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Spatio-Temporal Analysis of Gaza Strip Shoreline Using GIS and Remote Sensing

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ABSTRACT

The rapid increase of population on Gaza coastal area leads the depletion of the coastal zone resources and the change of the coastal morphology. In this research seven satellite imageries (MSS, TM and ETM+ Landsat) are collected from 1972 to 2012 and arranged into six periods. Spatio-temporal analysis is used to detect changes in the shoreline position as well as the change in the coast area using GIS and remote sensing techniques. Gaza Strip coastal zone is classified into seven regions; A) Rafah B) khan Younis C) Southern of the Middle Governorate, D) El-Wadi region, E) Southern of the Sea Port, F) Northern of the Sea Port, and G) North Gaza Governorate. This study indicates that regions A, B, and C are exposed to accretion in the first five periods, but regarding the last period, the erosion is the largest. Region D is exposed to erosion in all periods between 1972-2012, where, the average annual area erosion rate and the rate of change are 2,120 m^2 and 1.23 m/year, respectively. Most substantial changes have been observed in the south side of Gaza Sea Port (region E) which show positive annual area rate 14,940 m^2 and a change rate equal 2.2 m/year. Region F is exposed to a serious problem of erosion as the annual erosion area rate is about 9,550 m^2 and a linear rate of -2.21 m/year. Region G is also exposed to erosion patterns. It is necessary to move all stakeholders to monitor and protect Gaza Strip beach from the risk of drift that threatens vital installations and environmental parameters along the beach.

1. Introduction

Change information of the earth's surface is becoming more and more important in monitoring the local, regional and global resources and environment. The large collection of past and present remote sensing imagery makes it possible to analyze spatio-temporal pattern of environmental elements and impact of human activities in past decades [1]. The study of historical shoreline data can be useful to identify the predominant coastal processes operating in specific coastal locations using change rates as an indicator of shoreline dynamics. The real importance of such studies is to avoid decisions based on insufficient knowledge, wrong assessments or arbitrary decisions, leading to losses in resources and infrastructure that could have been prevented. Sediment is any particulate matter that can be transported by fluid flow and which eventually is deposited as a layer of solid particles on the bed or bottom of a body of water or other liquid. Sediment, moved by waves and wind, may be academically divided into cross-shore and alongshore sediment transport. Sediment movement can result in erosion or accretion (removal or addition of volumes of sand). Erosion normally results in shoreline recession (movement of the shoreline inland), accretion causes the shoreline to move out to sea [2]. The transport of material along the coast is linked to natural forces such as waves, tidal movements, long and cross-shore currents, and wind. Reference [3] discusses five of the primary factors that may change shoreline position: 1) wave and current processes, 2) sea level change, 3) sediment supply, 4) coastal geology and morphology, and 5) human intervention.

2. Gaza Strip Case

Gaza Strip is a coastal area along the eastern Mediterranean Sea, 42 km long and between 6-12 km wide, with total area of about 365 km^2. It is located on 31° 25′ N, 34° 20′ E; WGS84 coordinate system, bordering Egypt to the south, historical Palestine to the east and north and the Mediterranean Sea to the west as illustrated in Fig. 1.

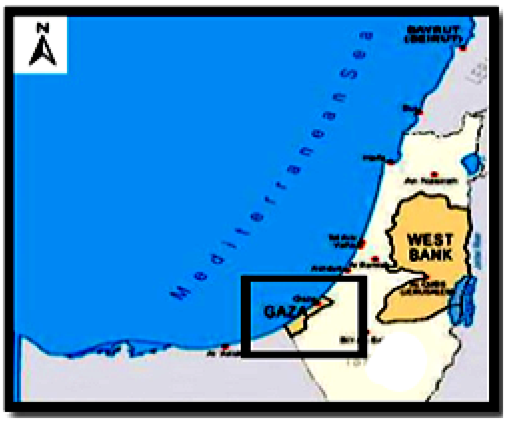

Fig. 1: Gaza coastline in the Mediterranean Context

The coastline of the Gaza Strip forms only a small section of a larger concave system (a littoral cell) that extends from Alexandria at the west side of the Nile Delta, via Port Said, Bardawil Lagoon, El Arish, Gaza, to the Bay of Haifa. This littoral cell forms the South East corner of the Levantine Basin. This entire coastline, including the coastline of the Gaza Strip, has been shaped over the last 15,000 years by the Nile river and especially its sediment yield originating from Africa's mountains. The Nile sand moves along the entire concave coastline in an anticlockwise direction, generally in a North East direction. Within this concave corner of the Mediterranean, the relatively short 42 km Gaza coastline is almost straight [4].

