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Determination of Change Detection of Landscape of the Kucuk Menderes Delta Using GIS and the Remote Sensing Techniques

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Abstract: Remote sensing and GIS offers an important means of detecting and analyzing temporal changes occurring in the earth surface. This research used remote sensing and GIS to quantify landscape changes at the Kucuk Menderes Basin, Izmir, Turkey. In this study, we concentrated on determining the geomorphology of the with time of the coastal strip and the coastal part of the Kucuk Menderes Basin towards terrestrial formation using aerial photographs and satellite images involving remote sensing techniques. Making use of satellite images of 2001, topographic maps and aerial photographs of previous years, were used to determine geomorphological aspects of change detection and geomorphology of the region.

Key words: Remote sensing, coastal, aerial photos, Landsat TM, change detection

INTRODUCTION

Advance in satellite technology in our time presents geologists with important, objective and current data about the Earth's natural resources with its increasingly growing spatial and spectral power of distinction. Coastal zones, where approximately 60% of the world's population lives, are considered areas where human interference in the landscape is at its highest level compared to other areas An increase in the human population, a rise in the use of natural utilisation and expansion of urban spaces are some of the factors affecting the environment and ultimately causing significant changes in the landscape over short periods of time[1].

In the light of pressures on the world's coastal systems, international awareness in recent years has risen regarding the protection and management of the natural resources and landscape of this coastal zone[2,3].

The fact that satellite technology has been able to monitor every part of the Earth with certain time intervals since the 1970s objectively presents the changes taking place on the Earth. In this context, the time scale of natural resources can be determined by remote sensing techniques. In examining the time scale in the morphology of the coastal part of the Kucuk Menderes delta, the situation was identified by making use of topographic maps of the year 1965 and aerial photographs of the year 1972 while the current situation was determined by using aerial photos of 1993 and 2001 satellite images from Landsat 7.

Kutiel *et al.*[4] realised a study to quantify, using remote sensing and GIS, the rate and extent of vegetation expansion and their resultant temporal changes on Israel's southern coastal dunes between the years 1965 and 1999. The results show that during the entire study period, the vegetation-covered area grew by 82% at an annual average growth rate of 1.75%. Concurrently, the bare shifting dune area was decreased by 37% at an annual average growth rate of 1.34%.

In the study area, we have come across coastal dunes lying on a naturally formed coastal strip and behind these dunes, we found a lagoon system in the form of marshland and another that has become hardened soil. Areas on the dunes that are continually under the effect of sea waves and on which no vegetation is present were named active shores (sandy beaches) while areas without intensive sea effect but still under the effect of wind and on which only halophytes are present were labelled as stationary dunes.

The research area has the appearance of a delta. Deltas are estuaries formed by the sedimentation of alluvium carried by rivers. Since the ability of a river to carry alluvium deposits disappears in places where rivers merge with seas, larger elements such as coarse sand and pebbles, which have been carried down from different parts of the drainage system, undergo sedimentation in a brief period. Precipitation of masses with smaller granule diameter, on the other hand, is slower and takes a longer period. Deltas give way to the formation of low shores. Border edges of these deltas, in general, appear to be in

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the form of vast beaches. A typical feature of deltas is that they are land formations of sedimentation type, which have been attached to the shores afterwards. These deltas sometimes form plains of which the surface areas reach up to hundreds of kilometers. Deltas are generally observed in places where the effect of tides are absent or felt very little[5]. Coastal dunes and beaches are sedimentary formations made up of sand and pebbles. Although the basic source of beach material is the outcome of inner land erosion, there exist rocks such as granite, sand stone, conglomerate and as a result of abrasion of these rocks, beach sand originate find source from these rocks. It is known that the desert sand carried by winds coming from inland deserts has an effect to some extent on the formation of beach sands. Parallel to the accumulating function of waves, terraces and wave banks are formed on the formations[6].

The Kucuk Menderes delta is a coastal delta plain formed at the mouth of the Kucuk Menderes by accumulation of alluvium carried by the river. While the delta gives way to the formation of low shores, their borders are shaped in the form of beaches. Since the typical features of deltas are that they are forms of sedimentation attached to the shores, changes are observed in their soil and geomorphological properties in different time scales. The active sand beaches and stationary dunes found in the region are determined as geologically formed sediments according to field observations. Meanwhile it can be easily seen from earlier aerial photographs and satellite images that underwater plains, which have been superficially determined within the lagoon system and which have been continuing to rise and entering the solidification phase in our time, were deeper during earlier periods. Swamp areas lying behind lagoon systems and showing marsh properties are classified within Typic Hydraquent and the regions of solid soil that follow are classified within the soil taxonomic unit of Typic Halaquept because of their high content of salinity and ground water.

