



# Perceptions of Public Officers Towards the Effects of Climate Change on Ecosystem Services: A Case-Study From Northern Portugal

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How institutional stakeholders perceive the supply and demand of ecosystem services (ES) under distinct contexts determines which planning actions are deemed priority or not. Public officers play a crucial role in social-ecological management and decision-making processes, but there is a paucity of research exploring their perceptions on ES supply and demand under a changing climate. We address this gap through an exploratory study that analyses the views of public officers on the potential impacts of climate-change related drivers on multiple ES in a major administrative region from Portugal (EU NUTS 3). We combined qualitative spatial data from participatory maps and semi-quantitative answers from questionnaire-based surveys with 22 officers from public institutions contributing to territorial planning. Contrary to other similar studies, public officers shared a common view on the importance of ES. This view aligns with scientific projections on how a changing climate is expected to influence ES in the region over the next decade. In agreement with other observations in Mediterranean regions, the most perceivably valued ES concerned tangible socio-economic benefits (e.g., periurban agriculture and wine production). Surprisingly, despite the region's potential for cultural ES, and considering the impacts that climate change may hold on them, recreation and tourism did not seem to be embedded in the officers' views. We explore the implications of our findings for territorial planning and social-ecological adaptation, considering that the way stakeholders manage the territory in response to climate change depends on the extent to which they are aware and expect to experience climatic consequences in the future.

**Keywords:** climate change adaptation, landscape planning, participatory mapping, questionnaires, social-ecological systems, stakeholder perceptions

## INTRODUCTION

There is an unprecedented concern on ecosystem degradation and biodiversity decline in political agendas worldwide (IPBES, 2019). Over the last decade, the supply of ecosystem services (ES) has been severely affected, with climate change ranking amongst the most challenging drivers globally (Mooney et al., 2009; IPBES, 2019). Climate change is expected to amplify extreme weather (e.g., heatwaves, droughts) and related biophysical phenomena (wildfires, pest spread, biological invasions) that may compromise ecological functioning and ES supply (Malhi et al., 2020). Nevertheless, ES can also contribute to climate adaptation and mitigation, particularly when managed to reduce local communities' exposure to climatic effects (Munang et al., 2013; Malhi et al., 2020).

A vast majority of worldwide climate adaptation and mitigation plans implemented at relevant administrative spatial units have been led by national and local governmental institutions (Reckien et al., 2018; Alves et al., 2020). As these entities play a paramount role in decision-making processes affecting environmental planning and ES, it is critical to understand the drivers and consequences of different management options (Felipe-Lucia et al., 2015). Increasing evidence has revealed that individual preferences and perceptions of managers and decision-makers affect how they assess the spatial distribution of ES supply and demand (García-Nieto et al., 2015; Zoderer et al., 2019). Nevertheless, there is a paucity of research addressing stakeholders' perception of the supply and demand of multiple ES (Zoderer et al., 2019) in a changing climate, particularly concerning public officers responsible for landscape planning and decision-making.

Knowledge of the local context by public and institutional officers can be advantageous to inform management decisions toward sustainability (Caniglia et al., 2021; Kuslits et al., 2021). Likewise, differences among the knowledge and perception levels of these stakeholders on ES supply and demand can influence which management actions or scenarios are deemed priority or not (Wilson, 2006; Jones et al., 2017; Capela Lourenço et al., 2019). While natural science researchers tend to perceive the biophysical and functional aspects of ecosystems as more prominent in ES assessments, public entities are particularly concerned with other socio-economic issues on the governance system, such as employment or education (Hummel et al., 2017).

Participatory mapping has become a popular tool to identify different aspects of ES, eliciting spatial data from different participants to support the identification of e.g., ES hotspots and the areas where ES may be most at risk (Crossman et al., 2013; López-Santiago et al., 2014; García-Nieto et al., 2015; García-Llorente et al., 2018; Kuslits et al., 2021). When qualitative spatial data from participatory mapping is combined with alternative methodologies based on socio-ecological analysis, such as deliberative discussions and questionnaire-based surveys, they can constitute a robust approach for capacity building and facilitate consensus around options for environmental planning and management (Sieber, 2006; Fagerholm and Palomo, 2017; García-Ayllón, 2019; Rice et al., 2020).

Here, we combine individual questionnaires, participatory maps and deliberative discussions, to assess the views of relevant public officers on the potential impacts of future climate on the supply and demand of multiple ES. Specifically, we aimed to answer the following research questions: (1) What are the key supplied and demanded ES for those public officers? (2) How do public officers expect future climate to affect those ES? and (3) Where are ES currently most supplied and potentially affected by climate change-related drivers? Our research was conducted in an Intermunicipal Community (CIM) administrative unit, equivalent to EU NUTS 3 units (European Union, 2020), in northern Portugal. The CIM unit is highly important for territorial and environmental planning in Europe, aggregating multiple municipalities (equivalent to EU Local Administrative Units) into a supra-municipal entity, with competences enforced by national legislation. The CIM plays a critical role in coordinating spatial planning, nature conservation and environmental management at the regional scale, as well as in promoting the local implementation of the national political agenda for climate (Sousa, 2019).