Gaza Strip coastal behavior must be understood to avoid the mistakes of the past and ensure that the best uses will be selected for each place. Every step toward a better understanding of the dynamics of the Gaza Strip coastal systems and forecasting its changes with the purpose of assisting in future developments will be one more step in the right direction. The main problem is there is no studies on the whole Gaza Strip coastal zone. Thus, the results of this research can be used by the concerned authorities to protect the beach from erosion. Coastal erosion is evidenced by collapsed trees, buildings, roads and other structures, including groins which prompting the need for immediate and local protection to prosperities, there is a need to ensure the long-term protection for the overall coast from serious problems such as erosion. Furthermore, the building and roads that have been constructed close to the shoreline are facing a stability problem and it is expected to have a serious erosion problem in the coming few years [5].

Previous studies regarding Gaza Strip concentrate on the region located to the north and south of Gaza sea port and study its effect on the shoreline [5] [6] [7] [8]. These studies show that the Gaza coast, especially to the north of sea port, have negative rates taken place and erosion is the predominant process. Gaza harbour causes a serious damage to the northern beaches and it prevents the free movement of sediments that lead to sedimentation in the south and erosion in the north. But none of these studies is concerned in detail about all Gaza Strip coastal zones.

This research aims to conduct a spatio-temporal analysis of the Gaza Strip shoreline between 1972-2012 based on satellite imagery using remote sensing and Geographic Information System (GIS) techniques.

3. Methodology

Fig. 2 illustrates the methodology followed in this research which involves; Imagery collection and preparation, pre-processing task, supervised classification, shoreline extraction, change detection analysis and finally discussion of results.

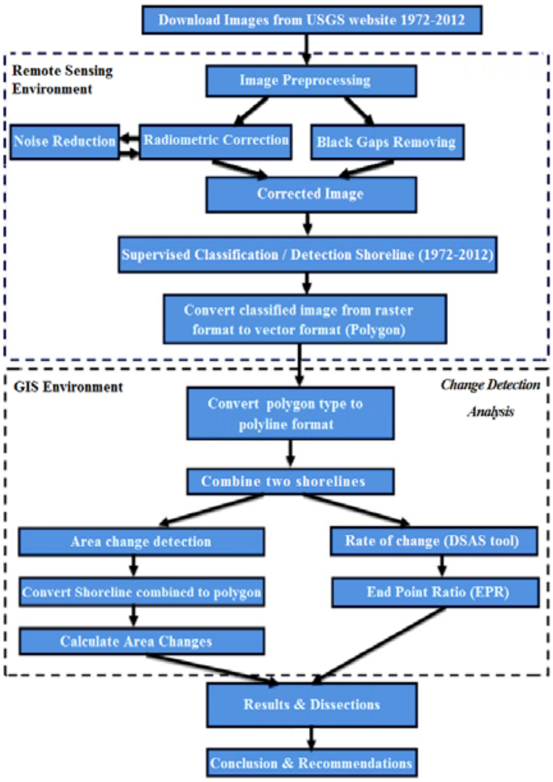

Fig. 2: Methodology framework

3.1. Data Collection

Data is mainly Landsat remotely sensed imageries downloaded from U.S. Geological Survey (USGS) website – Landsat archive from 1972 to 2012. TM imagery is given a priority over ETM+ and/or MSS since TM sensor life span is longer than ETM+ (approx. 23 years) so consistent data is collected. In contrast, Landsat ETM+ imageries have the problem of the Scan Line Corrector Failure (SLC-off) which is presented in black gaps. Moreover, Landsat ETM+ has the only advantage of the panchromatic band existence.

