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.

Keywords

Land cover; population; urban; rural; spatial analysis; trend; nature's contributions to people.

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The manuscript contains 9 Figures, 3 Tables, 65 References and 7 online appendices.

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 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).

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2.1. <u>Selection of Mediterranean cities</u>

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).

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2.2. <u>Defining the peri-urban areas</u>

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 core areas and the corresponding W_u and W_p areas for 2006.

The urban core area (A) was computed for the Mediterranean cities using the urban land cover determined by CLC and GLC using 2006 as reference time period. In the case of CLC, from the 44 land cover classes (Appendix 2), we selected the polygons belonging to *continuous* and *discontinuous urban fabric (*categories 111 and 112) whose centroid was inside the administrative boundary of the city. From the fourteen land cover classes of GLC (Appendix 1), class 10 (*urban and associated areas*) was used to determine the urban core area. In a second step, we repeated this process including those polygons whose centroid was within a radius of 1 km from the selected urban polygons, to calculate the final size and location of urban core area (A).

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2.3. Identification of land cover changes

Focusing the analysis on the peri-urban area (W_p), we identified land cover changes from 1990 to 2012 for the European cities and from 1990 to 2006 for Northern African cities. Spatial land cover data was extracted for the different time periods in each city and its belonging country, considering the Mediterranean biogeographical region boundaries (Olson et al., 2001). The land cover data (area by land cover category) for each year in each W_p area was normalized using the size of each peri-urban area, to be comparable across the different case studies. The same normalization was made for each country based on the proportion of that country classified as Mediterranean. In the remainder of this text we will refer to this area as the “national area”. The spatial information was analyzed using ArcGIS 10.2.2 (ESRI, 2013).

To allow for the comparison between land cover categories from CLC (1990) and GLC (2006) in North Africa, we developed weighing factors using Andalusia and Sicily as most closely representative sampling sites for the Northern African Mediterranean setting. The spatial information of CLC and GLC in 2006 was intersected and extracted to measure the contributions of each CLC category in each GLC class. To transform the spatial GLC information of North African cities into information on each of the 44 CLC classes, we defined X_x as the area of a specific GLC category and computed weighing factors (W_x) based on how the GLC categories in Andalusia and Sicily were composed of the different CLC categories. We applied these weighing factors in all calculations on North African areas to transform all GLC data into CLC data to allow for multiplication with the Stoll capacity matrix. This means that the surface of each CLC category (Y_x) is equal to a multiplication of the surface (km^2) for each GLC category (X_x) by weighing factors (W_x) (Equation 1).

Equation 1: $$Y_x = X_1 \cdot W_1 + X_2 \cdot W_2 + \ldots + X_n \cdot W_n$$

For the statistical analysis, the CLC categories were summarized in 7 different CLC groups (Table 3). To obtain the urbanization trends in Mediterranean cities, we estimated the total standardized surface by CLC group coming from W_p and compared it with the total standardized land cover from the respective Mediterranean parts of countries (Portugal, Spain, France, Italy and Greece; Tunisia and Morocco) over the different periods.

Assessments for Europe and North Africa follow the same methods, but were applied separately because the uncertainties and applied methods for the input data are different.

2.4. Conversion of land cover changes into ecosystem services supply dynamics

Following an approach developed by Burkhard et al. (2009, 2012), we related land cover data to expert-based values of the capacity for ES supply. In a recent study, Stoll et al. (2015) developed an ES supply capacity matrix based on CLC types combined with expert-based estimates of the supply capacity for thirty-one ES for European countries. Capacity estimates for ES supply range from 0 (no relevant capacity of the land cover type to provide this particular ecosystem service) to 5 (very high capacity).

To assess how land cover changes around the case study cities influence ecosystem service supply over time, we translated our land cover changes into ES dynamics using the ES supply matrix published by Stoll et al. (2015). Estimates for each ES (ES_x) at different time periods in every peri-urban area were calculated by multiplying the area of each CLC class (X_x) by the corresponding ES value from ES matrix ($ESstoll_{xn}$) (Equation 2). The resulting ES assessment included twenty-seven ES supplied by peri-urban landscapes.

Equation 2: $ES_x = X_1 \cdot ESstoll_{x1} + X_2 \cdot ESstoll_{x2} + \ldots + X_n \cdot ESstoll_{xn}$

2.5. Statistical analysis

The chosen statistics in this study responded to type of variables, sampling distribution and scientific objectives: 1) analysis of land cover changes around cities and comparison with trends at national level; 2) identification of common specific conversions of land cover among cities over time; and 3) assessment of spatio-temporal supply patterns of ecosystem services over the period 1990 – 2012 in Mediterranean peri-urban areas.

For each objective, a group of statistical analysis was conducted. To assess whether land cover change patterns around cities differ from trends at the national level, the standardized total surface of land cover groups was statistically compared over time. For this purpose, we selected the non-parametric Wilcoxon test and the parametric Two-sample t-test. According to sampling distribution of CLC and paired groups, non-parametric Wilcoxon test was suitable for the case of permanent crops, complex cultivation patterns and shrub and/or herbaceous. Based on the assumptions of normal sampling distribution and paired groups, the parametric Two-sample t-test was conducted for urban, non-irrigated and irrigated arable land, and forest land cover groups.

Multivariate analyses were conducted to identify land cover changes over time and to detect spatio-temporal trends in ES supply around Mediterranean cities. Variables included land cover data for European cities (for the years 1990, 2000, 2006 and 2012, see Appendix 3) and data for North African cities (for 1990 and 2006, see Appendix 4). The data for the European cities was assessed using Within-class Correspondence Analysis (WCA) (Benzécri, 1983; Chessel et al., 2003) through the "within.coa function" in the R package ade4 (RStudio, 2012). Data for the European and North-African cities was analyzed separately due to the differences in the input data (as discussed in section 2.3). Changes on ES supply in peri-urban areas over time were estimated conducting a Within-class Principal Component Analysis (WCP) (Benzécri, 1983; Chessel et al., 2003), evaluating separately ES estimates for European and North African peri-urban areas (see Appendix 5 and 6).

WCA and WCP are similar to standard Correspondence Analysis with a single constraining factor to remove (Chessel et al., 2003). As strong differences between cities may mask patterns over time, we used this analysis to compare spatio-temporal variations of land cover distributions and ES supply removing alternatively the effect of the city and the year variables as constraining factors.

3. Results

3.1. Land cover change under urbanization

Common patterns emerge for all selected Mediterranean cities when we compared land cover patterns over time between the selected Mediterranean cities and the trends in the respective countries (Fig. 4A and 4B). Overall, changes were more pronounced in the peri-urban areas than at national level. As expected, all peri-urban areas demonstrated a significant increase of urban fabric. Around the European cities this took place mostly at the expense of complex cultivation patterns, non-irrigated and irrigated arable land, and shrub and/or herbaceous and pastures from 1990 to 2012. The parametric two-sample t-test revealed significant differences over the time between peri-urban areas from selected cities and countries in Europe in the case of urban, non-irrigated and irrigated arable land, and forest (p-value = 0.05) (Fig. 4A).

In the North African peri-urban areas, the increase of urban area from 1990 to 2006 occurred in parallel with an increase in irrigated arable land, permanent crops, complex cultivation patterns and shrublands and/or herbaceous and pastures, at the expense of non-irrigated arable land and forest, both around in peri-urban areas as well as at the national level (Fig. 4B).

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3.2. Mediterranean peri-urban areas, spatio-temporal dynamics in land cover

Within-class Correspondence Analyses (WCA) were performed separately to assess how land cover changes differed over time in peri-urban areas of Mediterranean European cities (from 1990 to 2012) and in peri-urban areas of Northern African cities (from 1990 to 2006) (Appendix 7). Results from European cities (where city as a variable was removed) showed that 4.56% of the variation was due to time patterns in land use; whereas when WCA was based on the time period or year (enhancing the differences between cities) 97.87% of the variation was due to the difference between cities and peri-urban land uses. This means that the differences of surrounding land use between cities are a dominant pattern that masks common trends if it is not removed beforehand.

In the case of European cities (Fig. 5A), different dynamics of land cover change over time occurred in the peri-urban areas. A clear pattern of change from non-irrigated arable land in 1990 (negative scores of F1) to urban in 2012 (positive scores of F1) was identified in Madrid and Thessaloniki. Barcelona, Lisbon and Athens showed transitions of complex cultivation patterns, shrublands and pastures (negative scores of F2) to forest (in positive scores of F2) in 1990, and to urban in 2012 (in positive scores of F1). Peri-urban areas of Marseille and Florence were characterized by a transition from irrigated arable land (negative scores of F1) towards urban. Land cover change patterns in the peri-urban area of Rome are less pronounced, but mostly correspond to permanent crops, shrublands and pastures in 1990 transforming into urban land in 2012. In conclusion, for European cities the temporal gradient was dominated by an increase of urban areas and marginal changes in agricultural land uses.

Results from WCA in North African cities (where city as a variable was removed) showed that 62.86% of the variation was due to temporal patterns in land use; whereas when removing year variable 82.18% of variation is due to differences between cities and land uses.

North African peri-urban areas (Fig. 5B) in 1990 were characterized by a clear pattern from non-irrigated arable land and forest patterns (in negative scores of F1) to an increase in 2006 of urban land, shrubs and herbaceous associated vegetation and pastures (in positive scores of F2). Peri-urban areas of Sfax showed transitions of permanent crops (in positive scores of F1) to urban land, shrubs and herbaceous associated vegetation and pastures (in positive scores of F2) also, with an increase of irrigated arable land.