## MATERIALS AND METHODS

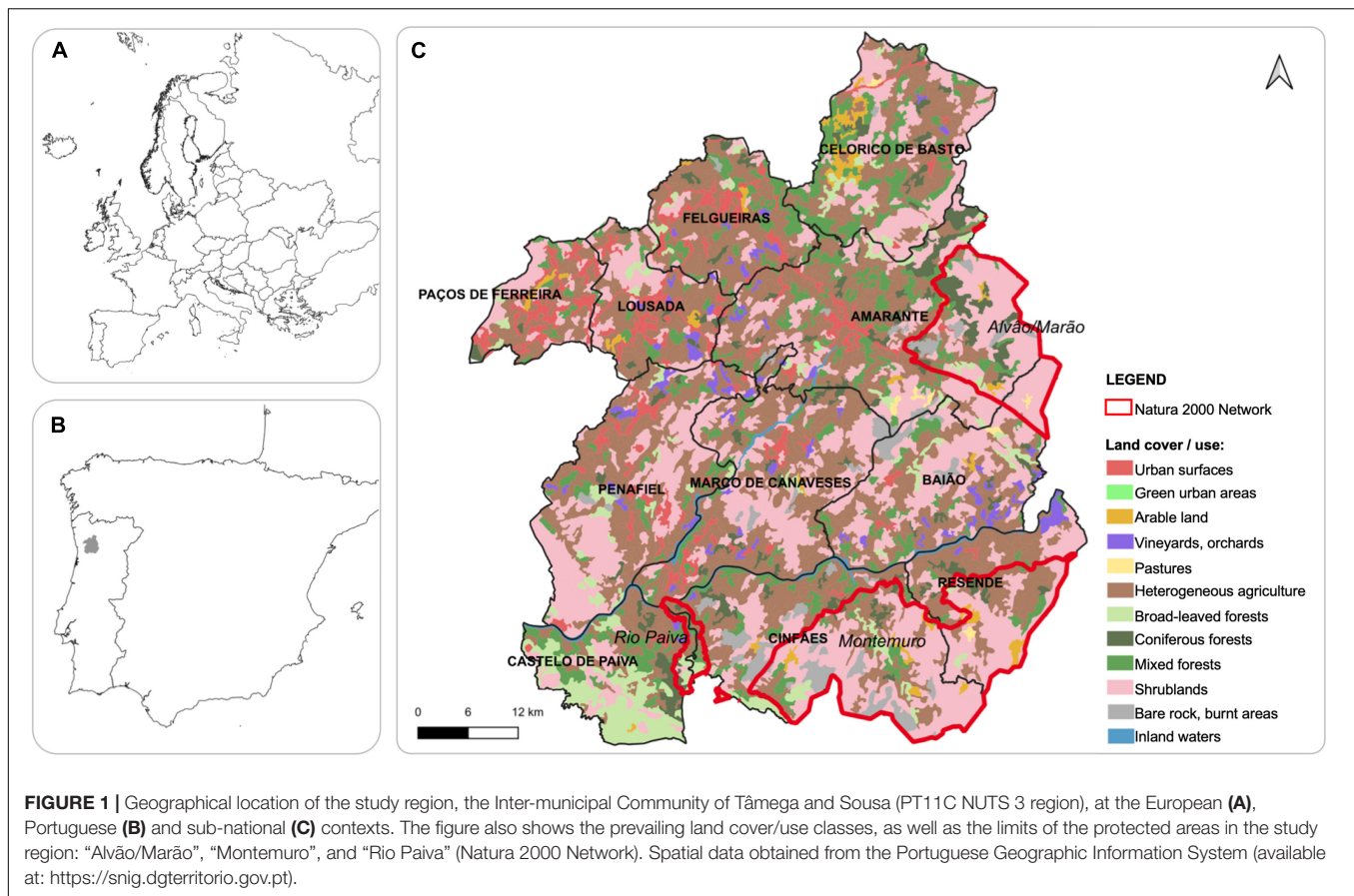
### Study Region

The study region was the Intermunicipal Community of Tâmega and Sousa (CIM-TS), located in northern Portugal (PT11C NUTS 3; **Figure 1**). It spreads over an area of 1,831 km<sup>2</sup>, with a population of approximately 433 000 inhabitants from 11 municipalities. Municipalities in the CIM-TS are characterized by distinct socio-economic, educational and accessibility levels, including urbanized municipalities with a strong industrial production (e.g., clothing and footwear), and periurban municipalities mostly devoted to the production of perennial crops (e.g., cherry and vineyards). The region is heterogeneous in terms of topography, with a mean elevation of ca. 500 m (a.s.l.) that ranges from less than 300 m, in westernmost areas, to 1,415 m, in the eastern mountains.

The CIM-TS exhibits a variety of natural values, with three main protected areas under the European Natura 2000 Network regime: Alvão/Marão (PTCON003), Montemuro (PTCON0025) and Rio Paiva (PTCON0059), as well as a diversity of historical, cultural, and artistic values, with recreational and touristic potential. The predominant climate is Temperate Mediterranean, with a strong maritime influence, windy and foggy summers, persistent heatwaves, and occasional hailstorms and thunderstorms in Winter and Spring. Future climate projections in the region indicate an increasing frequency of heatwaves and a general decrease of precipitation levels, with more frequent episodes of severe droughts and wildfires (Costa et al., 2017), favoring the expansion of pests and invasive alien species (Vicente et al., 2016).

### Participatory Approach

We organized two workshops with 22 public officers with decision-making responsibility at the operational, tactical, and strategic level in the CIM-TS and respective municipalities



(see **Supplementary Figure 1** for the photographic record). Before the start of any activity, the participants provided written informed consent to participate in this study and to use their responses for research purposes. Confidentiality was maintained in data analysis and result presentation to respect participants' privacy. The workshops comprised three main moments. The first moment consisted of a brief presentation by the research team, aiming to introduce the objectives of the workshop and relevant concepts concerning ES and climate change.

In a second moment, a questionnaire-based survey was conducted to first identify the most important ES (our research question 1) and the level to which those ES are expected to be affected by a changing climate (research question 2). To do so, each participant was asked to fill in a paper questionnaire, individually (the full questionnaire is shown in **Supplementary Material 1**). The questionnaire included three parts. The first part comprised questions concerning socioeconomic and professional information of each participant. In the second part, each participant could score a list of ES, considering: (1) the capacity level of the territory to supply each ES; and (2) the level of demand for each ES in the study region as whole. A semi-quantitative scale from 0 (no relevant supply/demand) to 5 (highest supply/demand) was used. A predefined list of 17 ES (5 provisioning, 7 regulating, and 5 cultural services) was considered, together with a short description (following MEA (ed.), 2005; **Table 1**). In the third part of the questionnaire, the

participants were asked to score the level of (negative) impact on each ES, considering eight potential climate change-related drivers of ES change, ranging from the occurrence of heat/cold waves to the prevalence of wildfires and invasive species. A semi-quantitative scale of 0 (minimum impact) to 5 (maximum impact) was used to evaluate the relative level of currently perceived and expected (in 10-years trends) impact of the eight climate-change related drivers on each of the 17 ES types. The list and definition of each ES and climate change-related drivers of ES change provided to the participants are shown in **Table 1**.

