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GIS-Based Soil and Land Suitability Assessment of Resting Areas for Biodiversity and Sustainable Use in Protected Areas

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Abstract

Protected areas (PAs) are increasingly challenged by the need to reconcile biodiversity conservation with sustainable human use, particularly in landscapes containing underutilized or resting area (RA). This study evaluated the potential of resting forest and agricultural lands to enhance biodiversity and support sustainable land use within protected areas of Cesme, Türkiye. A Geographic Information System (GIS)-based multi-criteria evaluation approach was employed, integrating land cover data, soil group maps, topographic parameters, and protected area classifications to generate Plant Suitability Maps (PSMs). Eight thematic layers were developed, incorporating soil depth, slope, erosion risk, and land capability classes to identify suitable plant species and land-use options. The results indicate that the strategic use of resting agricultural lands could contribute up to 35.5% to ecological enhancement, while resting forest lands could contribute an additional 18%. The proposed plant assemblages include medicinal and aromatic species, erosion-control plants, and economically valuable perennial species that support ecosystem services such as pollination, beekeeping, and agro-tourism. Overall, the findings demonstrate that integrating RA management into conservation planning can simultaneously strengthen biodiversity, improve ecosystem services, and generate socio-economic benefits for local communities. The proposed GIS-based framework offered a transferable and scalable methodology for sustainable land management in Mediterranean landscapes and other protected regions worldwide. Also, in this research, the aim was to determine plant species using GIS-based suitability analyses of multi-spatial datato guide vegetation decisions in multi-criteria PA.

Keywords: sustainability; naturally protected area; nature conservation; resting area; GIS

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1. Introduction

Rapid land-use changes, increasing population pressure, and the impacts of climate change have significantly challenged the management and planning of nature

conservation areas [1,2]. In particular, processes such as habitat fragmentation, biodiversity, loss, and the decline of ecosystem services underscore the need to move beyond static conservation approaches toward more dynamic, data-driven, and integrated management strategies [3,4]. For this reason, the descriptions of "abandoned land" and "abandoned forest" refer to places that have been removed from production or management activities due to various economic, ecological, and social factors [5]. These regions are usually characterized by agricultural abandonment, rural population decline, low productivity property constraints, and poor spatial planning. The ecological deterioration of abandoned forests is particularly serious due to insufficient post-harvest recovery efforts, fires, erosion, and improper land-use practices. Contemporary sustainability paradigms increasingly recognize abandoned lands not merely as unproductive areas, but as spaces with significant potential for natural regeneration, biodiversity enhancement, carbon sequestration, and ecosystem service restoration [6,7]. For all this, building sustainable land management is not merely a function of space, but an interdependent function whereby a strategy to reengineer the landscape with the use of an ecological equilibrium, natural resources, and environment for the benefit of the environment should emerge as an integrated part of spatial development, which includes the abandoned forest and land. From this perspective, soil is an important abiotic component that links the dynamics of abandoned land to the recovery or sustainability. Soil is essential to Earth's vital zone by promoting green recovery, maintaining biodiversity, and enhancing ecosystem resilience. Soil directly contributes to the United Nations Sustainable Development Goals (SDGs) by providing several core ecosystem-based services that support sustainable agricultural productivity (abbreviations of the terms are provided in Appendix A Table A1), biodiversity, and environmental resilience [8,9]. Moreover, protected areas are necessary to ensure the continued operation of sustainable management and the sustainability of natural land in the form of habitats and species and to protect natural resources from erosion processes, thereby preserving and maintaining their services to the ecosystem [10–12].

In this context, today's rapidly developing technologies and increasing need for decision support offer new opportunities for monitoring, evaluating, and sustainably managing nature conservation areas [13]. GIS and remote sensing technologies are emerging as important tools for planning and managing processes to assess ecosystem services and conserve biodiversity in nature conservation areas [14,15]. Case studies from protected areas in different ecological contexts demonstrate the contributions of these technologies in determining conservation priorities, identifying sensitive and critical areas, monitoring ecosystem changes, and evaluating the effectiveness of management strategies [16,17]. While significant progress has been made in this area in technologically advanced countries with a high level of conservation awareness, scientific research and planning efforts related to nature conservation areas are constantly being updated and developed due to changing environmental conditions, increasing population pressure, and global impacts such as climate change [18–21]. Advanced sensor technologies, big data analytics, and interdisciplinary approaches aid decision-support processes for ecosystem services and biodiversity conservation in nature conservation areas. Some research demonstrates the integrated use of GIS and remote sensing in applications such as nature conservation areas, map-based species distribution modeling, habitat suitability and assessments, and mapping of ecosystem services [22–24].

The main aim of this study was to develop a GIS-based plant suitability assessment framework to identify ecologically appropriate plant species for RAs within nature conservation areas by integrating soil characteristics, land-use dynamics, and protected area classifications. Furthermore, it aims to present science-based recommendations for alternative plant species to improve residents' quality of life and enhance the sustainable management and use of nature conservation areas. The research was conducted in the Cesme

District, one of Türkiye's internationally recognized tourism destinations, where extensive areas are designated as natural protected areas, including Qualified Natural Protected Areas (QNUAs) and Strictly Controlled Conservation Areas (SCCCAs). RAs within the agricultural and forest lands located within these protected areas were integrated and analyzed in a GIS environment using land-use characteristics, vegetation dynamics, and major soil group data, and each was evaluated according to its specific conservation status [25]. Based on these integrated datasets, PSMs were generated to support sustainable land-use planning compatible with the ecological and topographical characteristics of the protected areas. The proposed approach was intended to assist decision-makers at local, regional, and national scales in enhancing biodiversity conservation while providing socio-economic benefits through appropriate plant-based land-use alternatives. The specific objectives of this study were as follows:

(i) Evaluate the ecological contribution of RAs within protected areas by integrating land-use patterns, vegetation dynamics, and large soil group characteristics, thereby clarifying their role in ecosystem functioning and biodiversity conservation.
(ii) Determine sustainable land-use and plant-based production alternatives compatible with edaphic and ecological conditions in and around protected areas, with the aim of strengthening the integration of conservation priorities and sustainable agricultural practices.
(iii) Support the sustainability of nature-based livelihoods, particularly beekeeping and livestock production, by proposing ecologically appropriate plant species that enhance forage availability, habitat quality, and pollination services.
(iv) Identify the agrotourism potential of protected landscapes by linking RA use strategies with the region's conservation value, thereby contributing to the development of diversified, low-impact tourism models.

The proposed GIS-based framework was designed as a scalable, adaptable decision-support tool applicable to regions with varying protected area statuses and environmental conditions. This approach involves identifying the RA within agricultural and forest lands located within PAs (based on soil structure, depth, slope, and land capability classes), recommending suitable plant species, and displaying these areas on spatial maps. By emphasizing mapping-driven soil evaluation rather than biodiversity loss assessment, the framework supports evidence-based plant selection and sustainable land-use planning amid ongoing pressures from climate variability and land-use transformation.

In this study, "RAs" refer to agricultural or forest areas that are currently underutilized or abandoned due to socio-economic, environmental, or management-related factors. Resting agricultural lands typically arise from declining rural populations, reduced economic profitability, or land-use transitions, whereas resting forest lands often result from insufficient management, post-harvest neglect, or ecological degradation. These areas have recently attracted attention in sustainability research due to their potential for ecological restoration, biodiversity enhancement, and recovery of ecosystem services [8,26].

In the dilemma of nature conservation and utilization, it is a fact that individuals, society, and management layers are confronting one another at both horizontal and vertical levels [27]. One method used to protect natural and cultural resources, unique habitats, ecosystems, and landscapes, and to preserve them for the future, is to declare these areas "PAs" [28]. PAs are fundamental for biodiversity conservation, ecological sustainability and the protection of human well-being. Effective and sustainable protection requires the cooperation of all stakeholders and necessitates that conservation objectives and human use be addressed in harmony. PAs can significantly restrict human activities and land-use alternatives.

Participatory planning and monitoring processes contribute to achieving conservation goals, while 3D GIS can serve as a fundamental platform for planning [24]. GIS, defined as computer-based systems for capturing, storing, analyzing, and visualizing spatial

data, together with remote sensing technologies, provide powerful decision-support tools for evaluating ecosystem services and biodiversity conservation in protected areas. In this context, a study conducted by Durlevik et al. [29] evaluated soil erosion and forest fire susceptibility in Serbia's Šar Mountains National Park using GIS-based thematic maps. The study integrated the Erosion Potential Model (EPM), developed based on the soil structure and other natural and anthropogenic factors, with the newly created Wildfire Sensitivity Index (WSI) using a holistic approach. The resulting synthesis maps revealed that 21.3% of the area has high and very high fire susceptibility, while 8.2% has severe soil erosion. The study demonstrates that soil structure mapping and GIS-based analyses are critical for risk management and sustainable land planning. Takem et al. [30] examined the spatial distribution of human-induced activities to support the effective management of protected areas, using Takamanda National Park in Cameroon as an example. The study mapped anthropogenic activities such as agriculture, hunting/poaching, collection of non-timber forest products, and livestock farming, which were carried out in violation of regulations, using geospatial tools. A total of 2157 human-induced activities were identified between 2012 and 2017, of which the vast majority (71.5%) were hunting-related movements. The findings revealed the challenges in protected area management and highlighted the need for effective, comprehensive management systems within the Sustainable Development Goals framework.

In the study by Tezel et al. [31], the potential of 3D GIS, supported by high-resolution datasets, to determine protected area boundaries more accurately and comprehensively was investigated. The study used the Cesme Peninsula in Türkiye as an example; protected area boundaries were evaluated in relation to property boundaries and existing structures using a 3D city model. The conceptual approach developed from the research revealed that conflicts between conservation goals and human use could be reduced and that coordination among stakeholders could be strengthened. Tezel et al. [31] emphasized that 3D GIS-based analyses support ecosystem conservation efforts while also allowing the consideration of socio-spatial elements such as property rights and settlement pressures. Such holistic approaches enable ecosystem conservation objectives to be addressed in a manner consistent with socio-spatial realities [32].

According to Borrını-Feyerabend et al. [33] and Ward et al. [34], 9.7% of the world's protected areas are in terrestrial ecosystems. In particular, protecting and restoring natural vegetation in buffer zones is vital to achieving conservation objectives [35]. According to the World Union for Conservation of Nature (IUCN) [36], the ratio of protected areas to land area worldwide reached 13.2% in 2020. The ratio of protected areas to country area, which is currently 25.9% in the EU on average, is over 30% in countries such as Poland, Germany, and Greece [37]. The total protected area (land and sea) ratio to the country's surface area is 13.73% [38]. Increasing this area and establishing an effective PA management structure aligns with Türkiye's national objectives

GIS is widely used to monitor, analyze, and update spatial data in protected areas. The ratio of terrestrial protected areas to Türkiye's total land area is reported to be approximately 7–8% by various official and international sources [39,40]. For instance, the Ministry of Agriculture and Forestry reported that this ratio reached approximately 7.86% in 2024, while a WWF-Türkiye report indicated that it was around 8.7% in 2020 [41,42]. Although these values suggest that Türkiye is approaching the global average, they remain below the levels required to meet long-term sustainability and biodiversity conservation targets. The temporal and spatial changes in ecological indicators [43] in PA constitute an accurate, fast, unbiased, and low-cost quantitative variable [44].

According to previous studies, the impacts of climate and land cover change at local, regional, and global scales have been identified to enable countries to manage PA sustainably [45,46]. The main reason for the differences in land cover in these regions is human-

induced impacts and the socio-economic circumstances of the people living there. In studies by Kiwango et al. [47], Garrard et al. [48], Mango et al. [49], and Queiroz et al. [50], the temporal–spatial changes in land cover of PA were determined using GIS. However, these changes in land cover and vegetation dynamics have not been investigated together. It is concluded that PA plays an important role in biodiversity conservation, especially ecosystems that provide resources for people and living organisms [51,52]. In particular, the impacts of PA intertwined with or near urbanization have been demonstrated. As these areas are often surrounded by private agricultural land (land changes on private property), to achieve the preservation of natural vegetation or the regeneration of areas with insufficient vegetation cover, economic cycles, political conditions, laws, and environmental characteristics should be considered holistically [30–46].

