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Analysis of Temporal Change Taking Place at the Coastline and Coastal Area of the South Coast of the Marmara Sea

Marmara Denizi Güney Kıyılarında Kıyı Çizgisi ve Kıyı Alanda Meydana Gelen Zamansal Değişim Analizi

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Abstract

Owing to the fact that determining the temporal change at the coastline is highly significant in maintaining sustainable coastal development plans, this study focuses on the temporal coastline change in the south coasts of the Marmara Sea, which is one of the seas where coastal use and change are the most obvious. Therefore, old and new coastlines have been determined by using Landsat TM images with 30m resolution from the years 1984, 2003 and 2011 as well as colorful orthophotographs of the year 2008 with 0,45 cm resolution. Geometrical confirmation of satellite images were effectuated by using software and techniques of Erdas Imagine 10 and ArcGis 10 and then the coastal analyses from the obtained coastlines and land examinations have been conducted. According to the result of the study, an area of 5,76 km² have been filled between Çanakkale-Çardak and Yalova within 27 years of time between the years 1984 and 2011. The study also reached a conclusion that mining sand was effectuated in an area of 1,15 km² and thus the coast was pulled back. The line that was 521 km in 1984 reached 560 km in 2011. The most obvious coastal change was seen to be in the coasts of Yalova, Gemlik, Mudanya and Bandırma. The coastal bend, located in Lapseki, Gönen, Karacabey and in the south of Kapıdağ Peninsula, still remains to be a natural coastline. Even though irregular settlements in the coastal areas of cities cut off people's contact with the sea, the solution of filling the coasts was found for the purpose of recreating green spaces in the interest of the public. However, the coastal areas, which have sensitive ecological features, face with pressures of tourism and urban-based developments due to these landfills in the coasts. Therefore, coastal landfills in the southern coasts of the Marmara Sea gradually destroy the natural coastal spaces and the coastline also lost its original appearance.

The population growth and pressures on using the land in the coastal areas have always continued and will continue in the future. Hence, it is essential have new regulations and sustainable permanent plans for long term uses in the future.

Key Words: Coastline Change, Coast Area Change, Marmara Sea, Remote Sensing (RS), Geographic Information Systems (GIS).

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Özet

Kıyı çizgisinde zamana bağlı değişiminin belirlenmesi sürdürülebilir kıyı gelişim planlarının yapılmasında büyük önem taşımaktadır. Bu çalışmada kıyı kullanım ve değişiminin en belirgin olarak yaşandığı denizlerimizden birisi olan Marmara Denizi'nin güney kıyılarında zamana bağlı kıyı çizgisi değişimi belirlenmiştir. Bu amaçla 1984, 2003 ve 2011 yıllarına ait 30 m çözünürlüklü Landsat TM uydu görüntüleri ile 2008 yılı 0,45 cm çözünürlüklü renkli ortofotolar kullanılarak eski ve yeni kıyı çizgileri tespit edilmiştir. Erdas Imagine 10 ve ArcGis 10 yazılım ve teknikleri kullanılarak uydu görüntülerinin geometrik doğrulaması yapılmış ve daha sonra elde edilen kıyı çizgilerinden ve arazi incelemelerinden kıyı değişimi analiz edilmiştir. Çalışma sonucunda 1984 ve 2011 yılları arasında geçen 27 yıllık sürede Çanakkale-Çardak ile Yalova arasında 5,76 km²'lik alan doldurulurken, 1,15 km² alandan da kum alınarak kıyının geriletildiği tespit edilmiştir. 1984 yılında 521 km olan çizgisi de 2011 yılında 560 km'ye ulaşmıştır. Sahada en belirgin kıyı değişimin Yalova, Gemlik, Mudanya ve Bandırma kıyılarında olduğu görülmüştür. Lapseki, Gelibolu, Gönen, Karacabey ve Kapıdağ Yarımadası'nın kuzeyinde kıyı şeridi doğal kıyı olma özelliğini korumaktadır. Kıyı alanlarındaki düzensiz yerleşim, deniz ile insanların temasının kesilmesine neden olduğundan, kıyılarda kamu yararına yeşil alanların tekrar oluşturulması amacıyla kıyıya dolgu yapılması çözümü bulunmuştur. Ancak, kıyılara yapılan dolgular, hassas ekolojik özellikli kıyı alanlarının turizm ve kentsel kaynaklı gelişmelerin baskısı ile karşı karşıya kalmasına sebep olmuştur. Bu nedenle Marmara Denizi güney kıyılarında kıyı dolgu alanları ile yavaş yavaş doğal kıyı mekânı yok edilerek, kıyı çizgisi de asli görünümünü kaybetmiştir. Bu nedenle Marmara Denizi güney kıyılarında kıyı dolgu alanları ile yavaş yavaş doğal kıyı mekânı yok edilerek, kıyı çizgisi de asli görünümünü kaybetmiştir.

Görünen o ki kıyı alanlarında nüfus artışı ve kullanıma yönelik baskılar, sadece geçmişte ve günümüzde değil, aynı zamanda gelecekte de devam edecektir. Bu nedenle kıyı alanlarının gelecekte uzun süreli kullanımlar için sürdürülebilir ve kalıcı planlama ve yeni düzenlemelerin yapılması gerekmektedir.

Anahtar Kelimeler: Kıyıçizgisi Değişimi, Kıyı Alanı Değişimi, Marmara Denizi, Uzaktan Algılama (UA), Coğrafi Bilgi Sistemleri (CBS).

Introduction

Coastal regions, defined as transition zones (Fınkl, 2004; Boak et al., 2005) are the most populous places of the world due to their industry, commerce, fishing, economic development and ecological characteristics (Anfuso et al., 2013). Today, more than about 50 % of the world's population lives within the section covering 200 kilometers of the coastline because of their favorable features. For example, approximately 53 % of the population in the United States and 86 % of the Australian population reside along the coast (Cardille et al., 2003; Crowel et al., 2007; Scarfe et al., 2009). This increase of population in the coastal regions continues with each passing day particularly in the coasts of North America, Southeast Asia, India and South America. The coastal population in the United States is expected to reach 166 million in 2015 (Klemas, 2009; Anilkumar, 2010). Studies have demonstrated that a similar situation can also be seen in Europe. 200 million people, out of almost 680 million in Europe, continue to live within the coastal zone of 50 km (Duru,

2001). The population in the coastal regions is expected to increase about 75% in 2025 (Crowel et al., 2007; Scarfe et al., 2009).

