Cities as selective land predators? A lesson on urban growth, deregulated planning and sprawl containment

Andrea Colantoni~~1~~[a]

Efstathios Grigoriadis~~2~~[b]

Adele Sateriano~~3~~[c]

Giuseppe Venanzoni~~3~~[c]

Luca Salvati~~4~~[d,*]

colantoni@unitus.it

~~1~~[a]Department of Agriculture, Forest, Nature and Energy (DAFNE), University of Tuscia, Via S. Camillo de Lellis snc Viterbo, Italy

~~2~~[b]"Sapienza" University of Rome, Department of Architecture and Project, Via Flaminia 396, I-00196 Rome, Italy

~~3~~[c]"Sapienza" University of Rome, Department of Social and Economic Science, Piazzale A. Moro 5, I-00185 Rome, Italy

~~4~~[d]Italian Council of Agricultural Research and Economics (CREA), Via della Navicella 2~~-~~–4, I-00184 Rome, Italy

*Corresponding author.

Editor: Simon Pollard

Abstract

The present study investigates changes in the use of land caused by the expansion of an informal city in the Mediterranean region (Athens, Greece) and it proposes a simplified methodology to assess selective land take at the scale of municipalities~~-~~. The amount of land take over twenty years (1987~~-~~–2007) for cropland, sparsely vegetated areas and natural land was compared with the surface area of the respective class at the beginning of the study period (1987). Indicators of selective land take by class were correlated with socioeconomic indicators at the scale of municipalities to verify the influence of the local context and the impact of urban planning on land take processes. Evidence ~~indicate~~indicates that urban expansion into fringe land consumes primarily cropland and sparse vegetation in the case of the Athens' metropolitan region. Cropland and sparse vegetation were consumed proportionally more than the respective availability in 16 municipalities out of 60. Agricultural land take was positively correlated with population density and growth rate, rate of participation to the job market and road density. Sparse vegetation land take was observed in municipalities with predominance of high density settlements. As a result of second-home expansion in coastal municipalities, natural land was converted to urban use in proportion to the availability in the landscape. Urban planning seems to have a limited impact on selective land take.

Keywords: Urban containment; ~~l~~Land-use changes; Sprawl; Mediterranean region

~~1.~~1 Introduction

Economic development and population growth determined intense urban expansion over the last century (Kasanko et al., 2006; Turok and Mykhnenko, 2007; Schneider and Woodcock, 2008). Land take in wealthier countries has resulted in extensive urbanization and most metropolitan areas face growing problems associated with urban sprawl (Zhang, 2000; Antrop, 2004; Angel et al., 2011; Nijkamp and Kourtit, 2013). Theories predicting urban growth and the spatial patterning of cities consider economic performance and the social structure as relevant drivers of change but offer sometimes oversimplified explanations for the differential expansion of cities (Turner, 2005). The relationship between urban functions, regional development and territorial/landscape characteristics, is usually less studies (Camagni et al., 2002; Alphan, 2003; Anthony, 2004; Grekousis and Mountrakis, 2015).

To interpret the inherent complexity of contemporary urban models, Couch et al. (2007) highlighted the urgent need to integrate research over "patterns" and "processes" of urban expansion. Land-use transformations are expression of change in the contemporary city (Sinclair, 1967) and involve processes depending on the socioeconomic context, the planning framework and place-specific factors (Turner et al., 2007). Changes in urban patterns (e.g. from compact to dispersed expansion) are clearly linked to rapidly-evolving socioeconomic processes (Longhi and Musolesi, 2007; Scott and Kühn, 2012; Sarzynski et al., 2014).

The rate of developed land in different urban counties is influenced by multiple factors including land tenure, zoning directives and housing price (Kivell, 1993; Irwin and Bockstael, 2004; Christopoulou et al., 2007). However, the rate and spatial distribution of newly-developed land is also influenced by territorial factors such as land availability, soil quality, topography and other exogenous variables (Magliocca et al., 2015). The analysis of non-economic drivers of land development proved to be particularly important when assessing dispersed forms of urban expansion (Salvati et al., 2012).

Approaches investigating urban growth from a multi-dimensional perspective require an in-depth understanding of the aspects associated with urbanization and influencing type and extent of new settlements (Saunders, 2003; Deal and Schunk, 2004; Delattre et al., 2015). While land-use changes in metropolitan regions have been documented for vastly different socioeconomic contexts (Paul and Tonts, 2005; Catalán et al., 2008; Terzi and Bolen, 2009; Chorianopoulos et al., 2010), the land take indicators proposed up to now proved to be quite simple and conservative (Salvati, 2014). Hasse and Lathrop (2003) proposed a set of measures including density of new urbanization, loss of prime farmland, natural wetlands and core forest habitats, and the increase of impervious surface area. Jaeger et al. (2010) introduced metrics assessing the spatial configuration of land taken by urbanization. Salvati (2014) pointed out that "the relationship observed between the composition of land take areas (considered as a measure of land consumption) and the composition of the original landscape (considered as a measure of land availability) was poorly investigated over time (~~…~~...) and till now it was not considered a candidate indicator of land take".

Since the analysis of spatial patterns and processes of urban expansion provides a major contribution to sustainable land management in peri-urban districts, further investigation is required to develop a comprehensive indicator-based framework assessing land take (Laidley, 2015). In this view, investigating how the spatial arrangement of different land-use classes impacts urban expansion is a crucial issue in regional studies (Turner et al., 2007). As a matter of fact, urbanization reflects the spreading of urban settlements from a local ~~epicentre~~epicenter to cover large areas, with expansion rates enhanced (or contained) by factors such as the spatial distribution of (non-urban) land-use classes across the landscape (Coisnon et al., 2014a). If classes have the same probability to be developed, urban expansion would occur randomly. However, previous studies (Fekade, 2000; Doygun, 2009; Coisnon et al., 2014b) indicate that the probability of being converted to urban uses varies according to the socioeconomic context, planning directives and place-specific factors, in turn influencing the spatial pattern of urbanization.

Land take indicators may benefit from conceptual frameworks derived from the ecological theory (Alldredge et al., 1998); at the same time, operational approaches based on indicators of 'selective' land take may contribute to the identification of local contexts where urban containment strategies are more (or less) effective (Hasse and Lathrop, 2003). These indicators provide an informative basis to design more focused measures e.g. against sprawl (Alphan, 2003; Christopoulou et al., 2007; Terzi and Bolen, 2009). 'Selective' land take occurs when land resources are used disproportionately to their availability (Salvati et al., 2014). Selectivity in land take can be investigated referring to approaches and methodologies originally designed to study resource selection by natural predators (Lauria, 1982; Bond and Keeley, 2005; Nunes et al., 2005; Bajocco and Ricotta, 2008). Expanding urban areas are regarded as 'predators' and (non-urban) land is intended as a 'prey'; different city profiles can be drawn according to their 'predation' mode. Cities can be defined as 'generalist' predators if the probability of land conversion is equal (or similar) for all (non-urban) classes in the landscape or as 'selective' predators if land take for a given class is higher (preferred) or lower (avoided) than expected by a random null model.

Based on original definitions for urban growth and land take derived from the ecological science, the present study illustrates an operational framework based on indicators and a statistical inference procedure to investigate selective land take at the local scale in Europe (Kasanko et al., 2006). As one of the most intensively used continents on the globe, up to 80% share of land in Europe is currently used for settlement, infrastructure and production systems (Antrop, 2004). Based on a pan-European dataset (the Corine Land Cover map), the annual rate of land take was estimated as higher as 1000 km^2 between 2000 and 2006 (European Environment Agency, 2006). Classes with the highest contribution to uptake by urban and other artificial land development were arable land and permanent crop (45.9%), pastures and mosaic farmland (30.5%), forests and transitional woodland-shrub (14.2%), natural grassland, heath land and sclerophyllous vegetation (7.6%). Housing, services and recreation made up a third of the overall increase in urban and other artificial area. The second largest area (29%) was taken by construction sites. Land take for industrial and commercial sites covered 16% of the whole newly developed land.

