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MaxEnt modelling of the potential distribution areas of cultural ecosystem services using social media data and GIS

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Abstract
This study uses photographs on social media to spatially model the potential distribution of user preferences for cultural ecosystem services (CES). The areas within the administrative boundaries of the province of Isparta in Turkey's Mediterranean region constitute the study area. Hundred and sixty-six photographs with geographical coordinates, taken between the years 2012–2018 and shared on photograph sharing platform Flickr, were linked to CES, and the CES provided in the study area were identified and categorised. The species distribution model was used in the study, and the natural and cultural assets in the study area were taken as environmental independent variables. The study used MaxEnt and geographical information systems integrally. For every CES, hotspot areas were identified and the degrees of significance of environmental variables for generating CES potential were determined. The highest level of CES provision in the study area was for recreation. The most important environmental variables for determining CES distribution were roads, religious places and distance to historical and cultural areas, identified by degrees of proximity using Euclidian distances. Among the significant conclusions of the study are overlapping outcomes for closely related CES (such as aesthetic values and recreational values) and the relationship between the outcomes and the natural and cultural assets in the area (such as water surfaces, green fields.) The study is thought to contribute to the extant literature in terms of spatially assessing the intangible benefits of ecosystem services and land use decision-making.

Keywords Cultural ecosystem services · Social media · MaxEnt · Flickr · GIS

1 Introduction

An ecosystem is a dynamic complex that has functional interactions with groups of plants, animals and microorganisms and the inanimate environment. Ecosystem is defined as "a system composed of biotic communities and their abiotic environment interacting with

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each other" (Odum 1953). Humans are inseparable parts of ecosystems (MEA 2005). Since the very beginning of human-ecosystem relations, there have been certain interactions between them (Figueroa-Alfaro and Tang 2017). Ecosystem services studies focus on how humans use ecosystems, how they affect them and the kind of interaction that occurs between the ecosystem and society (Longsdon 2011). The Millennium Ecosystems Services Assessment Report (MEA 2005) defines the tangible and intangible benefits that are derived from ecosystems and are directly relevant to human welfare as ecosystem services and categorises ecosystem services as provisioning, regulating, supporting and cultural services. Cultural ecosystem services (CES) differ from other ecosystem services, as they include intangible benefits. MEA (2005) and TEEB (2011) define CES as "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" including cultural diversity, spiritual and religious benefits, knowledge systems, educational assets, inspiration, aesthetic values, social relations, sense of place, cultural heritage and recreation and tourism. Common International Classification of Ecosystem Services (CICES) also defines cultural services as the "non-material, and normally non-consumptive, outputs of ecosystems that affect the physical and mental states of people" (Haines-Young and Potschin 2013).

Identifying the corresponding value of an ecosystem service depends on understanding its socio-ecological content. The most significant distinguishing feature of ecosystem functions or processes is the significant participation of beneficiaries in ecosystem services (Brown and Fagerholm 2015) Without humans, ecosystem services cannot exist (Longsdon 2011; Chan et al. 2012). There is therefore a need to define the relationship between ecosystem services and humans, whose welfare depends on ecosystem services, and to specify the value of this relationship.

The fact that the benefits of CES derived from ecosystems include subjective and intangible evaluations makes quantifying and mapping CES a complicated matte (MEA 2005; Richards and Tunçer 2018). Researchers into CES have used various techniques to overcome this complexity, including focus groups (Norton et al. 2012), face-to-face interviews (Plieninger et al. 2013) and surveys with social content (Pleasant et al. 2014). These studies have generally been carried out at the local level and do not include regional or wider scale spatial assessments (Clemente and County 2019). These techniques have now become conventional; they are out of keeping with developing technology and also time consuming (Richards and Tunçer 2018).

Over the last few years, the use of data derived from geo-tagged photographs on social media to assess CES has become very popular (Martinez-Pastur et al. 2016; Tenerelli et al. 2016; Figueroa-Alfaro and Tang 2017; Yoshimura and Hiura 2017; Oteros-Rozas et al. 2018; Sinclair et al. 2018; Clemente and County 2019). Previous studies using social media data to map ecosystem services have utilised geo-tagged photographs to identify areas of high popular interest.