This excessive population growth and settlement in the coastal regions causes the emergence of irreparable and difficult environmental problems such as the destruction of nature, inadequate infrastructure and transportation system, excessive and improper use of resources, unconscious land and water use and the destruction of green areas (Özdemir, 2004). Improperly studied engineering structures be built near lakes, land reclamation and changes in the ecological balance that will happen due to urban, agricultural and industrial waste disposal have led to deterioration in the balance and morphological structures of these areas (Saïdi et al., 2010; Saïdi et al., 2012). Natural recreation resources, which are open to the public, continue to diminish with each passing day since other problems, such as noise and environmental pollution, brought by urban life due to technological developments, have turned people towards common areas in the coastal regions (Alonso and Cabrera, 2008).

The population growth in coastal regions and economic pressures did not only continue in the past or still continue in the present, but will also continue in the future. Therefore, there is a need for sustainable and permanent planning and new regulations for the long-term recreational use of coastal areas in the future (Brommer and Bochev, 2009). The problem is attempted to be resolved in Turkey by developing solutions like filling the coasts for recreational uses except for transportation purposes. The most obvious example of this can be seen in the coasts of İstanbul on the north of Marmara Sea. İstanbul, one of the most significant metropolitan cities of the world with its cultural and historial values, and especially its coasts in Bosphorus are under intense pressure of settlement due to excessive population growth (Demirci et al., 2009). As a result of this, the inhabitants of İstanbul are deprived of coastal and marine use for recreational purposes. Coasts were filled by İstanbul Metropolitan Municipality through many arrangements in the period after 1984 in order to let the public benefit from coasts as much as needed and the recreational uses were strived to be ensured in the acquired areas. An area of 1687 km was filled and organized between 1987 and 2007 for this purpose (Kurt et al., 2010).

There are 28 provinces with coastal lines in Turkey, a country encircled by seas on three sides. The total population of these provinces, which was 41.847821 people in 2013, constituted 54.5 % of the country's population which is 76.667864. 22.076466 people live in the coastal provinces (Çanakkale, Balıkesir, Bursa, Yalova, Kocaeli, İstanbul and Tekirdağ) of the Sea of Marmara which also includes the research area (TSI, 2014). However, coasts have faced with serious destruction particularly in recent years by planning practices that were made without taking the natural features into consideration and their natural appearances as well as coastal lines have been altered. Therefore, it is necessary to carry out works that are aimed at protecting these natural resources (Doğaner, 1992, Doğaner, 2001; İrtem and Karaman, 2004, Sayıstay, 2006; Sesli et al., 2007; Akova, 2009; Özşahin and Ekinci, 2012) that were

damaged due to rapid population growth and settlement connected industrialization and can not be renewed, to approach problems through farsighted perspective, to make accurate and sustainable planning and to implement necessary solutions in place and on time. The fillings made in coasts are needed to be identified in order to make a sustainable planning for the coastal regions of the Sea of Marmara. However, the amount of these fillings made in the coasts and for what purposes they were used can be determined by means of the analysis carried out through appropriate and correct methods. Today, Geographic Information Systems (GIS) and Remote Sensing (RS) methods are widely used for making these determinations. At the same time, Remote Sensing method is one of the most efficient methods used in coastal changes (Vinodkumar et al., 1998; Zhu, 2001, Kostiuk, 2002; Demirci et al., 2009).

There have been many studies on the Marmara Sea Doğaner, 1992, Doğaner, 2001; İrtem and Karaman, 2004, Sayıstay, 2006; Sesli et al., 2007; Akova, 2009; Saïdi et al., 2010; Özşahin and Ekinci, 2012). In this study, identifying old and new coastallines in the southern coasts of the Sea of Marmara and fillings made in a period of 27 years was aimed by using Principal Component Analysis, one of the Remote Sensing (RS) methods. Landsat satellite imagery with the resolution of 30 m for 1984, 2003 and 2011 and color orthophotos of 2008 with resolution of 0,45 cm. The areas with filling and changes that occured in coasts due to coastal erosion and sand mining were identified as a result of the study by determining temporal change in coastallines. Therefore, this study is significant base for future studies to be conducted on the planning of a sustainable coastal use in the Sea of Marmara.

Study Area

According to the Geographic Coordinate System, the research area, which lies between 26° 09' 49''–30° 22' 40'' eastern longitude and 40° 00' 00'' - 41° 18' 45'' northern latitudes and extends through a coastal area of 500 km, encompasses H17, H18, H19, H20, H21, H22, G19, G21, and G22 sheets in the topographic map of Turkey with 1/100000 scale (Figure 1). The area starts from Çanakkale-Çardak in southwest of the Marmara Sea and extends until Yalova-Kocaeli provincial border in the east. The study was conducted in the coasts of Çanakkale, Balıkesir, Bursa and Yalova with a population of 426.181 (TSI, 2014), situated in the southern shores of the Marmara Sea.

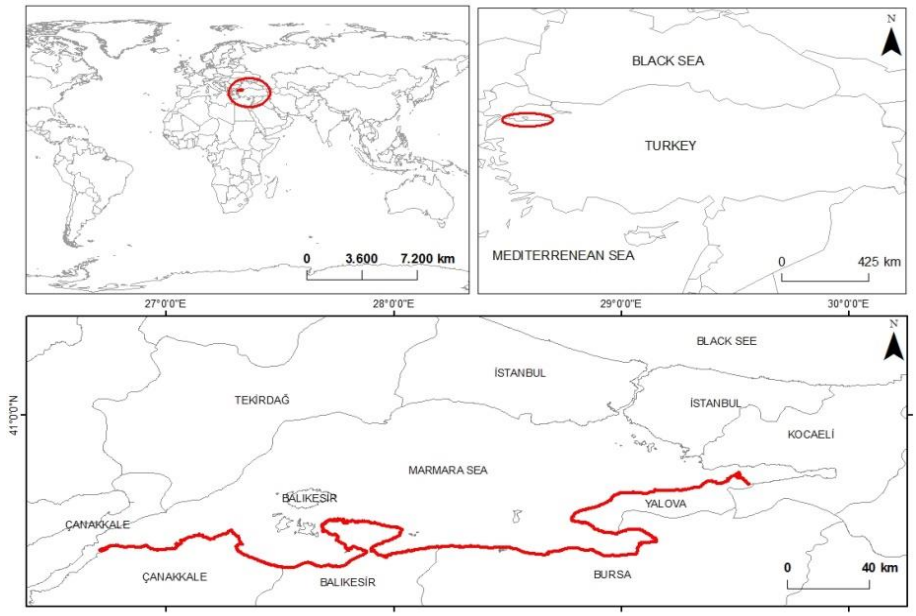

Figure 1: Location Map of the Study Area.

