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Full Length Research Paper

Mapping and monitoring temporal changes for coastline and coastal area by using aerial data images and digital photogrammetry: A case study from Samsun, Turkey

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Coastline and coastal areas are not only the supports for local economics based on fisheries and agriculture, but also, a source of food and energy, apart from offering diverse opportunities for recreation and tourism. Moreover, they provide protection to coastlines against storms and other meteorological perturbations. Coastline mapping and coastline change detection are critical for coastal resource management, coastal environmental protection and sustainable coastal development and planning. Changes in the shape of coastline may fundamentally affect the environment of the coastal zone. These may be caused by natural processes and human activities. The coastal areas of Turkey have been under an intensive restraint associated with a population press due to the internal and external touristic demands. Aerial photos with a medium spatial resolution and high resolution satellite imagery are ideal data sources for mapping coastal land use and monitoring their changes for a large area. This research is focused on the coastline monitoring and its potential change estimation by digital photogrammetry techniques using aerial data images at the eastern coasts of the Black Sea in Turkey. The study area includes the coastal zone located in Samsun, Turkey coasts. The aim of this study is to analyze coastline changes in 1935, 1972 and 2006 in Samsun, using aerial data images. Results show that digital photogrammetry, which is using the images as data source, are an effective approach for monitoring coastal land use status of large area, and over 95.32 ha areas were filled up along the coastal land between the 1935 - 1972 periods and over 70.74 ha areas were filled up along the coastal land between the 1972 - 2006 periods in the study area. Consequently, coastal land use change monitoring is necessary for coastal area planning in order to protect coastal areas from climate changes and other coastal processes. It is found that significant changes in land cover occurred during the study period.

Key words: Coast, coastline, digital photogrammetry, aerial photos, coastal mapping, coastal area.

INTRODUCTION

Knowledge of coastline is the basis for overcoming coastal problems, measuring and characterizing land and water resources such as the area of the land and the perimeter of the coastline (Kuleli, 2009). Coasts are unique environment in which atmosphere, hydrosphere and lithosphere contact with each other. The coastal areas are a highly dynamic environment whose multiple geophysical parameters are worth monitoring. Monitoring the evolution of the coastline is an important task in several applications such as cartography and the environmental management of the entire coastal zone (Alesheikh et al., 2004; Dellepiane et al., 2004). Understanding of coastal land use changes is essential for sustainable coastal zone planning and management as it allows decision makers to take a broader view of the ecosystem and its components (Doygun and Alphan, 2006). Coast lines, which are one of the components, are recognized as unique features on the earth (Lockwood, 1997; Li et al., 2003, 2001). The coastline can be defined as the line of contact between land and a body of water (Pajak and Leatherman, 2002; Alesheikh et al., 2004). This is a border line on a local scale representing the limit of dry land on a map (Almagor, 2002; Klein and Lichter, 2006).

In recent years, the coastal zone, probably more than any other part of the society has been exposed to pressure and processes of change. Among these changes are urbanization and new infrastructure, exploitation for recreation and tourism, acute nature and environmental problems, retreat of coastal occupations, reorganization of freight traffic between land and sea and changed functional demands and working conditions for harbours (Anker et al., 2004). Coastal areas are important natural habitats, which must be conserved (Williams, 1990). However, human activities in these areas may be fairly related to alternations of coastal lands (Ringrose et al., 1988; Jensen et al., 1995; Gerakis and Kalburtji, 1998; Chopra et al., 2001; Wang et al., 2006). Coastline changes may be caused by natural processes and/or human activities. The natural processes include phenomena such as waves, currents and storms. The human activities involve changes in the environment, sometimes expressed as modification at landscape levels. The magnitude of these activities and their effects are related to urban growth, and therefore, urban development must be seen as part of the ecological systems (Bailly and Nowell, 1996; Bedford, 1999; Ji et al., 2001; Jackson et al., 2001, Ruiz-Luna and Berlanga-Robles, 2003).

