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Assessing land take by urban development and its impact on carbon storage: Findings from two case studies in Italy

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ABSTRACT

Land take due to urbanization triggers a series of negative environmental impacts with direct effects on quality of life for people living in cities. Changes in ecosystem services are associated with land take, among which is the immediate C loss due to land use conversion. Land use change monitoring represents the first step in quantifying land take and its drivers and impacts. To this end, we propose an innovative methodology for monitoring land take and its effects on ecosystem services (in particular, C loss) under multi-scale contexts. The devised approach was tested in two areas with similar sizes, but different land take levels during the time-span 1990–2008 in Central Italy (the Province of Rome and the Molise Region). The estimates of total coverage of built up areas were calculated using point sampling. The area of the urban patches including each sampling point classified as built up areas in the year 1990 and/or in the year 2008 is used to estimate total abundance and average area of built up areas. Biophysical and economic values for carbon loss associated with land take were calculated using InVEST. Although land take was 7–8 times higher in the Province of Rome (from 15.1% in 1990 to 20.4% in 2008) than in Molise region, our findings show that its relative impact on C storage is higher in the latter, where the urban growth consistently affects not only croplands but also semi-natural land uses such as grasslands and other wooded lands. The total C loss due to land take has been estimated in 1.6 million Mg C, corresponding to almost 355 million €.

Finally, the paper discusses the main characteristics of urban growth and their ecological impact leading to risks and challenges for future urban planning and land use policies.

1. Introduction

Urbanization represents one of the main sources of disturbance and alteration of natural ecosystems (Churkina, 2008; Imhoff et al., 2004; Solomon et al., 2007), inducing the loss of several ecological functions (Foley et al., 2005). Land take, defined here as the area of land that is converted into settlements and artificial surfaces due to urban growth, alters environmental quality (Ellis and Ramankutty, 2008) and affects the provision of several ecosystem services, such as those related to climate and water regulation (Seto et al., 2012; Nelson et al., 2010). These environmental impacts produce direct and indirect effects on the quality of life of people living in cities (Chiesura, 2004; EEA, 2006; Escobedo et al., 2011; Elmqvist et al., 2013).

Urban areas emit a high proportion of the greenhouse gas carbon dioxide (Svirejeva-Hopkins et al., 2004) and contribute somewhere between 40 and 85% of total anthropogenic greenhouse-gas (GHG) emissions (Satterthwaite, 2008). The effects of urbanization on climate change are exacerbated by the loss of carbon (C) pools associated with the decreases in the vegetative cover caused by the land take associated with the expansion and intensification of urban areas (Hutyra et al., 2011a). Moreover, soils in urban areas have very low C densities (Pouyat et al., 2006), exacerbating the impact of urbanization on C sequestration. Land take by urban development yields both an initial loss in the carbon stock, as well as a permanent reduction in the carbon uptake potential by the land (Hutyra et al., 2011b). A few studies investigated this problem, by proposing methodologies to assess the carbon impact of growing urban regions. Seto et al. (2012) modeled the loss in aboveground biomass carbon from areas with high probability of urban expansion until 2030, and concluded that this loss is likely to be significant (equal to ~5% of emissions from tropical deforestation and land-use change). Raciti et al. (2012) focused on the effects of urbanization on soil carbon pools, by comparing the carbon content of open areas and impervious-covered soils. Their finding is that carbon content under impervious surfaces is 66% lower. Hutyra et al. (2011a) estimated

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the carbon consequences associated with urban land take in the Seattle metropolitan region, and concluded that it represents a substantial term in the regional carbon balance.

Despite the findings of these studies suggesting that the loss of carbon stock (and future carbon uptake) due to land take by urban development is potentially significant, this effect is often overlooked during the assessment of the future impacts of urban growth. For example, the treatment of climate-related issues in Strategic Environmental Assessment (SEA) of spatial and urban planning is still quite weak and largely based on general recommendations, as opposite to analytical evaluations (Geneletti, 2015). There is a need for further development of methods to assess the impact of land take on carbon storage that can be transferred to practitioners and used to support the proposal of more sustainable urban plans and policies. Particularly, these methods need to address two issues: the analysis of land take dynamics and the modeling of carbon loss associated with them.

The objective of this paper is to contribute to filling this gap by proposing and testing a method to quantify land take dynamics associated with urban growth, and estimate their effects in terms of carbon stock loss. Land take dynamics were analyzed through the construction of transition matrices (Pontius et al., 2004; ONCS, 2009). Specifically, a method proposed by Baffetta et al. (2011) used for urban forest coverage assessment over Italy (Corona et al., 2012a) was implemented in order to estimate urban patch abundance and average size. The sampled urban patches were then used as input for the assessment of change in carbon loss, both in biophysical and economic terms.