Materials and Methods

Landsat (TM) satellite imagery, obtained from USGS Global Visualization Viewer (GloVis) for discovering the coastal lines and comparing the change in an accurate way, constituted the main data source of the study. Non-cloud images belonging to different months were preferred for preventing the change perception error brought by the seasonal variations. These images, which have been analyzed in total of 3 periods since 1984, have spatial resolution of 30 m (Table 1; Figure 2). The display processing analyses of these images were carried out by using Remote Sensing and Geographic Information Systems technologies. Information on changes occurred in the coast due to fieldwork and the active use of coastline were collected.

Satellite images are widely used in determining many environmental problems today by converting them into numerical or visual images. In display systems, at what level the environmental problems of the past and the present have been can be calculated in a detailed manner by satellite images that were subjected to the enrichment and classification processes (Gazioğlu, 1997). GIS and Remote Sensing techniques, together with satellite images are widely used today in determining enviromental problems that occur in coasts and changes in land covers since coastal areas are places where population and urbanization are very intensive (Cardille and Foley, 2003). Some of the Remote Sensing techniques are Digital photogrametry, the Principal Component Analysis (PCA), Normalized Difference Vegetation Index (NDVI), Classification, Tasseled Cap (TC) transformation method (Genç et.al., 2010).

Table 1: Features of Satellite Images used in the Study.

Satellite	Perception Date	Resolution (m)	Number of Band
Landsat – 5 TM	1984 - TM	30	7
Landsat – 5 TM	2003 - TM	30	7
Landsat – 5 TM	2011 - TM	30	7

The data obtained from satellites make a major contribution to the study of the earth. The software, which was used because they both brought great impetus to data processing and helped in the storage of a large volume of data, had also proved to be significant in the realization of this contribution (Maktav, 1993). Therefore, all the data obtained in the study were evaluated by Erdas Imagine 10 software program which is a remote sensing sotware and then, they were also analyzed in GIS ArcGIS 10 software program.

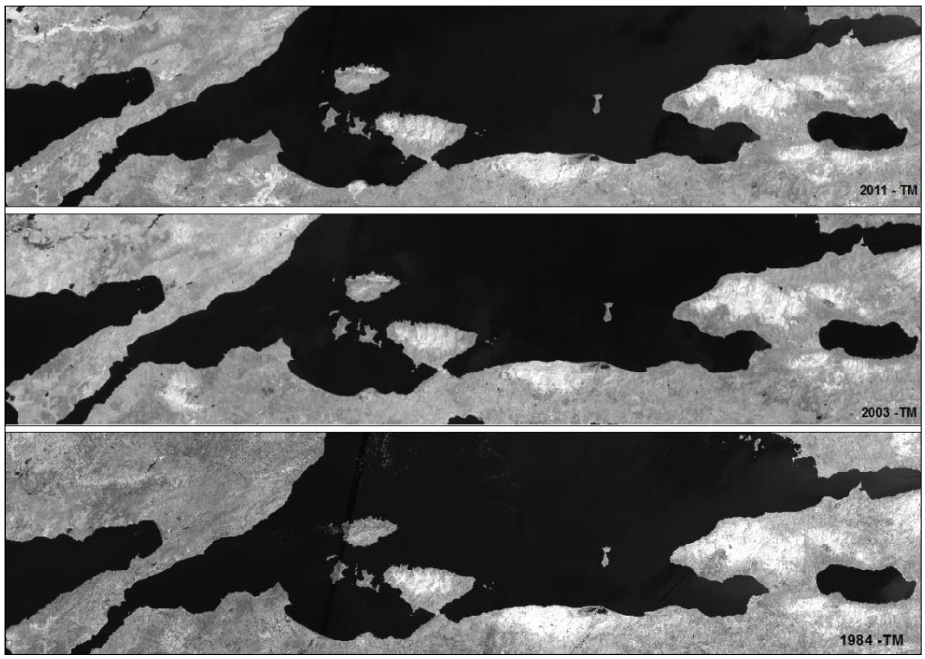

Figure 2: Landsat Satellite Image Used in the Study (Band 4).

Principal Component Analysis (PCA) technique was used due to its capacity to distinguish the difference between land and water in the determination of coastal line of the selected years. PCA is a technique used for the creation of new image after removing the relationship between multispectral images and reducing images in several bands into the desired number of bands (Munyati, 2004, Mausel, 2004; Almutairi and Warner, 2010). This technique is important because it gathers a significant part of the data in multispectral bands

into the channels of first component and reduces the correlation between image bands. Principal Component Analysis (PCA) is a method preferred in the reduction of the number of bands prior to image compression, image enhancement, change detection and classification (Loughlin, 1991; Akça and Doğan, 2002; Alparslan et al., 2004; Munyati, 2004). Thematic maps (TM), produced as a result, have been transferred to the environment of Geographic Information Systems through the conversion of raster data into vector data. Coastal lines have been revealed as a result of the analyses carried out by the newly-obtained images.

Results And Discussion

The north and northeast coasts (İstanbul and Kocaeli) of the Marmara Sea, which are under intensive industrial and population pressures, have been confronted with an enourmous change by being negatively affected due to improper development practices and intensive use. In order to prevent this, new areas were added to these areas by performing coastal fillings with the Reconstruction Act passed in 1984 and coastal areas have been tried to be expanded (KK; 1984; Gülez, 1997; Gülkal, 2004; Dede et al., 2004; Kurt et al., 2011; Döker, 2012; Kurt, 2012). Approximately an area of 3 km² was acquired from the sea through filling as a result of the work covering the period of 1963-2005. Coastline was changed by filling an area of 906 hectares between 1987 and 2007 (Döker, 2006; Kurt et al., 2010).

Other areas, where change in coastline can be seen as a result of similar land uses although at a lesser extent than the northern coasts, are the southern coasts of the Marmara Sea. They have been opened for intensive use in many places due to improper development practices and this caused the occurrence of coastal changes. A temporal change has taken place along the coastline starting from Çanakkale-Çardak and continuing until Yalova-Kocaeli provincial border due to filling operations. It was observed when looking at satellite images of 1984 and 2008 that coastline trailed the present coastal road in many places, but the original coastline was changed especially in the shorelines of city centers by landfills as seen in the images of next period, namely 2003 and 2011 (Photo 1; Figure 3).

The coasts of Yalova Province are one of the areas where the change in coastline can clearly be seen and which is located on the east of the research area between 39-40 northern latitudes and 29-61 eastern longitudes. Yalova, which has an area of 847 km² and a coastline of 126 km in length, is a coastal settlement inhabited by 220.122 people (TSI, 2014).