Examples of human activities affecting the coastline are land reclamation, recreation at beaches, land use practices and construction in coastal zones. Coastline changes produce a positive or negative impact. For instance, coastline accretion may create more usable land for recreation or other purposes, which is a positive phenomenon. However, a resort usually close to the beach may, after accretion, be out of the view of the new beach and thus, unattractive to tourist visitors. Also, this is a negative phenomenon. On the other hand, coastline erosion may cause problems if it develops towards, for instance, a residential area. As a result, it can be said that changes in the shape of the coastline may fundamentally affect the environment of the coastal zone (Li et al., 1998; Wang et al., 2006).

Coastal areas are easily accessible, making them centers of human activity, where people live and derive their recreation and means of livelihood. Industrialization and urbanization are recent phenomena and consequences of human activity looking for economic development, which is leading to serious degradation of the ecosystems, especially pollution and habitat encroachment along the coast of Samsun. Population increases, together with rural and urban activities, directly affect the availability and quality of natural resources, but also induce secondary effects that must be evaluated from a regional view (Sekhar, 2005; Ayad, 2005). Moreover, substantial changes are taking place in the coastal landscape as a result of rapid urbanization. A series of environmental and resource problems have emerged owing to rapid urban development, including encroachment of agricultural land, land reclamation, silt deposition in rivers and severe flooding.

The use of satellite-based remote sensor data has been determined to be a cost-effective approach to document changes over large geographic regions. However, results to date indicate that no uniform combination of data type and analytical method can be applied with equal success across broadly variable ecosystem conditions (Lunetta et al., 2002, 2004; Zhan et al., 2002). The recent development of geospatial technologies, such as remote sensing (RS) and geographic information systems (GIS), can play an important role in such tasks of coastal management (Mumby et al., 1995). Remote sensing and GIS have been used in various coastal zone studies, such as in the mapping of coastal ecosystems (Augusteijn and Warrender, 1998; Chauvaud et al., 1998; Henderson et al., 1999), change detection (Brivio and Zilioli, 1996; Ciavola et al., 1999; Sesli et al., 2009), biotope mapping (Downie et al., 1999), frontal systems (Uncles et al., 1999) and monitoring (Pasqualini et al., 1998; Rao et al., 1999; Donoghue and Mironnet, 2002).

In recent years, remote sensing and photogrammetry have been used in a widespread manner for the purpose of following the change in the coastal area management and the use of the coast. A change could be revealed as a result of assessing the photographs on these different time zones by taking old and new photographs of the region which are chosen in order to follow the change on the coast. Following the change on the coastal line with the help of photogrammetry, remote sensing is much more practical compared to topographic measurements. With these methods, developmental route of the environmental problems which are experienced in the past could be observed step by step. By this means, it is possible to calculate the dimensions and effects of the change (Chopra et al., 2001; Sesli and Karsli., 2003; Dellepiane et al., 2004; Kuleli., 2009). In various studies, different applications such as following the change on the coastal line, determining the amounts of the coastal erosion, determining the border line and immovable structures violating the border line, determining the size and changes of deltas and lakes, etc. have been carried out by using the methods of remote sensing, photogrammetry, digital photogrammetry, image processing and assessment by means of providing current, high-resolution satellite images or aerial photos of coastal areas (Weng, 2002; Chen, 2002; Shaghude et al., 2003; Alesheikh et al., 2004; Siddiqui and Maajid, 2004; Ayad, 2005; Kuleli, 2005; Muttitanon and Tripathi, 2005; Vanderstraete et al., 2006; Ekercin, 2007; Wu, 2007; Zhang et al., 2007; Bayram et al., 2008; Ghanavati et al., 2008; Sesli et al., 2009; Kuleli., 2009; Sener et al., 2009).

In this research, aerial photographs from 1935, 1972 and 2006 were used to investigate the coastal changes that took place over the last 70 years along the coastal area. Using the digital images, the digital photogrammetric technique was applied to collect graphic data such as coastline and other topographic features of the study area. The objective of this research was to apply the technique digital photogrammetry to monitor the coastal area of Samsun so as to provide valuable information for coastline changes and coastal land uses.

COASTAL LEGISLATION IN TURKEY (ACCORDING TO THE COASTAL LAW NUMBERED 3621/3830)

Coastline

It is a natural line that changes on the sea, lakes and rivers due to some meteorological events that are formed by the fusion of the points on which the water touches the earth on the positions other than flood.