Since each country has its own classification of "PA", their assessments are important for formulating national protection laws, implementing protection measures, and allocating human and financial resources [53]. Since the surface area of PA in Türkiye is approximately 8%, the evaluation and quantitative determination of RA within these areas require a scientific study, which warrants focused attention in the field of rural land sustainability research [54,55]. In this context, agriculture, settlement, and PA in Türkiye require multi-governance to balance them. Soil-related parameters, such as soil depth, slope, erosion severity, and land capability class, are widely recognized as key determinants of vegetation distribution, land productivity, and ecological stability. These soil properties directly influence plant establishment, water availability, nutrient dynamics, and resistance to environmental stress, making them essential criteria in land suitability assessments and conservation-oriented planning [56]. The integration of soil characteristics with spatial analysis enhances decision-making reliability in areas where detailed biotic data are limited.

2. Materials and Methods

2.1. Study Area

The research area (Cesme District), which constitutes the primary material of the study, consists of Ikonos satellite images from 2020, a 1/25,000-scale current site map of [57], and 1/25,000-scale soil maps (2018). ArcGIS 10.2 Software was used to determine land-use types from satellite imagery, query all datasets, and generate PSMs.

The study area is located at 38°13′–38°24′ North latitude and 26°13′–26°30′ East longitude within the borders of Cesme District of Izmir Province, and the area with QNUA and SCCCA characteristics is 42.3 km^2. Cesme is a district located on the Urla, west of Sakız Island (Figure 1). The district is 5 m above sea level. It is a peninsula surrounded by sea on three sides. Historically, it was located among the twelve Ionian colonies. Its most important sources of income are agriculture, livestock farming, and tourism. However, tourism shapes the district's economic structure. The district's total registered population is 50,058. This number increases approximately twentyfold during the summer months. Olive, artichoke, and Cesme melon are important agricultural products. Summers are hot and dry, while winters are mild and rainy. The prevailing wind direction is north–south, and there is strong wind potential [58]. Temperatures do not fall below 10 °C in winter or rise above 25 °C in summer. The lowest average temperature is in January (9.7 °C), and the highest is in August (26.8 °C). The month with the highest rainfall is January (9.5 kg/m^2), while the month with the lowest rainfall is July (0.05 kg/m^2) [59].

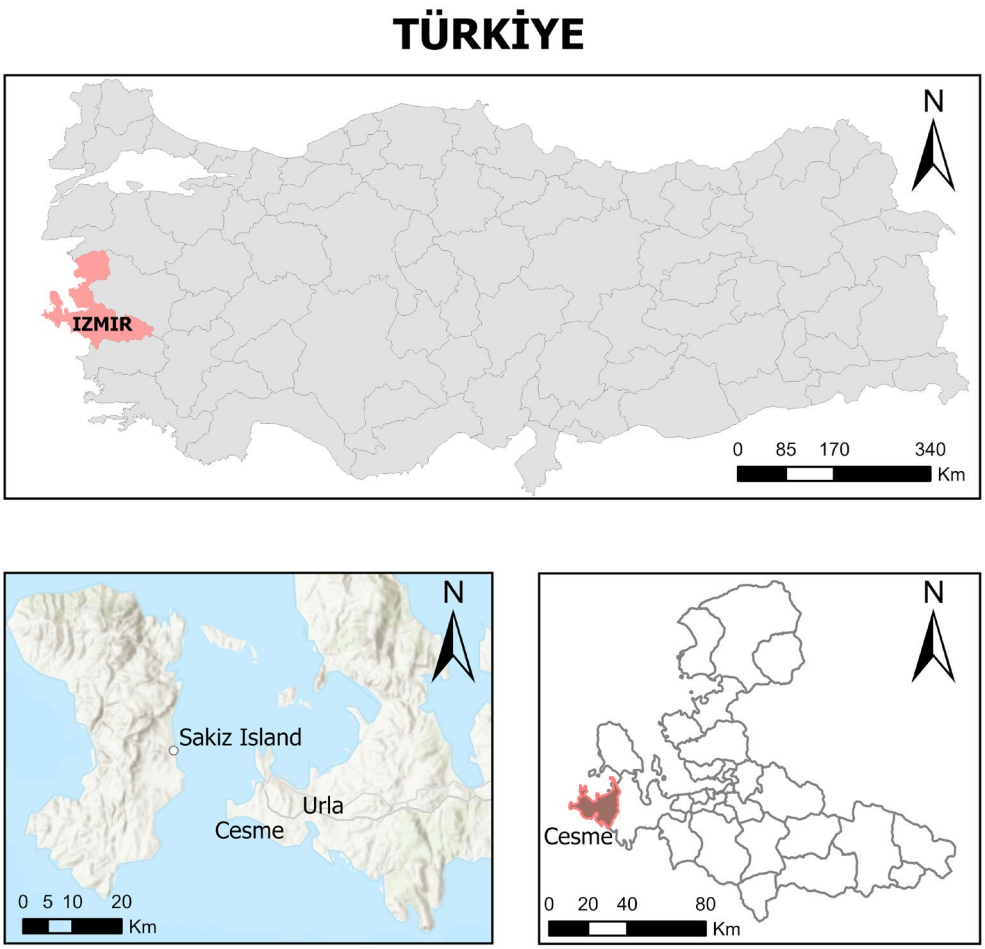


Figure 1. Natural projection map of the research area.

The vegetation cover of the area generally consists of *Pinus brutia* forests. However, as the research area is intertwined with settlement areas, in places where *Pinus brutia* has been destroyed, maquis communities (*Olea europea* L., *Quercus coccifera*, *Pistacia lentiscus* L., *Pistacia terebinthus* L., *Juniperus oxycedrus* L., *Ceratonia silique* L., etc.) are seen as secondary species. In addition, *Sarcopoterium spinosum* L., *Astragalus aaronsohnianus Eig.*, *Cistus* L., *Calicotome villosa (Poir)* L., and *Verbascum* L. are the third generation, comprising species such as ablution, rhizomes, thyme, spruce, goatbane, and mullein [60].

There are also cultivated gum trees (*Pistacia lentiscus var chia*) and wild gum trees (*Pistacia lentiscus* L.). This rare plant species only grows in the Cesme Peninsula and the southern part of the island of Chios (Greece). The gum tree has health, nutrition, fodder production benefits, environmental protection, and prevention of soil erosion [61,62].

2.2. GIS-Based Spatial Analysis and Data Integration

In the method, a literature review related to the subject and study area was conducted. Soil depth, slope, erosion degree, and land-use capability class (LUC) were selected as the main evaluation criteria because they represent the primary soil characteristics and site features controlling plant establishment, land productivity, and ecological stability in protected Mediterranean landscapes.

GIS-based land suitability analysis is widely used as a robust decision-support tool for evaluating spatial relationships between environmental variables and land-use potential [63]. In this study, a rule-based GIS querying approach was preferred, as it enables the objective, reproducible classification of suitability based on predefined ecological thresholds, such as soil depth, slope, erosion severity, and land capability classes. These

parameters are derived directly from nationally standardized soil maps and legally defined land-use capability classifications, ensuring both ecological relevance and regulatory compliance. Instead of applying weighted multi-criteria decision-making (MCDM) methods, a rule-based GIS querying approach was adopted, in which suitability classes were determined using threshold values defined by soil depth classes, slope ranges, erosion severity, and LUC categories. This approach was preferred to avoid subjective weighting and to focus on ecological feasibility under conservation-oriented land-use restrictions, particularly in areas with limited data availability. The resulting PSMs therefore reflect constraint-based spatial suitability rather than relative ranking, providing transparent and reproducible outputs for sustainable land-use planning in PA [64,65]. GIS-based land suitability analysis is widely used as a robust decision-support tool for evaluating spatial relationships between environmental variables and land-use potential [63].

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At this stage, the aim was to identify RA that could not be evaluated within the targeted land uses. In the first stage, the areas with QNUA and SCCCA status shown on the "Cesme projection map" (Figure 1) were digitized using 2020 Ikonos satellite images in a GIS environment, and their land-use types were identified. The Ikonos satellite has a temporal resolution of 14 days, with 1 m panchromatic and 4 m multispectral spatial resolutions. Land-use types were evaluated into two main categories: Forest Areas (FAs) and Agricultural Areas (AAs), which represent the dominant land-use structures within the protected zones. At this stage, the aim was to identify RA that could not be effectively utilized within these land-use categories.

In the second stage, the data belonging to the soil map (land-use capability, major soil group, erosion degree, soil depth, land slopes) were shown with the expressions in Table 1. These data were entered according to the layer logic in the ARGIS Pro software, and a database was created for the queries to be made. The Natural Protected Area status map and the soil map were combined with the "spatial intersection" method. Areas with QNUA and SCCCA status were evaluated separately. ArcGIS Pro software was used to determine land-use types from satellite images, query all other datasets, and produce the Plant Suitability Map. The major soil groups (MSGs) distributed throughout the Cesme District are A (Alluvial), E (Red–Brown Mediterranean), K (Colluvial), R (Rendzina), T (Red Mediterranean), U (Uncalcareous Brown), and RS (Reed Swamp) [66]. The most widely distributed large soil group is brown soil without lime, with 39.76%, while Rendzina (clayey and calcareous) soils rank second, with 23.37% [67]. In addition, very low hilly areas, coastal plains, and alluvial plains developed between them. The geomorphological features of the coastal area between Alaçatı Bay and the White Cape, which forms the westernmost part of the peninsula, are closely linked to the region's tectonic and lithological characteristics. The bay bottoms, which are filled with siliceous sandy materials brought by rivers from the slope, by waves in the cape sections, and by flooding, have high-quality beaches [68].

Table 1. Major soil group mapping units.

Major Soil Groups (MSGs)	
Symbol	**Name**
A	Alluvial
K	Colluvial
N	Calcareous Brown Forest
M	Brown Forest
U	Limeless Brown

E	Red–Brown Mediterranean
R	Rendzina
C	Chestnut
V	Vertisol
Y	High Mountain-Moorland
T	Red Mediterranean
L	Regosol
Ç	Saline-Alkali

Slope–Depth Combination (S-DC)

	Slope%	**Depth (cm) (measured relative to surface soil layer)**			
		Deep 90 + (A)	**Medium 90-50 (B)**	**Shallow 50-20 (C)**	**Very shallow 20-0 (D)**
1	Flat, close to flat 0–2	1	2	3	4
2	Light 2–6	5	6	7	8
3	Medium 6–12	9	10	11	12
4	Upright 12–20	13	14	15	16
5	Very steep 20–30	17	18	19	20
6	Sharp 30+	21	22	23	24

Land-use Capability (LUC)

Symbol	**Name**
I-II-III	Tillage land/crop production
IV	Can become suitable for agriculture
V-VI-VII	Meadow, pasture, and forest land
VIII	Place of entertainment and recreation

Erosion Classes (ECs)

Symbol	**Name**
1	No or little erosion
2	Moderately eroded
3	Severely eroded
4	Very severe erosion

3. Results

Cesme District, the research area, includes areas designated under different Natural Protected Area (NPA) statuses, as defined by the Conservation Board, including QNUA and SCCCA. Because these protection statuses differ in their conservation-use balance, eight thematic PSMs were generated using GIS-based queries by land-use type and alternative plant species recommendations for each status [59,69,70]. Within this framework, the PSMs were developed as a GIS-based decision-support tool, to help planners and decision-makers identify ecologically compatible plant species and sustainable land-use alternatives under different levels of protection. Detailed tables are provided in Appendix A (Tables A2–A9).