The MaxEnt species distributions model, which is based on the presence-only data and is used in ecosystem services studies that make use of photographs on social media as primary data to identify the spatial distribution or potential of ecosystem services by land cover, has emerged as a new methodological approach (Yoshimura and Hiura 2017; Clemente and County 2019). For spatial assessment, use is made of maps with a scale of 1/25000 created using mapping techniques based on geographical information systems and featuring information on land use characteristics, such as the Corine land use map (Tenerelli et al. 2016; Richards and Tunçer 2018; Clemente and County 2019)

There are few studies of ecosystem services in Turkey (Arslan-Muhacir and Tazebay 2017; Çoban and Yücel 2018; Duman and Atmiş 2018; Tezer et al. 2018), and there is no study that specifically treats of the spatial assessment of CES, as far as the authors of the present study are aware. In the literature, studies carried out using geo-tagged photographs on social media for spatial assessments are generally seen to have been carried out in Europe, and the number of studies referring to other geographical regions is quite low. As preferences regarding CES are related to cultural values (De Groot et al. 2010), a study of a geographical region that is home to a variety of cultures might be expected to make a significant contribution to the literature. A literature survey was undertaken to formulate the hypotheses to guide the present study, and the research questions to be answered were determined on the basis of these hypotheses (Table 1).

The main objective of this article, in the light of the hypotheses and research questions, is to identify preferences regarding CES using photographs on social media and to establish their relationship to the land cover in Isparta, which features prominent natural resources, recreational opportunities, geological formations and historical and cultural structures and provides resources for tourism activities. Geo-tagged photographs and digital technology are used to assess the CES as part of the present study.

2 Materials and methodology

2.1 Study Area

The study area is the town of Isparta, located on coordinates 37°.22′–38°.31′ N and 30°.00′–31°.36′ E, and its environs in southwestern Turkey, covering an area of 890,000 ha

Table 1 Hypotheses and research questions (De Groot et al. 2010; Schaich et al. 2010; Daniel et al. 2012; Brown and Fagerholm 2015;Yoshimura and Hiura 2017; Li and Wang 2018; Clemente and County 2019)

Hypotheses	Research questions
H1: CES involve subjective and intangible evaluations by their nature and are therefore difficult to quantify and map	S1: Can CES be expressed spatially by establishing a relationship between land use and user preferences?
H2: Photographs on social media which include the visual preferences of users and have geographical coordinates attached (are geo-tagged) may be used as data in the spatial analysis of CES, and this method has the advantage of making it possible to analyse large areas	S2: Is it possible to map CES and identify their areas of influence using photographs on social media?
H3: The mapping of CES and their relationship with land use makes it possible to identify the type of land cover on which user pressure is intense	RQ3: Is it possible to identify user pressure on land cover by establishing a relationship between land use and CES?
H4: Mapping CES in relation to land use and land cover is an effective means of emphasising the contribution of landscape characteristics to human welfare	RQ4: Is there a significant relationship between spatial assessments of CES in landscapes with different natural and cultural characteristics and the contribution of these areas to human welfare?
H5: Geographical Information Systems and the MaxEnt modelling programme are suitable means for modelling the intensity of CES and their spread over land cover as they are able to produce models for larger areas using data collected from small areas	RQ5: Is the integrated use of MaxEnt and GIS a suitable means for modelling the spatial distribution of CES and establishing their relationship with natural and cultural ecosystems?

with a population of 433,830 in 2017 (Fig. 1). Isparta is a region valued for its natural and cultural characteristics, and there are two nature reserves (Gölcük and Başpınar) in the province as well as the Kızıldağ National Park. There are two recreational areas in Isparta town centre—namely, Gökçay and Ayazmana. Isparta has a high potential for providing ecosystem services with the summer and winter recreation and tourism opportunities it offers and its proximity to ancient cities. The Davraz Skiing Centre in Isparta can be used for winter sports, and the ancient city of Sagalassos lies partially within the province.

2.2 Data collection and analysis

The popular Flickr platform was used to provide data for the spatial analysis of CES using photographs on social media. This free source provides many pieces of spatial information indicating the preferences of users for cultural values that can be brought to light through content analysis (Clemente and County 2019). Although there are other platforms (Table 2) which allow for users to share photographs and their locations free of charge, such as Panoramio, Instagram and Pinterest, Flickr was chosen for this study, as it has been used in many previous studies (Donaire et al. 2014; Guo et al. 2016; Spyrou and Mylonas 2016; Li and Wang 2018) and because Panoramio stopped photography sharing in November 2016, while Instagram and Pinterest require users to gain special permissions for access to some content. According to August 2018 data (https://expandedramblings.com/index.php/flickr-stats/), Flickr had more than 90 million users and one million shared items daily, making it the photography sharing platform with the most users and shared content.

