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Collaborative mapping of ecosystem services: The role of stakeholders' profiles

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ABSTRACT

Assuming the huge progress achieved in public participatory geographic information system (PPGIS) techniques and its current research gaps, this study aims to explore differences in the perception of spatial distribution of ecosystem services supply and demand between different stakeholders through collaborative mapping. The stakeholders selected included *high influence stakeholder* (with a high degree of interest on the ecosystem services' state and with an important influence into the environmental decision making process) and low *influence stakeholders* (with a high degree of interest on the ecosystem services' state and with a low influence in environmental management). Workshops took place in June 2013 in two regions of Andalusia; overall 29 participants were involved. Water provision, food from agriculture, livestock, erosion control, climate regulation, water purification, nature tourism, recreational hunting and tranquility were collaboratively mapped. Agriculture land-use and the protected area surface were also assessed in order to find patterns in ecosystem services supply, meanwhile the role of urban areas was assessed for ecosystem services demand. The results show that *low* and *high influence stakeholders* have different perceptions of the spatial distribution of ecosystem services and the scale of their demand. We call for the recognition of these knowledge differences (experiential and technical) and their inclusion in decision making processes regarding landscape planning.

1. Introduction

Complex environmental issues have to be handled with transdisciplinary methods and with the integration of collective decisions, in order to implement effective environmental management strategies. The combination of top-down and bottom-up approaches guide towards a greater acceptance by all the stakeholders involved (Pahl-Wostl et al., 2007). Following this argumentation line, the management and spatial planning of ecosystem services, as a complex environmental issue, should be addressed through transdisciplinary approaches (Chan et al., 2012), where biophysical and social angles are included, and where different stakeholders are involved. However, the prevailing economical worldview in ecosystem service assessments focused on direct use values have been mainly addressed through a biophysical and economic vision (Brown et al., 2012; Klain and Chan, 2012; Nieto-Romero et al., 2014), while social values have been less included (Bryan et al., 2010; Chan et al., 2012; Palomo et al., 2013; Raymond et al., 2009). Several researchers showed the relevance of participatory approaches to include other social values and/or knowledge forms, since monetarian valuation not reflect all the contributions that we receipt of ecosystems and this leads to limitations in environmental research and decision making process (Chan et al., 2012; Daniel et al., 2012; Raymond et al., 2013).

Recently, different methodologies are starting to consider the importance of social values for assessing ecosystem services and

Abbreviations: SPUs, Service-providing units; SBAs, Service benefiting areas; PPGIS, Public participation geographic information systems; GIS, Geographic information systems; PCA, Principal component analysis

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use different social sampling techniques such as questionnaires (Martín-López et al., 2012; Oteros-Rozas et al., 2014), interviews (Klain and Chan, 2012) or workshops (Oteros-Rozas et al., 2013; Palomo et al., 2011) for eliciting such values.

Among all these social valuation methods of ecosystem services, researchers have begun to map social values of ecosystem services with the idea of making them spatially explicit (Klain and Chan, 2012; Van Riper et al., 2012). In this sense, ecosystem services mapping have been gradually incorporated in social valuation approaches through the use of several different modes of valuation: surveys such as *mail-based surveys, online surveys or face-to-face surveys* (Brown et al., 2012; Brown, 2012a; Brown and Weber, 2012; García-Nieto et al., 2013), interviews (Bryan et al., 2010; Plieninger et al., 2013) and workshops (Palomo et al., 2013, 2014).

Since the early 1990s researchers have mapped stakeholder perspectives using public participation geographic information systems (PPGIS) (Brown and Reed, 2000; Raymond and Brown, 2006; Brown and Raymond, 2007; Brown, 2012b; Brown and Weber, 2012). PPGIS combines the practice of GIS and mapping at local levels for addressing different environmental problems, such as the spatial planning of urban and marine systems, as well as tourism planning and development (Brown and Weber, 2012; Pomeroy and Douvere, 2008; Stewart et al., 2008). PPGIS aims to collect the diversity of stakeholders' knowledge and empower people to participate in spatial decision making exercises regarding environmental issues (Craig et al., 2002; Hasse and Lathrop, 2003; Stewart et al., 2008). Considering the broadness of "public" concept, diverse stakeholders' profiles may be included (from decision makers to random public), consequently some factors (such as socio-demographic variables and participants' knowledge about the study area) are taking into account and transmitted into the analysis immediately (Brown et al., 2013). In this sense, recently the issue of sampling effects (Brown et al., 2013) and other threats in PPGIS (Brown and Kyttä, 2014) were analyzed and the results revealed the differences between stakeholders' interests. However, to our knowledge, there are no previous studies that compare the perceptions of the spatial distribution of ecosystem services among different stakeholder groups. Therefore, one of the challenges in participatory mapping of ecosystem services is to consider different stakeholder profiles and analyze their differences in ecosystem service mapping, because different stakeholders groups have different interests, perceptions and knowledge regarding ecosystem services (Kumar and Kumar, 2008; Lamarque et al., 2011a; Martín-López et al., 2012). Differences in stakeholder profiles linked to several interests and power or influence levels were analyzed during last years, resulting in "communities of interest" framework (Harrington et al., 2008) and "interest-influence" matrix (Reed et al., 2009).

In addition, although most of the recent conceptual frameworks integrate both the supply- and the demand-sides of ecosystem services- i.e., the function analysis framework (De Groot, 2002); the Millennium Ecosystem Assessment framework ((MA) Millennium Ecosystem Assessment, 2005); the 'cascade model' (Haines-Young and Potschin, 2010); few try to empirically operationalize a comprehensive ecosystem service assessment. Therefore, there is a challenge in the spatial analysis of ecosystem services for incorporating both the capacity of the ecosystems to deliver services to society and the social demand for using a particular ecosystem service (Castro et al., 2014).

In order to contribute to these two challenges in the ecosystem service mapping, the main purpose of this research was to identify the differences in the spatial perception of ecosystem services, both in the supply and demand between stakeholders groups. In this sense, we identify the service-providing units (SPU) and service benefiting areas (SBA). The service-providing units (SPU) consider the ecosystem structures and processes that provide a specific ecosystem service at a particular scale (Luck et al., 2009; Harrington et al., 2010; García-Nieto et al., 2013); the service