The last moment of the workshops consisted of an individual participatory mapping exercise to understand where ES are most supplied and affected by climate change-related drivers, considering the whole study region (our research question 3). The participants were invited to engage in a participatory mapping exercise and were asked to identify the locations where they perceive the highest supply of ES, as well as the highest negative impact of climate change-related drivers on ES. The identification of locations was carried out by each participant individually using two printed A3 page size maps, i.e., one for the location of ES and another one for the location of climate-related drivers of ES change. Maps provided to the participants included basic topographic and land cover information as well as common locations, roads and river names. The identification of locations by each participant was done using 1 cm round markers that respondents stuck to the map. Participants were instructed to

**TABLE 1 |** Predefined list of ecosystem services (ES) and climate change-related drivers of ES change considered to evaluate the views of public officers on the supply and demand of multiple ecosystem services and the expected climatic impacts during the workshops.

<b>Provisioning services</b>	
Agricultural food	Cultivated plants for human nutrition
Reared animals for food	Reared animals for human nutrition, including apiculture, dairy, meat
Wild food	Use of wild species (animals and plants) for human nutrition, including mushrooms and berries
Timber, wood, fibers	Cultivated plants for material production, including paper, fibers, and resin
Water production	Water production for both consumption and irrigation
<b>Regulating services</b>	
Habitat maintenance	Habitat regulation and maintenance, including genetic diversity protection, seed dispersal and pollination
Pest and disease control	Conditions for pest and disease control
Soil erosion protection	Ecological conditions that reduce the risk of erosion and increase soil protection
Fire prevention	Ecological conditions that reduce the risk of wildfires and increase fire protection
Water cycle regulation	Water regulation, including its purification and quality conservation
Carbon sequestration	Reduction of global greenhouse gas effects, and regulation of local temperature and humidity
Air quality regulation	Local air quality regulation, including ventilation and pollution reduction
<b>Cultural services</b>	
Recreational activities	Characteristics that allow outdoors physical interactions with nature
Research and education	Characteristics that allow intellectual interactions with nature, through the production of knowledge
Scenic beauty	Characteristics that allow esthetical representations of nature
Spiritual experiences	Characteristics that enable spiritual experiences, including religious or symbolic values, and cultural heritage
Sense of belonging	Characteristics that promote place attachment, identity and dependence
<b>Climate change-related drivers of ES change</b>	
Heatwaves	Prevalence of abnormally high temperatures for long time periods
Cold waves	Prevalence of abnormally low temperatures for long time periods
Droughts	Period of abnormal persistence of dry weather
Floods	Abnormal increase of water volume and speed, usually from abundant precipitation in a short time period
Soil erosion	Superficial removal of soils, usually caused by rain, wind, water bodies or temperature. Includes desertification in the case of humidity deficit
Wildfires	Increase in the number, frequency, and magnitude of uncontrolled wildfires
Pests and diseases	Uncontrolled expansion and occurrence of diseases and pests (on humans, animals, forest, agriculture)
Alien invasive species	Introduction and dispersal of alien species with uncontrolled expansion (by humans)

write different alphabetic letters (from A to Q) in the dots to identify the location of individual ES. Similarly, they were instructed to write different numbers (from 1 to 8) to identify the dots pertaining to the location of individual climate change-related drivers of ES change. For pragmatic reasons, we set a limit of 40 dots per participant, i.e., 20 dots for each map. In each dot the participants could identify several letters (ES) and numbers (climate-change related drivers) as needed.

## Data Analysis

Considering our small sample size and the absence of a normal distribution in our data, our analysis adopted non-parametric tests and descriptive statistics. The results from the individual questionnaires focused on the perceived supply and demand of ES were analyzed by computing the median values of the participants scores and respective interquartile intervals (IQR), being illustrated through box-plots. Statistically significant differences in the score values between the supply and the demand of each individual ES were analyzed using the Wilcoxon test (for dependent samples). Significant differences in the score values of ES supply and of ES demand among municipalities were tested using the Kruskal-Wallis test (for independent groups).

The results from the individual questionnaires focused on the perceived impacts of climate change-related drivers on ES were analyzed following do Rosário et al. (2019). Specifically, we computed the median values of the participants scores for each combination of individual ES and climate change-related drivers. A standardized median score value of 0, < 1, 1–2, or > 2, respectively, represents an absent, low, medium, or high impact of a given climate change-related driver on a particular ES. We further compared the standardized median scores between the perceived current and future impacts of climate change-related drivers on ES changes. Differences between these values resulting in 0 represent a stable trend, i.e., no expected changes in the magnitude of ES impacts between current and future climate change-related drivers. In contrast, a negative difference between standardized median scores indicates a decreasing trend, i.e., less impacts of future climate change-related drivers on ES changes compared to the present time of assessment. A positive difference in standardized median scores suggests an increasing trend, i.e., higher impacts of future climate change-related drivers on ES changes compared to the present time.

