Ecological Indicators 126 (2021) 107660

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Disentangling ecosystem services perception by stakeholders: An integrative assessment based on land cover

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ARTICLE INFO

Keywords:
Stakeholder participation
Multi-criteria decision analysis
Land cover change
CORINE land cover
Natural capital
Portugal

ABSTRACT

Understanding where ecosystem services (ES) are and quantifying their supply using stakeholderś information is key for effective sustainable management. This paper describes a participatory methodology for extracting stakeholders' ES perception for continental Portugal based on land cover using analytical hierarchy process (AHP), matrix-based approach with data visualization techniques, and scenario analysis. Results show that drought regulation was the most valued ES by stakeholders and recreation was considered the least important. Results also show that the "Agricultural areas and "Forests and semi-natural areas" land cover classes provide about two-thirds of the total ES for the country. An "Economic development" scenario will yield negative values for all ES except recreation and food supply, whereas an "Environmental development" scenario will increase all ES, except food supply. Finally, a "Sustainable development" scenario, presents values between the previous two scenarios and is the best for food supply. This operational methodology for extracting information from stakeholders and to report information on the mapping and assessment of ES can be helpful for sustainable planning in Portugal and elsewhere.

1. Introduction

Providing information about ecosystem services (ES) for decision-making is essential to preserve their supply and, consequently, their benefits to society (Jacobs et al., 2016; Millenium Ecosystem Assessment, 2003). Making these services visible through mapping biophysical, social and economic indicators enables understanding of potential trade-offs and the design of efficient conservation strategies (Crossman et al., 2013; Olander et al., 2018). The provision of ES is importantly influenced by land cover changes (LCC) and efficient land use planning is required for maintaining ES flow (Lawler et al., 2014; MEA, 2005). Overall assessments of multiple ES rely on trade-offs between improvements and declines of some services under different scenarios of land use change (Eigenbrod et al., 2011; Renard et al., 2015). Analysing these trade-offs in decision-making processes is essential to inform how stakeholders can weigh efficient strategies for the sustainable use of natural resources (Fontana et al., 2013; Schaefer et al., 2015). Different pathways are needed to incorporate development scenarios in a science-policy interface for ES assessments (Grêt-Regamey et al., 2017; Nicholson et al., 2019). Whenever supported by ecological theory, the use of ES associated with land cover scenarios provides a fundamental scientific basis for conservation decisions (Schröter et al., 2020). In most cases, addressing land use management in ES priority is a policy-relevant task, but the engagement of private sector and non-governmental organizations gives us a reason for optimism (Scarano et al., 2019). Therefore, the inclusion of scenarios in ES studies at regional scales can support the interplay between sustainable development and global environmental change on land systems (Capitani et al., 2019; Kareiva et al., 2011).

Land use planning can be supported by ES-based modelling tools, such as InVEST (https://naturalcapitalproject.stanford.edu/), to estimate ES supply based on land cover (Tallis et al., 2018). Other approaches include the use of remote sensing and related methods to study ecosystem dynamics and spatial distributions at different spatiotemporal scales (Alcaraz-Segura et al., 2013; Ramirez-Reyes et al., 2019). However, all these approaches require extensive data acquisition, processing and modelling skills making the task to select which method to use arduous (Harrison et al., 2018; van Oudenhoven et al., 2018). Another relevant method for obtaining information about ES is through stakeholder participatory methods, such as interviews and surveys, mapping, focus groups, and Multi-Criteria Decision Analysis (MCDA) (Lopes and Videira, 2019). However, the use of these techniques in ES

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https://doi.org/10.1016/j.ecolind.2021.107660
Received 4 August 2020; Received in revised form 19 March 2021; Accepted 26 March 2021
Available online 8 April 2021

studies should consider several aspects. For instance, interviews and surveys should ensure a representative number of stakeholder types/ responsibilities as well as an homogeneous level of ES knowledge (Mascarenhas et al., 2016). Participatory mapping can be effective for eliciting current ES but it can raise difficulties in mapping its distribution under future management scenarios (Reilly et al., 2018). Focus groups are collective reflections which enable the expression of many types of ES and shared norms and discourses related to nature's values (Scholte et al., 2015; Stålhammar and Pedersen, 2017). However, preference-based valuations may not express correctly the individuals' way to reflect on nature values (Stålhammar and Pedersen, 2017). MCDA has a strong potential for integrated assessments of ES but have limitations in dealing with incommensurable or non-replaceable values which may not capture all the relevant issues, especially the indirect benefits (Langemeyer et al., 2016; Mustajoki et al., 2020). Therefore, the effective inclusion of multiple ES values through participatory approaches is still a challenge and more research is needed to effectively use this information in ES assessments (Pascual et al., 2017).

Although ES assessments have been considered integral to the sustainable development agenda (Griggs et al., 2013), their potential to improve human well-being have not been systematically explored (Naeem et al., 2016). Participatory approaches such as Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES (http://www.ipbes.net) can advance multiple pathways to action for science-based solutions, with emphasis on decision-making processes (Ruckelshaus et al., 2020). In a world where land-use policies often constrain sustainable development, the inclusion of ES frameworks to connect social and ecological components is crucial for improved conservation outcomes (Ruckelshaus et al., 2020). Therefore, involving different stakeholders in ES spatially explicit assessments enables a valuable and more legitimate way of representing different perspectives of the perceived value of ES (Fagerholm et al., 2012; Kenter et al., 2016). Since different stakeholders value multiple ES differently, their decisions affecting ES provision should consider this diversity of values through participatory approaches (Martín-López et al., 2014; Spangenberg et al., 2015).

