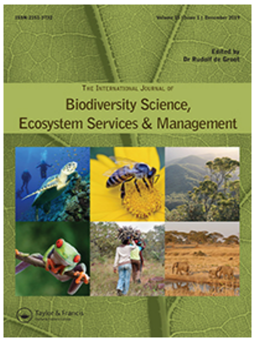

Ecosystems and People

ISSN: (Print) 2639-5916 (Online) Journal homepage: https://www.tandfonline.com/loi/tbsm22

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To cite this article: Ana P. García-Nieto, Elias Huland, Cristina Quintas-Soriano, Irene Iniesta-Arandia, Marina García-Llorente, Ignacio Palomo & Berta Martín-López (2019) Evaluating social learning in participatory mapping of ecosystem services, Ecosystems and People, 15:1, 257-268, DOI: 10.1080/26395916.2019.1667875

To link to this article: https://doi.org/10.1080/26395916.2019.1667875

Published online: 01 Oct 2019.

ECOSYSTEMS AND PEOPLE
2019, VOL. 15, NO. 1, 257–268
https://doi.org/10.1080/26395916.2019.1667875

RESEARCH

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Evaluating social learning in participatory mapping of ecosystem services

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ABSTRACT

Recent studies have shown the opportunities and limitations of participatory mapping for ecosystem services management, although it is an incipient research area. One of the research questions yet to be addressed is whether the composition of stakeholder groups has an effect on the outputs of participatory mapping. In this study, we assessed the influence of group composition on the mapped spatial distribution of ecosystem services. We developed two participatory mapping workshops of the ecosystem service supply and demand in the Nacimiento Watershed (Andalusia, Spain). In workshop 1, stakeholders were uniformly grouped according to their level of influence on land management. In workshop 2, we created mixed groups, with participants having dissimilar levels of influence on land management. The strategy of the second workshop aimed to foster social learning among participants, which was expected to influence the mapping outputs. We compared the outputs regarding the mapped spatial distribution of the ecosystem service supply and demand between the two workshops. Our results suggest that social learning occurred in groups with a mixed composition of participants, affecting the mapped spatial distribution of the supply and demand of ecosystem services. Finally, we discuss that knowledge exchange among participants can be supported through deliberative processes that occur in participatory settings, when stakeholders have different degrees of influence on land management. This can also enrich the assessment of the distribution of ecosystem services.

ARTICLE HISTORY
Received 8 December 2017
Accepted 10 September 2019

EDITED BY
Christian Albert

KEYWORDS
Deliberation; landscape management; participatory GIS (PPGIS); stakeholder diversity; workshop; knowledge exchange

1. Introduction

The participatory mapping of ecosystem services is a relatively new research method that offers a complementary approach to indicators and model-based mapping (Brown and Fagerholm 2015; Fagerholm and Palomo 2017). Participatory mapping has been used to facilitate stakeholders' engagement in landscape management because it provides room for the inclusion of different stakeholders' experiences, knowledge and worldviews (e.g. Brown and Fagerholm 2015; Darvill and Lindo 2015; García-Llorente et al. 2016) while building spatial information for ecosystem services (e.g. Palomo et al. 2013; Plieninger et al. 2013; García-Nieto et al. 2015). Participatory mapping generates information regarding the spatial distribution of ecosystem services and builds awareness about the capacity of different land uses to provide ecosystem services (e.g. Palomo et al. 2014; García-Nieto et al. 2015; Pérez-Ramírez et al. 2019). The design of participatory mapping in terms of the process (i.e. the inclusion of different stakeholders' experiences, knowledge and worldviews) can have effects on the output (i.e. the spatial allocation of ecosystem services and participants' understanding of ecosystem services) and potentially on the outcome (i.e. leverage collective decisions and actions around environmental concerns). In addition, participatory mapping can activate collective memory and promote social learning when the design aims to engage stakeholders in deliberative and learning processes and to foster appreciation of the perspectives and knowledge of other participants.

Social learning has been increasingly recognized as a key feature for landscape, environmental and natural resource management (Berkes 2009; Reed et al. 2010) and for building resilience in social–ecological systems (De Kraker 2017). Despite its essential role, research on social learning reveals a lack of conceptual clarity and empirical evidence (Muro and Jeffrey 2008; Reed et al. 2010; Cundill and Rodela 2012). In fact, the literature on environmental research and management that engages with social learning has often led to different understandings of how social learning occurs and what outcomes it involves (Reed et al. 2010; Cundill and Rodela 2012; Butler et al. 2016). For example, in natural resource management, the term social learning has evolved in alignment with the evolution of management paradigms, from 'command and control' until the end of the 1970s to 'adaptive co-management' in the 2000s (Cundill and Rodela 2012). Whilst social learning was implicitly seen as a domain to guard protected areas in the 'command and control' approach (Holling and Meffe 1996), in

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'adaptive co-management' (Armitage et al. 2008; Folke et al. 2005), social learning was used to engage stakeholders in the learning process through interaction and deliberation to foster appreciation of others' perspectives and knowledge and to promote collective action (Cundill and Rodela 2012). As the concept of social learning became more mainstream in research, confusion about its meaning, operationalization and potential outcomes also increased (Muro and Jeffrey 2008; De Kraker 2017). To counteract this confusion, recent literature has suggested that the processes supporting social learning necessarily entail 'sustained interaction between stakeholders, on-going deliberation and the sharing of their knowledge in a trusting environment' (Cundill and Rodela 2012, p. 7). Likewise, Reed et al. (2010) considered that one of the essential outcomes of social learning is to foster changes in understanding that go beyond the individual and occur through social interactions. These conceptualizations of social learning therefore encompass multiple outcomes, from reaching common understanding (e.g. Schusler et al. 2003; Scholz et al. 2014; Vander Wal et al. 2014) to changing relations between stakeholders by, for example, building more trust to enable collective action (Cundill and Rodela 2012; De Kraker 2017).

