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Methods

Characterising the rural-urban gradient through the participatory mapping of ecosystem services: insights for landscape planning

Sara Palomo-Campesino[‡,§], Ignacio Palomo[|,§], Javier Moreno[¶,#], José A. González[§]

‡ Departamento de Investigación Aplicada y Extensión Agraria, Instituto Madrileño de Investigación y Desarrollo Rural, Agrario y Alimentario (IMIDRA), Ctra. Madrid-Barcelona (N-II) KM. 38.200, 28802, Madrid, Spain
§ Laboratorio de Socioecosistemas, Departamento de Ecología, Universidad Autónoma de Madrid, C/ Darwin 2, Edificio de Biología, 28049, Madrid, Spain
| BC3-Centro Vasco para el Cambio Climático, Edificio 1, primera planta, Campus de la Universidad del País Vasco, 48940, Bilbao, Spain
¶ Grupo de Investigación Social y Acción Participativa, Universidad Pablo de Olavide, Carretera de Utrera km 1, 41013, Sevilla, Spain
# Pasos, Participación y Sostenibilidad. Avenida Francisco Ayala 79, 18014, Granada, Spain

Corresponding author: Sara Palomo-Campesino (sara.pal.cam@gmail.com)

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Abstract

The application of the ecosystem services (ES) framework in landscape planning has become particularly relevant in rural-urban gradients since it allows for the integration of the complex interactions between ES supply and demand. This framework might be a powerful tool to inform landscape planning and decision-making intended to maintain the current and future flow of ES. In this study, we developed a process of participatory mapping of ES in a rural-urban gradient in southern Spain, which comprises the Sierra Nevada mountain range, the Granada valley and the city of Granada. First, we interviewed 21 key stakeholders from different professional sectors and gradient zones. These stakeholders prioritised nine ES in terms of their importance for local human well-being and their vulnerability to current drivers of change. Then, a workshop was organised in which 23 local actors shared their experience and knowledge regarding ES in the studied landscape. Sorted into five groups (composed of stakeholders with different profiles), the participants spatially mapped the most important supply and demand areas for the nine ES previously prioritised. The results show that the city of Granada has a very high demand for ES and a very low supply, while the Sierra Nevada mountain range and the valley of Granada appear to be very important ES supply areas. According to 95% of the stakeholders that attended the workshop, participatory mapping of ES is a very important (69%) or an important (26%) methodology to elicit the views and perceptions of the population, to identify the main conflicts and potential solutions for the territory and to visualise the high dependence of urban areas on the ES provided by adjacent rural areas. Our results also highlight the importance of incorporating the analysis of ES flows to inform landscape planning at the regional scale. Participatory mapping of ES can enhance decision-making regarding the maintenance of human well-being and the sustainability of social-ecological systems.

Keywords

Ecosystem services, landscape planning, participatory mapping, rural-urban gradient, supply-demand

Introduction

Broadly defined as “the benefits people obtain from ecosystems” (MA (Millennium Ecosystem Assesssment) 2005,Pascual et al. 2017b), the ecosystem services (ES) concept has become widely developed within academic and political arenas over the last two decades (Radford and James 2013), particularly after the publication of the Millennium Ecosystem Assessment and the implementation of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Further, the ES framework has gained relevance within landscape planning policies intended to maintain social-ecological systems sustainability and human well-being (Crossman et al. 2013b).

The ES framework has demonstrated itself to be particularly useful for analysing the dynamics of rural-urban gradients (Martín-López et al. 2012,Yang et al. 2015). Worldwide, there is an increasing migration of population from rural to urban areas (Gutman 2007) and it is expected that, by the year 2030, 60% of the world's population will live in cities of over 75,000 inhabitants (Sørensen 2014). Consequently, humans are increasingly interacting less frequently with nature and the conception that urban areas do not depend on ecosystems is expanding (Soga and Gaston 2016,Gómez-Baggethun and Barton 2013). Since cities are usually important areas that demand ES (Kroll et al. 2012), there is a crucial need to make visible the relationship between rural and urban areas in order to make people aware of their own dependence on ecosystems and to ensure the maintenance of ES flows along rural-urban gradients.

In this context, mapping ES can be a useful tool to make rural-urban relationships visible since it allows the integration of complex information through the identification of the main supply and demand areas of ES within the territory (Egoh et al. 2008,Palomo et al. 2013). Although mapping ES has been rarely applied to policy-making and landscape planning, there are some cases where it has successfully influenced decision-makers (Barton et al. 2017,Saarikoski et al. 2017). Taking into account the supply and demand of ES allows the identification of those areas where demand is greater than supply, so certain human needs may not be satisfied. This consideration could also provide new information to include in decision-making and policy implementation (Baró et al. 2016Crossman et al. 2013b).

Further, including participation in ES mapping methodologies largely improves the visibility and awareness of the dependence of society on ecosystems (Klain and Chan 2012). Participatory mapping of ES relies on local stakeholders' knowledge. Stakeholders identify the benefits and indispensable elements of their environment and indicate the values they attribute to the territory (Nahuelhual et al. 2013). Therefore, although participatory mapping may not provide absolutely precise geographical information like other ES mapping techniques (e.g. InVEST, ARIES, ESValue etc.), it provides valuable information that otherwise would be dificult to obtain about the ES perceived by local stakeholders as relevant for their own well-being (van Oort et al. 2015). This brings a more realistic view of ES flows since the actual essence of ES is to provide benefits to populations (Fagerholm et al. 2012). Aditionally, participatory mapping can empower the local stakeholders through the inclusion of their views and aspirations in decision-making processes (Klain and Chan 2012). It can can also facilitate the interaction between key stakeholders and build trust and shared knowledge amongst them (Saarikoski et al. 2017). Therefore, mapping ES with participatory techniques can provide crucial perception-based information to decision-makers, facilitating the inclusion of human well-being and the sustainability of ecosystems through new policies (Hauck et al. 2013).

In this paper, we aim to uncover the existing relationships between ES supply and demand areas along a rural-urban gradient that comprises the Sierra Nevada mountain range, the Granada valley and the Granada city (southern Spain). By means of a participatory mapping workshop, we explored the existence of differences in the supply and demand of nine ES amongst different land use protection categories, municipality typologies and altitude intervals. Finally, drawing on the evaluation made by the local stakeholders who participated in the process, we analysed the strengths and weaknesses of participatory mapping, providing insights for a new integrated landscape planning model.

