JOURNAL OF ENGINEERING RESEARCH AND TECHNOLOGY, VOLUME 4, ISSUE 4, DECEMBER 2017

The Impact of Sea Groins in the Egyptian Side of Rafah on the Erosion of the Beaches of the Southern Area of the Gaza Strip Using Remote Sensing and GIS

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Abstract— Understanding spatio-temporal changes is essential to many aspects of engineering, geographic and planning researches. The coastal zone is the most important and the most intensively used area compared with the other populated areas in the Gaza Strip. The rapid increase of population on Gaza coastal area leads to depletion of the coastal zone resources and change the coastal morphology. In this research, five Landsat satellite imageries are collected during the period from 2008 to 2016, First, all satellite images are radiometric and atmospherically corrected. Remote Sensing techniques and Geographic Information System are used for spatio-temporal analysis in order to detect changes in the shoreline position and coastal areas of the southern governorates. Results indicate that the net change on the beach area of Rafah Governorate equals to -71 donum during the analysis period, which is equivalent to -8.9 donum/year. The net change on the beach area of Khan Younis Governorate equals to -105.5 donum with the rate of -13.2 donum/year. The analysis of Digital Shoreline Analysis System (DSAS) indicates that the net average rate for Rafah's beach is equal to -3.7 m/year (erosion) and -2.7 m/year for Khan Younis. All of these statistics indicate that the obvious trend in the Southern beach is under serious erosion problem. This study is emphasized that the coastal band is considered as a critical area, it is therefore necessary to move all stakeholders to monitor and protect the southern area of Gaza Strip beach from the risk of drift that threatens vital installations and environmental parameter along the beach, such as streets, hotels, tourism facilities, mosques and houses.

Index Terms— Gaza Strip, Shoreline Erosion, Remote Sensing, Spatio-Temporal Analysis.

I INTRODUCTION

The coastal zone is one of the most important and most densely populated areas than other regions in the Gaza Strip. The rapid increase in population in this region leads to an increase in the consumption of its resources and is therefore subject to high pressure from both human and geomorphological activities. In some parts of the southern coast of the Gaza Strip, the process of seashore erosion is sensitive as it threatens to demolish many buildings and roads that are directly on the coast. In 2010, Egypt built a sea groins at the coast of the Egyptian side of Rafah using large rocks. It is placed 2 km from the sea border between Gaza and Egypt, and extends for about 1 km inside the sea. Recently, erosion can be clearly seen in the southern governorates of Gaza Strip, Figure 1. The beach is deteriorated as a result of the sea waves hitting the beach and in the case of high waves, water reaches the sand dunes and thus removes parts of it. When the establishment of a sea obstruction to the movement of sea currents that are loaded with sand, sand accumulation occurred south of the southern groin and on the other hand, erosion took place north of the northern groin [1]. It is expected to face serious problems in the coming few years. In the absence of enough number of studies on the coastal area of the Gaza Strip, therefore, this study is performed to highlight the impact of the Egyptian marine groins on the erosion of the southern shores of the Gaza Strip using GIS. GIS is one of the most advanced technologies that is capable to deal with a large amount of data and conduct many computerized operations as well as extensive spatial analysis.

Figure 1 Seashore Erosion of Rafah City- Palestine

II THE STUDY AREA

Rafah is an Egyptian-Palestinian City, half of which is located inside the Egyptian border and is called Rafah-Egypt. The other half is located in the Gaza Strip and is called Rafah-Palestine. The latter is located in the southern part of the Gaza Strip. Its population in 2016 is about 233,490 people [2] and is located 13 km from Khan Younis, 16 km from the village of Sheikh Zuwayd in Sinai, and 45 km from the Egyptian City of El Arish, Rafah rises from the sea by 48 meters. It is characterized by sandy land, surrounded by sand dunes from each side, then less rainfall and ends fertile towards the desert. The average temperature is between 30 degrees in summer and 10 degrees in winter. The average rainfall in Rafah is 250 mm [3]. Figure 2 shows the Egyptian and Palestinian sides of Rafah City.