There is a great number of ES assessments involving stakeholders' participation applied to metropolitan areas (Mascarenhas et al., 2016), protected areas (Lopes and Videira, 2016; Mustajoki et al., 2020), development of infrastructures (Langemeyer et al., 2016), and many others, from local to regional scales. However, although the stakeholders' engagement has been applied in various local studies, there is still a research gap involving stakeholders' participation at national level for assessing, mapping and integrating multiple ES based on current and future land cover scenarios. Particularly for Portugal, some studies using participatory techniques with stakeholders have been proposed in ES assessments to support land-use policies. For instance, Mascarenhas et al. (2016) identified the most critical ES for each stakeholder group in the Lisbon Metropolitan area, referring to results from a focus group meeting with the regional authority and from the working groups in a participatory workshop. These authors also carried out a study to assess how ES information can be integrated in a regional spatial planning with the help of stakeholders through a survey (Mascarenhas et al., 2014). Rosário (2019) used a series of participatory workshops at local and regional levels to assess the current and future ES, focusing in the particular case of the "*montado*" (cork oak woodlands) landscapes. Lopes and Videira (2016) used a collaborative approach for eliciting multiple ES values in the Arrábida Natural Park. These authors, also for the same study area, used participatory mapping for a deeper understanding of ES (Lopes and Videira, 2017), and proposed a participatory articulation framework for an integrated valuation of ES values (Lopes and Videira, 2019). These and other studies contribute importantly to ES science as they put forward the relevance and perception of ES by stakeholders which may be decisive for designing sustainable policies. However, a national ES assessment with stakeholder information involving mapping and scenario analysis at country level is still missing for Portugal.

In this paper, we fill this gap by exploring an integrative strategy for including stakeholders through a participatory process on a national ES valuation in Portugal. Using ES indicators based on CORINE Land Cover (CLC) (Copernicus, 2018), we share the results of a stakeholders' meeting aimed at disentangling their ES perceptions in defining sustainable development policies, balancing economic and ecological goals. For this purpose, in this paper, we aim to: (i) know which are the most important ES perceived by stakeholders; (ii) quantify the perceived potential of ES supply based on land cover; (iii) understand the expected trends of ES supply according to different scenarios by 2030. Our results provide information for sustainable planning at national level conducted for the first time in Portugal, supporting the achievement of target 2 of the European Union Strategy on Biodiversity 2020 – Maintain and restore ecosystems and their services, and its related call for action on mapping and assessing the state of ES in the national territory. Based on our findings, we discuss the practical implications of ES mapping and stakeholder participation in ES management processes which may contribute to the achievement of the National Biodiversity Strategy and Action Plan, and several targets of the Sustainable Development Goals by 2030 (SDG's 10, 11, 13 and 15).

2. Materials and methods

2.1. Study area

The research was focused on continental Portugal (Fig. 1). The country is located in the Iberian Peninsula in south-western Europe sharing its border to the north and the east with Spain and the west and the south with the Atlantic Ocean. It has about 89 015 km^2 and a population of 10 144 000 inhabitants according to the last census in 2011 (INE, 2018). According to CLC (Copernicus, 2018), artificial surfaces counted for 3.8% of the whole territory, 47.8% corresponded to agricultural areas, 46.5% were forests and semi-natural areas, 0.3% were wetlands and 1.5% corresponded to water bodies.

2.2. Methods

This study included three steps (Fig. 2). In the first step, the selection of landcover data to represent ES was carried out. This step also included the selection of ES as well as the identification and invitation of the stakeholders to participate in a workshop during steps 2 and 3. In step 2, the current potential supply of ES was mapped according to stakeholders' perception. Finally, in the third step, ES trends were mapped according to three scenarios. These activities are detailed in the next subsections.

2.2.1. Selection of ecosystem services and stakeholders

For applied conservation outcomes, the ES should be credible, salient and legitimate for informing decision-making (van Oudenhoven et al., 2018). Based on this assumption, a set of eight ES indicators was preselected by the research team, considering the availability of open datasets for future calculations with modelling tools based on land cover (Table 1). To validate the preselection of ES, the feedback-sheet distributed in the beginning of the workshop included a question regarding whether there should be ES removed from the study and if there were other ES that should be assessed (Appendix A). For this study, the selected ES included provisioning (food supply), regulation (water purification, drought regulation, erosion prevention, climate regulation, pollination), supporting (habitat quality) and cultural (recreation) services, according to Millennium Ecosystem Assessment classification (Millenium Ecosystem Assessment, 2003).

The CORINE Land Cover (CLC) (Copernicus, 2018) dataset was selected to map ES in this study. This freely available dataset has been used to carry out regional national analysis on ES provision (Depellegrin et al., 2016). The research team included three independent scientific