In the context of ecosystem services, social learning has been recognized as an essential feature to operationalize ecosystem service research into landscape management (Opdam et al. 2013; Karimi et al. 2015) for two main reasons: (1) it might contribute to enhancing the understanding of the different stakeholders' perspectives on the spatial distribution of ecosystem services, and (2) it might support the creation of trustworthy relationships among stakeholders with different understandings, interests and needs. Different participatory methods can support processes involving the social learning of ecosystem services, such as deliberative valuation, mental models or scenario planning (e.g. Walker et al. 2002; Pahl-Wostl 2006; Palomo et al. 2011; Albert et al. 2012; Oteros-Rozas et al. 2015). However, despite the increasing application of participatory methods in ecosystem service research, it is not clear whether social learning takes place in participatory mapping processes.

In this study, we assessed the extent to which different compositions of stakeholder groups in participatory mapping can affect the resulting maps of ecosystem service supply and demand. In doing so, we developed two participatory mapping workshops of ecosystem services in the Nacimiento Watershed (Andalusia, Spain). In workshop 1, participants were uniformly grouped according to their level of influence on land management (see García-Nieto et al. 2015), and in workshop 2, the groups created had a mixed composition of participants (i.e. stakeholders with dissimilar levels of influence on land management). The second workshop was designed to foster social learning among participants belonging to different stakeholder groups. The outcomes of both workshops were assessed through the resulting maps of ecosystem service supply and demand. Following Reed et al. (2010), we define social learning as a 'change in understanding that goes beyond the individual to become situated within wider social units or communities of practice through social interactions between actors within social networks'. Here, we specifically assessed how the 'understanding' of the spatial allocation of ecosystem service supply and demand changed as a result of different compositions of stakeholder groups in participatory mapping exercises. Therefore, we analysed the potential effect of social learning (in the sense of understanding) by comparing the mapping outputs of the spatial distribution of ecosystem services supply and demand between the two workshops.

2. Study area

The research was conducted in the Nacimiento watershed, which is located in eastern Andalusia in Spain (Figure 1). The area covers 598 km^2 of the Nacimiento River watershed, which is characterized by steep slopes and an altitude ranging from 518 to 2565 masl (meters above sea level). The Nacimiento River borders two mountain ranges, the Sierra de Baza (up to 2269 masl) in the North and the Sierra Nevada (up to 2565 masl in the respective area) in the South. Climatic regions are also diverse, ranging from alpine to semi-arid Mediterranean environments, and include a variety of ecosystems: high mountain pastures, high mountain juniper and brushwoods, rocky areas, oak and chestnut forests, native and reforested coniferous forests, mixed bushes, subdesertic scrubland, watercourses, lagoons and croplands. Approximately 40% of the Nacimiento watershed is protected under the National Park, Natural Park and Biosphere Reserve figures (Blanca et al. 1998). The upper mountainous areas are protected and characterized by subsistence farming (e.g. olive and almond orchards in stone terraces). These areas are undergoing a process of rural abandonment because of the lack of intergenerational renewal, the exodus of people towards urban areas, the low valorisation of local products in markets and remoteness (Quintas-Soriano et al. 2016). By contrast, areas of the valley region have experienced a transformation from subsistence agriculture to intensive agriculture, particularly greenhouse horticulture (García-Llorente et al. 2015; Quintas-Soriano et al. 2016, 2019).

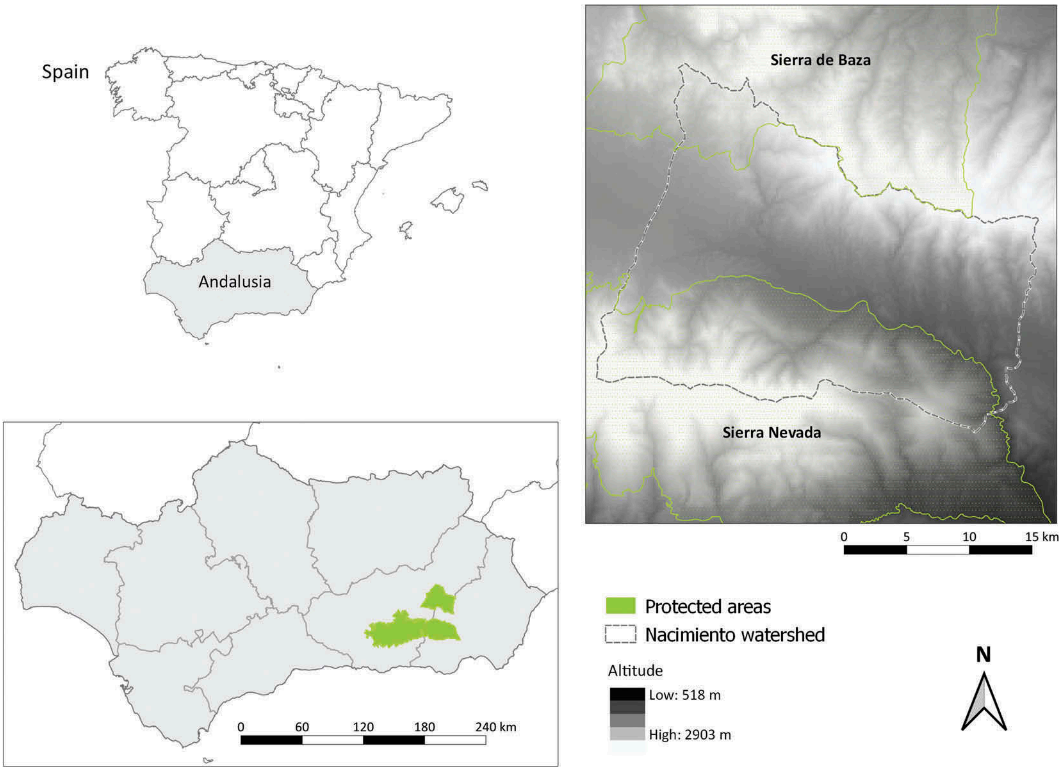

Figure 1. Location of the Nacimiento watershed in Andalusia and Spain. The protected areas of the Sierra de Baza and Sierra Nevada are indicated.

