Advanced Geomatics

http://publish.mersin.edu.tr/index.php/geomatics/index

e-ISSN: 2791-8637

3D Modeling and Land Management in Protected Areas: Fethiye-Göcek SEPA

Dilek Tezel*[1], Selçuk Aydemir, Cebrail Taşkın [3], Ünsal Gündoğan [4]

[1]*Ministry of Environment, Urbanization and Climate Change, Ankara, Türkiye.*
[2]*Ministry of Environment, Urbanization and Climate Change, Ankara, Türkiye.*
[3]*Verigo Digital Engineering, Ankara, Türkiye.*
[4]*Verigo Digital Engineering, Ankara, Türkiye.*

Keywords
Land Management,
Protected Area,
Photogrammetry,
3D Modeling,
Climate Change.

ABSTRACT

The increase in the world population cause a decrease in natural resources. In Protected Areas, which are the assurance of sustainability, effective land management should be ensured. It is aimed to protect the natural, cultural, social and economic values of the protected areas holistically, to plan and manage the terrestrial and marine areas in an integrated manner. On the other hand, the identification of spatial uses has traditionally been accomplished by drawing on paper and using digital maps based on two-dimensional information. With the developing technology, the use of remote sensing and three-dimensional (3D) models in mapping and zonning has become increasingly widespread, and besides data content and rich visualization, query and analysis functionality has made 3D maps a basic base for planning and monitoring. In this case, it is aimed to provide three-dimensional maps as a base for the research, planning, monitoring and management of protected areas. Fethiye-Göcek Special Environmental Protection Area, where forest lands, agricultural areas and coastal areas will be under the settlement pressure and where integrated coastal and land management will be carried out, has been determined as the study area. The study includes displaying the surface information with reality values and high resolution in a three-dimensional model, and performing customized spatial and statistical analyzes on the model. It is aimed to demonstrate the potential advantages of using high resolution digital terrain model and 3D model in protected areas. Land management, illegal building, determination of the changing natural areas, agricultural uses, changing village-urban uses, temporal display of changes were carried out. Effective decision support tools are provided to decision makers in land use planning by using land use changes density. The study showed that the 3D terrain model is an important decision support tool in land management and will support nature conservation efforts.

1. INTRODUCTION

The development of a worldwide network of protected areas is one of the greatest conservation achievements of the twentieth century. As the world's population increased and the demand for natural resources increased, protected areas became more important (Secretariat of the Convention on Biological Diversity, 2008).

For many years, protected areas have been defined as "parts of land and sea that are established and managed by law and other effective means to ensure the continuity and conservation of biodiversity, natural and cultural resources" (IUCN, 1994). Later, the definition was reconsidered as “clearly defined geographical locations established, sanctioned and managed by laws and other effective means to protect nature in the long term with ecosystem services and cultural values” (Dudley, 2008). Researhers carried out many academic studies on the

***Corresponding Author**

*(dilektezel@gmail.com) ORCID ID 0000-0002-1751-2948
(selcukaydemir@gmail.com) ORCID ID 0000-0003-3814-4467
(cebrail.taskin@gmail.com) ORCID ID 0000-0001-9331-2334
(unslgndgn@gmail.com) ORCID ID 0000-0003-2263-5835

Cite this;

Tezel, D., Aydemir S., Taşkın, C. & Gündoğan, Ü. (2022). 3D Modeling and Land Management in Protected Areas: Fethiye-Göcek SEPA. Advanced Geomatics, 2(2), 37-48.

protection of terrestrial and marine protected areas, and they created awareness by creating continuous reports on the need to protect areas (IUCN, 2018).

In 1978, the Mediterranean states signed the Barcelona Convention to protect the Mediterranean from pollution. This agreement established the legal framework for the implementation of the Mediterranean Action Plan (MAP). The Barcelona Convention was a tool for Mediterranean countries to monitor the state of the sea, to identify environmental problems and their sources. By this convention, Mediterranean countries are called upon to take all necessary measures to minimize marine pollution and protect the marine environment. Turkey, a Mediterranean country, ratified the Barcelona Convention in 2002. 21 countries and the European Union are parties to the convention. In order to protect the Mediterranean, each Mediterranean country tries to fulfill its protection activities in the most economical and effective way as per the contract. Turkey is divided into three regions, two terrestrial (Caucasus and Mediterranean) and one marine (Mediterranean) area, with its important biodiversity values, and is located in 200 ecological regions. These areas are shown among the most important ecological regions of the world in terms of the protection values they carry. Efforts are being made to establish an integrated management system for protected areas. It is aimed to reduce the impact of climate change on protected areas, to establish and manage marine protected areas, to improve marine, coastal and terrestrial ecosystems, to ecosystem-based planning, to expand the ecosystem network with ecological corridors and to establish a protected areas monitoring network.

Fethiye-Göcek Special Environmental Protection Area (PA) was declared in 1988 and has a very rich biodiversity. Many researches and studies have been carried out in the region until today.

The United Nations Aichi strategies aim to explore the underlying causes of biodiversity loss, reduce pressures on biodiversity, promote sustainable use, protect ecosystems, species and genetic diversity, and increase benefits for all from biodiversity and ecosystem services. It is desirable to develop practices through participatory planning, knowledge management and capacity building.

Emphasizing the importance of high ecological value areas based on ecosystem services in protected areas; It is aimed to make ecosystem-based planning and to create structures suitable for social and cultural texture in the planned regions.

This study investigates using high-resolution digital terrain model and 3D model in protected areas for evaluating the effectiveness of management actions. Monitoring provides information and feedback loops about the protected area for adaptive land management (Nichols and Williams 2006). Monitoring is critical to determine trends in the protected area. The investigations have been performed over Fethiye-Göcek SEPA in Mugla Province, Türkiye. The 3D city model of the area has been generated in PA which has been described in section 2. The study includes displaying the surface information with reality values and high resolution in a three-dimensional model, and performing customized spatial and statistical analyzes on the model. Land management, illegal building, determination of the changing natural areas, agricultural uses, changing village-urban uses, temporal display of changes were carried out. Effective decision support tools are provided to decision makers in land use planning. In Section 3, an overview of the study area and the datasets is provided. The study is concluded in the last Section.