MATERIALS AND METHODS

The study area lies within the border of the township of Selcuk near the city of Izmir. The study area is a part of the study of the Kucuk Menderes Basin and geographically it is located on the Selcuk plain being the delta area formed by the Kucuk Menderes River (Fig. 1). One of the main rivers of the Aegean region, the Kucuk Menderes flows in the direction of East to West and drains into the Aegean Sea. The river valley with the Bozdaglar mountain range to the North and the Aydin Mountains to the South turns to the South when it approaches the Kucuk Menderes Delta and passing through Belevi strait, it opens to the flowmantle plain where it reaches the sea. The study area covers mountainous land types surrounding Northern parts of the Kucuk Menderes Delta. The northern parts of these mountains are composed of high steep strong relief with rocks of carbonate content and those in the southern parts are composed of metamorphic rocks showing schist properties. In this context, run off on mountainous physiographic areas surrounding the plain is slow and thus displacement of alluvium deposits is less in amount due to the lack of erosion (Fig. 1).

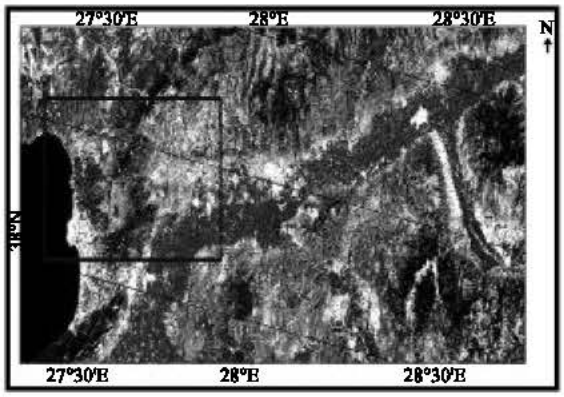

Fig. 1: Coordinated Landsat 7 satellite image showing the study area

The Plain of Selcuk was formed as a result of the filling of substances displaced by the Kucuk Menderes River from the horsts and graben areas formed by vast tectonic depressions. The slope of the plain is nearly flat. The difference in altitude is 5 m between the shores of Pamucak Township and the Belevi Mountain pass which is the entrance to the valley.

During the geological formation of the delta, civilizations profited but also suffered from the changes in the delta and the sand dunes on the riverbed. An interesting example is the ancient city Ephesus that used to have a harbour on one of the tributaries of the river Caistros. When the harbor was silted up, they had to move the harbor and the city twice. We know that they had three lagoons where they had their fisheries. Old documents indicate that starting from the 8th century B.C. Lelegians, Carians, Lonians and Romans had lived there respectively until the 5th century A.D. During their battles against the impact of the river, the most prosperous era was between the 1st century B.C. and the 3rd century A.D., which is the era of the Roman Empire.

Methodology: Topographic maps of the study area dating from 1965 were scanned and the borders of different

geomorphological formations were plotted. Obtaining three-dimensional images of aerial photographs belonging to the years 1972-1993 by a mirror stereoscope, borders of different geomorphological structures were interpreted and their borders were digitized after scanning process. For the 7.2.1 band combination of images from Landsat 7 were taken in 2001. Intergraph Advanced Imager software[7] was used and they were processed to delineate detailed soil properties of the research area quantified by using Microstation-Bentley software[8]. Geometric correction was made using 1/25.000 standard topographic maps. Finally, applying the Gausian enhancing method on the satellite images, thereafter an unsupervised classification was made. On the maps, showing different time scales of the study area, different geological and geomorphological structures in the study area were determined by using Geomedia (GIS) software and the changes were calculated numerically[9].