The results of the participatory mapping exercise were used to obtain qualitative spatial data on ES supply and on climate

change-related drivers of ES change in the whole study area. Following the specifications from Burkhard and Maes (2017), we digitized each individual map, using ArcMap 10.1 (ESRI, 2012). For each map we specifically annotated the spatial location of each ES and climate change-related drivers based on the letters and numbers assigned to each dot on the maps (see section “Participatory Approach”). We then combined each set of digitized locations and applied a Kernel Density function (based on point features) to identify the most prominent locations (“hotspots”) for ES supply as well as the locations most affected by climate change-related drivers (Fagerholm and Palomo, 2017; Sussman et al., 2019). The Kernel function was applied considering a minimum mapping unit (m.m.u.) of 250 m and a smoothing option (search radius) of 1 km, using the Spatial Analyst Toolbox in ArcMap 10.1 (ESRI, 2012). This procedure was applied to illustrate the perceived location of the total set of ES climate change-related drivers in the whole study area. It was also adopted to illustrate the perceived location of each set of provisioning, regulating and cultural ES, separately.

## RESULTS

From the group of 22 participants, 12 were females and 10 were males. Most participants were between 25 and 44 years old (59%), with the remaining holding 45–64 years old. All participants had a university-level education (graduation or master), and their main working areas were territorial planning, environment, agriculture and forestry, or tourism (see **Supplementary Table 1** for details).

### Perceived Supply and Demand for Ecosystem Services

Among the provisioning services, agricultural food ( $4 \pm 1$  IQR) and water provision ( $4 \pm 1$  IQR) were considered as the most supplied and demanded ES in the study region. For the regulating services, fire prevention and water regulation were identified as the most supplied (both,  $3 \pm 2$  IQR) and demanded (both,  $5 \pm 1$  IQR). Regarding cultural services, scenic beauty was scored as the most supplied ( $3.5 \pm 2$  IQR), whereas research and education as the most demanded ( $4 \pm 2$  IQR).

The Wilcoxon test revealed significant differences between the supply and demand scores for most ES ( $p < 0.05$ ), with ES demand being higher than ES supply (**Figure 2**). Exceptions were found for the provisioning services of agricultural food, timber, wood and fibers and water provision, as well as for the cultural service of scenic beauty, for which no differences were found (**Table 2**). The Kruskal-Wallis test did not result in significant differences ( $p > 0.05$ ) in the score values between municipalities, except for the supply of the cultural service sense of belonging which hold a significant result (test statistic = 18.22;  $p = 0.033$ ; **Table 2**).

### Perceived Impacts of Recent and Future Climate on Ecosystem Services

There was a general tendency for medium to high impacts of different climate change drivers on most ES, with special

emphasis on wildfires (**Figure 3**). Heatwaves and drought episodes appeared to be particularly relevant for the supply of provisioning and regulating services. Pests and diseases emerged as mostly affecting provisioning services, whereas soil erosion (and desertification) and heatwaves were seen as particularly problematic for regulating services.

Climatic impacts were perceivably expected to stabilize or to increase over the next decade. Cold waves were an exception, as they were expected to have a relatively low and decreasing impact on wildfire protection. Similarly, despite a perceived high impact of heatwaves on recreation activities, a decreasing future trend of their impact on this cultural service was expected by the participants (**Figure 3**).

### Mapping Ecosystem Services' Supply and Impacts of Climate Change-Related Drivers

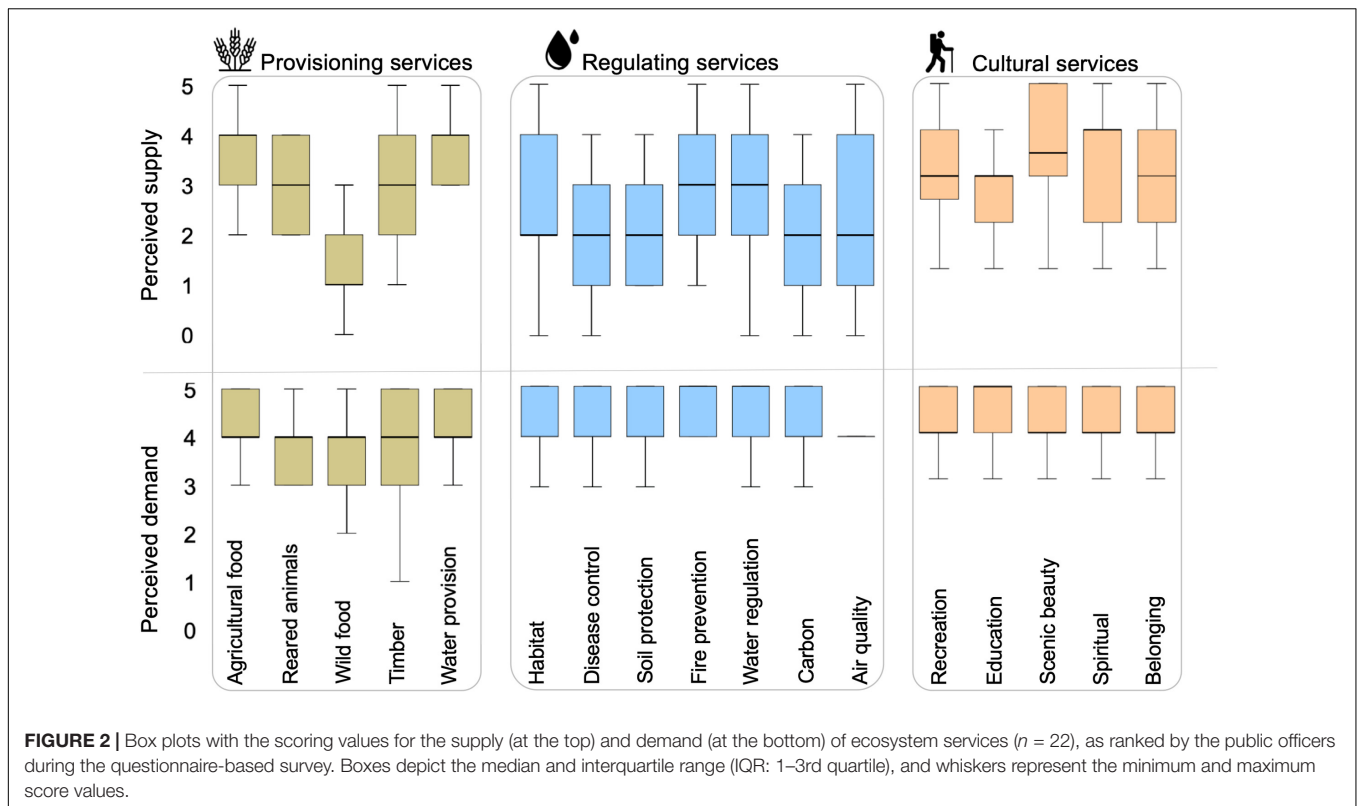
The spatial distribution of the locations perceived as most relevant for the supply of ES were, in general, distributed over a NW-SE gradient (**Figure 4**), being particularly dense at more densely urbanized areas (i.e., northwesternmost municipalities) as well as at agricultural lands and mountain areas within the Natura 2000 network (southernmost municipalities). From the mapping exercise, we observed a high density of areas supplying provisioning services, particularly at places of vineyard cultivation (cf. central municipalities). The supply of regulating and cultural services also showed a higher expression at urban spaces and protected mountain areas.