Table 1. Imagery used for analysis

Image Source	Date	Resolution (m)	Image Source	Date	Resolution (m)
Landsat1 MSS	10-1972	60 x 60	Landsat5 TM	05-2002	30 x 30
Landsat5 TM	05-1984	30 x 30	Landsat7 ETM+	09-2008	30 x 30
Landsat5 TM	09-1990	30 x 30	Landsat7 ETM+	09-2012	30 x 30
Landsat5 TM	10-1998	30 x 30			

However, the resolution in the multispectral bands in ETM+ is the same of TM, 30 m. A full-bands imagery in a Geostationary Earth Orbit Tagged Image File Format (GeoTIFF) is downloaded. Based on these criteria, seven imageries are downloaded as illustrated in Table 1. A subset image is created from each image, that only covers the study area on each date (1972-2012) using ERDAS Imagine 2014.

3.2. Pre-Processing Task

Preprocessing of image data often include radiometric correction, geometric correction and removing of black gaps. To correct the geometric distortions, one should apply two steps, geo-referencing and resampling using GIS. After correcting the coordinate system, the spatial characteristics of pixels may be changed. So, resampling should be applied to obtain a new image more pronounced in which all pixels are correctly positioned within the terrain coordinate system to more accurate feature extraction methods.

Radiometric correction involves the processing of digital images to improve the fidelity of the brightness value magnitudes. Any image contains radiometric errors and inconsistencies will be referred to as "noise" these errors should be corrected before the extraction and analysis of information from the image. The sources of radiometric noise and therefore, the appropriate types of radiometric corrections, partially depend on the sensor and mode of imaging used to capture the digital image data such as satellite image, optical scanners, sensors and others.

Removing black gaps in ETM+ is required since Landsat 7 ETM+ downloaded imageries (2008 and 2012) are SLC-off data (contains black gaps, DN=0). This type of gaps has been minimized by taking two ETM+ scenes, radiometrically corrected, and then combines them for more complete coverage. Another model has been built by the researchers, Fig. 3, to do this kind of correction to make it easier and less time consuming since this correction is to be run for two imageries (2008 and 2012) which each consists of several bands.

Fig. 3 represents the developed model which includes two inputs (a band from each year) and one output; the merged image. Where band N in image 1 > 0, use band N in image 1 data, Otherwise, use band N in image 2. In other words, Image 2 data will fill the gaps in Image 1. Black gap removing of satellite image acquired in 2008 is shown in Fig. 4.

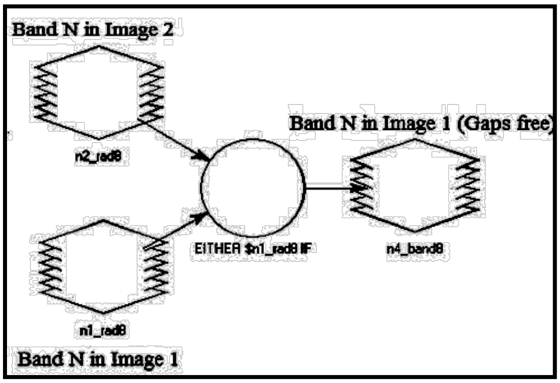

Fig. 3: Black gaps removing model

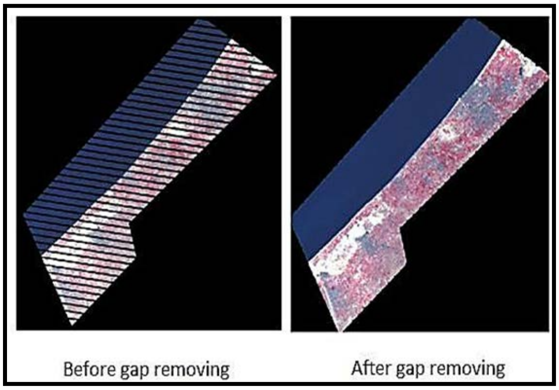

Fig. 4: A sample of black gaps removing

3.3. Supervised Classification

Supervised classification is used since the Area of Interest (AOI) is known and clear to be distinguished (water and land). Thus, the spectral signatures of the sea body and the land are developed and then the software assigns each pixel in the image to the type to which its signature is most similar.

Figure 5 represents the image supervised classification process which begins with identifying Area of Interests (AOI) as shown in Figure 6-a. Figure 6-b illustrates the resulted supervised classification; dark blue represents the water while dark brown represents the land. Figure 6-c is the classified image in a vector format exported to ArcGIS software to start change analysis process.