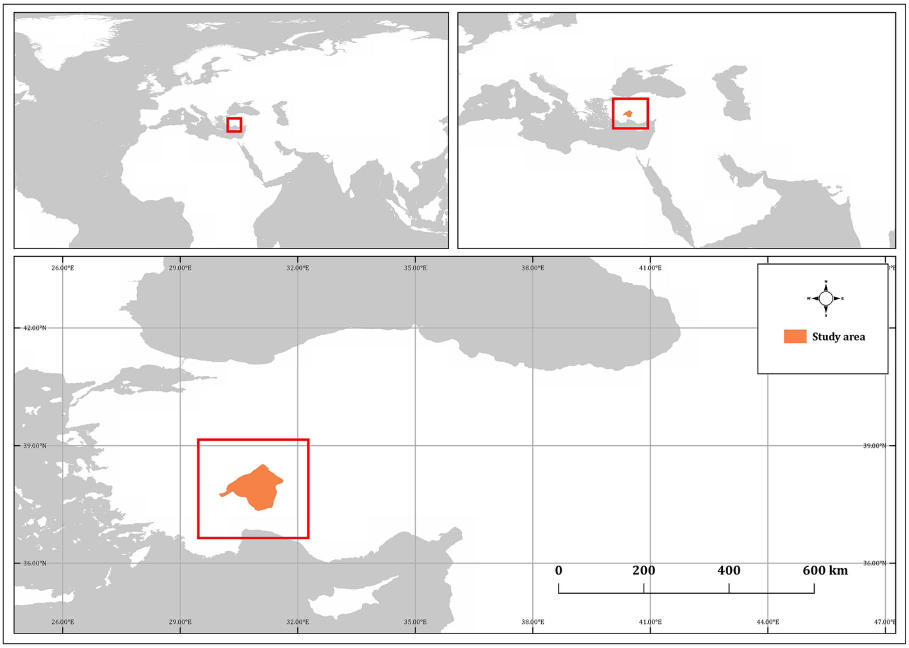

Fig. 1 Study Area

Table 2 Advantages and disadvantages of the photo sharing platforms

	Purpose	Geo tagging	EXIF data	Number of Users	Filter Hashtag	Private/ public	Resolution	Free	Storage	Mobile apps
Flickr	Photo sharing	●●●	●●●	●●	●●●	●	●●●	●●●	●●●	●●●
Instagram	Photo and video sharing	●●●	●	●●●	●●●	●●●	●	●●●	●●●	●●●
Facebook	Social media	●●●	●	●●●	●●●	●●●	●	●●●	●●●	●●●
Twitter	Social media	●●●	●	●●●	●●●	●●●	●	●●●	●●●	●●●
Pinterest	Photo and video sharing	●●●	●	●●	●●●	●●●	●	●●●	●●●	●●●
Snapchat	Social media	●●●	●●	●●	●●●	●●●	●	●●●	●●●	●●●
Tumblr	Blog	●●●	●●	●●	●●●	●●●	●	●●	●●	●●●
Google Photos	Photo sharing	●●●	●●	●●●	●●●	●●●	●●●	●●	●●	●●

●●● Available or common
●● Partially or uncommon
● Not available or not good

To process data, Flickr was accessed using the Application Programming Interface (API) that uses standard Hypertext Transfer Protocol (HTTP) methods. This allowed for position data for all geo-tagged photographs uploaded on to the Flickr platform to be transferred to an MS Excel worksheet.

The study examined 3647 photographs taken in Isparta between the years of 2012–2018 and shared on Flickr. Of these, 166 geo-tagged photos were included in the sample and transferred to the database. Those photos which were not tagged or were inaccurately tagged were left out of the sample. All selfie shots, photos of private gardens, shots containing logos or trademarks, photographs of animals and low-quality photographs were left out of the sample.

The MEA (2005) ecosystem services classification was used to categorise CES. The data transferred to MS Excel were evaluated by the authors, and a preliminary assessment was made of 50 sample photographs. During this assessment, a discrepancy of 2% was found in way the CES were classified, with the greatest variance in the categorisation of aesthetic and cultural heritage services. All the photographs taken as examples were then categorised to finalise the data pool. The CES assessed spatially in line with the content of the photographs taken as data included recreational, aesthetic, cultural heritage, spiritual and religious values (Table 3).