3. Methodology

3.1. Workshops design

3.1.1. Workshop 1: participatory mapping exercise with separate stakeholder groups

Data were collected during the first workshop developed in the valley of the Nacimiento watershed in June 2013. The aim of this workshop was to examine the perception of the mapped spatial distribution of ecosystem services supply and demand considering different stakeholder profiles (García-Nieto et al. 2015). In this workshop, sixteen participants were chosen according to their level of influence in landscape management and their interest in the state of ecosystem services. The individuals involved in the workshop were formerly identified by applying stakeholder analysis techniques, including semi-structured interviews, surveys and the matrix of dependence-influence (García-Nieto et al. 2013; Iniesta-Arandia et al. 2014). Based on the stakeholder analysis and prior to the development of the workshop activities, stakeholders were divided into two groups with uniform compositions of participants: *high influence stakeholders*, defined as those who have a high influence on the decision-making processes of local and regional landscape management (e.g. representatives of the municipalities, environmental and protected area managers and researchers) and *low influence stakeholders*, defined as those who have low influence on the decision-making processes of local and regional landscape management (e.g. local farmers, hunters or forestry labourers). Although both groups were characterized by a high interest in the state of ecosystem services in the Nacimiento watershed, they differed in their capacities to influence local landscape management (Iniesta-Arandia et al. 2014). During the workshop, we split the attendants into five groups: two groups of *high influence stakeholders* and three groups of *low influence stakeholders*. We did not intend to generate power imbalances but simply to differentiate between those participants 'officially' working for the local management and those who were not.

Each group was asked to map eight different ecosystem services. These ecosystem services included provisioning (i.e. food from agriculture and freshwater), regulating (i.e. erosion control, climate regulation and water depuration), and cultural ecosystem services (i.e. nature tourism and recreational hunting). Also, an additional ecosystem service was freely chosen by each group. In this case, the services chosen were livestock, energy (i.e. wind power, solar energy and biomass-based fuels) and relaxing values (Figure 2) (García-Nieto et al. 2015).

In the first workshop, mapping exercises were developed to compile knowledge about the supply and demand of ecosystem services of stakeholders with similar levels of influence. First, stakeholders mapped the areas where, according to their knowledge, each of the above-mentioned ecosystem services is supplied by the ecosystems of the Nacimiento watershed. Then, participants mapped the areas where they perceive each service is demanded by people. We therefore

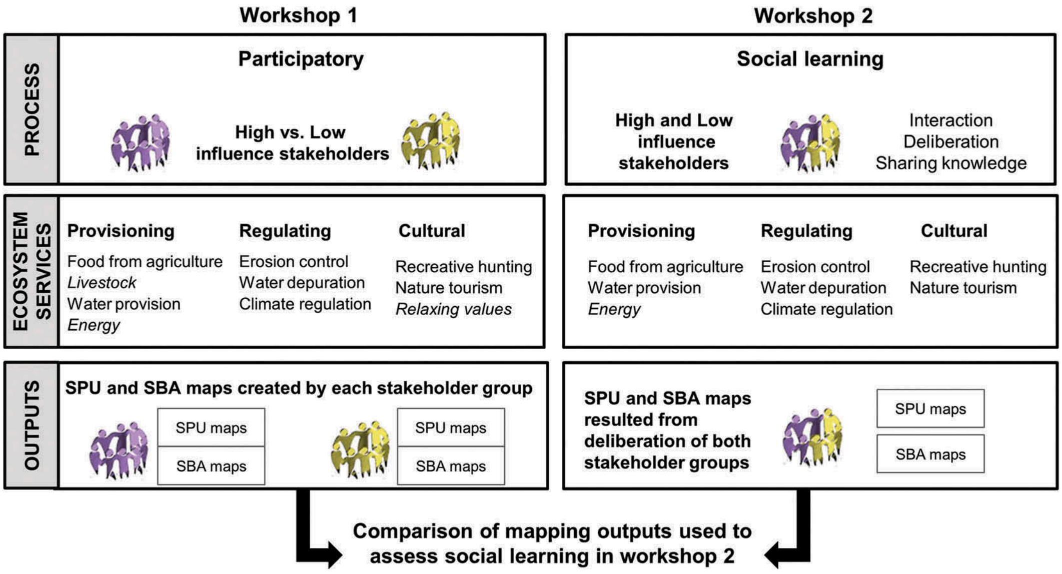

Figure 2. Overview of the methodological framework employed and allocation of specific ecosystem services to ecosystem service categories (ecosystem services in italic typeface correspond to the eight ecosystem services freely chosen by each subgroup in W1). (W1 refers to workshop 1; W2 refers to workshop 2). Figure adapted from Pahl-Wostl (2006).

used the concepts of service-providing units (SPUs) and service benefiting areas (SBAs). SPUs refer to the locations where ecosystem structures and processes provide ecosystem services (Luck et al. 2009; García-Nieto et al. 2013), and SBAs refer to the locations of beneficiaries who demand and use ecosystem services (Syrbe and Walz 2012; Palomo et al. 2013).