3.4. Shoreline Extraction

Shoreline can be extracted by using GIS Arc Toolbox to convert the polygon feature to line feature then using editor toolbar to remove the edge lines. The remaining line which separates two classify cluster represents shoreline. These steps should be repeated to extract all Gaza Strip shorelines from 1972-2012.

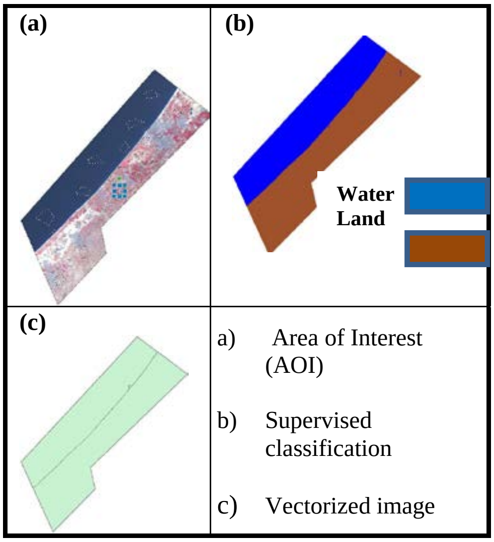

Fig. 5: Supervised classification and vectorization

3.5. Change Detection Analysis

In this stage, area change, and digital shoreline analysis are performed within GIS Environment. For this purpose, Gaza Strip coastal zone is classified into seven regions according to the rate of change and governorates borders; such as: A) Rafah 2.4 km, B) khan Younis 10.4 km, C) Southern of middle governorate 8 km, D) El-Wadi region 2.4 km, E) southern Sea port 6.4 km, F) northern sea port 3 km, and G) north Gaza governorate 6.2 km, as shown in Fig. 6. A sample of extracted shoreline of region A is shown in Fig. 7.

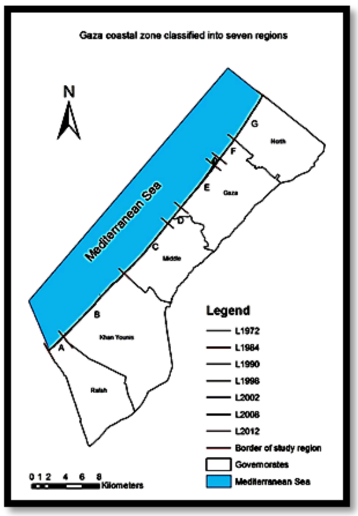

Fig. 6: Gaza coastal zone classification

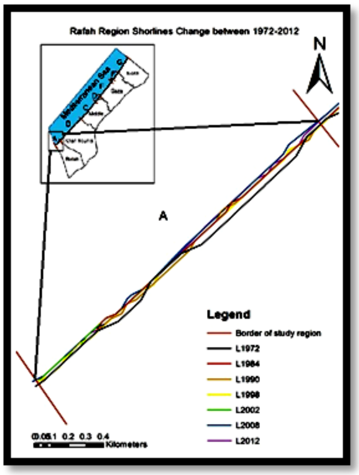

Fig. 7: Shoreline Change in region A

3.5.1 Change in Shoreline Area

Using GIS tools, the area enclosed between period intervals (six intervals) is counted. Then, the calculation results are listed and expressed graphically, with negative values representing erosion (recession) and positive values indicating accretion (advanced). During relatively stable periods, the advance or retreat areas are small, and their values are similar. Region A represents the coastal region from the borders of Egypt to the intersection between Rafah and Khan Younis Governorates. The amount of erosion and accretion rates are listed in Table 2 and graphically illustrated in Fig. 8.

Table 2: Erosion and accretion for region A

Image Period	Erosion		Accretion		Net of Change	
	Total x 10^3 [m^2]	Rate x 10^3 [m^2/yr.]	Total x 10^3 [m^2]	Rate x 10^3 [m^2/yr.]	Total x 10^3 m^2]	Rate x 10^3 [m^2/ yr.]
1972-84	-0.29	-0.02	48.5	4.04	48.2	4.01
1984-90	-2.40	-0.40	16.30	2.72	13.90	2.32
1990-98	-5.30	-0.66	14.80	1.85	9.50	1.19
1998-02	-2.60	-0.65	14.20	3.55	11.60	2.90
2002-08	-2.00	-0.33	25	4.17	23	3.83
2008-12	-5.20	-1.30	0.60	0.15	-4.60	-1.15
Total	-17.8	-0.43	119	2.98	101.6	2.54