Geological and geomorphological properties of the study area: Geomorphologically, the Kucuk Menderes Basin is a graben but it has gained the appearance of a plain as a result of sedimentation of alluvium carried by the Kucuk Menderes. The Kucuk Menderes basin extends in the direction of East West on the Menderes massif and with the effect of relatively recent structural formations (Palaeozoic, Mesozoic) on the massif, it is located in the direction of NE-NW, as we get closer to the coast. In the main valley part, which is located in the Belevi Mountain pass, there were more larger-grained deposits of substances to the driving force of the water. On the other hand, smaller grained substances undergo sedimentation in the delta region. Another effect as to why The Kucuk Menderes carried a lesser amount of substances to the shores of the townships of Pamucak and Selcuk is the fact that mostly rocks containing carbonate surround the plain. Since the rocks have a chemical composition that is readily affected by waters with carbondioxide content and the fact that they decompose easily, sedimentation was less in amount. The sedimentation of alluvium in the Kucuk Menderes Basin was brought about due to the control of maritime effect. This procedure of change that is effective on today's coastal strip had a wider effect during earlier periods when the delta did not have so much sedimentation. It is known that there used to be a wide bay where the Kucuk Menderes delta is presently situated and at that time the sea level was lower that it is today. During the late Wurm period, which is the last ice age, sea level was 100 m lower all over the world, than it is today and nearly 15.000 years previously glaciers began to melt in sequence with the global rise in temperature and thus sea levels began to rise fast. In this context, places which were lands before were invaded by seawaters and parallel to the river valleys, seawaters reached into the land. This fast rise in sea levels continued up to six thousand years before our time until the sea reached its present levels. When this rising period ended, another process began to occur: alluvium carried by rivers began to fill the bay. Thus, the coastal line quickly proceeded towards the open sea, forming the geomorphological structure of flow-mantle plains in places filled by alluvium. In the region where the Kucuk Menderes basin is located, these were structured in different features (e.g. coastal swamps, lagoons of still water) during the transition period from maritime conditions to terrestrial conditions[10].

RESULTS AND DISCUSSION

The formation and shaping of the Kucuk Menderes basin in the past and in our time has been depicted by aerial photographs. In determining the changes, scale 1/25.000 topographic maps of 1963 and aerial photographs of the years 1973 and 1993 and Landsat 7 images of 2001 were used.

Changes in properties of geomorphology and of soil in the coast and plain during different periods were converted into a map and the time scales between them were established. The Selcuk plain on the Kucuk Menderes of which the formation is delta in character comes to an end reaching as far as the sea. With the altitude difference of 5 meters, the slope of the plain is less than 0.5% in a distance of over 10 km from today's delta up to Belevi mountain pass. The two geomorphological structures differ from each other by the border difference between highlands and smooth-gently sloped parts of the plain. The highlands present the properties of the main substances on which they were formed while the plain part shows the complex properties of different substances which it contains. Areas of slope change determine the borders of areas of erosion and accumulation. As a result of stereoscopic interpretation of aerial photographs, it has been observed that not every part of the plain contained sedimentation of alluvium. The part of the delta towards the Belevi mountain pass that lies on the east of this line passing in the North-South direction and formed by the ridge of Cevasir Mountain, Kurudag mountain and Panayir Mountain is covered with agricultural areas and in this part of the plain, there are no marshlands, lakes or swamps. The intensity of agricultural activities here demonstrates there are no problems such as high ground water and salinity that would adversely affect the agriculture. Depending on the delta waters driving force, the elements, the larger-grained particles are found here.

Van der Meulen and Salman[11] emphasized that, 75% of dune spaces around the Mediterranean Basin have been disturbed or destroyed in the past 30 years due to extensive urbanization, industrialization and recreation- and tourism-based development

Nordstrom and Lotstein[12] noted that in various places in the world, great efforts have been made to stabilize coastal dunes in particular and foredunes in general. In an effort to stabilize the shifting dunes or to expand the beach necessary for recreational needs.

Northern parts of the delta are zig zag in shape due to mountain ridges in the North-South direction and depressions between them. During the Wurm period, there were transgressions between eroded valleys of secondary streams and the sea (depending on the depth of the sea-around 100 m in that period). In this context, small bays were undergoing a process of sedimentation due to the lack of substances being carried from the mountainous regions in the North, while in the South; alluvium substances carried by the Kucuk Menderes were filling the front parts. As a result of this filling process, small lakes were formed. The reason for this was that there were little amounts of substance inflow from the environment partly because of being located at the sides and lithological properties in comparison with the Kucuk Menderes being located in the middle. Fresh water springs around the village of Zeytinkoy top up these lakes and enable them to maintain their existence. Over the last 60 years, due to the drainage work undertaken in the plain, swamp areas around the lakes have been reduced in size. Upon examining the photographs taken between the years 1965-1972, wide marshlands around the lakes could be observed. Through examination of the aerial photographs of 1993 and satellite images of 2001 of these areas, it can be noted that most of these areas are agricultural fields saved for cotton growing.

