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RESEARCH ARTICLE

The change detection in coastal settlements using image processing techniques: a case study of Korfez

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Abstract
Coastal areas all over the world are usually exposed to intensive change and transformation processes resulting in a variety of natural, physical, and socio-economic problems. Körfez province, located along the İzmit Bay of Marmara Sea, Turkey, has been one of these coastal areas that has become a major point for industrial facilities and highly populated urbanized area since 1960s. Therefore, the analysis of the spatial changes in the land use patterns of the province has a critical role in the success of the physical planning processes and the protection of the coastal areas. In order to highlight this critical role, temporal change detection analysis for Körfez province covering a 6-year period and 5 land use classes was made using 2009 and 2015 SPOT imagery and thematic maps. Reclassified CORINE data, development plans, and land survey results were benefited for the supervised classification of the images. Four hundred eighty control points for each year were used to achieve a strong accuracy tested by Kappa coefficient. The spatio-temporal change detection results revealed a 22.5% and 2.3% decrease in agricultural lands and sea areas respectively, while there was an increase of 16.6% in forest-green areas, 6.4% in settlement areas, and 74.1% in lake areas. The results are believed to be significant input data to facilitate coastal and physical development planning over the area, and thus make sustainable land use decisions to protect the delicate landscape and coastal characteristics, while providing a sound risk management plan.

Keywords Geographic information systems · Remote sensing · Coastal change detection

Introduction

Besides providing significant ecosystem services, natural resources, agricultural capabilities, and energy generation opportunities (You et al. 2018; Zhang et al. 2020a, 2020b), coastal lands have been centers for a wide range of activities such as transportation, tourism, recreation, commerce, and industry and thus, significantly contributed to the economic and social development of the countries throughout history (Duan et al. 2016). However, this development has also resulted in continuous coastal population increase in the world (Zhang et al. 2020b), as well as the pressure on the coastal ecosystems (Tian et al. 2018) and exploitation and destruction of the natural and cultural landscape characteristics (Kim et al. 2017; Kotsoni et al. 2017). The countries that have either experienced or already foreseen the distressing consequences of this uncontrolled development have adopted sustainable coastal development policies and planning approaches (Garipağaoğlu and Uzun 2014).

Population densities are also considerably high in the coastal settlements in Turkey. This is because the coastal regions have diverse and rich resources to support agricultural and tourism activities. Moreover, the coastal regions in the country, which is surrounded by three seas, are intensely preferred for commercial and industrial activities, as export-import operations are mainly performed via maritime traffic. The

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utilization of coasts by a variety of sectors by all means contributes to the employment and economic development. Nevertheless, it is also the main reason for the rapid and usually disturbing changes in the natural, cultural, and physical patterns in the coastal regions. These changes do not have impacts only in the local and provincial scale but some reflections of these impacts are observed in the countrywide. Consequently, it is of great significance to determine and adopt a holistic approach to provide sustainable coastal development and planning, through which the natural and cultural characteristics along the coastal regions are protected, the environmental degradation is mitigated, and the changes are monitored and inspected (Bayraktutan and Özbilgin 2013).

Regarding the coastal land planning process in Turkey, traditional methods are very common in a good number of planning departments which results in the lack of major insights and practices to provide a sustainable planning framework for the coastal lands and their influence areas. Therefore, the adoption of advanced technologies such as remote sensing (RS) and geographical information systems (GIS), which have long been accepted as the major tools for planning activities worldwide, is of critical importance for the country. No doubt that RS and GIS provide fast, precise, and accurate data gathering, storage, management, analysis, and visualization functions for a wide range of disciplines (Malczewski 1999; Worboys and Duckham 2004; Cabuk et al. 2016). RS and GIS capabilities facilitate the planning and decision making processes (Ayhan et al. 2003). Especially in the coastal regions, it is crucial to determine the existing land use types, the temporal changes in land uses, and the impacts of these changes in various scales, which are essential inputs for the future planning activities.

In the literature, there are a good number of studies focusing on the utilization of RS and GIS capabilities for both change detection and coastal planning processes. Kızılelma et al. (2013) explained that RS is a major tool used for the detection of the temporal changes in the land use patterns and therefore RS and GIS technologies has been also used widely for a number of missions such as coastal land use and shoreline change detection. Dewidar (2003) aimed to determine the land use and land cover changes in the Nile Delta, Egypt, between 1984 and 1997 and predict the future coastal changes along the Nile River. Muttitanon and Tripathi (2004) conducted a study at the coastal area of Ban Don Bay, Thailand, to determine the changes in the shrimp farms, forests, urban sites, agricultural areas, and wetlands in 1990, 1993, 1996, and 1999. Kaliraj et al. (2017) used Landsat ETM+ and TM images to determine the land use and land cover changes between 2000 and 2011, in the South West coast of Kanyakumari, India, and found that urban expansion activities caused increase in the built-up environment. Nikolakopoulos et al. (2017) conducted an unmanned aerial vehicle (UAV) photogrammetry based study to acquire 5-cm resolution spatial data over the Rio coastline of western Greece and produced highly accurate maps of the area. The authors emphasized the importance of UAVs to perform accurate, fast, and more affordable surveys and coastal monitoring processes. Etemadi et al. (2018) analyzed the land type patterns over 14 years via multispectral Landsat images between 2000 and 2014 and applied a CA-Markov model to estimate the future loss in the coastal mangrove forests in southern Iran. In the study of Abdollahi and Dadashpoor (2019), the authors benefited from Landsat 5 and 8 (TM) images for the detection of the land cover changes in Gilan province, Iran, between 1996 and 2016, and applied Markov chain method for the prediction of the land use pattern in the study area in 2046. The results showed a dramatic increase in the amount of the residential areas, of which mostly transformed from agricultural lands. Zhang et al. (2020a) also used Landsat 5 (TM), 7, and 8 images both to extract the topographic maps and land use types for 1987, 2000, 2005, and 2017 in the coastal zone of Hebei province, China. The land use types were classified into 10 main and 28 secondary classes in accordance with the Current Land Use Classification system. Then, the authors determined the relation between the land use changes and the habitat quality using Habitat Quality Index. Kurniawan and Marfai (2020) highlighted the significance of the shoreline length of Indonesia and underlined the continuous human and nature induced changes in the coastal landscapes in the country. Accordingly, the authors performed a RS-based quantitative and statistical change detection research in Kendal Regency using Landsat 5 and 8 images for the periods of 1990–1999, 1999–2009, 2009–2017, and 1990–2017. Various results were revealed regarding the change in the shoreline resulting from either erosion or accretion.

Weismiller et al. used four techniques to determine the changes in the zonal environments in Matatgorda Bay area of Texas by using Landsat MSS data. These techniques are post classification comparison, delta data change detection, spectral temporal change classification, and layered spectral temporal change classification. Weismiller et al. Also reported that the post classification comparison technique reliably identified areas of change and was used as the standard for qualitatively evaluating the other three techniques (Weismiller et al. 1977a, 1977b).

El-Hattab 2016 conducted a study in Abu Qir Bay and applied post classification method to detect the changes in the Egyptian coastal zone. Recent studies in the world have shown that monitoring, assessment and detection of coastal changes during different works such as geographical surveys and observation of different data (Lu et al., 2004; Chen et al. 2012) were conducted with different techniques such as post classsification approach (Raja et al. 2013; El-Hattab2016), and the pixel pixel approach with multi spectral imagines (Nemmour and Chibani 2004; Hussain et al. 2013; El-Hattab2016).