2. MATERIAL AND METHOD

2.1. Spatial Datasets

Fethiye- Göcek Special Environmental Protection Area; It is located in southwestern Turkey between 36,15° and 37,00° north latitudes and 28.50 and 29.50 degrees east longitudes. Covering an area of 817 km^2, the region includes 12 settlements. The southern coast of the region is covered with steep mountains that rise out of nowhere. As a result of intense tectonic movements in the region, new bays and headlands have emerged with collapses and elevations. As a result of the collapses, the valleys opened by the rivers were filled with sea water, and the intermediate and side valleys turned into coves and gulfs that were well inserted into the land. The study area is shown in Fig 1.

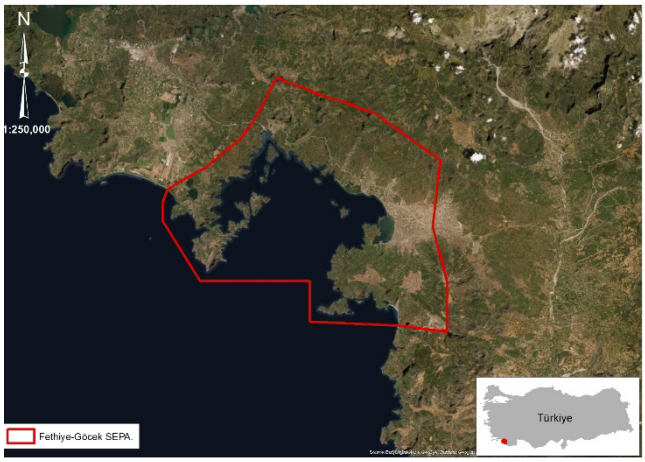


Figure 1. Study area.

Fethiye Beach is one of the breeding areas of Caretta caretta and Chelonia mydas species, which are protected by the Bern Convention and CITES (MoEUCC, 2022). Fethiye-Göcek Special Environment Protection Area is rich and interesting in floristic diversity. As a result of floristic studies conducted in the field, 408 plant species belonging to 71 families had been identified. 52 plant species are endemic to Turkey. 17 mammal species had been found in the region and there is no endemic species among the species. All species except Myotis capaccinii (long-fingered bat) are in Low Risk (LC) status according to IUCN categories of threat. Myotis capaccinii is in Vulnerable (VU) status. 126 bird species had been identified within the boundaries of the protected area. Garrulus Corasias is in the status of Near Threatened (NT) IUCN categories of threat. Other species are in Low Risk (LC) status. The area homes to 6 species of amphibians and 18 species of reptiles. Lyciasalamandra fazilae (Göcek Black Salamander) is an endemic species and its threat categories is Endangered (EN). This species is spread only in the region between Gökbel-Dalyan and

Fethiye. Testudo graeca (tortoise) is in Vulnerable (VU), Pseudepidalea variabilis (tailless frog) is in Data Deficient (DD) and the others are in Low Risk (LC) status according to IUCN categories of threat (MoEUCC, 2022).

In protected areas, it is aimed to make ecosystem-based planning based on ecosystem services and to provide sustainable protection.

Digital Aerial Photography (Flight) and Orthophoto Production, Digital Vector Data Production from Orthophotos, Fethiye-Göcek Special Environmental Protection Area, analysis and design studies for 3D modeling, Pre-planning studies, Advanced spatial analysis and calculations on the developed 3D Model The methodology was followed in the form of temporal representation of the studies created within the scope of SEPA, taking into account the historical data. The formats, sources, and the accuracies of datasets evaluated in the study are given in Table 1.

The city model, DTM, tools and methods have been developed by the Ministry of Environment, Urbanization and Climate Change (2020). Building models were produced using aerial photogrammetric mission data from the entire region in 2020 (Figure 2). In total, 67 flight corridors were created in 4 different blocks, and a total of 7752 aerial photographs were taken. In the images obtained within the scope of the project, 77% side overlap and 59% side overlap rates were achieved after the overhead balancing works.

By using photogrammetric methods, Point Cloud at 26 Point/m2 density, 8cm resolution Digital Surface and Terrain Model (DSM and DTM), 8cm Resolution True-Orthophoto Generation data were used. The Digital Terrain Model was produced at 8cm resolution. All structures were automatically obtained from 3D vector data and dense point cloud. Buildings are automatically mapped (Buyukdemircioglu et al 2018).

Table 1. Formats, sources, and accuracies of the datasets evaluated in the study.

Data Type/Name	Data Source (Produced by)	Format (Vector/Raster)	Accuracy
Buildings	MoEUCC	Vector	0.10 m
Greenhouses	MoEUCC	Vector	0.10 m
Water Quality Points	MoEUCC	Vector	0.20 m
Sea Turtle Nesting Data	MoEUCC	Vector	0.20 m
Master Plan Data	MoEUCC	Vector	0.20 m
Orthophoto (2020)	MoEUCC	Raster	0.08 m
Quickbird-1 (2005)	MoEUCC	Raster	6.5 m
CORINE Data (2018)	MoEUCC	Vector	5 m

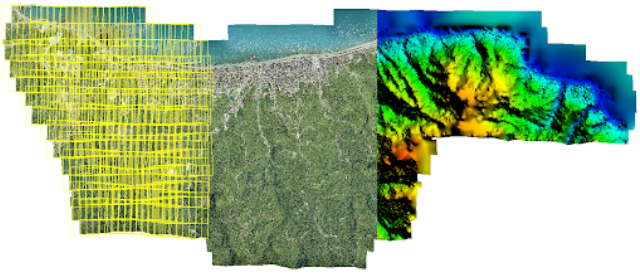


Figure 2. Photogrammetric Data Processing Steps.

