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Analysis of Multi Temporal Satellite Imagery for Total Suspended Sediments in a Wave-Active Coastal Area-Gaza Strip Coastal Water, Palestine

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Abstract

Sediment load materials is one of the key factors that determine the surface water quality, both of oceanic and river water, and it specifies water optical properties. Thus it provides a background for a plenty of applications and projects in the water and oceanography community. Landsat detects and classifies reflected solar energy from bodies on the earth's surface. Suspended sediments existing in water column have an optical influences. So that, Landsat images could detect suspended sediments concentration in such a water surface. In this study we have three main objectives to be achieved as; TSS Concentration maps generation in the Gaza Strip coastal zone, achieving analysis processes on TSS trend itself and TSS related coastal phenomenon, and investigation of the ability of Landsat images to detect TSS comprehensively in a wavy coastal zone. For this purpose two landsat TM5 images acquired in 1999 and 2010, one Landsat TM7 images acquired in 2003, and 2 Landsat Oli 8 images acquired in 2014 and 2015 were used for TSS mapping. In addition, 64 TSS in-situ tested samples were also to calculate a correlation equation between Digital Numbers - DN in each image pixels and TSS values in the ground data. All image analysis and remote sensing steps have been done in this study using Integrated Land and Water Information System - ILWIS software version ILWIS academic 3.3. Green and Red bands in all used Landsat images contained the highest linear correlation factors -R- for the images acquired in 1999, 2003, 2010, 2014, and 2015. Resulted correlation factors were higher by reducing time difference between acquisition time and sampling time. Generated maps showed that circulation in Gaza coastal area are counterclockwise, and it brings the sediments from Nile River Delta toward Gaza Strip.

Keywords: TSS, Landsat, circulation, water column

Introduction

Gaza Strip's economy is highly dependent upon recreational and touristic nature, and fishing activities in its coastal zone in Mediterranean. Based upon 2003 report of PCHR (Palestinian Centre for Human Rights) and the International Commission of Jurists - Geneva, fishing industry provides 2500 job opportunity and it operates 727 fishing boats, and produces 2309 metric ton of fish.

Gaza Strips' beach has a wealth recreational value for Gazians. Isolated from world as both Israel and Egypt tightly control Gaza's border, many residents turn to the beach as a temporary escape. It also provides an opportunity for residents of the territory to set up businesses with a relatively small financial investment (United Nations - UN, 2014).

Suspended solids reduce visibility and absorb light, which can increase stream temperatures and reduce photosynthesis. Impeding aquatic plant photosynthesis reduces the amount of food, habitat and dissolved oxygen available for other species. Fine particles may also clog and abrade fish and insect gills and tissue and, interfere with egg and larval development. Pollutants such as pesticides and PCBs adhere to the surfaces of TSS and can be transported into aquatic environments in this fashion [1].

Healthy coastal ecosystem is very crucial for Gaza's economy and coastal activities. Coastal ecosystem parameters must be monitored repetitively and comprehensively. Accurate estimate of water quality concentrations is also vital for determining the health of ecosystem (Guang 2009, Karr and Dudley 1981). Total Suspended Sediments - TSS is one of these parameters that must be always monitored in coastal surface.

Most sediments in surface water derives from surface erosion and comprises a mineral component, arising from erosion of bedrock and an organic component arising from soil forming processing (E. Ongley, UNEP\WHO, 1996).
While historical research on turbidity and suspended sediments has been thorough, studies of stream bed sedimentation have typically relied on semi-quantitative measures such as embeddedness or marginal pool depth (Mark S. Riedel, 2006). In Palestine, data about environmental and aquatic parameters like TSS are normally based on an individual shipboard from different points in the aquatic surface, in other words, it is non-comprehensive and does not provide a complete vision for TSS transport and deposition.

These are followed by laboratory measurements of the water constituents and interpolations between sampling stations to create maps illustrating the spatial distribution of the parameters (Pennock, 1985). This process is time and cost consuming and involves a reasonably high degree of inaccuracy .Moreover, all of the previous studies in TSS mapping were in an wavy non-active areas like rivers, valleys, deltas, or far shore oceanic areas, but this study is the first in a wavy active coastal zone, at least in Gaza Strip.