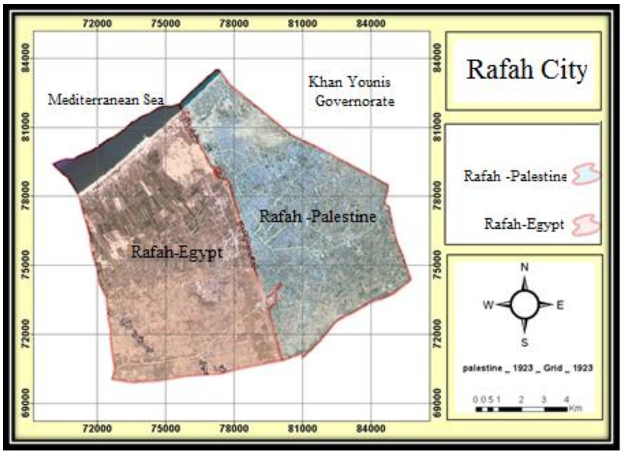

Figure 2 Rafah-Egypt and Rafah-Palestine

III THE STUDY AIM

This study aims to conduct spatio-temporal analysis to detect the changes of the southern coastline of the Gaza Strip during the period between (2008-2016) based on analyzing satellite imagery using remote sensing techniques and geographic information system. To implement this study, the following objectives should be achieved:

- Detecting the amount and rate of change in the area of the coast of the southern Gaza Strip.
- Calculating the linear rate of change along the shoreline using the Digital Shoreline Analysis System (DSAS).
- Making recommendations to those responsible for advancement.

IV METHODOLOGY

There are multiple approaches used in geographic research, as each approach meets the requirements of a particular stage of research, but this study depends mainly on: (A) descriptive approach: It addresses the geographical, historical, social and economic profile of the study area, as well as concepts and knowledge of GIS. It also involves data collection from the USGS website with the focus on satellite imagery captured by Landsat satellites,(B) Historical Approach: This approach is to follow a historical phenomenon, which is not to understand the past but for future planning as well, (C) Applied or analytical approach: The use of an appropriate image processing environment such as ERDAS software to preprocess, enhance, classify and transform imagery. In addition to, the use of ArcGIS and its tools in detecting changes and rates of change along the coast of the study area. Figure 3 outlines the overall framework of the used methodology.

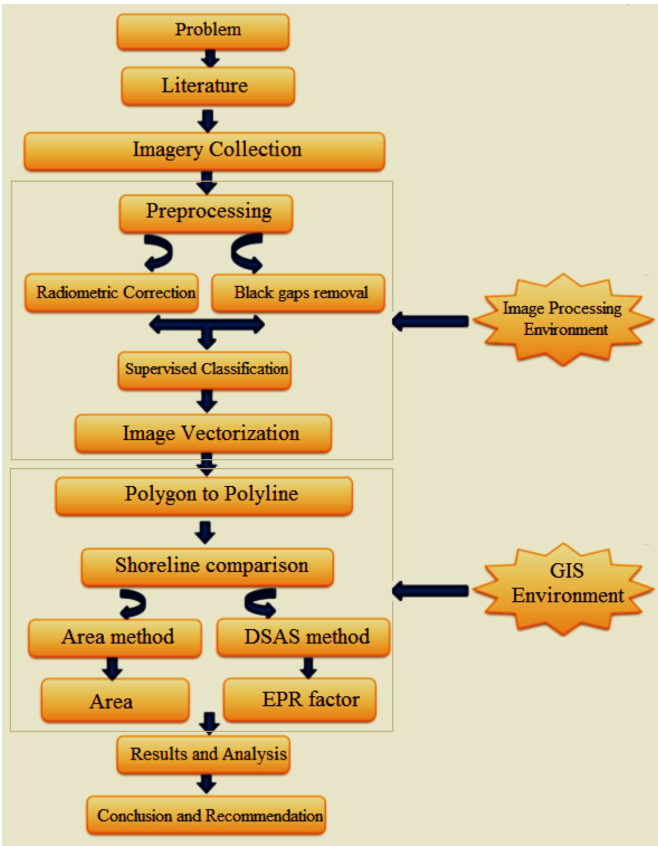

Figure 3 Methodology Framework

A Data Collection

In this study, satellite images from the U. S. Geological Survey (USGS) website are downloaded during the period between (2008-2016) as shown in Table 1 according to the following criteria: downloading images of January, choosing images that are nearly free from noise to reduce preprocessing operations, preferring Thematic Mapper (TM) images than Multi Spectral Scanner (MSS) and Enhanced Thematic Mapper plus (ETM+) to avoid black gaps [4]. Landsat 7 ETM+ downloaded imageries (2008-2012) are SLC-off data (contains black gaps, DN=0). This type of gaps should be minimized by taking two ETM+ scenes, radiometrically corrected, and then combines them for more complete coverage. At last, using all bands in GeoTIFF format.