El-Askary et al. (2014) conducted the research of change detection of coral reef habitat with applying for using Landsat-

5 TM, Landsat 7 ETM+, and Landsat 8 OLI data in the Red Sea, Hurghada, Egypt. Büttner (2014) used CORINE data for land use and land cover change maps in Europe. El-Hattab (2015a, 2015b) conducted of the decisions and improvement of the coastal change approach.

Within this context, the authors aimed to determine the coastal land use change in the Körfez district of Kocaeli province, located along the Marmara Sea in the northwest of Turkey, which is a major destination for many industrial activities and a highly risky settlement area in terms of earthquakes. To fulfill this aim, image differencing based change detection method, one of the most commonly used and simple methods in RS studies to perform quantitative analysis of the temporal changes in the land use/land cover types between 2009 and 2015. This method is preferred since it also facilitates the interpretation of the results (Lu et al. 2004). The land use classes (sea, lake, forest-green area, agricultural land, settlement area) were identified via supervised classification technique based on maximum likelihood method. Kappa coefficient method was applied for the accuracy testing process. In the light of the change detection analysis results, the changes in the land use types in the study area were evaluated, the decisions in existing physical plans were discussed, and the importance of change detection monitoring and auditing activities were highlighted.

Coastal planning and management in Turkey

Today, the negative impacts resulting from the rapid population increase in the coastal areas threaten most of the natural and cultural resources. Therefore, adopting sustainable national coastal planning and management policies for both rural and urban lands is significant for the protection of the resources and mitigation of the negative effects of rapid coastal urbanization. In the populated countries, mandatory regulations are put into force to sustainably manage and use the resources. In most of the Western Europe countries, regional planning frameworks, through which land uses are democratically determined, have been developed. In the USA, the coastal ecosystems were being degraded as a result of rapid increase in population. Consequently, the USA Coastal Zone Management Act was created in 1972, which is considered quite similar to the applications in Europe, but is only limited to the coastal areas (Garten 2016).

In Turkey, a good number of regulative and legislative works have been conducted for the coastal planning and management processes. The primary focus in the regulations is to prioritize the public benefit in the utilization of the coastlines via proving equal and free access for all individuals. Therefore, the proprietorship of the coasts legally belongs to the public, and the only authorized regulative and monitoring body of the coastal planning and management works in accordance with the 3621 numbered Coastal Law is the Ministry of Environment and Urbanization. Besides, according to the definitions and principles put forward by the Physical Plans Making Regulation, integrated coastal area planning (ICAP) requires a holistic and comprehensive evaluation of all the sectorial activities and plans within the coastal interaction site, so as to provide harmony between the coastal functions/activities and the targets of the coastal planning. ICAP is also aimed at the determination of the physical targets, strategies, and action proposals to ensure use and protection balance.

The sustainability of coastal area planning requires the implementation of an effective management. In Turkey, the works on coastal management started along with the discussions about the negative impacts of the coastal industrial zones on the sea and the land in the 1980s. Statutory Decree numbered 644 was the first legal regulation referring to the ICAP concept. ICAP aims to develop an institutional organization for the authorities, sector, and the society with different field of interest but acting with common targets to achieve the sustainable ecologic development through the consideration of different demands on coastal resources in a particular geographic context. Legally, General Directorate of Spatial Planning, Ministry of Environment and Urbanization, is assigned with the responsibility to conduct the works related to integrate coastal area management and planning, coastal area design, geological and geotechnical surveys, determination and approval of shore edge line, etc. (DGSP 2020). Current coastal planning process of the General Directorate unfortunately does not define a standardized approach for obtaining, processing and analyzing the spatial data. This uncertainty influences the whole process from plan development to the plan approval stages resulting in various problems in terms of integrity and auditing. Moreover, analysis of the current situation is mostly poor in accuracy and up-to-datedness. Although the process should be aimed at guiding the planning process for providing an integrated coastal area management, the lack of a standardized planning system causes duplications of various works and poor connection between the planning and management system.

The comprehensive examinations of former plan decisions and their impacts are significant to develop more sense and appropriate future decisions. In this case, one of the necessary input is the changes occurring over the planning context in time so that impacts of the former decisions are better understood and tendencies, pressures, and demands on the utilization of coastal zones are evaluated and benefited to produce sustainable and an integrated plan for the future. From this point, the tempo spatial changes in Körfez district were detected using RS and GIS capabilities both to highlight the significance of the spatial changes for coastal planning processes and evaluate the changes in the study area.

Research area

Körfez district is one of the 12 districts of Kocaeli province located in Marmara region in Turkey, surrounded by Dilovası on the west, İstanbul on the north, Derince on the east, and İzmit Bay of the south (Fig. 1). The district is located between 40 ° 46 ′ 36 ″ north and 29 ° 43 ′ 46 ″ east coordinates. Due to its location, the district has been a major center for industrial facilities and activities after the 1960s resulting in increase in population and change in land use patterns. Table 1 summarizes the change in population in the study area according to Turkish Statistical Institute (TUIK) records (TUIK 2017).

According to Körfez Chamber of Commerce Economic Data Report (2016), 90% of the current population is the immigrants, who have moved to the district to work in the industrial zones. The capacity and the density of the industrial