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3.3. <u>Ecosystem services supply: spatio-temporal patterns</u>

The supply of ESs (Appendix 5 and 6) was estimated through multivariate within-class Principal Component Analysis (WCP), considering European and North African cities over the indicated periods respectively.

Trends in ES supply differed between EU cities (Fig. 6). The first component was characterized by a gradient in ES supply, from the highest (in negative scores of F1) to lowest ES values (in positive scores of F1) for all services. This indicates a general trend of reducing ES supply capacity from 1990 to 2012 in peri-urban areas. The second axis is related to the contrast between two groups of services that are important for two different beneficiary groups. First, there is a group of ES relevant for farmers i.e. provisioning (fiber, livestock, crops, energy biomass, fodder, freshwater), regulating (water flow regulation, pest and disease control, local climate regulation), and cultural (knowledge systems and cultural heritage and cultural diversity) (in positive scores of F2). Second, there is a group of ES relevant for forest users i.e. provisioning (wild food, biochemicals and medicine, wood fuel, timber), regulating (erosion regulation, nutrient regulation, air quality regulation, global climate regulation) and cultural ES (recreation and tourism, natural heritage and natural diversity) (in negative scores of F2). All peri-urban areas from European cities followed this pattern, with the exception of Rome where ES supply capacity remained stable over time.

- Insert Fig. 6 around here -

The ES supply trends for North African cities changed from 1990 to 2006. Figure 7 shows the increase in the supply of provisioning (fodder, energy biomass, biochemicals and medicine, wild food), and regulating ES in 1990 (natural hazard protection, local climate regulation, water purification, nutrient purification) (in negative scores of F1). Whereas in 2006 the pattern changed to ES supply, i.e. provisioning (livestock, freshwater) and regulating (pollination, erosion regulation and water flow regulation) (positive scores of F1). The second axis indicates an opposition between the supply of cultural (cultural heritage and cultural diversity) and provisioning ES (i.e. wood fuel and timber) in Nabeul, Rabat and Tunis (negative scores F2). In the peri-urban areas of Sfax the opposition of ES occurs between cultural ES and regulating (pollination, water flow regulation) and provisioning (livestock, freshwater) (positive scores F2).

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All Mediterranean peri-urban areas show increases in the supply of air quality regulation, timber, wood fuel and religious and spiritual experience (Fig. 8). The European peri-urban areas show small or negative trends for the other ES. North-African peri-urban areas show much larger changes than those found in the European peri-urban areas, but this is maybe caused by the differences between CLC and GLC data. In general, the North-African peri-urban area showed stronger increases of ES supply capacities than the European peri-urban areas. In addition to the previously mentioned ES, the supply capacity of pollination, livestock, religious and cultural heritage increased in North-African peri-urban areas.

Peri-urban areas do not show the same patterns for ES supply over time (Fig. 9). In some peri-urban areas the supply of regulating and cultural ES was more important than for the provisioning ES (Lisbon, Barcelona, Marseille, Florence, Athens and Sfax) or the inverse in the case of Thessaloniki. In other cases, the supply of regulating ES was more important than provisioning and cultural ES (Madrid and Rome). Cultural ES increased around Nabeul, Rabat and Tunis.

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4. Discussion

4.1. Changes in land cover

Land cover changes in European Mediterranean peri-urban areas showed an expansion of urban and forested areas at the expense of agriculture land similar to described by d'Amour et al. (2016) and Depietri et al. (2016). Especially irrigated (Marseille and Florence) and non-irrigated arable land (Madrid and Thessaloniki) were reduced. Around Barcelona, Lisbon and Athens, complex cultivation patterns, shrublands and pastures were more abandoned. In Rome's peri-urban areas where the urban area increased less, general land cover change patterns are also less pronounced.

Peri-urban areas of all North African cities, showed the same general pattern of increases in urban land, but instead this coincided with increases of agricultural land, herbaceous associated vegetation and pastures while irrigated agriculture and forest areas were reduced for Rabat, Nabeul and Tunis. In the peri-urban area of Sfax the area of irrigated arable land increased, while complex cultivation systems reduced in area. This expansion of both urban areas as well as agricultural areas in North Africa had been observed earlier (Bouraoui, 2001).

Previous European focused studies demonstrated an expansion of woodlands in abandoned and marginal agricultural land (EEA, 2002; Zanchi, et al., 2007). Indeed, our results showed an increase in forest and shrublands for Europe at both peri-urban and national level. For the North African cities and countries, however, it is particularly shrublands which increased while the forest area showed a relatively slight decline.

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4.2. Implications of ES trends in peri-urban areas

The Mediterranean basin has some serious challenges to advance on global Sustainable Development Goals (UNEP/MAP, 2016), to which the ES supplied by peri-urban areas could positively contribute. In general, the ES supply capacity of peri-urban Mediterranean areas decreased over time, in particular for the supply of provisioning and regulating ES. If we consider the ES that are of most immediate concern for ensuring human well-being, i.e. supply of food, water and protection from hazards, then European and north-African peri-urban regions showed decreasing supply trends for the supply of food and protection from hazards. Supply of freshwater in Europe remains constant, but north-African peri-urban areas showed an increased supply of freshwater. This is linked to a growing surface of continental water bodies, since several dams and reservoirs have been built to address issues related to water scarcity and strong interannual variability of precipitation (Tramblay et al., 2016). However, as the ES of water purification decreased (Fig 8), we may have to be cautious as to the use of this water for all purposes.

Total area for crop production decreased over time in peri-urban areas, but this does not necessarily mean that the total food production also decreased. Changes in farm management may have increased the productivity of remaining agricultural land. Also, since these Mediterranean cities already rely heavily on food imports (Lead et al., 2005; Soulard et al., 2017), a reduction in locally produced food is likely not to lead immediately to a food deficit. However, an increased dependence on global food market prices does render countries more vulnerable to potential food crises.

Urbanization often implies the expansion of impermeable surfaces leading to an increase of surface water runoff, and consequently an increased risk of flooding (Gómez-Baggethun et al., 2013). Our results show that the regulation of natural hazards has been decreasing over the years in Mediterranean peri-urban areas which pose a particular threat to people living around urban and peri-urban areas.

Depending on whether the supply of ES needs to be local in order to provide benefits, the peri-urban area can supply ES in the urban area. Recent studies on ES mismatches between supply and demand in urban areas have predominantly indicated deficits in local climate regulation (carbon sequestration, urban cooling), air quality regulation, and recreation and nature tourism (Baró et al., 2016, 2015). Of these deficits, peri-urban land could provide air quality regulation to reducing the deficit in the future. Although urban areas represent relatively small areas at a global scale, their increase could negatively impact local climate (Foley et al., 2005; Verburg et al., 2011). Our results indicate that Mediterranean peri-urban capacity to supply climate regulation has been decreasing. The steady trend or the increase of potential supply of some cultural ES by peri-urban areas (religious and spiritual experience) was not considered in previous assessment on ES around the Mediterranean, (Nieto-Romero et al., 2014; Runting et al., 2017) and this study offers therefore, a first reflection on its trends.

There are ES supplied by the peri-urban areas which may not actually reach inhabitants of urban areas, for instance trees only provide shade locally. We can assume however, that for other ES for which distances are less relevant (e.g. global climate regulation) or for which people are likely to travel short distances (e.g. recreation and nature tourism), ES supply by peri-urban areas can be considered relevant for urban areas. For instance, the increased potential of cultural ES in peri-urban areas that we found (due to predominantly an increase in the non-irrigated agricultural and forest areas) is increasingly relevant for people seeking to spend their leisure time outside of urban areas. As the urban population grows, it could be possible that the demand for cultural services, notably in the nearby surroundings of cities, will increase. To determine whether or not the identified increase in supply will be able to meet this presumed increase in demand would need to a more detailed study.

Our use of the capacity matrix developed by Stoll et al. (2015) has several limitations, namely, 1) the capacity matrix was based on expert estimates only reflected the potential ES supply which can be different from the actual supply; 2) land cover information does not incorporate the type of management on arable lands and forest, prohibiting estimations of effects due to changes in land use intensity; 3) the matrix essentially represents a

European perspective on land use and potential ES supply, so a capacity matrix adapted to the Mediterranean biome should be required to obtain more accurate estimates.

Despite those limitations, we consider that our approach allows assessing land cover and ES changing patterns across Mediterranean peri-urban areas based on openly available data, identifying potential influence on ES supply. The multi-city approach used for this study allowed addressing the complexity of landscapes and management around the Mediterranean basin reflected by the different evolution of supplied ES over time. European peri-urban areas evolved from a bundle of ES provided mainly by agro-ecosystems to forest and natural vegetation ecosystems. Meanwhile, North African peri-urban areas supplied a bundle of ES from agro-ecosystems and natural vegetation ecosystems that change tending to rangelands over the years.

A first step to improve the estimates presented in this paper would be to take into account land management and its diversity, which is likely to entail a larger diversity in ES supply trends that can be obtained by focusing on land cover information only. In a second future step, the identified trends in ES supply should be confronted with the trends in demand for ES, to evaluate in a quantified manner how forecasted population increases in cities around the Mediterranean will affect ES deficits.

5. Conclusion

Mediterranean peri-urban areas can play an important role contributing to the supply of some ES to near urban areas (air quality regulation, timber, wood fuel and religious and spiritual experience). However, general trends indicated a decrease of ES supply due to land cover changes in Mediterranean peri-urban areas, induced by nearby urbanization.