TABLE 1
Imagery Characteristics.

Image No.	Image Source	Imagery Date	Spatial Resolution, m
1	Landsat7	9-1-2008	30 x 30
2	Landsat7	9-1-2010	30 x 30
3	Landsat7	9-1-2012	30 x 30
4	Landsat8	9-1-2014	30 x 30
5	Landsat8	9-1-2016	30 x 30

B Preprocessing Task

Preprocessing of downloaded images involves various operations as clipping the study area by image subset, performing the radiometric and geometric corrections, enhancing and reducing image noise by removing black gaps. Since the digital sensors record the electromagnetic radiation intensity of each point displayed on the surface of the earth in the form of Digital Number (DN) for each spectral range, the range of the DN value that is captured by the sensor depends on its radiation discrimination. The Landsat MSS sensors measure the radiation on a scale of DN (0 - 63) while Landsat TM and ETM + measure it on a scale of (0 – 255), which includes the correction of the digital image processing to improve the accuracy of the amount of brightness value [5]. It should be noted that the sources of noise and the correct ways to correct them depend in part on the type of sensor, the nature of the image and the nature of the imaging kind used to capture digital image data. Figure 4 shows examples of some preprocessing tasks of the collected imagery.

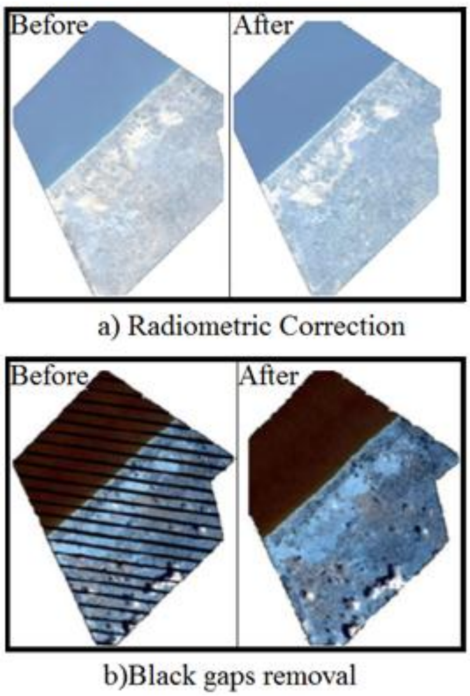

Figure 4 Part of Preprocessing Task

C Image Classification

The supervised classification is used because the difference is clear between land and water in the collected images [6]. Several land and water training samples are selected using ERDAS Imagine 2014 software. The user specifies the various pixels values or spectral signatures that should be associated with each class (here, land or water). This is done by selecting representative sample sites of known cover type called training sites. It is important to choose training sites that cover the full range of variability within each class to allow the software to accurately classify the rest of the image. The computer algorithm then uses the spectral signatures from these training sites to classify the whole image. Figure 5 shows an example of a supervised classification of one of the images under consideration