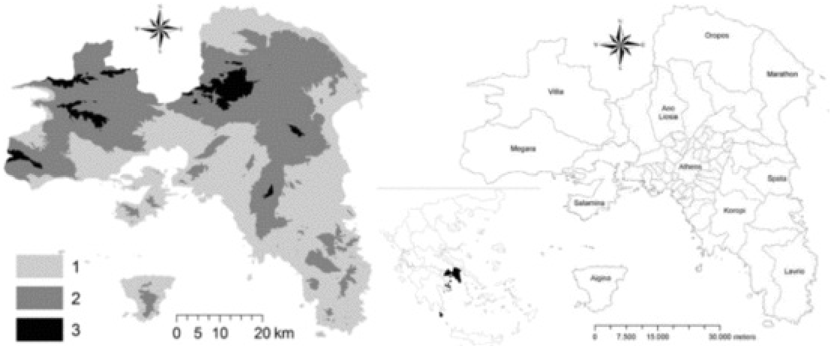
As a contribution to the long-term assessment of land-use changes in European metropolitan regions, our approach was used to ~~analyse~~analyze the recent expansion of a large Mediterranean city (Salvati, 2013). A multi-step statistical procedure was developed with to aim to identify non-urban land-use classes converted to urban use proportionally more than their availability in the landscape. The computation approach was based on four steps: (i) exploratory spatial data analysis, (ii) development of new indicators of land take, (iii) analysis of the role of the socioeconomic local context shaping land take processes, and (iv) statistical inference on 'selective' land take. This approach expands the framework originally proposed by Salvati (2014) which introduced the ratio of land take to the proportion of land available as an indicator of land consumption.

We studied urbanization-driven land take processes for three classes of non-urban land-use (cropland, sparsely vegetated areas, natural land) in the Athens' metropolitan region (Greece) over twenty years (1987–2007). The impact of socioeconomic factors and planning directives on land take was evaluated at the municipal scale through the use of contextual indicators providing insights in recent urbanization patterns and sprawl trends. Athens is an emblematic case for the study of land take processes in rapidly-expanding and planning-deregulated urban contexts, in both developed and emerging countries. Landscape transformations and changes in the urban form observed in the Athens' metropolitan region can be generalized to other cities in southern Europe: the study area underwent multiple waves of growth in the last two decades with both compact and discontinuous settlements expanding considerably into agricultural and natural land (Chorianopoulos et al., 2010). While urban containment measures have been rarely implemented, planning deregulation has contributed to the development of informal settlements (Salvati and Ferrara, 2013).

~~2.~~2 Methodology

~~2.1.~~2.1 Study area

Our study investigates a major part of the administrative region of Attica encompassing the metropolitan area of Athens, the capital of Greece, and includes Salamina and Aigina, the closest islands to Attica mainland (Fig~~ure~~. 1). Since 2011, when the national reform of local authorities (the so called "Kallikratis" law) was enforced in law, the study area is administered by 60 municipalities with 40 municipalities belonging to the Athens urban area (which includes the most dense urban ~~centres~~centers of the region) and 20 suburban municipalities (with a population density usually below 1000 inhabitants/km^2). Attica land is undulated due to the presence of four mountains bordering Athens (Parnitha, Pendeli, Imitos and Egaleo). Three flat districts (Thriasio, Messoghia, Marathona) situated outside the Athens' urban area are considered important sprawl poles hosting (planned or informal) residential settlements and industrial districts (Chorianopoulos et al., 2010). Despite recent suburbanization, population in the Athens' urban area is still growing and indicates the persistence of a mono-centric spatial structure (Grekousis et al., 2013). Attica's economy is service-oriented and ~~centred~~centered on constructions, commerce, tourism and the public sector (Delladetsima, 2006). Services accounted for 72% and 87% of the regional value added in 1988 and 2007 (Salvati and Ferrara, 2013). The importance of advanced services in finance, banking, insurance and real estate was rising in the last decade (Arapoglou and Sayas, 2009). Industrial activities, and especially manufacture, have experienced a progressive decline concentrating in few poles around Piraeus, and in delocalized places of Messoghia, Thriasio and northern Attica (Oropos, Avlon). The 2004 Olympic Games have had a major impact on the development of the city, attracting investments and creating new infrastructure (Chorianopoulos et al., 2010). The public debt resulting from major infrastructural works carried out during the Olympic decade was an important cause of the crisis of the Greek economy since 2008 (Salvati and Di Feliciantonio, 2014).



~~Figure 1.~~Fig. 1 Maps of the study area illustrating topography (1: elevation < 300 m; 2: 300 < elevation < 800 m; 3: elevation > 800 m; left) and municipal boundaries (right) with the names of relevant centers in Attica (the insert map indicates the position of Attica region (black) in Greece).

~~2.1.1.~~2.1.1 *Urban growth, land-use and regional planning in Athens*

Many studies demonstrated the limited effectiveness of urban and regional planning in the Athens' metropolitan region. As a general rule, authorities applied the approved master plans only partially. Leontidou (1990) has represented the growth of the city since the early 1950s as an addiction of different expansion waves — mainly informal and tolerated by local and central authorities. The informal expansion of the city was primarily observed during the 1960s and the 1970s and was fuelled by the uneven growth of the resident population reinforced by massive immigration from rural areas (Arapoglou and Sayas, 2009). A more subtle wave of urban expansion was observed in the 1980s and 1990s because Athens sprawled outside the territory of the old city (the lowland hosting the first urban nucleus of Athens extending 430 km^2). New settlements, mainly unplanned, were developed along the coastal zones and in more internal districts, even in mountainous areas with relatively high slopes (Delladetsima, 2006). The time period encompassing 2000s was characterized by a huge urban expansion due to public investments and the economic growth driven by the 2004 Olympic Games (Chorianopoulos et al., 2010). Informal settlements were developed in some rural places, possibly far from the central city, contributing to determine a sprawled pattern of urban expansion in the metropolitan region (Salvati and Ferrara, 2013). Informal buildings include second-home expansion in remote areas with natural amenities - especially forests. In this case, wildfires were set intentionally with the objective to clean up and "prepare" land for future development (Briassoulis, 1992). The number of wildfires, especially on fringe land, maintained high during the 1990s and the 2000s and it was only moderately reduced in the last years. The progressive destruction of Attica's landscape due to dispersed urbanization was described by Economidou (1993). Seismic areas were sometimes developed and vulnerable lands to erosion and flooding were commonly converted to residential, commercial and industrial uses (Mavrakis et al., 2015). In most cases, protected areas were designed in a relatively recent time. A national cadastre of land destroyed by wildfires was completed only in 2010, after the 2007 and 2009 mega-fires which destroyed the large part of the woodlands surrounding the Athens' urban areas (Salvati and Ferrara, 2013).

~~2.2.~~2.2 Land-use maps

The present study analyzed two comparable 1:25,000 land-use maps covering the study area at two points in time (1987 and 2007). Maps were derived from elaboration of two compatible Landsat TM satellite images processed according to Gitas et al. (2004). For each land-use class, an object-based classification was developed based on fuzzy logic and the determination of the so-called membership functions. Seven classes were considered: (i) artificial surfaces (AR), (ii) forests (W), (iii) shrubland (SH), (iv)

~~schlerophyllous~~sclerophyllous vegetation (SC), (v) sparse vegetation (SPA), (vi) cropland (A) and (vii) other classes including water bodies and rocky areas (O). The distribution of water bodies and rocky areas was confirmed by spatial overlay with the 2006 Corine Land Cover map. Additional details on land classification were provided by Gitas et al. (2004). A basic category representing 'natural areas' (NAT) was determined pooling together classes (ii), (iii) and (iv). A land-use change (1987–2007) map was also prepared by spatial overlap of the 1987 and 2007 shapefiles using ArcGIS 9.3 (Esri Inc., Redwoods, USA). Descriptive statistics and maps were produced by elaboration of the shapefiles described above.

~~2.3.~~2.3 Statistical analysis

The data analysis framework implemented in the present study is based on four steps: (i) an exploratory analysis of changes over time (1987–2007) in the spatial distribution of non-urban land, (ii) an empirical analysis of the spatial relationship between the amounts of non-urban land (1987) and of land converted to urban use (1987–2007), (iii) a multivariate analysis investigating the importance of the local socioeconomic context in land take processes, and (iv) an inferential procedure assessing selective land take at the local scale.

~~2.3.1.~~2.3.1 *Exploring changes over time (1987–2007) in the spatial distribution of non-urban land*

The proportion of class area in the total non-urban land (cumulating the six classes mentioned above from W to O was calculated at the scale of municipalities separately for 1987 and 2007 producing six indicators which assess landscape composition and provide a gross estimate of land take during the investigated time period. Indicators were expressed in relative terms (i.e. ranging from 0 to 1). A Principal Component Analysis (PCA) based on the correlation matrix was run with the aim to explore the composition of (non-urban) landscape by comparing the spatial distribution of the six classes in two groups of municipalities ('urban' and 'suburban', see Section 2.1). Components with eigenvalue > 1 were regarded as significant and the Keiser-Meyer-Olkin measure of sampling adequacy — which tests whether the partial correlations among variables are small — and Bartlett's test of sphericity, which tests whether the correlation matrix is an identity matrix — were used to assess the overall quality of the PCA. Land-use classes and municipalities were mapped within the same factorial plane using component loadings and scores. Entities placed close each other indicate spatial association, while entities placed far each other indicate spatial segregation (Salvati and Sabbi, 2011).