The mapping exercise was conducted using a paper-based method (using a topographic map) because this approach has been identified as the most feasible method for use in workshops (Pocewicz et al. 2012). Participants in each group received a set of dots (i.e. moveable plastic discs in green and blue colours with two sizes each for accuracy) to map the locations of SPUs (90 green dots) and SBAs (90 blue dots) on a topographic map (1:10.000). They could freely allocate as many dots as they needed to indicate the presence of SPUs and SBAs for each ecosystem service. During the whole process, a facilitator was present to guide the process and to clarify the doubts and questions of participants. After each ecosystem service was mapped, a photo from the zenith of the map centre was taken with a Digital Single Lens Reflex camera (see García-Nieto et al. 2015 for further details).

3.1.2. Workshop 2: mapping exercise with mixed stakeholder groups

We conducted a second workshop five months after the first workshop, in November 2013, in the same place. Fourteen stakeholders participated in this workshop, of whom eleven had already been part of the first one. Seven participants were *high-influence stakeholders*, and seven were *low-influence stakeholders*. In this follow-up workshop, we conducted the same mapping exercises, but with the purpose of promoting social learning between the two groups of stakeholders. We created four groups of stakeholders with dissimilar levels of influence in which *low* and *high influence stakeholders* were mixed to foster sustained interaction, deliberation and the sharing of their knowledge regarding the spatial locations of the supply and demand of ecosystem services. Each group was comprised of three or four participants, of which at least one and not more than two participants belonged to either the *high-* or *low-influence stakeholders*. To build a trusting environment, each group discussion was facilitated. Following the same dynamics as the first workshop, when we opened the sessions, we explained the ecosystem service concept, the difference between supply (and SPUs) and beneficiaries (and SBAs), the participatory mapping technique and the steps to be undertaken. In any case, we did not explicitly reveal to the participants the aim of comparing the mapping outputs obtained in both workshops to avoid bias. Participants first mapped SPUs and then SBAs for each ecosystem service. The only methodological difference was that the eighth ecosystem service to map was clean energy because it was the only one selected by both *high-* and *low-influence stakeholders* in the first workshop (García-Nieto et al. 2015).

3.2. Data analysis

We georeferenced the photographs taken in both workshops in ArcMap (using ArcGIS 10) and created polygon shapefiles that covered the dots indicating SPUs and SBAs for each ecosystem service. Then, shapefiles were converted into grid format and extracted to a point grid. The regular point grid had a point-distance of 50 metres, with a total of 796,470 points. The grids of each ecosystem service in the two workshops were aggregated to represent maps of SPUs and SBAs for provisioning (food), provisioning (non-food), regulating, and cultural ecosystem services. We decided not to overlap water provision and food from agriculture into the category of provisioning services because of their distinct nature and the different ecological structures and processes involved in their supply. We therefore obtained four maps (food, non-food, regulating and cultural ecosystem services) of SPUs in the first workshop (participatory workshop) and four maps of SPUs in the second workshop (social learning workshop). Likewise, we obtained four maps of SBAs derived from workshop 1 and four other maps of SBAs from workshop 2 (Figure 2).

We tested autocorrelation in each SPU and SBA map using Moran's index (Moran 1950). Because autocorrelation was significantly positive (~0.95) for the SPUs and SBAs of all ecosystem service categories, we randomly selected 10% of the point grid (as proposed by Willemen et al. (2010)), which resulted in 79,647 grid points. We then calculated the density of dots, i.e. number of dots per km^2, to compare the outputs between workshops 1 and 2. We performed the non-parametric Friedman test to compare the dots' densities between the maps obtained in workshops 1 and 2.

We then created hotspot maps of SPUs and SBAs for the four categories of ecosystem services for each of the workshops. We classified areas of SPUs and SBAs based on (1) areas that were only identified in workshop 1 by either *high* or *low influence stakeholders*, (2) areas identified only during workshop 2, (3) areas identified during workshop 2 and by one of the stakeholder groups in workshop 1, either *high* or *low influence stakeholders*, and (4) areas identified during workshop 2 and by both stakeholder groups (*high* and *low influence stakeholders*) in workshop 1.

Last, we compared the SPUs and SBAs of each ecosystem service mapped in workshop 2 with the distribution of SPUs and SBAs mapped in workshop 1, considering whether the SPUs and SBAs were mapped by *high influence stakeholders* or by *low influence stakeholders*. We used the non-parametric Friedman test for the comparisons of mapped spatial distribution of SPUs and SBAs between workshop 1, considering both groups of stakeholders (*high* and *low influence stakeholders*) and workshop 2. We also calculated the area shared by the SPU and SBA maps of provisioning (food), provisioning (non-food), regulating, and cultural ecosystem services between the maps created by (1) *high-* and *low-influence stakeholders* in workshop 1; (2) *high-influence stakeholders* in workshops 1 and 2; and (3) *low-influence stakeholders* in workshops 1 and 2.

4. Results

Overall, SPU maps presented higher dot densities than SBA maps (Figure 3). Regarding SPU maps, the average dot density used to map non-food provisioning and cultural ecosystem services SPUs by the participants in workshop 2 was higher than in the maps created by *high-* or *low-influence stakeholders* in workshop 1 (Figure 3(a,b)). However, there were no significant differences in the average dot density for SPUs (Friedman test, p-value = 0.0724; Table 1). By contrast, maps of SBAs resulting from workshop 2 had a significantly higher numbers of dots than the SBAs maps created by *high-influence stakeholders* during workshop 1 (Friedman test, p-value = 0.0022; Table 1).