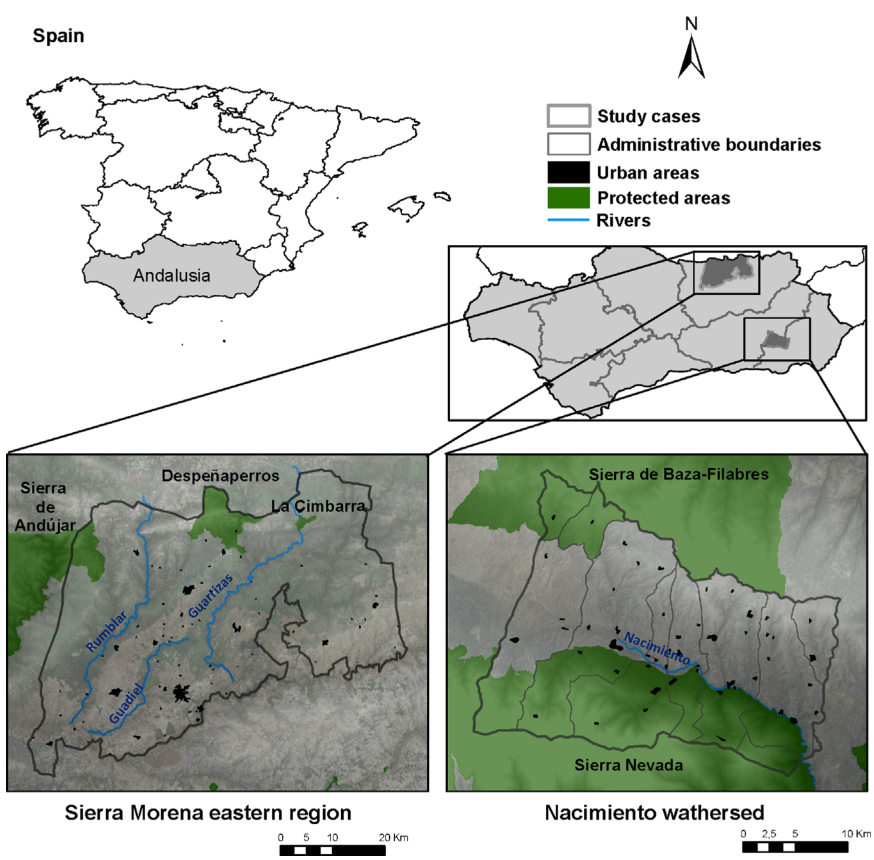

Fig. 1. Study areas location: Sierra Morena Eastern region and Nacimiento watershed. Municipality limits, main rivers and protected areas are shown.

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benefiting areas (SBA) include the spatial scale in which stakeholders identify the location of beneficiaries who demand ecosystem services (Syrbe and Walz, 2012; Palomo et al., 2013) with the aim of locate the areas in which these services were demanded (urban-rural nucleus or dispersed constructions).

In order to reach the principal aim, our specific objectives were to: (1) explore the differences between stakeholders groups of the spatial perception of SBAs, (2) explore the differences between stakeholders groups of the spatial perception of SPUs, (3) identify the SPUs relations among different ecosystem services (i.e., synergies and trade-offs) on the basis of different stakeholders' perceptions, and (4) identify the key factors determining the spatial distribution of SPUs and SBAs.

2. Study area

This research was conducted in two study sites of the Andalusia region (Spain): Sierra Morena eastern region and Nacimiento watershed (Fig. 1). Sierra Morena eastern region is located in the northeast of Andalusia (Jaén province) and is distinguished by mid-mountain regions (Moreira et al., 2005) in which the Mediterranean *dehesa* landscapes are common (i.e., agrosilvopastoral ecosystems consisting of pasturelands with scattered trees, primarily holm oaks) (Oteros-Rozas et al., 2014). Its altitude ranges between 203 m and 1818 masl (meters above sea level). Sierra Morena is characterized by private farms, multifunctional landscape of olive grove cultivation, Mediterranean *dehesas* and forest with forest harvesting and hunting activities. In the last years, olive grove cultivation is expanding to high slope hillside and livestock has been substituted by recreational hunting at Mediterranean *dehesas* because the processes of rural abandonment and depopulation (Araque et al., 2005). Sierra Morena eastern region covers partially three protected areas: Despeñaperros' and Sierra de Andujar's Natural Parks and Cascada de La Cimbarra's Protected Area.

Nacimiento region covers the watersheds of the Nacimiento River, characterized by a variety of topographic (the altitude ranges from 518 m to 2565 masl) and climatic conditions from alpine to semi-arid environments (PORN, 1994). Local population has experienced a process of aging due to rural exodus since the 1970s and, as a consequence, in the higher parts of Sierra Nevada mountain, traditional farming has been abandoned (García-Llorente et al., 2012a). While traditional agriculture characterizes the local activity at the bottom of the valley, an intensification of agriculture through greenhouses expansion has appeared in the lower parts of the watershed since the 1980s (Sánchez-Picón et al., 2011). Nacimiento watershed spreads across Sierra de Baza Natural Park and Sierra Nevada mountain northern slopes, which was declared National Park, Natural Park and Biosphere Reserve.

Table 1 presents full and comparative description of the two study sites. We use the terms Sierra Morena and Nacimiento to indicate Sierra Morena eastern region and Nacimiento watershed accordingly.

3. Methodology

3.1. Deliberative mapping workshops

We applied PPGIS to map ecosystem services supply and demand. With this purpose, one mapping workshop was developed in each study area in June 2013 (see Supplementary material, Table S1). Participants were chosen heeding to levels of influence on environmental management and interest on the ecosystem services' state as defining criteria on the basis of an influence-interest matrix (Reed et al., 2009).

We identified *high influence stakeholders,* characterized with a high degree of interest on the ecosystem services' state (Table 2) and with high influence in the environmental management. *High influence stakeholders* are linked to different stages of policy cycle (e.g., protected area and local development agents, environmental and protected area managers or researchers). On the other hand, we identified *low influence stakeholders,* characterized with a high degree of interest on the ecosystem services' state and with low influence in environmental management, meaning that stakeholders generate an immediate influence in parts of the territory through their actions both at individual or collective levels (e.g., farmers, hunters, forestry laborers or local livestock farmers' association). Table 2 provides an overview of the stakeholders groups identified in the two study areas, their interest on the ecosystem services and their influence in environmental management.

Attending to the stakeholders' categorization at both sites, we developed the workshop with *high* and *low influence stakeholders* working in different subgroups (from three to six people in each), to be able to assess the differences in ecosystem services maps due to the type of stakeholders that created the maps. The workshops' purpose was to achieve a consensus between stakeholders, and the main purpose of this research is largely descriptive in nature and does aim to generalize findings to other contexts. Overall, in Sierra Morena, 13 participants attended the workshop (seven *high influence stakeholders* -divided into two subgroups- and six *low influence stakeholders* -one subgroup-), meanwhile in Nacimiento, 16 assistants attended (6 *high influence stakeholders* -divided into two subgroups- and 10 *low influence stakeholders* -three subgroups-). Overall, eight services were mapped by each group. All groups mapped the seven most important ecosystem services identified in both study areas by previous studies (i.e., García-Llorente et al., 2012a, 2012b; Oteros-Rozas et al., 2014). These ecosystem services include the three service categories: provisioning (food -from agriculture- and non-food -water provision-), regulating (erosion control, climate regulation and water depuration) and cultural (nature tourism and recreational hunting). An extra ecosystem service was selected by each subgroup.

Following previous studies (Palomo et al., 2013) a set of dots (moveable plastic disks with two different sizes to allow to map more accurately) were given to each subgroup for mapping SPUs (90 green dots) and SBAs (90 blue dots) on a topographic map of each region (1:18,000 for Sierra Morena and 1:10,000 for Nacimiento). Participants could freely allocate as many dots as needed to map the location of SPUs and SBAs. Given the mismatch between supply and demand identified in previous studies in the area (García-Nieto et al., 2013; Palomo et al., 2013), we provided each group with an additional map that covered broader spatial scales (regional as Andalusia, national and international) for mapping SBAs located outside the topographic map provided. In every subgroup a facilitator helped participants to solve doubts and to reach a consensus in each service mapped. After each subgroup mapped a service, a vertical photograph of the map was taken with a Digital Single Lens Reflex camera.