Photo 1: Coastal Filling Area of Yalova City Center (Orthophoto Image of 2008).

The landfills in the coasts of Yalova were being made between 1984 and 2003 and, on the other hand, they also continued and were completed between 2003-2011 when comparing the results obtained from Landsat satellite data of the years 1984-2003-2011 (Figure 3). An area of 0.4 km² between the years 1984 and 2003, and 1.94 km² between the years 2003 and 2011 were acquired from the sea due to landfills. As a result of this, the coastline, which was 116 km in 1984, has reached to 126 km in 2011 (Tables 2 and 3). The reason why the most prominent change in coastline was observed between the years of 2003 and 2011 was because Yalova had become a province in 1994 and settlements in coastal regions, roads, touristic and industrial organizations have continued to increase as a result of the immigration the province attracted (Özdemir and Bahadır, 2008; Kurt and Haybat, 2014). During this period, fishing port, marina, ferry dock and green spaces were built in an area of 11 hectares according to the filling plans made with the aim of building a shipyard (Boat Berth, Construction, Maintenance and Repair) in the area between Topçular Pier-Tavşanlı District and Hersek Cape and approved by Ministry of Public Housing as well as several other sub-scale development plans accepted in 2005 (7069). An area of approximately 362.000 km² was filled only in the coasts of central district of Yalova province between 1984-2011 according to 1:1000 scale Development Plans of Housing and Urbanization Directorate of Yalova Municipality (Erdem, 2014).

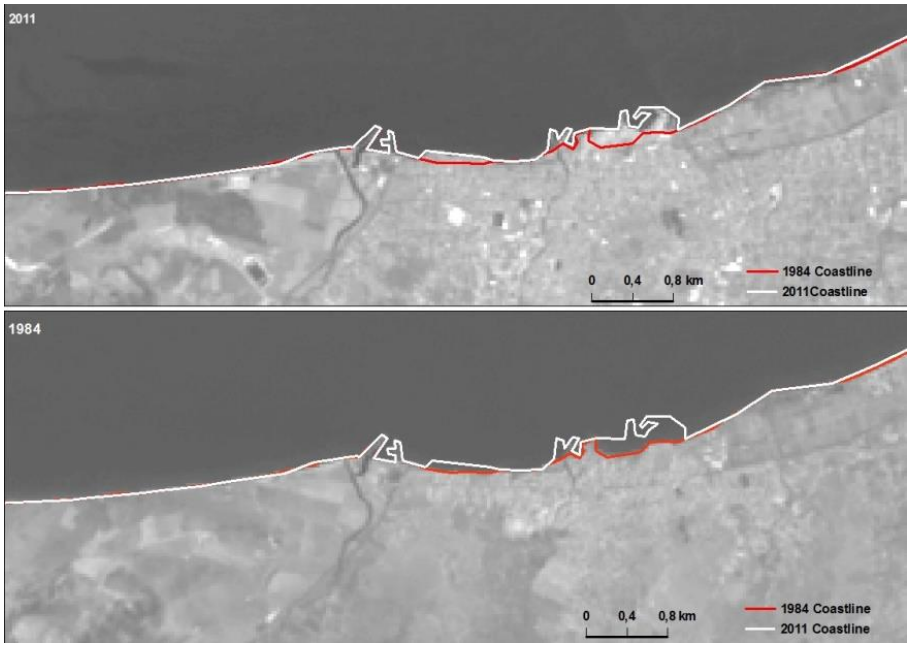

Figure 3: Coastline Evolution in Yalova Coast During the Period 1984 - 2011.

Table 2: Coastal Change (1984-2003)

City	Filling Area (km²)	Beach (km²)	Excevation (km²)	Coastal Length (km) (1984)	Coastal Length (km) (2003)	Coastal Length (km) (2011)
Çanakkale	0,42	0,86	0,05	110	110	117
Balıkesir	0,57	0,03	0,21	183	186	193
Bursa	0,68	0,37	0,21	112	120	124
Yalova	0,4	0,02	0,005	116	119	126
Total	2,07	1,28	0,475	521	535	560

Table 3: Coastal Change (2003-2011).

City	Filling Area (km²)	Beach (km²)	Excevation (km²)	Coastal Length (km) (1984)	Coastal Length (km) (2003)	Coastal Length (km) (2011)
Çanakkale	0,44	0,27	0,02	110	110	117
Balıkesir	0,68	0,26	0,01	183	186	193
Bursa	0,63	1,57	0,012	112	120	124
Yalova	1,94	0,03	0,008	116	119	126
Total	3,69	2,13	0,05	521	535	560

The coastal usage in filled areas has been utilized as transportation, shopping and recreation (Photo 2). The road, built in the meeting place of the

filling area and land, provides service for vehicle traffic. Recreation areas, pedestrian walkways, bike paths, sports fields and children's playgrounds extending parallel to the coast can be found between highway and new coastline. However, these areas are under great risks due to both ground conditions and their proximity to the fault line (Alpat, 1999; Şahin and Tari, 2000; YÜksel et al., 2000; Tercer, 2005).

Photo 2: Orthophoto Image of the Filling Area on the West of Yalova and Coastline of 1984.

Today, a coastline of approximately 5 km, which covers agricultural, touristic and residential areas in Altınova (Tavşanlı) region of Yalova Province, is planned to be made a ship-building yard after having been filled. Within the scope of the project, an area of 4.5 km in length and 300 meters in width, which remains on the sea-side of the coastline in the Civil Administration borders of Altınova district, is planned to be allocated for establishing ship-building yards, and social facilities and industrial areas in the background after being filled and ground filling operations were completed in 2008 (Figure 4). However, the area should be utilized for solution purposes due to environmental issues, pollution, agricultural activites, touristic and earthquake risks as well as ground problems when considering the long-term negative effects of improper use in coastal areas (Alpar, 2005; Yalman, 2012; Report of Yalova Governorship, 2014).

One of the coastal areas in Yalova province, where landfills were carried out although less than northern coasts, is the coast of Armutlu district in the south. The coastline and coastal appearance have changed as a result of the housing activites and filling operations that become a current issue in coastal regions of Armutlu which has the characteristics of a coastal settlement that meets with the holiday needs of metropolitan cities especially İstanbul due to its natural features and geographical location.

One of the areas seen the change of the coastal line and the coastal area of Hersek Delta. Hersek Delta protruding into the Gulf of Izmit where the intensive usage of coastal and changes of coast in regions of Turkey. Eastern of Hersek Delta has as well as for the long term development of the natural morphodynamic of the delta that have occurred over the last 10 years within the process of the humanities, where the changes originated in the area.