The average density of dots used by participants in workshop 2 to map SBAs for all the categories of

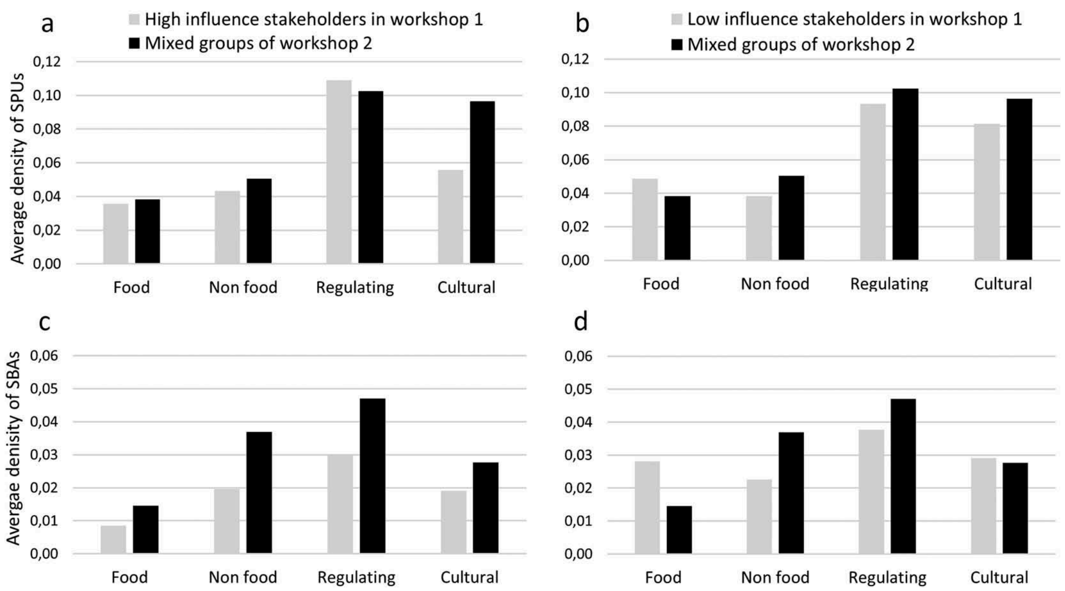

Figure 3. The average density of dots used by the groups in workshop 2 compared to the average density of dots used by *high influence* stakeholders (a, c) and *low influence* stakeholders (b, d) in workshop 1 for mapping service providing units (SPUs, a, b) and service benefitting areas (SBAs, c, d). Note that the Y-axes are different between the bar diagrams of SPUs (a, b) and SBAs (c, d).

Table 1. Results of Friedman test that compare the average density of dots for service providing units (SPUs) and service benefiting areas (SBAs) of ecosystem services between the maps developed in workshop 2 and the maps developed by high and low influence stakeholders in workshop 1. Mean values marked with the same letter are not significantly different (Dunn's test; $p<0.05$).

			Friedman test			
	Workshop	Type of stakeholder	*Mean*	*SD*	*Q*	*p-value*
SPU	1	Low influence stakeholders	0.028^{A}	0.008	5.25	0.0724
		High influence stakeholders	0.030^{A}	0.009		
	2		0.031^{A}	0.006		
SBA	1	Low influence stakeholders	0.012^{A,B}	0.003	12.25	0.0022
		High influence stakeholders	0.009^{A}	0.001		
	2		0.016^{B}	0.004		

ecosystem services was higher than the average dot density used by *high-influence stakeholders* in workshop 1 (Figure 3(c)). The only exception was that the SBAs for food and cultural ecosystem services were mapped with more dots by *low-influence stakeholders* in workshop 1 than in workshop 2.

Figure 4 shows the spatially explicit differences of the distribution of the SPUs for provisioning food and non-food, regulating and cultural ecosystem services between the maps obtained in workshops 1 and 2. Concerning the provision of food, the valley areas of the Nacimiento watershed were mapped as SPU by the two groups of stakeholders (i.e. *high* and *low influence stakeholders*) during the two workshops. However, when stakeholders mapped the SPUs for food in workshop 1, they were able to identify more SPUs in the forest areas of the Nacimiento watershed.

For the non-food provisioning service of freshwater provision, the overlap of SPUs derived from both workshops was very low. The maps developed in workshop 1 by *high-* and *low-influence stakeholders* showed a high density of dots in the high mountains of Sierra Nevada, representing the traditional irrigation ditches, while the maps derived from workshop 2 showed many new SPUs of freshwater in the valley plains, indicating other types of traditional ditches located under the riverbeds that are less known and protected as they are located outside of the Sierra Nevada protected area.

Regarding regulating services, the SPUs were mapped in the two workshops and by both stakeholder groups at the mountain peaks of Sierra Nevada and its northern slopes, which consist of forests and traditional agriculture allocated in terraces. Maps derived from workshop 2 showed a higher density of dots on the southern slopes of the Sierra Nevada and all over the Sierra de Baza mountains, while maps derived from the independent work of *high-* and *low-influence stakeholders* in workshop 1 presented more dots in the Nacimiento River plains. Finally, for cultural ecosystem services, similar results were obtained in the maps from both workshops, as participants mainly mapped the northern slopes of the Sierra Nevada, where the hiking, horse-riding and biking routes are established.

The maps of SBAs show that the demand and use of ecosystem services were clustered in few areas of the Nacimiento watershed, particularly around urban settings (Figure 4). SBAs of food were mostly mapped in the valley by participants in both workshops; although, participants from workshop 2 also placed dots in the southern slopes of the Sierra Nevada Mountains. The non-food provisioning service of freshwater was mapped considerably more often in workshop 2, especially in the valley of the Nacimiento River. Participants in workshop 2 also used more dots to identify areas benefiting from regulating services, which were scattered throughout the whole watershed. Finally, areas benefiting from cultural ecosystem services were mapped similarly by participants in both workshops.