3.2. Spatial data processing

The images were geopositioned in ArcMap (using ArcGIS 9.3) and polygon shapefiles were created using the locations of dots for each service mapped (SPUs and SBAs). Finally, shapefiles were converted to a raster format to allow operations among layers. We overlaid and summed each SPUs and SBAs maps differentiating between *high* or *low influence stakeholders* and considering four ecosystem services categories: food and non-food provisioning services, regulating and cultural.

Firstly, taking into account SPUs, we designed a regular point grid covering the surface of Sierra Morena (100 m point-distance;

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Table 1
Descriptive and comparative information between study areas.

	Sierra Morena eastern region	Nacimiento watershed
Management model	Multifunctional landscape vs. farming intensification/neglected Mediterranean dehesas	Intensive agriculture vs. traditional agriculture
Extension	3622 km^2	598 km^2
Surface protected	126.3 km^2	251.2 km^2
Population	95,000 inhabitants	54,000 inhabitants
Municipalities	15 municipalities in Jaén province	7 municipalities in Almería and 3 municipalities in Granada province
Socio-economic categorization	The main economic sectors are **livestock**, including pig (intensive farming) and sheep/bovine (extensive or semi-extensive farming); **agriculture**, mainly olive crop; **forestry** and **hunting.**	The economy is mainly characterized by **farming**, traditional cultivation (olive and almond trees orchards), and **forest harvesting**. Agriculture under plastics (horticulture greenhouses) is being introduced
Ecological characterization	Typical ecosystems in this region are Mediterranean holm-oak and cork-oak dehesas, oak forest patches and presence of gall-oak and Pyrenean-oak forest in the highest and wetter areas	Nacimiento watershed includes ten ecosystems: high mountain pastures, high mountain juniper and brushwoods, rocky areas, oak and chestnut forest, native and reforested coniferous forest, mixed bushes, subdesertic scrubland, watercourses, lagoons and croplands

$n=656{,}581$) and Nacimiento (50 m point-distance; $n=796{,}470$). Next, we used the Moran's index (Moran, 1950) to test the spatial autocorrelation of the data, one of the most employed methods in previous research on mapping ecosystem services (e.g. Raudsepp-Hearne et al., 2010; Palomo et al., 2014). As Moran's index showed autocorrelation in the spatial indicators, we randomly selected a sample containing a 10% of the total grid points to reduce it (Willemen et al., 2010) (Sierra Morena $n=65{,}658$; Nacimiento $n=79{,}647$). Secondly, SPUs and SBAs of the four ecosystem services categories were analyzed attending to the number of dots allocated by *high* and *low influence stakeholders*. In addition, dots' density – i.e., number of dots per km^2 – was estimated.

Agriculture land-use and conservation management (protected areas) were considered as variables which SPUs distribution. Urban areas were considered as the key factor determining SBAs distribution for both stakeholder groups and in both case study areas.

3.3. Statistical analysis

We used the nonparametric Wilcoxon test to compare the average dots density (number of dots used by each subgroup per km^2) of SBAs and SPUs mapped by stakeholders with *high* and *low influence stakeholders* in management. Moreover the density of dots in urban areas and the spatial scale (local, regional for Andalusia, national and international) at which ecosystem services are used and demanded were described in each of the stakeholders groups.

To explore the influence of agriculture land and protected areas on the spatial distribution of SPUs perceived by the two stakeholders groups, we performed the nonparametric Mann–Whitney U test. Finally, we analyzed trade-offs among ecosystem services through performing a Principal Component Analysis (PCA) using the SPUs of each ecosystem service. This multivariate analysis (PCA) allows us to identify the contrasting spatial trend in the provision of ecosystem services perceived by participants and, in turn, contributes to determine spatial tradeoffs (Mouchet et al., 2014). We carried out four different PCAs according to the two stakeholders groups and the two case studies. To ensure the reliability of the correlation matrices for the PCA (Bartlett, 1950), the Bartlett's test of sphericity was performed.

To avoid heteroscedasticity problems we log transform all the SPUs variables, as well as the agriculture land cover and protected areas variables. Statistical analyses were executed using the software package XLSTAT 2009.

4. Results

In Sierra Morena, all subgroups decided by consensus that livestock was an important ecosystem service and this was the eighth ecosystem service they mapped. In Nacimiento, *high influence stakeholders* identified by consensus energy as the eighth ecosystem service to be map (in both subgroups); whilst *low influence stakeholders* chose livestock, energy and relaxing value as the eighth ecosystem service important in each of the three subgroups.

4.1. Social perceptions of SBAs distribution

High and *low influence stakeholders* used a significantly different number of dots for mapping SBAs in Sierra Morena (Wilcoxon test, p-value$=0.016$). While *low influence stakeholders* used more dots for mapping SBAs of provisioning (food), regulating and cultural ecosystem services, *high influence stakeholders* used more dots in the case of non-food provisioning ecosystem services (Fig. 2A). In Nacimiento significant differences were found regarding SBAs between stakeholder groups mapping (Wilcoxon test, p-value$=0.088$) (Fig. 2C). In this region, *low influence stakeholders* used more dots than *high influence stakeholder* for mapping SBAs of all ecosystem services categories. SBAs maps for *high* and *low influence stakeholders* for Sierra Morena and Nacimiento and for the four categories of ecosystem services (i.e., food and non-food provisioning services, regulating and cultural) are showing in Supplementary Material (Fig. S1).

SBAs were mostly located in urban areas as 71.87% in Sierra Morena and 80.52% in Nacimiento of SBAs' dots match with urban land-use. In both case studies, *high influence stakeholders* mapped more SBAs in urban areas (i.e., 81.8% in Sierra Morena and 90.4% in Nacimiento) than *low influence stakeholders* (i.e., 62% in Sierra Morena and 70.7% in Nacimiento), except for cultural ecosystem services in Sierra Morena eastern region.

Finally, we identified the spatial scales at which ecosystem services are demanded. Fig. 3 shows the scale at which SBAs are located by stakeholders groups in Sierra Morena and in Nacimiento areas. In both areas, erosion control and water depuration presented a similar pattern: while *high influence stakeholders* identified SBAs at local and regional scales, *low influence stakeholders* identified the SBAs at regional and national scales. In addition, SBAs of energy and recreational hunting in Nacimiento were allocated at regional scale by *low influence stakeholders*, while *high influence stakeholders* identified them at national scale (in the case of energy) and international scale (in the case of

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Table 2
Profiles of stakeholders on the basis of interest – influence matrix.