Coastal marshes are effected from tidal actions and sea-level rise depends upon their ability to maintain their relative elevation through sedimentation, areas where the sedimentation rate is in excess of sea-level rise are considered areas of positive balance. These areas are frequently associated with estuarine marshes of rivers with high sediment discharge. Conversely, where relative sea-level rise exceeds coastal marsh sedimentation, erosion processes take place and flooding is inevitable; an 'elevation deficit' occurs[13-15] .

In maps prepared by using topographic maps of 1965 and showing the geomorphological distribution, beaches, coastal dunes, areas with sand-alkali textures were determined by their surface areas. Marshland that generally shows fresh water features was determined to be 8057 ha, the total surface areas of the lakes Gebekirse and Catal were 1556 ha, beaches and coastal dune areas with sand texture and showing saline-alkaline properties were 3255 ha (Fig. 2).

Reed[16], described salt marshes as transition zones between land and sea, they are also particularly vulnerable to sea-level rise as the sea rises, the outer salt marsh boundary will erode and new salt marsh will form inland.

In the map plotted by making use of aerial photographs of the year 1972, swamp areas were determined to be 7614 ha, the total areas of Gebekirse and Catal Lakes were 1503 ha, areas with sand texture showing saline/alkaline property and beaches and coastal dunes were at 3476 ha. When compared with data for the year 1963, a decrease was observed in the borders of the swamps and lakes while coastal dunes and saline/alkaline areas where halophyte plants were found showed an increase (Fig. 3).

Despite intensive drainage activities in the Kucuk Menderes delta today for agricultural purposes, there still exist large areas of swamp in the delta. The region between Zeytinköy, which is to the north west of the plain and the area where the Kucuk Menderes flows into the sea today is called the Eleman swamp, which has the resemblance of a lake covering a large area. In aerial photographs, traces of the old riverbed are clearly seen at the bed of the Eleman swamp. These beds might belong to the flow of access waters of Gebekirse and Catal lakes, or they might an the indication that the Kucuk Menderes had drained its waters from this part to the Aegean sea before its bed was transformed in the 1930s. When traces of the old bed, which is the last natural bed in the south; were compared with those of today's, it is seen that they are similar to each other in terms of their widths. This reveals that the Kucuk Menderes also flowed along the northern borders of the plain for a relatively long time.

Salt-marshes are able to react to sea-level rise by a negative feedback mechanism a small increase in sea level leads to greater mineral deposition due to extended submersion time and to reduced soil compaction due to reduced decomposition of organic matter in the soil[17].

In the map plotted by making use of 1/40.000 scaled aerial photographs of 1993, swamp areas were determined to be 4192 ha, the total areas of Gebekirse and Catal were 1224 ha and lands with sand texture showing saline/alkaline property and beaches and coastal dunes were 5561 ha. When compared with data from 1972, a decrease was observed in the borders of swamps and lakes while coastal dunes and saline/alkaline areas where halophytes were present showed quite a large increase (Fig. 4 and 5). This is mainly because intensive drainage canals were scooped up in the delta and swamps

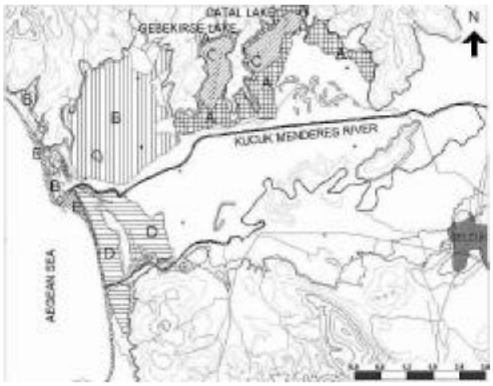

Fig. 2: A map drawn and digitalized from a topographic maps of the study area (1965); swamps (A), swamps with salty water (B), lakes (C), saline and alkaline areas (D) and coastal dunes (E)

Fig. 3: A map interpreted and digitalized from aerial photographs of the study area (1972); swamps (A), swamps with salty water (B), lakes (C), saline and alkaline areas (D) and coastal dunes (E)