Methods

Study area

This study was conducted in a rural-urban gradient in southern Spain that comprises the Alto Genil watershed, including part of the Sierra Nevada mountain range, part of the Granada valley and the city of Granada (Fig. 1). The study area comprises 32 municipalities and nearly 113,130 hectares. Altitude along the gradient varies from 500 metres a.s.l. in the Granada valley to 3,400 metres a.s.l. in the highest peaks of the Sierra Nevada mountain range.

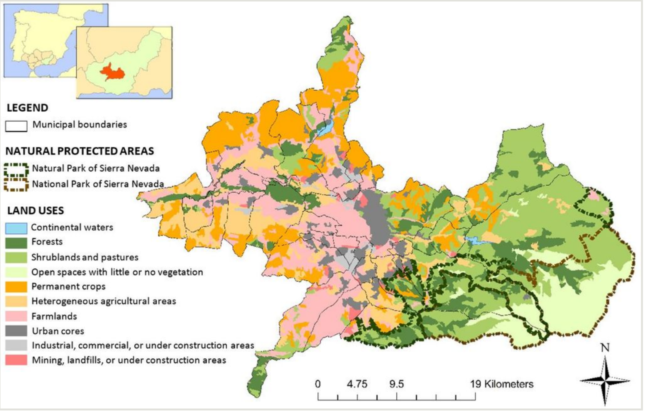

Figure 1.

Map of the study area.

Within the mountain range, two natural protected areas are present: the Sierra Nevada Natural Park, which was designated in 1989 and the Sierra Nevada National Park, which was designated in 1999, with 13,057 and 17,817 hectares respectively. While in the Sierra Nevada National Park, anthropic activities are highly restricted, the Sierra Nevada Natural Park conservation policies are less strict, allowing traditional practices such as livestock raising and important economic activities such as the Sierra Nevada ski resort (García-Nieto et al. 2013). The Sierra Nevada protected areas have the greatest diversity of plant species in the Iberian Peninsula (over 2,200 taxon) (Junta de Andalucía 2011), although they have suffered important land use changes from cereal crops, pastures and Mediterranean shrublands to coniferous plantations during the 1950s (Abellán 1981,Padilla et al. 2010). The Sierra Nevada protected areas are also characterised by the confluence of multiple land uses, such as tourism and agriculture (Junta de Andalucía 2011) and their function as a natural water reservoir for human consumption and agriculture in the lowlands (Moreno et al. 2014).

The Granada valley has historically been one of the most productive areas of Spain and directly depends on the Sierra Nevada mountain range water reservoir. There are three remarkable periods in the history of the Granada valley based on the dominant crops: flax and hemp (18th-19th centuries), beetroot (20th century) and tobacco (20th century) (Menor Toribio 2000). This situation changed during the 1950s and specially from the 1970s until today, when massive migrations from rural to urban areas occurred due to the loss of agriculture economic potential (Villegas Molina and Sánchez del Árbol 1997). These migrations favoured an urban expansion along peri-urban areas, leading to the destruction of rural community structure, the degradation of agrarian landscapes, the loss of local identity and the occupation of fertile areas by built infrastructure (Menor Toribio 1997).

The city of Granada is the fourth largest town in Andalusia and the sixteenth in Spain with over 230,000 inhabitants. Granada comprises 8,802 hectares, which is only 0.7% of the total surface area of the Province of Granada, but harbours 25.6% of the total population. This, combined with the fact that 30.3% of the population lives in peri-urban municipalities (which comprise 6.1% of the province's surface area), means that more than one half of the population of the province lives in urban and peri-urban areas. The city of Granada has become a focus of interest for the tourism industry, particularly for its Andalusí history and architecture and the castle of the Alhambra, which drew over 2.5 million tourists in 2016.

Methodological design

A participatory mapping process was developed to assess the supply and demand of ES within the study area and to identify key elements to be considered in a new integrated landscape planning scheme. First, we identified and interviewed local stakeholders to characterise the most important and vulnerable ES in the area; then, we developed a one-day participatory mapping workshop to identify the main supply and demand areas of ES; and finally, we analysed the results in terms of ES flows (Fig. 2). Here we refer to ES flows as the joint analysis of ES supply and demand, but we have not analysed the spatial connectivity nor the processes that affect ES flows (Bagstad et al. 2013).

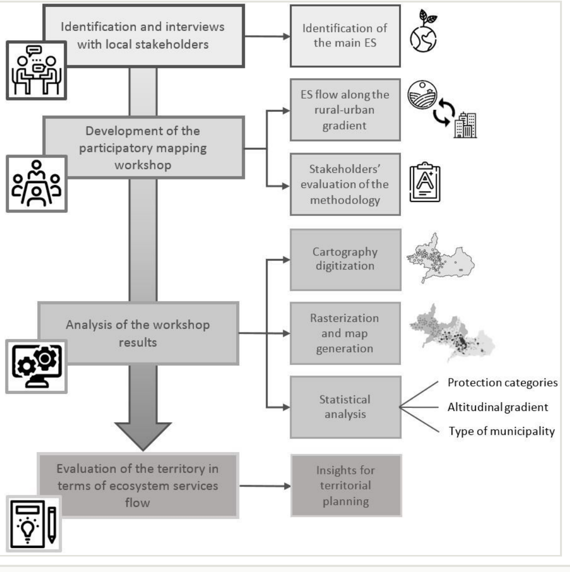

Figure 2.

Scheme of the methodological design.

Stakeholders' characterisation and ecosystem services' selection

Through consultation with experts, we selected an initial number of stakeholders representing different sectors, closely related to the study area and with sufficient knowledge of the territory to identify the main ES supply and demand areas. This initial list of stakeholders was later enlarged through "snowball sampling" in order to capture the different views and discourses that co-exist in the area. During March and April of 2016, we interviewed a total of 21 local stakeholders who interacted in many different ways with the study area and who belonged to different sectors (farmers, peasants, researchers, businessmen, managers etc.).

The main objectives of those semi-structured interviews were to characterise every stakeholder, to identify the ES that would be mapped in the workshop, to obtain more contacts (snowball sampling) and to build trust with the actors to later invite them to the workshop. For the characterisation, we asked the respondents in which ways they interacted with the different areas of the territory (Sierra Nevada, valley of Granada and the city of Granada) and what kind of activities they usually carried out in those areas. For the ES identification, we first explained to the interviewees the ES concept (introduced to them as the contributions of nature to human well-being) and then we gave them a list of 25 ES of which they had to prioritise the most important ones supplied on each area. Then, from those ES prioritised, the interviewees were asked to select the most vulnerable ones. We created a matrix with the importance and vulnerability given by the interviewees to the 25 ES from the list. This matrix, together with an expert consultation and the stakeholders' discourses during their interviews, allowed us to prioritise nine ES that would be mapped in the workshop.

