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Impacts of urbanization around Mediterranean cities: Changes in ecosystem service supply

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ABSTRACT

Urbanization is an important driver of changes in land cover in the Mediterranean Basin and it is likely to impact the supply and demand of ecosystem services (ES). The most significant land cover changes occur in the peri-urban zone, but little is known about how these changes affect the ES supply. For eight European and four North African cities, we have quantified changes in peri-urban land cover, for periods of sixteen years (1990–2006) in the Northern African, and twenty-two years (1990–2012) in the European cities, respectively. Using an expert-based method, we derived quantitative estimates of the dynamics in the supply of twenty-seven ES. The nature of land cover changes slightly differed between European and North African Mediterranean cities, but overall it increased in urban areas and decreased in agricultural land. The capacity of the peri-urban areas of Mediterranean cities to supply ES generally reduced over the last 20–30 years. For nine ES the potential supply actually increased for all four North African cities and three out of the eight European cities. Across all cities, the ES timber, wood fuel and religious and spiritual experience increased.

Given the expected increase of urban population in the Mediterranean Basin and the current knowledge of ES deficits in urban areas, the overall decrease in ES supply capacity of peri-urban areas is a risk for human well-being in the Mediterranean and poses a serious challenge for the Sustainable Development Goals in the Mediterranean basin.

1. Introduction

Approximately two thirds of the world's population (i.e., 6,4 billion people for the median projection) and 84% in Europe will be living in urban areas by 2050. In 2014 already more than half of the global population was urban, while in Europe this was 70% (Kabisch and Haase, 2011; United Nations, 2015a, 2014). The increase in total population entails a corresponding increase in demand for natural resources (MA, 2005), particularly for energy and water. The demand for water is expected to increase with 55% between 2000 and 2050 (United Nations World Water Assessment Programme, 2014). The effect of urban population growth on peri-urban landscapes is expected to be particularly prominent since urban land cover increases even faster than could be expected from demographic pressure, resulting in substantial land use conversions (Angel et al., 2011; Seto et al., 2013, 2012, 2011).

Urban populations in countries around the Mediterranean Sea increased from 152 million to 315 million between 1970 and 2010 (an average rate of 1.9 % per year) (UNEP/MAP, 2012). By 2030, the Mediterranean Basin will be the global biodiversity hotspot with the highest percentage of urban land (5%) (Elmqvist et al., 2013). Urbanization rates have been accelerated by environmental change; for example, intense drought conditions contributed to a rural exodus in Morocco between 1980 and 1990, and in Algeria and Tunisia in 1999 (FAO, 2001; Hervieu and Thibault, 2009). Tourism and housing development have led to the development of infrastructure close to coastal areas and near culturally important cities (EEA, 2011; Houimli, 2008). Mediterranean cities are considered attractive places to settle for

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retirees from northern Europe (Membrado-Tena, 2015), and for return migrants to the Maghreb countries (Cassarino, 2008).

The growth of urban areas often takes place at the expense of agricultural land and this can potentially lead to environmental degradation and socio-economic challenges (Orgiazzi et al., 2016). Although probably the most studied, the direct conversion of agricultural land into urban land is only one of the many impacts of urbanization on the structure and function of ecosystems and their services (McDonnell and Hahs, 2008; Modica et al., 2012). Examples of other impacts of urbanization include changes in demand patterns (Bennett et al., 2015; García-Nieto et al., 2013; Schulp et al., 2014), or the infrastructure construction for water distribution facilities, energy plants and internet connection (Kasanko et al., 2006; Seto et al., 2012), agricultural land abandonment (Hasse and Lathrop, 2003; Hervieu and Thibault, 2009) or the protection of traditional landscapes with the aim to maintain the aesthetic quality (Baró et al., 2016). Urbanization may also affect the diversity of the landscape, with agricultural land being managed by hobby farmers rather than for commercial production (Jarosz, 2008; Zasada, 2011).

As these examples show, the influence of urban areas on ecosystems extends well beyond the urban boundaries (Lead et al., 2005), but it is unclear how the changes in the peri-urban landscapes affect human well-being. A growing number of studies of human well-being and quality of life in urban areas focus on the benefits provided by natural elements within cities, so called urban ecosystem services (Bolund and Hunhammar, 1999; Kremer et al., 2016). Many of these studies have found that the natural elements currently present in cities often do not seem to provide ecosystem services (ES) in sufficient quantities in comparison to the demand for these services (Folke et al., 1997; Jansson, 2013). Baró et al. (2015) have recently shown mismatches between ES in supply and demand for five European cities. These mismatches may depend on many factors, e.g. differences in spatial distribution of goods and needs or access restrictions to resources for particular groups, such as women (Geijzendorffer et al., 2015). Some of these factors can be addressed through governance or land use management (Jansson, 2013). Potentially, land cover changes around cities affect ES supply, and these changes may therefore potentially reduce or enhance deficits for ES within cities.