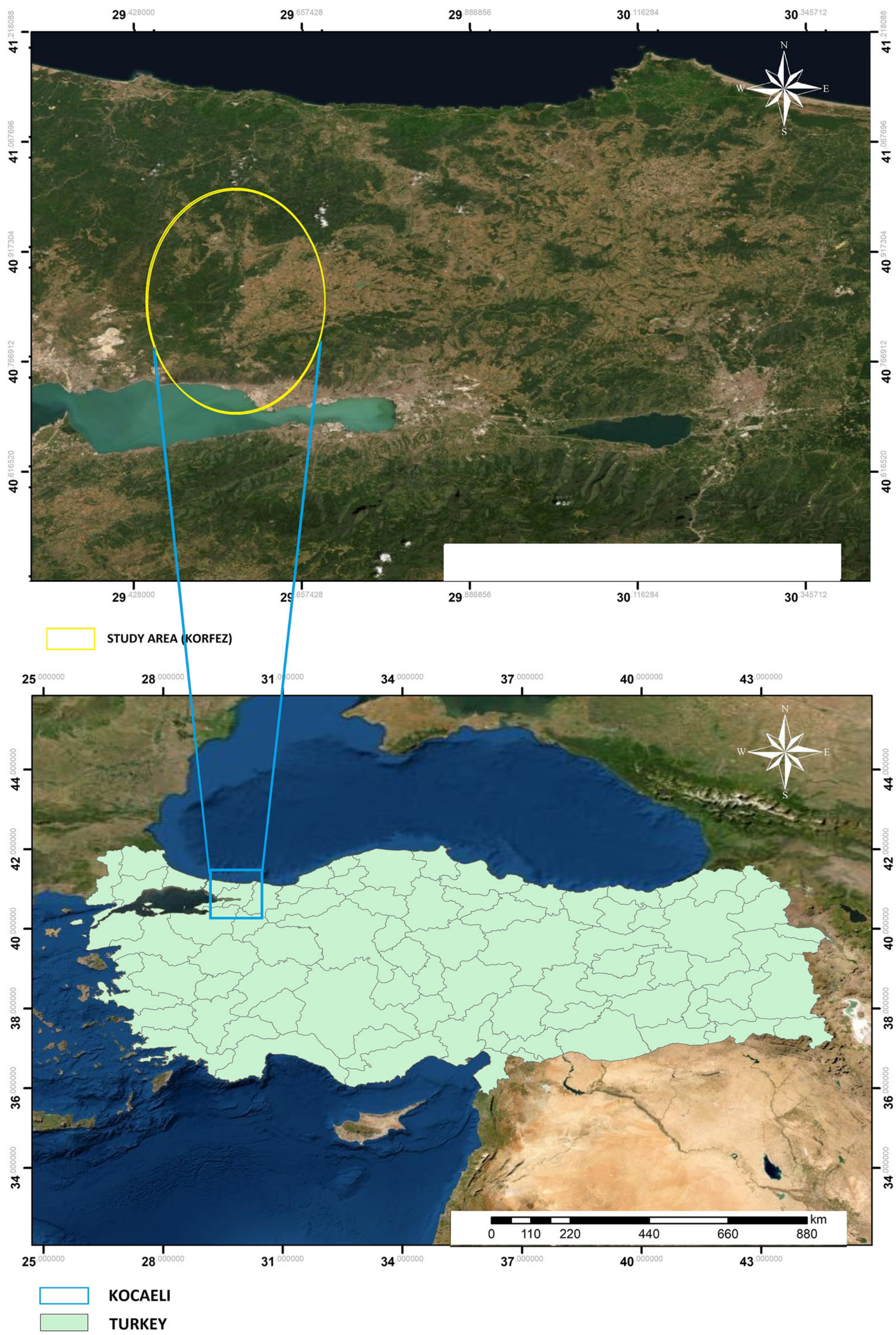


Fig. 1 Location of Körfez district

Table 1 Population change in Körfez district (TUIK 2017)

Year	Population (person)	Increase by year (person)
2009	126616	1604
2010	128750	2134
2011	131764	3014
2012	135379	3615
2013	142884	7505
2014	146210	3326
2015	151149	4939
2016	157282	6133
2017	126616	1604

facilities in Körfez has been the major motive for coining the district as a "region of industry." The rapid developments in the industrial zones however influenced the rural structure in Körfez and the district has become highly urbanized over the years. Rapid urbanization no doubt required the adoption and implementation of a spatial planning process. According to the oral information provided from both Körfez Manucipility Project Department and Strategy Directorate in 2018, the first development plans within the study area were 1/1000-scale development plan implementations produced for Yarımca town and Tütünçiftlik region respectively in 1971 and 1973. In 1975, 1/5000-scale general development plan of Körfez district was approved. After 1980, when Körfez was legally registered as a district of Kocaeli province, the boundaries of the district were expanded via additional development plans and the population and urbanization rate has continued increasing even more. Today, there are 1/25000-scale environmental arrangement plan, 1/5000-scale general development plan, and 1/1000-scale development plan implementation for the district. Moreover, Kocaeli-Yalova Integrated Coastal Area Plan, including the strategies and targets for Kocaeli province, was put into force.

Materials

The main materials of the study are the raster images used for change detection and ortorectification processes, and vector data utilized for image classification phases during the study.

The raster data are the SPOT and Landsat images. SPOT images of the study area, Körfez district, were provided from İstanbul Technical University, Application and Research Centre for Satellite Communication and Remote Sensing (UHUZAM). Landsat images were downloaded from USGS web site (landsat.usgs.gov). Ten centimeter/pixel orthophotos and 50 cm/pixel GeoEye and Worldview ortorectified archive images of Ministry of Environment and Urbanization, General Directorate of Geographical Information systems, were used for performing the orthorectification process of the satellite images.

SPOT 5 and SPOT 7 images (https://earth.esa.int/eogateway/missions/spot), respectively with 1.5 and 2.5 cm/pixels resolutions, were benefited for the spatial change detection between 2009 and 2015. SPOT5 image was captured on 11.10.2009, while the date of SPOT 7 image is 04.10.2015 on 1-b image level.

Figure 2 illustrates the SPOT images of the study area.

Besides, satellite images CORINE data and development plans were also used for the detection of the training data during supervised classification of SPOT images, as well as the evaluation of the detected tempo-spatial changes in Körfez district.

Since CORINE project is of 1/100000 scale with a minimum mapping unit of 25 ha, it was concluded that CORINE land cover data would make appropriate ancillary data for image classification process, and thus 2006 and 2012 data were provided from land, Copernicus web site (Copernicus 2020https://land.copernicus.eu/). Figure 3 shows the CORINE land cover map for the study area for 2006, reclassified and regrouped in accordance with the aim of the study.

As spatial plans are sources for land use decisions, they present multi-dimensional information regarding the area. Therefore, 1/25000-scale environmental arrangement plans 1/5000-scale and 1/1000-scale development plans were provided in digital format (.ncz files) respectively from Kocaeli Metropolitan Municipality and Körfez Municipality (Fig. 4), and utilized during the processes such as determination of the training data during supervised classification and evaluation of spatial-temporal changes in the study area.

Method

The main goal of this study is the determination of the spatial-temporal changes along one of the delicate coastal zones in Turkey, utilizing RS and GIS capabilities so that the role and the necessity of the planning processes, especially the integrated coastal plan process on the development of the coastal zones is better understood. To fulfill this aim, change detection process was made using 2009 and 2015 images of SPOT satellites.

Change detection is a widely used method by the RS community for quantitative analysis of the temporal changes in a range of application areas (land use/land cover change, forest/vegetation change, wetland change, landscape change, urban change, environmental change, crop monitoring etc.) (Mausel et al. 2004; Mishra et al. 2017). Change detection is simply the process of subtracting the initial land cover/land use types in a multispectral dataset from the final one to identify the differences in which the change thresholds are used to define the

