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Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey

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ABSTRACT

This research focuses on the shoreline change rate analysis by automatic image analysis techniques using multi-temporal Landsat images and Digital Shoreline Analysis System (DSAS) along the coastal Ramsar wetlands of Turkey. Five wetlands were selected for analysis: Yumurtalik Ramsar, the Goksu Ramsar, Kizilirmak and Yesilirmak wetlands and Gediz wetlands. Accretion or erosion processes were observed on multi-temporal satellite images along the areas of interest. Landsat images were geometrically and radiometrically corrected for the quantitative coastline delineation analysis. DSAS (Digital Shoreline Analysis System) was used as a reliable statistical approach for the rate of coastline change. For the detection of coastal change in Aegean part (Gediz wetland) of the study, zonal change detection method was used. As a result of the analysis, in some parts of research area remarkable shoreline changes (more than 765 m withdrawal and −20.68 m/yr erosion in Yumurtalik, 650 m withdrawal and −25.99 m/yr erosion in Goksu, 660 m withdrawal and −16.10 m/yr erosion in Kizilirmak and 640 m withdrawal and −4.91 m/yr erosion in Yesilirmak) were observed for three periods (1989, 1999 and 2009). Wetland in Gediz delta which is 35.57 km^2 was converted to sea or salt pan for the period 1975 and 2009.

1. Introduction

Coastal zone monitoring is an important task in national development and environmental protection, in which, extraction of shorelines should be regarded as fundamental research of necessity (Rasuly et al., 2010). The shoreline is one of the 27 features recognized by IGDC (International Geographic Data Committee). A shoreline is defined as the line of contact between land and a body of water (Li et al., 2001). Information about coastline position, orientation and geometric shape is also essential for autonomous navigation, geographical exploration, coastal erosion monitoring and modeling, and coastal resource inventory and management (Liu and Jezek, 2004). Shoreline change is considered as one of the most dynamic processes in coastal area (Bagli and Soille, 2003; Mills et al., 2005). In many coastal areas in the developing countries, dense population being placed next to the shoreline creates the more vulnerable areas. It has become important to map the shoreline change as an input data for coastal hazard assessment (Marfai et al., 2008). With no exception coastal wetlands have been adversely affected by natural or anthropogenic activities. Coastal wetlands are important geographic areas because of their unique floral and faunal characteristics and they are also a component of world coastal ecology.

According to the Ramsar Convention on Wetlands, Article 1.1; "Wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m" (Ramsar, 2004). Wetland components provide many goods of great value and function including; fish, timber, fuel wood and tree products, wildlife, fertile land for agriculture, water supply, water transport, peat, flood control, storm protection, groundwater recharge, sediment–pollutant–nutrient retention, evaporation and preservation (Barbier et al., 1997; Ramsar, 2004; Daily et al., 1997; Mitsch and Gosselink, 2000). Besides, this importance coastal wetlands are under various natural and human caused threats including coastal erosion. Coastal erosion is the permanent loss of land along the shoreline and is usually the result of a combination of both natural and human induced factors. Most important natural factors are winds and storms, near shore currents, relative sea level rise and slope processes on the other hand, human induced factors of coastal erosion include coastal engineering, land claim, construction of dams or reservoir, dredging, mining and water extraction (Coastal Engineering Manual, 2002). As a result of coastal erosion shoreline position can change over the time.

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Knowledge of shoreline position 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 coastline. The extraction of shoreline and water bodies is an important task useful for various application fields such as coastline change detection, coastal zone management, watershed definition and flood prediction. This task is difficult, time consuming and sometimes impossible for a large region, when using traditional ground survey techniques (Cracknell, 1999). Remotely sensed data can provide valuable preliminary estimates of change and is a unique tool for research and monitoring wetlands and deltaic environments (Ciavola et al., 1999; Yang et al., 1999). Moreover, maps generated from satellite data have a great potential to project recent changes of shorelines (Kevin and El Asmar, 1999; Shaghude et al., 2003).

Remotely sensed data were utilized for the analysis of shoreline change in coastal and deltaic environments in many researches. For example, Rebelo et al. (2009) used remote sensing and geographical information system (GIS) for wetland inventory, mapping and change analysis, Maiti and Bhattacharya (2009) analyzed shoreline change by using remote sensing and statistical approach, Genz et al. (2007) researched beach variation on Hawaii, Wal et al. (2002) researched long-term morphological change in the Ribble Estuary, northwest England, Ghanavati et al. (2008) used Landsat TM and ETM+ data in order to monitor geomorphologic changes of Hendijan River Delta, southwestern Iran. Wu (2007) monitored coastline evolution of Nouakchott region (Mauritania) using remote sensing methods, Vanderstraete et al. (2006) used different Landsat images to detect changes of the coastal zone near Hurghada in Egypt.

Remotely sensed data has also been used in Turkey as a powerful tool especially in coastal zone and city management. For example, Kuleli (2009) analyzed shoreline changes at the Mediterranean Coast in Turkey, Sesli et al. (2008) monitored the changing position of coastline using aerial photography and satellite images at the eastern coast of Trabzon. Bayram et al. (2008) monitored temporal coast line changes from Black Sea coast of European part of Istanbul, using Corona panoramic satellite photo, SPOT-4, PAN and IRS-1D PAN satellite images. Ekercin (2007) used multi-temporal Landsat images to monitor change detection at the Aegean Sea. Kuleli (2005) used multitemporal satellite image for assessment and change detection of North-East Mediterranean Coast.