The environmental layers required for the modelling stage were grouped into six categories using the land cover pattern and land use shown on the 1/25000 scale Corine land use map of the study area of 2012 and the Open Street Map (OSM) vector map dated 2017 (Table 4).

2.3 Modelling

This study uses the MaxEnt programme based on the species distribution model to model the potential distribution of CES. MaxEnt identifies the maximum entropy of observable points such as species, plants and environmental factors and uses machine learning

Table 3 Definition and classification of CES. Adopted from Clemente and County (2019) and MEA (2005)

Type of CES	CES	Definition	Examples of classification
Physical	Recreation values	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.	Photos showing people or without people but related to the recreational activities and recreational equipment
Experiential	Aesthetics values	Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives and the selection of housing locations	Photos showing natural and cultural landscapes
Intellectual	Cultural heritage values	Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species	Photos showing tangible and intangible values like landscapes, ancient or traditional buildings and objects
Inspirational	Spiritual and religious values	Many religions attach spiritual and religious values to ecosystems or their components	Photos showing mosques or a praying area

Table 4 Environmental variables (layers)

Categories	Roads	Rivers	Religious places	Historical and cultural sites	Recreational areas	Land use and land cover

to predict their potential distribution. Observable points are defined on the programme as the presence-data. The advantage of using MaxEnt is that the presence-data are sufficient to model the potential distribution and MaxEnt has been used widely since its launch in 2004 to model such distributions. Published examples of the use of MaxEnt include various aims (identifying the correlation of species formations, mapping present distributions, predicting future times and locations) in many ecological, evolutionary, conservation and bio-security applications (Elith et al. 2010). Point data derived from Flicker for sample sites in this study were used as the presence-data, allowing for assessments of the social value of CES (Fig. 2).

At this point in the study, natural and cultural values related to the study area were also used as data to procure more data and to ensure a stronger numerical expression of their relationship with space. For this, a three-stage method was applied and MaxEnt was used in integration with the ArcMap 10.5 and QGIS programmes.

In the first stage, point data for geo-tagged photographs obtained from social media (Flickr) were transferred to MaxEnt and used as species. In the second stage, the natural and cultural values present in the study area as described in Table 2 were first transformed into raster data using the Euclidean distance module of ArcMap 10.5 and afterwards into.

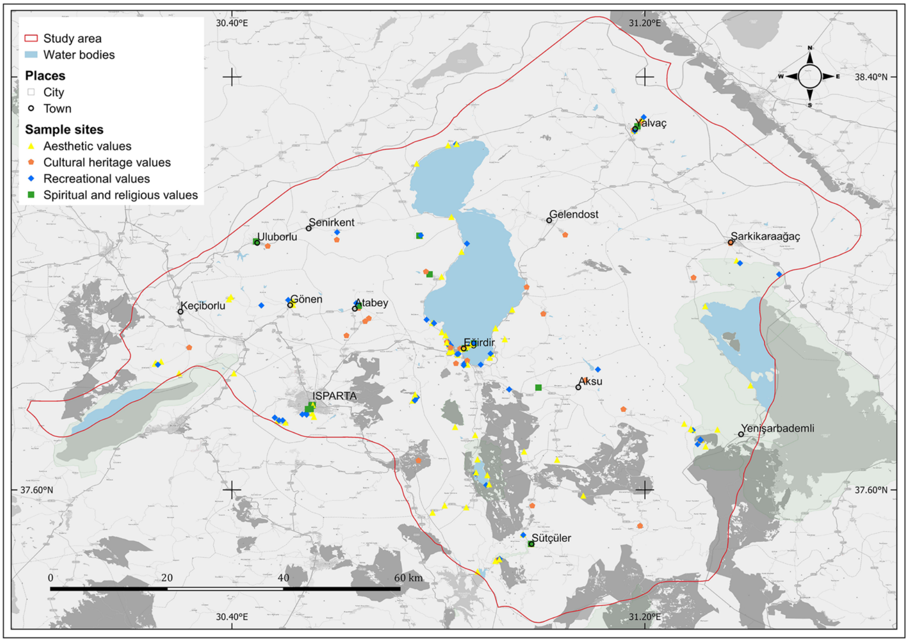

Fig. 2 Sample sites according to Flickr data

asc file format to be used as environmental layers on MaxEnt 3.4.1. ''The Euclidean distance output raster contains the measured distance from every cell to the nearest source. The distances are measured as the crow flies (Euclidean distance) in the projection units of the raster, such as feet or meters, and are computed from cell center to cell center'' (desktop.arcgis.com). This was undertaken for the purpose of applying Jackknife on MaxEnt to identify the significance of each environmental layer in modelling CES.