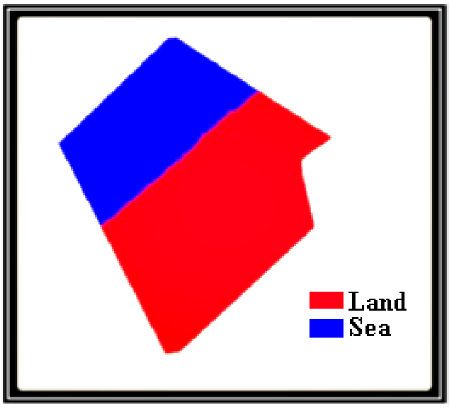

Figure 5 Supervised Classification of Images

D Change Detection Analysis

At this stage, two types of analysis are conducted.; the change of the beach area between any two sequent shorelines of any selected interval and the other is the linear rate of change of the shoreline of the considered interval using the Digital Shoreline Analysis System (DSAS) tool. To calculate the change in the area between the two shorelines of the beach, ArcGIS tools are used, first the shorelines are merged using the append tool until they become in one feature class. Then, they are processed to form a closed space and the lines are converted to polygon using "feature to polygon" tool. Finally, accretion and erosion areas for both Rafah and Khan Younis can be calculated. To calculate the linear rate of change along the shoreline, the DSAS is used. It enables the user to calculate the rate of change over different time periods for different locations along the shoreline. The DSAS tool creates vertical transects that are defined by the user and calculates statistics for the rate of change of the shoreline within the attribute table. The tool requires two shorelines and a reference line; the reference line is done by the user, which is the starting point for the generation of transects that are perpendicular to it at regular distances specified by the user and depend on the tool in the conduct of statistical calculations. Figure 6 illustrates the basic steps to generate transects and the corresponding statistical calculations by DSAS tool [7]. Thus, all data entered for the DSAS tool must be within the personal geodatabase, which involves the reference line and shorelines for every two-year periods in a single feature class. The End Point Rate (EPR) is calculated by determining the distance between the old date and modern date shorelines divided by the number of years between them. The basic advantage of this method is the simplicity of calculations and the spread of their application and also gives excellent accuracy over long periods. But the main drawback is that they cannot handle more than two beach lines.

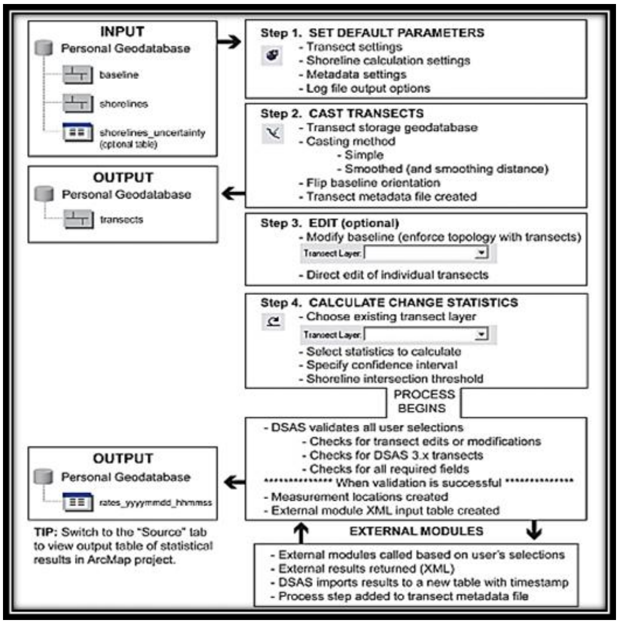

Figure 6 DSAS Basic Steps

V ANALYSIS AND RESULTS

The study area is classified into two zones; (A) Rafah, 2.4 km shoreline long and (B) Khan Younis, 10.4 km shoreline long. The two zones are shown in Figure 7.

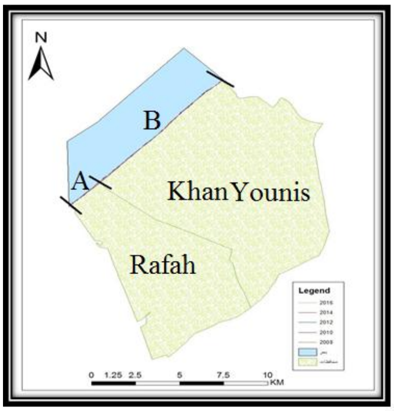

Figure 7 The study Area Zones

Figure 8 highlights the extracted shorelines of Rafah-Palestine in the period (2008–2016).

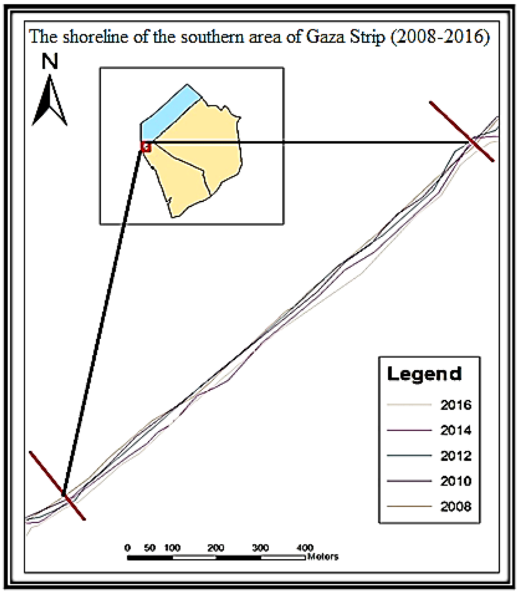

Figure 8 The shoreline of zone A (2008 – 2016)