The degree of overlap in the area mapped for representing SPUs and SBAs of provisioning (food and non-food), regulating, and cultural ecosystem services between (1) *high influence stakeholders* and *low influence stakeholders* in workshop 1; (2) *high influence stakeholders* of workshop 1 and mixed groups of workshop 2; and (3) *low influence stakeholders* in workshop 1 and mixed groups in workshop 2 is presented in Figure 5. For all SPUs and SBAs, the overlap between the maps resulting from workshop 2 and the maps resulting from workshop 1 for both *high* and *low influence stakeholders* was higher than the overlap between the maps created by the *high* and *low influence stakeholders* in workshop 1 (Figure 5). This indicates that considerable knowledge exchange occurred during workshop 2, which was purposely designed to foster social learning between *high* and *low influence stakeholders*.

5. Discussion

5.1. Methodological challenges

The evaluation and characterization of social learning remain methodological challenges in the current literature. In this study, we developed a participatory exercise to test whether social learning contributes to enhancing ecosystem services maps derived from participatory mapping. Although we developed an innovative approach, several challenges persisted in the methodol-

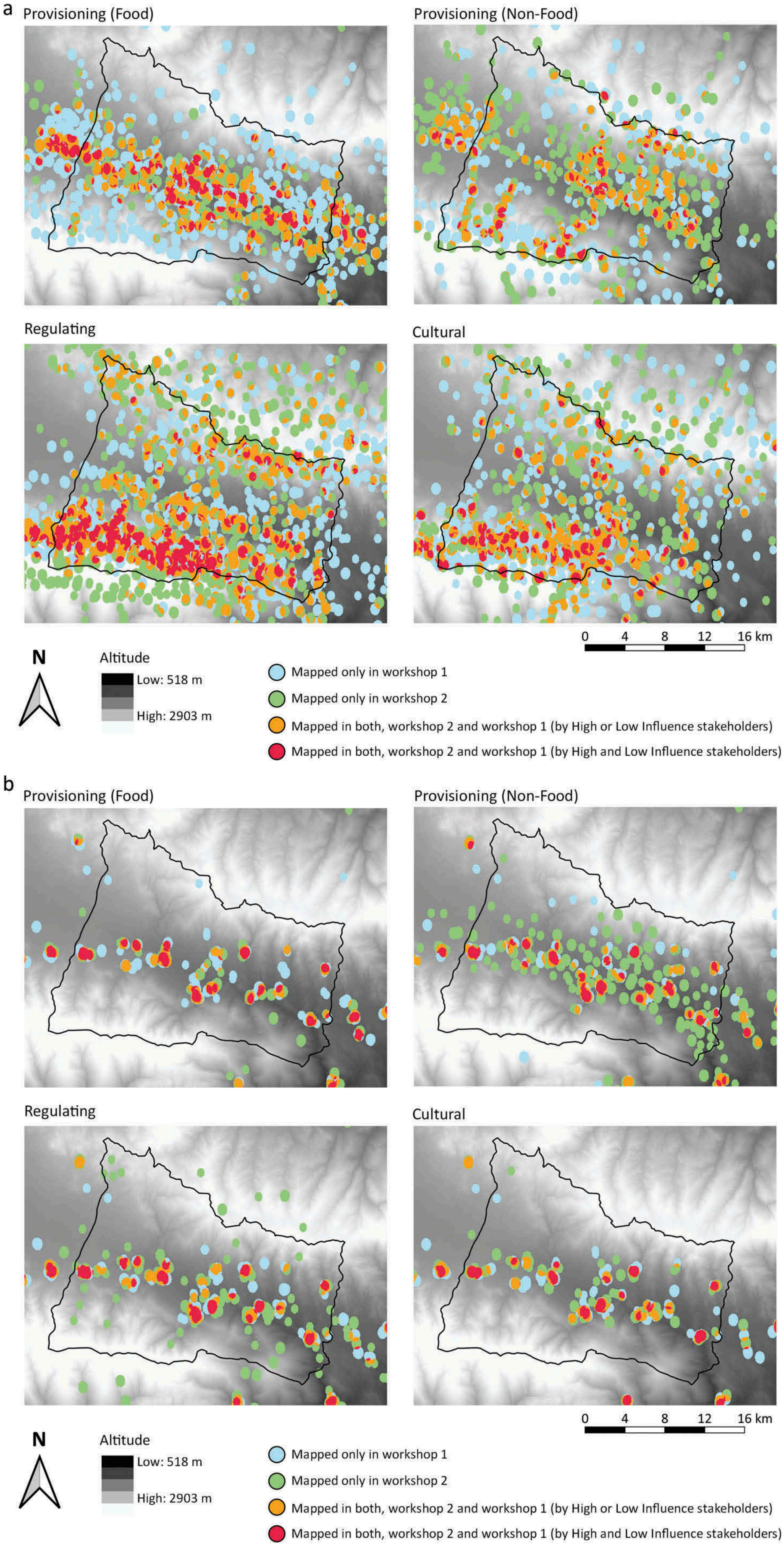

Figure 4. Level of match between the maps developed by *high* and *low influence* stakeholders during workshops 1 and 2 for (a) service providing units (SPUs) and (b) service benefitting areas (SBAs).