Groups of stakeholders		Interest			Influence		
		Ecosystems-Biodiversity	Water-land	Rural development	Public administration	Research	Cooperatives or associations
Low influence stakeholders	Farmers	x	x	x			x
	Hunters	x	x	x			x
	Forestry laborers	x	x	x			x
	Local livestock farmers' association	x	x	x			x
	Local associations	x	x	x			x
High influence stakeholders	Protected area						
	Technicians	x	x	x	x	x	
	Managers	x	x	x	x	x	
	Local development agents	x	x	x	x	x	
	Environmental managers	x	x	x	x	x	
	Researchers	x	x	x	x	x	

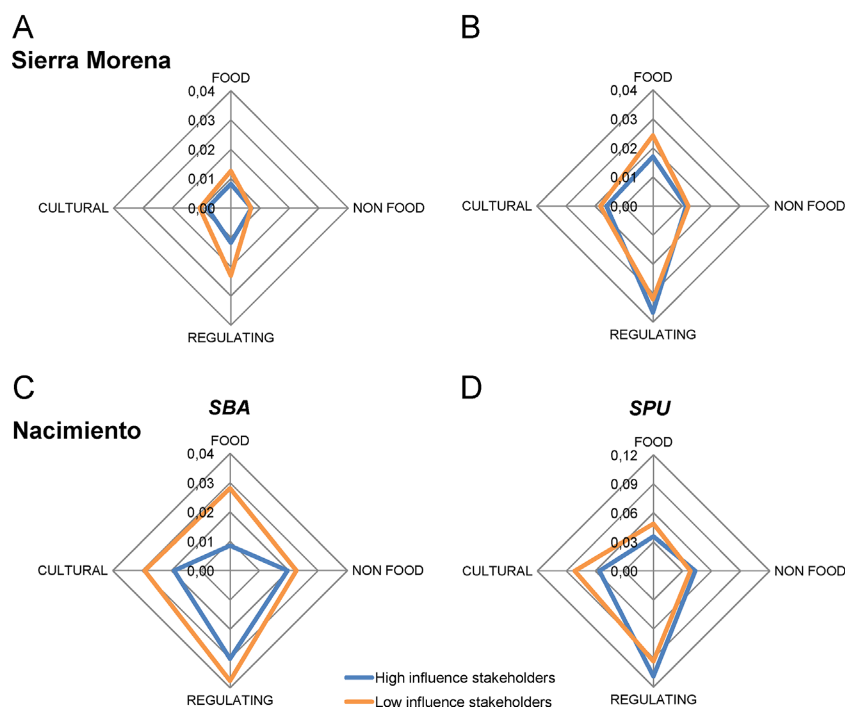

Fig. 2. Average density of dots employed by *high* and *low influence stakeholders* to allocate ecosystem services providing units (SPUs) and services benefiting areas (SBAs).

recreational hunting). The rest of SBAs in both case studies were similarly mapped by both stakeholders.

4.2. Social perceptions of SPUs distribution

Fig. 2B and D show that SPUs dots' density used by *low influence stakeholders* in both regions to map provisioning (food) and cultural services were higher than that used by *high influence stakeholders*, who use more dots to allocate regulating services SPUs, but no significant differences were shown (Wilcoxon test, p-value >0.1). Figs. 4 and 5 show the SPUs maps for *high* and *low influence stakeholders* for Sierra Morena and Nacimiento, respectively, and for the four categories of ecosystem services (i.e., food and non-food provisioning services, regulating and cultural).

The distribution of SPUs of four categories of ecosystem services was affected by protected areas except for non-food provisioning services mapped by *low influence stakeholders* in Nacimiento according to the Mann–Whitney U test (Fig. 6) (see Supplementary Material (Fig. S2)). Overall, in both areas *high influence stakeholders* mapped more SPUs of food provisioning, regulating and cultural within protected areas. However, while *high influence stakeholders* showed that non-food provisioning ecosystem services in Sierra Morena are more supplied in protected areas, in Nacimiento occurred in non-protected areas. Similarly, *low influence stakeholders* mapped more SPUs of regulating and cultural ecosystem services within protected areas than outside them; while food provisioning ecosystem services were more mapped outside protected areas.

Regarding the effect of agriculture land on SPUs distribution, the Mann–Whitney U test (for more details see Supplementary Material (Fig. S2)) demonstrated that agriculture fields in Sierra Morena are essential for the supply of ecosystem services for both stakeholders groups (Fig. 7). In Nacimiento, according to both stakeholders groups, agriculture lands supplied more food services, while cultural services were not associated to agriculture. Finally, while *high influence stakeholders* identified the delivery of regulating ecosystem services to be more intense in non-agriculture land, *low influence stakeholders* showed the opposite trend. The high values of standard deviation (Fig. 6 and 7) show the diversity of

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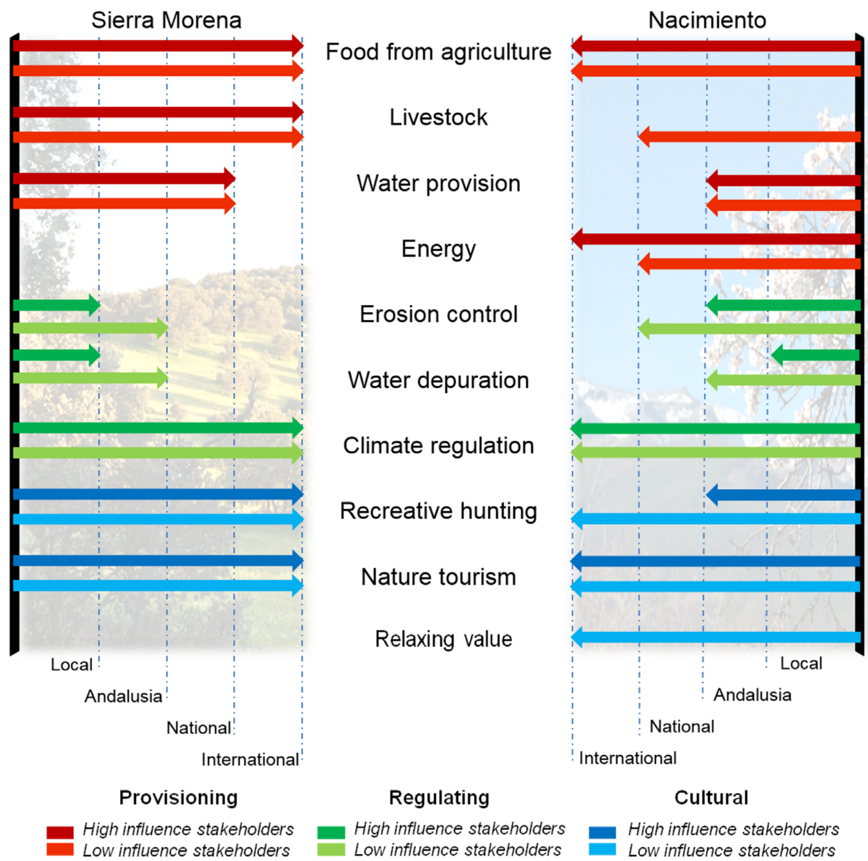

Fig. 3. Spatial scales of beneficiaries identified by *high* and *low influence stakeholders* groups through ecosystem services deliberative mapping in Sierra Morena eastern region and in Nacimiento watershed.

perceptions regarding the spatial distribution of ecosystem services for both study areas as well as stakeholders groups.

4.3. Relation between ecosystem services on the basis of SPUs distribution

Four PCAs were performed to analyze the existing ecosystem services relations (i.e., synergies and trade-offs) on the basis of both stakeholder perceptions in the two case studies (Table 3). All PCAs accomplished the chi-square Bartlett's test of sphericity (p-value < 0.001).