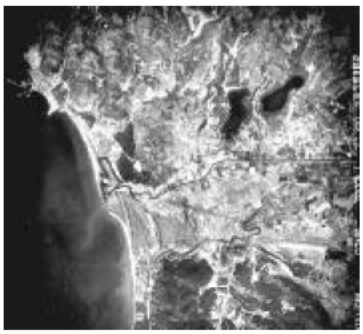

Fig. 4: A map interpreted and digitalized from aerial photographs of the study area (1972); swamps (A), swamps with salty water (B), lakes (C), saline and alkaline areas (D) and coastal dunes (E)

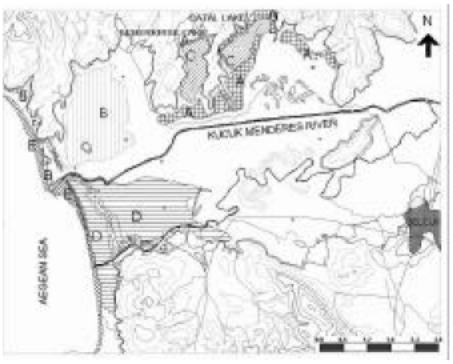

Fig. 5: It was interpreted and digitalized from 1/40.000 scaled aerial photographs of the study area in 1993; swamps (A), swamps with salty water (B), lakes (C), saline and alkaline areas (D) and coastal

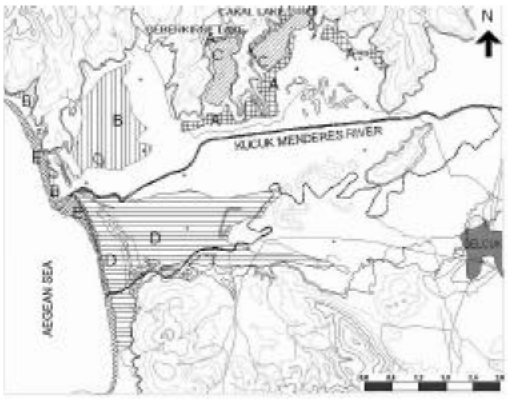

Fig. 6: A map plotted and digitalized by using 721 band combinations of images from Landsat 7 in 2001; swamps (A), swamps with salty water (B), lakes (C), saline and alkaline areas (D) and coastal dunes (E)

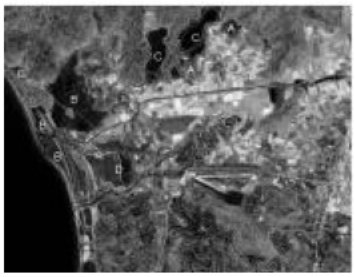

Fig. 7: Data about borders and altitudes of settlement areas, swamps (A), lakes (C), roads, coastal dunes (D) and saline-alkaline areas (E) shown by 721 band combinations of images from Landsat 7, 2001

were dried up for the purpose of agricultural use. In conjunction with the increase in agricultural activities, the need for irrigation arose. Thereby, intensive use of underground water sources caused shrinkage in the borders of the lakes and swamps, which were fed by these waters (Fig. 4 and 5).

Before being taken into the canal through which it flows today, the Kucuk Menderes River used to flow through the southern part of the delta. An examination of aerial photographs revealed that there exist many broken meander heads and deserted riverbeds. In this section of the plain lie swamp and arid areas rather than agricultural ones. Since the ground water in this region is continually in relation with the seawater, it has not been possible so far to use this area for agriculture. Ridges of dunes are stretch longitudinally towards the sea and lie along the coast in lines. These lines, formed by dunes are sandy ridges. These ridges that also depict the old coastal line from the utmost ridge towards inner parts. In graben places among these regions, swamps lying in conformity with these lines are present. Sand particles thrown towards inner parts by the winds also formed wide sandy areas.

In the map plotted by using 7.2.1 band combinations of Landsat 7 images of the year 2001, swamp areas were determined to be 3993 da; total areas of Gebekirse and Catal Lakes were 1105 da and areas with sand texture showing saline alkaline property and beaches and coastal dunes were 5929 da (Fig. 6 and 7).