Participatory mapping of ecosystem services workshop

The participatory mapping workshop occurred on 20 May 2016. Eleven previously interviewed stakeholders participated in the workshop and another twelve stakeholders were contacted through snowball sampling and invited to the session, making a total of 23 participants (Table 1).

Table 1.

Characterisation of the participants in the mapping workshop

Sector	Gender	Place of residence	Workshop group
Traditional irrigation ditches researcher	Male	Peri-urban area	1: valley
Urban planning university teacher	Male	Valley	1: valley
Retiree	Female	Peri -urban area	1: valley
Organic farmer	Male	Valley	1: valley
Architect	Male	Valley	1: valley
Ski resort manager	Male	Mountain range	2: mixed
Ski monitor	Female	Peri-urban area	2: mixed
Organic farmer	Male	Mountain range	2: mixed
Irrigation association	Male	Valley	2: mixed
Livestock researcher	Male	City	3: mountain range

Nature photographer	Male	City	3: mountain range
Sierra Nevada Natural Protected Areas manager	Female	Valley	3: mountain range
Touristic rural house owner	Male	Mountain range	3: mountain range
Farmer	Male	Valley	3: mountain range
Urban architect	Female	City	4: valley
Environmental impact university teacher	Male	Valley	4: valley
Environmental education association	Male	City	4: valley
Retiree	Female	Peri-urban area	4: valley
Geography university teacher	Male	City	4: valley
Ski equipment shop owner	Female	City	5: mountain range
Sierra Nevada Natural Protected Areas tour guide	Male	Peri-urban area	5: mountain range
Organic goat farmer	Male	Mountain range	5: mountain range
Farmer	Male	Valley	5: mountain range

Before starting the workshop, we explained to all the participants the theoretical framework and objectives of the project as well as the “scientific meaning” of the nine ES selected, the exercises that they would have to carry out and how we would analyse the results after the workshop. When we finished this introduction, we split the participants into five groups of four to five stakeholders according to their identified connections with the study area. Hence, two groups were represented by stakeholders who had stronger connections to the Sierra Nevada mountain range, two groups were represented by stakeholders with stronger connections to the Granada valley and one mixed group was represented by stakeholders with connections to either the Sierra Nevada mountain range and/or the Granada valley (Table 1). One facilitator, with previous experience in group dynamics, accompanied each group during the whole mapping session, to guide participants and resolve their doubts.

We separated the groups at five different tables and gave them two A1 size maps (1:65,000) of the study area, 60 red plastic dots and 60 yellow plastic dots. For each colour, the groups had 30 large plastic dots (2 cm diameter) and 30 small ones (1 cm diameter), covering a surface in the map of 1.33 and 0.33 km^2 respectively. The scale and size of the maps were chosen based on previous experience with this methodology (Palomo et al. 2014a, Palomo et al. 2013). We asked the participants to collaboratively and deliberatively place the red dots in those areas of the map that they considered supply areas of each ES (Fig. 3); thus, each group had to elaborate nine supply maps, one for each ES. Similarly, on the other map, they had to place the yellow dots in those places that they considered demand areas for each ES (Fig. 3). Each group could allocate for each map as many dots as they considered necessary, but they could not exceed the 60 dots they received. The reason we only gave them 60 dots for each map was that this way we forced them to prioritise the most important supply and demand areas in the territory. We also gave to each group a political map of Spain and a political map of Europe so they could place some yellow dots in those areas that they considered as demanding areas of ES that are located outside the regional system. These additional maps gave us qualitative information about the ES flows outside the study area. Finally, we photographed all the elaborated maps (18 from each group) from the azimuth.

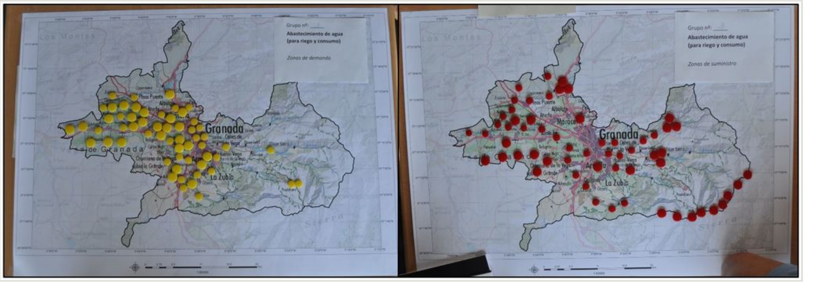

Figure 3.

Example of the water for humans and irrigation supply (left) and demand (right) maps obtained during the participatory mapping workshop.

To conclude the workshop, we asked the participants to fill out a brief questionnaire in which they could evaluate the potential role of participatory mapping of ES in landscape planning. We specifically asked the participants to indicate their perceptions about the importance (very important, important, less important or unimportant) of participatory mapping of ES for landscape planning and the reasons why they considered it important or not.

Analysis of the workshop results

The pictures of the maps taken during the workshops were processed with a geographic information system. We created a shapefile for every map and then we rasterised them. With the resulting raster, we elaborated 26 maps: nine maps representing the demand intensity and nine maps representing the supply intensity for each ES (the intensity represents the number of dots placed by the participants in each pixel of the study area, in this case ranging from 0 to 5); three maps representing the demand intensity and three maps representing the supply intensity for each ES typology (the intensity ranged from 0 to 15); and one map representing the total demand intensity and one map representing the total supply intensity for ES (the intensity ranged from 0 to 45). These maps gave us graphical information about the main supply and demand areas for every ES analysed.

Further, we explored the relationship amongst ES supply-demand areas and three different factors: (1) the degree of land protection; (2) the altitudinal gradient; and (3) the type of municipalities. To analyse these relationships, we first created a shapefile for each factor using the Andalusian Multi-Territorial Information System (SIMA) database. The land protection categories shapefile was created including four categories: non-protected areas, urban areas, Sierra Nevada Natural Park and Sierra Nevada National Park. The altitudinal gradient shapefile included 30 altitude intervals of 100 metres, ranging from 500 to 3,400 metres. Finally, to create the shapefile of municipality typologies, we performed a principal component analysis (PCA) and a hierarchical cluster analysis (HCA) to cluster the municipalities based on their differences in 19 socio-demographic and ecological parameters (Suppl. material 1).

For each of the three geographical factors, we created a point shapefile (100 to 200 random points per each factor category with an average density of around 1 point/km^2). Then we extracted to these point shapefiles, the information regarding ES supply and demand and the three factors created (land use category, altitude range, municipality typology).