In Sierra Morena the mapping performed by *high influence stakeholders* resulted in positive association between regulating services (e.g., erosion control, water depuration and climate regulation) (in positive scores of F1), which was also related with those non-agriculture and non-urban land covers. Also freshwater and livestock SPUs mapped by this type of stakeholders, showed a positive association (in positive F2 scores); while it exits a trade-off between these provisioning services and climate regulation (in negative F2 scores). In contrast, the SPU mapping exercise performed by *low influence stakeholders* resulted in a synergistic association between livestock, erosion control, water depuration and recreational hunting (in positive scores of F1), which altogether are associated with protected areas.

In Nacimiento, results from deliberative mapping of *high influence stakeholders* showed a positive link between erosion control, climate regulation and recreational hunting (in positive scores of F1), whereas those ecosystem services were negatively associated with urban areas (in negative F1 scores). In addition, *high influence stakeholders* SPUs' distribution of food from agriculture, freshwater and water depuration resulted in a positive association that matches with urban areas and agriculture land-uses (in positive scores of F2).

In the case of *low influence stakeholders*, the SPU mapping exercise showed a positive association between water depuration, climate regulation and relaxing value (in positive F1 scores). Moreover, there were a synergistic association between livestock, erosion control, recreational hunting and nature tourism (in positive scores of F2).

Fig. 8 combines the first factor of both stakeholder profiles PCAs (F1 high influence stakeholders and F1 low influence stakeholders) for each of the study areas. In Sierra Morena (Fig. 8A), ecosystem services and land-use categories are almost equidistantly distributed along the axes, showing that the perceived spatial distribution of SPUs were similar in both stakeholders, except for regulating services. On the contrary, in the Nacimiento (Fig. 8B) the spatial associations between SPUs were dissimilar between *high* and *low influence stakeholders*. While *high influence stakeholders* spatially perceived a positive association between erosion control and climate regulation, *low influence stakeholders* perceived a spatial synergistic relation among food from agriculture, freshwater, erosion control, recreational hunting and nature tourism.

5. Discussion

5.1. Ecosystem services participatory mapping: the importance of considering different stakeholders

In this study, different ecosystem services were considered important by different local stakeholders groups, involving different social interests (Tëngo et al., 2014). This occurred in terms of the density of dots employed in the mapping, but also in terms of the eighth services voluntarily selected by the participants.

The differences between stakeholders regarding ecosystem services are not only related to their importance for the human

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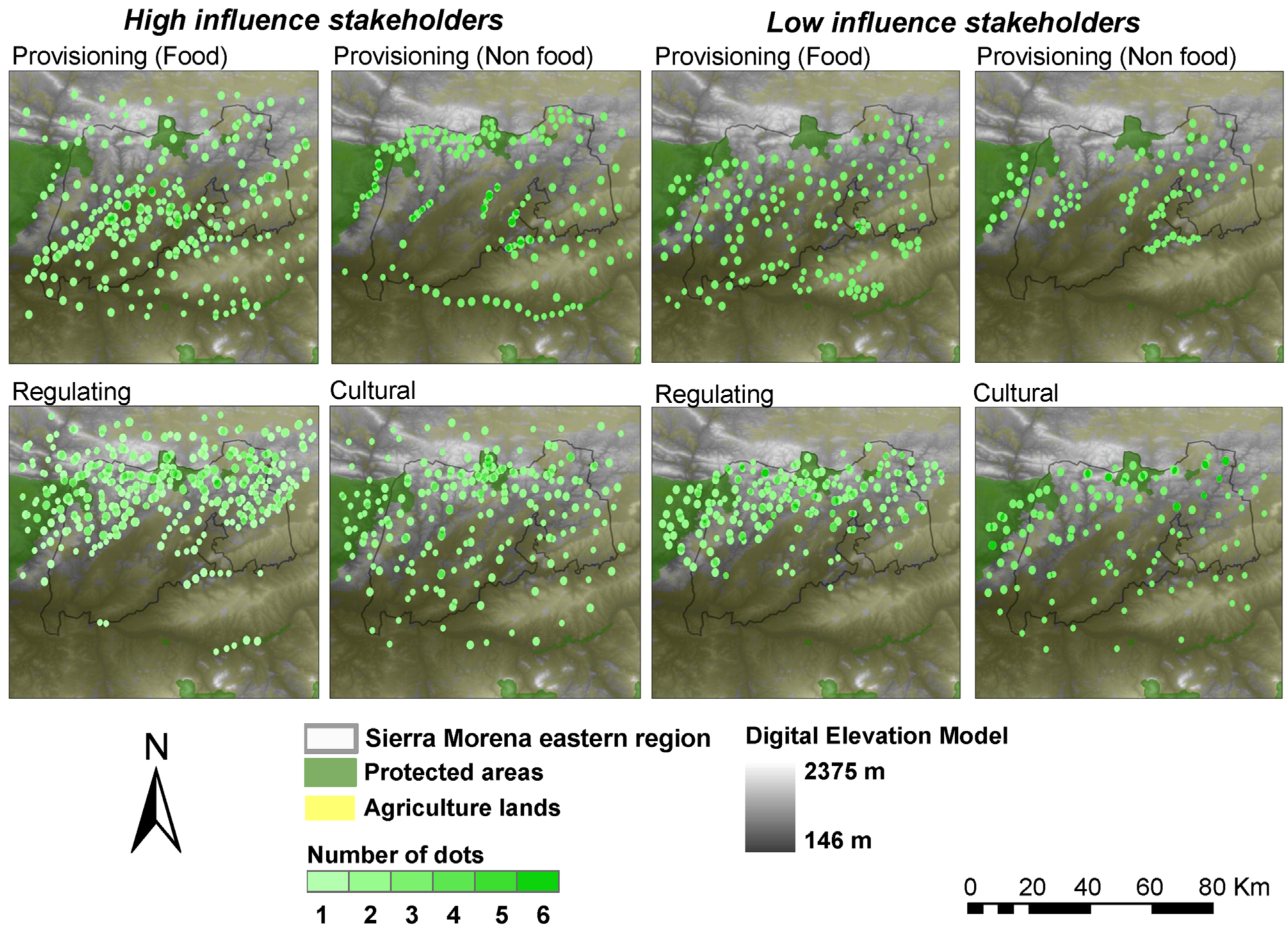

Fig. 4. Service providing units (SPUs) mapped by *high* and *low influence stakeholders* in Sierra Morena eastern region.