The coasts of Çınarcık, Çiftlikköy, Altınova and Central district are seen to be at risk when considering 86.7 % of total population (183.639 people) in Yalova live in the coastline (Kurt ve Haybat, 2014). Damages in 12 % of the housing (9474 units) and 10 % of the businesses (726 units) after the Marmara Earthquake of August 171.999 as well as the loss of 3000 lives during the earthquake also confirm this situation (Yüksel et al., 2000; Şahin and Tari, 2000; JICA, 2004; Alparslan et al., 2004; Bulut and Aktar, 2007; Özdemir and Bahadır, 2008; Alarslan, 2011). This region is expected to face significant risks in the next earthquake that will occur within the Sea of Marmara due to factors such as liquefaction, subsidence, and deformation of soft alluvial clay layer in the coastal structures and port management built on the landfills located within the domain of the (Yüksel et al., 2000; Yılmaz, 2005).

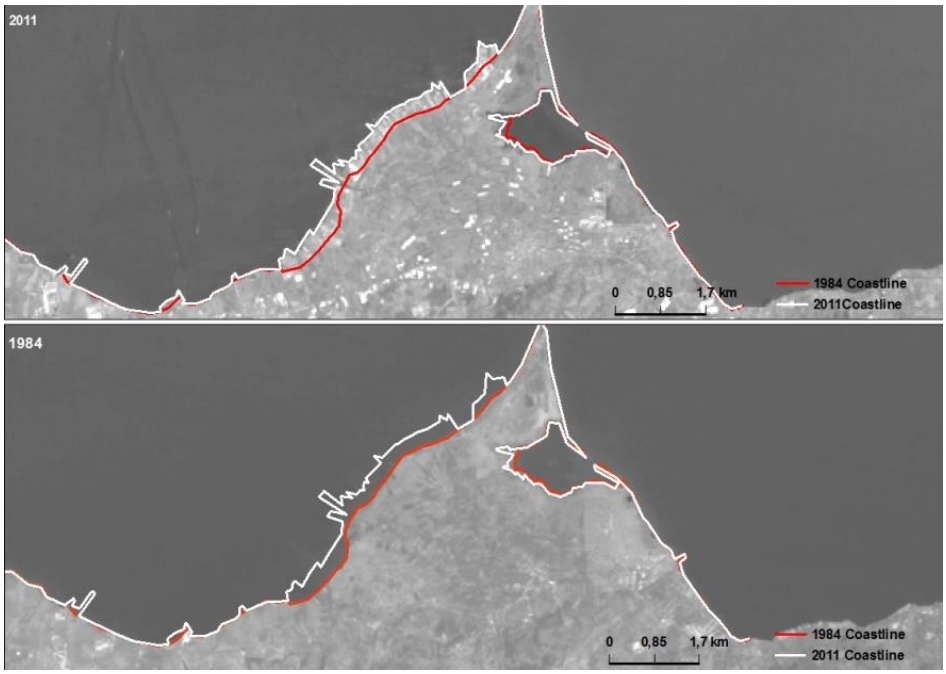

Figure 4: Coastline Evolution in Altınova Coast during the Period 1984 - 2011.

The coastline is seen to change with the coast filling operations in Gemlik and Mudanya districts of Bursa in the coasts of the Marmara Sea when satellite images of the years 1984, 2003, and 2011 as well as the coastlines

obtained from these were analyzed (Figure 5). An area of 0.68 km² between the years 1984 and 2003, and 1.31 km² between the years 2003 and 2011were acquired from the sea due to landfills (Tables 2 and 3). Landfills were being made in an area of 4000 m² with the length of 1200 m and widths ranging between 20 and 50 m² according to the data from of Science Affairs Directorate of Gemlik Municipality. The greening and landscaping work on the filled grounds still continue (Gemlik Municipality, 2014). The coastline, which was 112 km in 1984, has reached 124 km in 2011 with the effect of the landfills (Table 4).

Table 4: Coastal Change (1984-2011).

City	Filling Area (km²)	Beach (km²)	Excevation (km²)	Coastal Length (km) (1984)	Coastal Length (km) (2003)	Coastal Length (km) (2011)
Çanakkale	0,86	1,13	0,7	110	110	117
Balıkesir	1,25	0,29	0,22	183	186	193
Bursa	1,31	1,94	0,22	112	120	124
Yalova	2,34	0,05	0,01	116	119	126
Total	5,76	3,41	1,15	521	535	560

It was observed in the results obtained from its image in 1984 that the coastline, between Gemlik-Mudanya, continued throughout the existing coastal road, but the primary coastline changed in the images belonging to a later period of 2003 and 2011 due to the completed areas of coastal fillings. These landfills serve today as harbor, transportation, shopping and recreational areas. Seabus dock and passgenger terminal can be found on the Güzelyalı coast of the landfill. This dock carries passengers between İstanbul and Yenikapı (Photos 3 and 4). The main road, which partly passes through the acquired land from the sea and partly on the old coast, serves the heavy vehicular traffic in the joining area of the landfills between Gemlik-Mudanya and the land.

Photo 3: Güzelyalı Seabus Dock where Passage to İstanbul is Provided (2013).

Photo 4: Recreational Filled Area on the Coast of Gemlik (2013).

The length of coastline in Gemlik district, whose coasts are largely filled, is approximately 44 km. Gemlik district, like other port cities on the coasts of Southern Marmara, has been one of the cities which were greatly influenced by port cities such as Bergama, Efes, Milet and Bodrum, in terms of transportation at about 2600 years ago and it still continues to maintain its importance today as an area for sea trade together with 4359 sailors registered in the Port Authority. The length and depth of the Municipality Pier, which was built on the coast for import-export activities, are 125 m and 6 m respectively. Gemlik Pier was left for transportation services with the launch of Gemport Port which was built in 1992 as the first private port in Turkey. Other ports, built on the filled ground in the area, are Borusan and Roda Ports (Kamış, 1993; Yalman, 2012; Baki, 2013; Figure 5).

The place, in which the filling operations are the least in the coasts of Bursa at the Marmara Sea, is the district of Karacabey. The filled ground cannot be found in this region except small pier and fishing shelter. However, the coastline was seen to change due to sand removal for construction purposes from the mouth of Kocasu (Kocaçay) river (Figure 6). Sand was confirmed to be extracted from an area of 0.21 km² between the years 1984 and 2003 and from that of 0.22 km² between the years 2003 and 2011 in this area (Tables 2, 3, 4). The illegal sand extraction from one of the four areas with international significance and natural reserve features in the coasts of Nortwest Anatolia has disrupted the formation of weir and narrowed the connection between weir gates and the sea (Sayılı et al., 1997; Kazancı et al., 1999).