A The Change in Area Analysis

The study interval between 2008 to 2016 is divided into four periods, each of two-year period. Using GIS tools, the confined space between each of the four time periods is calculated and presented in Tables 2 and 3, where the negative values represent the erosion case and the positive values represent the accretion case. Table 2 illustrates the results of zone A that corresponds to the analysis of the shoreline of Rafah-Palestine Governorate. It is noticed that the quantities of the erosion are in the case of continuous increase with time, especially in the periods between (2012-2014) and (2014-2016). As for the amounts of accretion is somewhat instable and closer to be fixed with time. The total erosion area during the study period (2008-2016) is about 71 donum with a rate of -8.9 m^2/year.

TABLE 2

The change of area analysis for Rafah-Palestine shoreline

Image Period	Erosion		Accretion		Net of Change	
	Total x 10^3 [m^2]	Rate x 10^3 [m^2 / year]	Total x 10^3 [m^2]	Rate x 10^3 [m^2 / year]	Total x 10^3 [m^2]	Rate x 10^3 [m^2 / year]
2008-2010	-10.25	-5.12	4.28	2.14	-5.96	-2.98
2010-2012	-11.14	-5.57	6.05	3.02	-5.10	-2.55
2012-2014	-30.84	-15.42	1.18	0.59	-29.66	-14.83
2014-2016	-35.12	-17.56	4.54	2.27	-30.57	-15.29
Total	-87.35	-10.92	16.05	2.01	-71.29	-8.91

Note: (+) sign indicates accretion, (-) sign indicates erosion

Table 3 summarizes the results of zone B which corresponds to the analysis of the shoreline of Khan Younis Governorate. One can notice that starting in 2010, there is an increase in the quantities of erosion at a linear rate as expected due to the presence of the Egyptian marine groins, and the quantities of accretion are also oscillatory and atypical. The total erosion area is about 105.5 donum during the study period (2008-2016) with a rate of -13.2 m^2/year.

TABLE 3

The change of area analysis for Khan Younis shoreline

Image Period	Erosion		Accretion		Net of Change	
	Total x 10^3 [m^2]	Rate x 10^3 [m^2 / year]	Total x 10^3 [m^2]	Rate x 10^3 [m^2 / year]	Total x 10^3 [m^2]	Rate x 10^3 [m^2 / year]
2008-2010	-52.83	-26.42	26.25	13.13	-26.58	-13.29
2010-2012	-28.86	-14.43	67.43	33.72	38.57	19.29
2012-2014	-60.34	-30.17	2.02	1.01	-58.31	-29.16
2014-2016	-89.78	-44.89	30.62	15.31	-59.16	-29.58
Total	-231.8	-28.98	126.32	15.79	-105.48	-13.19
Note: (+) sign indicates accretion, (-) sign indicates erosion						

B The Linear Change in Shoreline Analysis

Coastline linear change rates are calculated using the DSAS tool with the EPR statistical technique. 341 transects are created and spaced at a regular distance of 40 m. Zone A is covered by 56 transects. Table 4 shows the average linear change rate results for zone A, Rafah-Palestine. Its average erosion rate is 3.7 m/year.

TABLE 4

Average linear change rate for Rafah-Palestine (2008-2016)

Image period	Transect	Erosion		Accretion		Net Average (m/year)
		Average (m/yr)	Max (m/yr)	Average (m/yr)	Max (m/yr)	
2008-2010	1-56	-5.45	-9.33	3.21	6.99	-3.44
2010-2012	1-56	-4.36	-9.00	3.32	8.87	-1.15
2012-2014	1-56	-8.03	-15.45	1.85	2.92	-6.78
2014-2016	1-56	-5.35	-15.97	6.34	10.83	-3.44
Average linear change rate from 2008-2016						**-3.70**
Note: (+) sign indicates accretion, (-) sign indicates erosion						

Transects from 57 to 341 are generated by DSAS tool to cover zone B, Khan Younis City which has a shoreline of 10.4 km long. Table 5 summarizes the average linear change rate of this zone. Its average erosion rate is 2.69 m/year.