For the study, QuickBird-1 satellite images from 2005 available in the Ministry of Environment and Urbanization were also used. Resolution in raw data of 60cm, resampling was done at 50 cm.

It is considered the most agile satellite among satellites. In addition to its high capacity feature, 60cm. It can provide local resolution panchromatic (black/white) images. QuickBird-1 has the ability to view an area of 200,000 km2 per day (60 cm. resolution) thanks to its ability to complete its tour in an average of 95 minutes. The satellite also has medium geometric accuracy, as well as fast shooting and stereo shooting features (Dial et al, 2003).

European Union countries determine their land assets, land use patterns and land cover types in the context of a project called CORINE (Coordination of Information on Environment) Environmental Information Coordination. The CORINE (Coordination of Information on the Environment) land cover program was initiated by the European Union Commission (CEC). The CORINE program was run by the European Commission. As of 1991, CORINE databases were created in 13 countries (Aydınoğlu and Yomralıoğlu 2009).

All data were converted and stored in the ESRI file geodatabase database in accordance with the TM30 WGS84 coordinate system. Raster data is stored in geotiff or ecw format. These databases have been converted to sqlite and geoJSON formats so that they can be transferred to the relevant 3D model. Non-spatial tabular data is also maintained in the ESRI file geodatabase.

2.2. Spatial Analysis Methods

Vector data of 2005 were produced from satellite imagery with 50 cm resolution and 6,5 m positional accuracy. Therefore, the spatial comparisons and vectorization results of 2005 were accepted as approximate and all spatial analyzes were carried out accordingly.

In the spatial analyzes made according to the satellite images of 2005, it has been determined that there are approximately 40315 buildings in the PA. The area covered by these structures is 529 ha. The density in Fethiye, Göcek and Ölüdeniz settlements, which are the most developed regions within the scope of the study area, is as shown in figure 4.

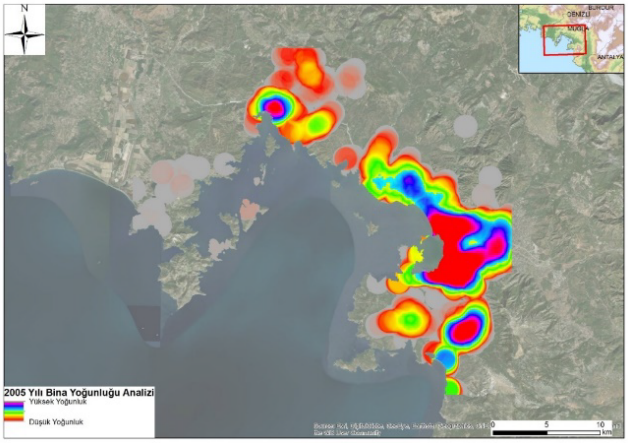


Figure 3. Building Density in 2005

Within the scope of the study area, the number and size of greenhouse areas in 2005 were analyzed and their distribution. In 2005, there were approximately 5036 greenhouses and these areas cover a total area of 534 ha. Greenhouses are concentrated in the Fethiye region, and the greenhouse density continues to decrease towards Göcek. Cultivated areas cover a total area of 534 ha in 2005.

When realizing the digitization works performed on orthophotos obtained with 8 cm resolution aerial photographs in the region, it has been concluded that there are approximately 48332 buildings and they cover an area of 693 ha. The density of building in Göcek and Ölüdeniz regions, especially in Fethiye, is higher than in other regions. Results show a local progression of the built-up areas of 20% in 15 years in PA.

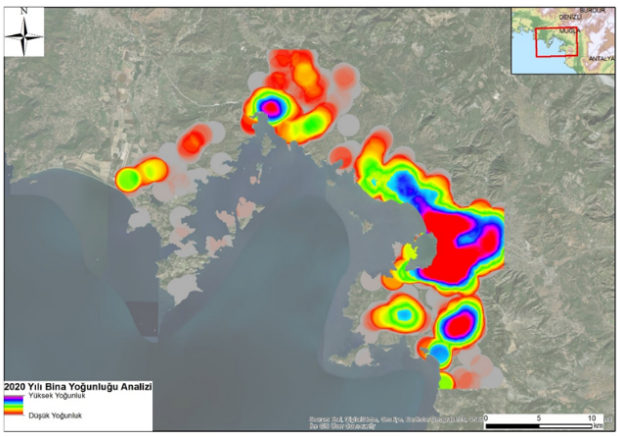


Figure 4. Buildings Density in 2020

The density map of building areas for 2020 is shown in figure 4. In 2020, the building density in Fethiye, Ölüdeniz and Göcek attracts attention. As a result of the analyzes on orthophotos for 2020, approximately 4591 greenhouses were identified, and the size of these areas is approximately 505 ha. Cultivated areas cover a total area of 872 ha in 2020. Fethiye-Göcek SEPA environmental master plan (approved in 2008) was taken from MoEUCC in vector data transformed to the database to be used in the three-dimensional model(figure.5).

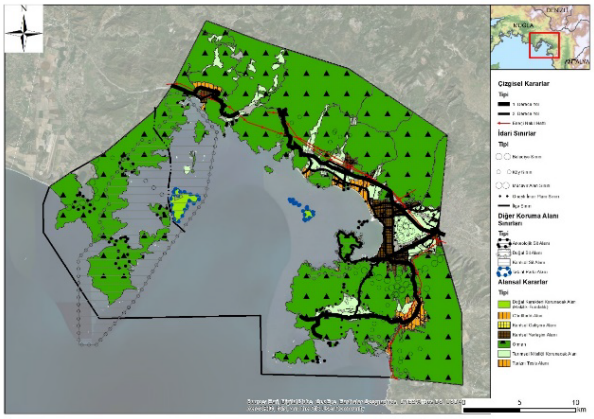


Figure 5. Environmental Master Plan of Fethiye-Göcek SEPA

In order to monitor physical, chemical and biological parameters in important rivers, lakes, drainage channels and sea areas in Special Environmental Protection Areas, to control pollution factors in order to prevent pollution and destruction of natural resources, to take necessary measures and to make use decisions, water quality is regularly monitoring studies are carried out. The efficiency of wastewater treatment plants operating in special environmental protection zones is also monitored within this scope.