In general, areas most prone to the impacts of climate change-related drivers overlapped with the supply of ES (**Figure 4**). Wildfires, heatwaves, and pests and diseases were the most spatially represented drivers, while drought episodes and cold waves were the least represented (see also **Supplementary Figures 2, 3**). During the mapping exercise, participants highlighted the prevalence of pests (and plagues) at locations of vineyard and orchard production. A prominent concern of flood episodes in the vicinity of water lines and urbanized areas was also emphasized. The incidence of heatwaves, drought episodes and invasive species was indicated as most affecting urban areas and sites of forest production.

## DISCUSSION

### Perceived Importance of Ecosystem Services

The well-being of present and future generations depends on the sustainable management of ecosystems and their services, which in turn is shaped by the views of actors responsible for decision-making and management implementation (Reed, 2008; Reed et al., 2009; Bennett et al., 2016). The public officers who participated in this study seemed to share a common perception of the importance of ES, which somehow highlights some contradictions with other studies at local and regional scales, showing opposing views and perceptions of different decision-makers and managers (García-Nieto et al., 2015;



Garau et al., 2020). Nevertheless, our target population was rather homogeneous regarding their level of decision and socio-cultural profile, i.e., they were all governmental representatives with similar educational backgrounds, possibly hampering any significant divergence among stakeholders. The only service potentially diverging among the officers' views was the sense of belonging, a cultural service difficult to measure and value, as it is shaped by a multitude of psychological factors that depend on the individual dimension and are, therefore, hardly captured at the societal level (Wartmann and Purves, 2018).

Our exploratory research suggests that provisioning services ranked amongst the most relevant services for the public officers of the administrative unit (cf. **Figure 2**). Other studies also showed higher scores attributed to provisioning services by diverse types of stakeholders at the expense of regulating and cultural services (Pereira et al., 2005; Oteros-Rozas et al., 2014; do Rosário et al., 2019), since the material socio-economic benefits generated by these services tend to be more easily recognized than regulating services (Hummel et al., 2017). Amongst the provisioning services, agricultural food and water provision were indicated as the most supplied and demanded ES in the territory by the public officers. This observation agrees with other participatory studies in the Mediterranean region, where socio-economy is typically supported by traditional agricultural practices (Pereira et al., 2005; García-Nieto et al., 2015). The socio-economy of the study region is largely marked by cherry exportation and by the cultivation of traditional vineyards that underlie the Green Wine production in the periurban and rural space. In fact, from the participatory mapping, we could

verify that the perceived distribution of provision services largely overlapped vineyards' location and that of other agricultural lands (cf. **Figure 4**).

Among the regulating services, wildfire prevention and water quality maintenance were highlighted as the most supplied and demanded services in the region. Over recent years, and particularly in 2017, Portugal (and the wider Mediterranean Europe) has been dealing with severe wildfire episodes, with major socio-economic consequences (Viegas, 2018). Such events have raised both social awareness and political concerns on promoting ecosystem recovery and more resilient landscapes to wildfires. Indeed, when referring to the social demand of ES, regulating services largely surpass the scores attributed to provisioning services (cf. **Figure 2**). Moreover, regulating services appear to show a higher relevance in mountain areas (cf. **Figure 4**). These trends may well reflect a growing social recognition of the need to cope with environmental change (e.g., climate and land-use change), particularly in the most sensible and vulnerable mountainous landscapes (Schröter et al., 2019).

The scenic beauty was indicated as the most supplied cultural service. However, research and education ranked amongst the most demanded, which is consistent with other studies suggesting that these services tend to be well recognized by environmental managers (García-Nieto et al., 2015). Yet, previous reviews on the valuation of cultural services suggest a general preference bias for tangible and easily quantifiable benefits on ecotourism and recreation (Hernández-Morcillo et al., 2013; Milcu et al., 2013; Blicharska et al., 2017). Of notice, recreation and ecotourism benefits did not rank amongst the most perceivably valued

**TABLE 2 |** Wilcoxon test results (Z-values) for significant differences between the score values for supply and demand of individual ecosystem services in the study region. Kruskal-Wallis test results (H) for significant differences in the score values of ES supply and ES demand among municipalities.