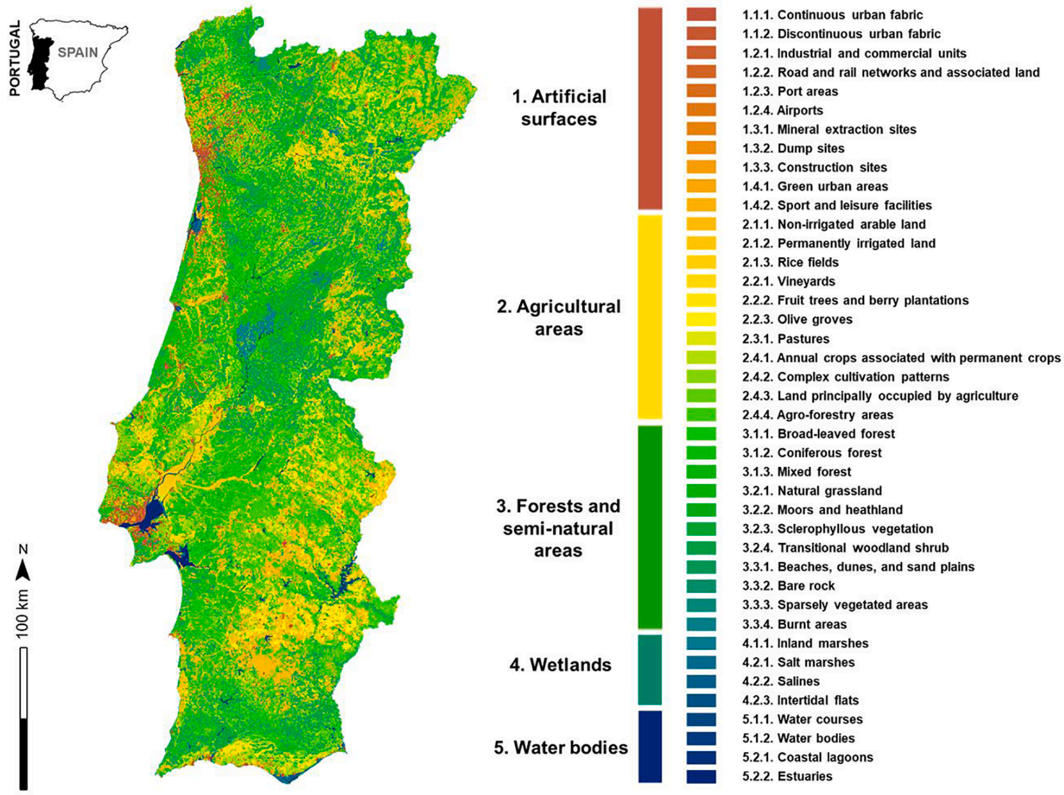

Fig. 1. Study area with land cover in 2018. Data source: CORINE Land Cover (Copernicus, 2018).

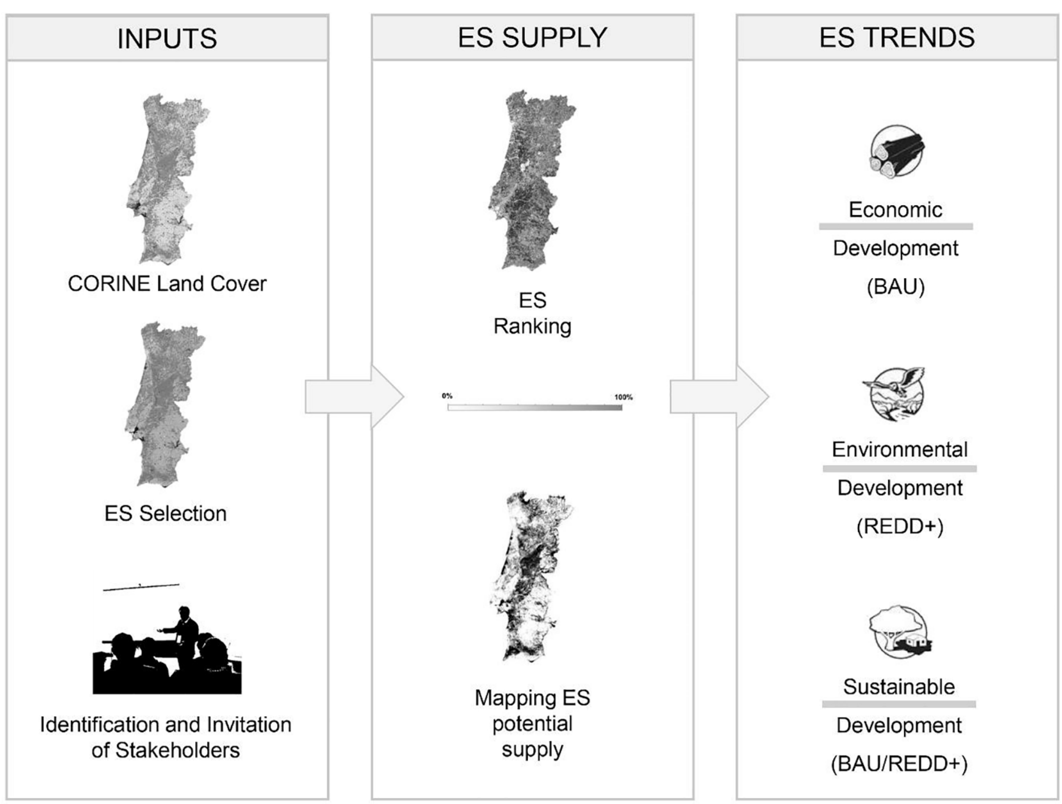

Fig. 2. Flowchart on methods used in the study.

Table 1
Ecosystem services indicators and potential tools/studies for mapping them.

Ecosystem Service	Description of indicators	Source
Climate Regulation	Estimation of carbon stored by the landscape.	(Tallis et al., 2018)
Water Purification	Maps nutrient sources from watersheds and their transport to the stream.	(Tallis et al., 2018)
Habitat Quality	Uses habitat quality and rarity as proxies to represent the biodiversity of a landscape.	(Tallis et al., 2018)
Drought Regulation	Estimation of the annual average quantity of water produced by a watershed.	(Tallis et al., 2018)
Recreation	Distance from urban areas to green areas and a minimum area.	(Niemelä et al., 2010)
Food Supply	Area of agricultural areas.	(Cabral et al., 2016)
Erosion Prevention	Estimation of the capacity of a land parcel to retain sediment.	(Tallis et al., 2018)
Pollination	Derives an index of pollinator abundance on each cell in a landscape.	(Tallis et al., 2018)

researchers with profiles related to environment, biology and Geographical Information Systems (GIS) and one mediation expert to help to organize the workshop and promote interactive discussions. The stakeholders' selection was made considering their representativeness in various national and regional sectors with a role in land use planning and management that would be able to provide an informed dialogue on ES. The identification process was made using our team's knowledge on this subject and by consulting institutional websites. Stakeholders included specialists from all walks of society, i.e. regional and central administration, politicians, academia, NGOs and industry (Table 2). A total of 60 potential stakeholders were invited by email, 35 signed up and 30 participated in the event.