Since remote sensing has enormous spatial and temporal operative abilities and techniques, it could be an ideal alternative to the shipboard in-situ, and can overcome a lot of its problems. Water quality mapping by using remote sensing provides better results at a relatively cheaper cost (Wheather Bee and Kleams, 1998).

In this study, 64 tested TSS samples from different locations along mid shore, near shore, and far shore of Gaza coastal zone were correlated with their corresponding digital number in each acquired Landsat images for five years. After that, correlation equations have been applied on each images using ILWIS remote sensing software to produce concentration maps for each image.

Brief Review of Landsat Applications in TSS Mapping.

Landsat satellites have repetitive, circular, sun-synchronous, near polar orbits, providing full coverage between 81° N and 81° S. The sensors always scan the ground at satellite nadir. (Eurimage, Landsat, 2013). The remote sensor signals results from the interaction between solar radiation and both water and atmosphere (Kirk, 1986).

Pure water presents high absorption in the red and infrared region in the electromagnetic spectrum. Total suspended solids (TSS) describe particulates of varied origin, including soils, metals, organic materials and debris that are suspended in a moving body of water. Turbulence keeps the particulates suspended in water allowing the solids to be transported downstream. The water spectral response is changed by their optically active components such as pigments, organic and inorganic matter, and organic dissolved substances (Maycira Pereira de Faras Costa, 1998).

Suspended inorganic matter are the main light scatters within the aquatic environment. Size, shape, and concentration are the main factors explaining the amount of scattering by inorganic matter (Novo et al., 1989).

Using this relation between substances concentration in water column and the scattered and reflected energy toward the satellite's sensor, statistics and analysis techniques in remote sensing find the way for TSS concentration detection in Gaza coastal zone.

Study Area

Gaza Strip (Qita'a Gazza), is a narrow area located on the Southern part of Palestinian coastal plains, and surrounded by Sinai Peninsula from South, Negev Desert from East, Israel from North, and Mediterranean Sea from the west. Gaza Strip is located between longitude 34° 20" to 34° 25" East and 31° 16" and 31° 45"North (Fgure 1). Gaza has 360 km2 gross area with 72 km2 as a border area, 59 km2 of this area has been made by Israel while the other 13 km^2 has been made by Egypt. Gaza Strip is 41 km long on the coast, 7 km wide from North, and 12 km wide from South along Sinai Peninsula.

According to the statistical surveying that was done in June 2015, the population of Gaza is more than 1,85 million inhabitant [1]. Population density in the Gaza Strip renowned as among the highest in the world-rose about 38.5 % in 1997, to an average of 3880 people per km2 . Gaza Strip has five governorates. The central one is Gaza City, while the largest one is Khanyunus in the South. Rest of the three governorates are North of Gaza, Deir Albalah, and Rafah (UNRWA, 2007).

Fig.1. Location of Gaza Strip

Average daily temperature in Gaza Strip ranges from 26 C° in Summer to 12 C° in Winter with the average daily maximum temperature ranges from 29 C° to 17 C°, and the minimum temperature ranges from 21 C° to 9 C° in Summer and Winter respectively (GMS, 2009). Rainfall occurs in the winter period between October and March, while the winter period from June to September is dry with no rainfall. The average rainfall varies between 200-400 mm. (PMO, 2008)

Materials and Methods

In this study two Landsat TM5 imagery, one Landsat TM7 imagery, and two Landsat Oli imagery were used. Landsat is an American satellite that has been launched by NASA, and recently they launched the last version of the satellite, Operational Land Imager - Lansat 8 Oli. Image data are nine spectral bands (Band Designation) with a spatial resolution of 30 meters for Band1 through Band7, while Band 8 (Panchromatic) is 15 meters. Scene size in Oli is 170 Km N-S by 183 km E-W (SEW, 2015).