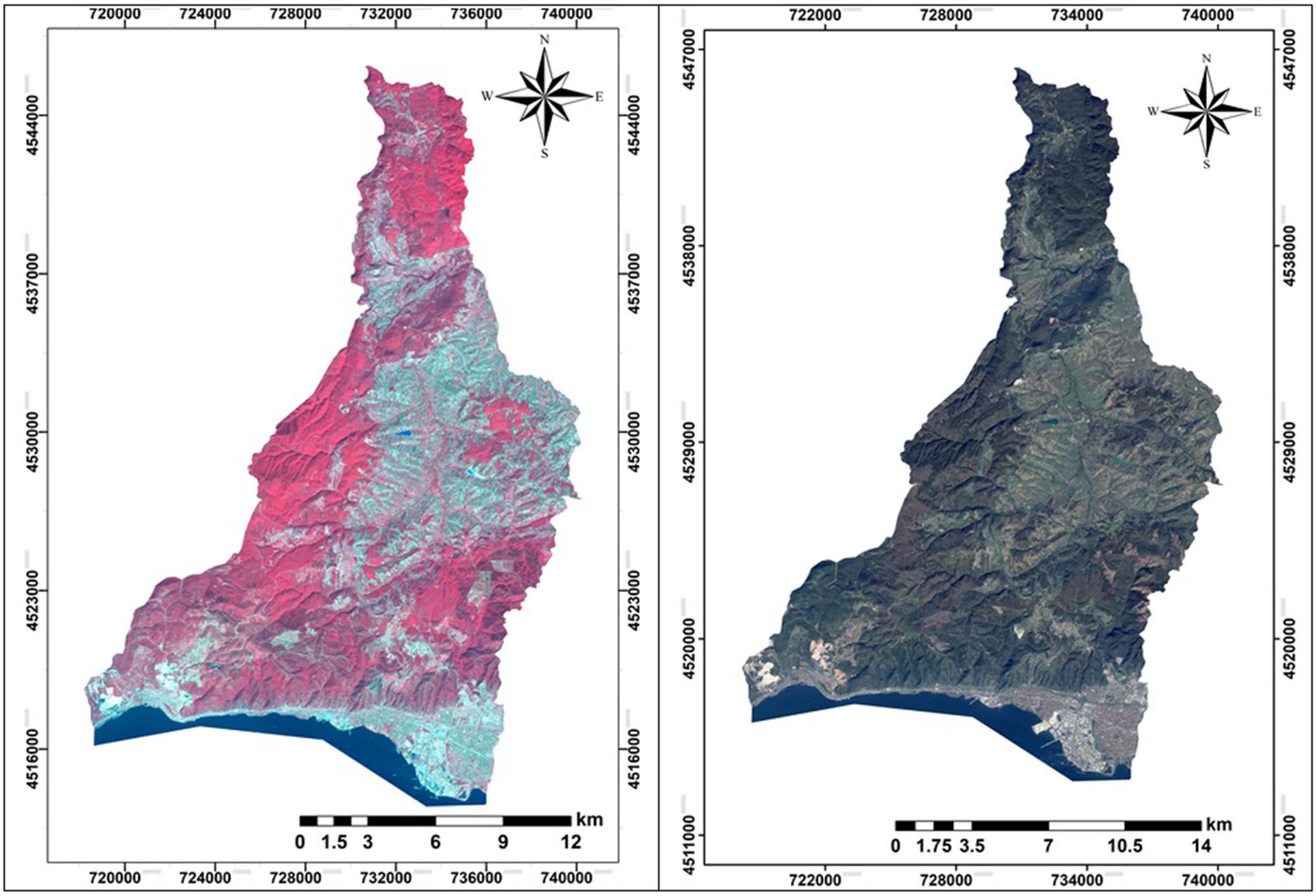


Fig. 2 SPOT 5 and SPOT 7 images of Körfez district (UHUZAM). (**a**) 2009 SPOT 5 image. (**b**) 2015 SPOT 7 image

classes. A good number of change detection techniques have been developed and adopted, which are mostly based on three approaches: pixel, feature, and object level processing (Blaschke 2005). In this study, pixel level processing, which is based on the image differencing of the spectral data for the given years, was used. Regarding the major outputs of a good change detection research suggested by Mausel et al. (2004), the following were also achieved via the image differencing method applied in this study: (1) the areas and rates for the change, (2) spatial distribution of the change, (3) change trajectories, and (4) accuracy assessment of the results. The land use types (classes) were identified by the supervised classification method.

Below, the main methods used during the study are explained in brief.

Orthorectification

As the SPOT satellite images were provided in 1B level (already normalized and radiometrically corrected), only orthorectification process was performed to correct the images in terms of tilt and terrain effects with the ortho engine module of PCI Geomatica software. A hybrid terrain model produced from SRTM and ASTER DEM was used for the orthorectification of the terrain. Ground control points were detected from 10 cm/pixel orthophotos and 50 cm/pixel GeoEye and Worldview orthorectification archive images. Figure 5 shows the orthorectified images.

Classification and change detection

In the first place, unsupervised classification method was used. The classes were determined as forest-green area, agricultural land; settlement area, sea, and lake, and an unsupervised classification was performed via ISODATA method. However, the results showed that polluted zones in the sea were classified under forest class, while some of the forest lands were grouped under agricultural lands. In other words, the pollution in the sea and the shadow effects on mountainous topography affected the accuracy of the classification. Therefore, supervised classification based on maximum likelihood method was realized to overcome this problem and obtain more accurate results. CORINE data and development plans were used for the determination of the training data. To clarify the land cover type on certain spaces in the study area,

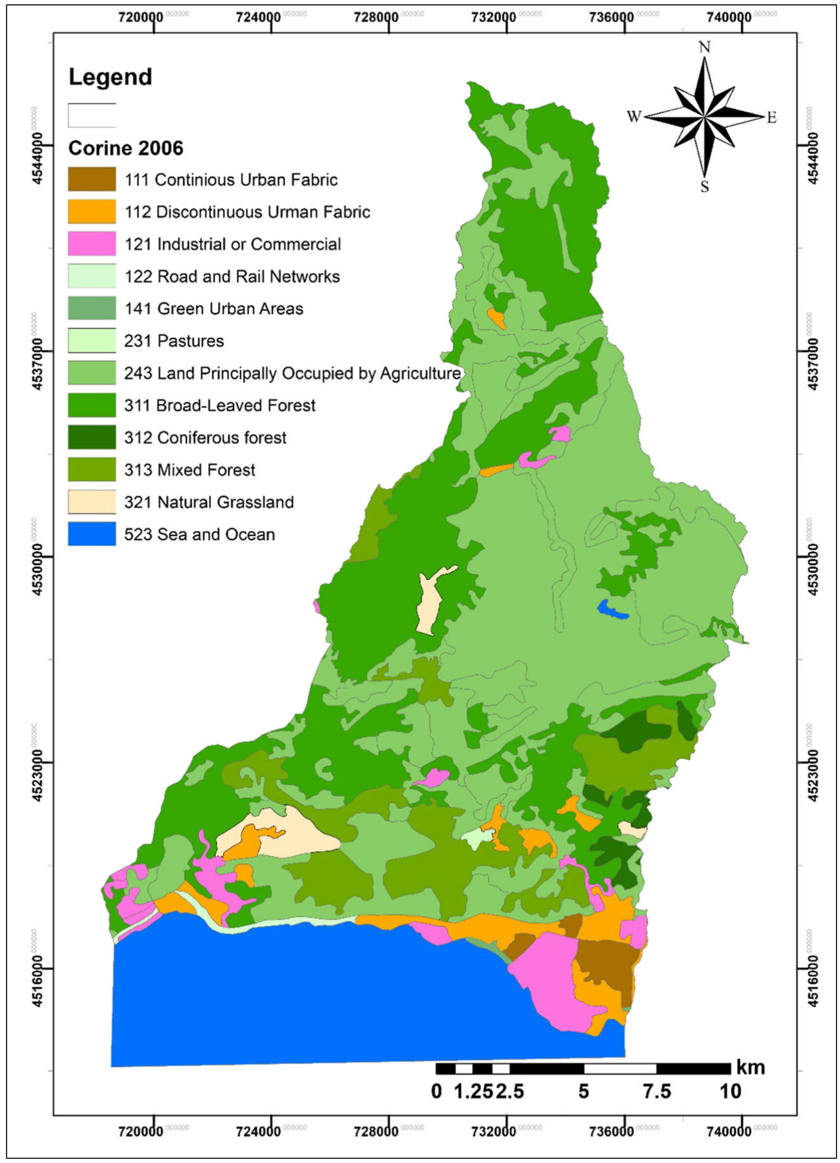


Fig. 3 Land use/cover map of Körfez district – 2006 (land.copernicus.eu)

the authors visited the predetermined areas in Körfez district and realized land surveys and observations. ArcGIS software was preferred for classification processes. Land cover classes/types in CORINE were reclassified in accordance with the land cover classes (Table 2) of the study, where classes with similar pixel attributes were merged, since the classification process is pixel-based. From this point, green urban areas and forests/woodlands were merged under "forest-green area" class. Industrial, commercial, and urban/settlement areas were grouped within "settlement area" class, and water bodies were merged to define the "lake" class.

After both images captured in 2009 and 2015 were separately classified via supervised classification method, they were then compared through change detection approach based on image differencing technique to determine 6-year change in term of the quantitative differences and their spatial representations in the land cover classes. Here, simply the values in the initial image (2009) are subtracted from the ones in the final image (2015) pixel by pixel, depending on the 5 classes of land cover in the study area.