Ecosystem service	Supply versus demand		Supply across municipalities		Demand across municipalities	
	Z-values	p-values	H-values	p-values	H-values	p-values
<b>Provisioning services</b>						
Agricultural food	-1.93	0.05	8.24	0.31	12.11	0.10
Reared animals (food)	-2.92	0.00*	6.37	0.50	11.24	0.13
Wild food	-3.44	0.00*	8.21	0.32	8.83	0.27
Timber, wood and fibers	-1.52	0.13	9.37	0.10	7.52	0.38
Water provision	-1.83	0.07	15.02	0.04	11.40	0.12
<b>Regulating services</b>						
Habitat maintenance	-3.45	0.00*	10.21	0.09	12.79	0.08
Disease control	-3.39	0.00*	7.20	0.41	8.73	0.27
Soil erosion protection	-3.52	0.00*	8.63	0.28	5.80	0.56
Fire prevention	-3.52	0.00*	3.28	0.86	7.26	0.40
Water regulation	-3.23	0.00*	10.44	0.17	11.09	0.14
Carbon sequestration	-3.55	0.00*	10.52	0.11	13.77	0.06
Air quality maintenance	-2.62	0.01*	11.22	0.13	11.40	0.12
<b>Cultural services</b>						
Recreation	-3.76	0.00*	9.09	0.25	9.63	0.21
Research and education	-3.86	0.00*	10.51	0.16	12.93	0.07
Scenic beauty	-1.78	0.08	9.81	0.20	11.25	0.13
Spiritual experiences	-2.13	0.03*	10.54	0.16	11.17	0.13
Sense of belonging	-3.58	0.00*	15.02	0.036*	11.22	0.13

An asterisk indicates significant differences, considering a p-value of 0.05.

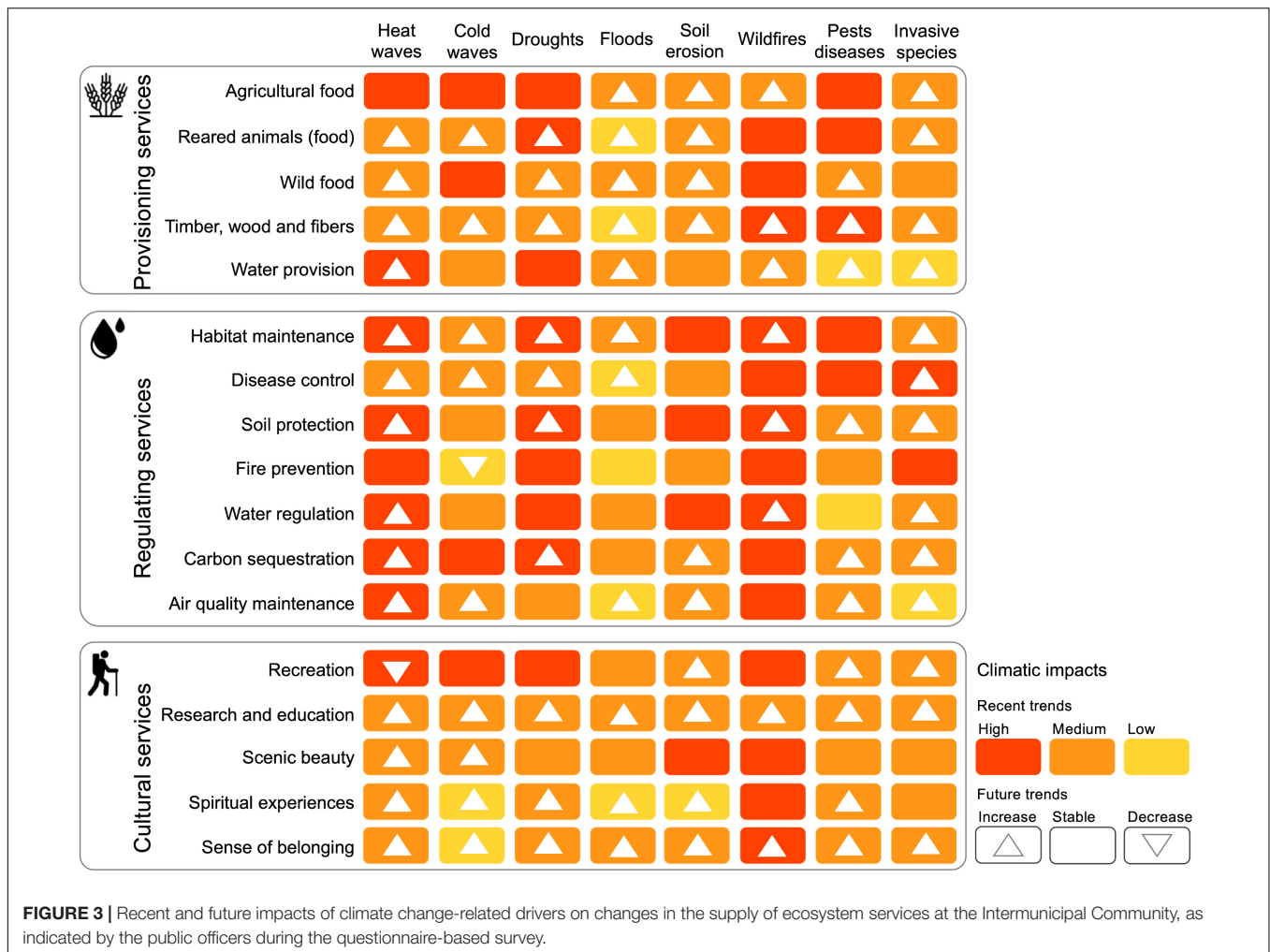
cultural services (cf. **Figure 2**), despite the region's esthetic natural landscapes (e.g., within the Natura 2000 protected areas) and historic cultural elements (e.g., the Romanesque route), as well as the recent national policies for promoting tourism in the country. This observation somehow differs from the results often obtained for protected areas, where cultural services tend to play a major role compared to provisioning or regulating services (e.g. Lopes and Videira, 2016; Ament et al., 2017). These results may suggest the need for better knowledge about the region's natural and cultural assets, particularly in urban and mountainous areas (cf. **Figure 4**), which agrees with other European studies (Harrison et al., 2010; Oteros-Rozas et al., 2014).