Data format in Oli is GeoTiff extension with 16-bit pixel value, while the map projection is Universal Transverse Mercator - UTM (Polar Stereographic for Antarctica) and the datum is WGS 84. We used 64 TSS tested and coordinated samples that were collected from three different shorelines, near, mid, and far shores from the Gaza coastal zone. These data were granted by the department of Applied Civil Engineering in University of Palestine - Gaza, and tested using the "Crucible Dishes" method using "Schleicher & Schuell" with pore size 62 micron and 110 mm in diameter.

ILWIS Input Data

ILWIS is an acronym for the Integrated Land and Water Information System. It is a geographic information systems - GIS with image processing capabilities. ILWIS has been developed by the international institute for Aerospace Survey and Earth Sciences - ITC, Enschede-Netherlands.

From the date you can generate information on the spatial and temporal patterns and processes on the earth surface (ILWIS ITC user guide book).

Used imageries in this study were taken in different dates as shown Table1. Furthermore, all ground data were collected through two marine tours in 2012 winter as shown in Table 2. Samples sites are all coordinated using manual GPS on the UTM projection and WGS 84 datum. Delivered images are all free of clouds and haze and they were georeferenced same as the samples (UTM and WGS 84).

Table 1. Used Landsat images and corresponding acquisition date

Landsat Version	Acquisition Date
Landsat TM5	11.02.1999 03.12.2010
Landsat TM7	20.10.2003
Landsat Oli 8	19.11.2014 22.01.2015

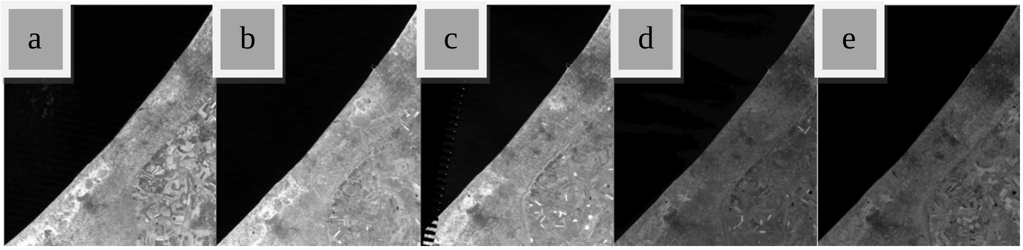


Fig 2. Illustrates Gaza Strip and its coastal zone for the five used landsat scenes in a) 1999, b) 2003, c) 2010, d) 2014, and e) 2015.

Fig. 3. Illustrates ground data samples sites along Gaza coastal area.

Methodology

The methodology used in this study is consisting six main steps beginning by data extraction and culminating by slicing and layout.

Step1: Extracting each corresponding pixel value (Digital Number - DN) for each sample site in the Green, Red, Blue, and Near Infrared - NIR bands in each imagery. Five tables were generated and each table consisted four columns (one for each band), and there was a 64 line or cell in each column (one for each sample). This step is completely done using ILWIS.

Step2: Statistical analysis was done for each image to find a correlation value between each band DN's values and the TSS values in tested samples. Highest correlation was being chosen as the trusted correlation for each image.

In this process we found the linear regression mathematical relation (Linear Equation) for the highest correlation value as a function of DN as input, and the output is TSS concentration values in mg\l. Thus we had five equations as illustrated in Table 3.