Finally, we tested the effect of the degree of land protection and the type of municipality on ES supply-demand using Kruskal-Wallis tests, with post hoc Dunn's multiple comparisons. We graphically represented the results with box-and-whisker plots. The effects of the altitudinal gradient was tested with Spearman correlation tests and the results graphically represented with scatter plots.

Results

Ecosystem services prioritisation

The matrix created from the interviewees' answers allowed us to select three ES from each category based on their importance and vulnerability: water for humans and irrigation, agricultural products and livestock products (provisioning services); habitat for species, air quality and soil fertility (regulating services); and aesthetic value, traditional ecological knowledge and rural and nature tourism (cultural services) (Fig. 4).

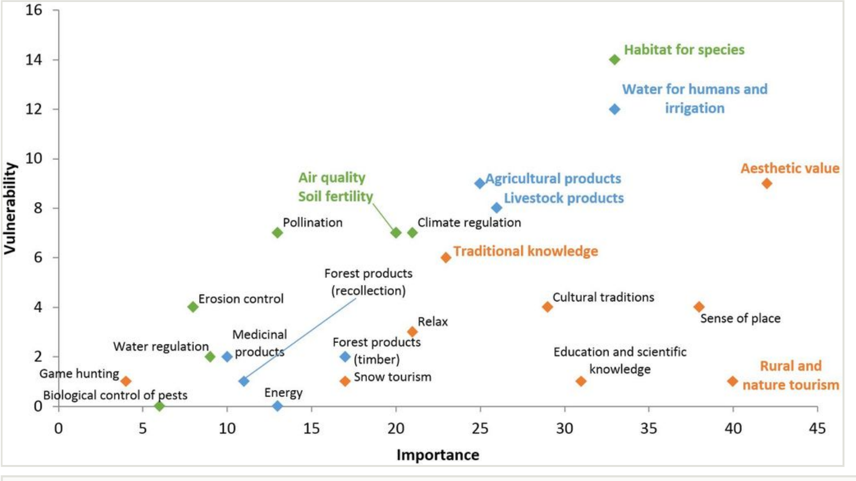

Figure 4.

Scatter plot of the importance (X axis) and vulnerability (Y axis) of ES as perceived by key stakeholders during the interviews. Blue, green and orange dots represent provisioning, regulating and cultural services respectively. The names in bold are the selected ES for the workshop.

Ecosystem services supply and demand areas

Overall, the maps did not reveal a clear pattern of supply areas for each typology of ES. The dots were quite uniformly distributed along the territory, but we found that the density was slightly higher in the Sierra Nevada mountain range and the Granada valley poplar groves. Regarding the results for each ES, (1) the Sierra Nevada mountain range was mainly characterised as a supplier of water, livestock products, habitat for species, tourism and aesthetic values and (2) the Granada valley was mainly characterised as a supplier of agricultural products, soil fertility and traditional ecological knowledge (Fig. 5).

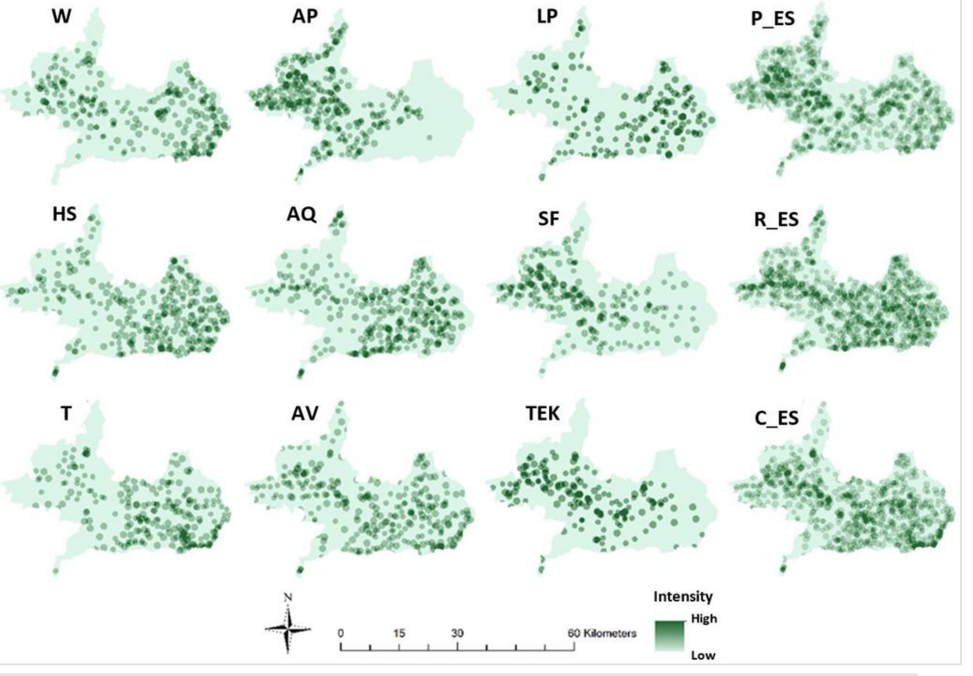

Figure 5.

ES supply areas resulting from the workshop. W: water for humans and irrigation; AP: agricultural products; LP: livestock products; P_ES: provisioning services; HS: habitat for species; AQ: air quality; SF: soil fertility; R_ES: regulating services; T: tourism; AV: aesthetic value; TEK: traditional ecological knowledge; C_ES: cultural services.

Maps of ES demand showed more clear spatial patterns. The areas with the highest demand for every ES were Granada city and other peri-urban areas, although demand was lower for soil fertility and traditional ecological knowledge. On the other hand, the services in greatest demand in the Sierra Nevada mountain range were habitat for species and air quality and the services in greatest demand in Granada valley were water for humans and irrigation, air quality and soil fertility (Fig. 6).

The participants also identified several other Spanish provinces and European countries where some of the ES supplied in the study area were demanded. Habitat for species, rural and nature tourism, aesthetic value and traditional ecological knowledge were identified as the most demanded ES in other European countries, while rural and nature tourism, aesthetic value and livestock products were identified as the most demanded ES in other areas of Spain.