~~2.3.2.~~2.3.2 *Exploring the spatial relationship between the amounts of non-urban land (1987) and of land converted to urban use (1987–2007)*

In this study, the 1987 (non-urban) landscape was considered as the 'stock' variable and class transformations towards urban use observed between 1987 and 2007 as 'flow' variables. For each municipality of the study area, the amount of land theoretically available for building at the beginning of the study period (1987) was determined by cumulating the surface area of cropland, sparse vegetation and natural land. The estimate of land available for building can be adapted to different operational definitions, e.g. areas below a given elevation threshold (Saiz, 2010). Shares of (i) land theoretically available for building and of (ii) land converted to urban use between 1987 and 2007 in the municipal surface area were also calculated. A scatterplot was prepared to illustrate the relationship between these two variables in each municipality of the study area ($n = 60$). For each class, the relationship between the percentage of non-urban land (1987) and the percentage of land converted to urban use between 1987 and 2007 was investigated at the scale of municipalities using a non-parametric Spearman rank correlation analysis testing for significant pair-wise coefficients at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

~~2.3.3.~~2.3.3 *Exploring the role of local contexts in land take processes*

The ratio of the amount of land converted to urban use between 1987 and 2007 to the amount of land theoretically available for building at the beginning of the study period (1987) was computed at the scale of municipalities separately for the whole landscape and for three basic classes (cropland, sparse vegetation, natural land). These four indicators (landscape-level and class-level) provide a preliminary assessment of land take (Salvati, 2014). The values of each land take indicator at the municipal scale were correlated pair-wise to 26 socioeconomic variables using non-parametric Spearman coefficients. The objective of this analysis is to investigate the relationship between the local context and land take processes. The variables selected in this study (see list in Table 1) assess relevant aspects of the local context in the field of demography (7 indicators), land-use (4 indicators), living conditions (4 indicators), settlements (6 indicators) and regional planning (5 indicators). All variables were derived from official statistics disseminated at the municipal scale or at a more detailed spatial resolution and then aggregated at the scale of municipalities. Significant correlations were tested using Spearman non-parametric coefficients at $p < 0.01$ after Bonferroni's correction for multiple comparisons.

~~Table 1.~~Table 1 List of the context variables considered in the present study.

Acronym	Variable	Theme	Source
DEN	Population density 2001 (inhabitants/km^2)	Demography/ Territory	Census of population (ELSTAT)
VAR	Annual population growth rate 2001–2011 (%)		
RAT	Ratio of present to resident population (2001)	|	
SUP	Municipal surface area (km^2)	|	Territorial statistics (ELSTAT)

<table>
<tr><td>DIS</td><td>Distance from the inner city of Athens (km)</td><td>|</td><td>|</td></tr>
<tr><td>ELE</td><td>Mean elevation (m)</td><td>|</td><td>|</td></tr>
<tr><td>SEA</td><td>Proximity to the sea (0: coastal municipality, 1: inland munic.)</td><td>|</td><td>|</td></tr>
<tr><td>URB</td><td>Built-up area 2010 (%)</td><td>Land-use</td><td>Elaboration on Urban Atlas map</td></tr>
<tr><td>ROA</td><td>Road surface area 2010 (%)</td><td>|</td><td>|</td></tr>
<tr><td>IND</td><td>Industrial and commercial sites 2010 (%)</td><td>|</td><td>|</td></tr>
<tr><td>RES</td><td>Residential buildings 2000 (%)</td><td>|</td><td>Census of buildings (ELSTAT)</td></tr>
<tr><td>INC</td><td>Per-capita income 2001 (euros)</td><td rowspan="2">Living conditions</td><td>Prodromidis (2014)</td></tr>
<tr><td>PAR</td><td>Rate of participation to the job market (2001)</td><td>Census of households (ELSTAT)</td></tr>
<tr><td>CL1</td><td>Highest rank jobs 2001 (%)</td><td>|</td><td>Salvati and Di Feliciantonio (2014)</td></tr>
<tr><td>CL9</td><td>Lowest rank jobs 2001 (%)</td><td>|</td><td>|</td></tr>
<tr><td>ADJ</td><td>Adjacent buildings 2000 (%)</td><td>|Settlement</td><td>|</td></tr>
<tr><td>COM</td><td>Compact urban fabric 2010 (%)</td><td>|</td><td>Elaboration on Urban Atlas map</td></tr>
<tr><td>HIR</td><td>Discontinuous high-density urban fabric 2010 (%)</td><td>|</td><td>|</td></tr>
<tr><td>MER</td><td>Discontinuous medium-density urban fabric 2010 (%)</td><td>|</td><td>|</td></tr>
<tr><td>LOR</td><td>Discontinuous low-density urban fabric 2010 (%)</td><td>|</td><td>|</td></tr>
<tr><td>VLR</td><td>Discontinuous very low density urban fabric 2010 (%)</td><td>|</td><td>|</td></tr>
<tr><td>EVE</td><td>Pielou's evenness index of landscape diversity (1987)</td><td rowspan="2">Planning/
Landscape</td><td rowspan="3">Elaboration on land-use map
Athens Spatial Planning Organization (ORSA)</td></tr>
<tr><td>OUT</td><td>Out-of-planning land (%)</td></tr>
<tr><td>YEA</td><td>Approval year of Municipal Master Plan (1985 = 0)</td><td>|</td></tr>
<tr><td>REV</td><td>Master Plan revision/improvement (dummy: 0 = No, 1 = Yes)</td><td>|</td><td>|</td></tr>
<tr><td>LAN</td><td>Land under environmental protection (%)</td><td>|</td><td>|</td></tr>
</table>

~~2.3.4.~~2.3.4 *Testing for 'selective' land take*

A simplified and flexible procedure based on statistical testing was proposed to assess 'selective' land take at both landscape and class (cropland, sparse vegetation, natural land) level using municipalities as the elementary analysis' domain. Statistical inference was used to verify if (i) the observed amount of land take for each class is coherent with the null hypothesis of 'equal land take' at the municipal scale ('landscape' level) and if (ii) the amount of land converted to urban use during 1987–2007 for each class is proportional to the amount of the total class area at the beginning of the study period (1987) ('class' level). The procedure can be adapted to different land-use nomenclature systems and generalized to different spatial units (administrative, socioeconomic and biophysical spatial domains, e.g. regions, prefectures, local ~~labour~~labor markets, large urban zones, industrial or agricultural-homogeneous districts, elevation zones).

If a city acts as a generalist predator, it was hypothesized that the proportion of land converted to urban use for each class resembles the proportion of land converted to urban use at the landscape scale. Positive (or negative) deviations from this pattern may indicate selective (or counter-selective) land take (Salvati, 2014). Based on these premises, the share of land converted to urban use for each class between 1987 and 2007 to the respective class area observed for 1987 was considered a random variable indicating the probability of conversion to urban use.

As far as the 'landscape' level is concerned, an independence chi-square test was run on the observed and expected values of land take for the three classes (cropland, sparse vegetation, natural land) under the null hypothesis of equal consumption rate at the municipal scale. Null hypothesis was rejected at $p < 0.01$ after Yates' correction for continuity. The expected value of land take was determined as the amount of land converted to urban use pooling together cropland, sparse vegetation and natural land for each municipality in the study area.

As far as the 'class' level is concerned, a standardized z-score was calculated by computing the absolute difference between the frequency of conversion to urban use for each class and the frequency of conversion to urban use observed for the whole landscape under the null hypothesis that non-selective land take occurs when the two probabilities converge. The z-score was calculated as follows:

$$z = \frac{p_{c,i} - p_c}{\sqrt{(p_c(1 - p_c)(1/n))}}$$

where $p_{c,i}$ is the ratio of the amount of land converted to urban use between 1987 and 2007 to the total amount of land in 1987 for the c-th class and the i-th municipality, p_c is the ratio of the amount of land converted to urban use between 1987 and 2007 to the total amount of land in 1987 for the c-th class at the study area level and n is the number of elementary analysis units. In general, the elementary analysis unit can be set up according to different criteria related to the characteristics of source data. In the present case, n is the number of municipalities with land classified at the c-th class in 1987. Under the central limit theorem (i.e. for enough large sample sizes), $z \sim N(0,1)$ and the null hypothesis of non-selective land take can be rejected with a defined confidence by computation on the percentiles of the z distribution. In the present case, the null hypothesis was rejected at $p < 0.01$ (two-tailed test). Positive (or negative) z-scores indicate selective (or counter-selective) land take.