2.2.2. Participatory workshop

We conducted a workshop to assess the researchers'/practitioners' perceptions on the ES availability in Portugal, based on their professional background and main interest in this topic. The approach taken to develop the workshop was adapted from previous ES assessments studies developed by the team of this project and the objectives of the research project supporting the study (Cabral et al., 2016; Rosário, 2019; Levrel et al., 2017). The workshop took place at the Nova Information Management School (NOVA IMS) in Lisbon, 30 January 2020, under the ASEBIO project – Assessment of Ecosystem Services and Biodiversity in Portugal (http://asebio.novaims.unl.pt). The working environment was fostered by the intense involvement of all participants who embraced the methodology easily and collaborated enthusiastically over the working day with a total duration of 4 h.

The workshop began with two presentations by the research team, who presented the project goals in general, the state-of-the-art of the actual research and the preliminary results for the ES assessment in

Table 2
Type of organization, description and number of stakeholders attended in the workshop.

Type of organization	Description	Number of stakeholders
Regional and central administration	Members of organizations with regulatory authority operating in areas important for the environment.	12
Politicians	Members of political parties with a seat in parliament.	3
Academia	Professors and students with scientific knowledge in areas related to ES.	9
NGO	Members of non-governmental organizations acting in areas related to the environment and biodiversity.	2
Industry	People from companies with activities connected to ecological systems.	4

Portugal using some of the ES indicators presented in Table 1. In order to avoid time-consuming discussions, but at the same time to offer an opportunity for feedback, all stakeholders received an individual feedback-sheet, containing questions related to the presentations, with a blank space for suggestions. Individual feedback-sheets included basic information of researchers, such as the area of expertise and the ES of interest, containing an optional identification field for follow-up contact. The reverse side was reserved for open comments related to the interactive exercises. In Appendix A are provided the additional questions used in the feedback sheet.

At registration, stakeholders were divided into six working groups to avoid that experts that work together on a day-by-day basis chose the same working group. After the opening and first presentations, stakeholders joined their groups and started to discuss the mutual relevance of the eight ES under analysis. The interactive exercises' design was aimed at understanding the relative importance of the eight ES assessed (Exercise 1), the ES supply potential for each land cover class (Exercise 2), future land cover scenarios and potential impacts on ES (Exercise 3). These exercises are detailed below. Raw results of the interactive exercises are available as supplementary data (Appendix A). Group-dynamic processes were explained with details prior to the application of the exercises to avoid misunderstandings or misinterpretations of concepts related to the interactive exercises. Throughout the workshop, the research team acted as project experts ready for consultation in the case of doubts, but not participating in the proposed activities.

2.2.3. Ranking ecosystem services (Exercise 1)

In the first exercise, we conducted a debate to rank the relative importance of the eight ES: climate regulation, water purification, habitat quality, drought regulation, recreation, food supply, erosion prevention and pollination. The ES ranking was developed using the Analytical Hierarchical Process – AHP (Saaty, 1987, 2008), a classification procedure often used in Multi-Criteria Decision Analysis (MCDA) to derive weights through pairwise comparison processes on a 9-step-scale from "9 = extremely important" to "0 = not important at all". Each participant had an individual sheet that she (he) had to fill individually after a short group discussion.

2.2.4. Potential ES production by each land cover class (Exercise 2)

In the second exercise, after a coffee-break, the working groups were re-convened to discuss the potential supply of ES by the 44 land cover classes of CORINE land cover (CLC), level 3. This exercise started once again with a group-discussion followed by an individual scoring of the potential of each land cover class to deliver each of the eight ES assessed on a 5-point-scale from "0 = no potential at all" to "5 = maximum potential". The geometrical mean of the judgements made by the stakeholders was used to synthesize individual judgments (Saaty, 2008). A consistency ratio was calculated to assess the consistency of the judgements by the stakeholders (Saaty, 2008).

An overall ES potential supply index was created for the country after standardizing scores obtained for each ES and weighting them with the weight derived from the AHP process used in the first exercise. To represent the intensity of the relationship between the CLC classes and each ES, we will use a clustered heat map generated by the Unweighted Pair Group Method with Arithmetic Averages (UPGMA) on Euclidean distance also known as a dual dendrogram, using the "heatmap" function of the stats package in R software (R Development Core Team, 2019). This pairwise visualization idiom will use cells displayed in a dual dendrogram as color rectangles along a color gradient to show the data obtained in the first exercise. The order of the rows and columns results from a hierarchical cluster analysis making that similar rows and columns are positioned together (Munzner, 2014).

2.2.5. Future scenarios of land cover and potential impact on ES (Exercise 3)

In the third exercise, the research team presented three possible land-use scenarios for ES assessments by 2030, as a guide to future environmental management, according to the sustainable development agenda. The first scenario was defined as an economic development under a Business-as-Usual (BAU) approach, representing the regional policies of the territory based on historical land-use trends. The second scenario represented an environmental development focused on policy strategies for Reducing Emissions from Deforestation and Forest Degradation (REDD +) (REDD+, n.d.), contributing to global climate mitigation efforts. Then, the third scenario was designed as an applied proposal for making a balance between economic and environmental developments, combining both BAU and REDD + approaches in the same land-use strategy, here suggested as sustainable development. To do this exercise, the working groups were re-mixed, again constituting six different groups. The new groups were encouraged to discuss and evaluate the positive or negative impacts of the eight ES on those three development scenarios with comparative values from "−5 = extremely negative impact" to "+5 = extremely positive impact". A quick share of findings allowed each table to present its results to all other stakeholders.