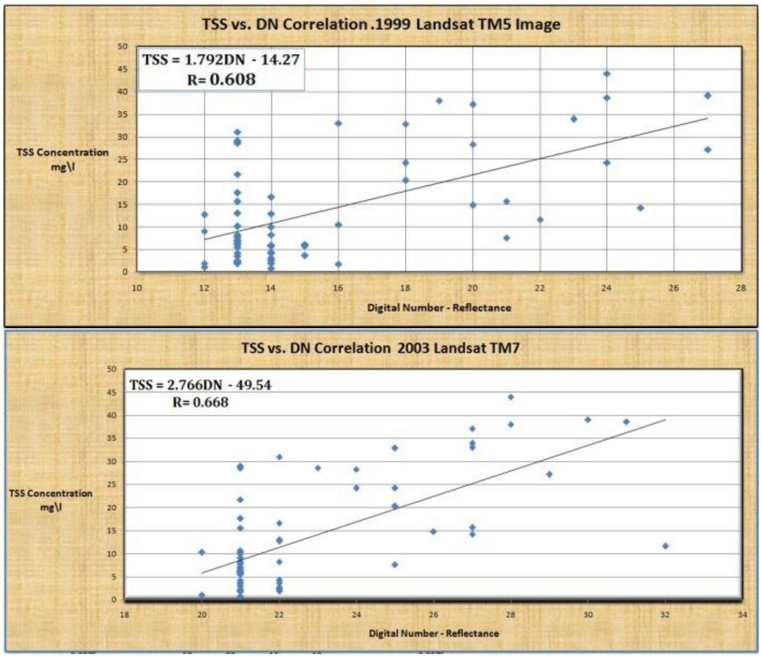
Step 3: Extraction Gaza zone from the whole imagery of Palestine. This step was done by specifying the number of columns and lines for the Top-most-left and Bottom-most-right corners pixels for each image. Each image consists approximately 1450 pixels N-E and 1150 pixels W-E (total are more than 1.6 x 10^6 pixels).

Step 4: Land-Sea masking, is the process of Gaza Sea water surface lineation to separate it from land. NIR band was used to discriminate between land and sea, because there is a high difference in pixel values between the land and sea features. Therefore a specific pixel value has been selected as a threshold value for sea. Writing a short code in ILWIS command window can do the step. For instance, the NIR band in 1999 image is named as (B4LSM99), and the threshold pixel value is 30, here is the code:

```
B4LMS99 = Iff(B4LMS99<=30, B4LMS99, 0)
```

Table 3. Correlation formulas and factors for each image

Acquisition Year	Equation f(DN)	Correlation Factor-R	Band
1999	TSS = 1,790 DN - 14,27	0.068	Red
2003	TSS = 2,766 DN - 49,54	0.668	Green
2010	TSS = 2,855 DN - 45,51	0.700	Green
2014	TSS = 0,017 DN - 109,1	0.702	Green
2015	TSS = 0,048 DN - 288,6	0.644	Red



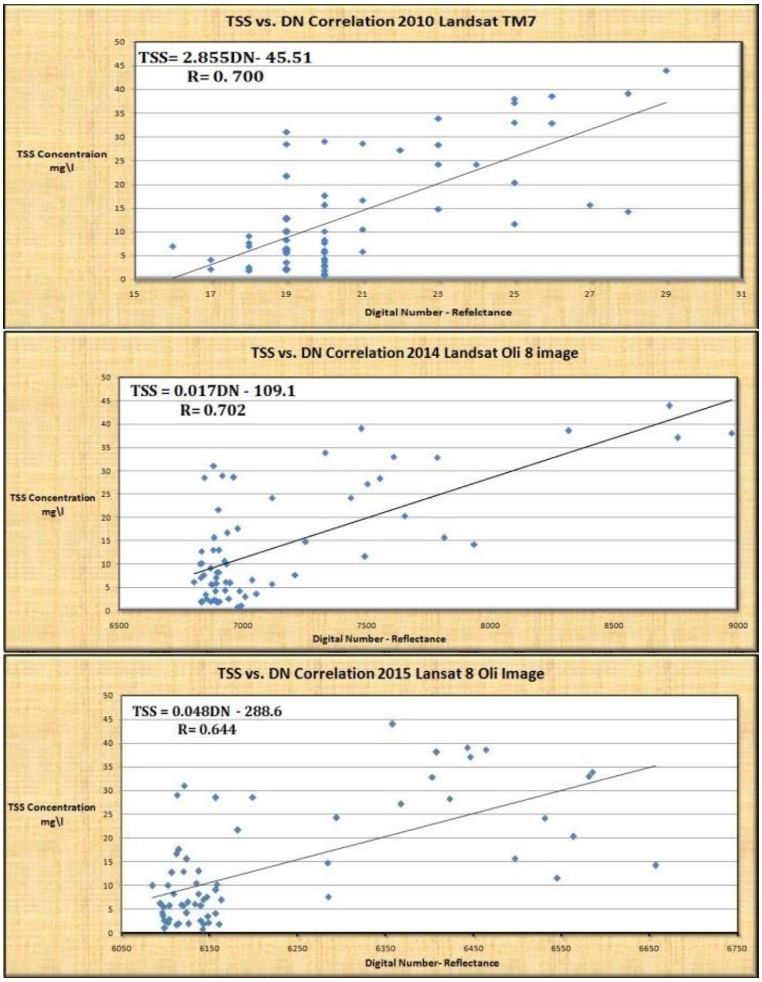


Fig. 4. Illustrates correlation curves, equations, and factors for years a)1999, b)2003, c)2010, d)2014 and e)2015.