PSM-1 Inquiry Criteria: Within the NPA, areas with the status of QNUA, land-use type FA, LUC; VI, VII, soil depth (C + D) were defined as "PSM-1" (Figure 2). Accordingly, it was determined that the areas with a soil depth of 0–50 cm shallow and very shallow, land slope of 6–30%, and moderate to very severe erosion degree (ED) were distributed on red–brown Mediterranean (R), brown without lime (U), and rendzina (R) MSGs. Plant

species that can grow in areas defined as "PSM-1" with severe erosion, sloping terrain, and shallow soil depth, considering MSG and LUC classes, are as follows: *Mentha pulegium* L., *Rosa canina* L., *Crataegus orientalis Pall. ex M. Bieb*, *Rubus discolor*, *Amygdalus orientalis*, *Hedera helix* L., *Lonicera etrusca Santi*, *Cotoneaster acuminatus* Lindl., *Pyrus elaeagnifolia Steud.*, *Jasminum fruticans* L., *Daphne oleoides* Schreb., *Mentha piperita* L., and *Prunus* L. Primarily, priority was given to species that provide economic and ecological contributions to the people of the region by prioritizing species that increase erosion prevention and support beekeeping activities, along with medicinal aromatic plants.

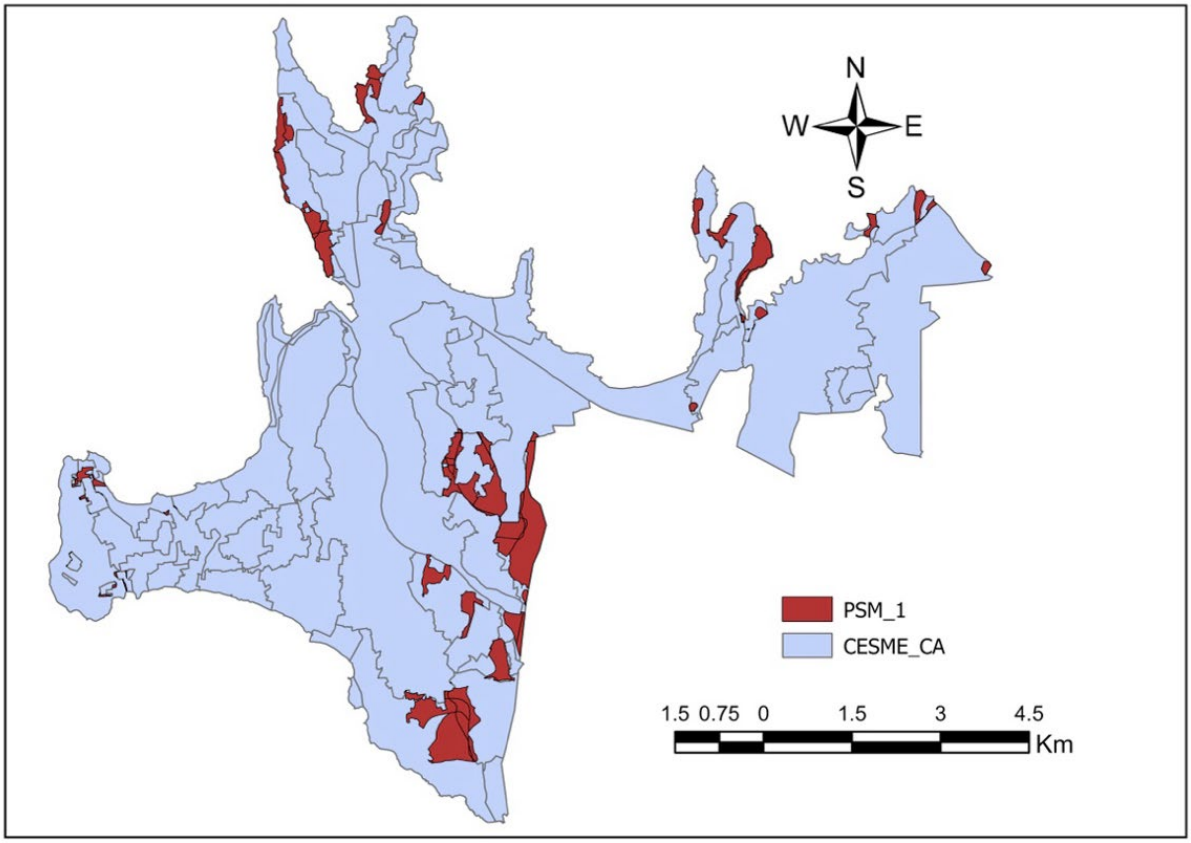


Figure 2. Plant Suitability Map 1 "PSM-1".

Following the identification of highly constrained areas in PSM-1, a second suitability class PSM-2 was defined to represent areas with more favorable soil and topographic conditions within the same protection status. PSM-2 Inquiry Criteria: Within the NPA, areas with the status of QNUA, land-use type FA, LUC; I, II, III, soil depth (B) were defined as "PSM-2" (Figure 3). Accordingly, it was determined that the areas with a soil depth of 50–90 cm (medium–deep), a land slope of 2–12%, and a mild erosion degree were distributed on Colluvial (C) and Rendzina (R) MSGs. Plant species that can grow in areas defined as "PSM-2" with severe erosion, sloping terrain, and shallow soil depth, considering the MSG and LUC classes, are as follows: *Pinus pinea* L., *Pinus brutia var. brutia*, *Pinus halepensis* Mill., *Ziziphus jujuba* Mill., *Eucalyptus camaldulensis* Dehnh., *Fraxinus excelsior* L., *Gleditsia triacanthos* L., and *Robinia pseudoacacia* L. Primarily, plants were to provide ecological contributions by favoring fire-resistant, fast-growing and evergreen species in possible afforestation works.

In contrast to the QNUA areas evaluated in PSM-1 and PSM-2, PSM-3 focuses on areas classified under the SCCCA status, reflecting stricter conservation conditions and different land-use limitations. PSM-3 Inquiry Criteria: Within the NPA, areas with the status of SCCCA, land-use type FA, LUC; VI,VII, soil depth (C+D) were defined as "PSM-3"

(Figure 4). Accordingly, it was determined that the areas with shallow and very shallow soil (depth of 0–50 cm), a land slope of 6–20%, and an erosion degree of severe erosion in general were distributed on red–brown Mediterranean (K), Uncalcareous brown (U), and Renzina (R) MSGs. Plant species that can grow in areas defined as "PSM-3" with severe erosion, sloping terrain and a shallow soil depth, considering the MSG and LUC classes, are as follows: *Mentha pulegium* L., *Pyracantha coccinea M.Roem., Rhus typhina* L., *Rosa canina* L. *Tamarix aeruginosa Sickenb. Vitex* L., *Crataegus monogyna* Jacq., *Narcissus pseudonarcissus* L., *Pistacia vera* L., *Celtis australis* L., *Rosmarinus officinalis, Cotinus coggygria Scop., Rhamnus erythroxyloides subsp. Iranica, Cotoneaster Medik., Thymus serpyllum subsp. Serpyllum Vitex agnus-castus* L., *Lavandula stoechas* L., and *Salvia officinalis subsp. lavandulifolia (Vahl).* First of all, the aim is to make an economic and ecological contribution to the people of the region by favoring species that increase erosion prevention and support beekeeping activities, along with medicinal aromatic plants.

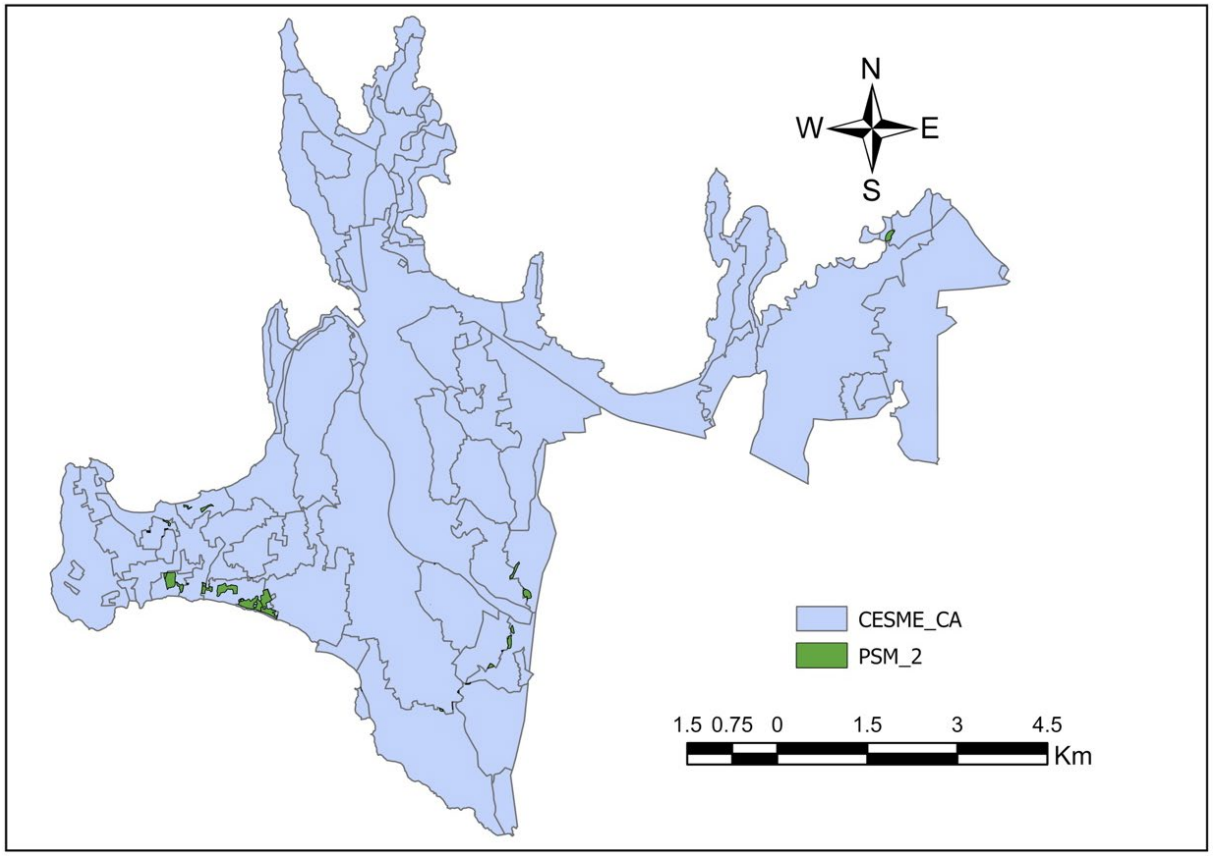


Figure 3. Plant Suitability Map 2 "PSM-2".