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Land cover database	Year	Spatial resolution	Cities	LC categories
Corine Land Cover	1990 2000 2006 2012	100 m	Lisbon (Portugal), Madrid (Spain), Barcelona (Spain), Marseille (France), Florence (Italy), Rome (Italy), Athens (Greece), Thessaloniki (Greece)	44
	1990	250 m	Rabat (Morocco), Tunis (Tunisia), Sfax (Tunisia), Nabeul (Tunisia)	
GlobCorine	2006	300 m		14

Table 1. Land cover data.

	LISBON	MADRID	BARCELONA	MARSEILLE	FLORENCE	ROME	ATHENS	THESSALONIKI	RABAT	TUNIS	SFAX	NABEUL
Urban core (km^2)	103,39	175,20	74,07	104,01	43,50	296,05	163,07	44,77	251,89	427,33	149,85	23,72
Adjacent urban area Wu (km^2)	348,61	431,82	219,95	441,96	145,01	1483,68	452,86	135,46	410,34	790,00	209,41	43,37
Peri-urban area Wp (km^2)	1412	2409,41	1000,45	1849,99	657,24	5031,76	2107,68	640,91	3451,95	5715,11	1884,03	350,25

Table 2. Urban and surrounding areas (km^2)

CLC groups	CLC categories
Urban	111, 112, 121, 122, 123, 124, 131, 132, 133, 141, 142
Non-irrigated arable land	211
Irrigated arable land	212, 213
Permanent crops	221, 222, 223
Complex cultivation patterns	241, 242, 243, 244
Forest	311, 312, 313
Shrubs and/or herbaceous vegetation association and pastures	231, 321, 322, 323, 324

Table 3. CLC categories summarized into CLC groups.

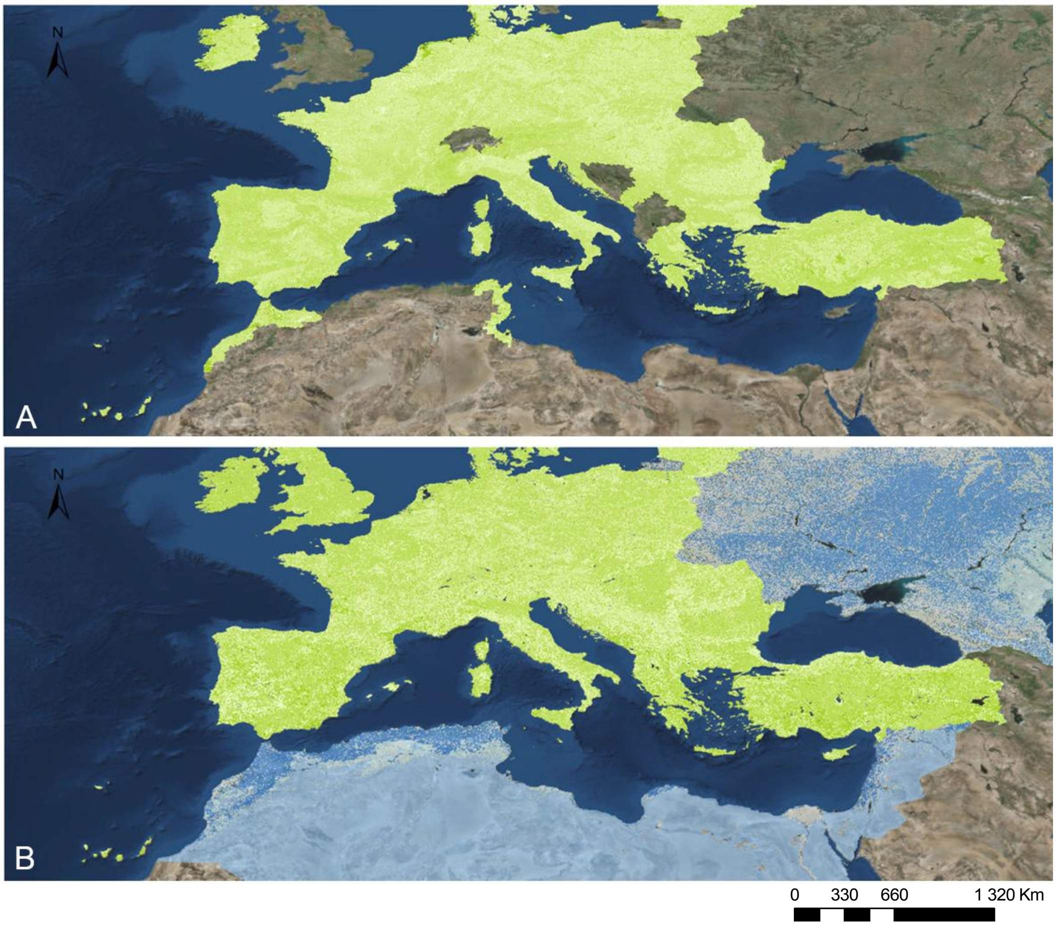


Figure 1. Land cover information. A – Spatial information for 1990 (Corine Land Cover – green colour); B – Spatial information for 2006 (Globcorine – blue colour); spatial information used in 2000, 2006 and 2012 covers only Europe (Corine Land Cover – green colour).

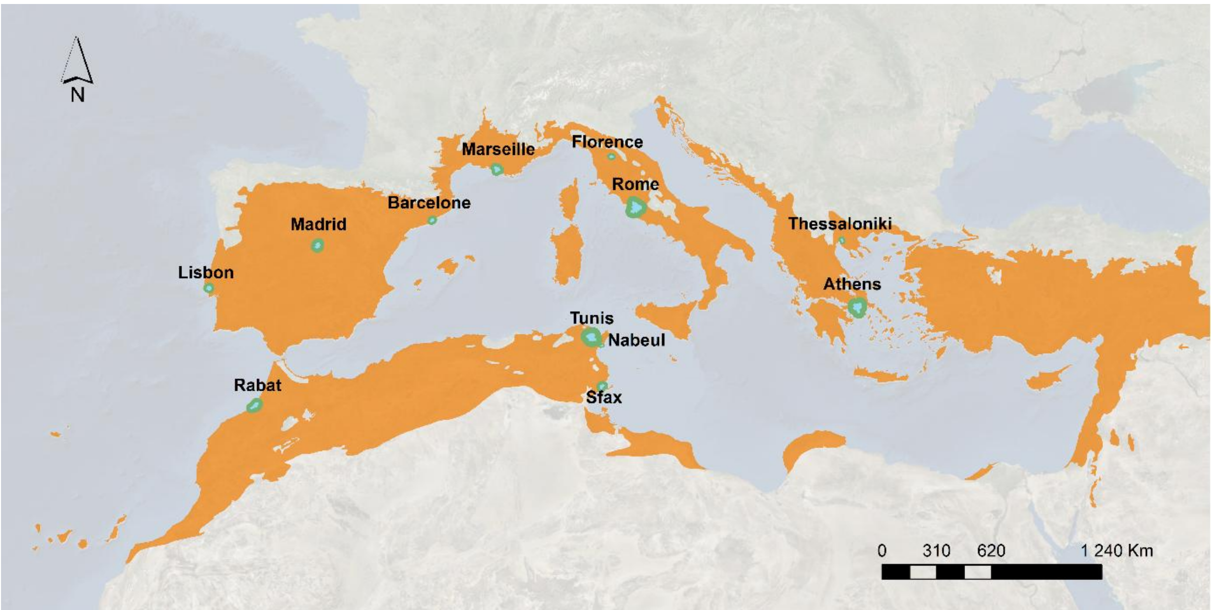


Figure 2. Mediterranean biogeographical region (Olson et al. 2001) and selected study sites.