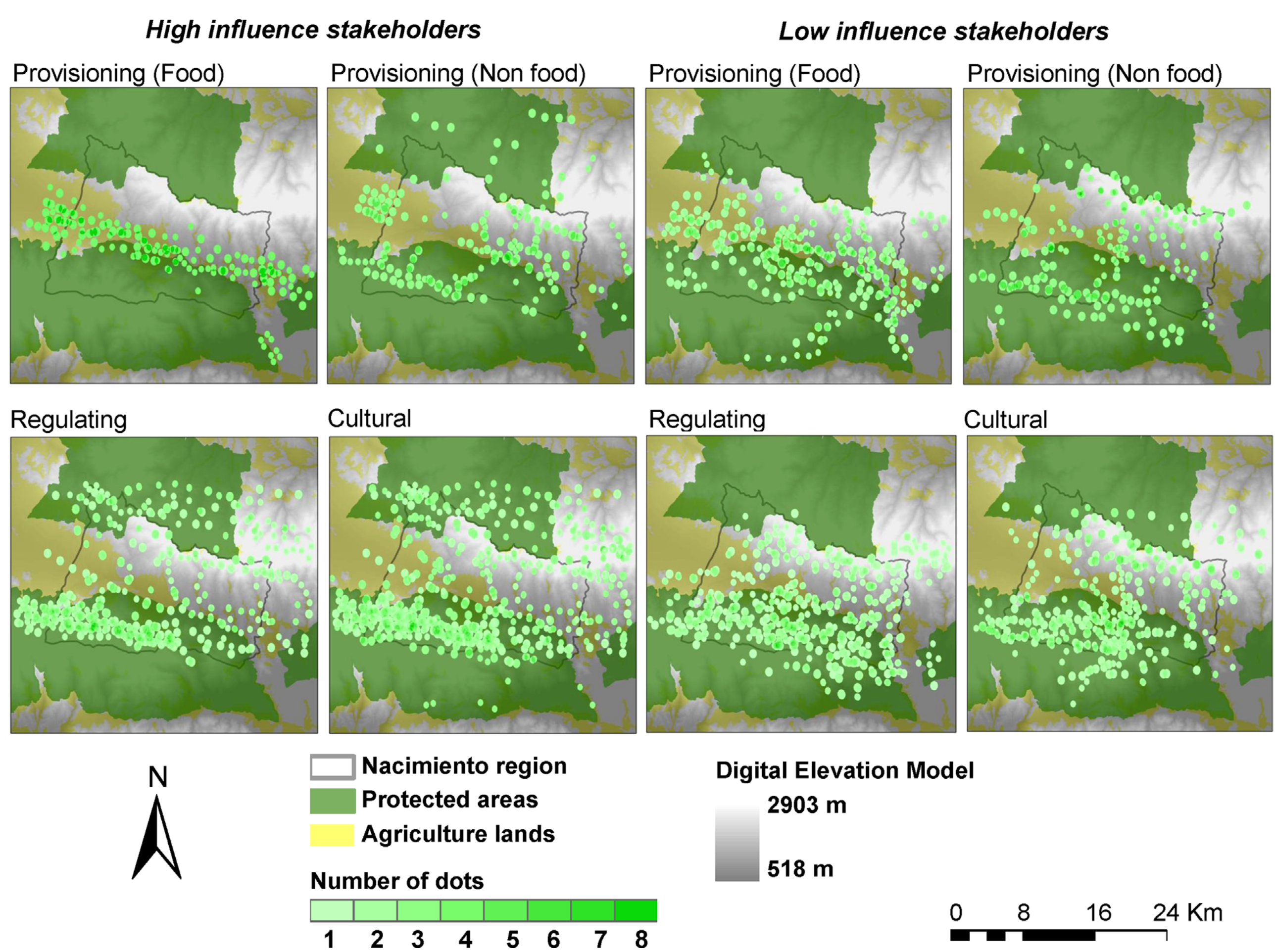

Fig. 5. Service providing units (SPUs) mapped by *high* and *low influence stakeholders* in Nacimiento watershed.

wellbeing, but also to the spatial distribution of supply and demand.

Previous studies have concluded that the inclusion of different stakeholder groups, particularly local stakeholders and environmental managers, is needed in ecosystem service valuation exercises because they have different types of connections to the landscape and knowledge, i.e., local or experiential and technical or experimental, respectively (Lamarque et al., 2011b; Martín-López et al., 2012). In fact, conflicts may be solved more successfully with the incorporation of different prospects since knowledge from both stakeholder groups is complementary, (Pretty, 2011; Tëngo et al., 2014), and therefore allows us to better understand the social and ecological factors determining the spatial distribution of the ecosystem services demand and supply.

In addition, because participatory mapping describes and reflects spatially stakeholders' perceptions of ecosystem services, the involvement of local stakeholders with different levels of influence in the decision-making process can empower stakeholders (Fagerholm et al., 2012) and generate a collective vision for landscape planning (Swetnam et al., 2011). Moreover, engaging different types of stakeholders consists on a complex and iterative process that promotes knowledge sharing and collective action (Tëngo et al., 2014). Of special interest is analyzing the differences in ecosystem services maps produced using local knowledge as it derives from the continue interaction (both physically or psychologically) with the land (Pretty, 2011), and, therefore, the spatial representation of ecosystem services is based on the continuous reading of signs and signals of the landscape. This cultural understanding of the landscape can not only give rise to sustainable management practices (Pilgrim et al., 2007, 2008), but also to knowledge for designing those multifunctional landscapes that ensure the delivery of ecosystem services (García-Llorente et al., 2012b).

Although the necessity to consider both types of knowledge in ecosystem services mapping because their complementarities (Pretty, 2011), to our knowledge there are not previous studies that explore the spatial distribution of ecosystem services (supply and demand), through the lens of different knowledge-sources linked to the different levels of influence of stakeholders in environmental decision-making. This fact can cause that specific socio-cultural realities of communities, such as those related to local stakeholders or "communities of interest" with low influence in the decision-making process, would be ignored in landscape planning and environmental management decisions (Maguire et al., 2012; Young et al., 2013).

5.2. Urban and protected areas, agriculture lands and ecosystem services bundles: exploring differences among stakeholder types

Identification of ecosystem services' beneficiaries revealed differences among stakeholder groups. One interesting aspect is that *low influence stakeholders* identified a more spread distribution of SBAs while *high influence stakeholders* identified SBAs mainly in urban areas.

Regarding the effect of protected areas and agricultural areas in the delivery of ecosystem services, protected areas are considered more able to deliver regulating and cultural services than non-protected areas. This result indicates that both stakeholder groups identify similarly the effects of protected areas in the delivery of ecosystem services. Previous studies have also support the idea of the positive influence of protected areas in the delivery of ecosystem services (Dudley et al., 2011; Palomo et al., 2014). Regarding agriculture lands, all stakeholder types identified that these areas deliver more services than the rest of the land in Sierra Morena. This is probably a result of deep-routed traditional farming activities, which have built multifunctional landscapes, such as dehesas. Differently, in Nacimiento, agricultural lands are more associated with food-related services due to a highest agricultural tradition (García-Llorente et al., 2012b) and the progressive implementation of intensive agriculture. The main difference among stakeholder types in this area is that *low influence stakeholders* identified also more regulating services in agriculture lands than the *high influence stakeholders*. This is explained because *high influence stakeholders* mainly mapped regulating services in the high areas whereas *low influence stakeholders* mapped them also in the lower parts of the valley. In addition, we did not find differences in the spatial distribution of non-food SPUs, i.e. water provision, between agriculture and non-agriculture lands. This can be explained because *low influence stakeholders* recognized the complex network of irrigation channels, created during the Muslim period, for freshwater conduction from Sierra Nevada summits to the valley.