## Perceived Climatic Impacts on Ecosystem Services

Despite a consensus among the research community on the consequences of climate change, how stakeholders view the existence and extension of climatic impacts is a topic of great importance for strategic territorial decisions (Weber, 2010; Capela Lourenço et al., 2019). In the study area and the wider Mediterranean region, climate change has been associated with increasing temperature extremes (Fonseca and Santos, 2018), more frequent droughts (Costa et al., 2012), expansion of pests and invasive species (Vicente et al., 2016), and increased wildfire activity (Dupuy et al., 2020), which are indeed expected to be intensified in the upcoming decade(s). From our results, the targeted public officers seem to share a common negative view together with the scientific community on the potential

escalating impacts of climate change (cf. **Figure 3**). This trend is in line with Hummel et al. (2017), who already suggested that despite existing ambiguities in the views of scientists and decision-makers, climate change is seen as a common threat to ES in European protected landscapes. However, in this specific administrative region, those climatic threats were perceived by public officers as already existing and increasing in the next decade, thus hinting at a possible contradiction with the common idea that decision-makers may see climate change projections as of low probability or at a distant future occurrence (Capela Lourenço et al., 2019).

From the different set of climatic factors, stakeholders highlighted wildfire intensification as the most expected to drive ES supply. As previously emphasized, the rising magnitude and impacts of wildfire episodes in the Mediterranean region (Viegas, 2018; Dupuy et al., 2020) inevitably put them as a socio-economic priority. Despite the undeniable (natural) role of wildfire on shaping Mediterranean landscapes (Keeley et al., 2012; Pausas and Keeley, 2019), its extreme behavior in response to climate has brought severe consequences for the regulation and maintenance of ecosystem functions and respective natural resources (Sil et al., 2019), coupled with catastrophic socio-economic impacts (Tedim et al., 2013; Viegas, 2018). Alongside with wildfires, drought episodes and heatwaves appear to be particularly relevant for the supply of the most recognized ES, i.e., provisioning and regulating services. This pattern agrees with the results obtained by Cabral et al. (2021), who evaluated stakeholders' ES perception from a participatory methodology for continental Portugal based on land cover, and found drought



regulation and associations to extreme fire as regulating ES of highest concern. Heatwaves, drought episodes, and wildfires are expected to act synergically (compound events), with the occurrence of one exacerbating the occurrence of another (Parente et al., 2019). Nevertheless, it is perhaps interesting to notice that the spatial representation of drought episodes during the mapping exercise was less prevalent and more scattered than for wildfires and heatwaves. Following Owen et al. (2012), extreme weather and climate episodes, and their effects, are likely to be more recognized by individuals who have directly experienced them. This may possibly be the case in the present study region, in which the social memory of public officers on the effects of heatwaves and wildfires may be more prominent than droughts, and that a direct link between droughts and wildfire occurrence might not be obvious. In any case, the information obtained in this study, and the lack of wider studies on the issue, leave us to pure speculations on why droughts were apparently less prevalent in the mapping exercise than wildfires and heatwaves.

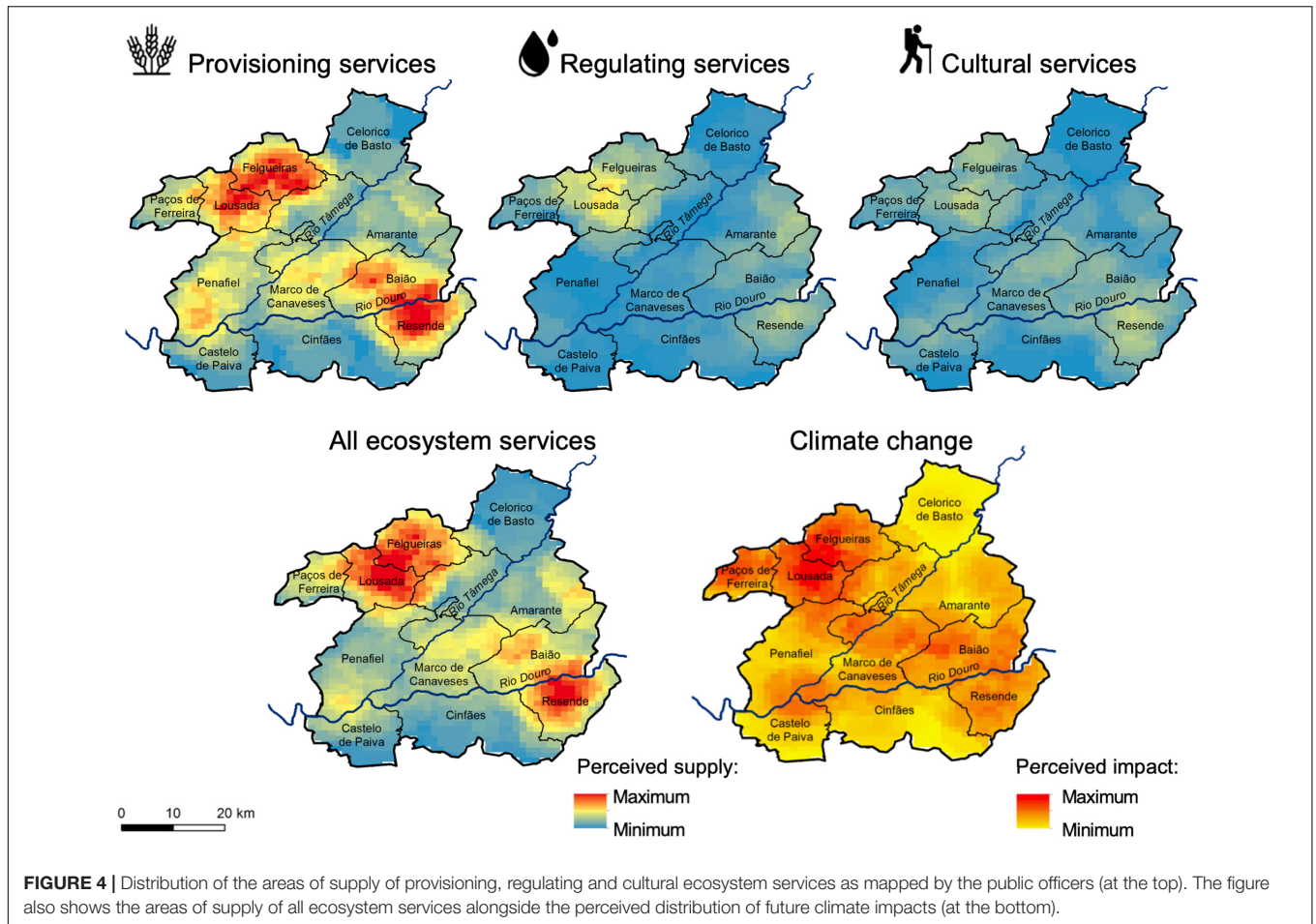
Besides the aforementioned factors, pests, diseases, and desertification were also prominent and particularly incident over the provisioning services of agriculture and water production.