Shore border line

It is a natural border of sandy, gravel, rocky, marsh, rushy and other similar areas formed by the water mations against the earth after the coast line of sea, lakes and rivers. This border can not be changed even though the sea is filled to obtain land.

Coast

This is an area between the coast and shore border line.

Shore buffer zone

It is an area of at least 100 m and is horizontally located from the shore border line of the sea, lakes and rivers to the earth.

The detection of a sash as shore buffer zone especially in the developing countries, aims to prevent it from coastal erosions, provide public reach to the coast and be open to coastal view (Sorensen, 1993). According to the article 43 of the Constitution Law of Turkish Republic, the coasts are at the disposal of the government. In utilizing from the sea, lake and river coastlines, one must first take care of all the ‘public benefit’. According to the 2001 till date Turkish Civil Law, the places with no property and goods in the benefit of the public are in no one’s landownership and can never be a subject of a private landownership. According to the Coastal Law numbered 3621/3830, the detection of the shore border line is obligatory to be able to make plans and also plan the implementation on the coast and shore buffer zone; but unfortunately, the usage of public benefit is being seen because of the agitation in planning and the detection of shore border line not in the way or at the time it must be done (Sonmez, 2002).

COASTAL ASSET IN TURKEY

In the present day, the population in coastal areas is equal to the entire global population in the 1950s. Most of the world's largest cities are located in coastal areas. Various estimates suggest that the populations of the world's coastal zones represent approximately 60% of the total world population (Sorensen, 1993). The world's population is predicted to reach 8.5 billion by the year 2050 and the growth in coastal areas is estimated to be disproportionately higher (Fernandes and Read, 1997).

Turkey has a very long coastal zone and three sides of its area are surrounded by the Mediterranean, Aegean and the Black Sea, which are 1707, 3484 and 1701 km long, respectively. The Sea of Marmara (1441 km) located between the Black and Aegean Sea is a water body connecting these two basins via the Turkish Strait Systems (Istanbul and Canakkale Strait). Littoral of the Turkey land totals 8333 km with the islands (Burak et al., 2004). There are totally 28 cities and about 220 municipalities in only the coastal area of the Mediterranean, Aegean, the Black Sea and the Marmara regions. Generally, these are 38% of the total cities and have 53% population of the entire population in Turkey. Of the Turkish population, 20% live in coastal cities and towns, located wholly in coastal regions. Besides, the population of the cities in coastal areas has rapidly increased due to new policies and encouragements of the tourism after 1985 (Ongan, 1997).

Environmental conditions such as the climate, topography and the characteristics of habitation vary in the coastal regions of Turkey. Therefore, several problems appear in the applications related to coastal planning. In addition, Turkey has cultural and historical merits, especially natural attractiveness. So, various investors prefer these areas. However, this situation causes many environmental problems in coastal areas. In the coastal region of Turkey, sea and water pollution prevented the public from accessing the coastline. Also, contradictions and insufficiencies in legal arrangements, coastal erosions, filling the coasts with the aim of acquiring property, unbalanced construction that caused unplanned urban areas, scattered buildings, environmental buildings, destroying water sources, coastal region having insufficient social and technical infrastructure, uncontrolled urbanization and insufficient service appearance, unbalanced developments in coastal areas that result in land occupation and filling to obtain land parts that violates the public benefit prevented the public from accessing the coastline (Kuleli, 1998; Sesli and Aydinoglu, 2003).