For this purpose, physical, chemical and biological parameters are taken as monthly and periodic samples and analyzed at certain analysis points in important rivers, lakes and drainage channels, sea areas and wastewater treatment plants. Monthly data were combined annually and categorized as stream, sea, lake and treatment. They are stored in database for spatial analysis (Figure.6).

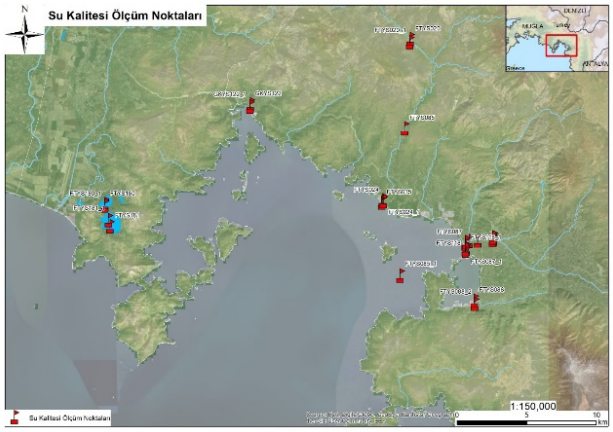


Figure 6. Water quality points in Fethiye-Göcek SEPA

The data received from MoEUCC regarding sea turtles are for the years 2017, 2018 and 2019. These data, taken in table format, were first adapted to the database for analysis, and then point data was created in the geographic information systems environment (Figure.7). The database design was made by organizing the layers of archived tabular data in line with the international and national legislation.

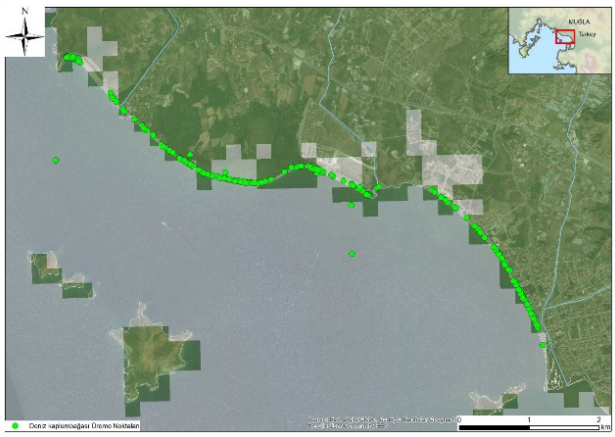


Figure 7. Sea Turtle Nesting points in Fethiye-Göcek SEPA.

Conservation plans are approved in order to protect the natural, cultural, social and economic values of the protected areas totally. Spatial analysis methods have been used for land management, illegal building, determination of land use changes, agricultural uses, changing village-urban uses, temporal representation of changes. Making decisions based on location on the data stored in the geographic information system is possible by querying, viewing and analyzing the geographic data. In the spatial analysis processes, new information sets are produced by making use of the existing data. In the study, overlay, proximity, density analysis, surface analysis and other spatial analysis were performed by means of ArcGIS software. CityGenius software was used to visualize the datasets produced within the scope of this study. This program also have visualization, and advanced spatial analysis tools like that building filters, terrain filter, field of view, shadow tool, viewshed tool etc. We use these tools to evaluate human use demands on the model and decide on land management. The building filter is a very effective tool to determine illegal building, especially for visualizing and mapping with terrain model in the PA.

(a) (b)

Figure 8. (a) and (b) are spatial analysis using CityGenius software on 3D model.

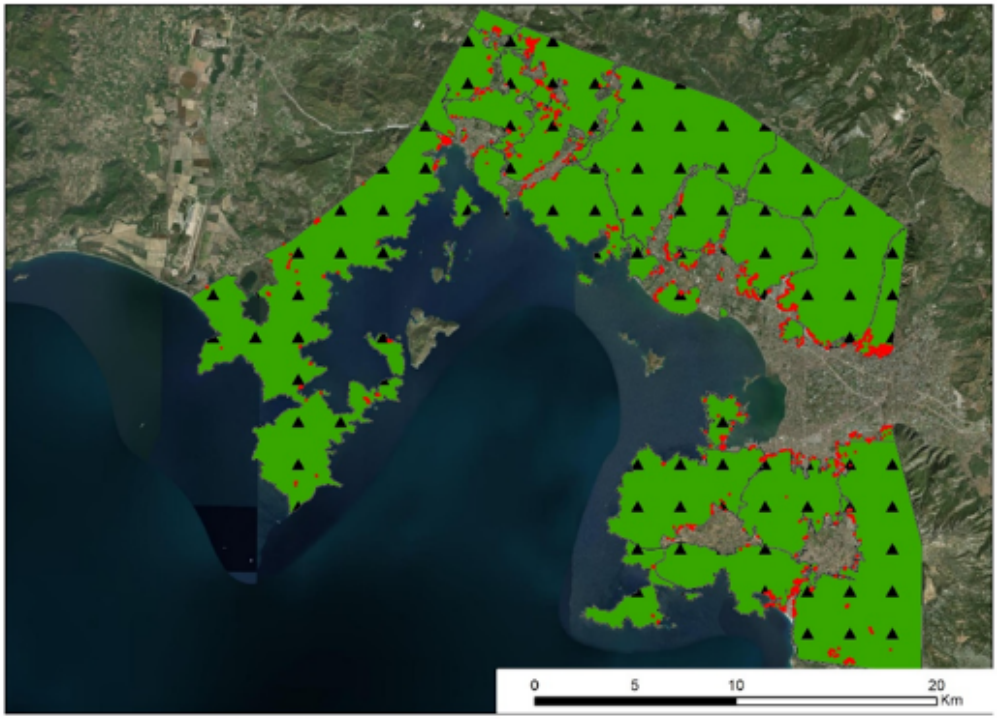


Figure 9. Illegal Buildings-Settlement pressure in forest areas

The 1/25000 scale environmental master plan, which was approved in 2008, and the vector data produced from orthophotos of 2020, were compared to develop land use plan.