It has been observed that swamp areas shown at 8057 ha in 1963 increased to 3993 ha in 2001; the total areas of Gebekirse and Catal Lake decreased from 1556 to 1105 and areas with sand texture showing saline/alkaline property and beaches and coastal dunes increased from 3255 to 5929. Today, the coast, costal strip areas and dunes following the north-south direction and cutting the new bed of the Kucuk Menderes have formed a small delta that has the appearance of a swamp. While we cannot see any accumulation of sand band where the old riverbed opens to the sea, the recent part of the delta extended towards the west. That is, towards the sea. An examination of aerial photographs of 1963 and 1972 reveals that, a nose-like protrusion, which is located at the place where the river flows into the sea, has eroded in a period of 40 years-beginning with the change of the river bed up to today-and this part of the shore has become smooth (Table 1 and Fig. 8).

Table 1: Results of Change Detection of the Kucuk Meander Delta

Areas/Year	1965	1972	1993	2001
Swamp areas (da)	8057	7614	4192	3993
Lake areas (da)	1556	1503	1224	1105
Coastal dunes and saline and alkaline areas (da)	3255	3476	5561	5929
Total areas (da)	12868	12593	10977	11027

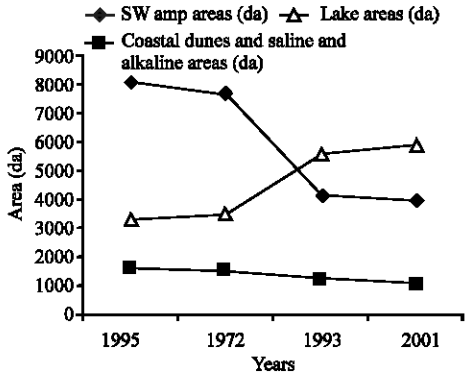

Fig. 8: Results of change detection of swamp areas, lake areas, coastal dune areas and saline-alkaline areas

An examination of the total square area of the new delta revealed that the sediments carried by the Kucuk Menderes is small in amount. Sedimentation reaching the sea by the Kucuk Menderes River's driving force has begun to be carried away by marine effects more than in the past. The surface area of the new delta on topographic maps scaled 1/25000 and belonging to the years 1963 and 1980 were compared. It was calculated that surface area of the delta in the south has enlarged to 1100 m^2 in the last 17 years whilst there is not much change in the northern part. Similarly, in the aerial photographs, it was observed that movement of sedimentation was roughly southward in direction[18]. As the coastline proceeds into the open sea, the effect of waves and currents seems to have increased. On the other hand, in the west, there are such features as swamps and ridges of dunes that prevent people from utilizing agricultural activities. In addition to this, due to sand accumulations, seawaters proceeded inland, affecting underground waters and as a result, saline water caused the formation of saline-alkaline soils. In addition, for agricultural products, that needs irrigation such as cotton, underground waters and thus agricultural fields have been becoming saline. Once a part in ancient times, Ephesus lies 7.7 km inland now due to the accumulation of alluvium.

CONCLUSIONS

On the delta, which has been open to tourism for quite a long time, agricultural activities continue. In order for the continuity and sustainability of deltas, which are natural protection areas, it is important that the delta is used in an organized way and be protected. In land-planning studies to be undertaken in the delta, geomorphological growth of the plain should be considered first. This is especially important for draining the swamp areas and for agricultural irrigation. The

western part of the delta is under the marine effect more than the eastern part is. As a result of irrigation to be put into effect in these areas, it is possible that saline water would penetrate inland easily from sand-textured accumulations. The study area has been determined as a model formed of coastal dunes located on this strip, a lagoon system with a swamp-like appearance and an area that has become solid land behind them. Coastal dunes and the places that have recently become solid land are not appropriate for any sort of agricultural use. Intensive saline content in these areas, low topography, high ground water and saline sea water have been determined as limiting factors for agriculture.

Swamps, lagoons, dunes, coastal areas and the delta of the Kucuk Menderes on which halophytes have been found present should be protected for wildlife. The Kucuk Menderes delta has undergone changes both by the effects of the Kucuk Menderes River and by anthropogenic effects. Attempts to drain them and utilize them for agricultural activities have spoiled the ecosystem of these areas. In the forthcoming future, these areas would get saline depending on the salinity of the irrigation waters. Continuity and sustainability of the coastal areas and the endemic plants and fauna depend on the continuation of ecological balances. Taking into consideration the fact that the concept of coast is a part of the ecosystem, it would be a wise approach to leave these places to natural life and to ecotourism holidays.

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