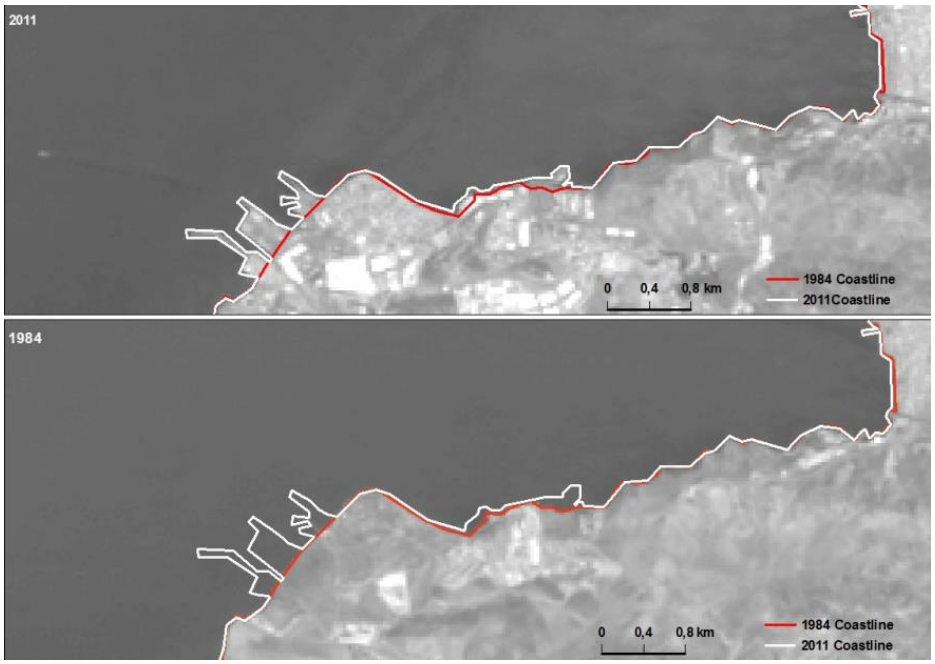

Figure 5: Coastline Evolution in Gemlik Coast during the Period 1984 – 2011.

It is worth-noting when satellite data from the years 1984 and 2011 were analyzed that the coastline is apparent in the coasts of Balikesir at the Marmara Sea especially in the residential areas found in the Gulf of Bandirma and Erdek. The factors, which caused the coastline change in this region, are coast filling operations carried out in the coasts of Bandırma and Erdek districts and sand extractions from the shores of Gönen Stream. The coastline was changed for the purpose of port, pier, road and recreation by filling an area of 0.57 km² between the years 1984 and 2003, that of 0.68 km² between the years 2003 and 2011 and an area of 1.25 km² between the years 1984 and 2011 in total. As a result of this, the coastline, which was 183 km in 1984, has reached to 193 km in 2011 (Tables 2, 3, 4).

Bandirma, which is Balikesir's gateway to the Marmara Sea, is the district where the coastline change can be monitored most apparently. The district, which is established in the southern coast of the gulf in 31 km in length with the same name, is one of the busiest areas of the South Marmara with its surface area of 690 km² and population of 143.171 people (TSI, 2014). The coastline of 1984 in the coastal band of Bandırma district passes at some places from the residential housings and in front of cliffs yet in other places according to the results obtained from the data and coastline of 1984. However, the coastline changed with landfills and these structures took cliffs within the coasts (Photo 5).

Photo 5: Coastal Landfills that Serve to the People of Bandırma as a Walking Area (2013).

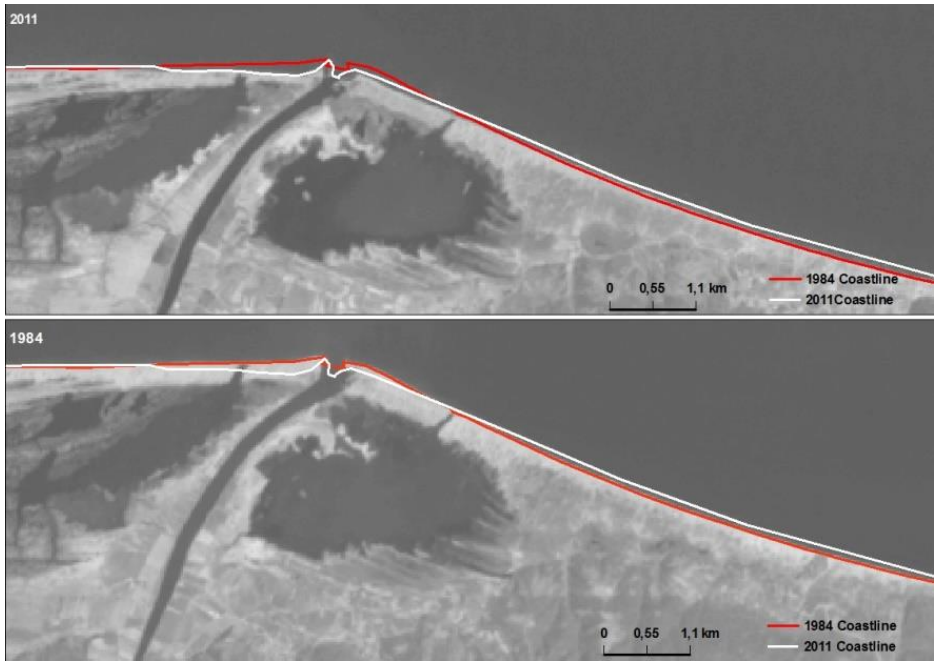

Figure 6: Coastline Evolution in Kocaçay Coast during the Period 1984 - 2011.

Pedestrian excursion and recreational areas, which are located in the area extending from Bandırma Yacht Port to Ferry Terminal and which are built on landfills, also cause change in coastline. Other proofs of historical coastline change are Haydar Çavus Mosque and historical structures located on the coastline of Bandırma coast in 1930. These structures, together with Bandırma Fortress and walls, remained inside with the construction of Bandırma Port and Ferry dock (Photo 6). The coastal change in this region during the construction of Badırma Port was also reflected in the satellite images of 1984-2003. These

coastal arrangements also continued in these years when looking at the Landsat data obtained in the years of 2003-2011.

Photo 6: Bandırma Coast in 1930 (on the left) and today (on the right).