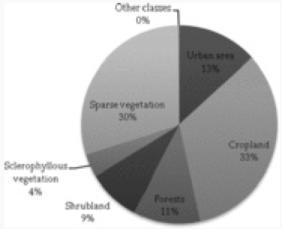
~~3.~~3 Results

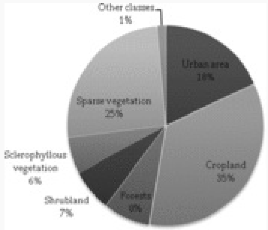
~~3.1.~~3.1 Descriptive statistics

Built-up areas in Athens extended 13.2% of the regional surface area in 1987 and increased to 18.1% in 2007 (Table 2). Cropland was the most stable (non-urban) class covering 33% and 35% of the study area respectively in 1987 and 2007 and displaying the highest rate of conversion to urban use. Sparsely vegetated areas decreased from 30% to 25% over the study period with 66% of stable class area and an intermediate rate of conversion to urban use. Natural land showed the largest decrease in class area, the lowest percentage of stable class area and the lowest rate of conversion to urban use. The three classes forming natural areas (forests, shrubland, sclerophyllous vegetation) showed a distinct spatial pattern with declining class area of forests and shrubland and with sclerophyllous vegetation expanding into natural and agricultural land.

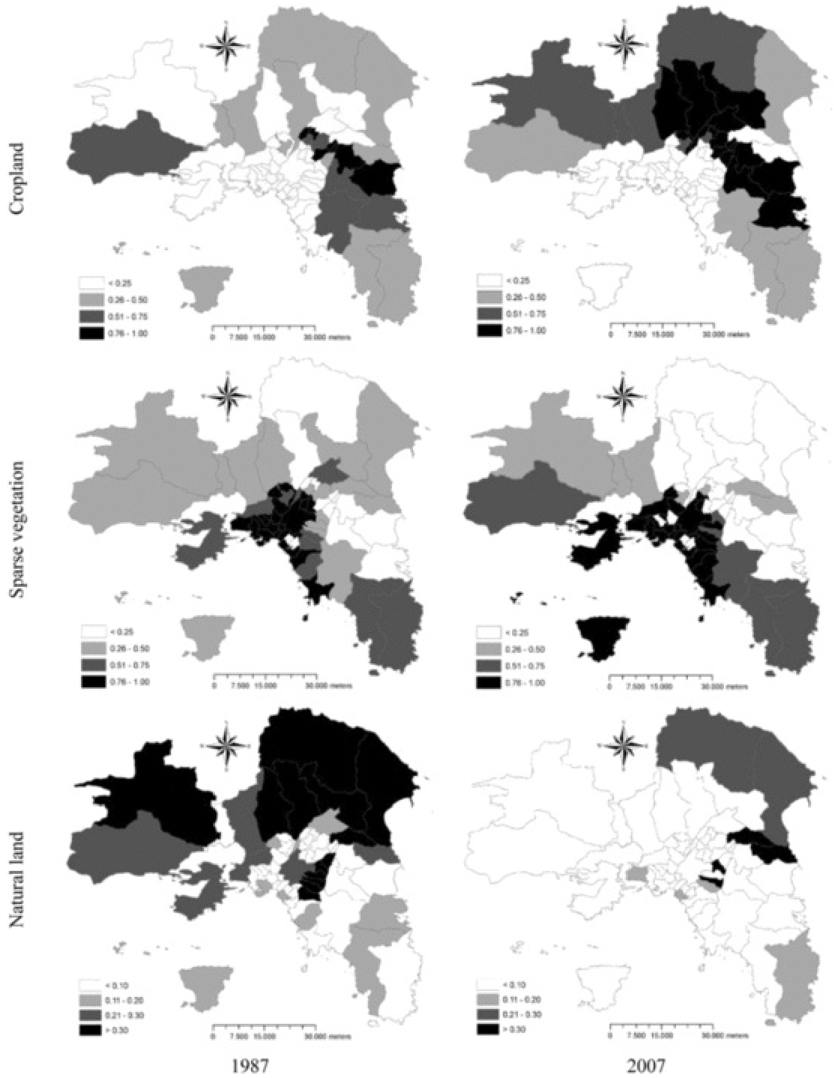
~~Table 2.~~Table 2 Land-use changes in Attica during the study period (left chart: 1987; right chart: 2007).

Class	1987	2007	Annual change (%)	Stable class area (%)	Developed land (%)
Urban area	13.2	18.1	1.85	94.6	–
Cropland	33.3	34.6	0.19	81.1	3.5
Sparse vegetation	29.7	25.5	–0.82	66.3	1.6
Natural areas	23.7	21.6	–0.49	59.2	0.4





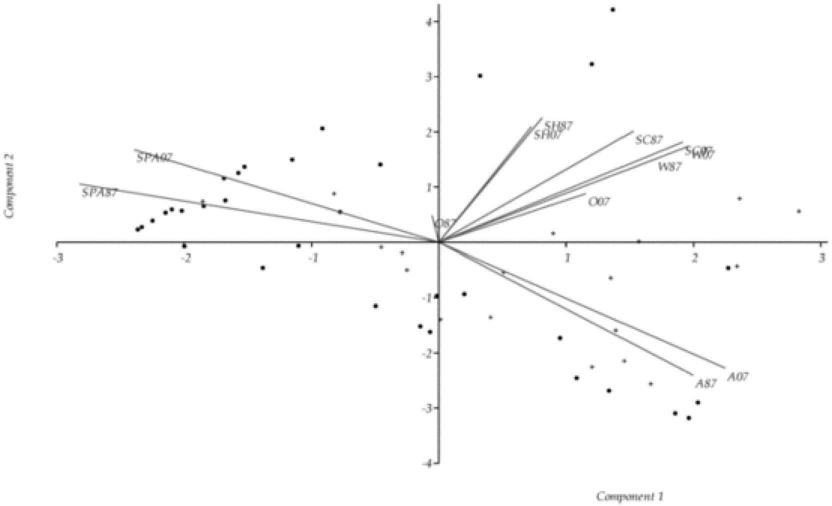
Using percent class area, changes over time in the composition of non-urban land were mapped in Fig~~ure~~. 2. Maps illustrate a process of polarization in the use of land along the urban gradient with specific classes prevailing in the landscape at a given distance from the central city. In 1987 cropland was the dominant use of non-urban land in some fringe municipalities east of Athens (Messoghia district) becoming the most relevant use of land in northern and eastern Attica in 2007 (Oropos, Marathona, Keratea and Lavrio districts). Sparse vegetation showed a more stable spatial distribution along the study period, being the most representative use of land in fringe municipalities in 1987 and expanding slightly in 2007, especially in Salamina and Aigina islands. Natural land was distributed rather homogeneously across the study region at the beginning of the study period and declined rapidly in the subsequent twenty years, becoming quite scarce in the majority of Attica municipalities and concentrating in upland and mountainous areas.



~~Figure 2.~~Fig. 2 The proportion of non-urban class area in the total non-urban land at the scale of municipalities in the study area by year.

~~3.2.~~3.2 Exploring changes over time (1987~~-~~–2007) in the spatial distribution of non-urban land

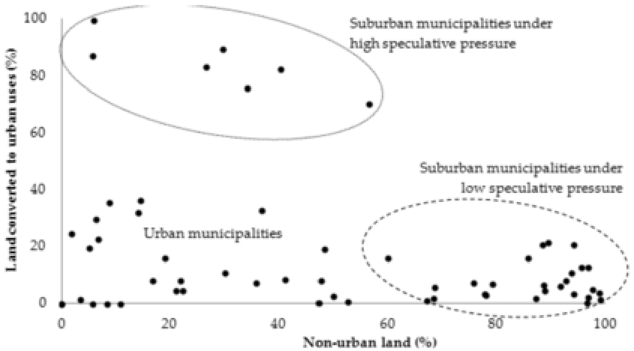
The PCA run on the six indicators assessing the percent cover of non-urban land classes for 1987 and 2007 identified two components explaining together 52.5% of the total variance (respectively 27.3% and 25.2%). The biplot illustrating loadings and scores along the two principal components (Fig~~ure~~. 3) indicated distinct spatial patterns for cropland, sparse vegetation and natural land. Loadings of cropland and sparse vegetation were associated to component 1 with different signs (respectively positive and negative). Classes forming natural land were positively associated to component 2. Component 2 discriminated urban from suburban municipalities better than Component 1, with the percentage of natural land being the most important variable at larger distances from Athens.