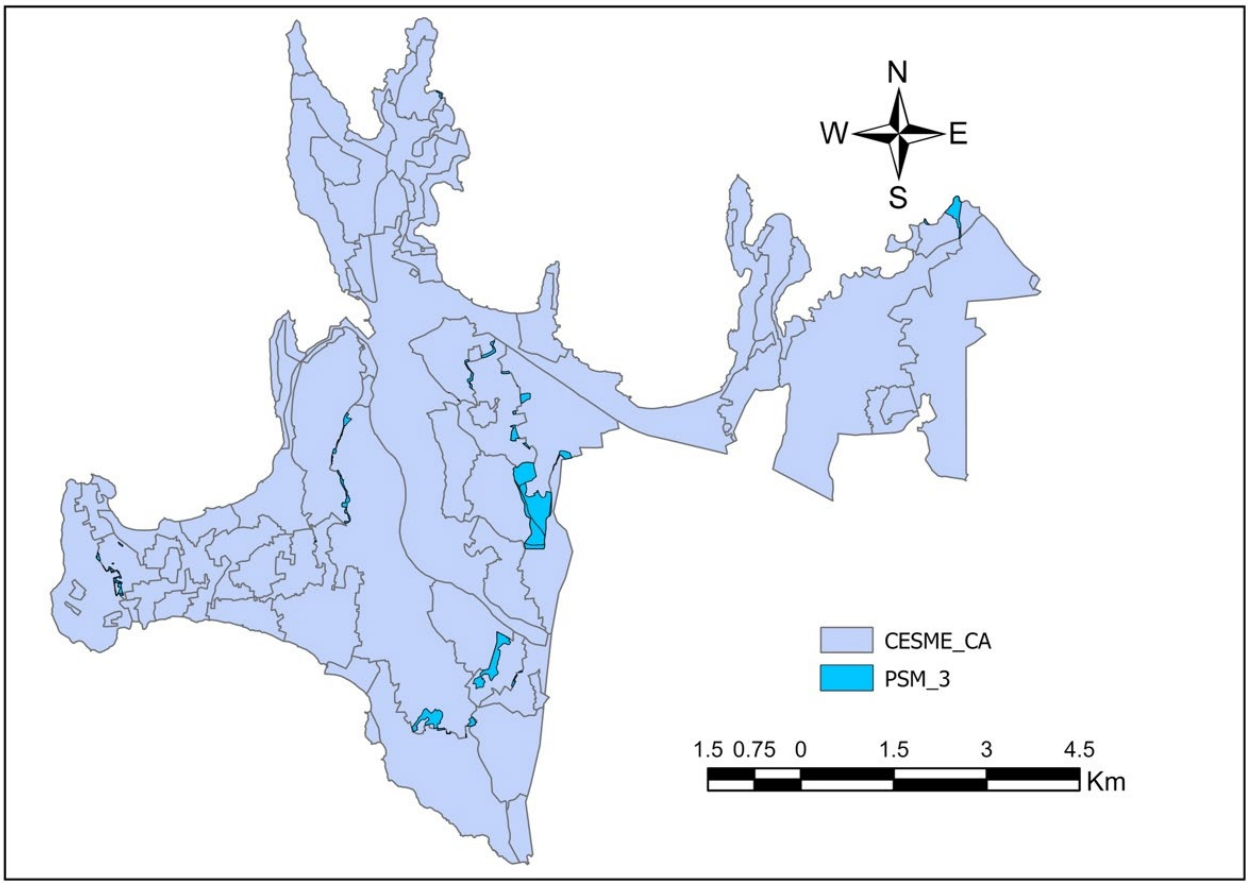


Figure 4. Plant Suitability Map 3 "PSM-3".

While PSM-3 represents highly constrained areas within SCCCA, PSM-4 was developed to identify relatively more suitable areas with the same protection status, characterized by an improved soil depth and lower slope conditions. PSM-4 Inquiry Criteria: Within the NPA, areas with the status of SCCCA, land-use type; FA, LUC; I, II, III, soil depth (B) were defined as "PSM-4" (Figure 5). Accordingly, the soil depth is 50–90 cm (medium–deep), the slope of the land is 0–12%, and the degree of erosion is distributed on Colluvial (C) and Rendzina (R) MSGs in medium areas. Plant species that can grow in the areas defined as "PSM-4", with low and moderate erosion severity, mild and moderate slopes, and moderate soil depth, considering the MSG and LUC classes, are as follows: *Pinus halepensis Mill.*, *Pinus elderica*, *Pinus brutia var. brutia*, *Quercus* L., *Acer negundo* L., *Alnus incana* (L.) *Moench*, *Betula pendula Roth*, *Pinus nigra J.F. Arnold*, *Pinus pinea* L., *Pinus sylvestris*, *Populus alba* L., *Populus tremula* L., *Prunus* L., *Prunus spinosa* L., *Elaeagnus angustifolia* L., *Salix* L., *Pistacia lentiscus* L., and *Hesperocyparis macrocarpa (Hartw.) Bartel*. The aim is to make an ecological contribution by favoring fire-resistant, fast-growing and evergreen species in possible afforestation works.

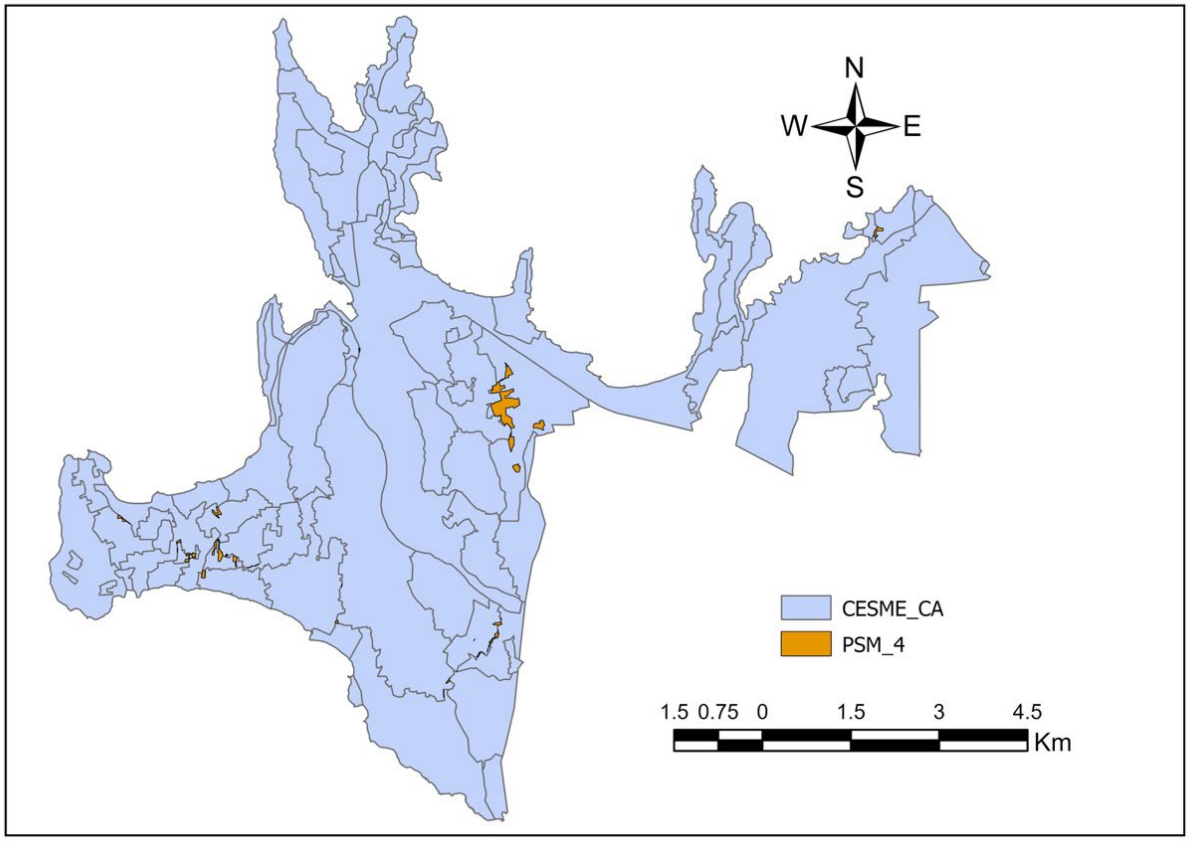


Figure 5. Plant Suitability Map 4 "PSM-4".

After evaluating FA under different protection statuses, the analysis was extended to AA, starting with "PSM-5", which represents more constrained agricultural lands. PSM-5 Inquiry Criteria: Within the NPA, areas with the status of QNUA, land-use type; AA, LUC; VI, VII, soil depth (C + D) were defined as "PSM-5" (Figure 6). Accordingly, it was determined that soil depth 0–50 cm (shallow and very shallow), land slope 12–30%, erosion degree moderate and severe, areas are distributed on Colluvial (C), Red–Brown Mediterranean (E), Brown without Lime (U), and Rendzina (R) MSGs. Plant species that can grow in areas defined as "PSM-5", with moderate and severe erosion, sloping terrain, and a shallow soil depth, considering the MSG and LUC classes, are as follows: *Clematis* L., *Arbutus unedo* L., *Lavandula stoechas* L., *Melissa officinalis subsp. officinalis*, and *Vitex agnus-castus* L. Since agriculture cannot be practiced in these areas due to the 12–30% slope, the aim is to make an economic and ecological contribution to the people of the region by favoring species that primarily prevent erosion and support beekeeping activities, along with medical aromatic plants.

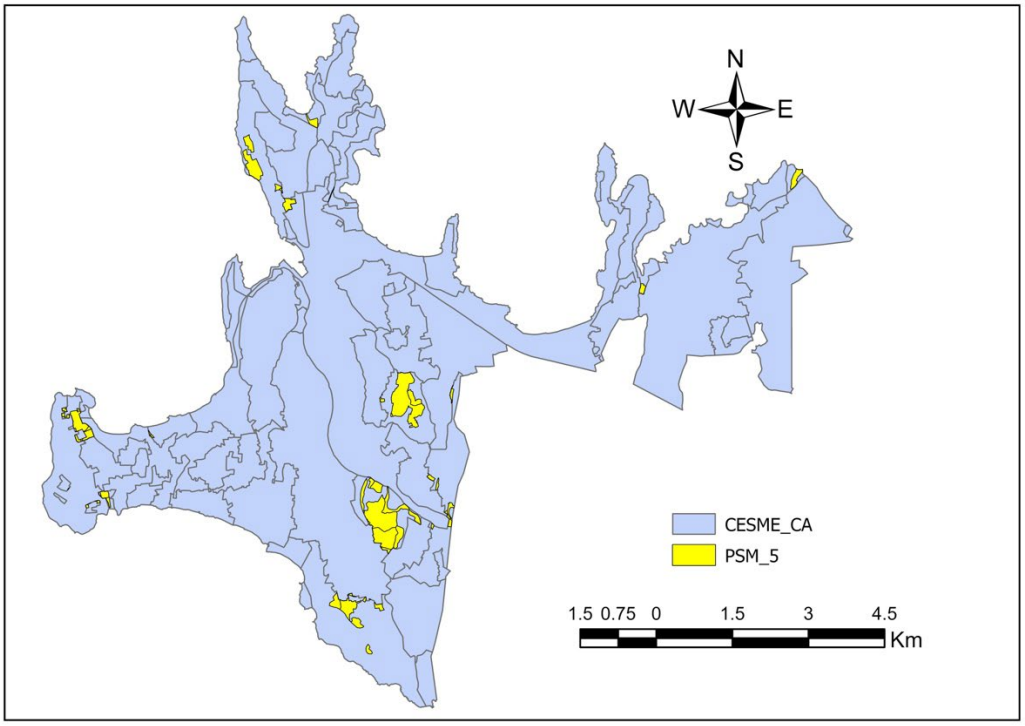


Figure 6. Plant Suitability Map 5 "PSM-5".

Compared to the more restrictive conditions identified in PSM-5, PSM-6 includes agricultural areas with a more suitable soil depth and slope conditions, allowing for a wider range of plant species and land-use options. PSM-6 Inquiry Criteria: Within the NPA, areas with the status of QNUA, land-use type; AA, LUC; I, II, III, soil depth (B) were defined as PSM-6 (Figure 7). Accordingly, it was determined that the areas with a moderate soil depth of 50–90 cm, land slope of 0–12%, and moderate erosion degree were distributed on Renzina (R) and Colluvial (C) MSGs. Plant species that can be grown in areas with a low and moderate erosion degree, gently sloping land and medium soil depth, defined as "PSM-6", considering the MSG and LUC classes, are as follows: *Prunus amygdalus* Batsch., *Prunus armeniaca* var. *armeniaca.*, *Prunus cerasus* L., *Cydonia oblonga Mill.*, *Prunus spinosa* L., *Pyrus communis* L., *Cotoneaster acuminatus* Lindl., *Eriobotrya japonica (Thun b.) Lindl.*, *Sorbus aucuparia subsp. aucuparia, Juglans nigra* L., *Ziziphus jujuba Mill.*, *Punica granatum* L., *Pistacia lentiscus* L., *Olea europaea* L., and *Cercis* L. First, this aimed to contribute economically and ecologically to the region's people by favoring perennial plants with economic value as an alternative to annual agricultural plants.