The study areas are the Province of Rome and the Molise Region in Italy (see Fig. 1). These two areas represent different socio-economic contexts that lead to different population densities and urban growth patterns. In Rome, this produced a typical polycentric urban form, but in Molise very fragmented urban growth characterized by small patches surrounded by mostly rural lands. In Italy urban areas cover 7.1% of the land area, and grew by 500,000 ha from 1990 to 2008, at the expense of croplands in plains and low hills (Corona et al., 2012b; Marchetti et al., 2012a). However, few studies have addressed the impact of urban growth in Italy (Romano and Zullo, 2013), due to the lack of reliable data and the high costs of production. This lack highlights the need to improve land use monitoring systems and develop new methodologies aiming to increase their informative power while containing the costs of realization and updating.

2. Materials and methods

2.1. Study area and available data

Analyses were performed on two very different study areas in central Italy, one of the ancient human dominated areas within the Mediterranean Basin, which has been indicated by Myers et al. (2000) as one of the four most significantly altered hotspots on Earth (Fig. 1). In these areas natural capital has been altered by human population for thousands of years (Falcucci et al., 2007) and its pressure is still rising, especially along the coast (Salvati et al., 2012; Romano and Zullo, 2014). The Province of Rome is one of the most populated and urbanized areas in Italy. It covers about 5352 km^2 with a total population of 4,061,543 inhabitants (ISTAT, 2008). The territory mainly consists of hills (~50%), lowlands (~30%), and mountains (~20%). Like other Mediterranean cities, Rome went through a rapid transition from the historic compact model to a scattered and polycentric urban form, characterized by huge expansion around the urban area (Salvati, 2013).

However, the Molise region is among the least dense and urbanized areas in Italy, with a decreasing population during the past decades (ISPRA, 2014a; Sallustio et al., 2013). This region has an area of 4438 km^2 with 313,660 inhabitants (ISTAT, 2008) and a mountainous

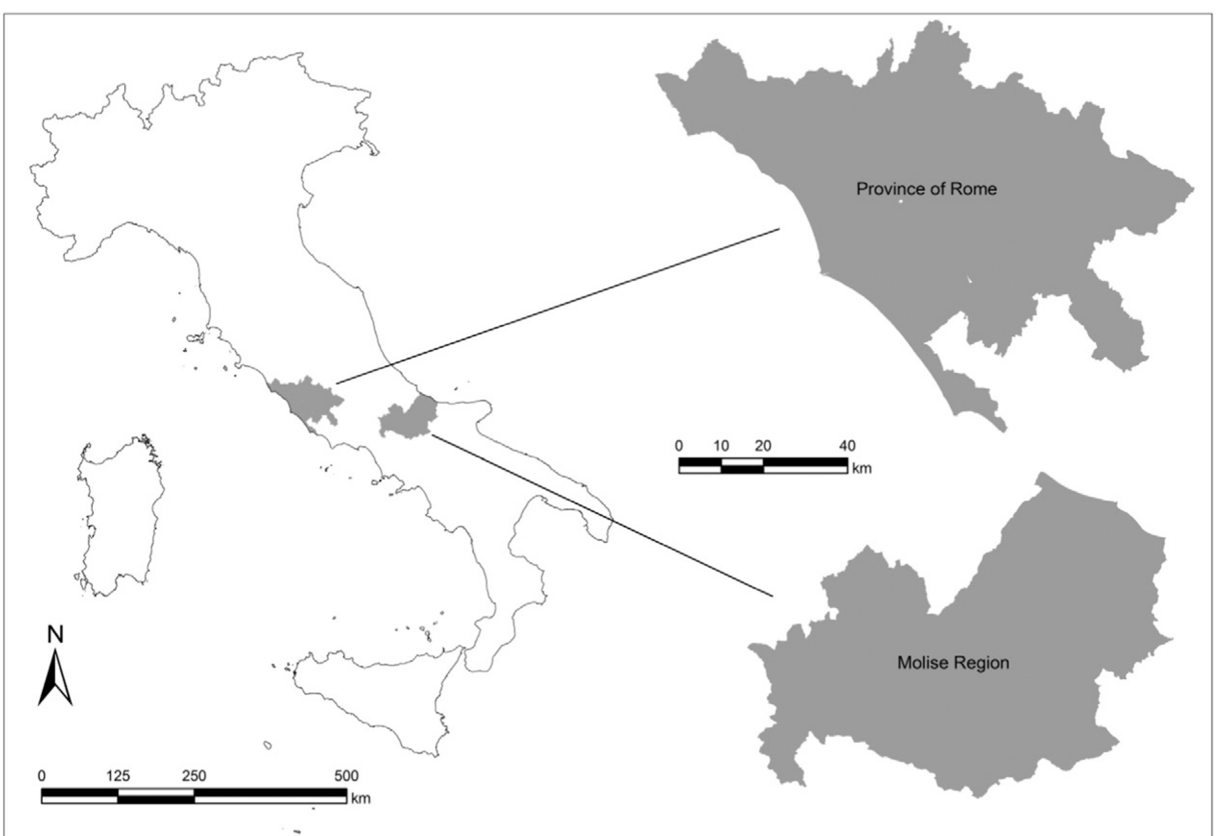

Fig. 1. Geographical location of the study areas.