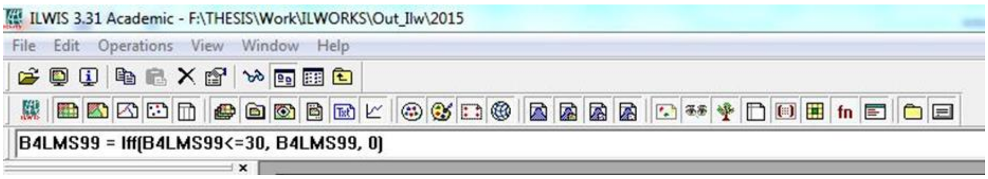


Fig. 5. Writing lineation code in ILWIS command window.

It means that keep any value less than or equal 30, and give zero for the rest of the values in the layer band B4LMS99.

In the same step all the non-zero valued pixels have been replaced by their corresponding pixels in the bands that has the highest correlation value (Green or Red). Generated bands are land-Sea masked bands, and they are ready to continue the required calculation on them.

Step5: Total Suspended Sediments calculations were done by applying the regression equation on the bands that had the highest correlation values. For instance, in 2014 image, highest correlation was on Green band, and the regression equation was TSS = 0,017 DN - 109,1. Writing a code in ILWIS could perform this calculation.

```
B314CSS = ((0.017xB314)-109.1)
```

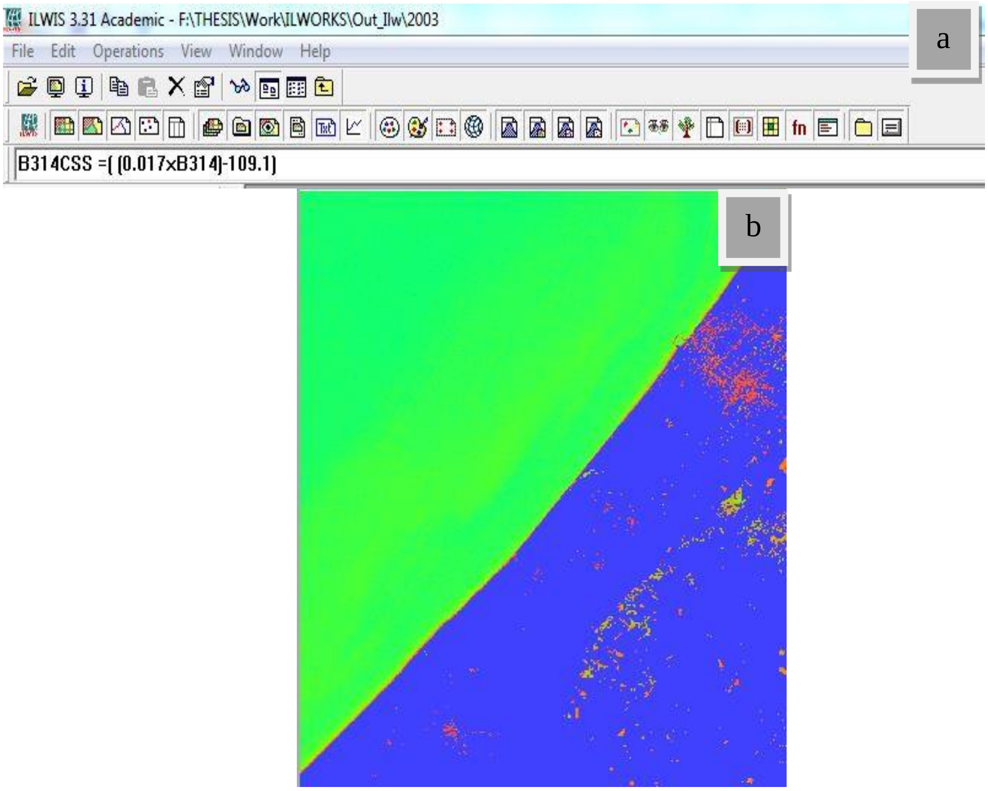
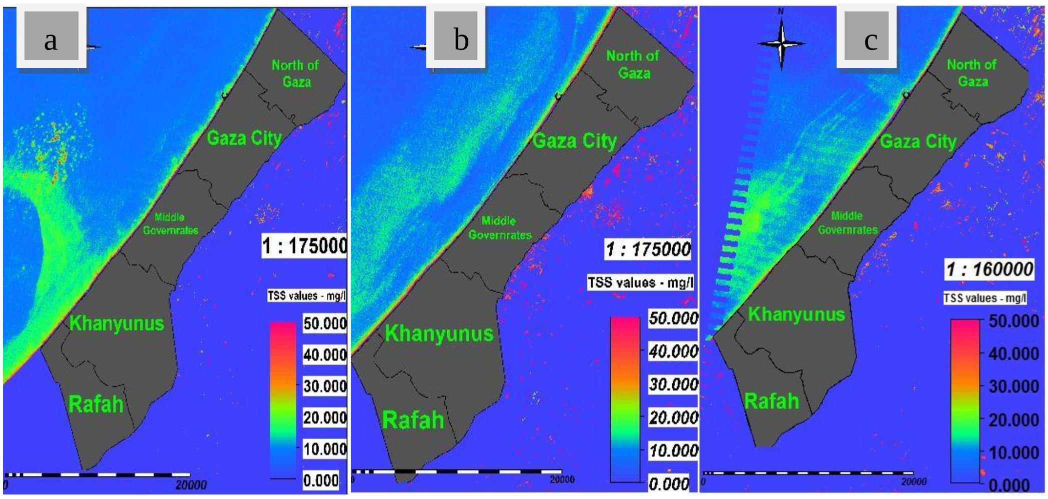