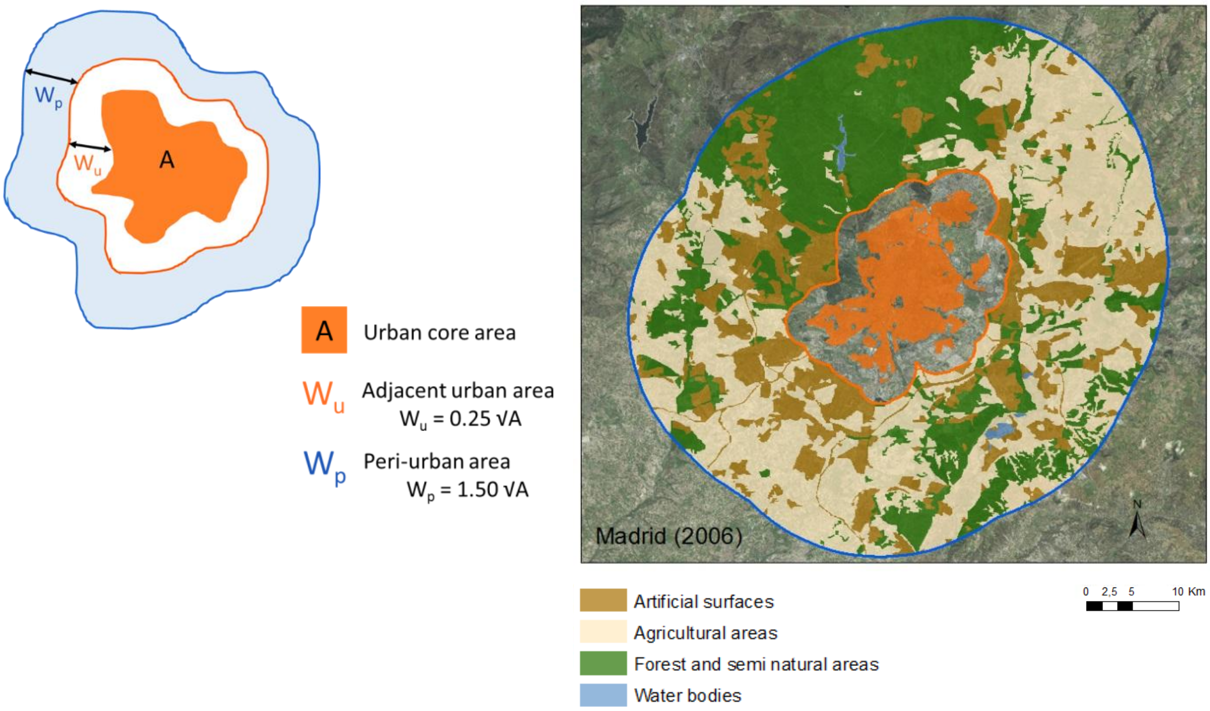
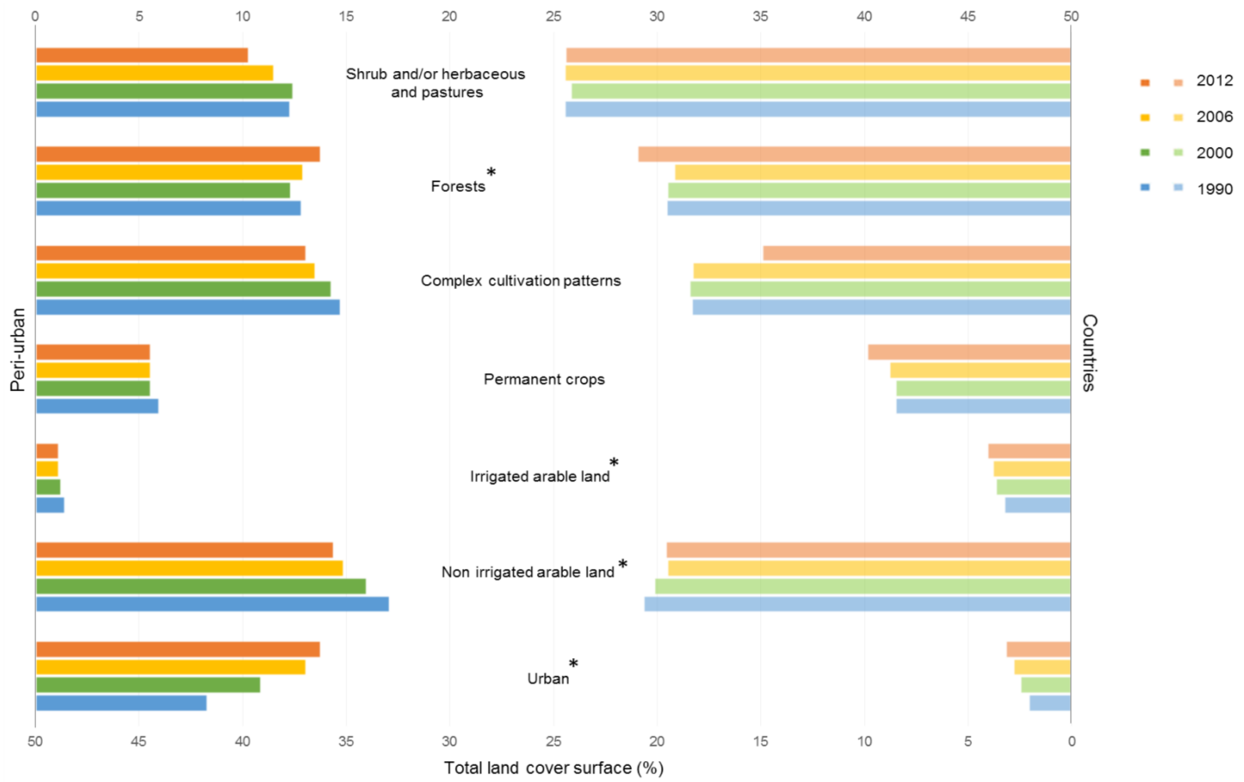


Figure 3. Boundaries definition concept and applied example.

A



B

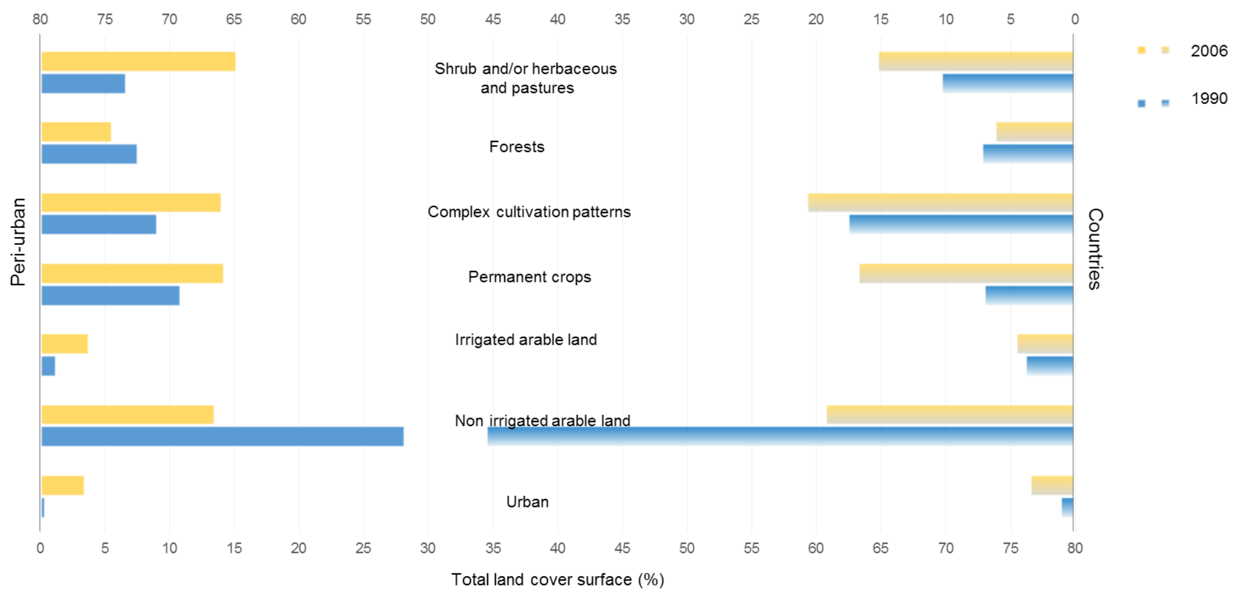


Figure 4. Wilcoxon and Two-sample t-test's results related to standardized total surface of land cover groups over the time comparing: (A) peri-urban areas in European cities and Mediterranean part on European countries (Portugal, Spain, France, Italy, Greece); and (B) peri-urban areas from North African cities and Mediterranean part on North African countries (Morocco and Tunisia). Trends between cities and countries were significantly different at the *5 % level.

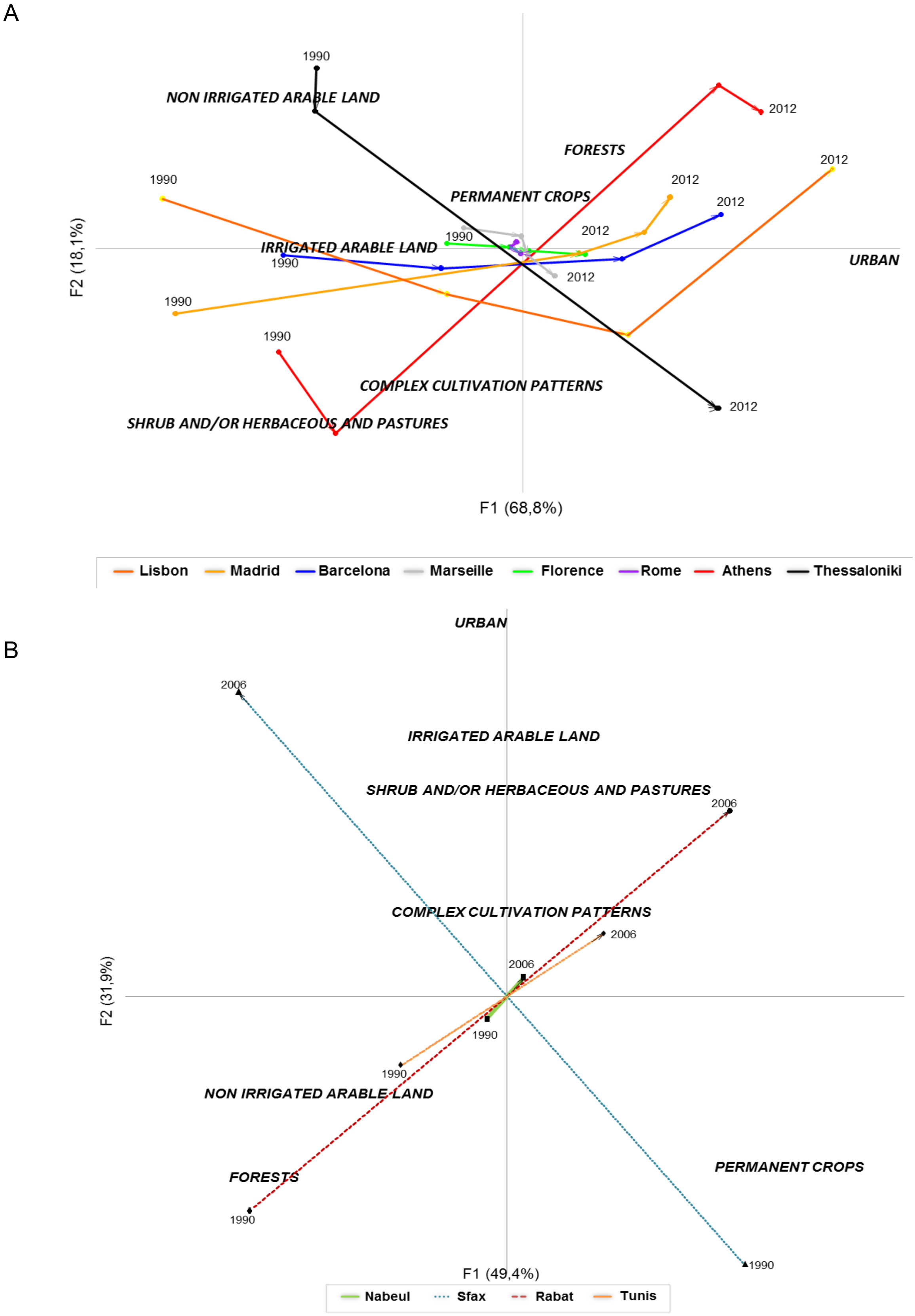


Figure 5. Biplots of the Within-class Correspondence Analysis (WCA) for the land cover groups and their relationship with (A) the European peri-urban areas and (B) Northern African peri-urban areas.