Today, various environmental arrangements have been made on the filled area which is situated between IDO Terminal and old pier after preparing a plan that includes touristic and social facilities, recreation and relaxation areas as well as sports facilities (Figure 7). The construction of fishing shelter and environmental arrangements on Levend coast, through a project pursued in 1995 by General Directorate of Railways, Ports and Airports Construction, also confirm that these filling operations still continues (Baykal and Büyükgüllü, 1996; Demir et al., 2000). However, the structures, built on the filled area, are at greatest risk since Bandirma is located on the first degree seismic belt.

Fıgure 7: Bandırma Coastal Band Project.
Source:http://www.gmka.org.tr/uploads/downloads/dosya/bandirma_ilcesi_bilgi_notu.pdf

Being the most developed district of South Marmara in terms of tourism located on the western coasts of Kapidag Peninsula, Erdek district has long beaches (6 km) that start from the coasts of Edincik and extend until Çuğra in addition to landfills built on the coasts of city center for recreation and port purposes. The presence of large trade wharf apiece in Greek sea was mentioned in accordance with the information about Erdek obtained from the travels of Evliya Çelebi in 1659. It was suggested about the physical characteristics of Erdek that city had a busy pier on the coast of the sea, its southern coats were

hilly and its slopes were covered with vineyards throughout (Çelik, 2012; Kurt and Ekinci, 2014).

It was observed when analyzing the satellite data and orthophoto images that there was no change in the coastlines of the northern areas except Erdek and Bandırma Bays of Kapıdağ Peninsula. No landfilles or coastal arrangements were seen in this region except a small pier and fishing shelter.

Gönen district, which has a coastline of 26 km located on the coast of Balıkesir in the Sea of Marmara, is an area where no landfills can be seen. However, the coastline, especially in the mouth of the river and its surroundings, was seen to change due to sand extraction for construction purposes from an area of 0.22 km² in the shores of Gönen stream between 1984 and 2011 (Figure 8).

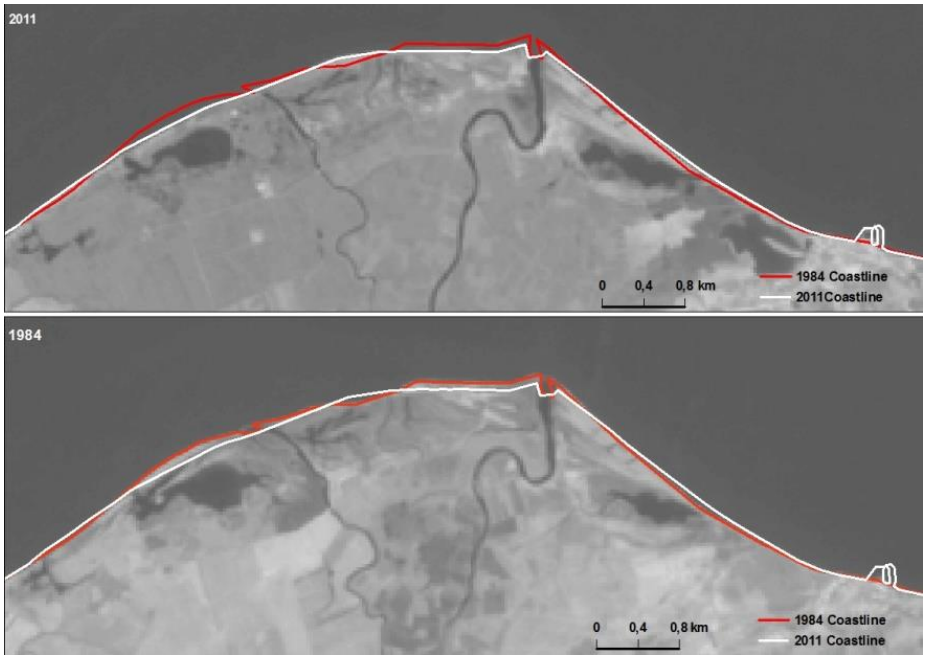

Figure 8: Coastline evolution in Gönen Coast during the period 1984 - 2011.

The coastline change between Çanakkale-Çardak and Balıkesir-Gönen also emerges before us when the satellite data of 1984-2003-2011 were analyzed. The factors that cause the coastline change in this region are the landfills made for the purpose of pier in Lapseki and Biga districts. An area of 0.42 km² was filled according to the satellite data belonging to 1984 and 2003. A total area of 0.82 km² was filled due to new arrangements until 2011 and thus the coastline was changed (Figure 9; Tables 2, 3, and 4). While the length of coastline (Çardak-Gönen) in the research area of Canakkale province, which was

established in an area of 9737 km² on Gelibolu and Biga Peninsula, was 110 km in 1984 as a result of these works, it reached 117 km in 2011(Table 4).

No major change was observed in the coastline between Çardak and Gönen since coastal filling and arrangement operations in the coasts of Çanakkale's research area at Marmara Sea were only in port, pier and fishing shelters. The primary changes in coastline are in the shores of provincial center. The coastline and natural appearance in this region were changed with the construction of yacht marinas and freight and passenger transportation ports, as well as landfills and arrangements for the recreational purposes. For example, Çanakkale Yacht marina, one of the latest arrangements made in the coast, was designed to be built on the filled area of approximately17852 m² and on the area of 7667 m² in the land (Gülver ve Batmaz, 2011).

The coasts of Lapseki and Biga districts mostly consist of holiday resorts for touristic purposes. The arrangements, which were made in Dalyan and Çardak Beaches in the West, Şevketiye Holiday Resort, Gürecealtı, Adatepe and Suluca and throughout the coasts of Kemikalan and Kangırlı, meet the needs of both the locals and the tourists. Çardak Sand Sets, Azmak Laguna Lake, Çardak Natural Protected Area, Bayramdere Archaeological Site and Dalyan Archaeological sites are also other important areas (Veznikli et al., 2007; Akdemir et al., 2008). Biga district, which has the longest coasts of Çanakkale province, covers 10.65 % of total coastal length of Çanakkale with the length of 71.6 km (Strategic Plan, 2013). The coastline was changed by filling an area of 044 km² in district shores for the purpose of building pier.