TABLE 5

Average linear change rate for Khan Younis (2008-2016)

Image period	Transect	Erosion		Accretion		Net Average (m/year)
		Average (m/yr)	Max (m/yr)	Average (m/yr)	Max (m/yr)	
2008-2010	57-341	-5.23	-13.83	4.91	13.45	-1.71
2010-2012	57-341	-3.53	-8.43	4.59	11.05	1.70
2012-2014	57-341	-8.11	-21.24	1.51	4.15	-7.51
2014-2016	57-341	-6.00	-15.54	5.74	12.87	-3.25
Average linear change rate from 2008-2016						**-2.69**
Note: (+) sign indicates accretion, (-) sign indicates erosion						

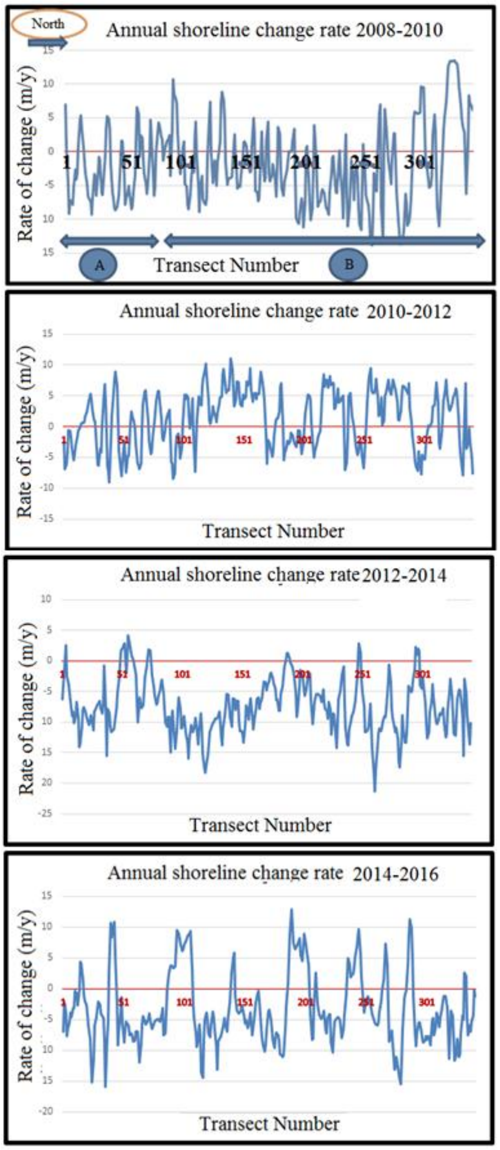

Figure 9 Annual shoreline linear change rate (2008–2016)

The results for both zones which are obtained above is presented graphically in Figure 9. From Figure (9), the following notes can be concluded:

- During the period (2008-2010), fluctuations in the values of erosion and accretion along the coast before the construction of the Egyptian marine groins is observed.
- During the periods (2010-2012), (2012-2014) and (2014-2016), the prevailing pattern on the shoreline is the erosion as the quantities of shoreline deterioration are much larger than the amounts of accretion that are negligible on these periods.
- The period (2012-2014) is the most exposed period of erosion relative to otherl periods.
- Presence of accretion amounts distributed along the shore during the period (2014-2016) is noticed, due to the construction of several small marine groins on the Palestinian side as a partial solution to reduce the erosion of the shore.
- The effect of the Egyptian marine groin is equal to both Rafah and Khan Younis governorates as the pattern during each period is similar to the entire length of the beach.

VI CONCLUSION

The analysis of satellite observations of Landsat for the Mediterranean coast in the governorates of Rafah and Khan Younis during the period (2008-2016) shows that there are a change in the patterns of erosion and accretion. The results reveal that the net change in the area of Rafah Governorate equals about 71 donum of sand at an erosion average of -8.9 donum annually. The net erosion on the area of Khan Younis beach equals about 105.5 donum at a rate of -13.2 donum annually. The impact of the Egyptian sea groin on Rafah, about three times greater than Khan Younis. This confirms the previous results that the mean net change of Rafah beach using EPR analysis is equal to 3.7 m / year (erosion) and for Khan Younis is 2.69 m / year (erosion). It is recommended to support researchers and projects in this field as its greatest importance. For future studies, it is suggested to calculate the volume change of critical areas and to refine the analysis taken into account the tidal data. The concerned authorities should conduct periodic studies to follow the future changes. To benefit from the results of this study, strategies and systematic steps to solve the problem of erosion of the coast of the study area, namely Rafah and Khan Younis should be made.

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