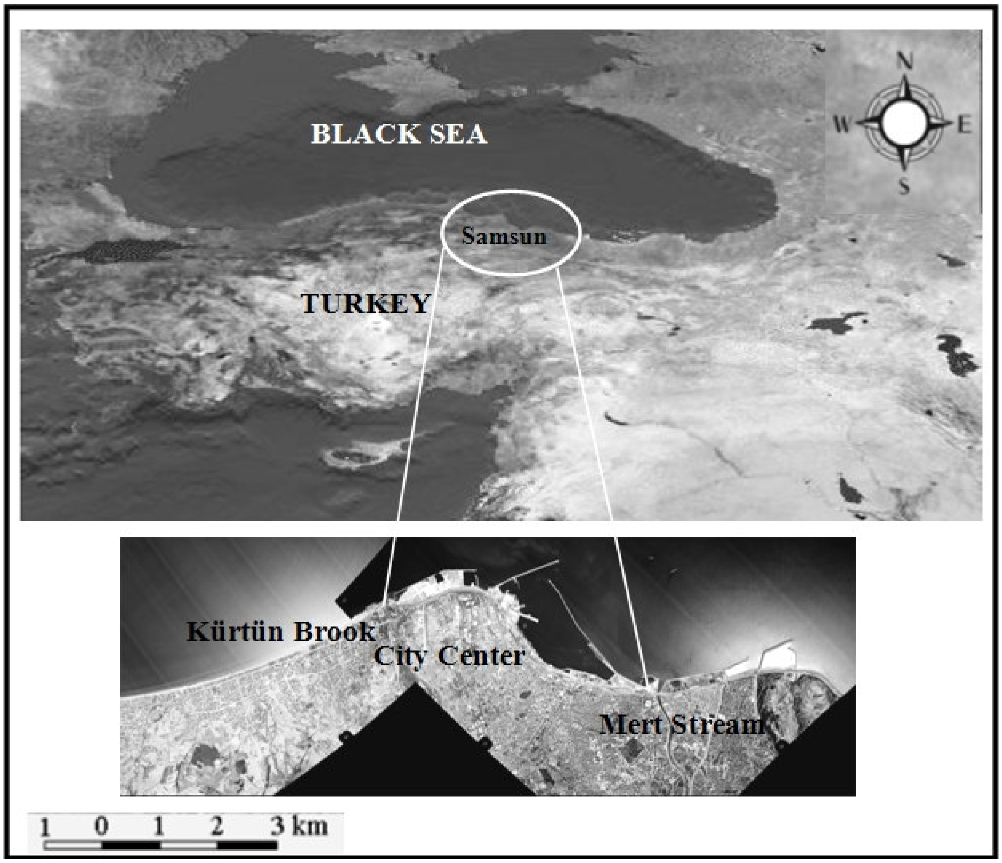

Figure 1. Location of the study area.

Table 1. Technical specifications of images.

Aerial images			
Date	**Scale**	**Type**	**Obtained agency and institute**
1935	1/35000	Panchromatic	General Command of Mapping
1972	1/25000	Panchromatic	General Command of Mapping
2006	1/35000	Panchromatic	General Command of Mapping

STUDY AREA AND DATA SOURCES

The study area covers part of the Samsun province located in the middle of the Black Sea region, northern Turkey. Samsun has an important role in the commercial structure of the region. The population of the study area was about 885 000 in 2000 (DIE, 2000); however, the study area extends between longitudes 36.18◦ and 36.21◦ E and latitudes 41.16◦ and 41.19◦ N (Figure 1). The study area lies on the western side of Samsun, from Kürtün Brook to Mert Streem, approximately 7 km. This area covers the Samsun city, Atakum district. The study area is located in Samsun and extends about 7 km westward along the shoreline with a width that ranges from 0.5 to 1 km inland. The eastern coastal zone of Turkey, where the study area is located, may be divided in the main physiographic part, that is, a western part between Atakum district and Samsun city center. The width of the study area was selected based on an area bounded by the shoreline from the north and the contour line 10 m above sea level from the south.

A series aerial image from 1935, 1972 and 2006, including the study area, was provided from the General Command of Mapping (GCM). The images are of varying quality and scale (Table 1), and they provide a good indication of change detection of the study area, which is very important in terms of accuracy and precision. Topographical maps with the scale of 1:1000 were also available, creating the reference situation in this study. Time independent features as control points on topographical maps were used to register the aerial images. Using the control points, the transformation between image space and ground space were carried out with 0.5 m for aerial images precision, respectively.

The technical specifications of the aerial images used in this work are shown in Table 1. The hardware and software used in the study included digital photogrammetric workstation (Z/I Imaging) for photogrammetric evaluation, ArcGIS 9.2 and AutoCAD. In order to obtain high quality mapping products, standard photogrammetric procedure was followed to acquire aerial images and in processing the related data. The information data such as the coastal line were collected by map vectorisation using photogrammetric system.