3. Results

3.1. Ranking of ES according to stakeholders

The results of the ES pairwise comparison was produced and then normalized by summing the eigenvectors and dividing each value by the sum in order to obtain the weights of each ES (Table 3). Drought regulation was considered as the most important ES (0.17) and recreation the least important ES (0.04). The consistency ratio was 0.01 which means that the judgements were consistent (Saaty, 2008).

3.2. Location of ES according to stakeholders

Maps were produced for each of the ES to depict the average perception of stakeholders regarding ES supply (Fig. 3). Average values were transformed into five classes and associated with CLC classes ranging from "No Potential" using dark red colour to "High Potential" using dark green colour. Climate regulation services have none to minimum potential nearby main cities (Fig. 3a). Overall, this ES obtained an average of 2.45 for the whole country, the 2nd highest value after habitat quality (2.72) (Fig. 3c). Water purification services also have the worst values nearby major cities but most of the country ranges between medium to high potential (Fig. 3b) with an average value of 2.36 for the whole country, the third highest value. Yellow is the predominant colour for drought regulation (Fig. 3d) corresponding to an average potential of 2.26 for this ES, the sixth-highest value in the country, although there many areas with red colour (minimum potential) (Fig. 3c). Recreation (Fig. 3e) obtained a similar pattern to drought regulation but with more red areas, being the fifth-highest value for the country (2.34). Food supply (Fig. 3f) is by far the map with more red areas, from north to south, being this the ES with the lowest average level of supply (2.03). Erosion prevention (Fig. 3g) and pollination (Fig. 3h), obtained an average value of 2.35 (fourth highest value) and 2.23 (seventh-highest value), respectively.

3.3. Overall ES supply potential and importance of each CLC class for each ES

The map in Fig. 4 shows the overall ES supply potential according to stakeholders' perception for Portugal, ranging from 0 (light blue) to 100% (dark blue). The clustered heat map, also known as a dual dendrogram, uses the same colour gradient as the map to show the level of ES supply potential according to stakeholders' perception grouping the land cover classes hierarchically. It is possible to observe that, for the climate regulation ES, the darker blue cells correspond to the top land cover classes which are related to agriculture. For this ES, the urban areas are the least important contributors according to stakeholders' perception. Almost all forest and some agriculture classes are the classes which contribute most to all ES (except climate regulation). Urban classes are the ones which contribute less to all ES.

According to the ES overall potential for the land-use classes, our results indicate that the greater values are provided from Agricultural areas (35.56%) and Forests and semi-natural areas (31.44%). The lower values are provided by Water bodies (13.07%), Wetlands (11.65%) and Artificial surfaces (8.28%).

3.4. Trends of ES to 2030 according to stakeholders using different scenarios

The Fig. 5 shows the average values of stakeholders' perception of ES supply for each scenario. These values ranged from –5 (extremely negative) to 5 (extremely positive). The "Economic development" scenario obtains negative values for all ES except recreation (0.25) and food supply (2.1). The "Environmental development" scenario outperforms the other two scenarios in all ES, except for food supply (1.40). Finally, the "Sustainable development" scenario, presents values between the other two scenarios and is the best for food supply (2.53).

3.5. Feedback provided by stakeholders regarding the workshop

The pre-selection of eight ecosystem services was considered suitable for this study by most of the stakeholders as mentioned in the feedback sheet. From the 30 stakeholders involved in the workshop, none of them suggested to remove any ES from the study. When asked if they would have liked to have seen other ES assessed, 20% answered that they would like to include marine-related ES in the study; 13% mentioned extreme events control, such as fires, droughts and floods; and 13% suggested to include mineral resources extraction for materials or energy production. Other suggestions made were already included in the study and/or were only suggested by only one participant.

Another interesting feedback obtained from stakeholders was regarding how they would like to see the results of this study used. Most of the stakeholders that answered this question mentioned that they would like to see these results mainstreamed into planning instruments (30%), some said that they would like to see the results published in official reports (17%), and others said that they would like to have access to the data produced in the exercises through the Internet including the geographical data sets to be made accessible through a WebGIS.

Table 3
Results of the pairwise comparison using AHP (1. Climate regulation; 2. Water purification; 3. Habitat quality; 4. Drought regulation; 5. Recreation; 6. Food supply; 7. Erosion prevention; and 8. Pollination).

Ecosystem services	1	2	3	4	5	6	7	8	Weight
1	0.14	0.18	0.17	0.17	0.13	0.12	0.15	0.09	0.14
2	0.11	0.14	0.18	0.15	0.16	0.18	0.15	0.10	0.15
3	0.14	0.13	0.17	0.21	0.13	0.17	0.17	0.19	0.16
4	0.13	0.16	0.13	0.16	0.18	0.20	0.15	0.22	0.17
5	0.04	0.03	0.05	0.03	0.04	0.03	0.03	0.04	0.04
6	0.14	0.09	0.11	0.09	0.12	0.11	0.13	0.14	0.11
7	0.09	0.09	0.09	0.10	0.13	0.08	0.09	0.10	0.09
8	0.20	0.18	0.11	0.10	0.13	0.11	0.13	0.13	0.13

