CALCULATION OF EROSION AND ACCRETION RATES ALONG THE GAZA COASTAL ZONE USING REMOTE SENSING AND GEOINFORMATION SYSTEMS

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ABSTRACT

The coastal zone is the most important and the most intensively used area compared with the other populated areas. The rapid increase of the population on Gaza coastal area leads to depletion of the coastal zone resources and change the coastal morphology. Gaza coastal zone are affect by both anthropological factors and coastal processes, such as; the dynamics of the sediments on the coastal shelf, marine currents, waves, tides, surface circulations and coastal erosion. The objective of this study was to use remote sensing and geoinformation systems (GIS) to monitor and analyze the coastline dynamics during the last two decades using medium resolution satellite images. We were studied rate of change along Gaza coastal zone. Moreover, the effect of Gaza seaport on the reshaping of the coastal zone was investigated. The study was performed using three different sets of images: a series of Landsat ETM+ images (30m resolution), Landsat TM-5 imagery (30m), SPOT-5 panchromatic imagery (5m) for long-term evaluation. Based on this, it was examined whether it would be possible to get a reasonable result from medium resolution imagery especially for a narrow coastal zone such as Gaza coastal zone. First the images were geometrically corrected and registered with RMS vary from 0.015 to 0.2 pixel. Atmospheric correction was performed using ENVI FLAASH Model. MS ETM Landsat images (30m) were pan-sharpened using A'trous Wavelet Transformation (ATWT) in order to improve the spatial quality of MS ETM images to 15 m. Principle Component Analysis (PCA), Tasselled Cap Transformation, Band Ratio and Normalized Difference Vegetation Index (NDVI) were used in order to automatically extract the coastline. Accuracy assessment was performed between the these different methods using manually digitized coastlines. PCA and Band Ratio exhibit the best results compared to the other methods. The coastline were then automatically extracted from all images. Following, the Digital Shoreline Analysis System (DSAS) was used to calculate the rate of change along Gaza coastal zone. The rate of change was firstly calculated between 1999 and 2005 using the pan-sharpened Landsat ETM+ images, secondly between 2002 to 2008 using SPOT-5 images, and finally between 1987 and 2008 using all co-registered scenes. The results indicate a negative rate in general, i.e. erosion has been the predominant process on Gaza Coastal zone and the increasing of sea level has surely affected Gaza coastal zone. The southern side of Gaza seaport obtains a positive rate and accretion in the beach area. This positive rate is due to Gaza seaport which interrupts the natural flow of the longshore currents and traps the sediments on the south western side.

Keywords: Coastal monitoring, erosion rate, accretion rate, Gaza Coastal zone

INTRODUCTION

The rapid increase of the population on and around the Gaza coastal zone and the new coastal constructions such as seaport, electricity plant and recreational area have led to misuse of coastal resources and cause several coastal problems. Due to the limited land resources, the physical isolation of the area and the rapid growth of the population involve serious threats. A number of researchers studied the south eastern of Mediterranean coast. A few of them studied the rate of coastal cliff retreating [1, 2] and several were studied the sediment transport along the south eastern part of Mediterranean coast [3-6]. Others were studied the impact of the coastal constructions on the coastal zone [7-10]. In [1], the environmental impact of the Gaza Strip coastal constructions were studied. But none of these studies was concerned in details about Gaza coastal zone. Different methods were used to study the coastal zone such as aerial photograph, field surveying and remote sensing. Therefore, the aim of this study to use remote sensing and geoinformation systems (GIS) to calculate the rate of coastal change along Gaza coastal zone and to assess the effect of Gaza seaport on reshaping the coastal zone. Medium spatial resolution satellite images (ETM, SPOT) were used in this study. This study carried out with a lack of field work and oceanographic in situ data because of the political situation in this region.

STUDY AREA

The coastline of the Gaza strip forms only a small section (42 km) of a larger concave system, a litoral cell, that extends from Alexandria at the west side of the Nile Delta to the Bay of Haifa. This litoral cell forms the SE corner of the Levantine Basin (Figure 1). This coastline has been shaped over the last 15,000 years by the Nile river. The Nile sand moves along the entire concave coastline in an anti-clockwise direction, generally in a NE direction.