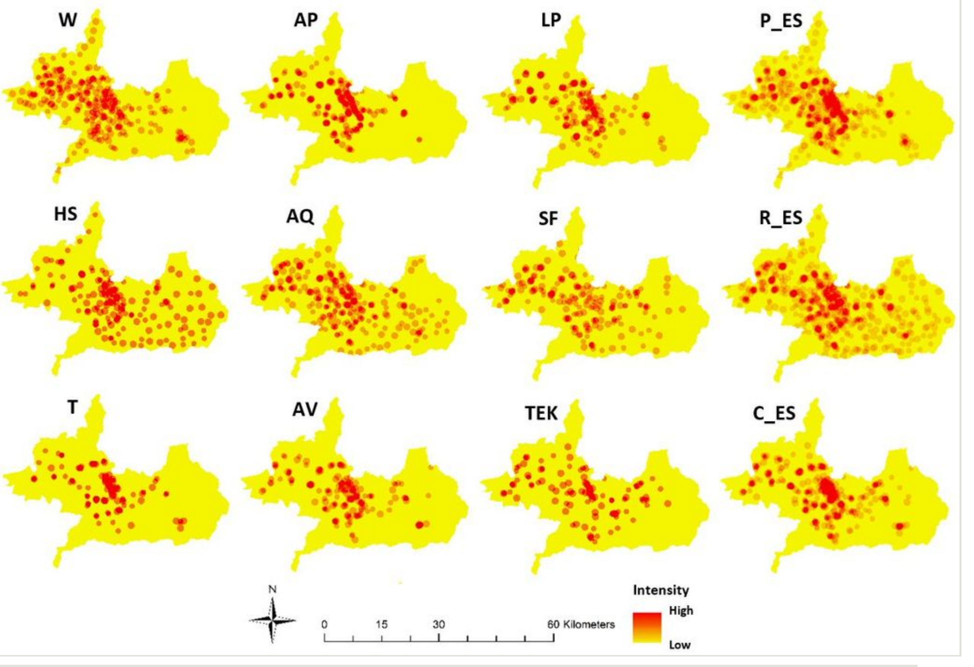

Figure 6.

ES demand areas resulting from the workshop: W: water for humans and irrigation; AP: agricultural products; LP: livestock products; P_ES: provisioning services; HS: habitat for species; AQ: air quality; SF: soil fertility; R_ES: regulating services; T: tourism; AV: aesthetic value; TEK: traditional ecological knowledge; C_ES: cultural service.

Land protection categories and ecosystem services flows

There were statistically significant differences in the supply of ES amongst the different land protection categories (Kruskal-Wallis; χ^2=100.76; p-value<0.001). ES supply of Sierra Nevada National Park was significantly higher than the supply of non-protected areas and urban areas; Sierra Nevada Natural Park also showed higher supply than urban areas (Dunn's test, p<0.05). On the other hand, there were no statistically significant differences betweenSierra Nevada Natural Park and non-protected areas and between Sierra Nevada National Park and Sierra Nevada Natural Park. The highest mean supply values corresponded to Sierra Nevada National Park ($\bar{x}$=4.80) and Natural Park ($\bar{x}$=4.43), followed by non-protected areas ($\bar{x}$=4.10) and urban areas ($\bar{x}$=2.45) (Fig. 7).

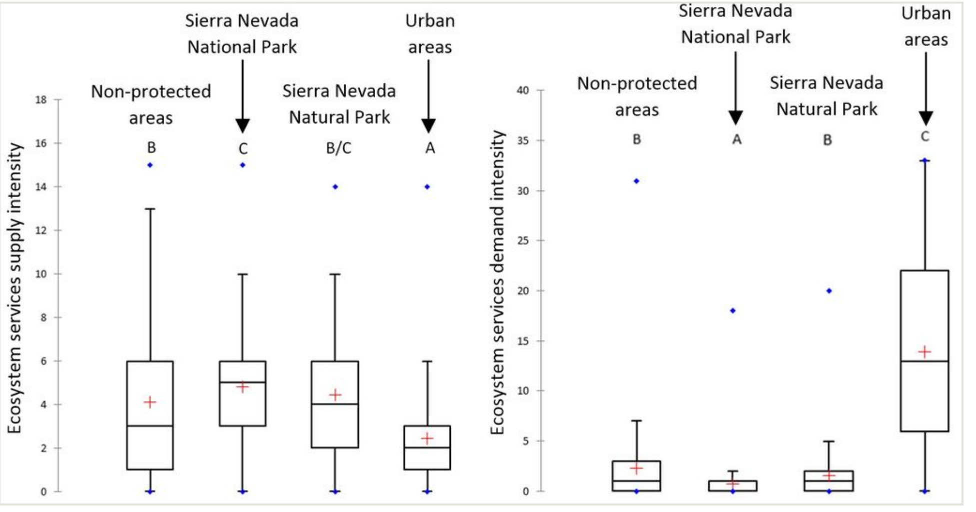

Figure 7.

Boxplots of the intensity of ES supply (left) and demand (right) in the different land protection categories of the study area. Capital letters below the name indicate if there is any statistically significant difference between the areas (different letter) or not (same letter) with a significance level of 0.05.

There were also statistically significant differences amongst land protection categories in ES demand (Kruskal-Wallis; χ^2=373.66; p-value<0.001). Contrary to the supply results, urban areas had a significantly higher demand, while Sierra Nevada National Park had a significantly lower demand (Dunn's test, p<0.05). The highest mean demand value corresponded to urban areas ($\bar{x}$=13.900), followed by non-protected areas ($\bar{x}$=2.30), Sierra Nevada Natural Park ($\bar{x}$=1.53) and Sierra Nevada National Park ($\bar{x}$=0.76) (Fig. 7).

Altitudinal gradient and ecosystem services flows

There was a significant positive correlation (r_s=0.74; p-value<0.001) between ES supply and altitude; the higher the altitude along the gradient, the greater the intensity in the supply of ES. Nonetheless, between 500 and 800 metres altitude, the supply intensity progressively decreases and reaches a minimum at 700 metres. The intensity values between 800 and 2,500 metres altitude remain relatively stable with similar values to those found at 500-600 metres. Between 2,500 and 3,300 metres altitude, the intensity tends to increase again with small oscillations, reaching a maximum at 3,300 metres (Fig. 8).

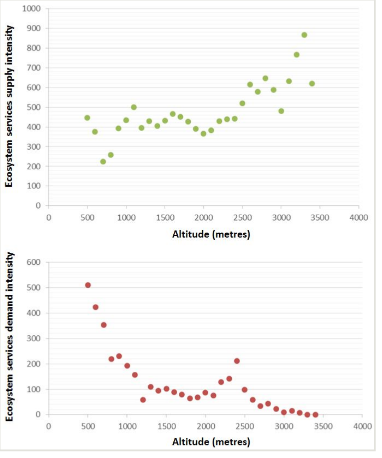

Figure 8.