Regarding ecosystem service bundles, we found interesting differences between stakeholder types. In Sierra Morena, *high influence stakeholders* found bundles among regulating services and among provisioning services, with a trade-off between provisioning services and climate regulation. This result aligns with previous ecosystem service assessments (e.g., MA, 2005; Rodríguez et al., 2006; Santos-Martín et al., 2013) and ecosystem service mapping (e.g., Bai et al., 2011; Schneiders et al., 2012; Palomo et al., 2014). Differently, *low influence stakeholders* found synergies in the delivery of livestock, erosion control, water depuration and recreational hunting. Given the multifunctional landscape of Sierra Morena, it is logic to think that this bundle among provisioning, regulating and cultural services exist to a certain extent. Similarly, in Nacimiento, *high influence stakeholders* found synergies between two ecosystem service types (regulating and cultural), whereas *low influence stakeholders* found synergies among three ecosystem service types (provisioning, regulating and cultural). Therefore, on the evidence of the two case studies, we can conclude that *low influence stakeholders* show a more comprehensive mental model of ecosystem services delivery than *high influence stakeholders* and different types of connections to the landscape.

Analyzing the associations of SPUs in detail, it is remarkable the one identified by *low influence stakeholders* for recreational hunting-erosion control in both study areas, since hunting activity in these regions emerges in areas where vegetation provides shelter to fauna. This association was also found in previous studies where biophysical information of ecosystem services delivery in forests was analyzed (García-Nieto et al., 2013).

In this sense, spatial bundles of ecosystem services (Raudsepp-Hearne et al., 2010) can be determined by using social preferences of different stakeholders' groups (Martín-López et al., 2012), which in turn depend on their knowledge-systems (i.e., experiential vs technical) as well as the type of connection to their environment (i.e., high dependency to the provision of ecosystem services vs. low dependency) as Iniesta-Arandia et al., 2014 have recently demonstrated.

As seen in this section, different stakeholder types express different patterns in the selection and mapping of ecosystem services. These are sometimes related to the different information that stakeholder groups have and in other cases these different patterns might be associated with the mental models, connections to the landscape or values that different stakeholders have. For example, *low influence stakeholders* mapped several farmhouses as SBAs because some of them live and use them in their lives while *high influence stakeholders* focused more in urban areas.

In this context, policy making, managers and researchers requires the engagement of stakeholders at different levels of social organization (Berkes, 2001; Pahl-Wostl, 2002; Pomeroy and Douvere, 2008).

All these results together demonstrate that ecosystem services participatory mapping' results are a highlighting tool "for grasping the socio-cultural realities of communities, regions,

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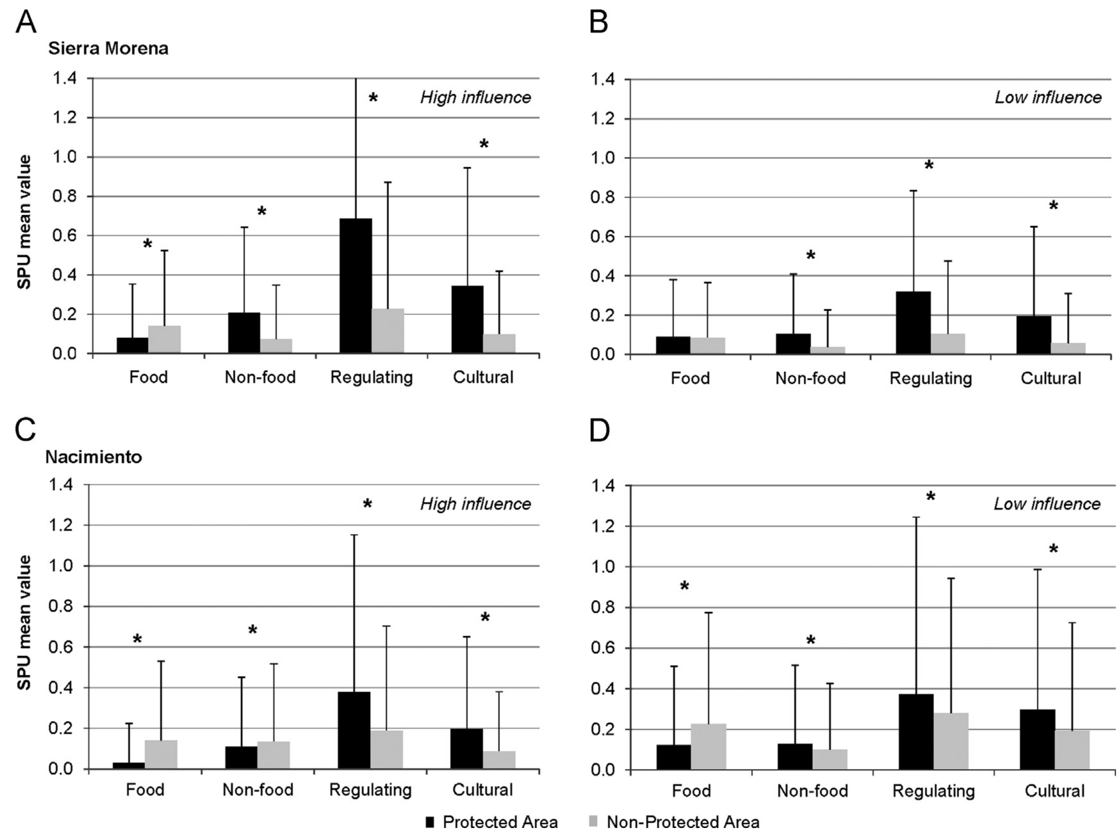

Fig. 6. Mann–Whitney U test results related to Protected Area and SPUs ecosystem services categories in Sierra Morena and Nacimiento: (A) high influence stakeholders and (B) low influence stakeholders in Sierra Morena; (C) high influence stakeholders and (D) low influence stakeholders in Nacimiento. Statistical significance at the *5% level.