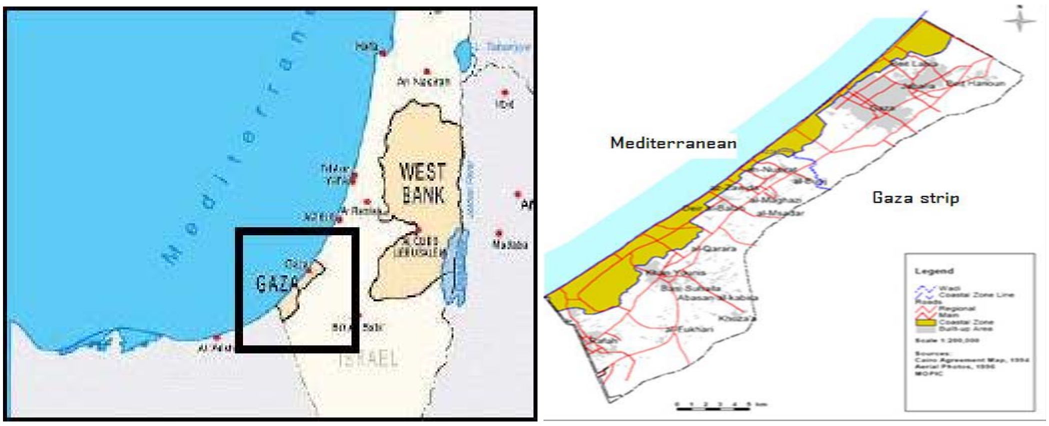

Figure 1: Location of Gaza Strip on the Lavantine Basin (left) and the coastal zone of Gaza Strip (right). (Gaza Coastal and Marine Environmental Action Program, Ministry of Environmental Affairs, 2000)

The coastal zone includes the sand dunes in the south and north, the coastal cliffs (exposed Kurkar ridges) in the middle to north. American National Oceanic Atmospheric Agency (NOAA) presents the shoreline habitats delineated for the coastline of the Gaza strip In 1999. The majority of the coastline consists of upper-medium to coarse grained (49.41%) and fine to lower-medium grained sand beaches (38.46%). In front of Gaza City part of the coast (6.05%) consists of riprap (shore protection of concrete rubble and rock). Natural, exposed, and wave-cut platforms in rock can be found along 3.81% of the coastline.

The south-eastern Mediterranean coast has been shaped by the sediment transport from the Nile river, upwards via the north coast of Sinai to Gaza. The average net longshore sediment transport at Gaza coastal zone was estimated 350,000 - 400,000 (m3/year)[11], [12]. [12] shows that the average net LST along the southern Israeli coast decreases from 450,000 m3/yr at Ashkelon, to about 200,000 m3/yr at Ashdod. Empirically-based studies [12],and [13] concluded that the region's net sand transport is directed northward along the Israeli coast until Haifa Bay (Figure 2).

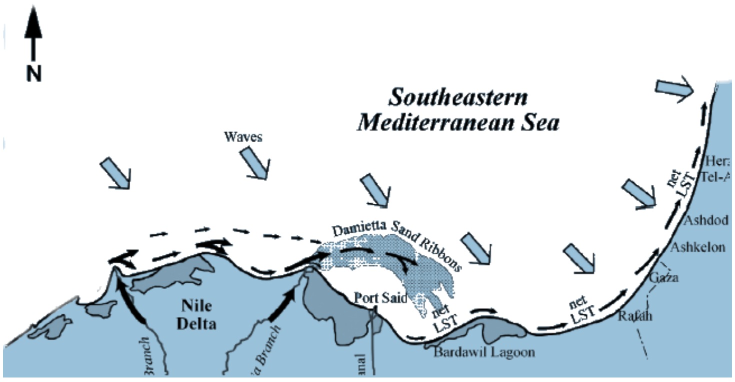

Figure 2: Longshore sediments transport along the South-eastern Mediterranean Coast, (Zviely, 2006)

DATE SET AND IMAGES PREPROCESSING

Two sets of satellite images were used to calculate the rate of change along Gaza coastal zone (Table 1). Landsat ETM images were pan-sharpened using A'trous Wavelet Transformation (ATWT) in order to improve the spatial information. Panchromatic image was used for each individually. ATWT obtained a good result in field of preserving both spatial and spectral quality of the resulting image[14]. All the image atmospherically corrected using ENVI's FLAASH model. Image-to image-registration was performed with RMS error vary from 0.015 to 0.2 for the images. The most of images were taken from the same month.

Table 1: Images data set.