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

There is not a consistent pattern, it is evident that

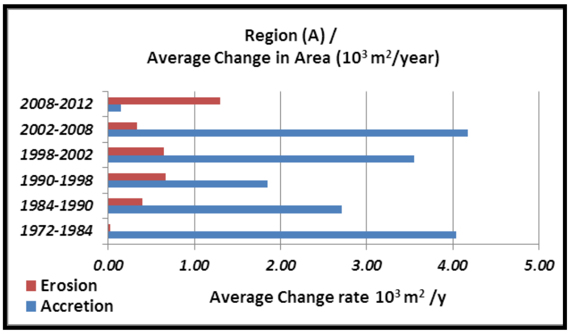

Fig. 8: Average area change rate for region A

in this sector accretion processes are dominant during the first five periods; the total area gain to accretion is larger than the total area loss to erosion. Except in a time at 2008 to 2012 the erosion appears larger than the accretion. This could be attributed due to human intervention in the Egyptian Rafah side such as groins [5]. A large trend in the ratio between eroded and accreted area, which varies over time. Erosion is growing during these periods. In general Rafah coastal area is being exposed to increase in the coastal areas at a rate of 2,540 m^2/year. In some interval of time, there is roughly balance between erosion and accretion for region B. In addition to, the first five periods, accretion is larger than erosion except the period between 2008 to 2012. During the whole study period, the portion of this sector that exposed to the highest amount of accretion with a rate of 5,310 m^2/year. It can also be noticed that eroded area is increasing rapidly against accretion amounts as shown in Fig. 9.

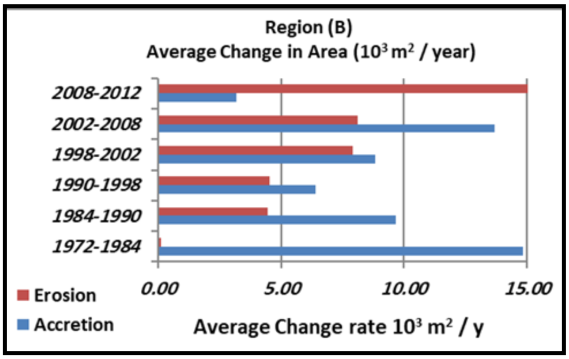

Fig. 9: Average area change rate for region B

Fig. 10 shows that in the first five intervals, the accretion is larger than the erosion. Except the last interval between 2008-2012 which is exposed to erosion larger than accretion. During the whole study periods, the portion of this sector that exposed to the highest amount of accretion with a rate of 7,000 m^2 / year.

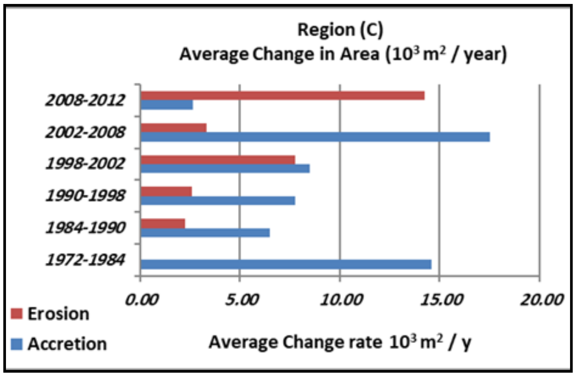

Fig. 10: Average area change rate for region C

Fig. 11 shows the dominance of negative rates in general for region D, which means that erosion is the predominant process, except the interval 2002 to 2008 which shows positive rates. The main causes of erosion in this region are due to Gaza valley (Gaza-Wadi). In general, El-Wadi region is being exposed to decrease in the coastal areas at a rate of 2,120 m^2/year.