3% of the buildings in the study area are in the forest area. This settlement pressure in the forest area has spread to the whole PA. 60% of the buildings are located in the Urban Settlement Area in accordance with the environmental master plan. 15% of the greenhouse areas remain within the settlement area. Most of the greenhouses in the settlement area are located in Fethiye.

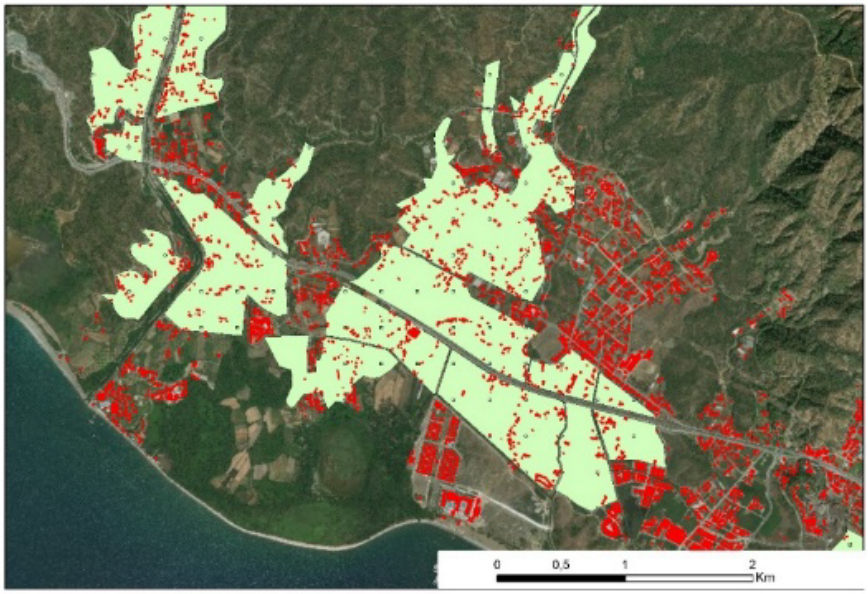


Figure 10. Illegal Building-settlement pressure in agriculture areas.

2.3. Visualization of Land use changes between 2005-2020

Land use criteria include property rights, which is a main problem sustainable conservation. Determination of land use criteria with conservation planning is an effective tool to ensure the balance between protection and use in protected areas. The creation of land use planning bases with the required accuracy facilitates collaboration with all stakeholders. 3D maps can serve as a foundation for conservation planning and monitoring. 3D modeling and visualization has become an important component, especially for the effective land management. Topographic data and terrain visualization are essential for land management.

A model was created for the three-dimensional representation and analysis of Fethiye-Göcek Special Environmental Protection Area in order to develop the potential of using high-resolution data sets, digital terrain model and three-dimensional model needed in the research, planning, monitoring and management stages of protected areas.

It includes displaying the surface information of Fethiye-Göcek Special Environmental Protection Area in three-dimensional environment with reality values and high resolution and performing customized analyzes on the data.

For land management, visulation and mapping the land use in detail, the reflections of the changing village/urban and urban/village relationship on land use, examining the land use changes, periodic analysis of the trends (agricultural structuring-coastal structuring) for effective planning is very important.

Detection of illegal buildings in the protected area, determination of forest, agricultural areas and village settlements and settlement areas and processing of building details facilitate planning. For sustainable biodiversity and sustainable agriculture, it is necessary to determine the land use values and monitore the changes.

In the study area, by providing a temporal display of the changes from the past to the present, it will be ensured that the approaches related to land use planning and the principles of area protection and monitoring will be revealed.

Land use changes in residential areas between 2005 and 2020 were analyzed. The results of these analyses, the structures in the protected area increased by 20% over a 15-years period. In particular, the buildings in Kayaköy have increased more than in other regions in the last 15 years. The land use change in settlement centers and coastlines draws attention. The structures (fishing huts, etc.) on the islands in the bay affect the analysis results.

By land use change analysis in greenhouse areas, greenhouse areas decreased by 5% between 2005 and 2020. Most of the greenhouse areas have turned into residental area in the last 15 years. There may be many different reasons for the reduction in greenhouse areas between 2005 and 2020. The areas that were greenhouse areas in 2005, which have now turned into residental, were investigated. According to this analysis, 7% of the existing buildings in 2020 had greenhouses in 2005. Most of these greenhouse areas, which have been converted into building, are designated as "Agricultural Area" according to the 1/25000 Environmental Master Plan.

Density maps of greenhouse areas varying between 2005 and 2020 were produced. The most change occurred in the east of Fethiye centre.