Similar to the distinction made between protection statuses in forest areas, PSM-7 evaluates agricultural lands under SCCCA conditions, reflecting stricter conservation constraints. PSM-7 Inquiry Criteria: Within the NPA, areas with the status of SCCCA, land-use type AA, LUC; VI,VII, soil depth (C+D) were defined as "PSM-7"(Figure 8). Accordingly, it was determined that the areas with a shallow and very shallow soil depth of 0–50 cm, land slope of 12–30%, and severe erosion degree were distributed on Colluvial (C), Red–Brown Mediterranean (K), Brown without Lime (U), and Rendzina (R) MSGs. Plant species that can grow in areas defined as "PSM-7", with moderate and severe erosion, sloping terrain and a shallow soil depth, considering the MSG and LUC classes, are as follows: *Clematis L.*, *Arbutus unedo* L., *Lavandula stoechas* L., *Trifolium Tourn. ex* L., *Melissa offici-nalis subsp. officinalis*, *Vitex agnus-castus* L., *Phleum pratense* L., *Poa pratensis* L., *Poa compressa* L., *Agrostis alba* L., *Axonopus compressus (Sw.) P. Beauv.*, and *Lespedeza cuneata.* Since agriculture cannot be practiced in these areas due to the 12–30% slope, the aim is to mak

an economic and ecological contribution to the people of the region by favoring species that primarily prevent erosion and support beekeeping activities, along with medical aromatic plants.

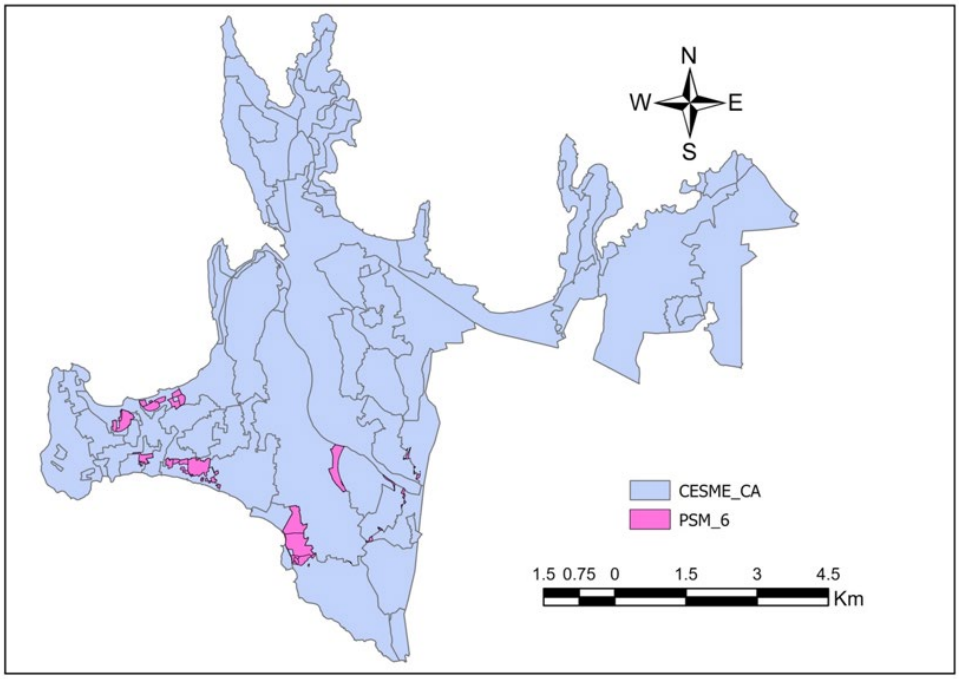


Figure 7. Plant Suitability Map 6 "PSM-6".

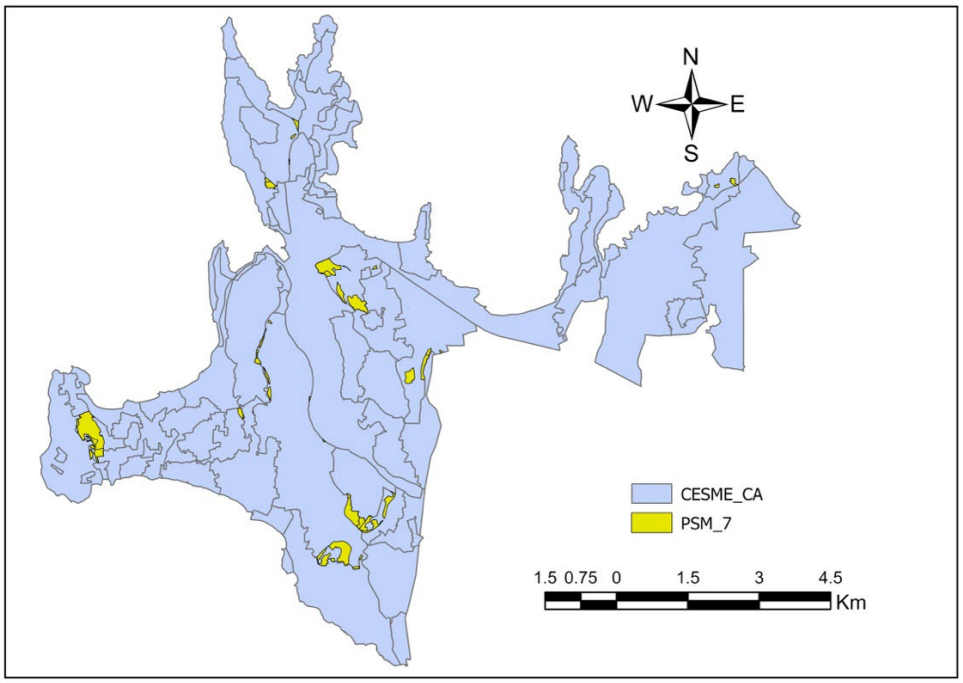


Figure 8. Plant Suitability Map 7 "PSM-7".

Finally, PSM-8 represents the most suitable agricultural areas within SCCCA, characterized by moderate ecological constraints and higher potential for sustainable land-use practices. PSM-8 Inquiry Criteria: Within the NPA, areas with the status of SCCCA, land-use type AA, LUC; I, II, III, soil depth (B) were defined as PSM-8 (Figure 9). Accordingly,

it was determined that the soil depth of 50–90 cm is medium–deep, the slope of the land is 2–12%, the erosion degree is moderate, and the severe areas are distributed on colluvial (C) and Rendzina (R) MSGs. The plant species that can grow in the areas defined as "PSM-8" with a moderate erosion severity, mild and moderate slope, and medium soil depth, considering the MSG and LUC classes, are as follows: *Olea europaea* L., *Prunus argentea* (Lam.) Rehder, *Prunus armeniaca var. armeniaca.*, *Prunus cerasus* L., *Cydonia oblonga* Mill., *Pyrus communis* L., *Crataegus* L., *Eriobotrya japonica* (Thunb.) Lindl., *Sorbus aucuparia subsp. aucuparia*, *Juglans nigra* L., *Ziziphus jujuba* Mill., *Punica granatum* L., *Pistacia lentiscus* L., and *Cercis* L. First, this aims to contribute economically and ecologically to the region's people by favoring perennial plants with economic value as an alternative to annual agricultural plants.

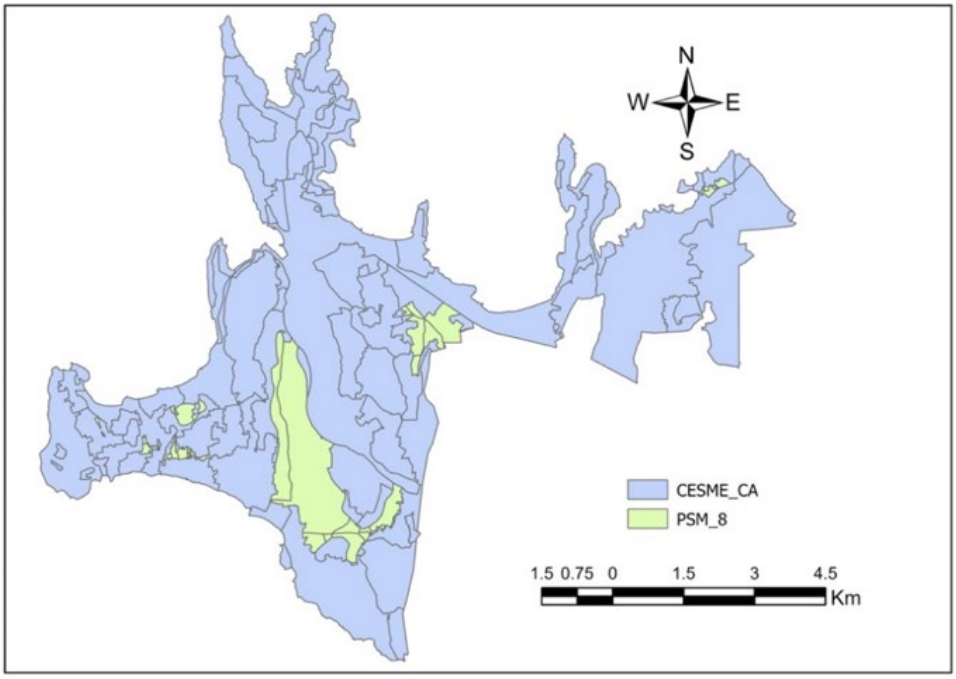


Figure 9. Plant Suitability Map 8 "PSM-8".

The eight PSMs collectively reveal a clear spatial differentiation in ecological constraints and land-use potential across the PA of Cesme. PSM-1, PSM-3, PSM-5, and PSM-7 represent areas characterized by shallow soil depth, steep slopes, and moderate to severe erosion, where plant recommendations primarily focus on erosion control, habitat stabilization, and low-impact ecological functions. In contrast, PSM-2, PSM-4, PSM-6, and PSM-8 correspond to areas with deeper soils, gentler slopes, and lower erosion risk, allowing the integration of perennial woody species, agroforestry practices, and economically valuable plant production compatible with conservation objectives. When evaluated comparatively, forest-dominated PSMs contribute mainly to ecological resilience and biodiversity support, while agricultural PSMs provide higher potential for socio-economic benefits through sustainable perennial cultivation. This synthesis demonstrates that the PSM framework enables a functional classification of RAs, linking soil-based constraints with differentiated management strategies rather than treating suitability outputs as isolated spatial units. Overall, the transition between PSM classes highlights a clear gradient from highly constrained to more suitable areas, demonstrating the role of soil and land characteristics in shaping sustainable land-use strategies within PA.

4. Discussion

The findings of this study demonstrate that soil- and land-based GIS analysis provides a reliable framework for identifying ecologically suitable plant species in PA where detailed biotic data are limited. Unlike conventional approaches that rely heavily on vegetation data, this study emphasizes the role of soil properties in guiding sustainable land-use decisions. In addition, the preference for a rule-based GIS approach over commonly used multi-criteria decision-making methods, such as Analytic Hierarchy Process (AHP), distinguishes this study from previous research. Although the AHP is frequently used in multi-criteria decision-making studies to assign relative weights to evaluation criteria, it was not applied in this study. This is because the primary objective was not to rank alternatives based on subjective expert judgments, but to generate a transparent, data-driven, and constraint-based spatial suitability framework. Therefore, the methodology focuses on ecological feasibility rather than weighted prioritization, increasing both the objectivity and transferability of the results [1,12,62,63]. While many studies rely on weighted evaluation techniques to rank land suitability [62,63,65], the present study prioritizes ecological feasibility by using threshold-based classification derived from the soil depth, slope, erosion, and land capability classes. This approach minimizes subjectivity and increases transparency in spatial decision-making processes. Similar findings have been reported in studies emphasizing that constraint-based GIS models can provide more reproducible and policy-relevant outputs in conservation-oriented planning contexts [71]. Therefore, the methodological framework adopted in this study contributes to the literature by offering a more objective and transferable alternative for land suitability assessment in PA. The results reveal a clear spatial differentiation between areas with high ecological constraints and those with greater land-use potential. In highly constrained areas (e.g., PSM-1, PSM-3, PSM-5, and PSM-7), a shallow soil depth, steep slopes, and high erosion risk limit intensive land-use options, making them more suitable for erosion control, habitat stabilization, and low-impact ecological functions. In contrast, areas with deeper soils and lower slopes (PSM-2, PSM-4, PSM-6, and PSM-8) offer opportunities to integrate perennial plant species and sustainable production systems. From a practical perspective, the proposed framework provides a decision-support tool for planners and policymakers by linking ecological constraints with appropriate plant species and land-use strategies. This approach helps balance conservation priorities with socio-economic benefits, particularly in regions where human pressure on PA is increasing.