Accuracy analysis

The accuracy of the supervised classification is assessed either via using error matrix or Kappa (κ) coefficient. In this study, both methods were utilized. In the error matrix, the accuracy of the classification for all classes is computed by the average of the accuracy percentages of each class. Kappa coefficient on the other hand uses weighted values for the assessment of the classification and also allows for the non-diagonal elements. As the accuracy rate obtained from error matrix can

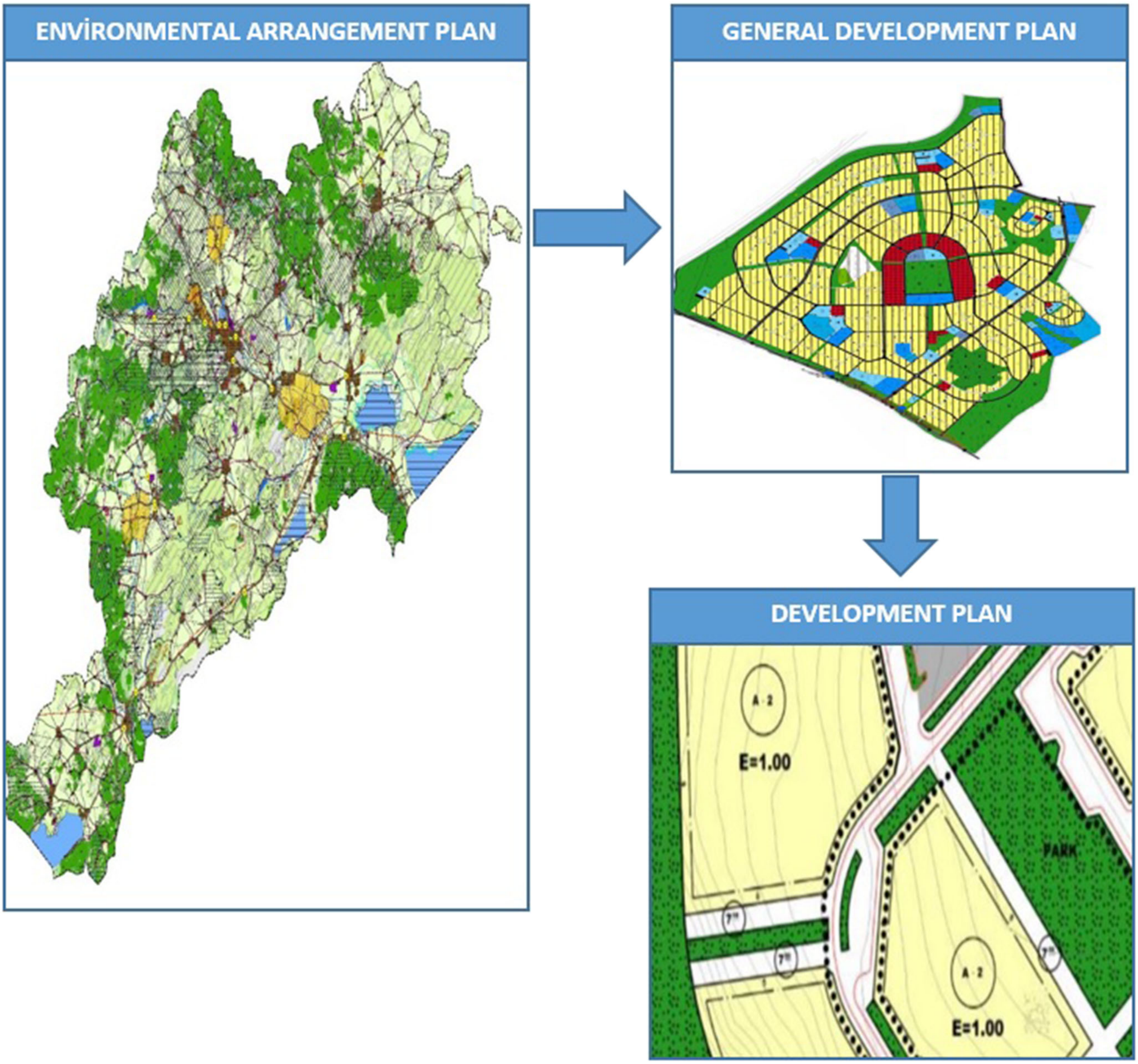


Fig. 4 Development plans of Körfez district

result in mistakes in interpretations, it is significant to calculate the Kappa coefficient (Mather and Koch 2011).

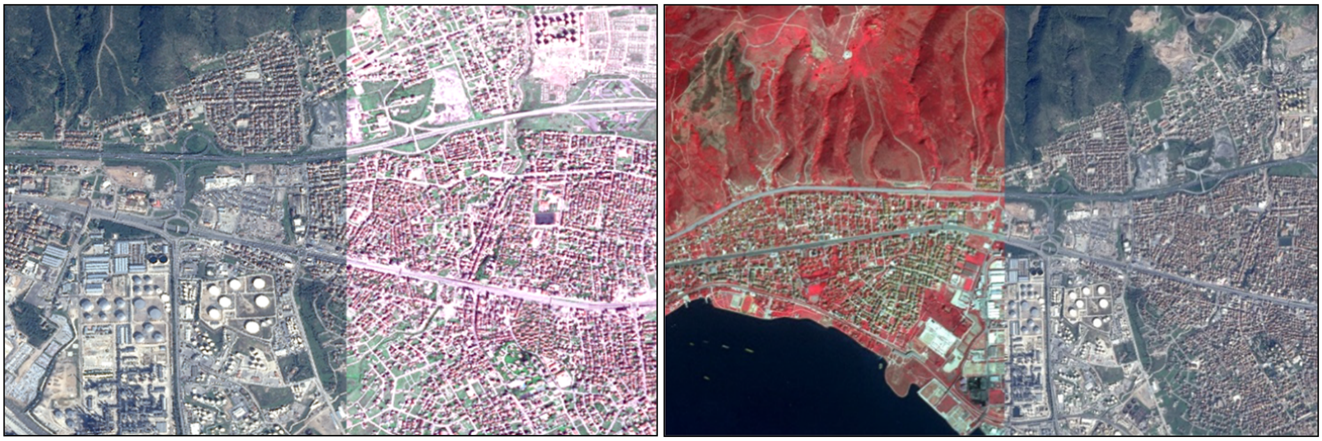
The following equation gives the formula for Kappa coefficient (Eq. (1))

$$K = \frac{N\sum_{i-1}^{r} x_{ii} - \sum_{i-1}^{r} (x_{i+} * x_{+i})}{N^2 - \sum_{i-1}^{r} (x_{i+} * x_{+i})} \quad (1)$$

Where;

N represents the total number of observations, r is number of rows and columns in error matrix, x_{ii} is the number of observations along the diagonal (in row i and column i), x_{i+} is marginal total of row i, and x_{+i} is marginal total of column i.

Kappa was developed by Cohen in 1960 and became popular for the classification accuracy testing of remote sensing imagery in the beginning of the 1980s. In Kappa coefficient, the proportion of agreements in the absence of the change agreements are calculated. As change agreement decreases, Kappa takes positive values (increases to one), and decreases below zero when the change agreement increases. In case the agreement is equal to chance agreement than the Kappa is zero (Banko 1998). Accordingly, when the Kappa value is equal or



a) SPOT 5 - 2009 b) SPOT 7 - 2015

Fig. 5 Orthorectified SPOT images for Körfez district. (**a**) SPOT 5 – 2009. **b**) SPOT 7 - 2015

bigger than 0.75, then the classification performance is assumed strong, and the values equal and below 0.40 are accepted as an indicator of weak performance (Ayhan et al. 2003).