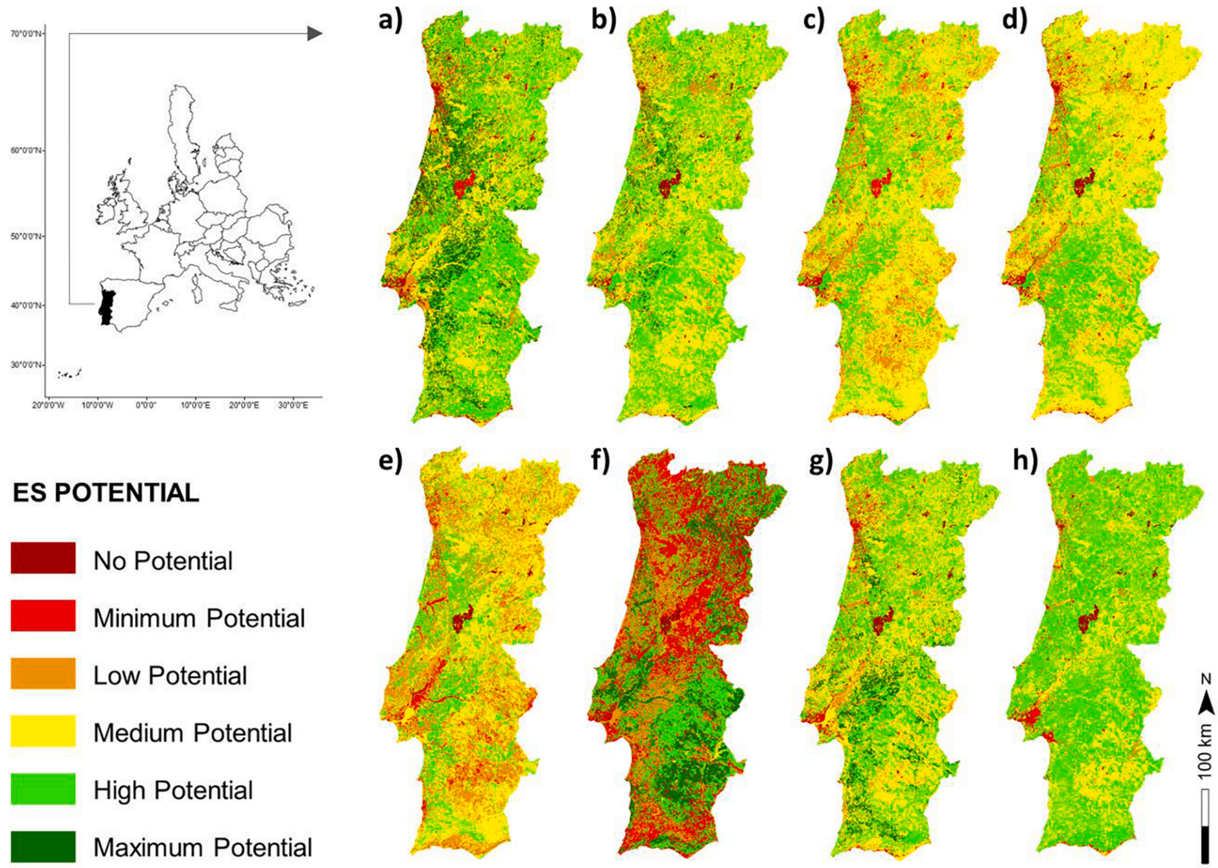

Fig. 3. ES supply in Portugal according to the stakeholder perception: a) Climate regulation; b) Water purification; c) Habitat quality; d) Drought regulation; e) Recreation; f) Food supply; g) Erosion prevention; h) Pollination.

When asked for general comments regarding the workshop, the major remark made was regarding the need to clarify some concepts which were not clear regarding the exercises (17%). Some stakeolders considered the methodological approach too simplistic and that the scale of analysis with CLC was not enough to provide meaningful results (10%). A need for assessing specific sectorial policies, such as the Common Agriculture Policy, and its impacts on ES was also mentioned (3%).

4. Discussion

This study carried out a participatory workshop to obtain new information for Portugal about ES provision based on land cover according to stakeholders' perception. The pre-selection of eight ES, considered suitable by the stakeholders, followed data and tools/indicators availability for ensuring future calculations, offering an opportunity to advance the 2030 Agenda for Sustainable Development at the science-policy interface. Additional ES, as the ones referred by the stakeholders (e.g. marine-related ES, extreme events control and mineral resources extraction for materials or energy production) could be easily integrated in future studies if necessary. The collaborative process and participatory methods used enabled the extraction of information from stakeholders with different levels of knowledge and experience. The transparency of ES indicators was improved by involving stakeholders in a collective exercise through a didactic approach about the involved methods including supporting documentation. As a result, new spaces for knowledge sharing and co-creation are now open for the creation of ES-based policies which will be better communicated and adopted in the future.

Using an AHP procedure, in the first exercise, we found that drought regulation was the most important ES perceived by the stakeholders, and recreation was the least important one. These results are different from the ones obtained by Lopes and Videira (2016) in the assessment of the relative importance of ES to stakeholders study for the Arrábida Natural Park, Portugal. These authors found that cultural services were the ES that stakeholders valued the most and regulation services the ES that stakeholders valued the least. These results are not surprising as this study was applied to a protected area for which cultural services play a major role (Ament et al., 2017). Also, for Portugal, in the *montado* landscape, stakeholders valued provisioning of materials the most, revealing the importance of cork and animal feed in this landscape. However, regulation services were also highly valued regarding its role to prevent desertification. Cultural services, as in our study, were considered the least important ones and were higher valued at local (farm) level. Other studies have also ranked ES based on different methodologies for different locations and using different analysis scales (Ali et al., 2020). However, the comparison of results is not possible unless we use the same type of study area, scale of analysis and stakeholders. Nevertheless, under a practical perspective, our findings can be used by multiple actors and sectors, from governments to academia, to support further ES assessments at regional and national scales. The use of decision-making tools, such as AHP, and the use of maps to represent results provide an excellent communication tool for future planning decisions.