In the plant suitability classes derived from the basal abiotic data, soil depth, slope, erosion degree and land-use capability, they demonstrated that ecologically feasible and spatially transparent planting strategies can be produced after considering the existing natural potential of the landscape. These results were consistent with previous ones, suggesting that abiotic spatial indicators can be useful when considering conservation and planning strategies in data-constrained terrains [12,24,67–70,72–75]. Consistent with Geneletti [71], the application of soil- and land-structural aspects helps in identifying appropriate land-use decisions and decreases uncertainty in processes of conservation-minded decisions. Thus, from a planning perspective, the addition of soil-based suitability analysis into the planning of plant is advantageous. It supports ecosystem-informed decision-making, connecting species to soil that is more sustainable in the long run, while minimizing short-term or individual interest levels based on land-use decisions. Spatial patterns from the PSM reveal sites for ecological enhancement without conflicts with the protection status, enabling a conservation–use relationship equilibrium in highly regulated landscapes such as Cesme District. Some of the findings were particularly relevant to PA under increasing human pressure, as highlighted in previous studies that emphasize the need to balance conservation objectives with socio-economic demands [20,46].

The results are also consistent with ecosystem service-based approaches, highlighting the multifunctional role of land-use planning in PA.

Previous studies have demonstrated that integrating ecological suitability with land-use strategies can enhance biodiversity conservation while simultaneously supporting local livelihoods [2,3]. In particular, the use of underused or RA has been identified as a key strategy for restoring ecosystem functions, improving habitat quality, and increasing resilience against environmental pressures [8,30]. In this context, the findings of the present study support the view that RA should not be considered unproductive areas but rather strategic resources for sustainable landscape management.

Similar results were reported by Boza and Hepaksoy [76] and Viciani et al. [77]. This study demonstrated that abiotic indicators—thanks to their measurability and spatial representability—are reliable surrogates for ecological analysis in areas where biotic data may be insufficient. While previous studies focused on either vegetation representation or conservation value assessment, this research fills a gap in the literature by transforming soil-based suitability assessments into application-specific, implementable planting actions for PA. Despite its contributions, the study has several limitations. First, the analysis is primarily based on abiotic parameters and does not incorporate detailed biotic data such as species interactions or habitat connectivity. Second, the use of static spatial data limits the ability to assess temporal changes and long-term ecological dynamics. In addition, socio-economic factors and stakeholder perspectives were not directly included in the evaluation process, although they play a critical role in the success of conservation strategies. Including climatic and temporal scenarios would also improve the robustness of plant suitability evaluations. Further, the interplay between GIS integrated ecological studies and socio-economic and participatory planning perspectives would enhance the model's applicability for policy formulation and adaptive management. Additional testing of the proposed framework across other ecological systems is also expected, as it provides proof of concept and supports wider application in global conservation and ecologically sustainable land-use planning [8,17]. To conclude, we aim to demonstrate, using soil-based GIS analytics, that ecologically responsible, appropriate, and policy-relevant plant planning decisions can be applied within PA where biotic knowledge is scarce. The proposed approach adopts a transferable, ecosystem-based approach to guide the discourse on sustainable land use and conservation planning and provides practical implications for decision-makers operating under data limitations. Future studies should integrate biotic data, climate scenarios, and temporal monitoring to improve the accuracy and applicability of plant suitability assessments. Furthermore, combining GIS-based ecological analysis with participatory planning approaches would enhance the effectiveness of conservation-oriented land-use strategies.

5. Conclusions and Implications

This study showed that GIS-based soil and land suitability analysis can provide an effective framework for identifying ecologically appropriate plant species in PA. By integrating soil characteristics, topographic parameters, and land-use classifications, the proposed approach enables a spatially explicit evaluation of RA and their potential for sustainable use. Based on the PSM results, the expected outcomes of the proposed planting strategies can be summarized as follows. Implementation of plant proposals in areas identified by PSM-1 and PSM-3 is projected to increase overall green space within the study area by approximately 14.8%. In areas defined by PSM-4, the expansion of naturally distributed and rare species such as *Pistacia lentiscus L.* and *Pistacia lentiscus L. var. chia* is expected to result in an increase of approximately 1.16%. Combined planting interventions within PSM-2 and PSM-4 are estimated to contribute an additional 2.2% increase in total green space. Furthermore, perennial woody agricultural plantations proposed for

areas identified by PSM-6 and PSM-8 are projected to increase green space by approximately 24.5%, while supporting coastal–sea tourism and agrotourism activities and enhancing the cultural landscape value of the region. Similarly, perennial herbaceous agricultural plantations proposed for PSM-5 and PSM-7 are expected to contribute an additional 11.06% increase in green area coverage. The results highlight that RA within PA represents a significant opportunity to enhance biodiversity, improve ecosystem services, and support sustainable land management practices. The differentiation of PSMs based on ecological constraints provides a practical tool for linking site conditions with appropriate plant species and land-use strategies. From a policy and planning perspective, the proposed framework offers a transferable and scalable decision-support tool that can assist stakeholders in balancing conservation objectives with socio-economic development. Therefore, integrating GIS-based suitability analysis into conservation planning processes has the potential to significantly contribute to sustainable landscape management in PA.

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Appendix A

Table A1. List of abbreviations used in the study.

PA	Protected Area
GIS	Geographic Information System
RA	Resting Area
PSMs	Plant Suitability Maps
QNUA	Qualified Natural Protected Area
SCCCA	Strictly Controlled Conservation Area
FAs	Forest Areas
AAs	Agricultural Areas
MSGs	Major Soil Groups
LUC	Land-use Capability
EC	Erosion Class
NPA	Natural Protected Area

Table A2. Soil characteristics and area covered under "PSM-1".

Area Number (AN)	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m^2)
1	FA	QNUA	R	4	VII	D	4	180
2	FA	QNUA	R	4	VII	D	4	6.637
3	FA	QNUA	R	4	VII	D	4	89.061
4	FA	QNUA	R	3	VI	D	4	1.498

5	FA	QNUA	E	4	VII	D	3	1.418
6	FA	QNUA	E	3	VI	D	4	10.438
7	FA	QNUA	R	3_4	VII	C_D	4	974.610
8	FA	QNUA	E	3	VII	D	5	1.320.765
9	FA	QNUA	U	3	VI	D	3	114.609
10	FA	QNUA	U	3	VI	D	3	673
11	FA	QNUA	R	3	VI_VII	C_D	4_5	947.023
12	FA	QNUA	R	3	VII	D	4	395.075
13	FA	QNUA	U-R	3	VI	D	2_4	65.238
14	FA	QNUA	E	3	VII	D	4	116.504
15	FA	QNUA	U	3	VI	D	3	32.679
16	FA	QNUA	R	4	VII	D	4	6.804
17	FA	QNUA	E	3	VII	D	4_5	458.375
18	FA	QNUA	R	3	VII	C	5	358.124
19	FA	QNUA	E	4	VII	D	4	28.896
20	FA	QNUA	E	3	VI	D	4	5.660
							TOTAL	4.934.267

Table A3. Soil characteristics and area covered under "PSM-2".

Area Number (AN)	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m²)
1	FA	QNUA	K	1	I	B	1	8.241
2	FA	QNUA	R	1	II	B	2	7.722
3	FA	QNUA	R	2	III	B	3	76.000
4	FA	QNUA	R	2	III	B	3	243.266
5	FA	QNUA	K-R	1	II	B	2	3.743
6	FA	QNUA	R	1	II	B	2	37.902
7	FA	QNUA	R	1	II	B	2	2.626
8	FA	QNUA	R	1	II	B	2	31.344
9	FA	QNUA	K	1	II	B	2	260
								411.104

Table A4. Soil characteristics and area covered under "PSM-3".

Area Number (AN)	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m²)
1	FA	SCCCA	R-K	3	VI-VII	C-D	3_4	43.617
2	FA	SCCCA	E-R	3	VII	D	4	216.310
3	FA	SCCCA	E	3	VI	D	4	6.062
4	FA	SCCCA	R	3	VI	D	4	811
5	FA	SCCCA	U	3	VI	D	3	98.762
6	FA	SCCCA	E-R	3	VII	C	4	11.900
7	FA	SCCCA	R	3	VI	C	4	43.050
8	FA	SCCCA	E-R	3	VI-VII	C-D	4	754.404
								1.174.916

Table A5. Soil characteristics and area covered under "PSM-4".

Area Number	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m²)
1	FA	SCCCA	K	1	I	B	2	314
2	FA	SCCCA	R	2	III	B	2_3	71.220
3	FA	SCCCA	K	1	II	B	2	7.254
4	FA	SCCCA	R	2	III	B	3	938
5	FA	SCCCA	R	1	II	B	2	20.609
6	FA	SCCCA	R	2	III	B	3	19.097
7	FA	SCCCA	R	1	II	B	2	352.044

8	FA	SCCCA	R	2	II	B	2	1.320
								472.796

Table A6. Soil characteristics and area covered under "PSM-5".

Area Number (AN)	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m²)
1	AA	QNUA	K	3	VI	C	4	513
2	AA	QNUA	R	4	VII	D	4	18.527
3	AA	QNUA	K-R	4	VII	C_D	4	181.681
4	AA	QNUA	R	3	VI	C_D	4	282.022
5	AA	QNUA	E	3	VII	D	5	74.081
6	AA	QNUA	U	3	VI	D	4	59.562
7	AA	QNUA	R	3	VI-VII	C	4_5	587.527
8	AA	QNUA	U	2	VI	D	4	21.852
9	AA	QNUA	E	3	VII	D	4	19.214
10	AA	QNUA	R	3	VII	C	5	953.017
								2.197.996

Table A7. Soil characteristics and area covered under "PSM-6".

Area Number	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m²)
1	AA	QNUA	K	1	I	B	1	159.639
2	AA	QNUA	R	2	II	B	2	112.360
3	AA	QNUA	R	2	III	B	2	70.362
4	AA	QNUA	R	2	III	B	2	360.689
5	AA	QNUA	K	1	II	B	2	638.951
6	AA	QNUA	R	1	II	B	2	23.976
7	AA	QNUA	R	1	II	B	2	1.958
8	AA	QNUA	R	1	II	B	2	28.508
9	AA	QNUA	K	1	II	B	2	238.413
								1.634.856

Table A8. Soil characteristics and area covered under "PSM-7".

Area Number (AN)	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m²)
1	AA	SCCCA	K-R	4	VI_VII	C_D	4	431.422
2	AA	SCCCA	E-R	3	VII	C_D	4_5	523.372
3	AA	SCCCA	R	3	VI	D	4	25.415
4	AA	SCCCA	U	3	VI	D	4	679
5	AA	SCCCA	R	3	VII	C	5	144.254
6	AA	SCCCA	R	3	VI	C	4	18.084
7	AA	SCCCA	E	3	VII	D	5	135.950
								1.279.176

Table A9. Soil characteristics and area covered under "PSM-8".