Scatter plots showing the relationship between altitude and the supply and demand of ES in the study area.

Unlike the results for ES supply, there was a negative correlation (r_s=-0.84; p-value<0.001) between ES demand and altitude. In this case, the higher the altitude along the gradient the lower the intensity in ES demand. We found the highest values of demand between 500 and 900 metres altitude, where Granada valley and most of the urban cores are located. Demand values start to decrease from there to the higher areas, until 2,200-2,400 metres altitude, where the Pradollano ski resort is located, creating another important ES demand peak (Fig. 8).

Municipality typology and ecosystem services flows

Four groups of municipalities were clearly distinguished in the study area (HCA dissimilarity coefficient = 60.6) (Suppl. materials 2, 3). The first group (G1) was formed by municipalities in the Granada valley and it is characterised by having the highest percentage of agricultural areas and population mostly employed in the primary and secondary sectors. The second group (G2) was formed by peri-urban municipalities, which have a high percentage of altered and constructed areas, population employed in the tertiary sector and a high population density. The third group (G3) was mostly composed of municipalities of the Sierra Nevada mountain range, with a high percentage of forest areas and Natural Protected Areas and with a high number of touristic rural establishments. Finally, the fourth group (G4) was only represented by the municipality of Granada, mainly characterised by having a high percentage of employed population in the tertiary sector, the highest population density and a high number of hotels and hostels (Fig. 9).

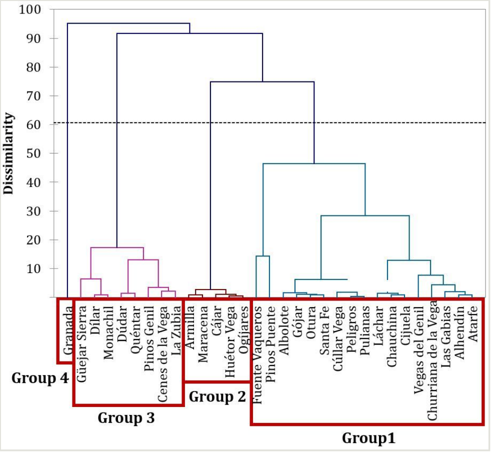

Figure 9.

Hierarchical cluster analysis results, showing the four groups of municipalities (see Suppl. materials 2-3 for a more detailed information).

We found statistically significant differences in the supply of ES amongst the four groups of municipalities (Kruskal-Wallis; χ^2=134.44; p-value<0.001). Group 1 was significantly different from groups 2, 3 and 4; while group 2 was significantly different from groups 1, 3 and 4; and groups 3 and 4 were significantly different from groups 1 and 2 (Dunn's test, p-value<0.001). Groups 3 and 4 did not show significant differences between them (Dunn's test, p-value=0.46) (Fig. 10). The highest mean supply value corresponded to municipalities clustered in group 1 ($\bar{x}$=4.71), followed by groups 3 ($\bar{x}$=3.60), 4 ($\bar{x}$=3.50) and 2 ($\bar{x}$=1.87).

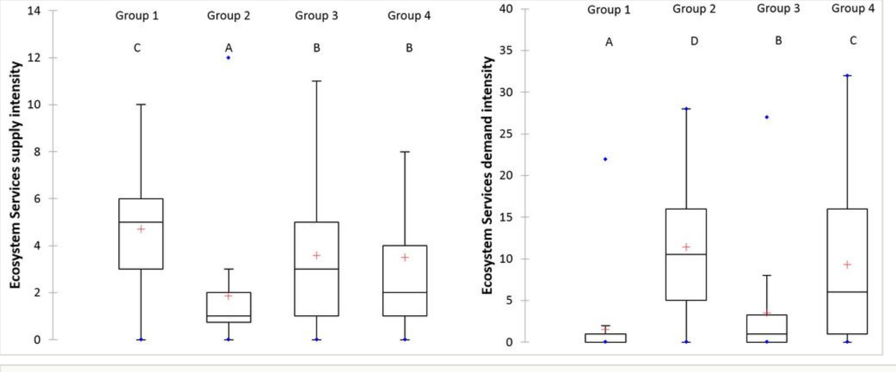

Figure 10.

Boxplots of the intensity of ES supply (left) and demand (right) in the four groups of municipalities in the study area. Capital letters below the name indicate if there is any statistically significant difference between the areas (different letter) or not (same letter) with a significance level of 0.05.

We also found statistically significant differences amongst the four groups of municipalities in their demand of ES (Kruskal-Wallis; χ^2=281.21; p-value<0.001). Here, every group was significantly different from every other group and the groups with the highest mean demand values were those related to the urban cores, namely, groups 2 ($\bar{x}$=11.38) and 4 ($\bar{x}$=9.27) (Fig. 10).

Stakeholders' evaluation

The results of the questionnaires completed after the workshop revealed the perceptions of the stakeholders about the utility and applicability of participatory mapping of ES. As a result, 68.4% of the participants considered this methodology a very important tool to reveal the existing relationships between rural and urban areas. On the other hand, 26.3% of participants considered the process important to reveal and contrast the different perspectives and opinions of the population, as well as to clarify concepts and to provide information about territorial planning. Finally, only one participant thought that the method was not very useful and that, in order to be operative, it should be more closely linked to concrete actions in the territory (Fig. 11).