~~Figure 3.~~Fig. 3 Principal Component Analysis biplot illustrating the spatial relationship between non-urban land-use classes for 1987 and 2007 (dot and cross indicates respectively urban and suburban municipalities; see Section 2.3.1 for definitions).

~~3.3.~~3.3 Exploring the spatial relationship between the amounts of non-urban land (1987) and of land converted to urban use (1987~~-~~–2007)

The relationship between the amount of land theoretically available to building in 1987 and the share of land developed between 1987 and 2007 in the total municipal surface area was illustrated in Fig~~ure~~. 4. The scatterplot classifies municipalities into homogeneous groups based on the percentages of land (i) theoretically available to building and (ii) converted to urban use. Three groups were identified: (i) strictly urban municipalities and two classes of suburban municipalities respectively under (ii) low speculative pressure (with medium-high land availability and low rate of conversion to urban use) and (iii) high speculative pressure (medium~~-~~–low land availability and medium-high conversion rate). While suburban municipalities classified under high speculative pressure concentrated on Athens fringe, municipalities classified under low speculative pressure were situated in remote areas of northern and eastern Attica.

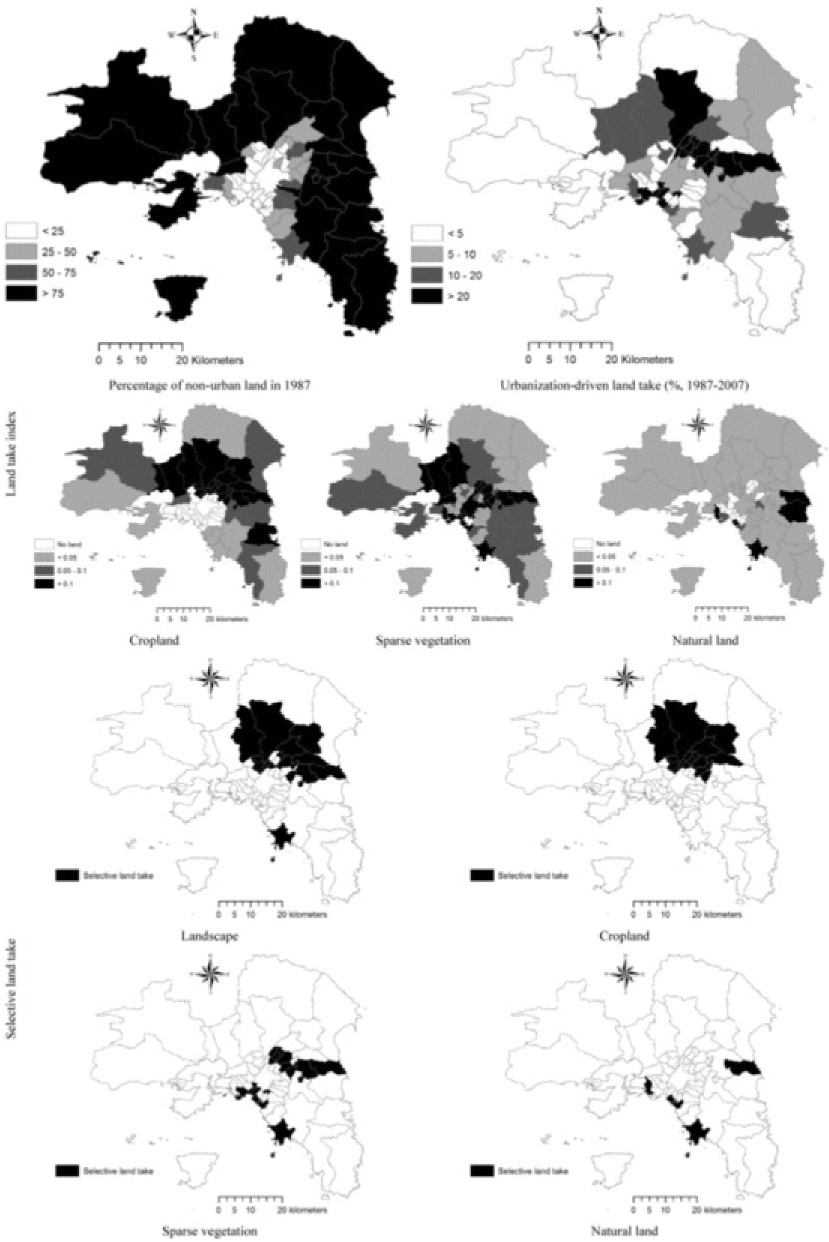


~~Figure 4.~~Fig. 4 The relationship between the percentage of non-urban land in 1987 and the percentage of land converted to urban uses between 1987 and 2007.

Spearman non-parametric rank tests were run for each land-use class with the aim to identify significant correlations between land theoretically available to building (1987) and the rate of land conversion to urban use (1987–2007). Land take increases with the proportion of cropland and sparsely vegetated areas in the landscape (respectively $r_s = 0.88$ and 0.65, both $p < 0.01$). By contrast, the three classes forming 'natural land' showed a homogeneous correlation profile with lower and non-significant Spearman coefficients (shrubland: $r_s = 0.49$; sclerophyllous vegetation: $r_s = 0.41$; forests: $r_s = 0.36$). This result indicates that the amount of natural land taken by urbanization was less affected by the proportion of forests, shrubland and sclerophyllous vegetation in the landscape.

~~3.4.~~3.4 Exploring the role of local contexts in land take processes

The amount of land converted to urban use (1987–2007) to the amount of land theoretically available to urbanization (1987) was computed separately for the whole landscape and for three basic classes (cropland, sparse vegetation, natural land) and mapped at the municipal scale (Fig~~ure~~. 5). The percentage of non-urban land in the 1987 landscape increased with the distance from Athens ($r_s = 0.79$, $p < 0.01$, $n = 60$) and decreased with population density ($r_s = 0.91$, $p < 0.01$, $n = 60$). The index of land take (landscape level) increased in fringe municipalities around Athens and decreased with the distance from the central city being correlated positively with the percentage of high-density, discontinuous residential settlements in the landscape (Table 3).



~~Figure 5.~~Fig. 5 Land take indicators for Attica.

~~Table 3.~~Table 3 Spearman non-parametric coefficients between land take indicators and context variables (significant coefficients at $p < 0.05$ after Bonferroni's correction for multiple comparison; acronym's list in Table 1).

Variable	Land take index			
	Landscape	Cropland	Sparse vegetation	Natural land
DEN		0.69		
DIS		~~-~~– 0.65		
VAR		0.62		
RAT		~~-~~– 0.56	0.53	
SUP		~~-~~– 0.66		
URB		~~-~~– 0.56		
SEA		~~-~~– 0.67	0.63	
PAR		0.54		
HIR	0.44			0.45
ROA		0.54		

The highest values of the land take index for cropland were observed in fringe municipalities north of Athens (Oropos district). The land take index was correlated positively with population density and growth, participation rate and road density. Negative correlations were observed with the distance from Athens and from the coastline, the ratio of present-to-resident population, the municipal size and the percentage of urban areas in the total municipal surface area. The highest values of the land take index for sparse vegetation were observed for some urban municipalities and fringe municipalities in both northern and eastern Attica (Oropos and Messoghia districts). Sparsely vegetated land take increased with the percentage of high-density residential settlements. Finally, the highest values of the land take index for natural areas were observed in eastern Attica (Nea Makri) and in some fringe municipalities south of Athens (Vari district) increasing with the distance from the coastline and the ratio of present-to-resident population.

~~3.5.~~3.5 Testing for ~~'~~‘selective~~'~~’ land take

Selective land take was verified for each spatial unit and land-use class (Fig~~ure~~. 5) using the test statistics illustrated in Section 2.3.4. Out of 60 municipalities, selective land take was found in 17 municipalities concentrated in the northern fringe of Athens (Ano Liosia, Pendeli and Vari districts) and extending 18% of the study area. A different number of municipalities was considered for assessing selective land take by class depending on the presence of the respective land-use class in the 1987 landscape (cropland was observed in 36 municipalities, sparse vegetation in 58 municipalities and natural land in 46 municipalities). Urbanization-driven selective consumption of cropland was observed in 16 municipalities out of 36 (15% of the total investigated area) concentrated in the northern fringe of Athens (Pendeli and part of the Parnitha districts). Selective sparse vegetation land take was observed in 16 municipalities out of 58 (6% of the total investigated area) situated in the northern and southern fringe of Athens (Pendeli and Vari districts). Selective natural land take was observed in 6 municipalities out of 46 (3% of the total investigated area) being sparse across the Athens' fringe (e.g. Nea Makri, Vari).