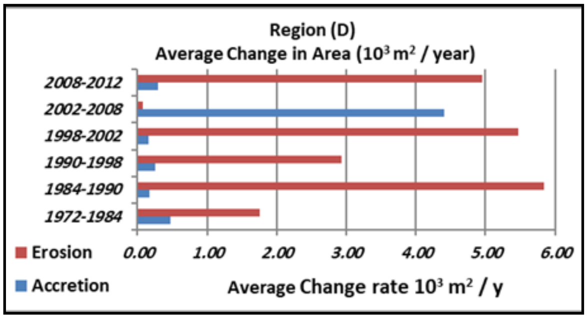

Fig. 11: Average area change rate for region D

As shown in Fig. 12, it is evident that in region E accretion processes are dominant during the whole periods; the total area gain to accretion is the largest where the erosion process is very small. This could be attributed due to human activities such as: groins which built at the early of seventy and Gaza sea port which are completely constructed in 1998. These structures have interrupted the prevailing north-ward flowing alongshore current; consequently, its load of sediment has been deposited south of the structures. In general, this region is being exposed to increase in the coastal areas at a rate of 14,940 m^2/year. The results have proved again the expectation of previous studies, where the positive rate have appeared in the southern side of the Gaza sea port.

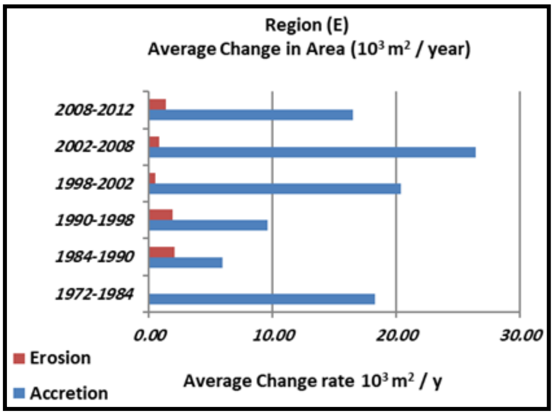

Fig. 12: Average area change rate for region E

The result regarding region F shows negative rates in general, which means that erosion was the predominant process this region. Gaza Sea port caused a serious damage to the northern beach especially after removing the nine detached breakwaters. The study show that the erosion is growing during this period, and these patterns of change will treat the public and private property. This study shows the average rate of erosion about 9,550 m^2/y. The results have proved again the expectation of previous studies, where the negative rate have appeared in the northern side of the coastal zone.

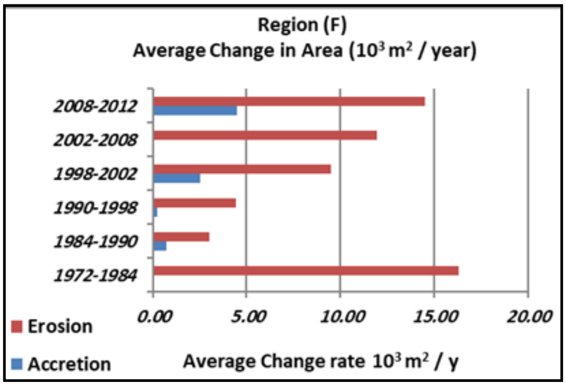

Fig. 13: Average area change rate for region F

The result of region G, Fig. 14, shows negative rates in general, where total accretion is considerably less with respect to erosion. This pattern of erosion and accretion indicates that the equilibrium between erosion and accretion processes in this spatial unit is towards negative. This study shows the average rate of erosion that is about 4,420 m^2/y.

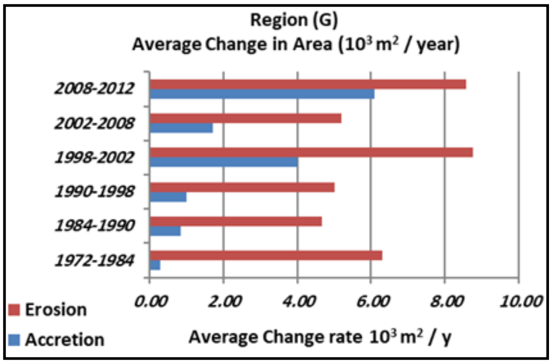

Fig. 14: Average area change rate for region G

3.5.2 Linear Change Rate Analysis

To calculate the linear change rate along Gaza Strip coastal zone, the Digital Shoreline Analysis System (DSAS) is 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. DSAS works by generating orthogonal transects at a user-defined separation and then calculates rate of change and associated statistics that are reported in an attribute table.