Satellite images	Date of acquisition	Resolution
Landsat MS ETM + Panchromatic images	28/10/1999	30m, pan-sharpened to 15m
	28/10/2000	
	07/11/2001	
	18/10/2002	
	14/05/2003	
	10/05/2005	
SPOT Panchromatic	--/--/1993	10 m
	01/09/2002	5 m
	24/01/2008	
Landsat TM	15/10/1998	30 m
	22/11/1986	

MEHODOLOGY

Several methods of automatic coastline extraction were introduced in the literature [15-18]. In this study four different methods were performed to extract the coastline: Band Ratio, Tasseled Cap Transformation, Principle Component Analysis (PCA) and Normalized Vegetation Index (NDVI). Since these methods consider different mathematical parameters to extract the coastline the result should not be identical (Figure 3). In order to determine the most appropriate method for coastline extraction with regard to the calculation of the rate of change, accuracy assessment was performed. As reference, the coastlines were manually digitized in each image. (Figure 4). The average difference between the automatic extracted coastlines and the reference (manual) coastline was calculated. The difference was calculated at each 50 meter along the entire coastline. The result shows that the extracted coastlines by Band Ratio and First Principle Component demonstrate the best results (Figure 5).

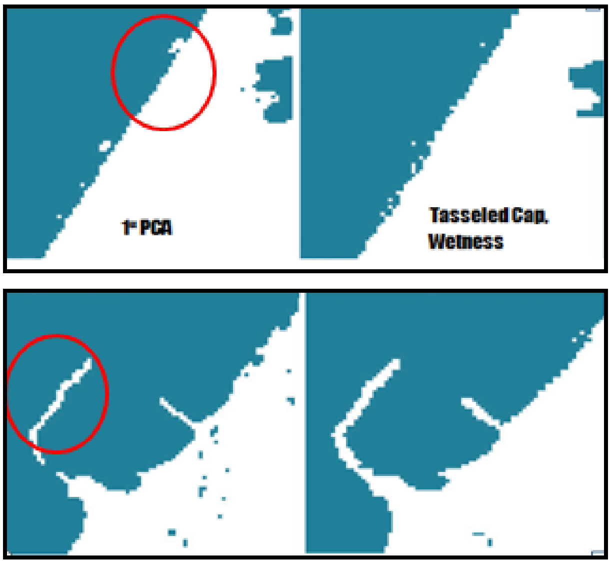

Figure 3: Example of the problem of coastline extraction, where the different in seaport dimension is clear.

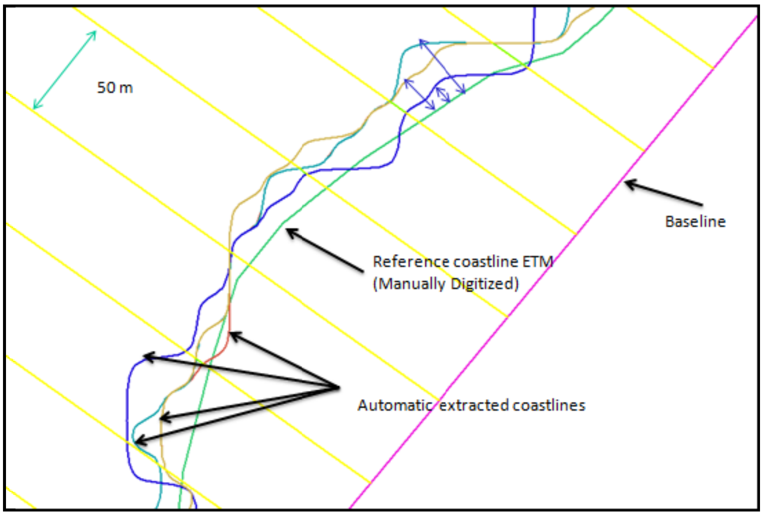

Figure 4: Accuracy assessment of the automatic extracted coastlines.

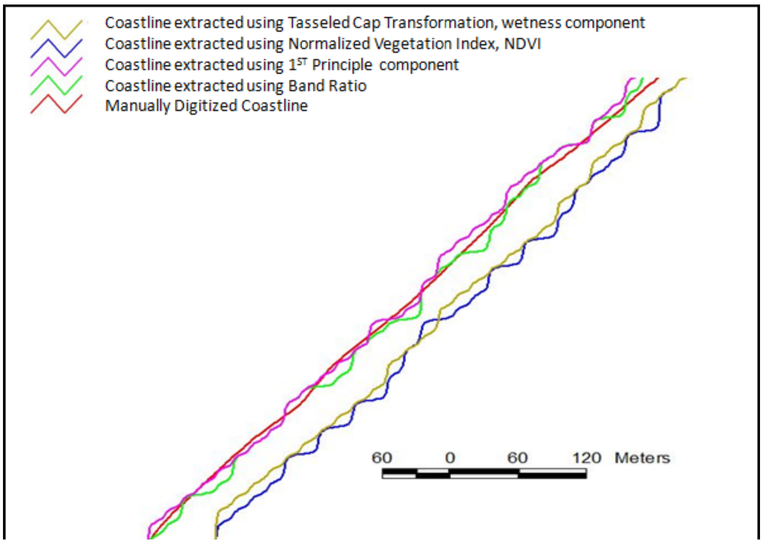

Figure 5: Accuracy assessment of the automatic extracted coastlines, where PCA and Band Ratio coastlines almost coincided with the manual digitized coastlines.