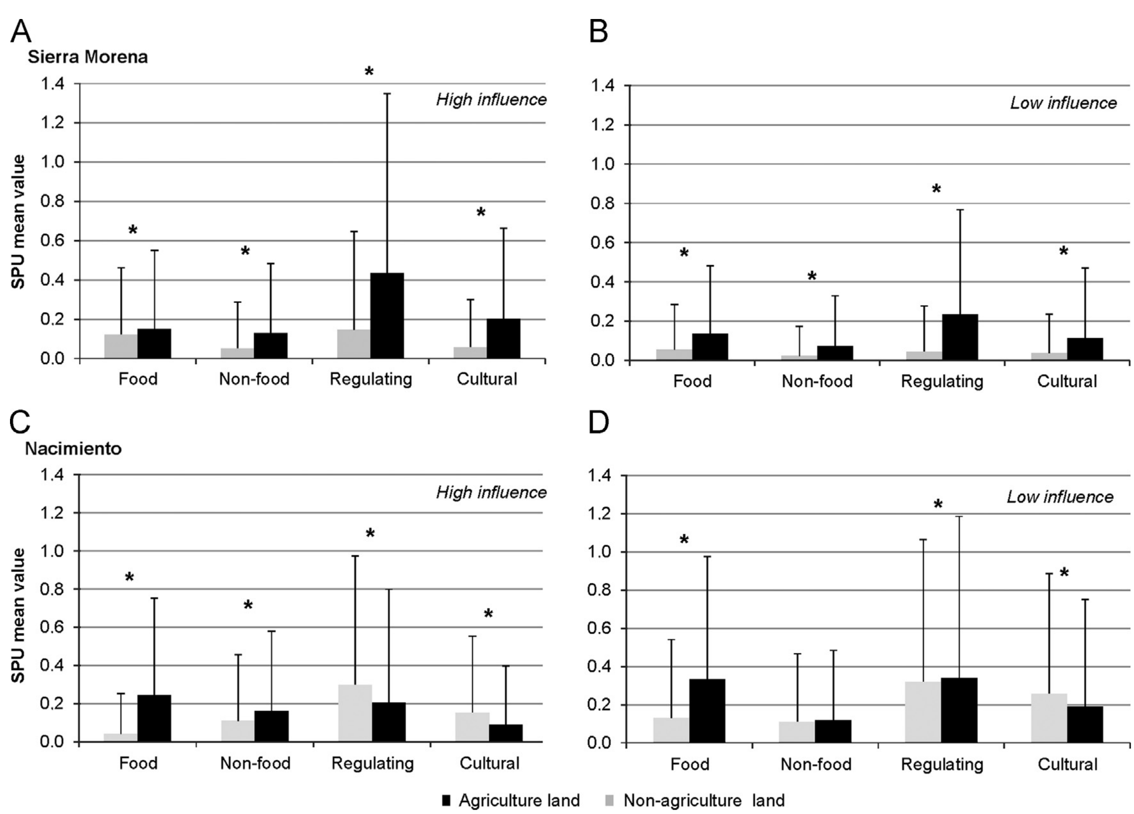

Fig. 7. Mann–Whitney U test results related to Agriculture-Land and SPUs ecosystem services categories in Sierra Morena and: (A) high influence stakeholders and (B) low influence stakeholders in Sierra Morena; (C) high influence stakeholders and (D) low influence stakeholders in Nacimiento. Statistical significance at the *5% level.

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Table 3
Factor loadings derived from the principal component analysis (PCA) applied to analyze the trade-offs and synergies between ecosystem services based on service-providing units (SPU) in both case studies considering *high* and *low influence stakeholders*.

Case studies		**High influence stakeholders**			**Low influence stakeholders**		
Sierra Morena		F1	F2	F3	F1	F2	F3
Provisioning	Food from agriculture	−0.016	0.015	**0.094**	−0.021	−0.053	**0.120**
	Freshwater	0.064	**0.105**	0.028	0.046	0.007	−0.032
	Livestock	0.091	**0.101**	0.007	**0.077**	−0.057	−0.033
Regulating	Erosion control	**0.166**	0.058	−0.019	**0.071**	0.001	0.014
	Water depuration	**0.151**	−0.073	−0.021	**0.077**	**0.079**	0.044
	Climate regulation	**0.130**	−**0.094**	−0.019	0.055	0.053	0.027
Cultural	Recreational hunting	0.047	−0.044	**0.163**	**0.078**	−**0.077**	0.002
	Nature tourism	0.024	−0.006	0.007	0.045	−0.005	0.008
Land-use	Protected Area	0.039	−0.004	−0.002	**0.040**	0.012	−0.003
	Urban	−**0.004**	0.000	−0.002	−**0.004**	0.000	−0.001
	Agriculture	−**0.149**	0.027	0.024	−**0.128**	−**0.056**	0.039
	Variance accumulated (%)	31,007	46,376	60,430	21,349	36,065	49,687
Nacimiento							
Provisioning	Food from agriculture	0.002	**0.129**	**0.154**	0.085	−0.037	**0.183**
	Freshwater	0.067	**0.118**	−**0.102**	0.071	0.052	−0.057
	Livestock	–	–	–	0.050	**0.090**	0.042
	Energy	−0.007	0.027	0.037	0.005	0.001	0.009
Regulating	Erosion control	**0.180**	−0.027	0.021	0.092	**0.157**	0.048
	Water depuration	0.065	**0.091**	−0.047	**0.181**	−0.077	−0.008
	Climate regulation	**0.168**	−0.043	0.038	**0.181**	−0.077	−0.008
Cultural	Recreational hunting	**0.107**	−0.036	0.012	0.064	**0.094**	−0.076
	Nature tourism	0.043	0.045	−0.042	0.093	**0.102**	−0.096
	Relaxing value	–	–	–	**0.178**	−0.074	−0.008
Land-use	Protected Area	0.084	−0.049	−**0.086**	0.013	0.029	−**0.079**
	Urban	−**0.001**	**0.001**	0.000	0.000	0.000	**0.001**
	Agriculture	−0.036	**0.078**	**0.093**	0.034	−0.024	**0.082**
	Variance accumulated (%)	28,728	44,622	58,990	32,584	50,516	64,181

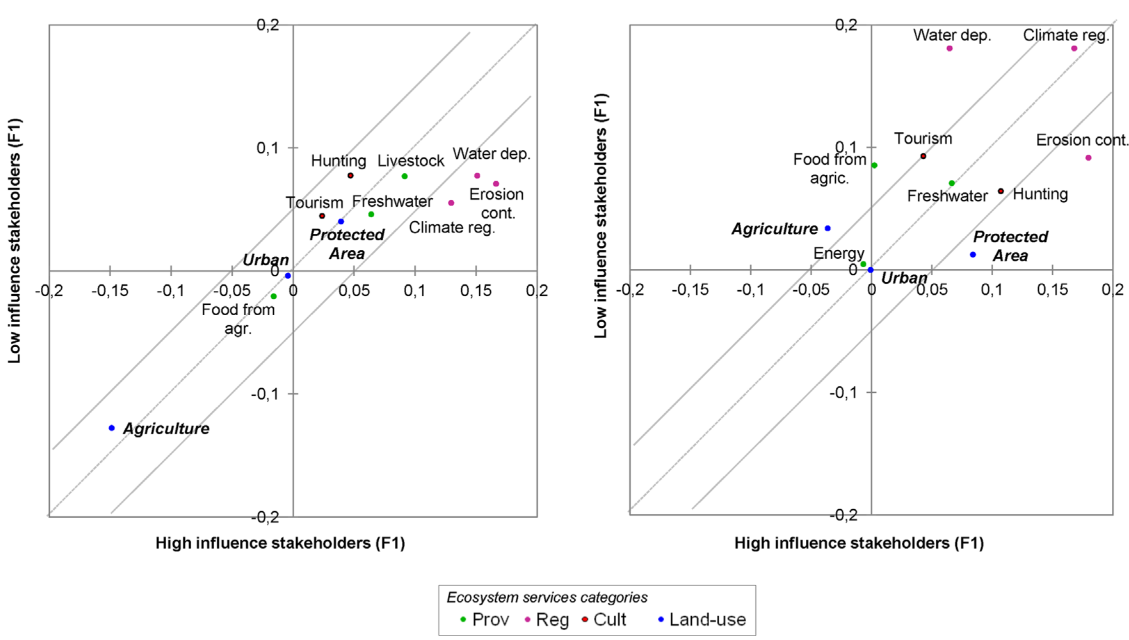

Fig. 8. Scatter-plot of first components emerged from the PCAs (see Table 3) performed in the case of *high influence stakeholders* (*x*-axis) vs. (*low influence stakeholders*) (*y*-axis) in (A) Sierra Morena and (B) Nacimiento.

landscapes and ecosystems" (Plieninger et al., 2013; Ryan, 2011) and, make evident the need of including different stakeholder groups in ecosystem service mapping to capture the diversity of knowledge sources, human-environment relations, and value-systems.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ecoser.2014.11.006.

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