Fig. 6. a)Illustrates the used code in ILWIS command window for TSS concentrations calculations. b) Resulted TSS map from the used equation (TSS=0.017DN-109.1) as an example.

Step 6: Classifying and slicing the resulted TSS concentration maps using Psedu colors graduation to start analysis through maps.



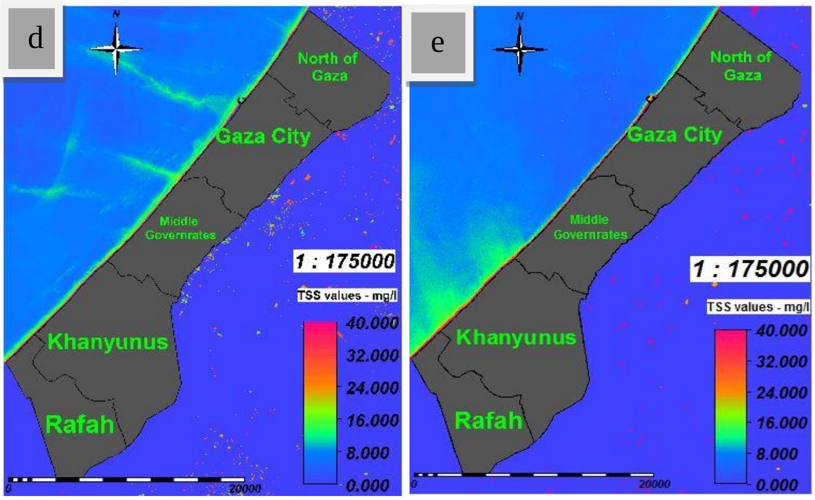


Fig. 7. Final layout for the generated TSS concentration maps from Landsat images scenes that were acquired in a) 1999, b) 2003, c) 2010, d) 2010, and e) 2014.

Results and Discussion

The results are relatively near the expectation and coincides for high degree with the other studies.