~~4.~~4 Discussion

The present study illustrates a simplified and flexible procedure quantifying urbanization-driven land take over a given time interval. By considering expanding cities as ~~'~~‘generalist~~'~~’ or ~~'~~‘selective~~'~~’ land predators, our approach integrates exploratory spatial analysis, non-parametric correlations, multivariate and inferential statistics to assess land availability to building, changes in landscape composition and the relationship between these two variables. The indicators of land take proposed in this study can be generalized to different socioeconomic contexts and territorial conditions. Spatial trends in land take indicators suggest that urbanization-driven land consumption increases in the study area showing heterogeneous spatial patterns for three basic uses of land (cropland, sparse vegetation and natural land) with different economic and environmental values.

As a general rule, open areas with sparse vegetation, often bordering the consolidated urban areas, represent the largest stock of land for building (Balta and Eke, 2011). Most of the undeveloped land in urban spaces is represented by this class - showing little natural value and limited capacity for reconversion to non-urban productive uses, such as agriculture. These areas are rarely protected and are more frequently considered as building, sometimes with some constraints in terms of size and structure of settlements (Magliocca et al., 2015). Agricultural areas are generally classified under moderate building restrictions. Cropland ~~are~~ is urbanized occasionally although ~~they~~ it can accommodate more frequently rural buildings and service infrastructure for farms (Scott and Kühn, 2012). In many cases, these infrastructures have represented the first elements of a more organized settlement that has gradually expanded consuming arable land (Coisnon et al., 2014a). Natural land requires specific protection regimes for the socio-environmental services that these areas can provide cities (Kivell, 1993). The level of protection of natural areas around cities is variable but generally the construction of buildings is prohibited or restricted, especially in national (or regional) parks or where there are landscape or hydro-geological constraints (Irwin and Bockstael, 2004).

With landscape transformations reflecting the deregulated urban expansion which took place in Greece after the accession to the European Union, the subsequent economic growth and, finally, the 2004 Olympic games, distinct selective land take patterns were observed at the regional and local scale in the Athens' metropolitan region (Chorianopoulos et al., 2010). Based on our results, selective land take for agricultural areas and sparse vegetation was observed in 16 municipalities (out of 60) covering nearly 18% of the study area. These municipalities are situated on Athens' fringe at a distance from the inner city ranging between 5 and 15 km. Real estate speculation is considered one of the most effective drivers influencing land take in such context (Salvati et al., 2012). Natural land is consumed proportionally to the availability in the landscape; selective land take was observed in sparse municipalities at higher distances (> 20 km) from the central city.

In line with previous studies carried out in the Mediterranean region (Paul and Tonts, 2005; Catalán et al., 2008; Moliní and Salgado, 2012; Salvati and Gargiulo Morelli, 2014), the socioeconomic context has been proved to influence land take processes in Athens. The probability of selective land take increases with the percent cover of medium-high density settlements in each municipality. This is a particularly interesting result since compact settlements are generally associated to land-saving (and possibly more sustainable) urbanization processes (Deal and Schunk, 2004; Bogart, 2006; Kasanko et al., 2006; Schneider and Woodcock, 2008). Based on these evidence, land-saving strategies can orient compact and medium-density urbanization towards partly developed areas by converting low-quality fringe land (e.g. sparse vegetation, pastures, abandoned non-vegetated sites) already fragmented by urban expansion (Razin and Rosentraub, 2000).

In Athens, selective consumption of agricultural land was observed more frequently in fringe municipalities with growing population. Cropland — especially where extensive farming with moderate returns on land is practiced — is the preferred use of land to building in municipalities with intense house demand. Results are in line with previous evidence from the analysis of pan-European land-use maps (European Environment Agency, 2006) that identified agricultural land as the primary ‘victim’ of either compact and dispersed urban expansion, suggesting that the methodology implemented here can be generalized to vastly different socio-environmental contexts. Measures designed for the protection of peri-urban agriculture are particularly needed in deregulated Mediterranean contexts (Antrop, 2004).

The development of natural land reflects more heterogeneous patterns of urban expansion (Christopoulou et al., 2007). Natural areas were converted to urban uses mainly in municipalities situated along the sea coast and where the present (e.g. seasonal) population is greater than the resident population, prefiguring an amenity-driven sprawl model based on second-home expansion (Arapoglou and Sayas, 2009). In these areas, natural land (mainly forests and shrubland) was often developed after (intentional) wildfire occurrence (Briassoulis, 1992).

Sparse vegetation may represent the intermediate step in the conversion from natural to urban land (Alphan, 2003). As a general rule, these areas, characterized by limited natural value and close to pre-existing settlements, were consumed proportionally more than the availability in the landscape (Salvati, 2013). In Athens, sparsely vegetated areas were developed mainly in municipalities with discontinuous (medium–high density) residential settlements irrespective of the distance from the central city. The transformation of natural land into urban areas proceeded through multiple conversion steps from natural land to cropland (driven by agricultural intensification in the 1960s and 1970s), from cropland to sparse vegetation (due to cropland abandonment in the late 1980s and 1990s) and from sparse vegetation to discontinuous settlements in the late 1990s and 2000s. Taken as an indirect evidence of this model, fallow land increased significantly from 1971 to 2000 in Attica, passing from less than 300 km^2 to nearly 360 km^2 (Salvati and Ferrara, 2013). Results of the correlation analysis investigating the spatial relationship between the amounts of land available to building in 1987 and of land converted to urban use between 1987 and 2007 confirm what was illustrated above.

Correlation analysis also outlines the limited effectiveness of urban planning in determining patterns of ‘selective’ or ‘generalist’ land take. These findings are in line with previous studies documenting the pervasiveness of informal settlements and planning deregulation, suggesting that other factors — e.g. social, economic, and territorial — have influenced the processes of urban expansion in a much more relevant way (Fekade, 2000). At the same time, the effectiveness of measures designed to the protection of natural land (forests, pastures, wetlands) should be further investigated using diachronic land-use mapping (Catalán et al., 2008; Chorianopoulos et al., 2010; Salvati, 2013). Improved conceptual and operational frameworks are needed to adapt land take indicators to the large information base provided by extensive land-use mapping at the global scale (Bogart, 2006).

Taken together, our results suggest how the analysis of patterns and processes of urban sprawl will benefit from comparative studies carried out in metropolitan areas characterized by a different degree of planning deregulation (Salvati, 2014). Spatio-temporal trends in the land take indicators proposed here provide a base to evaluate informal urban expansion (Oueslati et al., 2015). Their contribution to urban growth monitoring and to the design of policies for the containment of urban sprawl is relevant and deserves further investigation.

5.5 Conclusions

The transformation of the regional economy and the emergence of new urban forms featuring settlement dispersion, social fragmentation and economic polarization suggest that urban dynamics will inevitable drive the use of land towards impressive changes. In this sense, peri-urban areas are exemplificative of the land cover changes and landscape rearrangement observed along the urban–rural gradient because of the dynamic human pressure they experience. Indicators of land take coupled with statistical frameworks assessing landscape selectivity for urbanization are promising tools when analyzing the interaction between the probability of land conversion, landscape attributes (e.g. patchiness, patch size and shape) and socioeconomic factors (e.g. land tenure, price and level of environmental protection). By fixing specific land take thresholds (e.g. intended as a policy target), our methodology can represent a base to monitoring over time the differential land consumption by class of land-use and to evaluate the effectiveness of land management/conservation measures.

Our results definitely outline the importance of an integrated analysis of socioeconomic, functional and morphological aspects of urban development at both the regional and the local scale. In this sense, the municipality proved to be an enough detailed spatial domain for quantitative analysis. Further investigation can address the objective of a complete integration of intra-municipal data on settlement patterns as a support to sustainable planning measures and urban design. Providing valuable insights into the mutual interactions between landscape structure and urbanization may contribute to the understanding of complex processes of growth and change in contemporary cities. The conservation of natural areas intermixed with cultivated land along urban fringes contributes to the development of green infrastructures preserving important ecosystem services and securing rural traditions and local food systems.