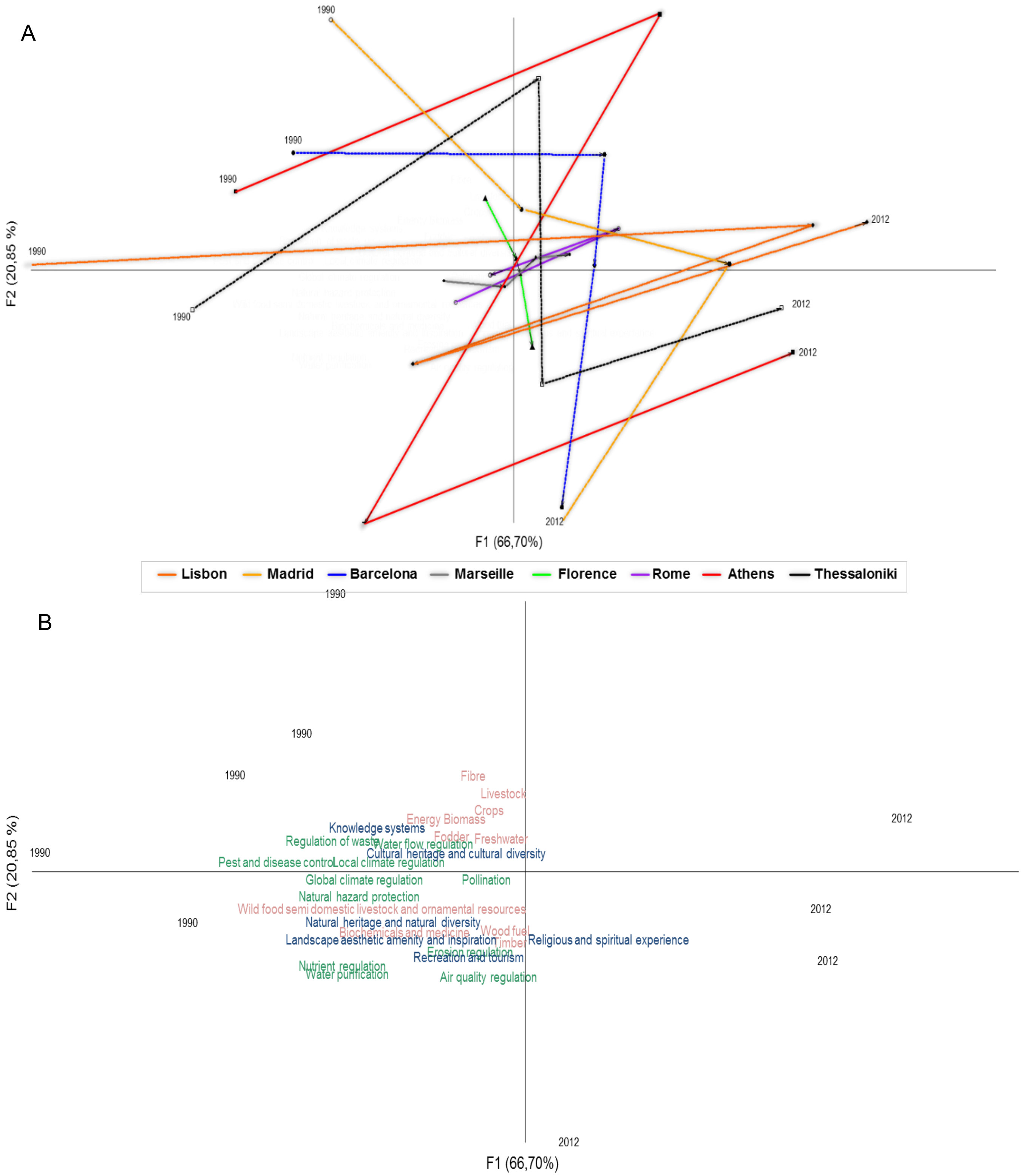


Figure 6. Biplots of Within-class Principal Component Analysis (WCP) for the most statistical significant ecosystem services and their relationship with the European peri-urban areas (i.e., Lisbon, Madrid, Barcelona, Marseille, Florence, Rome, Athens, Thessaloniki). A: variables, B: observations.

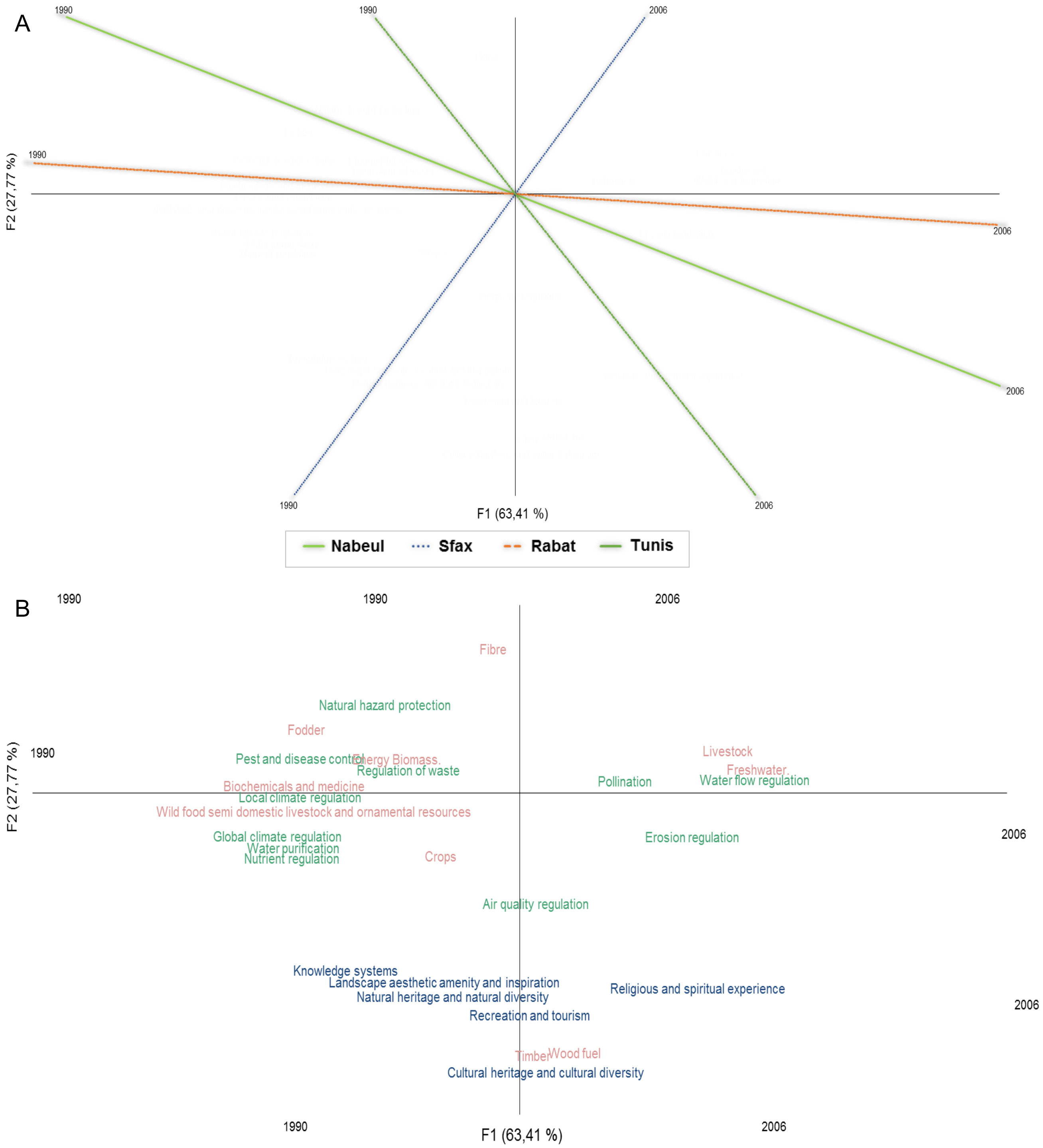


Figure 7. Biplots of the Within-class Principal Component Analysis (WCP) for the most for the most statistical significant ecosystem services and their relationship with the North African peri-urban areas (i.e., Nabeul, Sfax, Rabat, Tunis). A: variables, B: observations