ogy we adopted. First, organizing two workshops with the same stakeholders entailed a large amount of economic and time resources, not only for researchers (Jacobs et al. 2018), but also for the participants, who normally had to take a day off from their commitments. This is possibly the reason why only fourteen and sixteen participants attended the first and second workshops, respectively, from a total of twenty-five stakeholders invited. We aimed to minimize the possibility of underrepresentation of a certain stakeholder group by carefully selecting participants with diverse backgrounds and by having an even representation of *low-* and *high-influence stakeholders*. By contrast, having small groups in participatory mapping can enhance the engagement of all participants and the process of sharing perspectives and knowledge. Second, engaging the same individuals (eleven participants) in both workshops can lead to stakeholders' fatigue, which has been recognized by previous research on participatory methods (e.g. Leitch et al. 2015). However, we did not evaluate the effect of stakeholders' fatigue during workshop 2. Third, there can be some biases associated with the fact that this research entails two subsequent workshops. As the first workshop took place in summer and the second workshop took place in late autumn, the change in season might entail a different perception of the spatial distribution of ecosystem services, as these are enjoyed differently during different seasons. In addition, after workshop 1, participants could have exchanged opinions with other individuals about ecosystem services and landscape management that would prevent us from concluding that social learning only occurred during workshop 2. Finally, we are also aware that some social learning occurred through informal discussions in both workshops that was not represented by the resulting maps. We are also aware that some of the discussions occurring in both workshops went beyond the spatial distribution of ecosystem services and included landscape management history or influence of different drivers of change on the provision of ecosystem services (e.g. droughts, land-use intensification or rural abandonment) (Iniesta-Arandia et al. 2014; García-Llorente et al. 2015). This is particularly interesting and desirable as this create opportunities for in-depth discussions to enhance the collective memory of the land-use changes occurring a particular area as a first step to reflect about future land-use pathways (Pérez-Ramírez et al. 2019).

5.2. The influence of social learning in the participatory mapping of ecosystem services

Social learning takes place in participatory workshops, such as participatory scenario-based landscape planning (Albert et al. 2012), and participatory workshops around ecosystem services can promote social learning (Fürst et al. 2014). However, to the best of our knowledge, this is the first study that specifically assessed how social learning can affect the outputs of the participatory mapping of ecosystem services by comparing two participatory mapping workshops designed with different compositions of stakeholder groups.

Recent literature shows that stakeholders' knowledge about ecosystem services is not equal for all service categories and that stakeholders may have different perceptions, expectations and priorities regarding ecosystem services (e.g. Iniesta-Arandia et al. 2014; García-Nieto et al. 2015). For example, regulating services have been less elicited by stakeholders when participatory approaches are used (Lewan and Söderqvist 2002; Hartter 2010), including participatory

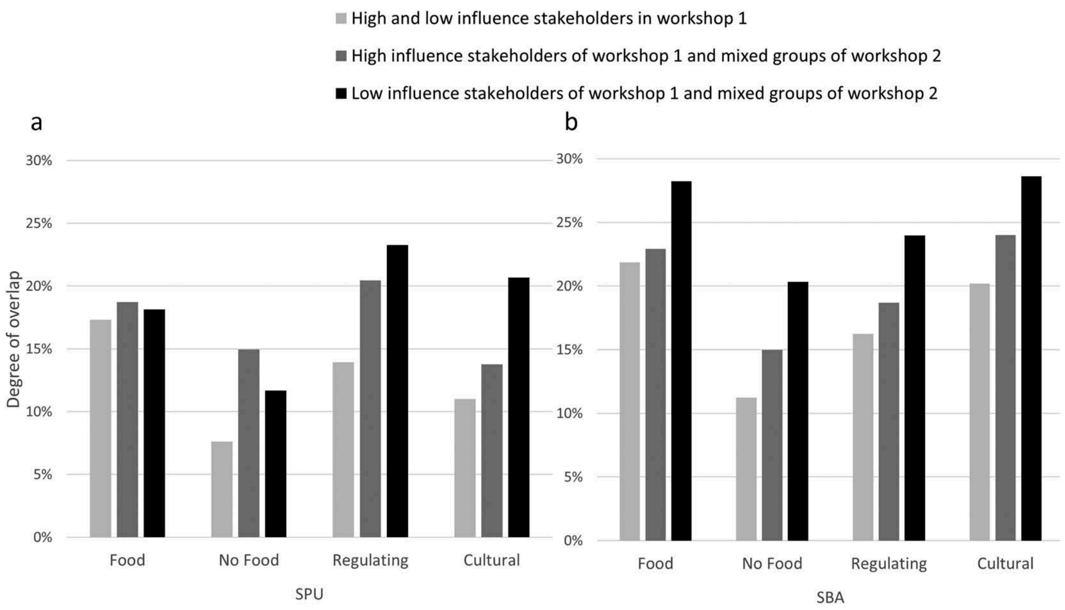

Figure 5. Degree of overlap (percentage of area) between maps for SPUs (a) and SBAs (b) created by *high influence* stakeholders and *low influence* stakeholders in workshop 1 (light grey bar), maps created by *high influence* stakeholders in workshop 1 and during workshop 2 (grey bar) and maps created by *low influence* stakeholders in workshop 1 and during workshop 2 (dark grey bar).

mapping (Raymond et al. 2009; Brown et al. 2012; Klain and Chan 2012). Our results confirm these previous findings to a great extent: while all stakeholders mapped food provisioning SPUs similarly in both workshops, there were differences in SPUs for regulating and cultural ecosystem services between both workshops (Figure 5). These differences demonstrate that during workshop 2, a change in the stakeholders' understanding of the geographical distribution of SPUs for regulating and cultural services occurred.

Regarding regulating services, stakeholders identified the northern slopes of the Sierra Nevada mountains as important SPUs in both workshops, including *high* and *low influence stakeholders* in workshop 1 (Figure 4). The forests located in this area provide erosion control and climate regulation, and irrigation ditches and riparian forests provide water purification for downstream flows (García-Llorente et al. 2015, 2016). Despite the agreement on the importance of the northern slopes of the Sierra Nevada mountains as SPUs of regulating services between stakeholders and workshops, new SPUs were largely identified in the summits of the Sierra Nevada and Sierra de Baza mountains during workshop 2, irrespective of the stakeholders' level of influence in decision-making (Figure 4).