~~Acknowledgements~~Acknowledgments

Thanks are due to Prof. Ioannis Gitas for the continuous support during the study period. Maps were provided courtesy of WWF-Ellas and Laboratory of Cartographic Analysis, University of Thessaloniki.

References

Alldredge J.R., Thomas D.L. and McDonald L.L., Survey and comparison of methods for study of resource selection, *J. Agric. Biol. Environ. Stat.* **3**, 1998, 237–253.

Alphan H., Land use change and urbanisation of Adana, Turkey, ~~*Land Degradation and Development*~~*Land Degrad. Dev.* **14**, 2003, 575–586.

Angel S., Parent J., Civco D.L., Blei A. and Potere D., The dimensions of global urban expansion: estimates and projections for all countries, 2000~~-~~–2050, ~~*Progress in Planning*~~*Prog. Plan.* **75**, 2011, 53–107.

Anthony J., Do ~~S~~state ~~G~~growth ~~M~~management ~~R~~regulations ~~R~~reduce ~~S~~sprawl?, ~~*Urban Affairs Review*~~*Urban Aff. Rev.* **39** (3), 2004, 376–397.

Antrop M., Landscape change and the urbanization process in Europe, ~~*Landscape and Urban Planning*~~*Landsc. Urban Plan.* **67** (1–4), 2004, 9–26.

Arapoglou V.P. and Sayas J., New facets of urban segregation in southern Europe, *Eur. Urban Reg. Stud.* **16** (4), 2009, 345–362.

Bajocco S. and Ricotta C., Evidence of selective burning in Sardinia (Italy): which land-cover classes do wildfires prefer?, ~~*Landscape Ecology*~~*Landsc. Ecol.* **23** (2), 2008, 241–248.

Balta M.O. and Eke F., Spatial ~~R~~reflection of ~~U~~urban ~~P~~planning in ~~M~~metropolitan ~~A~~areas and ~~U~~urban ~~R~~rent; a ~~C~~case ~~S~~study of Cayyolu, Ankara, ~~*European Planning Studies*~~*Eur. Plan. Stud.* **19** (10), 2011, 1817–1838.

Bogart W.T., Don't Call It Sprawl: Metropolitan Structure in the 21st Century, 2006, Cambridge University Press; Cambridge.

Bond V.J. and Keeley J.E., Fire as a global ‘herbivore’: the ecology and evolution of flammable ecosystems, *Trends Ecol. Evol.* **20**, 2005, 387–394.

Briassoulis H., The planning uses of fire: reflections on the Greek experience, ~~*Journal of Environmental Planning and Management*~~*J. Environ. Plan. Manag.* **35** (2), 1992, 161–173.

Camagni R., Gibelli M.C. and Rigamonti P., Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion, ~~*Ecological Economics*~~*Ecol. Econ.* **40** (2), 2002, 199–216.

Catalán B., Saurí D. and Serra P., Urban sprawl in the Mediterranean? Patterns of growth and change in the Barcelona Metropolitan Region 1993–2000, ~~*Landscape and Urban Planning*~~*Landsc. Urban Plan.* **85** (3–4), 2008, 174–184.

Chorianopoulos I., Pagonis T., Koukoulas S. and Drymoniti S., Planning, competitiveness and sprawl in the Mediterranean city: ~~T~~the case of Athens, *Cities* **27**, 2010, 249–259.

Christopoulou O., Polyzos S. and Minetos D., Peri-urban and urban forests in Greece: obstacle or advantage to urban development?, ~~*Journal of Environmental Management*~~*J. Environ. Manag.* **18**, 2007, 382–395.

Coisnon T., Oueslati W. and Salanié J., Urban sprawl occurrence under spatially varying agricultural amenities, ~~*Regional Science and Urban Economics*~~*Reg. Sci. Urban Econ.* **44**, 2014a, 38–49.

Coisnon T., Oueslati W. and Salanié J., Spatial targeting of agri-environmental policy and urban development, ~~*Ecological Economics*~~*Ecol. Econ.* **101**, 2014b, 33–42.

Deal B. and Schunk D., Spatial dynamic modeling and urban land use transformation: a simulation approach to assessing the costs of urban sprawl, ~~*Ecological Economics*~~*Ecol. Econ.* **51** (1–2), 2004, 79–95.

Delattre L., Chanel O., Livenais C. and Napoléone C., Combining discourse analyses to enrich theory: ~~T~~the case of local land-use policies in South Eastern France, ~~*Ecological Economics*~~*Ecol. Econ.* **113**, 2015, 60–75.

Delladetsima P., The emerging property development pattern in Greece and its impact on spatial development, *Eur. Urban Reg. Stud.* **13** (3), 2006, 245–278.

Doygun H., Effects of urban sprawl on agricultural land: a case study of Kahramanmaraş, Turkey, ~~*Environmental Monitoring and Assessment*~~*Environ. Monit. Assess.* **158** (1–4), 2009, 471–478.

Economidou E., The Attic landscape throughout the centuries and its human degradation, ~~Landscape and Urban Planning~~Landsc. Urban Plan. **24**, 1993, 33–37.

European Environment Agency, Urban sprawl in Europe ~~–~~— the ignored challenge, In: *EEA Report no. 10, Copenhagen,* 2006.

Fekade W., Deficits of formal urban land management and informal responses under rapid urban growth, an international perspective, *Habitat Int.* **24** (2), 2000, 127–150.

Gitas I.Z., Mitri G.H. and Ventura G., Object-~~B~~based classification for ~~B~~burned ~~A~~area ~~M~~mapping of Creus Cape, Spain, using NOAA—AVHRR ~~I~~imagery, ~~Remote Sensing of Environment~~Remote Sens. Environ. **92** (3), 2004, 409–413.

Grekousis G. and Mountrakis G., Sustainable ~~D~~development under ~~P~~population ~~P~~pressure: ~~L~~lessons from ~~D~~developed ~~L~~land ~~C~~consumption in the ~~C~~conterminous US, ~~Plos One~~PLoS One **25**, 2015, http://dx.doi.org/10.1371/journal.pone.0119675.

Grekousis G., Manetos P. and Photis Y.N., Modeling urban evolution using neural networks, fuzzy logic and GIS: ~~T~~the case of the Athens metropolitan area, *Cities* **30**, 2013, 193–203.

Hasse J.E. and Lathrop R.G., Land resource impact indicators of urban sprawl, ~~Applied Geography~~Appl. Geogr. **23**, 2003, 159–175.

Irwin E.G. and Bockstael N.E., Land use externalities, open space preservation, and urban sprawl, ~~Regional Science and Urban Economics~~Reg. Sci. Urban Econ. **34** (6), 2004, 705–725.

Jaeger J.A.G., Bertiller R., Schwick C., Cavens D. and Kienast F., Urban permeation of landscapes and sprawl per capita: ~~N~~new measures of urban sprawl, ~~Ecological Indicators~~Ecol. Indic. **10** (2), 2010, 427–441.

Kasanko M., Barredo ~~J. I.~~J.I., Lavalle C., McCormick N., Demicheli L., Sagris V. and Brezger A., Are European ~~C~~cities ~~B~~becoming ~~D~~dispersed? A ~~C~~comparative ~~A~~analysis of ~~F~~fifteen European ~~U~~urban ~~A~~areas, ~~Landscape and Urban Planning~~Landsc. Urban Plan. **77** (1—2), 2006, 111–130.

Kivell P., Land and the City: Patterns and Processes of Urban Change, 1993, Routledge; London.

Laidley T., Measuring ~~S~~sprawl: ~~A~~a ~~N~~new ~~I~~index, ~~R~~recent ~~T~~trends, and ~~F~~future ~~R~~research, ~~Urban Affairs Review~~Urban Aff. Rev. 2015, http://dx.doi.org/10.1177/1078087414568812.

Lauria M., Selective urban redevelopment: a political economic perspective, *Urban Geogr.* **3** (3), 1982, 224–239.

Leontidou L., The Mediterranean City in Transition, 1990, Cambridge University Press; Cambridge.

Longhi C. and Musolesi A., European cities in the process of economic integration: towards structural convergence, ~~Annals of Regional Science~~Ann. Reg. Sci. **41**, 2007, 333–351.

Magliocca N., McConnell V. and Walls M., Exploring sprawl: ~~R~~results from an economic agent-based model of land and housing markets, ~~Ecological Economics~~Ecol. Econ. **113**, 2015, 114–125.