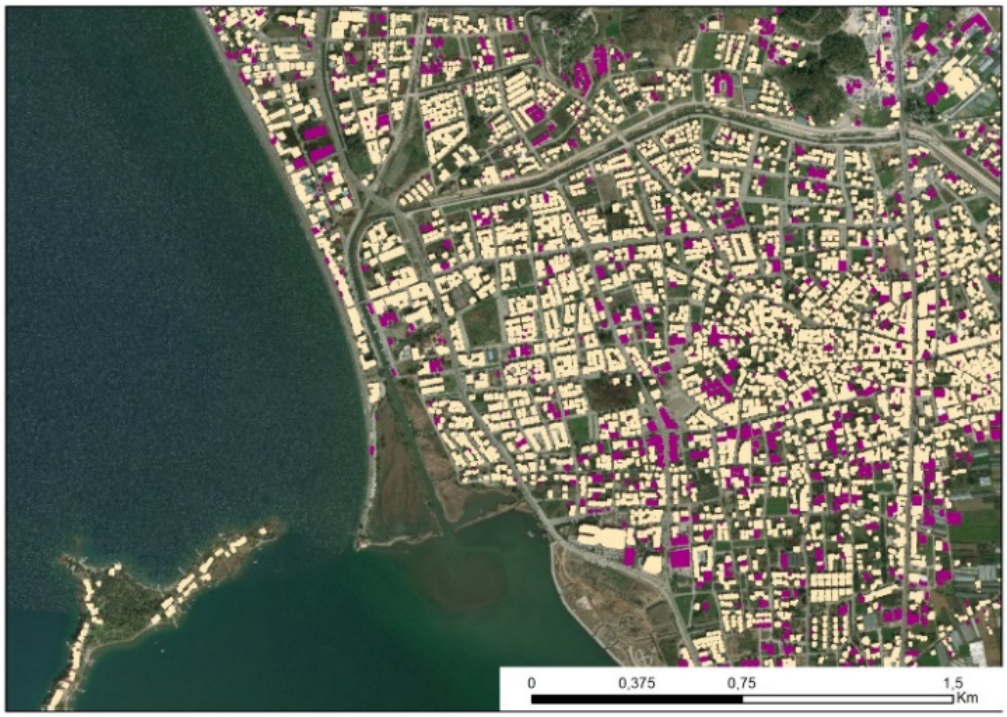


Figure 11. Between 2005 and 2020, buildings area in the PA increased by 20%.

Figure 12. Between 2005 and 2020, coastal area changes in the PA.

Land use status determination using remote sensing techniques is a low-error and calculable method. However, there are many remote sensing data analysis and evaluation methods that have been introduced independently of each other. For this reason, common standards have been tried to be brought to the classification criteria used in remote sensing studies within the framework of the CORINE program (Yılmaz and Erdem 2011).

European Union countries determine their land assets, land use patterns and land cover types in the context of a project called CORINE (Coordination of Information on Environment) Environmental Information Coordination. The CORINE (Coordination of Information on the Environment) land cover program was initiated by the European Union Commission (CEC). Studies on the CORINE project, which was initiated by the European Commission in 1985 and then carried out under the responsibility of the European Environment Agency, started in 1998 in Turkey. The CORINE program was run by the European Commission. As of 1991, CORINE databases were created in 13 countries (Aydınoğlu and Yomralıoğlu 2009).

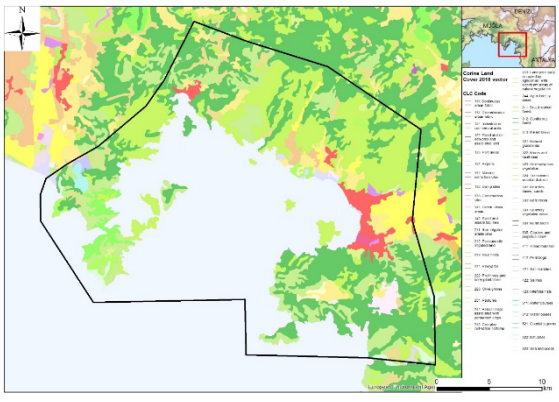


Figure 13. CORINE-2018 map for Fethiye-Göcek PA.

CORINE-2018 land use and orthophoto-2020 structures, agriculture and tourism land use patterns were analyzed together. Land use patterns were found to be similar.

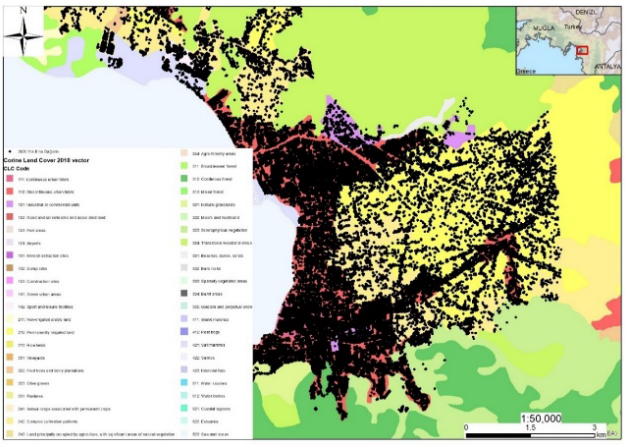


Figure 14. CORINE-2018 and Buildings-2020.

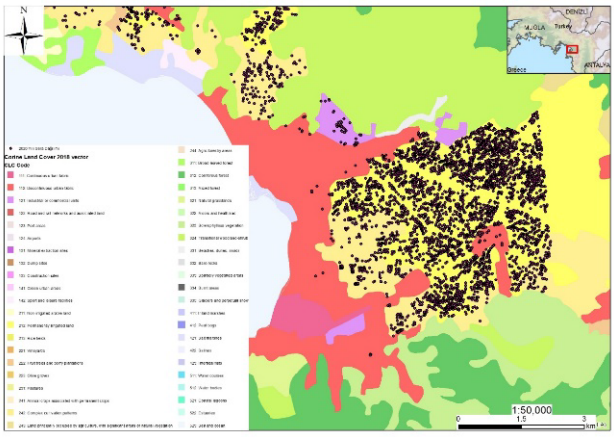


Figure 15. CORINE-2018 and Greenhouses-2020.

3. DISCUSSION AND RESULTS

The study includes displaying the surface information with reality values and high resolution in a three-dimensional model, and performing customized spatial and statistical analyzes on the model. It is aimed to demonstrate the potential advantages of using high resolution digital terrain model and 3D model in protected areas. Land management decicions, illegal building, determination of the changing natural areas, agricultural uses, changing village-urban uses, temporal display of changes were carried out.