The DSAS tool requires different shorelines and a baseline. The baseline is created by the user and serves as the starting point for generating. The DSAS extension generates transects that are cast perpendicular to the baseline at a user-specified spacing alongshore. The transect intersections are used by the program to calculate the rate of change statistics. So, all DSAS input data must be managed within a personal geodatabase, which includes all the baseline created for study area and shorelines for 1972, 1984, 1990, 1998, 2002, 2008, and 2012. Totally, 794 transects are generated with 50 m spacing and the length of each transect is 300 m.

The End Point Rate (EPR) is calculated by determining the distance between the oldest and most recent shoreline in the data and dividing it by the number of years between them. The main advantages of the EPR approach are the simplicity of computation and its widespread application and provides an accurate net rate of change over the long term. But the major disadvantage is the EPR is not able to manage information about shoreline behavior provided by additional shoreline in cases where more than two shorelines are available, and this method does not use the intervening shorelines, so it may not account for changes in accretion or erosion rates that may occur through time.

As an example, 61 transects for region F are generated from 610-670 and oriented perpendicularly to the baseline at 50 m spacing along 3 km shoreline. This study area is located at the north of the Gaza sea port. Table 3 indicates that erosion occurs during the study period with an average rate of 2.21 m/year.

Table 3: Shoreline change rate for region (F)

Image period	**Transect**	**Erosion**		**Accretion**		**Net Avg. (m/y)**
		Avg. (m/y)	**Max. (m/y)**	**Avg. (m/y)**	**Max. (m/y)**	
1972-84	610-670	-2.80	-5.60	----	----	-2.80
1984-90	610-670	-0.65	-3.5	0.55	2.50	-1.20
1990-98	610-670	-1.80	-4.30	----	----	-1.80
1998-2002	610-670	-2.80	-7.30	0.73	2.30	-1.87
2002-2008	610-670	-3.80	-7.80	0.50	2.02	-3.20
2008-2012	610-670	-3.20	-5.70	1.90	4.70	-2.40
Average Change from 1972-2012						**-2.21**
Note: (+) sign indicates accretion, (-) sign indicates Erosion						

The average of linear change rate of all regions is summarized and shown in Table 4.

Table 4: DSAS results for all regions

Region	**Location**	**Avg. (m/y) 2008-12**	**Avg. (m/y) 1972-2012**
A	Rafah	- 1.50	+ 0.91
B	Khan Younis	- 1.18	+ 0.69
C	South Wadi Gaza	- 1.74	+ 0.71
D	North Wadi Gaza	- 2.00	- 1.23
E	South Sea Port	+ 1.90	+ 2.20
F	North Sea Port	- 2.40	- 2.21
G	North Gaza	- 1.76	- 1.49
Note: (+) sign indicates accretion, (-) sign indicates Erosion			

Fig. 15 concludes all the result that are tabulated above and graphically expressed. For regions A, B and C, they are exposed to accretion in the first five periods, but for the last period the erosion is being larger; this is attributed to human activities especially the groins which the Egyptian North Sinai Governorate built near to the Rafah borders. Region D is exposed to erosion in a whole period, this unbalance due to the influence of Gaza Valley. Most substantial changes have been observed in the south side of Gaza sea port which obtained positive rate, where Gaza seaport interrupts the natural movement of the sediments along the coast. Finally, Regions F and G are exposed to a serious problem of erosion especially the beach camp.