Mavrakis A., Papavasileiou C. and Salvati L., Towards (Un)sustainable ~~U~~urban ~~G~~growth? Climate aridity, land-use changes and local communities in the industrial area of Thriasio Plain, Greece, *J. Arid Environ.* **121**, 2015, 1–6.

Moliní F. and Salgado M., Sprawl in Spain and Madrid: ~~A~~a ~~L~~low ~~S~~starting ~~P~~point ~~G~~growing ~~F~~fast, ~~European Planning Studies~~Eur. Plan. Stud. **20** (6), 2012, 1075–1092.

Nijkamp P. and Kourtit K., The "~~N~~new ~~U~~urban Europe": ~~G~~global ~~C~~challenges and ~~L~~local ~~R~~responses in the ~~U~~urban ~~C~~century, ~~European Planning Studies~~Eur. Plan. Stud. **21** (3), 2013, 291–315.

Nunes M.C.S., Vasconcelos M.J., Pereira J.M.C., Dasgupta N., Alldredge R.J. and Rego F.C., Land cover type and fire in Portugal: do fires burn land cover selectively?, ~~Landscape Ecology~~Landsc. Ecol. **20**, 2005, 661–673.

Oueslati W., Alvanides S. and Garrod G., Determinants of urban sprawl in European cities, ~~Urban Studies~~Urban Stud. **52** (9), 2015, 1594–1614.

Paul V. and Tonts M., Containing urban sprawl: trends in land use and spatial planning in the Metropolitan Region of Barcelona, ~~Journal of Environmental Planning and Management~~J. Environ. Plan. Manag. **48** (1), 2005, 7–35.

Prodromidis P., The Evolution of Personal Incomes Across Greece: 2001—2008, 2014, Stamoulis; Athens.

Razin E. and Rosentraub M., Are ~~F~~fragmentation and ~~S~~sprawl ~~I~~interlinked? North American ~~E~~evidence, ~~Urban Affairs Review~~Urban Aff. Rev. **35** (6), 2000, 821–836.

Saiz A., The geographic determinants of housing supply, ~~The Quarterly Journal of Economics~~Q. J. Econ. **125** (3), 2010, 1253–1296.

Salvati L., 'A chronicle of a death foretold': ~~U~~urban shrinkage and land consumption in Rome, Italy, ~~European Planning Studies~~Eur. Plan. Stud. **21** (8), 2013, 1176–1188.

Salvati L., Land ~~A~~availability vs ~~C~~conversion by ~~U~~use ~~T~~type: ~~A~~a ~~N~~new ~~A~~approach for ~~L~~land ~~T~~take ~~M~~monitoring, ~~Ecological Indicators~~Ecol. Indic. **36**, 2014, 221–223.

Salvati L. and Di Feliciantonio C., Exploring social mixité in the urban context through a simplified diversity index, *Curr. Pol. Econ. Eur.* **24** (3/4), 2014, 203–214.

Salvati L. and Ferrara C., Do changes in vegetation quality precede urban sprawl?, *Area* **45** (3), 2013, 365–375.

Salvati L. and Gargiulo Morelli V., Unveiling ~~U~~urban ~~S~~sprawl in the Mediterranean ~~R~~region: ~~T~~towards a ~~L~~latent ~~U~~urban ~~T~~transformation?, *Int. J. Urban Reg. Res.* **38** (6), 2014, 1935–1953.

Salvati L., Munafò M., Morelli V.G. and Sabbi A., Low density settlements and land use changes in a Mediterranean urban region, ~~*Landscape and Urban Planning*~~*Landsc. Urban Plan.* **105** (1~~-~~–2), 2012, 43–52.

Sarzynski A., Galster G. and Stack L., Typologies of sprawl: investigating United States metropolitan land use patterns, *Urban Geogr.* **35** (1), 2014, 48–70.

Saunders P., Social Theory and the Urban Question, 2003, Routledge; London.

Schneider A. and Woodcock C.E., Compact, dispersed, fragmented, extensive? A comparison of urban growth in twenty-five global cities using remotely sensed data, pattern metrics and census information, ~~*Urban Studies*~~*Urban Stud.* **45** (3), 2008, 659–692.

Scott J.W. and Kühn M., Urban change and urban development strategies in Central East Europe: ~~A~~a selective assessment of events since 1989, ~~*European Planning Studies*~~*Eur. Plan. Stud.* **20** (7), 2012, 1093–1109.

Sinclair R., Von Thunen and urban sprawl, *Ann. Assoc. Am. Geogr.* **57**, 1967, 72–87.

Terzi F. and Bolen F., Urban sprawl measurement of Istanbul, ~~*European Planning Studies*~~*Eur. Plan. Stud.* **17** (10), 2009, 1559–1570.

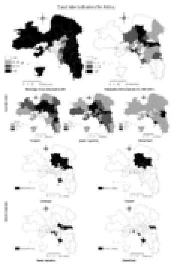
Turner B.L., Lambin E.F. and Reenberg A., The emergence of land change science for global environmental change and sustainability, ~~*Proceedings of the National Academy of Sciences*~~*Proc. Natl. Acad. Sci.* **104** (52), 2007, 20666–20671.

Turner M.A., Landscape preferences and patterns of residential development, ~~*Journal of Urban Economics*~~*J. Urban Econ.* **57** (1), 2005, 19–54.

Turok I. and Mykhnenko V., The trajectories of European cities, 1960~~-~~–2005, *Cities* **24**, 2007, 165–182.

Zhang T., Land market forces and government's role in sprawl: ~~T~~the case of China, *Cities* **17** (2), 2000, 123–135.

Graphical abstract



Highlights

- We investigated land take processes driven by urbanization at the municipal scale in Athens' region.
- We used socioeconomic indicators to assess how the local context may influence land take.
- Urban expansion into fringe land consumes primarily cropland and sparse vegetation.
- Urban planning seems to have no direct impact on selective land take.

Queries and Answers

Query:

Please check the layout of Table 1 if correct, and amend as necessary.

Answer: Put settlement at the line of indicator ADJ below living conditions and delete all the symbols | I found hard to edit in the table, sorry!

Query:

Please check the layout of Table 2 if correct, and amend as necessary.

Answer: fine to me

Query:

Your article is registered as a regular item and is being processed for inclusion in a regular issue of the journal. If this is NOT correct and your article belongs to a Special Issue/Collection please contact a.louis@elsevier.com immediately prior to returning your corrections.

Answer: fine to me

Query:

The author names have been tagged as given names and surnames (surnames are highlighted in teal color). Please confirm if they have been identified correctly.

Answer: Affiliation of Adele Sateriano is the same of Luca Salvati. Both (Adele Sateriano + Luca Salvati) should be corrected to: Council for Agricultural Research and Economics (CREA), Via della Navicella 2-4, I-00184 Rome, Italy

Query:

Please check the presentation of the authors' affiliations if correct, and amend as necessary.

Answer: Affiliation of Andrea Colantoni please insert in the address Via San Camillo de Lellis, I-01100 Viterbo, Italy

Query:

"Couch et al. (2007)" is cited in text but not given in the reference list. Please provide details in the list or delete the citation from the text.

Answer: Couch C., Petschel-held G., Leontidou L. (2007). Urban sprawl in Europe: landscapes, land-use change and policy. Blackwell, London.

Query:

"Allredge et al., 1998" has been changed to match the author name/date in the reference list. Please check here and in subsequent occurrences, and correct if necessary.

Answer: fine with me

Query:

"Salvati et al., 2014" is cited in text but not given in the reference list. Please provide details in the list or delete the citation from the text.

Answer: replace with Salvati (2014).

elsevier_STOTEN_18841

Query:

"Bond and Keely, 2005" has been changed to match the author name/date in the reference list. Please check here and in subsequent occurrences, and correct if necessary.

Answer: fine to me

Query:

Would it be appropriate to modify "Keiser" to "Kaiser"? Please check, and amend as necessary.

Answer: kaiser would be fine, please modify it

Query:

"Salvati and Sabbi, 2011" is cited in text but not given in the reference list. Please provide details in the list or delete the citation from the text.

Answer: please delete it

Query:

This sentence has been slightly modified. Please check and confirm if the meaning is still correct.

Answer: fine to me

Query:

"Catalàn et al., 2008" has been changed to match the author name/date in the reference list. Please check here and in subsequent occurrences, and correct if necessary.

Answer: fine to me

Query:

"Catalàn et al., 2008" has been changed to match the author name/date in the reference list. Please check here and in subsequent occurrences, and correct if necessary.

Answer: fine to me