In the third stage, all data obtained were modelled on MaxEnt to identify the potential distribution of CES and the significance of each environmental variable in the model. The. asc files were transformed to raster format on QGIS and were used to show the degrees of CES provision on the maps formed and to improve the visual quality of the model.

3 Conclusion

The database formed using the photographs on social media made it possible to identify the potential distribution of CES in the study area and measure the degree of significance of each environmental variable. The area under cover (AUC) on the receiver operating characteristic (ROC) curve is used to assess a MaxEnt model.

While ROC measures the efficiency of a MaxEnt model, the AUC represents its level of sensitivity. While an AUC value of 0.5 signifies a random model, a value of 1 signifies a model that perfectly categorises the presence-data. An AUC value between 0.50 and 0.70 signifies a more correct model, a value between 0.70 and 0.90 a sensitive model, and a value over 0.90 a very sensitive model (Swets 1988; Yoshimura and Hiura 2017).

An examination of the ROC curve for each CES in the study area yielded the following AUC values for each: AUC = 0.912 for aesthetic values, AUC = 0.914 for cultural heritage, AUC = 0.999 for spiritual and religious values and AUC = 0.919 for recreational values (Fig. 3).

Accordingly, the models produced under the present study are highly correct models under the ROC curve. The potential areas for each CES examined in the study are shown in the maps below (Fig. 4).

The geographical coordinates of each photograph were used to produce maps showing the distribution, intensity and diversity of CES. The red areas in Fig. 4 depict areas which have a potential to supply high levels of CES (hotspots), while black points depict points that have CES value. As described in the methodology section, natural and cultural assets within the study area were used as independent variables in the study and were used as environmental layers on MaxEnt in the formation of the model. This made it possible to measure the degree of significance of each independent variable in forming the model. The degrees of significance were calculated using the Jackknife option on MaxEnt. The Jackknife approach allows for gains corresponding to the models to be calculated i) with all variables ii) with only one variable and iii) without variables. A Jackknife of regularised training gain was produced for each CES in the study area.

Figure 5 below shows the results of the Jackknife test for each CES in the study area. Roads are observed to be the environmental variable that bring the greatest gain for aesthetic values and make the greatest contribution to the provision of aesthetic value. The environmental variable that contributes the most to cultural heritage is religious places that which contributes the most to religious and spiritual values is land cover and land use, and

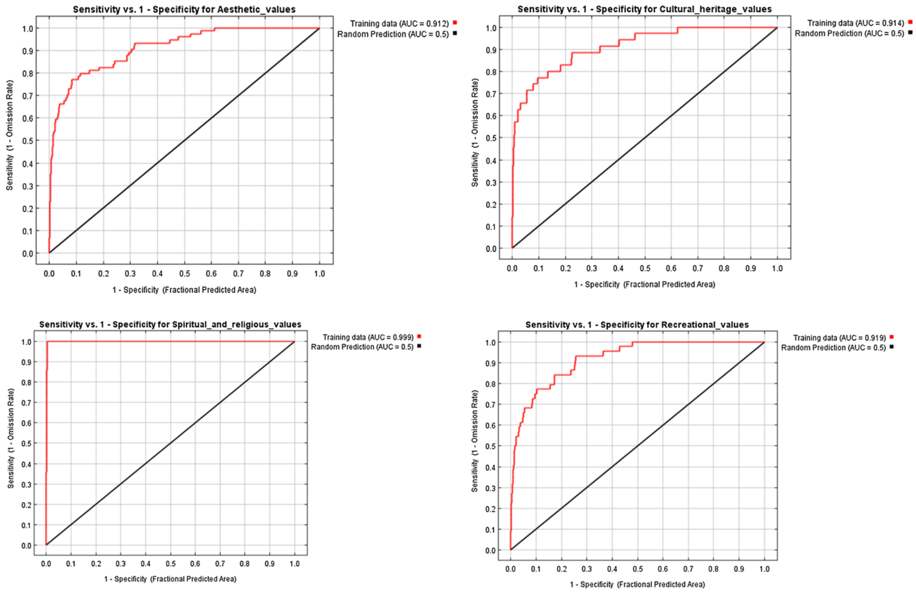

Fig. 3 ROC curves for each CES

that which contributes the most to recreation value is historical and cultural areas. Table 5 below shows the percentage contribution and significance of each variable for each CES.