In this research, Yumurtalik Ramsar wetland including the coastal zone located in the Cukurova Delta, the Goksu Ramsar wetland located on Goksu River delta as a part of southeast Mediterranean Sea, Kizilirmak and Yesilirmak Ramsar wetlands in the Black Sea coastal zone and Gediz Ramsar wetland on Aegean coastal zone were investigated in point of coastline changes. Sedimentation, deposition, erosion and human uses for instance coastal agriculture, coastal engineering, land claim, dredging, mining and construction dams or reservoir have caused the morphological changes (accretion or erosion) of coastline along some parts of these important Ramsar wetlands. Natural and human induced processes and coastline changes were analyzed with the use of image processing methods, DSAS (Digital Shoreline Analysis Software) software, multi-temporal Landsat data and zonal change detection method.

2. Study area

Turkey presently has 13 sites designated as Wetlands of International importance, with a surface area of 179,898 ha and 5 of 13 wetlands are located in the coastal zone. These are Kizilirmak Delta (21,700 ha) in Black Sea coast, Gediz Delta (14,900 ha) in Aegean Sea coast, Akyatan Lagoon (14,700 ha), Goksu Delta (15,000 ha) and Yumurtalik Lagoons (19,853 ha) in Mediterranean Sea coast (URL-1).

Goksu Delta was designated as Ramsar Area in 13.07.1994 (Fig. 1). The site has approximately 15,000 ha surface in between 0 and 5 m elevations. Goksu Delta has been under protection as Specially Protected Area and Wildlife Reserve by national act. An important wetland delta located on a bird migration route. Sands and saline steppe cover large areas. The site supports reed beds, marshes, swamps, meadows and, in the surrounding area, agricultural fields. It is a refuge for internationally important numbers of wintering ducks. Up to 327 bird species occur, including the globally endangered *Phalacrocorax pygmeus* and *Pelecanus crispus*. Two species of endangered marine turtles nest in the area. Reptiles and amphibians (34 species) form a primary link in the food chain of waterbirds. Human activities include fishing, tourism, and conservation education. Remains of cities from Neolithic times through many subsequent civilizations are found there, including nearby Silifke Castle and ancient Seleucia. Non-point agricultural pollution and proposed dams present potential threats.

Yumurtalik Lagoons was designated as Ramsar Area in 13.07.1994 (Fig. 1). The site has approximately 19,853 ha surface in between 0 and 3 m elevations. Yumurtalik Lagoons have been under protection as Nature Conservation Site by national act. Lagoons comprise the whole of the alluvial delta formed by several rivers in the eastern Mediterranean Sea, with a broad array of freshwater and coastal habitat types which support sand dune vegetation, salt marsh vegetation, stream bank vegetation and ruderal vegetation of roadsides and field margins. The threatened sea turtles *Caretta caretta* and *Chelonia mydas* are supported, and the site is one of the key points where migratory birds on the Palearctic-Africa route meet, using the site as both a stopover and a wintering site. It is also a key area for fish reproduction. The main uses of the area are irrigation agriculture, commercial and artisanal fishing, and recreation.

Kizilirmak wetland site include dunes, beaches, shallow lakes, seasonal marshes, and wooded areas (Fig. 1). Dominant vegetation includes vast reed beds and seasonally flooded forest. Numerous species of waterbirds breed at the site, several of which are globally threatened. Over 92,000 waterbirds of various species winter at the site. Human activities include cattle grazing, reed cutting, fishing, and agriculture. In recent years, eutrophication, deforestation, illegal constructions, and coastal erosion have become increasingly problematic in Kizilirmak coastal wetland (URL-2).

Yesilirmak wetland is a candidate wetland that it is to be registered by Ramsar and it is also under national protection law of wetlands in Turkey (Fig. 1). Yesilirmak site is important for breeding waterbirds and congregations of wintering wildfowl. The majority of the latter are forced to spend the day at sea as a result of human disturbance, returning to feed in the delta at night. Yesilirmak is one of the largest delta on the Turkish Black Sea coast, the majority of which is now under agriculture. Ongoing drainage and irrigation projects threaten the areas of natural wetland. Pinus forests designed to stabilize the dunes and *Salix/Alnus* plantations threaten to native vegetation (URL-3).

Gediz delta has extensive coastal wetland with bays, salt and freshwater marshes, large saltpans, and four highly saline lagoons located at the mouth of the Gediz River near Izmir (Fig. 1). The site supports dry grasslands, arable land, and some woodland. The globally threatened pelican *P. crispus* breeds at the site. Delta is an important area for breeding, feeding, wintering, and sheltering internationally important numbers of numerous species of waterbirds. Human activities include fishing, agriculture, cattle grazing, and the largest salt production center in the country. A number of ancient cities, such as Leukai and Larissa, are found there. The Gediz River is of vital importance for agriculture in the region, but is becoming significantly polluted.