Photogrammetric evaluation

Photogrammetry is the technique of measuring objects (2D or 3D) from photographs. It is the goal of photogrammetry to derive geometrical parameters of remote objects from photographs. The imaging process is mathematically formulated by a perspective transformation which gives the relation between the position of a point in the photograph (described by image co-ordinates) and its objects co-ordinates (X, Y, Z). The results of a photogrammetric process can be coordinates of the required object-points, topographical and thematical maps and rectified photographs (orthophoto) (Kraus, 1993; Atasoy et al., 2006).

The orientation process includes three steps, that is, interior, relative and absolute orientation. Interior orientation reconstructs the bundle of light rays so that they are geometrically identical to those entered in the camera lens at the time of exposure. Relative orientation reproduces the same perspective conditions between a pair of images so that the corresponding light rays in these two photographs are intercepted in space and a stereo model is formed. Following the relative orientation, the process of absolute orientation involves using control points with known horizontal and/or vertical positions to make the stereo model conform in scale and position with respect to the reference plane of the map sheet. At the completion of absolute orientation, the position of any point in the stereo model can be measured at the intersection of two corresponding light rays. The orientation process was completed using the mensuration software (ISDM) module provided by Intergraph ImageStation.

After completing the orientation process, the original imageries were resampled to generate epipolar images, which were used to form the stereo model. The images were viewed in stereo on the monitor using the CrystalEyes stereo viewing system. While viewing the images in stereo, topographic features of interest such as roads, buildings and coastal line were collected. Together with other reference data, the images and collected topographic features were analyzed and special features were digitized as needed.

Photogrammetric system

In this study, Z/I Imaging Digital Photogrammetric system for photogrammetric evaluation and Microstation V.8 by Bentley Inc. were used as a CAD tool. Photogrammetric processes were conducted by Stereo Softcopy Kits (SSK) provided by Z/I Imaging (2001).

Evaluation of the aerial images

Stereo photogrammetric evaluation was performed with Digital Photogrammetric Workstation Zeiss SSK, and aerial photographs of the study area in Samsun were used to digitize the coastal line and other features such as buildings, roads, etc. Pre-processing phases of the aerial images were conducted according to Z/I Imaging instructions, then, image orientation was carried out. Pre-defined reference points such as school, building and mosque corner were used to get the best result for the references. The coordinates of these points were measured from the maps with 1/1000 scale covering the same area. These points were selected as ground control points. To establish the relationship between object space and image space, the ground control points were selected in the model area to conduct all measurements in the National Coordinate System; then, inner, relative, and absolute orientations were respectively performed. As a result of the absolute orientation, the accuracy was obtained as 70 cm in planimetry (x, y) and 50 cm in height (z). The panchromatic and infrared aerial images taken among 1935, 1972 and 2006 in scales of 1/35000 (for 1935), 1/25000 (for 1972) and 1/35000 (for 2006), respectively were used. The vector maps were produced from the images by using the existing roads, coastal line and the other important features. However, the data were evaluated using ArcGIS 9.2 software.

Examining the changes on coastline and coastal area

The developments on information technologies, satellite and aerial images, made it possible for the study to track the changes on the coastal line and coastal zone. The aerial images taken in different times were aimed at examining the changes in coastal zone and coastal line in this part of the work. For this work, the aerial images (1/35000 scale and panchromatic (B/W) taken in 1935 and 2006) were gotten from the General Command of Mapping, and 1/25000 scale and panchromatic (B/W) taken in 1972 is also added to the dataset. To monitor between the 1935 - 1972 and 1972 - 2006 periods, aerial photos that dated 1935, 1972 and 2006 were used (Figure 2).

In the photogrammetric system, priority operations were performed to evaluate digital images. In the first step, the images were arranged using the Many-Files-Converter module and it is composed of the image pyramid. This process provides a low coverage area that is easy for use and it makes the system to be used faster. Instead of using the images of which the coverage area is high, it utilizes the image pyramids of which the coverage is low. After this step, the orientation process was carried out. After the orientation process, the digitizing process in the 3D model was carried out by the usage of crystal glasses for each model. The drawings were made in ISDM module and the Microstation was instantly transformed in the desired format. Subsequently, the features boundary layers were transferred to CAD software with dxf file format. The corrections in drawings which were converted to Data Exchange Format (.dxf) were corrected by using AutoCAD software. It was imposed on the layers that belong to different dates and the changes coastline was examined by ArcGIS 9.2 software.