Based on this results, the coastlines extracted by the first principal component. in order to calculate the rate of change along Gaza coastal zone, the Digital Shoreline Analysis System (DSAS) was used. DSAS is an ESRI Arc-GIS extension that enables users to calculate shoreline rate-of-change statistics from a time series of multiple shoreline positions[19]. DSAS works by generating orthogonal transects at a user-defined separation and then calculates rates-of-change and associated statistics that are reported in an attribute table. The DSAS tool requires different shorelines and baseline. The baseline is created by the user and serves as the starting point for generating transects (Figure 6). The DSAS extension generates transects that are cast perpendicular to the baseline at a user-specified spacing alongshore. The transect/shoreline intersections are used by the program to calculate the rate-of-change statistics.

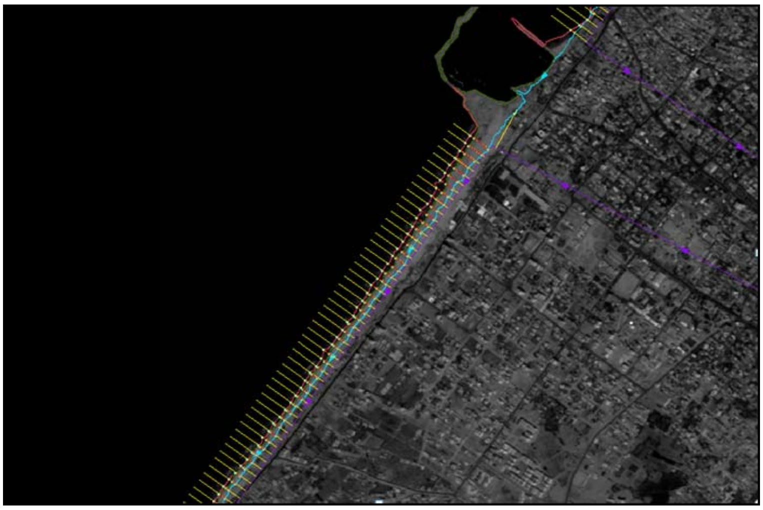

Figure 6: Transects generated perpendicular to the baseline.

The rate of change was computed using two methods. The first calculation technique is End Point Rate (EPR), which divides the distance of shoreline movement by the time elapsed between the earliest and latest measurements. The major disadvantage is the EPR is not able to manage information about shoreline behaviour provided by additional shorelines in cases where more than two shorelines are available..

The second method is a Linear Regression Rate-of-change (LRR), which can be determined by fitting a least squares regression line to all shoreline points for a particular transect. The advantages of linear regression that all the data are used. All the images were taken at the same month to reduce the effect of seasonal variation, tide effects are considered to be negligible in this study.

RESULTS

The rate of coastline change was calculated for each 50 meter using EPR and LPR. The results indicate that the rate of change varies along the coastline. In general, Gaza coastline has exhibited a negative rate along the coastline. Meanwhile, the southern side of Gaza seaport has obtained positive rate, where Gaza seaport interrupts the natural movement of the sediments along the coast. The sediments, which move in NE direction with an estimated volume of 400,000 (m^3/year), were trapped and accumulated in the southern side of Seaport for an extent of four kilometres. Our results have proved again the expectation of many studies such [20] where the negative rate have appeared in the northern side of the coastal zone, even after starting the United Nation organization "UNRWA" a project to protect the northern side of Gaza coastal zone by contracting wave breaker and protect the beach by concrete constructions. Based on this results, Gaza coastal zone could be classified into five regions according to the rate of change (Table 2) and (Figure 7). The obtained rates by EPR are different from LRR, because EPR calculates the rate just between two coastlines (the earliest and the latest), while LRR involves all coastlines in the calculation. The findings in general are similar to that achieved by other studies in the region[21]. Figure 8, shows the variation of the rate of coastline change, the remarkable thing is the positive rate in the southern part of the seaport. The new constructed seaport causes positive and negative effects on Gaza coastal zone: it gains some land on the southern side of the seaport, whereas beach at the northern side of the seaport is eroded. The only applicable methods to protect the northern part, firstly by initiating coastal constructions to protect the beach face from the marine process and secondly, bypassing the sediments to the northern side ensure the continuity of natural nourishment for the northern side.