4 Discussion

The potential distribution areas of CES were expressed spatially in this study using GIS and MaxEnt software. Geo-tagged photographs found on social media and numerical data regarding natural and cultural values that furnish resources for CES in the study area were used to this end. The number of geo-tagged photographs uploaded by social media users was higher in previous studies using MaxEnt to model the spatial distribution areas of CES (Richards and Tunçer 2018; Clemente and County 2019). Given the working logic and principles of MaxEnt, it is clear that the number of photographs is not a parameter that will shift the outcome in another direction. MaxEnt software makes it possible to obtain effective results with time savings on modelling, as it can use a small number of points. The novelty of this study is that it proposes a framework for the development of the use of MaxEnt, which was developed for the modelling of species distribution areas, in the modelling of the potential distribution areas of CES. The study contributes to previous assessments, which only used land use and land cover maps, by utilising as environmental layers the environmental variables for the study area obtained from Open Street Map vector maps, areas of historical, cultural and religious value, rivers and roads and area land use data obtained from the 2012 Corine map and identifying their impact values for the provision of CES.

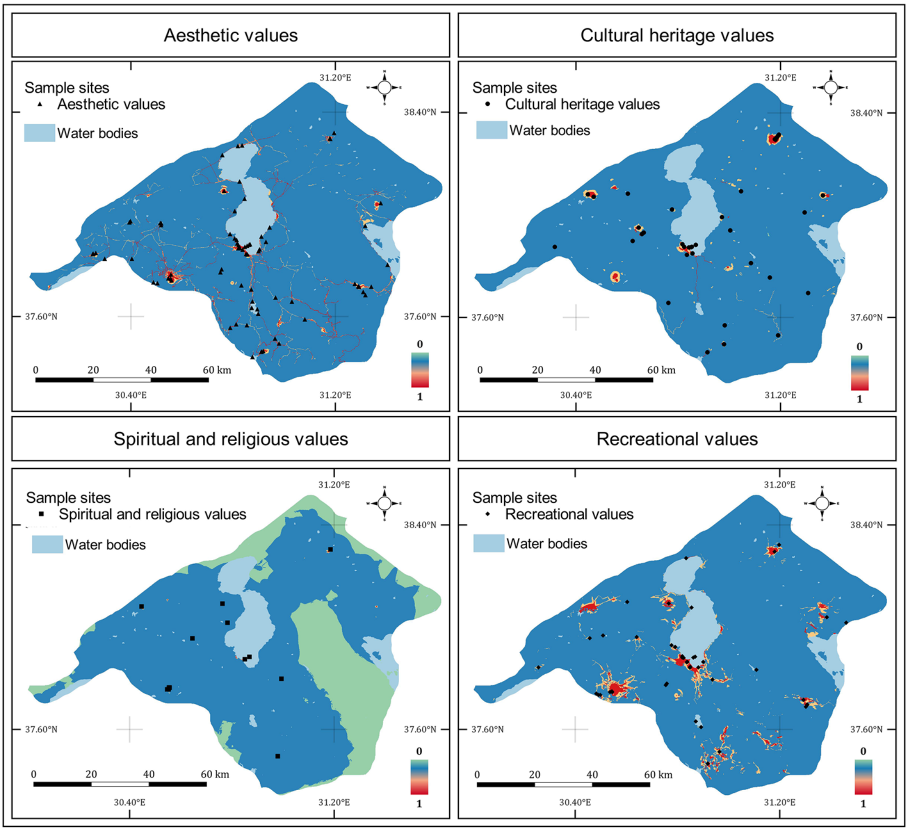

Fig. 4 The potential distribution areas of CES

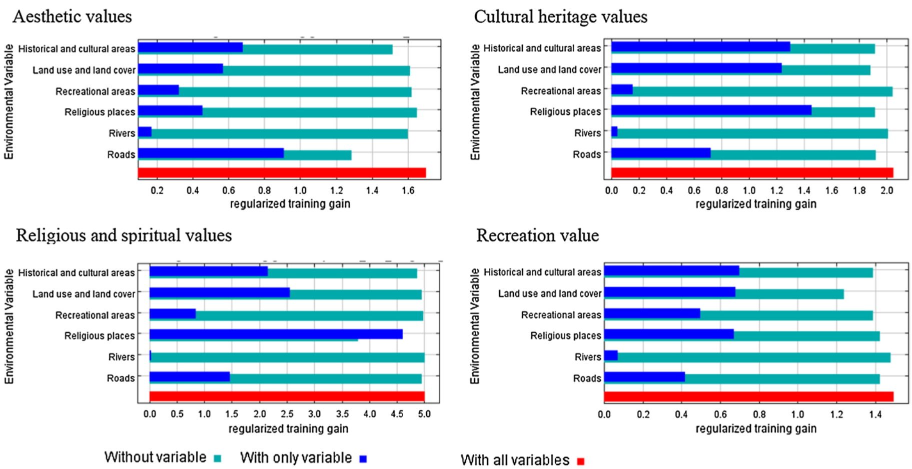

Fig. 5 Jackknife results for each CES

Table 5 Importance of environmental variables

Variables	Aesthetic		Cultural heritage		Spiritual and religious		Recreational	
	C	*I*	*C*	*I*	*C*	*I*	*C*	*I*
Religious places	46.5	44.1	48	6.9	92.5	54.8	26.8	8
Historical and cultural areas	33.1	19.2	23.9	15	3.1	12.7	26	40
Roads	7.5	6.2	14.4	4.9	1.7	16.5	17	21.5
Land use and land cover	7	7.4	11.9	66.7	1.6	0.4	15.4	15.7
Recreational areas	5	14.6	1.4	6.6	1.2	15.5	13.4	8.4
Rivers	0.9	8.5	0.3	0	0	0	1.4	6.4

C contribution (%), *I* importance (%)

The study, which covered the province of Isparta, overcame the difficulties in mapping CES arising from the inclusion of subjective and intangible evaluations by relating user preferences to land use (H1, S1). As Brown and Fagerholm (Brown and Fagerholm 2015) have stated in their study, identifying the spatial relations among user preferences helps with alleviating difficulties in mapping. The results obtained by this means yield the conclusion that user preferences and the natural and cultural assets in the land cover overlap. Aesthetic and recreational CES are observed in Fig. 4 to concentrate around still and flowing water surfaces, which represent natural assets. Viewed in terms of the aesthetic and recreational potential of bodies of water, there is a meaningful relationship between land cover and land use and this is directly related to the provision of CES.