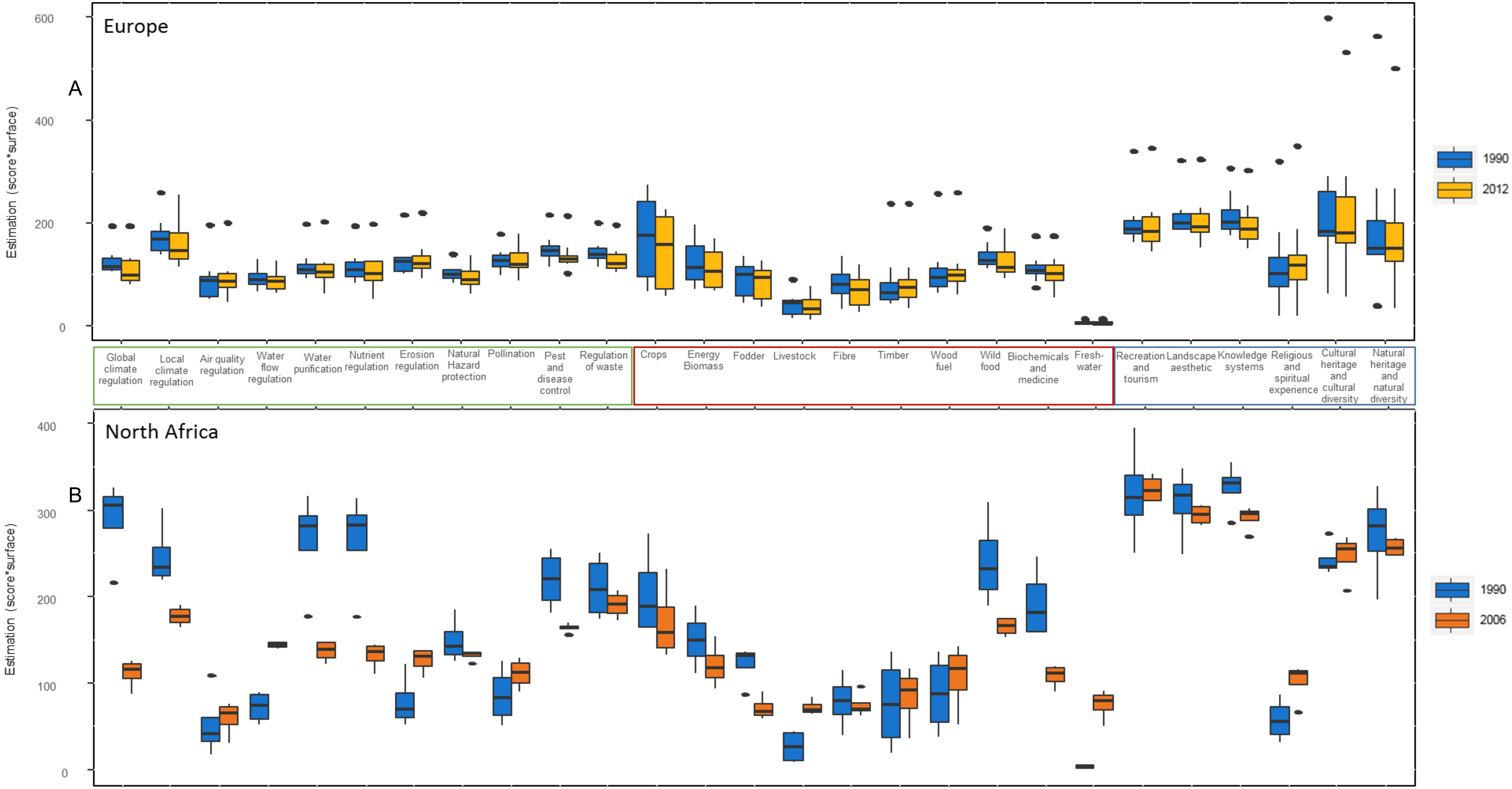


Figure 8. Ecosystem service capacity provision estimations for (A) European (1990 and 2012) and (B) North African (1990 and 2006) peri-urban areas. Units Stoll capacity matrix score * standardized land cover surface (km^2)).

Figure 9. Total ecosystem service capacity provision (by category) estimated for each European (1990 and 2012) and North African (1990 and 2006) peri-urban areas. Units (Stoll capacity matrix score * standardized land cover surface (km^2)).

Appendix 1. Correspondence between the Globcorine and Corine land cover nomenclatures (S. Bontemps et al., 2009)

VALUE	LABEL	CLC CODES (LEVEL 3)	CLC LABELS (LEVEL 3)
10	Urban and associated areas	111	Continuous urban fabric
		112	Discontinuous urban fabric
		121	Industrial or commercial units
		122	Road and rail networks and associated land
		123	Port areas
		124	Airports
		131	Mineral extraction sites
		132	Dump sites
		133	Construction sites
		141	Green urban areas
		142	Sport and leisure facilities
20	Rainfed cropland	211	Non-irrigated arable land
		221	Vineyards
		222	Fruit trees and berry plantations
		223	Olive groves
30	Irrigated cropland	212	Permanently irrigated land
		213	Rice fields
40	Forest	311	Broad-leaved forest
		312	Coniferous forest
		313	Mixed forest
50	Heathland and sclerophyllous vegetation	322	Moors and heathland
		323	Sclerophyllous vegetation
60	Grassland	231	Pastures
		321	Natural grasslands
70	Sparsely vegetated area	333	Sparsely vegetated areas
80	Vegetated low-lying areas on regularly flooded soil	411	Inland marshes
		412	Peat bogs
		421	Salt marshes
		423	Intertidal flats
90	Bare areas	332	Bare rocks
		331	Beaches, dunes, sands
100	Complex cropland	241	Annual crops associated with permanent crops
		242	Complex cultivation patterns
110	Mosaic cropland / natural vegetation	243	Land principally occupied by agriculture, with significant areas of nat. veg.
		244	Agro-forestry areas
120	Mosaic of natural (herbaceous, shrub, tree) vegetation	324	Transitional woodland-shrub
200	Water bodies	511	Water courses
		512	Water bodies
		521	Coastal lagoons
		522	Estuaries
		523	Sea and ocean
210	Permanent snow and ice	335	Glaciers and perpetual snow

Appendix 2. Corine land cover categories in different levels of complexity.

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1 Urban fabric	1.1.1 Continuous urban fabric
		1.1.2 Discontinuous urban fabric
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units
		1.2.2 Road and rail networks and associated land
		1.2.3 Port areas
		1.2.4 Airports
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites
		1.3.2 Dump sites
		1.3.3 Construction sites
	1.4 Artificial, non-agricultural vegetated areas	1.4.1 Green urban areas
		1.4.2 Sport and leisure facilities
2. Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land
		2.1.2 Permanently irrigated land
		2.1.3 Rice fields
	2.2 Permanent crops	2.2.1 Vineyards
		2.2.2 Fruit trees and berry plantations
		2.2.3 Olive groves
	2.3 Pastures	2.3.1 Pastures
	2.4 Heterogeneous agricultural areas	2.4.1 Annual crops associated with permanent crops
		2.4.2 Complex cultivation patterns
		2.4.3 Land principally occupied by agriculture with significant areas of natural vegetation
		2.4.4 Agro-forestry areas
3. Forests and semi-natural areas	3.1 Forests	3.1.1 Broad-leaved forest
		3.1.2 Coniferous forest
		3.1.3 Mixed forest
	3.2 Shrub and/or herbaceous vegetation associations	3.2.1 Natural grassland
		3.2.2 Moors and heathland
		3.2.3 Sclerophyllous vegetation
		3.2.4 Transitional woodland scrub
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sand plains
		3.3.2 Bare rock
		3.3.3 Sparsely vegetated areas
		3.3.4 Burnt areas
		3.3.5 Glaciers and perpetual snow
4. Wetlands	4.1 Inland wetlands	4.1.1 Inland marshes
		4.1.2 Peat bogs
	4.2 Coastal wetlands	4.2.1 Salt marshes
		4.2.2 Salines
		4.2.3 Intertidal flats
5. Water bodies	5.1 Continental waters	5.1.1 Water courses
		5.1.2 Water bodies
	5.2 Marine waters	5.2.1 Coastal lagoons
		5.2.2 Estuaries
		5.2.3 Sea and ocean

Appendix 3. Land cover standardized surface in peri-urban European cities from 1990 to 2012.