There are five land use classes defined by the 1/25000 scale Environmental Master Plan of Fethiye Göcek Special Environmental Protection Area (Table.3). 84.25% of the study area is forest area. The area it covers within the total protected area is approximately 38333 ha. The protected area boundary is 45500 ha excluding the sea surface. 7.56% of the study area is agricultural area, 4.98% is urban settlement area, 2.21% is tourism facility area.0,99% of study area is natural area which is strictly protected area.

Table 3. Land use class of Fethiye-Gocek SEPA Environmental Master Plan (2005-2020).

Land use	Area (ha)
Natural Area	452
Settlement Area	2266
Forest	38333
Agricultural Area	3442
Tourism Area	1007

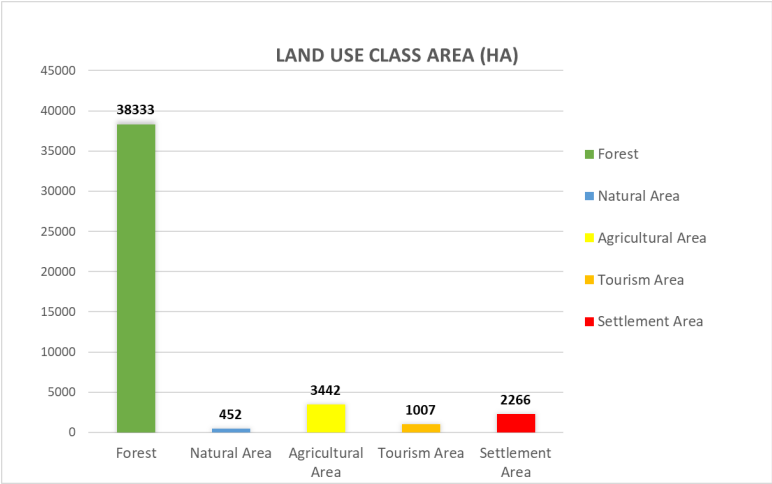


Figure 16. Land use class areas in Fethiye-Göcek PA.

Table 4. Land use class of Fethiye-Gocek SEPA with buildings number and percentage.

Land use	Area (ha)	Number of buildings (2020)	Building Density (number per hectare)
Natural Area	452	4832	10.69
Settlement Area	2266	29000	12.80
Forest	38333	1450	0.04
Agricultural Area	3442	5800	1.69
Tourism Area	1007	7250	7.20

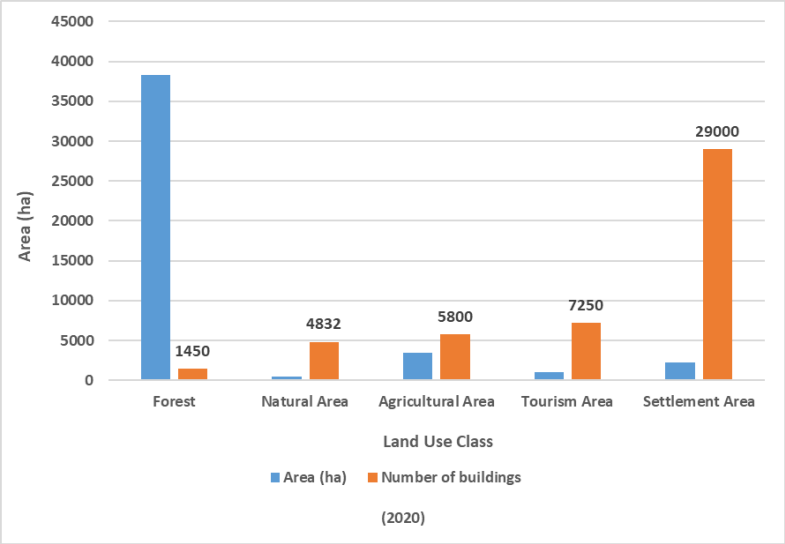


Figure 17. Number of Buildings for each Land Use Class in Fethiye-Göcek PA.

Number of buildings have determined from the orthophotos of 2020.Then number of buildings in each land use class have determined and calculated the number per hectare for all class, realized building density analysis and land use change analysis (Theobold, 2005).

We mapped land use changes using heat map analysing tool of ArcGIS software. A heat map uses the features in the layer to calculate and display the relative density of points on the map as smoothly varying sets of colors ranging from cool (low density of points) to hot (many points) – hence the name heat map(www.esri.com). So heatmap is the most usefull thematic map for small scale planning stages.

Land use change density map has shown in figure 18. When the planning studies to conservation of natural areas in Fethiye-Göcek PA, this thematic map which shown high and low land use changes provides to comprehend settlement pressure and hot spots in PA.