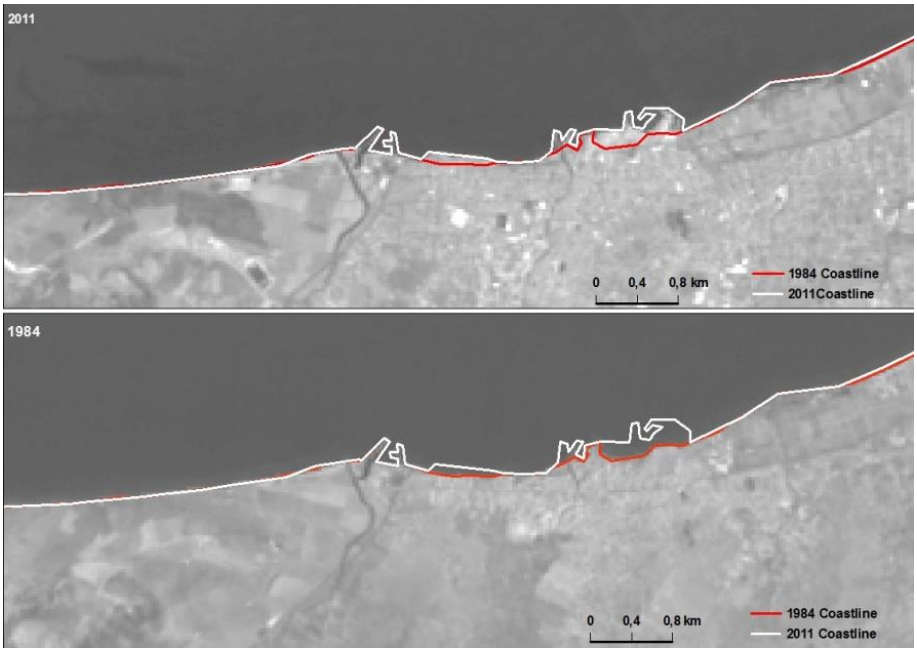

Figure 9: Coastline evolution in Degirmencik (Biga) Coast during the period 1984 – 2011.

There is a sand and gravel accumulation in the shape of fish hook with the length of 4.3 km in an area of 15-45 km in width located on the coast of Çardak towards Dardanelles (Figure 10). A lagun and lake of 400-800 m in width and 4 km in length were formed behind this set due to acculumation of gravel and sand in 2.5 km southwest carried by Bayramdere, which is 5 km in the east of Çardak, to the Marmara Sea. It has been declared as a natural protected area in order to prevent the deterioration of natural landscape by extracting sand from the coasts of the area with its rare reeds and grasses (Atabey, 1998).

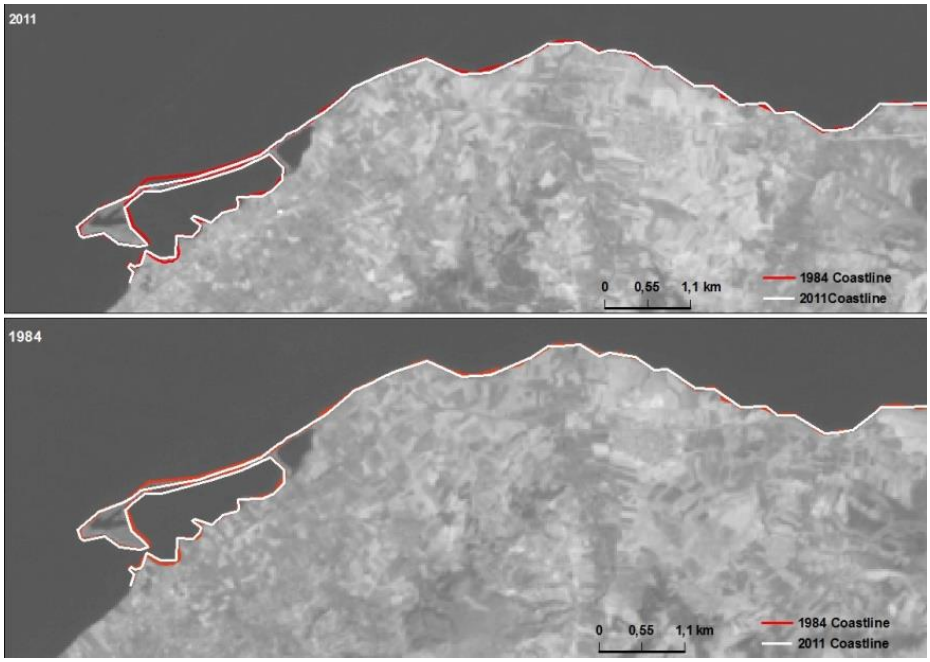

Figure 10: Coastline Evolution in Çardak Coast During the Period 1984 - 2011.

Conclusion

The change in the southern coasts of the Marmara Sea was determined by using backdated temporal satellite data (Landsat satellite data of 1984-2003-2011) in this study conducted using Remote Sensing and Geographic Information Systems methods. As a result of the analysis from these data, the coastal length between Çardak-Yalova, which was 521 km in 1984, was identified to be 560 km in 2011 when looking at the southern coats of the Marmara Sea. An area of approximately 5.76 km² was acquired from the sea through landfilling. In this study, the most obvious coastal change was seen to be in the coasts of Yalova, Gemlik, Mudanya and Bandırma. The coastal bend,

located in Lapseki, Gelibolu, Gönen, Karacabey and in the south of Kapıdağ Peninsula, still remains to be a natural coastline.

Coastal landfills are generally used as recreation, transportation, accommodation and shopping areas. The landfills for recreational purposes comprise of usages such as pedestrian and bicycle paths, tea gardens, children's playgrounds and recreation and picnic areas. Units of sea transportation and coastal road located just behind the coast attract attention in the areas allocated for the use of transportation.

Even though irregular settlements in the coastal areas of cities cut off people's contact with the sea, the solution of filling the coasts was found for the purpose of recreating green spaces in the interest of the public. However, the coastal areas, which have sensitive ecological features, face with pressures of tourism and urban-based developments due to these landfills in the coasts. Therefore, coastal landfills in the southern coasts of the Marmara Sea gradually destroy the natural coastal spaces and the coastline also lost its original appearance. Since no study was found on the prevention of coastline change in the research area, this increases the possibility for the continuation of coastline changes in the future. However, the coasts are one of the areas to conduct studies on the preservation of the natural environment.

Other issues that draw attention in the research area are the existence of active faults in the Marmara Sea and its surroundings and damages to the buildings in Yalova in the Gölcük-centered earthquake in 1999. This case reveals a great risk in landfills. The coastal areas will suffer greatly due to waves to be occurred in the coast as a result of the earthquake. Although how much was the risk for landfills that will come up as a result of seismicity not known before the earthquake of 1999, this risk is needs to be considered for current landfills. Settlements and housing should be shifted from the coastal areas to inner lands due to the risk of earthquake.

Preserving ecological balance and providing sustainability of natural environment should be aimed while making coastal landfills and by preventing housing in the coasts.

It is necessary to carry out actions intended to preserve these non-renewable natural resources that are damaged due to rapid population growth and housing associated with industrialization, to approach problems with an insightful perspective, to make accurate planning, and to implement necessary solution suggestion in place and on time.

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