STANDARISED SURFACE % (land cover groups)	Year	URBAN	NON-IRRIGATED ARABLE LAND	IRRIGATED ARABLE LAND	PERMANENT CROPS	COMPLEX CULTIVATION PATTERNS	FORESTS	SHRUB AND/OR HERBACEOUS VEGETATION ASOC AND PASTURES	OTHERS CATEGORIES
LISBON	1990	10,739	4,419	0,830	0,129	27,795	7,248	11,590	37,250
	2000	18,272	2,955	0,513	0,889	23,866	5,928	10,585	36,992
	2006	19,499	2,857	0,548	0,865	23,133	5,798	10,263	37,037
	2012	19,998	2,649	1,682	0,624	21,883	6,040	10,005	37,119
MADRID	1990	9,969	41,753	4,952	2,057	7,805	7,353	25,769	0,342
	2000	16,950	36,069	4,250	1,910	7,135	7,456	25,801	0,430
	2006	21,689	33,182	3,873	1,699	6,335	7,247	25,522	0,454
	2012	24,829	31,340	3,432	1,755	5,637	13,383	18,864	0,760
BARCELONA	1990	19,749	8,023	4,481	1,261	4,204	15,084	8,750	38,447
	2000	22,411	7,078	3,820	1,232	3,768	14,851	8,356	38,483
	2006	25,470	6,233	3,082	1,180	3,411	14,914	7,378	38,332
	2012	25,990	4,807	2,566	1,294	1,545	17,633	7,888	38,278
MARSEILLE	1990	10,020	2,773	0,000	2,252	9,017	17,166	14,777	43,994
	2000	11,291	2,566	0,000	2,144	8,871	17,120	15,056	42,953
	2006	11,541	2,530	0,000	2,135	8,738	16,552	15,328	43,176
	2012	12,172	2,268	0,000	2,136	8,441	16,364	15,975	42,644
FLORENCE	1990	8,216	15,634	0,000	24,596	15,808	32,859	2,401	0,485
	2000	9,658	14,518	0,000	24,552	15,282	33,217	2,166	0,608
	2006	10,138	14,168	0,000	24,516	15,210	33,317	2,136	0,516
	2012	11,205	12,872	0,000	25,276	14,493	33,694	1,963	0,497
ROME	1990	4,206	21,181	0,000	11,299	16,693	13,739	3,386	29,495
	2000	4,378	21,506	0,000	10,200	17,522	13,750	3,052	29,593
	2006	4,569	21,341	0,000	10,223	17,476	13,656	3,115	29,620
	2012	4,569	21,341	0,000	10,223	17,476	13,656	3,115	29,620
ATHENS	1990	8,237	1,344	0,000	3,223	19,286	11,588	20,912	35,410
	2000	10,246	1,066	0,000	3,027	18,005	9,117	23,048	35,491
	2006	15,122	0,574	0,000	3,070	13,413	14,310	16,822	36,689

	2012	15,289	0,521	0,000	3,061	13,310	12,063	15,027	40,729
THESSALONIKI	1990	7,124	29,634	7,175	0,443	14,032	7,117	14,420	20,055
	2000	7,678	29,709	7,088	0,000	13,938	5,893	15,634	20,060
	2006	15,018	19,820	7,177	0,000	16,724	5,446	15,971	19,845
	2012	15,045	19,839	7,094	0,000	16,765	5,472	15,942	19,843

Appendix 4. Land cover standardized surface in peri-urban North African cities from 1990 to 2006.

STANDARISED SURFACE % (land cover groups)	Year	URBAN	NON-IRRIGATED ARABLE LAND	IRRIGATED ARABLE LAND	PERMANENT CROPS	COMPLEX CULTIVATION PATTERNS	FORESTS	SHRUB AND/OR HERBACEOUS VEGETATION ASOC AND PASTURES	OTHERS CATEGORIES
NABEUL	1990	0,429	0,43	12,23	2,68	5,68	15,91	11,982	51,018
	2006	7,412	7,41	8,09	3,13	11,03	11,43	14,094	39,552
SFAX	1990	0,219	0,22	5,48	0,00	34,76	10,29	1,256	47,984
	2006	4,818	4,82	10,84	2,81	4,38	12,55	9,062	53,864
RABAT	1990	0,267	0,27	28,22	0,03	1,18	5,60	2,950	41,476
	2006	3,754	3,75	11,11	2,44	14,08	13,35	16,647	32,238
TUNIS	1990	0,622	0,62	36,66	2,29	9,17	10,31	10,323	27,819
	2006	2,691	2,69	16,20	4,94	17,78	15,17	16,383	20,464

Appendix 5. Ecosystem service capacity provision estimated for European peri-urban areas from 1990 to 2012.

EESS PROVISION – EU (km^2 * estimation)	Year	Global climate regulation	Local climate regulation	Air quality regulation	Water flow regulation	Water purification	Nutrient regulation	Erosion regulation	Natural hazard protection	Pollination	Pest and disease control	Regulation of waste	Crops	Energy (Biomass)	Fodder	Livestock	Fibre	Timber	Wood fuel	Wild food, semi-domestic livestock and ornamental resources	Biochemicals and medicine	Freshwater	Recreation and tourism	Landscape aesthetic, amenity and inspiration	Knowledge systems	Religious and spiritual experience	Cultural heritage and cultural diversity	Natural heritage and natural diversity
LISBON	1990	104,945	146,094	52,712	76,263	93,706	83,958	104,976	91,634	97,049	165,774	154,361	136,308	93,783	99,078	48,168	90,359	48,780	69,098	113,234	73,984	9,905	186,355	186,888	189,761	71,990	174,361	140,182
	2000	81,677	118,387	46,108	66,024	63,712	53,603	91,949	63,890	90,640	126,148	114,791	120,533	81,791	86,971	46,470	75,527	43,413	62,703	88,290	56,307	9,135	165,358	153,388	153,729	88,236	153,579	105,086
	2006	91,473	123,161	45,036	64,557	83,133	74,155	89,405	79,142	89,591	143,037	135,594	118,531	89,452	88,420	44,721	73,541	41,897	60,720	108,176	62,028	9,083	189,302	178,143	174,508	91,149	164,917	120,896
	2012	79,364	115,634	47,099	65,324	62,740	53,385	92,397	61,996	88,735	121,708	111,654	116,718	84,229	83,894	50,448	73,522	44,639	62,422	91,044	54,868	9,705	162,858	151,809	150,777	92,415	152,091	102,510
MADRID	1990	137,797	199,918	56,863	108,995	111,356	121,370	132,650	110,338	142,564	135,914	148,838	274,137	195,064	135,375	90,761	135,202	50,567	79,411	162,637	127,094	4,652	201,209	225,817	261,502	89,716	250,232	148,864
	2000	130,689	186,171	57,627	103,281	111,629	121,891	131,774	103,995	140,643	127,803	141,433	242,262	178,412	124,303	85,941	118,698	49,981	79,663	158,859	121,162	4,575	204,671	228,131	253,178	101,874	244,149	147,914
	2006	123,451	174,879	56,463	98,327	105,735	114,796	128,026	98,353	136,908	122,045	137,988	223,268	169,395	119,798	85,268	108,876	48,865	78,175	153,020	113,923	4,896	202,429	221,640	242,784	105,976	236,262	141,380
	2012	131,432	188,827	82,577	102,726	118,983	126,120	148,076	106,672	145,994	129,522	144,785	208,887	169,671	127,089	78,080	93,980	82,616	101,141	160,224	129,146	5,733	221,928	228,805	232,985	113,354	238,321	152,210
BARCELONA	1990	104,597	139,139	88,391	65,725	107,207	106,103	105,470	84,387	109,993	114,706	115,719	90,618	93,764	46,019	43,271	52,729	68,616	85,006	111,394	85,945	3,829	170,836	189,225	175,857	117,118	176,564	136,369
	2000	90,790	126,253	86,867	62,620	94,903	93,991	102,600	75,901	107,380	103,571	104,711	81,508	86,375	40,758	38,859	46,318	67,230	82,956	100,715	76,276	3,512	160,800	178,281	163,086	119,090	168,926	124,043
	2006	95,075	125,564	86,586	59,491	100,586	99,067	98,178	76,513	105,049	104,425	105,097	72,774	82,363	39,385	32,015	39,924	66,829	81,916	103,691	78,496	3,458	163,040	179,719	161,798	117,983	165,671	125,924
	2012	93,834	130,124	100,189	66,236	106,400	105,671	117,187	80,173	115,280	101,974	103,284	58,125	76,210	37,244	28,351	26,481	77,559	92,762	101,322	83,260	1,991	165,372	183,837	153,062	120,179	164,404	133,256
MARSEILLE	1990	111,411	157,355	106,099	82,843	131,348	131,976	133,360	108,164	135,612	133,547	131,249	67,212	72,312	45,323	23,159	32,200	73,884	107,622	120,187	114,603	1,850	189,120	215,081	184,777	113,303	172,073	183,176
	2000	106,295	151,825	107,475	82,517	126,013	127,594	133,514	107,041	138,397	131,674	128,779	65,940	70,985	44,775	21,833	32,220	73,202	108,238	118,007	116,612	1,643	186,608	215,665	182,889	117,600	172,633	180,830
	2006	105,661	149,557	104,906	81,011	124,507	126,091	130,315	105,637	136,935	130,942	128,995	65,374	70,968	44,759	22,872	32,533	70,935	106,469	118,177	114,907	1,635	185,909	214,075	182,918	117,106	171,136	178,250
	2012	103,419	146,747	104,621	80,854	122,703	124,202	129,828	104,603	138,177	129,288	128,160	63,504	70,686	43,747	24,031	31,800	70,143	106,866	117,562	113,602	1,643	186,138	214,294	182,850	120,036	171,013	177,062
FLORENCE	1990	193,919	258,570	195,260	128,613	196,728	192,867	215,729	138,292	177,815	215,029	198,635	241,838	150,413	113,109	15,457	75,417	236,077	256,816	189,705	173,841	5,022	339,559	321,765	305,446	182,269	289,536	266,320
	2000	193,160	256,651	196,341	127,204	197,859	194,424	216,145	137,630	177,685	213,766	197,500	234,689	147,249	110,606	13,717	72,073	236,730	256,974	189,730	173,045	4,846	340,556	322,355	303,497	184,748	288,627	266,316
	2006	193,097	256,172	196,780	126,939	198,312	194,873	216,556	137,464	177,697	213,674	197,462	232,615	146,659	109,854	13,635	71,143	237,083	257,356	189,882	172,910	4,874	340,651	322,917	303,481	185,496	288,566	266,537
	2012	193,283	254,591	199,142	126,494	200,625	197,478	218,644	137,548	178,392	212,681	195,734	226,819	145,902	107,364	12,309	66,968	237,373	257,985	190,031	173,269	4,195	345,555	324,019	301,760	187,129	288,851	266,849
ROME	1990	128,936	179,164	92,054	95,175	105,090	97,349	122,211	97,375	118,235	151,830	136,329	215,767	131,043	101,459	23,823	86,372	114,023	122,393	137,078	108,127	13,292	212,913	189,015	202,580	78,021	189,790	151,108
	2000	119,253	173,531	91,193	94,273	93,847	86,800	121,234	93,358	118,361	147,843	132,092	216,578	125,779	101,790	22,568	90,082	114,381	120,867	129,743	102,619	13,082	201,318	181,481	194,963	78,664	186,099	142,797
	2006	126,792	177,599	90,815	94,060	101,553	94,491	120,832	96,304	118,125	152,158	136,533	215,792	127,021	103,013	22,659	89,697	113,834	120,506	135,717	106,952	13,102	207,970	187,891	201,081	78,921	189,145	148,904
	2012	126,792	177,599	90,815	94,060	101,553	94,491	120,832	96,304	118,125	152,158	136,533	215,792	127,021	103,013	22,659	89,697	113,834	120,506	135,717	106,952	13,102	207,970	187,891	201,081	78,921	189,145	148,904