In the study area, after having evaluated images dated 1935, 1972 and 2006 using digital photogrammetric methods, coastline layers were digitized separately on 3D model and their maps were obtained. The changes in coastline, as a result of the filled area, coastal erosion, sand taken from the sea, etc., were also examined from those maps. In addition to these, the overlapping layers which belong to different date periods (1935 - 1972 and 1972 – 2006) and the area between the intersected layers have been calculated. If the area is found towards the sea (caused from the filled area) or towards the land, it happened because of the coastal erosion or as a result of taking something from the seaside. In the following, the figure is a sample of the calculation of the areas which were gained by filling, erosion, sand taking, etc. The drawings, which were transferred to Microstation and saved as dxf, were transferred to the ArcGIS 9.2 software by ESRI for topology building. After that, the area of the coastline changes was calculated separately in the time periods of 1935 to 1972 and 1972 to 2006.

RESULTS AND DISCUSSION

After the assessment of the aerial photos dated 1935, 1972 and 2006 with the method of digital photogrammetry, the maps showing the current situation were constituted by digitizing the available coastline of that date through the models constituted. It was determined that an area of 95.32 ha in total were gained

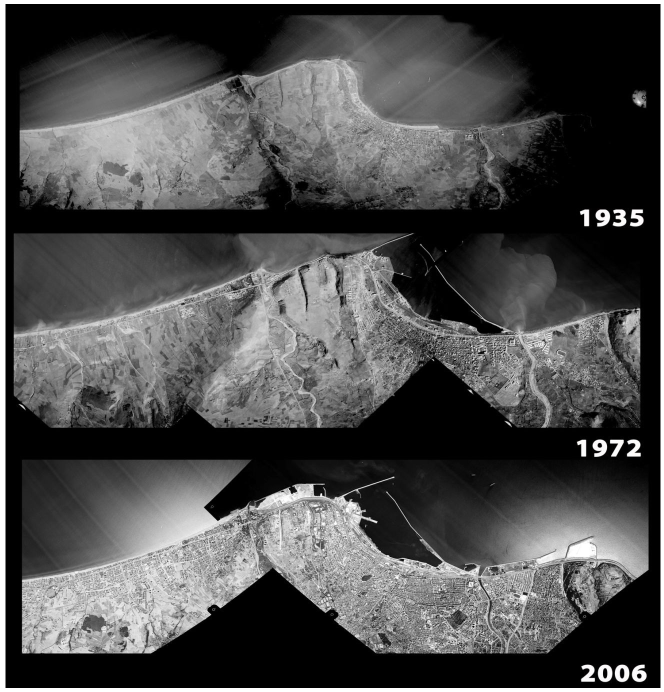

Figure 2. An overview of images covering the same coastal zone (Samsun Province).

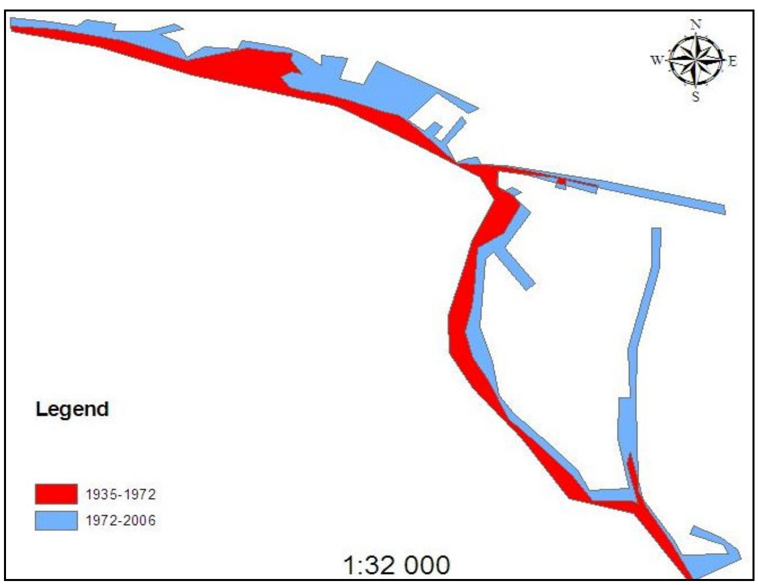

Figure 3. An example for areas which are extended and arranged by filling (Temporal changes of Samsun Coastline).