Regarding cultural ecosystem services, we found that workshop 2 led to a wider spatial distribution of SPUs. This can be explained because the exchange of knowledge of different stakeholders in workshop 2 about the supply of cultural ecosystem services might have provided a richer picture of the spatial distribution of SPUs than in workshop 1. In the first workshop, *high-* and *low-influence stakeholders* mapped rather different areas (e.g. *low-influence stakeholders* mapped SPUs in the southern part of the Sierra Nevada, and *high-influence stakeholders* mapped SPUs in the Sierra de Baza (García-Nieto et al. 2015)), but during workshop 2, participants identified other places as relevant for the provision of cultural ecosystem services (Figure 4). While in the case of regulating services a discussion take place to select the most suitable areas for SPUs and SBAs, which usually implies compromises and decisions. In the case of cultural services the social component and individual subjectivity that mediate their perception (as SPU and SBA) is larger. So, in the case of cultural services mapping, a compromise is not taken, but all potential pinpoint areas are included from an inclusive and open view.

Significant differences were also observed for the mapped spatial distribution of SPUs and SBAs of non-food provisioning services (Figures 3 and 5). Most of these differences were placed on agricultural areas of the valley, which were only mapped during workshop 2 (Figure 4). In the first workshop, SPUs of freshwater were only detected in some spots of the Sierra Nevada summits and in creeks flowing down its northern slopes, and in the surrounding towns in the valley, SBAs were only identified in the towns themselves and in very few isolated settlements (Figure 4). However, by fostering social learning in workshop 2, participants were able to identify new SPUs and SBAs along the valley and in different streams of the slopes of the Sierra Nevada and Sierra de Baza Mountains (Figure 4).

Our results suggest that participatory mapping exercises, in which participants belonging to different stakeholder groups can interact, deliberate and share their own knowledge in a trusting environment, lead to social learning regarding the distribution of SPUs and SBAs of ecosystem services. Fostering social learning through participatory mapping might also have other advantages, such as translating, mediating, and visualizing (Jeantet 1998; Castella 2009). First, this research shows that the knowledge of each stakeholder group was translated into maps, allowing all participants to share the same communication tool. Second, the existing differences between *high-* and *low-influence stakeholders* that were found in workshop 1 were dissipated by fostering social learning in workshop 2. Thus, participatory mapping can contribute to mediation in settings where different stakeholders express different ideas, knowledge and perceptions. Finally, maps provide visual outputs of the workshop process and can be easily understood and consulted by different stakeholders. Consequently, participatory mapping can be a successful tool for generating an enriched picture of the distribution of ecosystem services by enhancing the legitimacy and relevance of different stakeholders' perspectives and knowledge (Tengö et al. 2014; García-Llorente et al. 2016). The positive effects not only derive from changing the understanding and knowledge of stakeholders but also from increasing their involvement in the participatory mapping, which can lead to their engagement in landscape management (Brown and Kyttä 2014).

Although participatory mapping has been used as a diagnostic tool in ecosystem services research (Brown and Fagerholm 2015), our results show that it can also contribute to change and enrich the understanding of multiple stakeholders regarding the distribution of ecosystem services and potentially foster collaboration for landscape management. As such, the potential of participatory mapping to identifying priorities, opportunities and conflicts through the stakeholder's groups involvement could be an opportunity to addressing gaps in the decision-making process.

6. Conclusions

Although the participatory mapping of ecosystem services has been increasingly applied to explore the spatial distribution of ecosystem services (Brown and Fagerholm 2015), this is the first study that assesses the potential role of social learning in participatory mapping by comparing the outputs of two participatory mapping workshops. In this research, we assessed the changes in understanding regarding the geographical distribution of the SPUs and SBAs of provisioning, regulating and cultural ecosystem services for two stakeholder groups involved in two participatory mapping workshops. Workshop 1 was purposely designed with a uniform composition of stakeholder groups, where similar groups of *high-* or *low-influence stakeholders* independently mapped SPUs and SBAs without interacting. In workshop 2, we intended to foster social learning between *high-* and *low-influence stakeholders* by creating mixed groups of stakeholders with dissimilar levels of influence. In the second workshop, we guaranteed that the main characteristics of the social learning process (i.e. interaction between stakeholders, on-going deliberation and knowledge sharing in a trusting environment (Cundill and Rodela 2012)) were achieved. By comparing the outputs of the two workshops in terms of SPU and SBA maps, we found that knowledge regarding the geographical distribution of SPUs and SBAs was enriched in workshop 2. Precisely, this change in the understanding of the stakeholders involved in deliberative processes is considered one of the main outcomes of social learning (Reed et al. 2010). Consequently, we can conclude that participatory mapping exercises that promote discussion between participants belonging to different groups of stakeholders can foster social learning, enhance participants' knowledge regarding the distribution of ecosystem services and potentially encourage their collaboration for landscape management.

Acknowledgments

We thank Dr. Christian Albert, as the assigned editor, and two anonymous reviewers for their constructive and useful comments. Funding for the development of this research was provided by the Seventh Framework Programme of the European Commission (FP7, 2007–2013) under the OpenNESS Project (Operationalization of Natural capital and Ecosystem Services: From concepts to real-world applications; Contract No. 308428). IIA acknowledges financial support from the Spanish Ministry of Sciences, Innovation and Universities, through the "Juan de la Cierva-Incorporación" program (Grant IJCI-2017-33405) and the "María de Maeztu" program for Units of Excellence (MDM-2015-0552). IP was funded by the Ministry of Economy and Competitiveness of Spain (Grant FJCI-2014-20236). APGN appreciates very deeply all those great years working near to all the colleagues and friends who showed her another way of living science. We express our sincere gratitude to all the workshops' participants for their engagement and kindness. We also appreciate the support in different stages of this research of the Social-Ecological Systems Laboratory, particularly Violeta Hevia, Elisa Oteros-Rozas and Federica Ravera.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research has partially been funded by the European Community's Seventh Framework Programme (FP7/2007-2013) under grant number 308428, OpenNESS Project (www.opennessproject.eu).

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