edification. Previous studies indicate that standard land-use maps (e.g. Corine Land Cover maps) can provide information to this issue but high-resolution building maps generally allow a more precise diachronic evaluation of soil sealing in rural areas (Munafò et al., 2010; Salvati, 2013b).

Based on these premises, the present study contributes to the deserving issue of land and soil consumption monitoring in developed and rapidly transforming regions, assessing soil depletion by edification over a relatively long time interval (80 years) and at enough detailed spatial resolution (urban districts). Compared to previous research (Salvati, 2013a), this work focuses on an administrative region of northern Italy with a traditional rural landscape and a definite specialization on agriculture (both annual and perennial crops). This region underwent a huge urban expansion in the aftermaths of World War II. Interestingly, this process first involved fringe areas and then rural areas progressively further away from the main urban agglomerations producing discontinuous, low-density settlements associated with the road network and to pre-existing rural villages (Ceccarelli et al., 2014).

The hypothesis introduced in this study is that settlement expansion consumes high-quality soils in a spatially asymmetric way thus altering the distribution of the soil resource base (and consequently, the availability of suitable land for agriculture) on a regional scale. This hypothesis was verified through the analysis of various layer maps: a high-resolution building density map available at three points in time (1945, 1971 and 2001) and a soil quality map. Results indicate a possible mismatch between the spatial distribution of agricultural land and high-quality soils as a consequence of landscape transformations directly (or indirectly) driven by urbanization. By contributing to the debate on the spatially-balanced, sustainable development of the Mediterranean region, the present study may suggest policies that contain the depletion of soil resources driven by the economic growth.

2. Methods

2.1. Study area

The investigated area, located in north-eastern Italy, covers the whole Emilia-Romagna region (which is administered by nine provinces and more than 300 municipalities) extending for nearly 22,000 km^2 with varied morphology and landscapes ranging from the Adriatic coast to the Po river valley and to the Apennine mountain range (Fig. 1, left). Especially after World War II, Emilia-Romagna, one of the most affluent regions in Italy, experienced economic development together with population growth in both urban and rural areas. The economic structure of the region is mainly based on manufacture industry, high-tech services, tourism and high-income agriculture.

Resident population grew in the investigated area from 2,558,714 inhabitants in 1951 to 3,336,725 inhabitants in 2011. Urban expansion firstly involved the largest city in the region (Bologna) and then intensified in smaller cities. More recently, small-size towns experienced the highest population and settlement growth contributing to (re) balance the urban network that assumed a more homogeneous and possible polycentric form (Ceccarelli et al., 2014). Fig. 1 (right) illustrates the spatial distribution of an indicator of settlement concentration and population densification (inhabitants per buildings). Relatively dense settlements concentrate along the main road network ('via Emilia') while medium-density settlements are found especially in rural lowland and hilly areas.