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Short communication

Do land cover changes shape sensitivity to forest fires in peri-urban areas?

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ABSTRACT

The present study assesses the spatial distribution of selected land cover classes at two years (1975 and 2000) in a Mediterranean urban area (Athens, Greece) to test the hypothesis that land cover changes determine an increase in the sensitivity of landscape to forest fires on a regional scale. While urban and agricultural areas increased, although with different rates of growth, forests and semi-natural areas decreased in the study area. These changes are reflected in a significant increase of vegetation sensitivity to forest fires measured by the forest fire risk (FR) index developed in the framework of MEDALUS project. The cover classes which contributed the most to the increase of the FR index were crop mosaic, mixed agricultural-natural areas and discontinuous, low-density settlements. Results of the present study indicate that the transformation of the fringe landscape towards low-quality agricultural and pasture areas and fragmented forest patches is potentially detrimental for environmental quality and the ecological fragility of land.

Introduction

Peri-urban land shaped by urban expansion and, more in general, rural areas surrounding big cities are characterized by a variety of land cover types, which is reflected in a highly fragmented morphology (Antrop, 2004). Land cover changes in such regions tend to create functionally homogeneous and structurally heterogeneous landscapes with new elements and structures superimposed upon the traditional agro-forest mosaic (McDonnell et al., 1997; Allen, 2003; Alberti, 2010). This process may alter the original structure, composition and diversity of rural landscapes determining an increased ecological fragility especially in already sensitive areas (Johnson, 2001; Jim, 2004; Basso et al., 2010).

Southern European urban regions were considered as 'laboratories' of landscape transformations because of the rapid settlement expansion observed since the 1950s that determined the irreversible loss in land resources and cultural heritage of a natural ecosystem likely unique in the world (Economidou, 1993; Antrop, 2004; Atmiş et al., 2007; Catalàn et al., 2008; Chorianopoulos et al., 2010). The urbanization-driven consumption of arable land, olive groves, vineyards, annual crops as well as shrubland, pastures and forests was documented in several Mediterranean periurban areas (Paul and Tonts, 2005; Bajocco et al., 2012; Barbati et al., 2013; Salvati et al., 2013a).

In these areas, however, little is known of how semi-natural landscape elements are evolving, how patterns are created and how the ecological functioning of the landscape is affected (Marull et al., 2009). Moreover, there is a deserving need for research assessing the (direct or indirect) impact of land cover changes and the (increased) sensitivity to forest fires in the urban-wildland interface (Falcucci et al., 2007). As an example, previous studies explored the relationship between forest fires and landscape transformations on both regional and local scale (Nunes et al., 2005; Moreno et al., 2011). Barros and Pereira (2014) also demonstrated that the selectivity of Mediterranean fires to different cover classes changed with their size and shape.

Understanding the spatio-temporal distribution of forest fires and their driving factors (both bio-physical and socioeconomic) is an essential goal of research aimed at ascertain the latent relationship between landscape structure and fire regime (Moreira et al., 2010). Further studies are needed to assess changes in land sensitivity to forest fires and landscape transformations at the urban-wildland interface. In these areas, forest fires are one of the most relevant factors shaping the ecological functioning of landscapes and sometimes determining land degradation and

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biodiversity erosion in fragile environmental conditions (e.g., in sloping areas: Kosmas et al., 2000a,b; Simeonakis et al., 2007; Salvati and Bajocco, 2011).

Based on these premises, the present study hypothesizes that long-term land cover changes had a non-neutral impact on the ecological fragility of a territory triggering, for instance, an increased sensitivity of landscapes to forest fires caused by the uneven modifications of the different vegetation classes. Based on a survey of land cover changes over 25 years (1975–2000), changes in an index of vegetation sensitivity to forest fires have been studied in a Mediterranean urban region (Athens, central Greece) that experienced landscape transformations and high exposure to forest fires. Information derived from the analysis may prove useful in planning strategies for the containment of forest fires and the mitigation of land degradation in peri-urban areas.

Methods

Study area

The study area extends for nearly 3000 km^2 (Fig. 1) and covers a large part of the Nuts-2 region of Attica, central Greece. The investigated area was subdivided in 115 mainland municipalities (including two municipalities in Salamina island) of which 58 formed the strictly urban area of Athens (430 km^2). The region mostly consists of mountains with the highest elevation in Mount Parnitha reaching 1413 m at only 25 km further away from the centre of Athens. Three coastal plains (Messoghia, Marathon and Thriasio) are located in the Attica region outside the urban area (Salvati et al., 2012). Population residing in the study area amounted to 1.6 million people in 1951, growing to 2.7 million people in 1971 (with a density of 914 inhabitants/km^2) and reaching 3.8 million people in 2011 with a density of 1248 inhabitants/km^2 while urban population declined from 92% in 1971 to 82% in 2011. Mainland Attica is the most urbanized and industrialized region in Greece experiencing urban diffusion and exurban development especially in the last two decades (Salvati et al., 2013a).