This pattern converges with local-scale observations and future projections for the administrative unit (Fonseca and Santos, 2019), which place pests and diseases as factors benefiting from a changing climate, with serious socioeconomic implications for the maintenance of vineyards and wine production in the study region (Fraga et al., 2017). By contrast, public officers seemed to expect weaker impacts from any climatic factor on recreation and tourism. Strategic measures being currently considered in the region at fine scales (e.g., development of shelter infra-structures) may mitigate the impacts of extreme weather and climate events in tourist flows in the region, following Hall et al. (2016). Still, caution should be granted since visions shared by public officers in our study suggest a negative future impact on other cultural dimensions of the region, with putative changes in landscape esthetics, knowledge, spiritual values, and cultural identity.

### Considerations for Territorial Planning and Management

The way people manage the territory in response to climate change depends on the extent to which they are aware and expect to experience the impacts of climate change-related





events (Marshall et al., 2019). As examples, leading international organizations, such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES), have emphasized the need to integrate local knowledge to explore the impacts of climate change on ES at regional and local levels (Yohe et al., 2007; Díaz et al., 2015). Therefore, understanding stakeholders' perceptions is of utmost importance for the implementation and success of sustainable management, fostering climate change adaptation and impact mitigation on natural capital and human well-being (Moser and Ekstrom, 2010; Munang et al., 2013).

Our study suggests that public officers with decision power already show a common agreement on the importance of provisioning and regulating ES, being attached to tangible socio-economic consequences which are easier to recognize, such as those associated with the wine production. They also appear to recognize the increasing role of heatwaves, wildfires, pests and diseases on shaping those ES over the next decade, in agreement with the climate change predictions provided by the research community. In this study, the areas of the territory seen as most relevant for the supply of ES were coincident with those most expected to be exposed to climatic impacts, thus reflecting the importance of socio-economic activities, such as agriculture. Despite the region's cultural and natural value, the

role of cultural ES, and particularly the impacts (such as wildfires) that a changing climate may hold on to recreation and tourism, does not seem to be embedded in public officers' views.

The observed perceptions may reflect larger efforts of public institutions in securing agricultural food provision, water supply, and fire-resilient landscapes, hence emerging as a priority for the region's adaptation to climate change. This agrees with Mascarenhas et al. (2016) and Cabral et al. (2021), who also found agricultural food, water supply, and fire/drought-resilient landscapes as priority services when conducting participatory approaches with multiple stakeholders in Portugal. In our region, the perceptions of public officers concerning ES importance and future impacts of climate change also seem to be strongly linked to the socio-economic activities currently dominant in the study region (e.g., agriculture), thus underlining the importance of local knowledge for ES management. Following the observations from other studies based on participatory approaches (Boeraeve et al., 2018; Spyra et al., 2019), our research facilitated knowledge sharing among officers of neighboring municipalities and supported the reinforcement of a shared vision for the intermunicipal region, contributing to include diverse experiences and perspectives, as well as to increase awareness on current and future climatic risks on ES. These are

of utmost importance at the inter-municipal level, where each municipality that works under particular (socio-economic and administrative) dynamics needs to place effort on a shared vision with its neighboring municipalities to develop and implement successful strategic planning and management actions.

## Research Limitations and Prospects

Some limitations concerning our approach should be highlighted. Even though no significant differences in the perceived supply and demand of ES were found among municipalities, we cannot ensure some participants have not biased their responses to the parts of the study area for which they are more familiar with, and therefore our analysis can still overlook possible differences in the actual ES supply and demand due to distinct knowledge levels of the territory by participants, and diverse biophysical or socio-economic characteristics among municipalities.

Also, caution must be granted to the implications of our results, since a common awareness and perception of the impacts of climate change on ES does not necessarily translate into effective governmental engagement in the prioritization of this matter in action-oriented decision-making (Hummel et al., 2017; Luís et al., 2018). In addition, diversified engagement from citizens and other relevant private and public entities should also be accounted (Runting et al., 2017; Brown et al., 2020). Subsequent research should explore to what extent the awareness of climate change impacts in ES is effectively incorporated into regional planning and management, given their influence in decision-making processes shaping large portions of the landscape.

Finally, our exploratory study focused on the social dimension of ES, by addressing the perceptions of public officers. The assessment of ES benefits, beyond people's perceptions, should constitute a future research effort to better comprehend the role of ES accounts and values on the prioritization of territorial planning (García-Ayllón, 2019; Watson et al., 2019). Likewise, understanding the multiple dimensions of ES, including ecosystem functions and the ecological flows of ES at fine spatial scales should nevertheless be considered for an integrative management of the territory (e.g., Harrison et al., 2018; Lautenbach et al., 2019).

## DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

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## ETHICS STATEMENT

Ethical review and approval was not required for this study with human participants, in accordance with the local legislation and institutional requirements. The participants provided written informed consent to participate in this study and to use their responses for research purposes.

## AUTHOR CONTRIBUTIONS

ASV: conceptualization, data curation, formal analysis, methodology, writing—original draft, and writing—review and editing. MG: data curation, methodology, writing—original draft, and writing—review and editing. CC-S, EP, and JRV: data curation and writing—review and editing. JPH: writing—review and editing and supervision. JAS: writing—review and editing, supervision, funding acquisition, and project administration. All authors contributed to the article and approved the submitted version.

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