In the second exercise, we mapped using CLC 2018 the potential ES supply over the Portuguese territory using stakeholders' perception. We were able to show the varying spatial patterns of the eight ES over the territory for the first time for Portugal. The matrix-based approach is prevalent in ES assessment studies and, despite some identified disadvantages (Jacobs et al., 2015), has the benefit of enabling a rapid

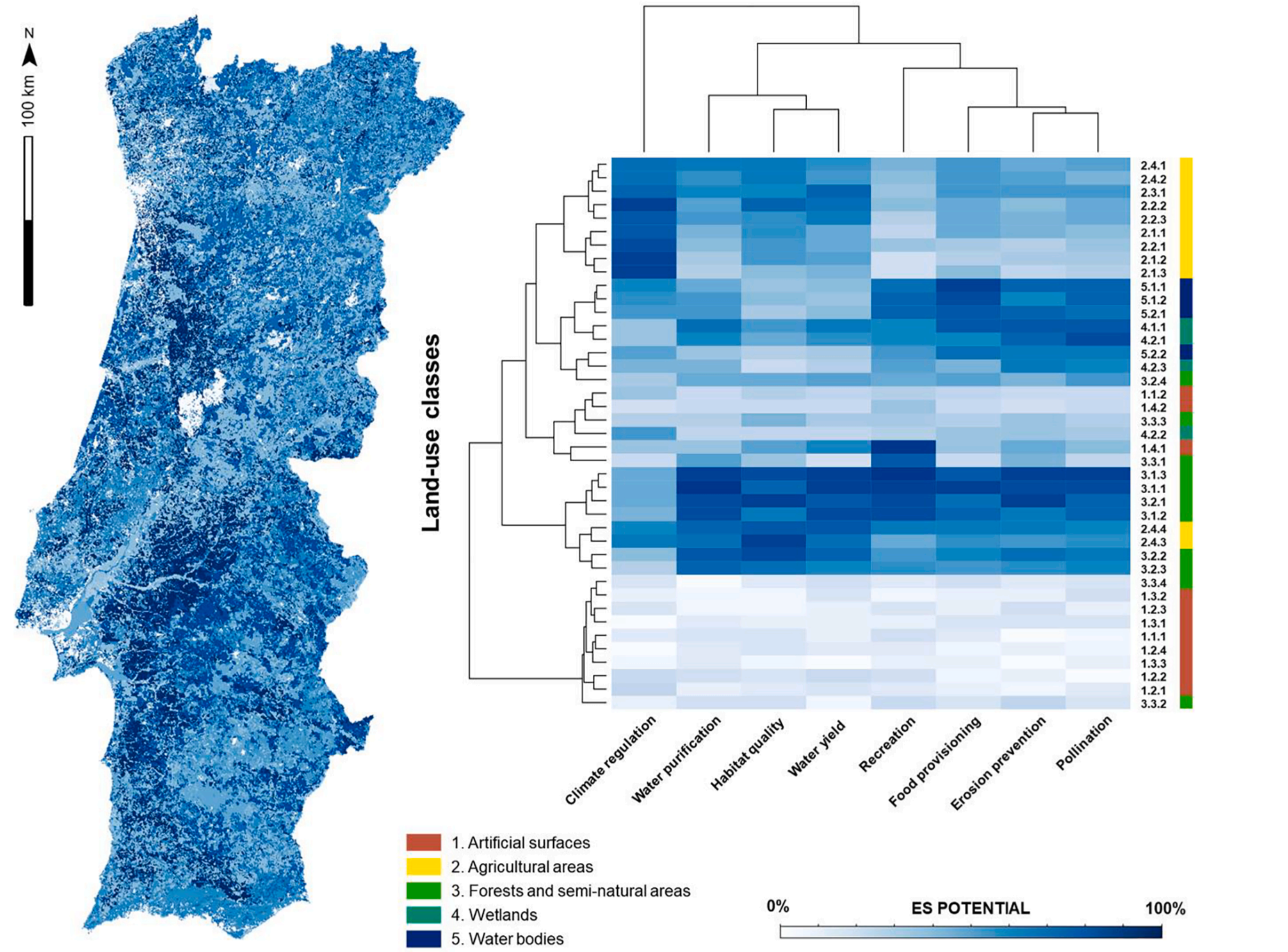

Fig. 4. Overall ES potential map and heat map depicting the intensity of the relationship between CLC classes and the ecosystem services under analysis.

mapping of ES to geospatial units (Burkhard et al., 2009). Although the stakeholders who participated in this study were representatives of organizations related to ES, their knowledge and experience in ES was not homogeneous as we were able to understand through the interactions occurred during the workshop. A variability and confidence analysis should be envisaged in future steps of this research to improve the consistency of the results (Campagne et al., 2017, 2020; Elliott et al., 2020).

Also using information obtained from the second exercise and through advanced data visualization techniques (i.e. clustered heat map), we were able to quantify the contribution of land cover classes to each ES. We found that, according to stakeholders' perception, the "Agricultural areas and "Forests and semi-natural areas" provide about two-thirds of the total ES. However, agricultural areas were considered by the stakeholders to be more critical to climate regulation ES than forests and semi-natural areas as shown in the clustered heat map. This somewhat surprising result may suggest that most stakeholders have a more sustainable development view on the role of agriculture for the country as opposed to an environmental development view (e.g. REDD +). Forest and semi-natural areas and its poor management in Portugal, which have been responsible for many catastrophic fires in the last years with negative consequence on ES (Sequeira et al., 2020), could also have weighted importantly on these results.