Area Number (AN)	Land-Use Type	Area Status	LSG	ED	LUC	Soil Depth	Slope	Area (m²)
1	AA	SCCCA	K	1	I	B	2	12.864
2	AA	SCCCA	R	2	III	B	3	475.834
3	AA	SCCCA	K	1	II	B	2	6.281.277
4	AA	SCCCA	R	2	III	B	3	23.782
5	AA	SCCCA	R	1	II	B	2	492.266
6	AA	SCCCA	R	2	III	B	3	61.750
7	AA	SCCCA	R	1	II	B	2	942.529
								8.290.302

References

1. Liu, J.; Qin, K.; Xiao, Y.; Xie, G. Multi-criteria decision-making scenario insights into spatial responses and promotion under ecosystem services. *Land* **2024**, *13*, 1964. https://doi.org/10.3390/land13111964.
2. Palomo, I.; Martín-López, B.; Zorrilla-Miras, P.; García Del Amo, D.; Montes, C. Deliberative mapping of ecosystem services within and around Doñana National Park (SW Spain) in relation to land use change. *Reg. Environ. Chang.* **2014**, *14*, 237–251.
3. Mandle, L.; Shields-Estrada, A.; Chaplin-Kramer, R.; Mitchell, M.G.E.; Bremer, L.L.; Gourevitch, J.D.; Hawthorne, P.; Johnson, J.A.; Robinson, B.E.; Smith, J.R.; et al. Increasing decision relevance of ecosystem service science. *Nat. Sustain.* **2021**, *4*, 161–169.
4. Perez-Navarro, M.A.; Broennimann, O.; Esteve, M.A.; Bagaria, G.; Guisan, A.; Lloret, F. Comparing climatic suitability and niche distances to explain populations responses to extreme climatic events. *Ecography* **2022**, *2022*, e06263. https://doi.org/10.1111/ecog.06263.
5. Maseko, Z.T.M. Urban Open Space Utilization for Subsistence Agriculture: A Study of Esikhaleni Township. *J. Asian Afr. Stud.* **2024**, *61*, 316–339. https://doi.org/10.1177/00219096241287716.
6. Duan, P.; Wang, Y.; Yin, P. Remote Sensing Applications in Monitoring of (PA): A Bibliometric Analysis. *Remote Sens.* **2020**, *12*, 772. https://doi.org/10.3390/rs12050772.
7. Nizamani, M.M.; Zhang, Q.; Muhae-Ud-Din, Q.; Awais, M.; Qayyum, M.; Farhan, M.; Jabran, M.; Wang, Y. Application of GIS and Remote-Sensing Technology in Ecosystem Services and Biodiversity Conservation. In *Deep Learning for Multimedia Processing Application*, 1st ed.; Taylor & Francis: London, UK, 2024; pp. 284–321. https://doi.org/10.1201/9781032646268.
8. Knozowski, P.; Nowakowski, J.J.; Stawicka, A.M.; GoÃÅrski, A.; Dulisz, B. Effect of Nature Protection and Management of Grassland on Biodiversity-Case from Big Flooded River Valley (NE Poland). *Sci. Total Environ.* **2023**, *898*, 165280.
9. Barrena, J.; Nahuelhual, L.; Báez, A.; Schiappacasse, I.; Cerda, C. Valuing cultural ecosystem services: Agricultural heritage in Chiloe island, southern Chile. *Ecosyst. Serv.* **2014**, *7*, 66–75.
10. Martínez-Graña, A.M.; Merchán, L.; Valencia Ortiz, J.A. A GIS-Based Approach for Use Recommendations and Limitations in Sustainable Coastal Planning in the Southeastern Margin of the Ría de Arosa (Pontevedra, Spain). *Appl. Sci.* **2025**, *15*, 4582.
11. Palomo, I.; Martín-López, B.; Potschin, M.; Haines-Young, R.; Montes, C. Incorporating the social–ecological approach in (PA) research. *Conserv. Biol.* **2014**, *28*, 645–653.
12. Ebrahimi Sirizi, M.; Taghavi Zirvani, E.; Esmailzadeh, A.; Khosravian, J.; Ahmadi, R.; Mijani, N.; Soltannia, R.; Jokar Arsanjani, J. A Scenario-Based Multi-Criteria Decision-Making Approach for Allocation of Pistachio Processing Facilities: A Case Study of Zarand, Iran. *Sustainability* **2023**, *15*, 15054. https://doi.org/10.3390/su152015054.
13. Keesstra, S.D.; Bouma, J.; Wallinga, J.; Tittonell, P.; Smith, P.; Cerdà, A.; Montanarella, L.; Quinton, J.; Pachepsky, Y.; Van der Puten, W. The significance of soils and soil science towards realization of the United Nations Sustainable Develop- ment Goals. *Soil* **2016**, *2*, 111–128.
14. Pettorelli, N.; Safi, K.; Turner, W. Satellite remote sensing, biodiversity research and conservation of terrestrial ecosystems. Remote Sensing in Ecology and Conservation (dergi). *Philos. Trans. R Soc. Lond. B Biol. Sci.* **2014**, *26*, 369–376.
15. Rodrigues, A.S.; Andelman, S.J.; Bakarr, M.I.; Boitani, L.; Brooks, T.M.; Cowling, R.M.; Fishpool, L.D.C.; da Fonseca, G.A.B.; Gaston, K.J.; Hoffmann, M.; et al. Effectiveness of the global protected area network in representing species diversity. *Nature* **2004**, *428*, 640–643. https://doi.org/10.1038/nature02422.
16. Quintas-Soriano, C.; Castro, A.J.; Castro, H.; García-Llorente, M. Impacts of land use change on ecosystem services and implicationsfor human well-being in Spanish drylands. *Land Use Policy* **2016**, *54*, 534–548.

17. Han, C.; Chen, S.; Yu, Y.; Xu, Z.; Zhu, B.; Xu, X.; Wang, Z. Evaluation of agricultural land suitability based on RS, AHP, and MEA: A case study in Jilin Province, China. *Agriculture* **2021**, *11*, 370.
18. Mishra, M.; Desul, S.; Santos, C.A.G.; Mishra, S.K.; Kamal, A.H.M.; Goswami, S.; Kalumba, A.M.; Biswal, R.; da Silva, R.M.; dos Santos, C.A.C.; et al. A bibliometric analysis of sustainable development goals (SDGs): A review of progress, challenges, and opportunities. *Environ. Dev. Sustain.* **2024**, *26*, 11101–11143. https://doi.org/10.1007/s10668-023-03225-w.
19. Adriaensen, F.; Chardon, J.P.; De Blust, G.; Swinnen, E.; Villalba, S.; Gulinck, H.; Matthysen, E. The application of 'least-cost' modelling as a functional landscape model. *Landsc. Urban Plan.* **2003**, *64*, 233–247.
20. Snyman, S. Assessment of the main factors impacting community members' attitudes towards tourism and (PA) in six southern African countries. *Koedoe* **2014**, *56*, 12.
21. Fang, X.; Ma, Q.; Liu, Z.; Wu, J. Landscape sustainability and land sustainability: A bibliometric analysis. *Land Use Policy* **2024**, *147*, 107374.
22. Silva-Rivera, E.; Vázquez- Domínguez, G.; Mota-Sánchez, Ó.H.; Hernández-De la Cruz, I.; Franco-José, R.M.; Velázquez-Rosas, N.; Martínez-Mota, R. The Value of Stingless Bee Bioproducts for Human Health and Conservation: A Systematic Review. *Diversity* **2025**, *17*, 191. https://doi.org/10.3390/d17030191.
23. Kullberg, P.; Di Minin, E.; Moilanen, A. Using key biodiversity areas to guide effective expansion of the global protected area network. *Glob. Ecol. Conserv.* **2019**, *20*, e00768.
24. Türkyılmaz, B.; Kurucu, Y.; Bolca, M.; Altınbaş, Ü.; Gülgün, B.; Özen, F. A GIS Based Model for Rating Natural Protection Areas According To Natural Protection Priorities. *Int. J. Sustain. Dev. World Ecol.* **2007**, *14*, 278–286.
25. Steiner, A.; Calo, F.; Shucksmith, M. Rurality and Social Innovation Processes and Outcomes: A Realist Evaluation of Rural Social Enterprise Activities. *J. Rural Stud.* **2021**, *in press*.
26. Zhou, T.; JGuanghui, J.; Wenqiu, M.; Li, G.; Yanbo, Q.; Yingying, T.; Qinglei, Z.; Yaya, T. Dying villages to prosperous villages: A perspective from revitalization of resting rural residential land (IRRL). *J. Rural Stud.* **2021**, *84*, 45–54.
27. Anderson, M.G.; Clark, M.; Mcrae, B.H. *Permeable Landscapes for Climate Change the Nature Conservancy, 2015*; Eastern Conservation Science: Boston, MA, USA, 2015.
28. Wang, J.; Xing, Y.; Chang, X.; Yang, H.; Yang, C.; Xue, G.; Li, C. Identification of priority conservation areas for Natural Forest Protection Project in Northeastern China based on OWA-GIS. *Ecol. Indic.* **2024**, *160*, 111718.
29. Durlević, U.; Srejić, T.; Valjarević, A.; Aleksova, B.; Đenanski, V.; Vujović, F.; Lukić, T. GIS-Based Spatial Modeling of Soil Erosion and Wildfire Susceptibility Using VIIRS and Sentinel-2 Data: A Case Study of Šar Mountains National Park, Serbia. *Forests* **2025**, *16*, 484. https://doi.org/10.3390/f16030484.
30. Takem, B.M.; Mbuh, J.; MLepatio-Tchieg, A.S. The Use of GI Science in Detecting Anthropogenic Interaction in (PA): A Case of the Takamanda National Park, South West Region, Cameroon. In Geographic Information Science for Land Resource Management. 2021. Available online: https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119786375.ch4 (accessed on 13 July 2024).
31. Tezel, D.; Buyukdemircioglu, M.; Kocaman, S. Accurate assessment of protected area boundaries for land use planning using 3D GIS. *Geocarto Int.* **2021**, *36*, 96–109. https://doi.org/10.1080/10106049.2019.1590466.
32. Yıldız, M.; Çobanoğlu, N. An Applied Ethical Evaluation for Environmental Ethics of Decision Makers' Perception at Nature Conservation and Forestry Management in Turkey. *Ank. Univ. J. Soc. Sci.* **2017**, *8*, 74–119.
33. Borrını-Feyerabend, G.; Kotharı, A.; Ovıedo, G. *Indıgenous and Local Communıtıes and (PA): Towards Equıty and Enhanced Conservatıon-Guıdance on Polıcy and Practıce for Co-Managed (PA) and Communıty Conserved Areas*; Best Practıce Protected Area Guıdelınes Serıes No. 11; International Centre for Integrated Mountain Development: Iucn, Gland, 2004; 139p.
34. Ward, M.; Saura, S.; Williams, B.; Ramírez-Delgado, J.P.; Arafeh-Dalmau, N.; Allan, J.R.; Watson, J.E. Just ten percent of the global terrestrial protected area network is structurally connected via intact land. *Nat. Commun.* **2020**, *11*, 4563. https://doi.org/10.1038/s41467-020-18457-x.
35. Weiskopf, S.R.; Rubenstein, M.A.; Crozier, G.Z.; Gaichas, S. Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. *Sci. Total Environ.* **2020**, *733*, 137782.
36. IUCN (International Union for Conservation of Nature). Ensuring Effective Nature-Based Solutions. 2020. Available online: https://iucn.org/our-work/nature-based-solutions (accessed on 13 July 2024).
37. Sharda, V.N.; Mandal, D.; Dogra, P. Prioritizing soil conservation measures based on water erosion risk, production, and bioenergy losses in peninsular South Indian states. *CATENA* **2021**, *202*, 105263. https://doi.org/10.1016/j.catena.2021.105263.
38. Kubacka, M.; Zywica, P.; Subir'os, J.V.; Br'odka, S.; Macias, A. How do the surrounding areas of national parks work in the context of landscape fragmentation? A case study of 159 (PA) selected in 11 EU countries. *Land Use Polic.* **2022**, *113*, 105910. https://doi.org/10.1016/j.landusepol.2021.105910.