ATHENS	1990	113,068	146,677	85,671	82,287	114,243	110,934	129,314	92,356	134,158	148,577	139,569	96,617	78,479	63,284	46,926	65,878	60,262	101,040	120,086	105,884	5,750	181,755	208,424	201,081	18,556	61,988	39,373
	2000	92,633	126,313	75,064	77,396	92,753	89,640	117,404	80,931	129,405	132,619	127,237	89,870	74,853	58,148	51,204	63,888	49,300	94,418	105,749	92,215	5,618	164,652	191,603	188,511	18,317	58,793	34,432
	2006	110,525	142,303	94,250	77,242	121,486	118,819	129,790	91,032	132,630	139,484	131,413	74,723	74,514	57,621	36,942	44,376	67,672	106,038	121,562	109,146	4,423	190,175	211,711	189,463	19,716	59,197	38,499
	2012	88,793	125,752	81,091	74,093	101,116	98,565	120,289	81,288	121,935	124,459	111,326	74,026	68,138	55,001	38,090	42,742	58,631	93,117	105,010	96,477	4,395	180,025	197,139	172,515	19,749	57,520	35,183
THESSA LONIKI	1990	117,510	178,528	55,660	100,109	91,191	94,486	100,697	101,271	116,576	144,519	131,552	240,847	167,882	125,328	52,279	129,664	42,002	63,560	134,987	107,776	5,141	162,875	186,291	213,034	318,720	597,785	561,152
	2000	100,224	165,622	49,362	95,119	69,034	70,128	91,844	92,801	114,360	133,498	125,396	238,606	165,581	121,462	61,864	134,154	37,186	61,732	115,665	97,525	4,977	146,246	169,680	201,209	311,819	555,889	495,746
	2006	102,450	155,985	49,606	91,497	81,958	84,854	92,892	90,083	110,168	138,786	123,525	201,948	146,025	113,646	51,704	119,170	35,295	61,316	121,027	96,828	4,753	155,449	185,303	203,661	383,423	574,958	543,387
	2012	88,737	147,750	49,704	91,528	68,256	71,084	93,205	84,663	110,227	130,477	115,218	201,783	143,016	110,946	51,495	118,924	35,482	61,417	110,027	88,646	4,798	144,593	174,359	192,603	349,169	530,562	499,209

Appendix 6. Ecosystem service capacity provision estimated for North African periurban areas from 1990 to 2006.

EESS PROVISION – North Africa (km^2 * estimation)	Year	Global climate regulation	Local climate regulation	Air quality regulation	Water flow regulation	Water purification	Nutrient regulation	Erosion regulation	Natural hazard protection	Pollination	Pest and disease control	Regulation of waste	Crops	Energy (Biomass)	Fodder	Livestock	Fibre	Timber	Wood fuel	Wild food, semi-domestic livestock and ornamental resources	Biochemicals and medicine	Freshwater	Recreation and tourism	Landscape aesthetic, amenity and inspiration	Knowledge systems	Religious and spiritual experience	Cultural heritage and cultural diversity	Natural heritage and natural diversity
NABEUL	1990	312,489	242,464	17,653	52,478	286,019	288,058	51,679	150,971	66,351	240,647	233,519	163,389	137,769	133,886	44,313	89,420	20,001	37,991	250,279	204,304	0,457	308,984	311,816	331,790	32,051	234,060	271,570
	2006	110,537	172,486	59,746	147,179	146,541	141,885	124,268	135,472	103,582	164,796	207,246	143,518	111,302	63,028	66,528	62,382	82,525	105,668	173,900	105,718	90,949	342,044	305,668	297,387	115,534	251,342	264,913
SFAX	1990	299,783	220,164	43,534	61,011	279,125	278,395	62,622	125,707	50,959	200,164	184,150	212,441	111,120	86,580	8,308	39,803	136,523	136,534	213,487	159,586	2,043	395,276	348,311	355,137	86,595	272,984	328,299
	2006	87,839	164,908	31,465	142,043	121,429	110,244	106,321	135,262	89,403	170,484	184,249	133,374	93,498	59,496	64,994	68,992	36,825	52,307	153,494	90,600	84,466	310,582	282,710	269,165	66,221	207,049	247,250
RABAT	1990	326,601	302,231	108,664	86,251	316,500	313,650	122,225	184,568	125,280	254,858	250,813	165,262	162,117	128,870	11,538	70,644	107,736	114,476	308,826	246,184	6,067	321,737	322,791	331,931	67,908	227,962	292,171
	2006	121,146	182,818	71,328	147,142	148,046	144,343	137,294	133,701	120,929	164,786	198,491	172,874	124,335	71,461	72,245	70,545	101,461	128,755	174,431	116,848	75,826	334,781	304,327	302,295	113,677	258,980	268,210
TUNIS	1990	216,298	224,977	37,844	88,996	177,533	176,861	76,849	135,210	98,911	181,707	174,019	273,091	189,307	136,028	42,442	114,581	43,040	59,951	189,404	158,934	4,822	251,206	248,653	285,513	42,793	235,044	196,021
	2006	125,511	190,205	75,822	139,873	132,022	130,222	137,189	122,203	129,075	156,309	172,357	232,339	154,723	90,106	83,330	96,172	116,172	142,650	158,694	119,711	50,553	311,060	285,848	294,556	108,999	268,805	248,358

Appendix 7. Factor scores derived from the within-class Correspondence Analysis applied in European and North African Mediterranean peri-urban areas (Wp).

	European			North African		
Land cover groups	F1	F2	F3	F1	F2	F3
Urban	0,227	-0,002	-0,029	-0,047	0,675	0,521
Non-irrigated arable land	-0,131	0,083	-0,029	-0,390	-0,177	-0,163
Irrigated arable land	-0,092	0,002	-0,063	0,004	0,469	0,044
Permanent crops	0,003	0,012	-0,012	0,620	-0,310	0,054
Complex cultivation patterns	-0,057	-0,073	0,046	0,051	0,151	-0,130
Forests	0,039	0,054	0,056	-0,510	-0,328	0,463
Shrub and or herbaceous and pastures	-0,072	-0,078	-0,035	0,088	0,371	-0,038
Ecosystem services						
Global climate regulation	-0,210	-0,015	0,010	-0,966	-0,141	0,039
Local climate regulation	-0,181	0,010	0,055	-0,874	0,002	-0,221
Air quality regulation	-0,036	-0,094	0,058	0,076	-0,365	-0,502
Water flow regulation	-0,121	0,032	0,065	0,955	0,051	-0,211
Water purification	-0,176	-0,102	-0,020	-0,902	-0,180	-0,047
Nutrient regulation	-0,173	-0,098	-0,026	-0,907	-0,193	-0,027
Erosion regulation	-0,070	-0,078	0,070	0,704	-0,143	-0,404
Natural hazard protection	-0,278	-0,029	0,001	-0,533	0,291	-0,441
Pollination	-0,079	-0,022	0,063	0,434	0,044	-0,388
Pest and disease control	-0,242	0,006	-0,034	-0,858	0,118	-0,176
Regulation of waste	-0,285	0,019	-0,033	-0,443	0,107	-0,293
Crops	-0,094	0,133	0,032	-0,308	-0,208	0,306
Energy Biomass	-0,108	0,090	0,033	-0,479	0,112	-0,009
Fodder	-0,103	0,044	0,037	-0,848	0,214	0,054
Livestock	-0,023	0,160	0,013	0,844	0,145	0,050
Fibre	-0,124	0,222	0,000	-0,097	0,478	0,081
Timber	-0,023	-0,072	0,051	0,065	-0,858	-0,142
Wood fuel	-0,025	-0,050	0,037	0,231	-0,849	-0,111
Wild food semi domestic livestock and ornamental resources	-0,198	-0,037	-0,026	-0,813	-0,015	-0,237
Biochemicals and medicine	-0,146	-0,048	0,041	-0,895	0,003	-0,146
Freshwater	-0,033	0,039	0,012	0,968	0,082	-0,145
Recreation and tourism	-0,083	-0,080	-0,018	0,049	-0,725	0,021
Landscape aesthetic amenity and inspiration	-0,127	-0,056	-0,047	-0,295	-0,621	-0,048
Knowledge systems	-0,171	0,070	-0,053	-0,691	-0,580	0,127
Religious and spiritual experience	0,072	-0,108	-0,003	0,724	-0,642	-0,103
Cultural heritage and cultural diversity	-0,120	0,024	-0,011	0,112	-0,916	0,319
Natural heritage and natural diversity	-0,143	-0,046	-0,018	-0,271	-0,623	-0,072