For the development of error matrix for the supervised classification analysis results for 2009 and 2015 images in the study area, 470 control points were created randomly using "create random points" tool of the software. Then, each point was separately checked for its suitability to represent the class for which it was assigned. The results showed that "lake" class was not represented properly by the randomly created control points. Therefore, 10 points were assigned manually, and a total of 480 control points were used for the accuracy analysis. Figure 6 gives the locations of the control points in the study area. Tables 3 and 4 give the error matrix for 2009 and 2015 supervised classifications

In order to introduce the "real" value of 480 test points one by one, operations were carried out in the ArcGIS program and at the end of these procedures, the error matrices were created in Table 3 for 2009 and in Table 4 for 2015.

According to the error matrix given in Table 3, the accuracy of the supervised classification of 2009 image was calculate 89.8%. The accuracy according to Kappa coefficient was

Table 2 Existing and reclassified CORINE land cover classes/types

CORINE Land Cover Classes/Types	Reclassified Land Cover Classes/Types
Continous Urban Fabric	SEA
Discontinuous Urban Fabric	LAKE
Industrial – Commercial	FOREST-GREEN AREA
Road And Rail Networks	AGRICULTURAL LAND
Port Areas	SETTLEMENT AREA
Mineral Extraction Sites	
Construction Sites	
Green Urban Areas	
Non-İrrigated Arable Land	
Pastures	
Complex Cultivation Patterns	
Land Principally Occupied By Agriculture	
Broad-Leaved Forest	
Coniferous Forest	
Mixed Forest	
Natural Grasslands	
Transitional Woodland	
Water Bodies	
Sea And Ocean	

Table 3 Error matrix for 2009

ObjeID	Classes	Value	Real 1	Real 151	Real 295	Real 323	Real 673	Total
Unit class type reference data	Settlement area	1	33	0	0	3	7	43
	Sea	151	0	23	0	0	0	23
	Lake	295	0	0	11	0	0	11
	Agricultural land	323	15	0	0	157	21	193
	Forest–green area	673	0	0	0	1	190	191
	Total		*48*	*23*	*11*	*161*	*218*	*461*

found 0.84 (84%). As to the accuracy of the supervised classification of 2015, the error matrix value was computed 85.9% and Kappa value was found 0.78 (78%). Consequently, the accuracy of the supervised classification process for both of the years was strong.

Results

The SPOT images of the study area were classified under 5 classes, namely forest-green area, agricultural land, settlement area, sea, and lake, as explained previously to perform a pixel-based classification based on maximum likelihood method. Accordingly, the change rates and the areas as well as their spatial distribution over the area were obtained. Figure 7 shows the land use maps of the study area for 2009 and 2015 which was obtained after supervised classification process.

After the classification of the area in accordance with the predetermined land use classes, the results for 2009 revealed that most of the study area comprised forests and green lands (14474.02 ha, 45%) followed by a considerably large amount of agricultural lands (13325.45 ha, 41%) mostly in the central and to the northwest parts of the region. TAs seen in Fig. 7 the forested areas are mostly on the western and northern parts of Körfez district, as well as the southeast sections above the highly populated settlement areas. On the other hand, only 8.9% of the district (2888.12 ha) is reserved for the settlement areas mainly located at the coastal sections, especially towards the southeast. The sea and lake classes cover 1590.75 ha and 13.66 ha of the study area boundaries respectively.

According to the results of the supervised classification made for 2015, the share of the forests and green areas are even more (17306.89 ha, 54%) and seem to have noticeably increased in former agricultural lands in the east, west, and south parts of the district. Accordingly, the amount of the agriculture areas shows a decrease (10333.29 ha, 32%). The increase in the settlement areas (3073.83 ha, 9.5%) in 2015 is observed both on the south east, east, and south west territories. Besides, there is an increase in the lake class (23.78 ha) in 2015, which can be related with the cleaning of the sediments and mud accumulated in the Sipahiler Reservoir conducted in 2013, as well as water retention works in the study area. Lastly, a decrease in the sea class (1554.21 ha, 5%) was noticed due to the land filling on the south east part of the coastline.

In accordance with the above mentioned results in terms of land use classes in the study area in 2009 and 2015, changes in the land use classes were also determined. Table 5 summarizes the land use change results between 2009 and 2015 in Körfez district.

The change detection results revealed that there was an increase of 185.71 ha in the settlement areas. The sea class and the agricultural lands on the other hand decreased (36.54 ha and 2992.16 ha respectively). The amount of increases in the lake and forest-green area classes were detected 10.12 ha and 2832.9 ha.

Table 4 Error matrix for 2015

ObjeID	Classes	Value	Real 1	Real 151	Real 295	Real 323	Real 673	Total
Unit class type reference data	Settlement area	1	19	0	0	0	0	19
	Sea	1231	0	10	0	0	0	10
	Lake	257	1	0	35	7	2	45
	Agricultural land	581	0	0	5	128	15	148
	Forest–green area	935	0	0	0	36	211	247
	Total		*20*	*10*	*40*	*171*	*228*	*469*