1. Linear regression analysis was applied to data from each sampling point. Results indicated that the best correlation for 2003, 2010, and 2014 were on the Green bands (0.52 - 0.6 µm). Highest correlation factor values in 1999 and 2015 images were at Red bands (0.64 - 0.67 µm). Thus, the best bands for TSS mapping are Green or Red bands. This variation in bands refers to TSS composition, Organic and Inorganic substances. If the dominant composition was inorganic (Clay and sand), red band is expected to contain highest correlation and vice versa. Soil reflectance decreases as organic matter increase [3].

2. Results showed that the highest TSS concentration in all images are in Near-Shore area (Near the beach), and concentrations is inversely proportional with distance from beach. That's because near-shore area is wavy active and waves always suspense the Bed load in the water column. Moreover, bathymetry depth in near-shore area is low, so that reflectance is high.

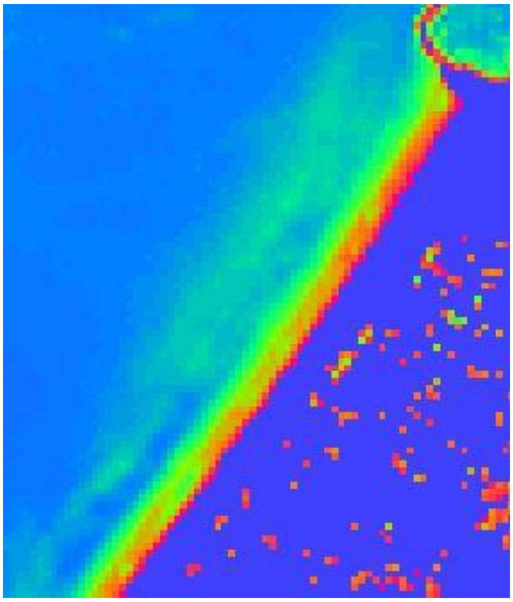


Fig. 7. TSS concentration manner by going toward far shores in the area.

3. Suspended sediment concentration increases by going to the southern direction (Egypt) toward Nile river Delta, which is considered the main sediment discharging source in the Mediterranean

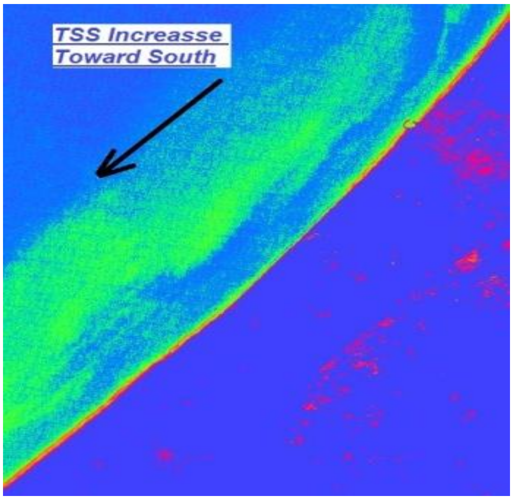


Fig. 8. TSS concentration manner by going toward south, to Egyptian side.

4. Circulation direction in Gaza coastal area is counterclockwise as shown, especially in 1999 and 2003 maps. This visually explains the cause of discharging sediments from Nile delta to Gaza Area.

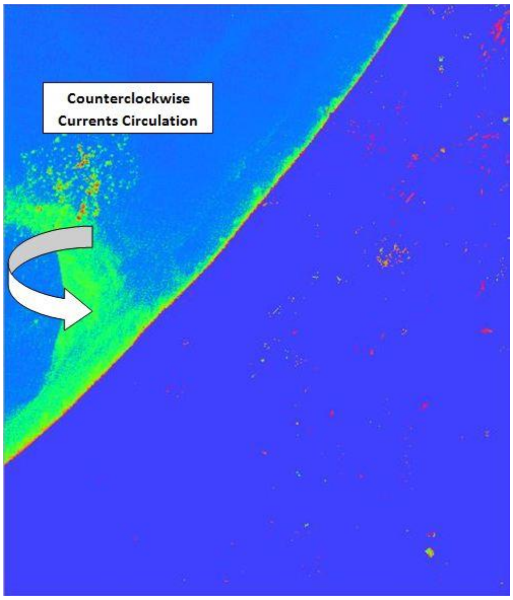


Fig. 9. Illustrates the counterclockwise direction for currents circulation in the Gaza coastal area.