The objective of this study is to assess how growing urban areas in the Mediterranean Basin modify the peri-urban landscapes and, consequently, ES supply. With the current urban population being expected to increase to 385 million people by 2025 (UNEP/MAP, 2012) and the objective of improved human well-being of the Sustainable Development Goals (United Nations, 2015b), an increase of ES is required for this growing urban population. Therefore, there is a particular need to assess the recent dynamics in ES supply, both within cities and in their peri-urban areas. The European Mediterranean areas are estimated to be particularly vulnerable with respect to ES supply, mostly due to climate and land use change (Schröter et al., 2005). Although similar studies for the north-African Mediterranean countries are missing (Nieto-Romero et al., 2014), it is highly likely that these countries are subject to similar, if not higher, anthropogenic pressures, experience more rapid population increases and are undergoing significant landscape changes. The importance of this knowledge gap goes beyond its implications for regional assessments, by additionally increasing the uncertainty of supra-regional assessments of sustainable futures.

The need to evaluate land use and land cover changes and their impacts for future conditions is increasingly being recognized (EEA, 2011; Fichera et al., 2016). To inform land management improvements, land use - land cover assessments should take into account spatial and temporal patterns along urban-rural gradients (Kroll et al., 2012). Previous land use - land cover assessments in the Mediterranean have focused on areas where spatial data was available and, as a consequence, the north-African region has received little attention (Haase et al., 2014; Luederitz et al., 2015). Also, most studies to date focus on single city case studies and are limited to the dense urban fabric. A multi-city analysis therefore fills an important knowledge gap by allowing for a comparison of the impacts of urbanization in peri-urban land and its consequences for ES supply in the Mediterranean Basin. For this study we selected both European and north-African Mediterranean cities: eight Mediterranean European cities (Lisbon, Madrid, Barcelona, Marseille, Florence, Rome, Athens, Thessaloniki) and four Northern African cities (Nabeul, Sfax, Tunis, Rabat).

2. Material and methods

For this study, we analyzed: 1) whether land cover changes around cities differed significantly from trends at national level; 2) whether different specific conversions of land cover are common for groups of cities occurred over time and finally 3) whether the spatio-temporal supply patterns of ES over the period 1990 – 2012 were shared among these Mediterranean cities, depending on data availability.

The assessment was carried out in six steps. First, we selected twelve major Mediterranean cities as case studies. We used a systematic approach to define the peri-urban area for each city. Based on time series of available land cover maps (Fig. 1), we assessed land cover changes in each peri-urban area and we compared them with national dynamics per country. In addition, we identified the main patterns in land cover changes across all peri-urban areas. Finally, we identified changes in land cover with expert based estimates of ES supply (Stoll et al., 2015) and searched for specific or general dynamics in ES supply.

Data were available for the period 1990–2006 for Northern African cities, and for 1990–2012 for European cities (Table 1). These periods allowed for the analysis of important dynamics and they correspond to the used expert-based ES estimates (see below).

2.1. Selection of Mediterranean cities

In the selection of cities we aimed to achieve a geographical distribution in the Mediterranean biogeographical region (Olson et al., 2001) (Fig. 2), with a special attention to include both cities on northern and southern Mediterranean shores. An additional search criterion was that land cover data should be available on at least two moments in time. These criteria allowed for the selection of twelve cities in total, four in Northern Africa (Nabeul, Sfax, Tunis, Rabat) and eight in Southern Europe (Lisbon, Madrid, Barcelona, Marseille, Florence, Rome, Athens, Thessaloniki).

Spatial land cover data is available for the entire Mediterranean basin, but the categories, spatial resolution and time series differ (Fig. 1). CORINE Land Cover (CLC) (Feranec et al., 2016) is a spatial database with a resolution of 100 m and it is available for all European countries for the years 1990, 2000, 2006 and 2012 (Table 1). For the North African countries, CLC is available only for 1990. We used GlobCorine Land Cover (GLC) (Bontemps et al., 2009) to include another point in time (2006) for these countries. The GLC land cover map was developed by the European Environmental Agency and European Space Agency attempting to ensure compatibility with CLC (Appendix 1).

2.2. Defining the peri-urban areas

There are many different approaches to define the urban and peri-urban areas of a city (Orgiazzi et al., 2016). For our study we searched for a simple, yet objective delineation of the urban areas that could be adapted to include peri-urban areas. We defined the peri-urban area as the rural area located in proximity around the urban area. In addition, the delineation method should be able to deal with the differences in data resolutions between the European countries and the north-African Mediterranean countries. The approach published by (Kasanko et al., 2006) assumes a fixed relationship to estimate the boundary of the urban area, separating it into the urban core area (A) and the adjacent urban area (W_u) ($W_u = 0.25\sqrt{A}$). For our study, we used this method to additionally define the peri-urban areas (Wp). To parameterize the equation of Kasanko et al. (2006) for the boundary of the peri-urban area (W_p), we used the peri-urban estimate published by Kroll et al. (2012), obtaining a general equation for peri-urban areas: $W_p = 1.5\sqrt{A}$ (see Fig. 3). By using these criteria, the width of the adjacent urban area and the peri-urban area are assumed to depend only on the area of the urban core in each city. Table 2 shows the resulting urban