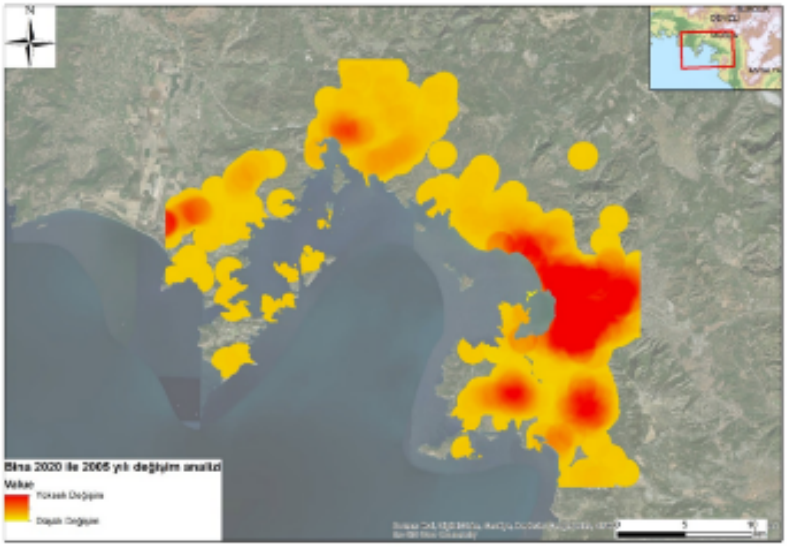
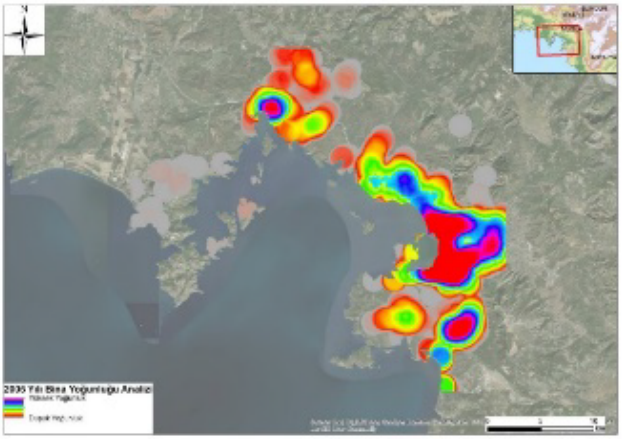
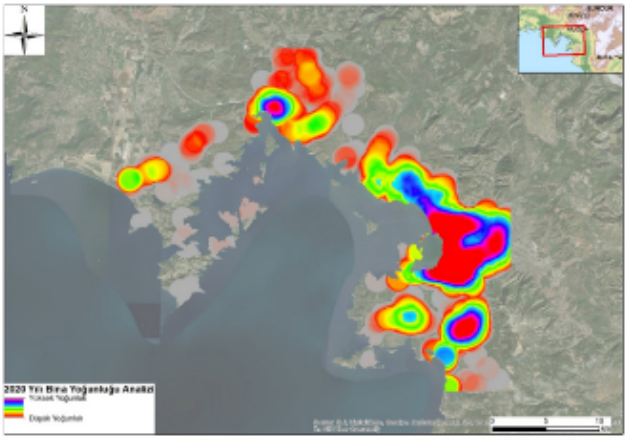
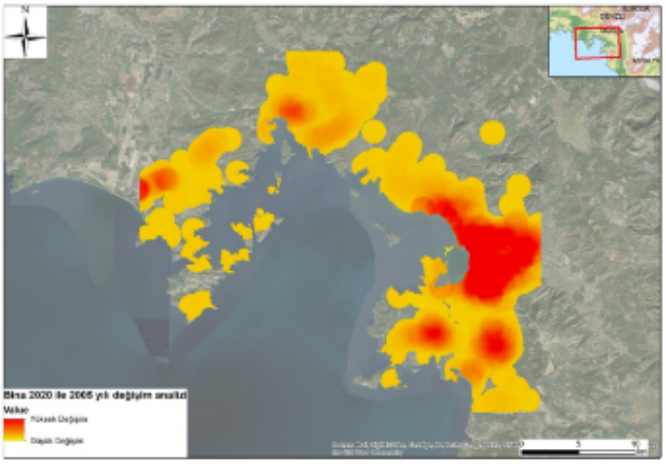


Figure 18. Land use changes density in Fethiye-Göcek PA.

A 3D model is created for the three-dimensional representation and analysis of Fethiye-Göcek Special Environmental Protected Area, to investigate the potential of using high-resolution data sets, digital terrain model and three-dimensional model for planning, monitoring and land management.

The 3D model enabled the surface information of Fethiye-Göcek Special Environmental Protected Area to be displayed in three-dimensional environment with reality values and high resolution, and customized spatial analyzes were made on the data.

Table 5. Land use changes and building density (2005-2020).

	2005	2020
Buildings		
Greenhouses		
Density		
Land Use Changes		

4. CONCLUSION

Spatial use criteria include property rights, which is a fundamental right. Determination of spatial use criteria with conservation planning is an effective tool to ensure the balance between protection and use in protected areas. With the developing geographic information technologies, land use planning bases can be determined accurately. Thus, the cooperation of all stakeholders in the field management is provided more easily. The use of remote sensing and three-dimensional models in land management and planning has become increasingly widespread. 3D maps can serve as a foundation for conservation planning and monitoring. 3D modeling and visualization has become an essential component for effective land management. Topographic data and terrain visualization play important roles in protected area land use planning. In addition to the data content and visualization of the 3D model, the query and analysis functionality is also very important for planning and monitoring.

For nature conservation and protected area monitoring to collect all spatial and non-spatial data regularly is important to create effective spatial analysis. There are many applications and tools that can be used for error-free collection and storage of data from the first source. With the online application, it is possible to evaluate, import, analyze and report large-scale environmental data. Applications should be used to verify monitoring data at the time of collection.

As a result of the land use change analysis, it is noteworthy that the areas where the settlement pressure is determined, they are agricultural areas, forest areas and natural areas. On the other hand, according to the environmental plan, it is seen that there is a propensity to do agriculture in the places specified as settlement areas. To comphere buildings characteristic (hotel, residence, site, etc.) in the tourism areas, field works should be realized.

The 3D model which was developed in this study also is provided as the main base for conservation of coastal and marine ecosystems, coastal planning and coastal management studies in protected areas. Thanks to the 3D model and spatial analyzes, the water quality and the submarine biodiversity monitoring studies also is supported. It also supports the efforts to protect the seagrass meadows, which are the carbon sink areas and defined as the forests of the seas.

Land use changes density map provides to desicion makers an effective tools for land management in the Fethiye-Göcek protected area. The study showed that the 3D terrain model is an important decision support tool in land management and will support nature conservation efforts. Biodiversity changes about protected area vulnerability should also be investigate by geograhic information technologies.

ACKNOWLEDGEMENT

The authors thank to the Ministry of Environment, Urbanization and Climate Change, General Directorate for Protection of Natural Assets for provision the data for protected areas.

Author contributions

The authors declare that they have contributed equally to the article.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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