Land cover data

The surface area covered by defined land cover classes was assessed at two years (1975 and 2000) according to comparable digital maps covering the whole investigated region: (i) the LaCoast (LC) digital cartography available for 1975 at 1:100,000 scale and covering the European coastal areas (Perdigao and Christensen, 2000) and (ii) the Corine Land Cover (CLC) pan-European digital cartography available at the same scale for 2000 (European Environment Agency, 2006). The CLC project was aimed at providing land cover maps at various times for the whole of Europe and was coordinated by the European Environment Agency (EEA). The CLC inventory is based on satellite images as the primary information source. The choice of scale (1:100.000), minimum mapping unit (25 ha) and minimum width of linear elements (100 m) for CLC mapping represents a trade-off between production costs and level of detail of land cover information. The standard CLC nomenclature includes 44 land cover classes reported in Salvati and Bajocco (2011) and grouped into a three-level hierarchy (1: urban areas, 2: agricultural areas, 3: forests and semi-natural areas, 4: wetlands and 5: water bodies). The 44 CLC classes provided a comprehensive description of the landscape in the study area (Economidou, 1993).

Assessment of vegetation sensitivity to forest fires

The information on sensitivity of vegetation to forest fires have been derived from the two available land cover maps (see Section 'Land cover data') following the environmentally sensitive area approach developed in the framework of Medalus II project (Kosmas et al., 1999; Ferrara et al., 2012; Salvati et al., 2013c) to assessing sensitive areas to land degradation. This framework was applied on regional and local scales in several Mediterranean areas (Portugal, Spain, Italy and Greece) showing locally differentiated environmental conditions and was extensively validated on the ground in several target sites (Brandt, 2005).

Table 1
Indicator's weighting system adopted in this study.

Land-use	CLC code	Description	FR coefficient
Urban areas	112	Discontinuous urban fabric	1.6
	124	Airports	1.0
	131	Mineral extraction sites	1.0
	141	Green urban areas	1.3
	142	Sport and leisure facilities	1.0
Agricultural areas	211	Non-irrigated arable land	1.3
	221	Vineyards	1.0
	222	Fruit trees	1.0
	223	Olive groves	1.0
	241	Annual crops associated with permanent crops	1.3
	242	Complex cultivation patterns	1.3
	243	Land principally occupied by agriculture, with significant areas of natural vegetation	1.3
	244	Agro-forestry areas	1.3
Forests and natural areas	311	Broad-leaved forest	1.3
	312	Coniferous forest	2.0
	313	Mixed forest	1.3
	321	Natural grassland	1.3
	322	Moors and heathland	1.6
	323	Schlerophyllous vegetation	1.6
	324	Transitional woodland-shrub	1.3
	331	Beaches, dunes, sands	1.5
	333	Sparsely vegetated areas	1.0
	334	Burnt areas	1.0

The sensitivity to fire of the different vegetation types observed in the study area was evaluated by attributing a weight ranging from 1 to 2 to each land cover class (Table 1) to obtain a final indicator called FR ('forest Fire Risk', see Salvati and Bajocco, 2011 for further details). A preliminary analysis (Kosmas et al., 2000a; Salvati et al., 2009; Salvati et al., 2013b) was carried out to define the correlation between each land cover type and the sensitivity to forest fires based on field and bibliographic information collected in the framework of Medalus project (Basso et al., 2000; Kosmas et al., 2000b; Salvati et al., 2013c). Weights were derived from the previously described analysis and from additional information gathered from the available literature (Brandt, 2005; Basso et al., 2010). A sensitivity analysis and a focus group analysis were finally carried out in order to indicate the most valid, low-cost and efficient weight set (Kosmas et al., 1999; Ferrara et al., 2012). The FR indicator ranges from 1 (the lowest sensitivity to forest fires) to 2 (the highest sensitivity to forest fires). Zero values were attributed to some land cover classes that were excluded from the analysis (e.g., compact urban areas, industrial areas, bare rocks, water bodies: Salvati and Zitti, 2012).

Data analysis

The spatial distribution of FR index was mapped separately for 1975 and 2000 using the same resolution offered by the CLC cartography. Changes in the statistical distribution of the FR score in the two years were assessed using the non-parametric Mann–Whitney U statistic testing for the no-change null hypothesis at $p < 0.05$. Land cover changes and the related variations in the FR indicator were tabulated at the first CLC class level. A further analysis provided

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