39. Ministry of Agriculture and Forestry of the Republic of Türkiye, General Directorate of Nature Conservation and National Parks. (PA) Statistics. Available online: https://www.tarimorman.gov.tr/DKMP/Menu/18/Korunan-Alan-Istatistikleri (accessed on 12 June 2025).
40. WWF Turkey, Korumazsak Kaybederiz: Sürdürülebilir Bir Türkiye İçin Korunan Alanlar Hedef: 2030'a Kadar %30. WWF-Türkiye. Available online: https://wwftr.awsassets.panda.org/downloads/korunanalanlar_korumazsakkaybederiz__rapor__web.pdf?utm (accessed on 22 May 2025).
41. OECD, (PA) (Dataset). OECD.Stat. Available online: https://stats.oecd.org/Index.aspx?DataSetCode=PROTECTED_AREAS (accessed on 20 July 2024).
42. Republic of Turkey Ministry of Environment, Urbanization and Climate Change. 2024. Available online: https://cevreselgostergeler.csb.gov.tr/korunan-alanlar-i-85778 (accessed on 12 December 2024).
43. Willis, K. Remote sensing change detection for ecological monitoring in United States (PA). *Biol. Conserv.* **2015**, *182*, 233–242.
44. Meyer, S.; Birnbaum, P.; Bruy, D.; Cazé, H.; Garnier, D.; Gildas Gâteblé, G.; Lannuzel, G.; McCoy, S.; Tanguy, V.; Veillon, J.M. The New Caledonia Plants RLA: Bringing Botanists Together for the Conservation of the Archipelago's Crown Jewel. In *Imperiled: The Encyclopedia of Conservation*; Elsevier: Amsterdam, The Netherlands, 2022; pp. 859–874. https://doi.org/10.1016/B978-0-12-821139-7.00171-9.
45. Larrieu, L.; Burric, Y.; Corriol, G.; Gouix, N.; Sylvie, L.; Laroche, F.; Maille, S.; Py-Saragaglia, V.; Jean-Marie, S.; Brin, A. Are the remnants of old-growth mountain forests always relevant to inspiring close-to-nature forest management and efficient biodiversity conservation? *Biol. Conserv.* **2023**, *279*, 109954. https://doi.org/10.1016/j.biocon.2023.109954.
46. Mcguire, J.L.; Lawler, J.J.; McRae, B.H.; Nuñez, T.A.; Theobald, D.M. Achieving Climate Connectivity in a Fragmented Landscape. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 7195–7200. https://doi.org/10.1073/pnas.1602817113.
47. Kiwango, W.A.; Komakech, H.C.; Tarimo, T.M.C.; Martz, L. Decentralized environmental governance: A reflection on its role in shaping wildlife management areas in Tanzania. *Trop. Conserv. Sci.* **2015**, *8*, 1080–1097.
48. Garrard, R.; Kohler, T.; Price, M.F.; Byers, A.C.; Sherpa, A.R.; Maharjan, G.R. Land use and land cover change in Sagarmatha National Park, a world heritage site in the Himalayas of Eastern Nepal. *Mt. Res. Dev.* **2016**, *36*, 299–310.
49. Mango, J.; Valerian-Peter, R.; Kanja, K.; Ngondo, J.; Maobe, A.; Lubida, A.; Ijumulana, J.; Lİ, X. Evaluating the land cover dynamics in the (PA) using GIS and remote sensing techniques: The case of Nyerere National Park, Tanzania. *Geocarto Int.* **2022**, *37*, 17361–17381. https://doi.org/10.1080/10106049.2022.2127927.
50. Queiroz, D.; Pannunzio Ribeiro, M.; Tavares, P.; Mello, K. The role of forest plantations for the native vegetation conservation in the (PA) surroundings. *J. Nat. Conserv.* **2024**, *78*, 78126551. https://doi.org/10.1016/j.jnc.2023.126551.
51. Eklund, J.; Jones, J.P.; R¨as¨anen, M.; Geldmann, J.; Jokinen, A.P.; Pellegrini, A.; Balmford, A. Elevated fires during the COVID-19 lockdown and the vulnerability of (PA). *Nat. Sustain.* **2022**, *5*, 603–609. https://doi.org/10.1038/s41893-022-00884-x.
52. Saura, S.; Bertzky, B.; Bastin, L.; Battistella, L.; Mandrici, A.; Dubois, G. Protected area connectivity: Shortfalls in global targets and country-level priorities. *Biol. Conserv.* **2018**, *219*, 53–67. https://doi.org/10.1016/j.biocon.2017.12.020.
53. Akodewou, A.; Oszwald, J.; Saidi, S.; Gazull, L.; Akpavi, S.; Akpagama, K.; Gond, V. Land Use and Land Cover Dynamics Analysis of the Togodo Protected Area and its Surroundings in Southeastern Togo, West Africa. *Sustainability* **2020**, *12*, 5439. https://doi.org/10.3390/su12135439.
54. Cumming, G.S. Protected area management has significant spillover effects on vegetation. *Nature* **2026**, *650*, 642–651. https://doi.org/10.1038/s41586-025-09837-8.
55. Tavares, P.A.; Brites, A.; Guidotti, V.; Molin, P.G.; de Mello, K.; dos Santos, Z.L.; Sparovek, G. Test temporal benchmarks' effects on implementing the new Brazilian Forest Act. *Environ. Sci. Policy* **2021**, *126*, 213–222. https://doi.org/10.1016/j.envsci.2021.09.024.
56. Malczewski, J. Integrating multicriteria analysis and geographic information systems: The ordered weighted averaging (OWA) approach. *Int. J. Environ. Technol. Manag.* **2006**, *6*, 7–19.
57. Bozyel, D. Flora and Ecological Features of Mediterranean Vernal Pools in Ceşme penïnsula, Ege University, Institute of Science and Technology, Department of Biology. 2019. Available online: https://tez.yok.gov.tr/UlusalTezMerkezi/ (accessed on 14 June 2025).
58. General Directorate of Meteorology. Turkey. 2023. Available online: https://mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=IZMIR (accessed on 23 July 2024).
59. Koçman, A. Climate of the Aegean Plains, Ege U., Faculty of Letters, Publication Environmental Impacts of the Climatic Regime in Aegean Plains (Western Anatolia), 6(1), 1992, İzmir. Available online: https://dergipark.org.tr/tr/pub/ecd/article/67119 (accessed on 14 June 2025).

60. Ankaya, F. Investigation of the Natural Protected Areas of Çeşme District, İzmir Province Within the Context of Landscape Criteria. Ph.D. Thesis, Ege University: İzmir, Türkiye, 2018; Thesis No. 526851. Available online: https://tez.yok.gov.tr/UlusalTezMerkezi/ (accessed on 14 June 2025).
61. Akyol, Y.; Gemici, Y. Vegetation Ecology and Ecological Management of Biodiversity of Coastal Aegean (Between Edremit and Gökova Gulfs) in Turkey. *Kastamonu Univ. J. For. Fac.* **2017**, 17, 116–123. https://doi.org/10.17475/kastorman.296909.
62. Karaelmas, D.; Tekdamar, K.; Cengiz, C.; Cengiz, B.; Tekdamar, D.A. GIS and AHP-Based Agricultural Land-Use Suitability Analysis in Semi-Arid Regions of Southeastern Türkiye. *Sustainability* **2026**, *18*, 3508. https://doi.org/10.3390/su18073508.
63. Malczewski, J.; Rinner, C. *Multicriteria Decision Analysis in Geographic Information Science*; Springer: Berlin/Heidelberg, Germany, 2015.
64. Tuesta-Trauco, C.K.M.; Salas López, R.; Barboza, E.; Zabaleta-Santisteban, J.A.; Medina-Medina, A.J.; Rivera-Fernandez, A.S.; Sánchez-Vega, J.A.; Noriega-Salazar, N.M.; Oliva-Cruz, M.; Tariq, A.; et al. Land Suitability for Pitahaya (Hylocereus megalanthus) Cultivation in Amazonas, Perú: Integrated Use of GIS, RS, F-AHP, and PROMETHEE. *Remote Sens.* **2025**, *17*, 637. https://doi.org/10.3390/rs17040637.
65. Zabaleta, J.A.; Salas, R.; Rojas-Briceño, N.B.; Gómez, D.; Medina, A.J.; Tuesta, K.M.; Rivera, A.S.; Lévano Crisóstomo, J.; Oliva-Cruz, M.; Silva-López, J.O. Optimizing Landfill Site Selection Using Fuzzy-AHP and GIS for Sustainable Urban Planning. *Civ. Eng. J.* **2024**, *10*, 1698–1719.
66. Al-Taani, A.; Al-Husban, Y.; Farhan, I. Land suitability evaluation for agricultural use using GIS and remote sensing techniques: The case study of Ma'an Governorate, Jordan. Egypt. *J. Remote Sens. Space Sci.* **2021**, *24*, 109–117.
67. Elbared, P.; Nassif, N.; Hassoun, G.; Mulas, M. GIS-Based Land Suitability Analysis for Sustainable Almond Cultivation in Lebanon. *Agriculture* **2025**, *15*, 1974. https://doi.org/10.3390/agriculture15181974.
68. Oakes, H. *Türkiye Toprakları*; Ege Üniversitesi Matbaası: İzmir, Türkiye, 1958. Available online: https://books.google.com.tr/books/about/Türkiye_topraklari.html?id=q3ldmQEACAAJ (accessed on 14 June 2025).
69. Şenol, S.G.; Eroğlu, V.; Şentürk, O.; Kaçmaz, F.; Avcı, B. The Pollination and Reproduction Success of Salvia sclarea. *Biol. Diver. Conserv.* **2017**, *10*, 130–135.
70. Keçeci, A. Determınatıon of Essentıal Oıl Specıfıcatıons in the Leaves of Wıld (*Pistacia lentiscus* L.) and Cultıvated (*Pistacia lentiscus* var. chia. Durham.) Mactıc Trees Grown in Cesme Penınsula. Master's Thesis, Tekirdağ Namık Kemal University, Graduate School of Natural and Applied Sciences Department of Field Crops: Tekirdağ, Turkiye, 2019.
71. Geneletti, D. A GIS-based decision support system to identify nature conservation priorities in an alpine valley. *Land Use Policy* **2004**, *21*, 149–160. https://doi.org/10.1016/j.landusepol.2003.09.005.
72. Sac, M.M. Measuring of Soil Erosion Rate Using Radioactive Cesium Technique in Yatağan Basin. Ph.D. Thesis, Ege University, Department of Natural Sciences, Nuclear Sciences: İzmir, Turkey, 2003. Available online: https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp (accessed on 21 July 2024).
73. Semenderoğlu, A. The Relations of Socio-Economic and Natural Factors in Urla-Cesme Peninsula. Ph.D. Thesis, Dokuz Eylül University/Institute of Educational Sciences, 1999. Available online: https://tez.yok.gov.tr/UlusalTezMerkezi/giris.jsp (accessed on 11 October 2024).
74. Sarika, M.; Bazos, I.; Zervou, S.; Christopoulou, A. Flora and vegetation of the European-network "Natura 2000" habitats of Naxos island (GR4220014) and of nearby islets Mikres Kyklades (GR4220013), Central Aegean (Greece). *Plant Sociol.* **2016**, *52*, 3–56. https://doi.org/10.7338/pls2015522/01.
75. Okutan, A.E.; Çavuş, G. Forest fires that may arise after the earthquake; Measures passive Obtainable in the Field of Landscape Architecture. *For. J.* **2012**. Available online: https://dergipark.org.tr/tr/pub/duzceod/article/289323 (accessed on 14 June 2025).
76. Boza, A.; Hepaksoy, S. Oil Some leaf properties of natural Laurus nobilis L. population in Karaburun Peninsula (Izmir/Turkey) In Proceedings of the VII International Scientific Agriculture Symposium, "Agrosym 2016", Jahorina, Bosnia and Herzegovina, 6–9 October 2016. Available online: https://www.cabidigitallibrary.org/doi/full/10.5555/20173053705 (accessed on 23 July 2024).
77. Viciani, D.; Lastrucci, L.; Geri, F.; Foggi, B. Gap analysis comparing (PA) with potential natural vegetation in Tuscany (Italy) and a GIS procedure to bridge the gaps. *Plant Biosyst.—Int. J. Deal. All Asp. Plant Biol.* **2016**, *150*, 62–72. https://doi.org/10.1080/11263504.2014.950623.

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