through filling the sea, from 1935 to 1972. Also, it was determined that an area of 70.74 ha in total were gained through filling the sea from 1972 to 2006. While examining the aerial photos, it was seen that on the filled areas (mainly areas such as highways), other facilities for transportation purposes, green areas, trekking mills, parks, a wide range of green areas and children's playground were built. Areas were gained through filling the harbor in Samsun, which is a coastal city, and at the same time, its harbors and facilities were extended (Figure 3).

The large part of West Park was completed with filling

Figure 4. The arranged state of the fill areas; (a) green fields and (b) parks (Uzun, 2008).

studies, in that the activities of forestation and surface-arrangement have started. However, Samsun Marina was constructed between West Park and Samsun harbor. Samsun Metropolitan Municipality constituted two public beaches by arranging the small beaches that were formed afterwards, except for the breakwaters surrounding the harbor. Among these, the one between the southern breakwater of the Harbor and Mert Stream is called Mert Beach and the one between the northern breakwater and marina is called Fener Beach. Coastal arrangements within the harbor enabled the city to attain a new apprearance. Between the two breakwaters of the harbor, the only place where the townspeople could securely go to the beach were the coasts of the fairground and it stank due to polluted water streaming from a distance through the harbor. Opening of a road through removing barracks and storerooms along the coast where people could easily take a walk became one of the pioneers for the positive projects within the harbor. Besides, the old road stretching from the 'station' building in the east to the 'free' zone in the west was extended and the surrounding was planted after removing the barracks. Sevgi lake was constructed in the position of the boathouse within the harbor, while the surrounding was arranged as a park. The overpass of the railroad which attracts attention with the zoo established by its unique architecture constitutes the major elements of this area. Moreover, Bandırma Steamboat is located on the eastern end of the Doğu Park fill area. In memory of the steamboat which brought Atatürk to Samsun, it was reconstructed in accordance with the original size. The inside was turned into a museum and arranging the surrounding, a new touristic attraction area was formed for the city. Tobacco seaport, protocol road, railroad, exchange site and surrounding, foreigners market, fishing port and Samsun shipyard are among other arrangements (Uzun, 2008).

In the study, it was determined that areas of 1.80 ha in total were coastal areas that were wasted due to reasons such as coastal erosion, sand pulling, material purchase, etc. between 1972 and 2006.

New projects, which were put into practice after 1999, conditioned the coasts of Samsun City Center. Today, the large part of filling studies in West Park has been completed and activites of forestation and surface-arrangement have started. However, this is pleasing in that it is the first time that an arrangement of fill area, which is convenient for the provisions of legislation, is being carried out on the fill areas in Samsun (Uzun, 2008) (Figure 4).

Conclusions

Photogrammetry and digital photogrammetry have a great significance in terms of planning activities. They provide great benefits on subjects such as attaining healthy and current data, following the temporal change (for wide areas), ecological and environmental sources and determining the extent of the changes. In this study, it was seen that it is possible to follow the changes in wide coastal areas with the method of digital photogrammetry and maps that would be required for the production of coastal areas. It is conceived that utilization of large scale aerial photos that would enable the manufacture of large scale maps or high resolution satellite images shall be preferred in other studies to be carried out with the purpose of following the temporal change on the coastal line and coastal area. Planning has a great importance in the coastal areas which gradually disappear today. Before doing a planning in the coastal areas, physical structure, geology, current utilization, etc. of coastal areas shall be revealed. A large part of these data could be determined easily and in a short time with the help of remote sensing and photogrammetry technologies. In order to hand down Samsun coasts to the next generations without destruction, the structuring against the legislation shall not be permitted and positive arrangements carried out in the coastal areas especially after 1999 shall be continued.

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