Over the recent years, studies aimed at identifying and mapping values for land use and land cover have frequently made use of geo-tagged photographs on social media (Tenerelli et al. 2016; Yoshimura and Hiura 2017; Clemente and County 2019). The present study too has used photographs on social media to permit the spatial assessment of large areas (H2), treating them as primary data for the mapping of CES (S2). Furthermore, the integrated use of GIS and MaxEnt as instruments of the present study has played an active role in ensuring savings on time in modelling areas providing CES (H5, S5).

Mapping CES through the use of photographs on social media and user-based data has made it possible to identify the types of land cover upon which services are used most intensively (H3, S3). The areas within the study area on which CES are provided the most are forests, waterfronts and urban areas. This information will be useful in developing strategies based on land use and land cover by producing future scenarios for CES. Assessments to be made of the landscape characteristics of land cover (slope, aspect, ecological characteristics etc.) may be used as an effective means of measuring the impact of these characteristics on human welfare. For example, it was found that areas providing intense aesthetic ecosystem services are to be found in areas with steeper gradients. In this sense, it may be said that there is a significant relationship between the slope or gradient and the provision of aesthetic ecosystem services (H4, S4).

In conclusion, data obtained from this study will be useful in decision-making for the modelling of future scenarios based on CES and the planning and management of tourism and protected areas. However, account should be taken of limitations such as the possibility that the behaviour of the social media users may not be representative of the entire society, and the bias shown by the persons analysing the photographs when categorising them. Future studies might use various means to minimise these limitations such as obtaining information about user profiles or analysing the comments accompanying the photographs. In addition, although MaxEnt is generally utilised for predicting species distribution with maximum entropy, it could be useful tool for determining the social values of cultural ecosystem services. On account of using environmental variables, MaxEnt could be easily integrated for analysing community preferences and measuring other social values on landscape.

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