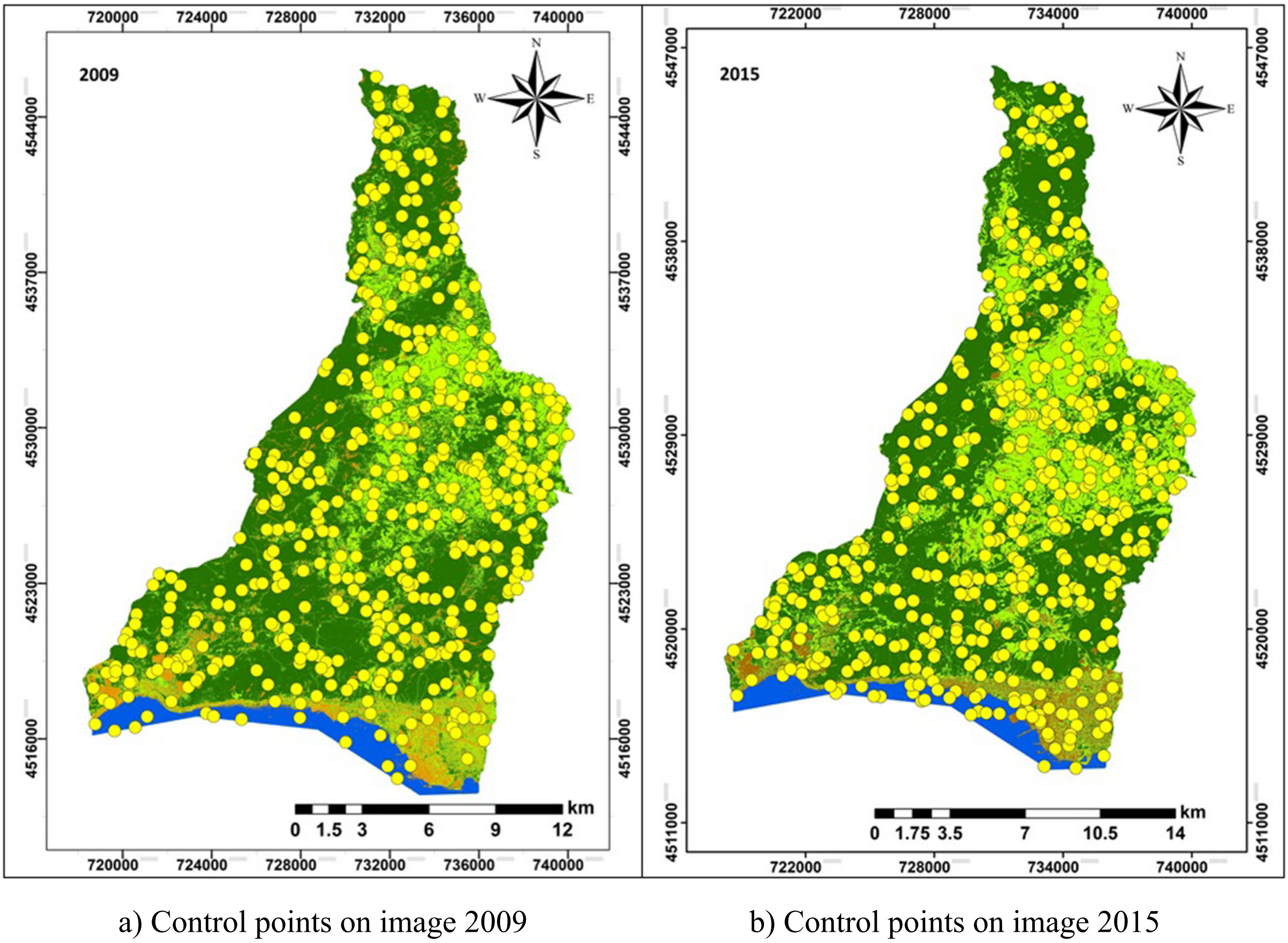


Fig. 6 Location of control points used for accuracy analysis. (**a**) Control points on image 2009. (**b**) Control points on image 2015

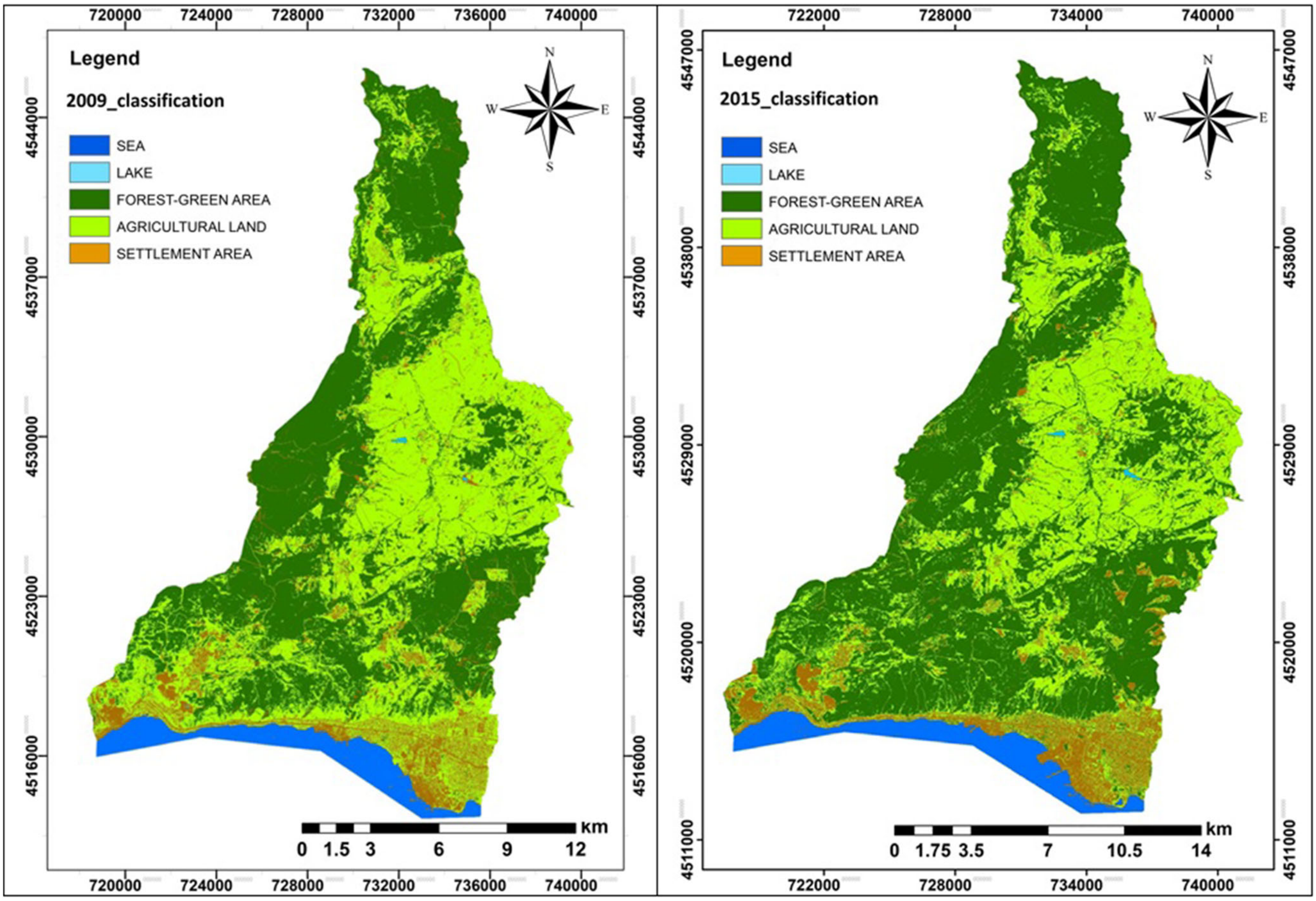
Discussions

Coastal lands are important natural sources that are in need of a comprehensive planning, protection and management. Any land use/cover change on the coastal zones has direct impacts on other resources and sectors, of which pose critical risks on the sustainability of the coastal resources and surrounding environments. Therefore, changes in the coastal fabric should be carefully evaluated to better understand the possible threats and make forecasts for the future which would drive the spatial planning actions and approaches.

Change detection analyses facilitate the process aimed at the comprehension of the impacts of the urbanization/development styles and habits on the natural environment and vice versa. Spatial-temporal change detection processes, therefore, play a significant role in the determination of the existing status of any land and possible changes in the land use in the future, thus provides precious inputs for planning frameworks. In the literature, a rich variety of different change detection techniques from image differencing methods to principal component analysis and to advanced hybrid models have been adopted in accordance with the research goal and the target geographic context. Within this study, supervised classification method was preferred for the determination of the selected land use classes, and image differencing method was utilized to identify the temporal changes. Still there are other methods to achieve more accurate results. However, the high number of the assigned control points during supervised classification and verification via site surveys have been significant stages to obtain accurately and well defined classes. The method adopted in this study is also considered suitable to assess the land use shift within the study area and provide valuable inputs for further planning practices.

Weismiller et al. (1977a, 1977b) discussed with the results of four techniques for ordering them delta data change detection required for simple and single classification. Post classification requires logical corporation for two separate classifications. Spectral temporal change classification was complex and more classification and features. Layered spectral temporal change classification was complex and logical interrelationship of classes (Weismiller et al. 1977a, 1977b).

El-Hattab (2016) reported that using post-classification change detection technique made more accurate results than



a) 2009 results b) 2015 results

Fig. 7 Land use maps of Körfez district (supervised classification). (**a**) 2009 results. (**b**) 2015 results

traditional change detection techniques in applying reach area in Egypt.