5. Since circulation in Gaza coastal area is counterclockwise, Gaza seaport prevents sediment passing toward the Northern of Gaza seaport. This explains the cause of coastal erosion in the area on the Gaza seaport northern side, and the accretion on the southern side of Gaza Seaport.

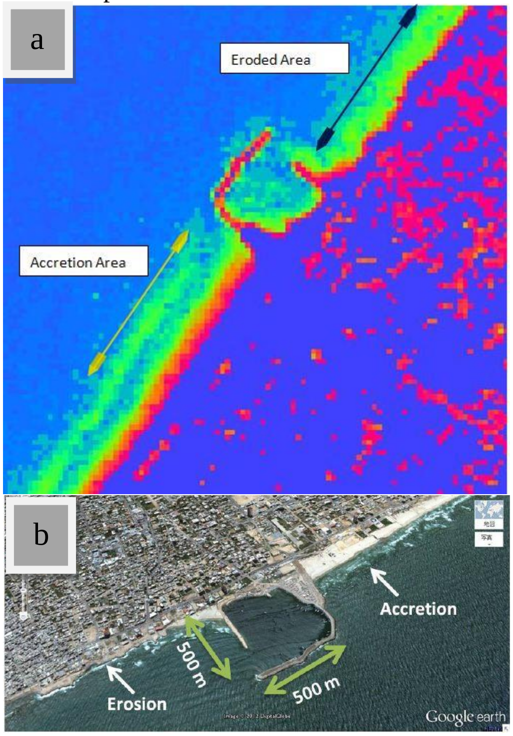


Fig. 10. a) TSS accumulation on one side and lacking on the other side of Gaza seaport. b) Beach erosion and accretion around Gaza seaport as a result to TSS disturbance in distribution around the seaport.

6. Straight correlation line slope in each correlation model is positive. It means that the higher TSS concentration (Less pure water) is the higher energy reflectance, thus higher pixel's DN.

7. Correlation factor values - R are inversely proportional with the time difference between time acquisition date and sampling date. Lower time period between sampling data acquisition date leads to higher correlation values.

8. Correlation factors-R for the 2010 and 2014 images were approximately the same, 0.700 and 0.702 respectively. This is because the time duration between acquisition and sampling were the same for both of the mages, 2 years.

9. Landsat images have been used effectively in TSS mapping for serving coastal monitoring, although an error margin is included. This errors

could be through errors in DN as a result to bottom reflection, sunlight, and\or atmospheric conditions.

10. Suspended sediment concentrations depends on 3 main factors. Firstly, TSS is high in rainy season because of high flooding toward sea. Secondly, TSS is lower in low tidal conditions where higher water levels. Thirdly, waves activity suspends bed load in water column, thus increases the TSS concentrations. Therefore, stronger and higher waves lead to higher TSS concentration.

Conclusion

In this paper, Landsat images have been effectively used in coastal monitoring regarding mapping TSS concentration comprehensively in Gaza coastal area as a wavy area. Where all works that have been done in this sector were in a non-wavy areas. Works included an error margin for many reasons that I previously mentioned. Simply, if those reasons are taken into consideration, highest possible accuracy could be achieved. Moreover, this is the first study that shows TSS in Gaza coastal area generally, and especially in a comprehensive form under the siege and hard situations there. All the coastal parameters that have been studied agreed with the coastal studies that were done previously, such as circulation and the eroded areas around Gaza seaport. Furthermore, Gaza seaport is big environmental problem and it must be either modified by opening a holes in its walls to allow sediment passing, or construct a new one within Gaza land.

Higher TSS concentrations also affect the aquatic marine life through reducing the required light penetration amount for photosynthetic processes for aquatic species. Finally, TSS in Gaza coastal area is highly influenced by surrounding environmental factors and realities, such as rainfall, winds, tidal conditions, etc.

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