In the third exercise, we show the potential impact of different scenarios which translate impacts of different planning strategies on ES supply. The use of scenarios and their ability to represent alternative options for the future of a territory is an essential tool for sharing information based on different perceptions (Levrel et al., 2017). Although it is a speculative exercise by nature and because not all changes in ES are caused by land cover changes, it enables decision-makers to have insights on the possible consequence of planning instruments which can promote sustainable policies. The challenge in future will be how to mainstream effectively this knowledge into planning instruments and decision-making (Greenhalgh and Hart, 2015; Maes et al., 2013; Rozas-Vásquez et al., 2019).

Future developments of this study should include the calculation of the eight ES presented in this study using modelling approaches through software, such as InVEST and other ES indicators (see Table 1). The assessment of these ES indicators would allow to see how different stakeholders' perception is from modelling results, which can confirm the adherence to ES matrix approaches (Burkhard et al., 2009). The identification of areas in which stakeholders perception of ES supply differs significantly from the results of the models, i.e. hard-spots, are the ones in which it will be more important to act (Larondelle et al., 2016). Other future developments are based on the suggestions made by the stakeholders during the workshop (Section 3.5). For instances, activities regarding the data dissemination (e.g. through a WebGIS) and the integration of these results into planning instruments need to be carried out. This study will only be meaningful and effective for natural capital sustainable management if the data and results are used by authorities in environmental decision-making processes. The use of higher spatial data resolution should also be pursued for providing meaningful results at more detailed scales of analysis.

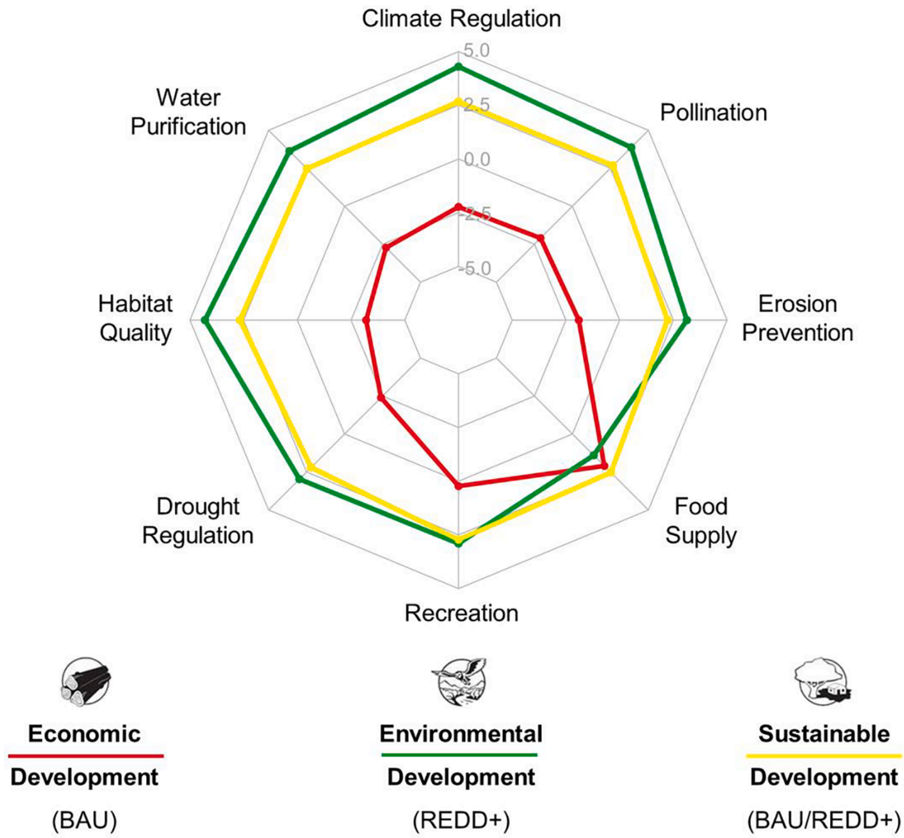

Fig. 5. Development scenarios and their potential impacts on the ES supply by 2030.

5. Conclusion

We assessed stakeholders' perception of ES supply in Portugal using CLC as base land cover. The methodology to extract information about eight pre-selected ES supply from stakeholders and map them included the use of MCDA, matrix-based approach with data visualization techniques, and scenarios. We found that climate regulation was the most valued ES by stakeholders and that recreation ES was considered the least important. We also found that the "Agricultural areas and "Forests and semi-natural areas" provide about two-thirds of the total ES according to stakeholders perceptions. Scenario analysis showed that an "Economic development" scenario will yield negative values for all ES except recreation and food supply. The "Environmental development" scenario increases all ES, except food supply. Finally, the "Sustainable development" scenario, presents values between the previous two scenarios and is the best for food supply. This study contributes with an operational methodology based on open data to extract and map information from stakeholders which generated new insights on ES supply for Portugal. Our findings can be integrated in the definition of future planning policies with a direct impact on ES conservation and land-use scenarios, improving the way we do business with the natural world. We expect that this study provides a starting point for the assessment of ES in Portugal through a spatially explicit approach.

CRediT authorship contribution statement

Pedro Cabral: Conceptualization, Methodology, Investigation, Writing - review & editing, Project administration, Supervision. **Felipe S. Campos:** Conceptualization, Methodology, Investigation, Formal analysis, Writing - review & editing. **João David:** Conceptualization, Methodology, Investigation, Formal analysis. **Ursula Caser:** Conceptualization, Methodology, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the 30 stakeholders for their active involvement in the workshop.

Funding

This study was supported by national funds through FCT (Fundação para a Ciência e a Tecnologia) under the projects PTDC/CTA-AMB/28438/2017 - ASEBIO and UIDB/04152/2020 - Centro de Investigação em Gestão de Informação (MagIC).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2021.107660.

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