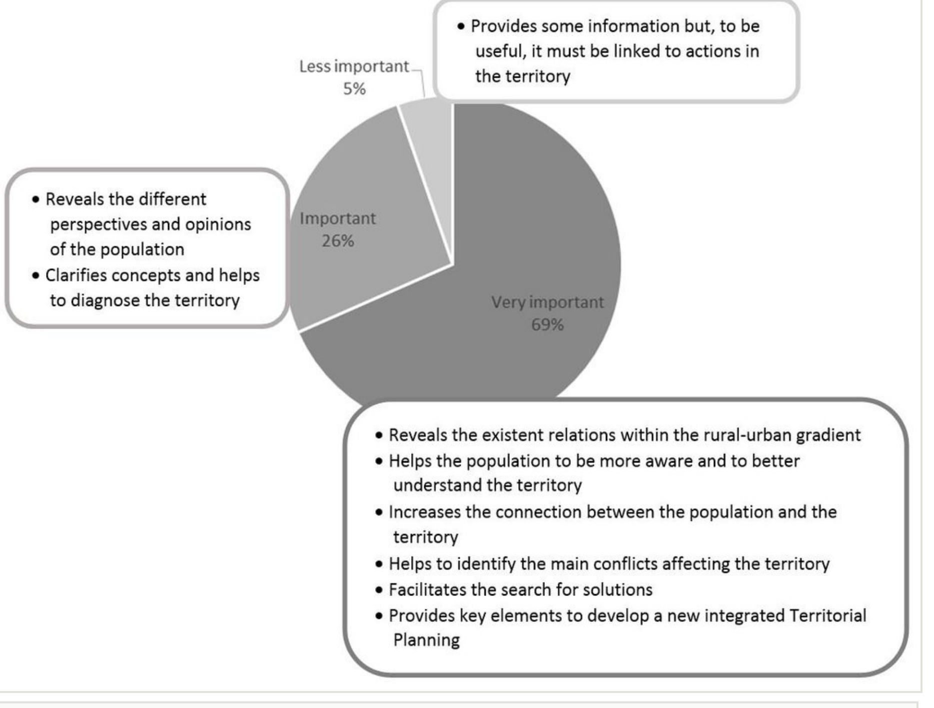

Figure 11.

Summary of the most frequent perceptions of the stakeholders, revealed after the workshop, about the utility and applicability of participatory mapping of ES.

Discussion

Mapping ecosystem services supply and demand: Insights for landscape planning

This study provides valuable information about ES flows along the rural-urban gradient of the Sierra Nevada mountain range, the Granada valley and the city of Granada. Our participatory mapping exercise revealed that the city of Granada and other peri-urban cores are high demand areas for ES with little supply, while Granada valley and, especially, the Sierra Nevada Natural and National Parks are high supply areas of critical ES. Our analyses also revealed the great importance of the valley as a supply area, especially of agricultural products, soil fertility and traditional ecological knowledge; however, this supply directly depends on the demand of a key ES supplied by the Sierra Nevada mountain range: water for human consumption and for agriculture. Our results are consistent with previous studies that highlight that the growing population and expansion of cities is leading to a growing demand for ES provided elsewhere (Burger et al. 2012, Liu et al. 2015, Pascual et al. 2017a). In an increasingly interconnected world, a specific management strategy applied at a local level could impact distant ecosystems and this should be taken into account when developing integrated landscape planning schemes (Liu et al. 2015, Pascual et al. 2017a).

On the local scale, our results are consistent with those of Palomo et al. (2013) who reported that protected areas at higher altitudes are critical suppliers of ES, which have a scale of beneficiaries that reaches from the local to the global. The differences in ES supply observed along the altitudinal gradient might be related to changes in the predominant land uses at different altitude intervals, although this hypothesis needs further research. Considering that the mountain areas are key elements to maintain the supply of ES in the valley, it is essential that landscape planning schemes preserve the ES supply capacity within the mountain range in order to maintain human well-being and to achieve ecosystem sustainability. Since the mountain range and the valley municipalities had the highest supply of ES rates, they would be key elements in regional policies. For example, as Rodríguez-Loinaz et al. (2015) suggest, these municipalities could be potential beneficiaries of government funds for their contribution to human well-being and landscape sustainability. Further, our results also highlight the need for increasing institutional efforts to enhance the supply of ES in the urban and peri-urban areas, taking into account their great demand and dependence from ES generated in other areas of the rural-urban gradient.

It seems urgent to include the existing relationships between ES supply and demand within decision-making processes if we take into account the most pressing drivers of change currently affecting our study area: abandonment of agriculture and expansion of urban areas in the Granada valley (Ruiz 2017) and climate change (Palomo 2017). These two main drivers of change have different origins and scales of impact: while the first responds to regional economic dynamics, the latter is a global process. This also occurs in some cases with the supply of ES, where the beneficiaries of the supplied services include the whole range from local to global beneficiaries (Burkhard et al. 2014). Our results show that several provisioning and cultural ES are highly demanded services in other provinces of Spain and countries of Europe, which highlights the ecological and cultural relevance of the study area.

Although many studies have analysed the supply of ES through mapping techniques, few have also integrated the demand to reveal ES flows (Beier et al. 2008, Brown et al. 2012, Nedkov and Burkhard 2012, Syrbe and Walz 2012, Wolff et al. 2015). The number of studies is even lower if we consider participatory techniques for mapping ES flows (Brown and Fagerholm 2015). On the other hand, few studies have been used to support decision-making or have been applied to landscape planning (Guerry et al. 2015, Ruckelshaus et al. 2015), but many studies acknowledge the potential applications of the mapped data to achieve these goals (Brown and Fagerholm 2015). Since political measures and landscape planning directly impact ecosystems and their capacity to supply ES (Crossman et al. 2013a), there is an urgent need to quantify and include the stocks and flows of ES in decision-making processes (Burkhard et al. 2013).

Mapping ES provides information and indicators about the current status and the trends of ES (Maes et al. 2012), allowing decision-makers to identify drivers of change affecting ecosystems and the services they provide (Palomo et al. 2014a, Maes et al. 2012, Hauck et al. 2013). Furthermore, including the flow of ES across the landscape would contribute to identifying mismatches between supply and demand, that is, situations where beneficiaries have an unsatisfied demand or where the uptake is higher than the stocks (Baró et al. 2016, Burkhard et al. 2012). Therefore, mapping the flow of ES provides relevant information to decision-makers that would contribute to the development of science-based policy-making as well as to enhance the sustainable use of ES (Hauck et al. 2013).

Within this framework, the preservation of the flow of ES must be a priority in landscape planning that could be approached through the integration of the participatory mapping of ES in decision-making processes, making it easier to prioritise the actions that are needed in plans or policies affecting the system (Baró et al. 2016). Thus, questions such as where to preserve biologically important areas (Cox et al. 2014), where to preserve areas that are potentially threatened or vulnerable to overuse (Hauck et al. 2013, van Riper et al. 2012), or where to restore ecosystems and how much to invest in green infrastructure (Maes et al. 2012) would have a much more informed answer if ES supply and demand areas have been previously identified. Our results suggest the need to change landscape planning schemes from their current approach based on administrative boundaries to a more comprehensive approach that considers the landscape as a whole: an integrated system based on social-ecological limits that includes the areas of supply and the beneficiaries of the ES (Fagerholm et al. 2013, Palomo et al. 2014b).