Mas (1999) conducted that were tested six change detection procedures using Landsat Multi Spectral Scanner images for detecting areas of changes in the region of the Terminos Lagoon, a coastal zone of the State of Campeche, Mexico Monitoring land-cover changes: a comparison of change detection techniques. Post-classification comparison was determined to be the correct procedure and represented the advantage of indicating the nature of the changes. Low performances given by image enhancement works were contributed to the spectral variation because of the differences in vegetation phenology and in soil moisture between both scenes. Using these methods based on classification determined to low sensitive at these spectral differences and more robust when working with data captured at different times of the year.

Halmy et al. (2015) worked Land use/land cover change detection and prediction in the north-western coastal desert of Egypt using Markov-CA. The technique was successful in predicting LULC distribution in 2011 and the results were comparable to the actual LULC for 2011. The projected

Table 5 Land use change in Körfez district between 2009 and 2015

Land cover classes	2009 results (ha)	2015 results (ha)	Change (ha)	Change (%)
Agricultural lands	13325.45	10333.29	− 2992.16	− 22. 5
Sea	1590.75	1554.21	− 36.54	− 2.3
Lake	13.66	23.78	+ 10.12	74.1
Forest-green area	14474.02	17306.89	+ 2832.9	19.6
Settlement area	2888.12	3073.83	+ 185.71	6.4
Total	*32292*	*32292*	–	

LULC for 2023 revealed more urbanization of the landscape with potential expansion in the croplands westward and northward, an increase in quarries, and growth in residential centers, and El-Asmar and Hereher (2011) found to study with change detection of the coastal zone east of the Nile Delta using remote sensing. These changes were attributed mainly to the control of the River Nile flooding and the land use change by anthropogenic activities by using satellite imagines. Ramírez-Cuesta et al. (2016) reported for the effectiveness of the changes detection techniques to find the various geomorphological units identified in Ebro River mouth 1957-2013. h is particularly relevant on highly vulnerable environments, such as coastal deltaic areas

Current regulations in the coastal legislation in Turkey, where still traditional approaches are mostly in action, reveal the necessity of adopting contemporary and holistic perspectives to provide sustainable planning for coats and their interaction zones. Hence, spatial data as well as advanced technologies, such as GIS and RS, should be efficiently utilized by the authorities in charge of coastal planning and management process in the country. GIS and RS capabilities, no doubt, present a good number of advantages and efficiency such as rapid, efficient, precise, and accurate data gathering, storage, manipulation, analysis and presentations, savings from time, manpower and money, increased comprehension, and interrelating capabilities. GIS and RS are also utilized frequently to detect the spatial changes over a coastal place in a determined time period. Within this context, GIS and RS are highly beneficial and necessary for the detection of the changes and transformation in the coastal zones in the country and develop strategies for sustainable and integrated coastal planning and management for the realization of a sustainable development. This reveals the necessity to develop a national planning model based of GIS and RS supported processes and implementations. This model should define a method putting a lens on the former plan decisions and their reflections and results on the plan boundaries so that the former actions are evaluated in a comprehensive, multidimensional, and holistic manner and future perspectives are delicately determined for the sake of the both coastal resources and the societies.

In this regard, the main objective of this study was to perform a change detection analysis using GIS and RS capabilities in Körfez district, which has gone through a rapid change since the 1950s due to its coastal resources and location. When the study area is examined in terms of spatial planning implementations, it is seen that most of the planning implementations in the district has lacked a properly defined and adopted contemporary perspective methodology, as well as standard data, software, and hardware utilization. This point of view unfortunately has resulted in highly populated coastline and intense settlement areas engaged with industrial and commercial constructions where inflammable and explosive materials are either produced or used. Since the majority of the industrial areas are located along the coastal zone, and sea land reclamation (land fill) implementations and ports also engage the coast, the natural coasts in the district nearly fully disappeared. When the destructive results of the 1999 earthquake in Körfez district is also regarded, the suitability of the former plans and its applications in the area is highly criticized. Improper land use decision in the study area is far from a sustainable planning apprehension.

For all these reasons, it is vital to assess the reflections of the old plan decisions and the effects of the existing land use types on the new planning practices in a holistic and sustainable way strengthened with the implementation of advanced technologies and scientific analyses. When the results achieved in this study are interpreted together with the socio-cultural data, municipal implementations, formerly prepared plans and further planning goals within the district, the effect of the economic developments in the district on the land use has been clearly determined. In this sense, it will not be wrong to mention that the planning processes have mostly neglected the characteristics of the land and the necessity to perform comprehensive data analysis allowing for the delicate coastal dynamics, earthquake risks, land characteristics, carrying capacity, etc. Therefore, in parallel with the new national requirements and legislation forcing the authorities to prepare integrated coastal plans for the protection and sustainability of the coastal regions, approaches and implementations like the ones presented in this study should be taken into consideration in the new development plan decisions. Thus, by determining the reflections and consequences of the old plan decisions to the space, future risks can be determined, and it is ensured that the most appropriate land use decisions can be made for the area.

As the change detections results showed the increase in the amount of the settlement areas and the other referred documents (plans) as well as site surveys revealed that the coastlines were intensively occupied by multi-storey buildings, the relevant stakeholders and authorities are suggested to reconsider the density of the structures especially along the coastline in the new development plans. Besides, large afforestation areas can be reserved between the industrial regions and the housing to provide efficient buffering. It is also necessary to preserve the existing agricultural lands and prevent their transformation into settlement areas. Considering the population density in the area and the unconscious use of resources accordingly, it can be suggested to use smart solutions in recycling systems and urban services.

When the problems, requirements, and deficiencies in the current system are evaluated, it is concluded that new generation technologies are required at every stage of planning for a sustainable physical planning. Performing spatio-temporal change analysis in accordance with the developing and changing technology, especially in order to determine the dimensions of the change and transformation in the coastal and interaction areas, is of significance. Currently used traditional methods in the country are time consuming, narrowly scoped, mostly inaccurate, and lack the capability to comprehensively evaluate and analyze all the necessary data as well as the predict the future changes.

Conclusions

When examining the change analysis, it is important to evaluate it together with the accuracy analysis in order to make a healthy result interpretation. In this study, auxiliary data were taken into consideration both when performing the classification process and interpreting the result of the study. When land use changes are analyzed with the help of auxiliary data; it is concluded that since 2011, the lake area has increased due to dam and water retention facilities, while the sea area has decreased due to the increase in the coastal filling areas. The increase in the forest and green areas has been due to the afforestation works within previously the unfrosted (vegetated) lands in accordance with the cadastral works and the increase in the green areas in the city center. The decrease in the amount of the agricultural areas is believed to be mostly linked with the increasing construction works in the province and the shifting of the district's livelihood from agriculture to the industrial sector. Lastly, in Körfez district, the population is highly concentrated in the coastal parts, and the effects of change are most noticeable in these areas.

Despite of the ongoing efforts to implement national GIS standards framework driven with the coordination of the Genera Directorate of GIS, Ministry of Environment and Urbanization, unfortunately, there is still a big gap in the determination of standard data collection, processing, and analysis in the current system of coastal planning practice. This results in uncertainty and deficiencies in the format and preparation of the plan proposals, which cause many problems along with the integrity and monitoring requirements.

While taking the plan decisions in coastal areas, the results and impact areas of the existing land use and the land use change should be examined, the future predictions should be made by taking lessons from the past, and the most appropriate land use decisions should be developed for the future of the area. Otherwise, it will not be possible to talk about the sustainability of planning.

Author contribution Gulenay Sahin, Saye Nihan Cabuk, and Mehmet Cetin: design, resources, and writing; materials, data collection and/or processing; and materials, literature search, analysis, and/or interpretation.

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Declarations

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