Table 2. Calculated rate of change along Gaza coastal zone

Date of shorelines	Region	EPR	LRR
Shorelines from 1986 to 2008	A (north Gaza)	-0.06	-0.32
	B (northern Seaport)	-0.26	-0.16
	C (southern Seaport)	0.98	0.80
	D (Wadi region)	-0.26	-0.36
	E (south Gaza)	0.32	0.30

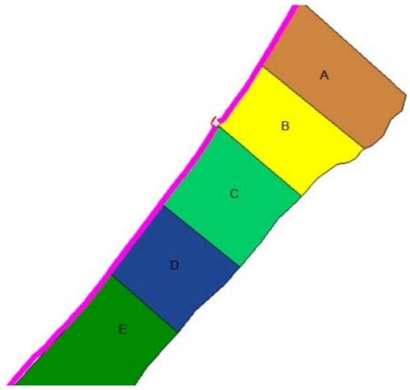

Figure 7: Gaza coastal zone classified into five regions according to Rate of coastal change

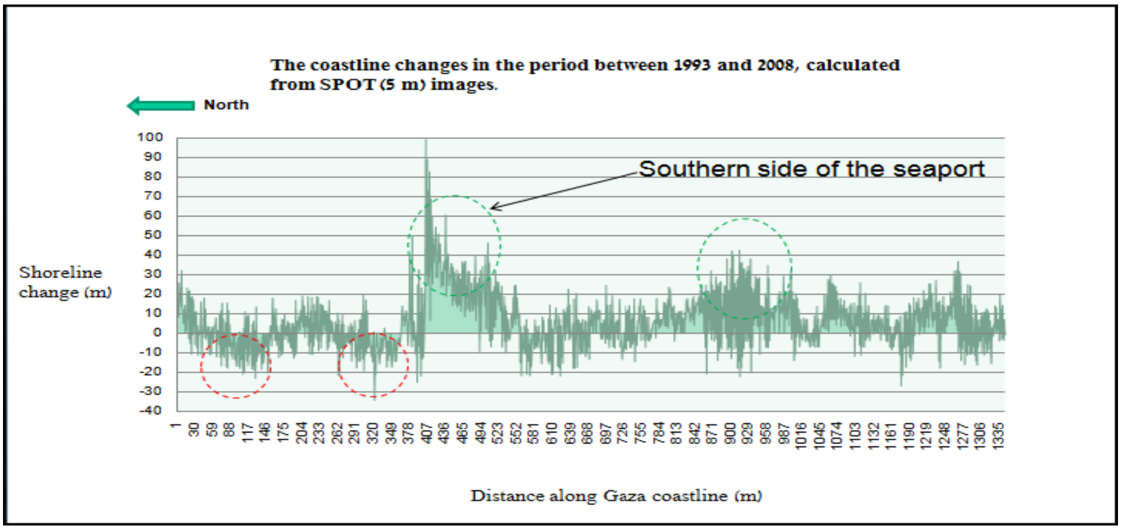

Figure 8: Rate of coastal change along Gaza coastline

In [21]indicate that the rate of cliff retreat is (- 0.41 m/year) in regions 3km north of Khan-Yunis City. Based on your study, we calculated that the rate of coastal change in the same region varies between -0.26 to -0.36 m/year[1]. Accordingly, analysing medium resolution satellite imagery can give an indication on the coastal changes, however, precise spatial results cannot be expected.

CONCLUSIONS

Since very high spatial resolution images is expensive and also not available with an resolution better than 2 meters over Gaza strip, we conducted the study based on medium spatial resolution satellite images. The results exhibit that we could obtain a reasonable results for the rate of coastal change from the medium spatial resolution satellite images. Different methods of automatic coast-line extraction from satellite images might lead to different results, therefore there is a need for an accuracy estimation of the extracted coastline. In general, a negative rate was calculated along the Gaza coastline. For the southern side of Gaza seaport, a remarkable positive rate was found due to the accumulation of the transported sediments by longshore currents. Further studies will be carried out in order to calculate the volumetric change in the southern side of Gaza seaport using high spatial resolution images.

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