Participatory mapping of ecosystem services: Strengths and limitations

The participatory and deliberative process provided a significant amount of information that reveals some of the strengths and limitations of participatory mapping of ES, some of which have been previously mentioned in literature (Table 2). We identified and characterised some of the advantages and disadvantages of applying this methodology during a post-workshop meeting with the facilitators and analysing the recordings of the deliberations that took place in each group of participants. In our study case, participatory mapping of ES provided valuable information about the perceptions and knowledge of the participants regarding supply and demand of nine ES, which is a considerable number to operationalise the ES framework (IFAD 2009). The whole participatory process also helped us to identify key elements to lay the foundation for more integrated landscape planning, although combining this information with biological and ecological GIS data would increase the efficiency of management decisions (Cox et al. 2014). The study also revealed the existing flows of ES within the system, making the relationships among the three main geographic areas of the rural-urban gradient more visible for participants. Another strong point of the methodology is the fact that it allowed the mapping of some cultural ES (e.g. aesthetic value and traditional ecological knowledge) that otherwise would be difficult to evaluate using other mapping techniques (Hauck et al. 2013, Plieninger et al. 2013). Cultural services should be considered as key elements for the participatory mapping of ES since they provide information about the contribution of ES to non-material dimensions of human well-being and can thus contribute to preventing unwanted trade-offs in land management (Brown et al. 2012, Plieninger et al. 2013).

Table 2.

Analysis of the strengths, weaknesses, opportunities and threats (SWOT) associated with the participatory mapping of ecosystem services and its potential applications in landscape planning (based on a literature review and the analysis of questionnaires completed by participants in the workshop)

	Positive	**Negative**
Internal origin	**Strengths** · Provides information about the perception, values and knowledge of the local stakeholders (IFAD 2009) · Provides information about the spatial distribution of ecosystem services and the existing mismatches and trade-offs (Burkhard et al. 2012, Maes et al. 2012) · Fosters the exchange of knowledge amongst participants, leading to collective learning (Sayer et al. 2013) · Facilitates the identification of existing and potential conflicts affecting the territory (Raymond et al. 2009) · Facilitates the mapping of ecosystem services that are difficult to quantify using other methods (Hauck et al. 2013, Plieninger et al. 2013)	**Weaknesses** · It cannot support determinant decisions by itself regarding landscape planning (Brown and Kyttä 2014); it should be complemented by other methodologies, such as biological and ecological GIS analyses (Cox et al. 2014) · It has been applied a few times to landscape planning and decision-making (Nahuelhual et al. 2013) · It has no practical relevance if it is not linked to actions in the territory · Time, space and human capital are limiting elements for the number of participants and the number of ecosystem services to be mapped

External origin	**Opportunities** · Provides useful information to decision-makers to develop evidence-based policies and to prioritise the key elements to include in landscape planning (Hauck et al. 2013, Brown and Kyttä 2014) · Empowers the local population by including them in the decision-making process, leading to the generation of more trust towards the landscape planning mechanism and associated policies (Brown and Kyttä 2014, García-Nieto et al. 2015) · Facilitates the management of conflicts within the territory and the discussion about potential solutions (Brown and Weber 2012, Hauck et al. 2013) · Depending on the results wanted and the available resources, the methodology and development of the workshop can be easily adapted (IFAD 2009)	**Threats** · During the workshop, conflicts could arise from different opinions or interests amongst the participants (IFAD 2009) · Some stakeholders (usually the more powerful ones) are reluctant to get involved in participatory processes, which hinders the results, as their visions and expectations are not reflected in the final maps · The heterogeneity of the participants could influence the resulting maps (Hauck et al. 2013) · Some results could lead to the misunderstanding that areas with no relevance for ES supply could be areas where exploitation could be increased (Hauck et al. 2013)

An important limitation that should be acknowledged relates to the necessarily high investment in time and human capital. Participatory workshops require the active involvement of many actors from different sectors and it is not always easy to motivate these actors to participate and to bring them together to discuss these issues. In our case, it took more than three months to establish contact and interview the key stakeholders.

Despite the limitations outlined above, we conclude that including participation in ES mapping greatly helps decision-makers to better value the contribution of ES to human well-being (Crossman et al. 2013a) and to better understand the management preferences of the stakeholders and what is or is not important to them. Thus, decision-makers would have a practical toolset to make informed decisions that would be more easily supported by the public and to reduce conflicts over changing policies (Cox et al. 2014, van Riper et al. 2012).

Additionally, we consider it necessary to incorporate the participation of citizens in strategic landscape planning. First, because participation fosters a citizenship that is active, organised and aware of the problems that affect their territory and stakeholders can feel that they are part of the planning process (Klain and Chan 2012, Manero 2010). Second, because citizens are experts in the territory with important traditional ecological knowledge, the deliberative processes become enriched and more complete than technicians and researchers could achieve by themselves (García-Nieto et al. 2013, Martín-López et al. 2012).

Conclusions

Mapping ES along the rural-urban gradient of the Sierra Nevada mountain range, the Granada valley and the city of Granada revealed the existence of clear geographic mismatches between the supply and demand of ES. While the Sierra Nevada mountain range and the Granada valley are relevant and interconnected ES supply areas, the city of Granada and the peri-urban areas are huge focuses for ES demand.

Evaluating the flows of ES though participatory mapping and integrating this information in decision-making processes could facilitate the prioritisation of those actions that may be applied in the territory to improve ecosystem sustainability and human well-being. However, it is necessary to combine participatory mapping with other methodologies to provide decision-makers with enough tools to develop new integrated landscape planning schemes that go beyond administrative boundaries. Only by considering the territory as a whole and taking into account where the ES are delivered and where the beneficiaries are located, would it be possible to enhance current policies and management strategies to preserve ecosystem integrity and ensure ES flows.

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Supplementary materials

Suppl. material 1: Appendix I doi

Authors: Palomo-Campesino, S., Palomo, I., Moreno, J., and González, J.A.
Data type: Pdf document
Brief description: List of the 19 socio-demographic and ecological parameters used for the study area clustering and their values for each municipality of the study area.
Filename: supplementary material 1.pdf - Download file (272.49 kb)

Suppl. material 2: Appendix II doi

Authors: Palomo-Campesino, S., Palomo, I., Moreno, J., and González, J.A.
Data type: Pdf file
Brief description: Eigenvalue, percentage of explained variablity and accumulated percentage of explained variability of the five factors (with an eingenvalue higher than 1) result of the PCA analysis and used for the HCA analysis.
Filename: Supplementary material 2.pdf - Download file (189.01 kb)

Suppl. material 3: Appendix III doi

Authors: Palomo-Campesino, S., Palomo, I., Moreno, J., and González, J.A.
Data type: Pdf file
Brief description: Factors' loadings for each of the 19 socio-demographic and ecological variables analysed. Values in bold are statistically significant at $P>0.05$.
Filename: supplementary material 3.pdf - Download file (218.25 kb)