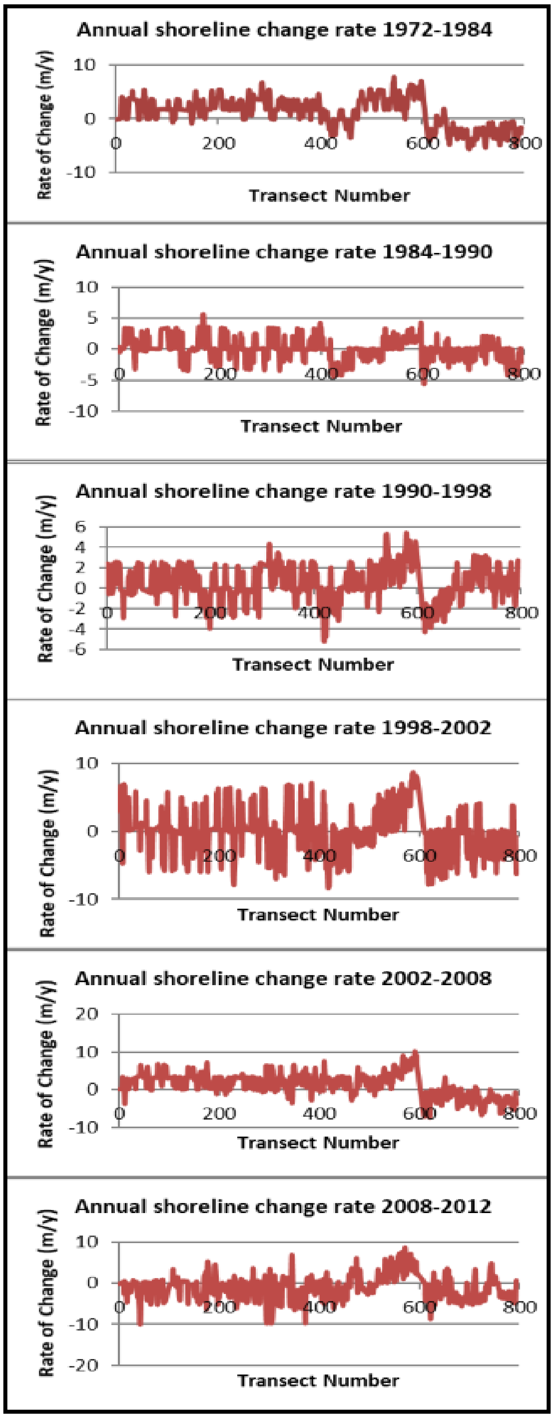

Fig. 15: DSAS results for all regions

4. Conclusion and Recommendations

Analysis of satellite Landsat images for the Mediterranean coast of Gaza Strip for the years from 1972 to 2012 show shoreline changes in response to erosion and accretion patterns. Gaza coastal zone is classified into seven regions according to the rate of change and governorates borders. Results indicate that regions A, B, and C expose to accretion in the first five periods, but for the last period the erosion is being large. Region D is exposed to erosion in the whole period 1972-2012, the average annual erosion rates and rate of change from 1972 to 2012 are 2,120 m^2 and 1.23 m, respectively. Most substantial changes have been observed in the south side of Gaza sea port (region E) which shows positive annual rate 14,940 m^2 and change rate about 2.2 m/year. Region F expose to a serious problem of erosion. The annual erosion rates are about 9,550 m^2 and 2.2 m/year. Finally, region G is also expose to erosion patterns.

The following recommendations should be taken into consideration:

- Utilization of the result of this study to find strategies to keep Gaza shoreline alive.
- The stockholders should perform periodic check on the critical regions which face serious problem.
- Protect northern beach of Gaza city and Rafah which expose to a real threat and could form a serious problem to structures which are near the beach such as: Roads, restaurants, mosque and hotels

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References

[1] Jianya, Gong, et al., “A review of multi-temporal remote sensing data change detection algorithms”, The International archives of the photogrammetry, remote sensing and spatial information sciences, Hong Kong, 2008.

[2] J. Kamphius, "Introduction of coastal engineering and management", Second Edition, World Publishing Scientific Co. LTD, London, England, 2010.

[3] F. Anders, M. Byrnes," Accuracy of shoreline change rates determined from maps and aerial photographs", Journal of Shore and Beach Vol. 59, pp. 17-26, 1991.

[4] M. Ali, “The coastal zone of Gaza Strip-Palestine management and problems", Presentation for Mama first kick-off meeting 11-13 March Paris, 2002.

[5] M. A. El-Hallaq, “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”, Journal of Engineering Research and Technology, Vol. 4, Issue 4, pp. 124-129, 2017.

[6] K. Abu-Alhin, I. Niemeyer, " Calculation of erosion and accretion rates along Gaza coastal zone using remote sensing and geographic information system", 4th EARSeL Workshop Remote Sensing of the Coastal Zone, Greece, 2009.

[7] M. Abualtayef, S. Ghabayen, A. Abu Foul, A. Seif, A. Abd Rabou, and O. Matar, " Mitigation measure for Gaza coastal erosion", Journal of Coastal Development Vol. 16 (2):135-146, 2013.

[8] D. Zviely, M. Klein, “The environmental impact of the Gaza Strip coastal constructions”, Journal of Coast Research Vol. 19, No. 2, pp. 1122-1127, 2003.