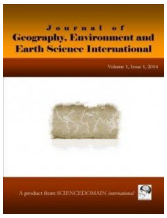

*Journal of Geography, Environment and Earth Science International*

*11(4): 1-18, 2017; Article no.JGEESI.36233*
*ISSN: 2454-7352*

# Performance Evaluation of Shoreline Extraction Methods Based on Remote Sensing Data

**Sameh B. El Kafrawy[1], Mohamed E. Basiouny[2], Essam A. Ghanem[3] and Ahmed S. Taha[3*]**

*[1]Department of Marine Sciences, National Authority for Remote Sensing and Space Sciences (NARSS), Egypt.*
*[2]Department of Civil Engineering, Faculty of Engineering, Egyptian Chinese University (ECU), Egypt.*
*[3]Department of Civil Engineering, Benha Faculty of Engineering, Benha University, Egypt.*

***Authors' contributions***

*This work was carried out in collaboration between all authors. All authors participated equally in the study idea, literature review, data collection and analyses, methodology, statistical analyses, tabulating the data, results validation, writing and revising the whole manuscript. All authors read and approved the final manuscript.*

***Article Information***

DOI:10.9734/JGEESI/2017/36233
Editor(s):
(1) Kaveh Ostad-Ali-Askari, Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Iran.
Reviewers:
(1) Isin Onur, Akdeniz University, Turkey.
(2) Kakoli Saha, school of planning and architecture Bhopal, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/20986

***Original Research Article***

***Received 19th August 2017***
***Accepted 8th September 2017***
***Published 14th September 2017***

## ABSTRACT

Coastal zones monitoring is an important task in sustainable development and environmental protection. For coastal zones monitoring, shoreline extraction is a fundamental work. The shoreline is defined as a line of contact between land and water body. The main purposes of this study were to compare and evaluate six of shoreline extraction methods based on remotely sensed data. Those methods were digitizing, Thresholding band ratio, and classification, Normalized difference water index (NDWI), Normalized Difference Vegetation Index (NDVI), and Improved method. Those methods were applied on landsat8 2015 image to extract the shorelines position for Ras El-Hekma coastal zone. The extracted shorelines were compared with reference 2015 shoreline which detected by high resolution image Pleiades B1 (0.50 m) special resolution. A comparative study has been done depending on four evaluation criteria. The results show that all shorelines which are extracted by six methods are accepted which 90% of shifting distances with in one pixel (30 m), but

**Corresponding author: E-mail: ahmedo354@yahoo.com;*

The shoreline extracted by Thresholding band ratio method is the most one closed to the true shoreline where the mean value is 11.04 m, RMSE is 9.54 m about one third the value of the pixel size (30 m) of landsat 8 image, and 94.44% of the shoreline segments lie within 1 pixel distance of the true shoreline. The fourth evaluation criteria D90% is 22.35 m, which 90% of shifting distances between extracted and true shoreline is ling in.

*Keywords: Shoreline; shoreline detection; coastal zones monitoring; Ras El-Hekma.*

## 1. INTRODUCTION

Satellite imagery provides a complete spectral characterization of an area in digital form. These data are being used for a number of important applications preparing a range of Thematic maps such as land use land cover, forest, agriculture, and shoreline detection in coastal zones etc. The term coastal zone is "a region where interaction of the sea and land processes occurs". Both the terms coast and coastal are often used to describe a geographic location or region. The line of contact between land and a water surface can be defined as a Shoreline which is one of the most important linear features on the earth's surface [1]. It's a one of the most unique features on the earth's surface which have a dynamic nature. Shoreline detection and Shoreline mapping are critical for safe navigation, coastal resource management, coastal environmental protection, and sustainable coastal development and planning. Changes in the shape of shoreline may fundamentally affect the environment of the coastal zone. These may be caused by natural processes or human activities.

Generation of the shoreline maps date back to year 1807, when it was obtained by the traditional methods of conventional field surveying. Later in year 1927 conventionally, shoreline maps have often been derived from Aerial photography [2]. This conventional methods are impractical in mapping large areas as it is time consuming and expensive [3,4]. In recent years, the remote sensing technique has become more widely used in shoreline extraction and mapping. This development helped in extraction of shoreline mapping by making it cost effective and time efficient. To extract the shoreline position from satellite data several techniques were developed. In most of the studies, the shorelines were extracted by manual digitization or automatic techniques [5,6,7,8]. The manual interpretation of features is depending on individual skills of an interpreter [9,10]. Few researchers proposed a method based on histogram thresholding approach to detect the position of shoreline. They concluded that this method when applied alone lead to an error in classification by classifying the vegetation area as water [11]. However, as shown in [2], the combination of histogram thresholding and band ratio techniques for the same objective for a set of 9 LANDSET images with the bands selected between 4 and 2 and 5 and 2 provided a superior accuracy of 1.3 pixels when compared with the results from the ground truth images. Classification techniques adopted to extract surface water are normally more accurate compared with single-band methods [12]. Muslim AM et al. [13] use a classification method to detect land/water boundary. Hard and soft classification methods were applied to detect the shoreline position .For instance, the Normalized Difference Water Index (NDWI) was developed for the extraction of water features from Landsat imagery [14]. Since water features extracted using the NDWI include false positives from built-up land, a modified NDWI (MNDWI) was developed in which the middle infrared (MIR) band was replaced with the near infrared (NIR) band [15]. Hongxu M et al. [16] proposed a new Method to extract shoreline depending on Interconnecting NDWI, NDVI methods. The new method (improved method) is applied to Poyang Lake based on the time series remote sensing images from March 2011 to December 2012. The results showed that: Comparing improved method with NDWI, NDVI, and supervised classification methods, the improved method is not only good at differing the building features from the water features, but also sensitive to the small tributary streams. In this study, a comparison between many shoreline extraction methods was done and the performance is evaluated.

### 1.1 Shoreline Definition

The terms shoreline and coastline are often similarly used in coastal research communities [8,9] and it is defined as "the instantaneous boundary between water and land". But this boundary is continually changing according to dynamic environmental conditions such as

seaborne influences (waves and tides), climate (winds and storms) or geomorphological processes (erosion and accretion [17]. Also shoreline can be defined as "a bridge between aquatic life and terrestrial life, and it is usually a fragile eco zone". An ideally definition of shoreline is that "the physical interface between land and water" [7]. In spite of its apparent simplicity, this definition is in practice a challenge to apply. The instantaneous shoreline is the position of the land/water interface at one instant in time. As has been noted by many authors [18] and [19], the most significant and potentially incorrect assumption in many shoreline investigations is that the instantaneous shoreline represents ‘‘normal’’ or ‘‘average’’ conditions. A shoreline may also be considered over slightly longer time scale, such as a tidal cycle, where the horizontal/vertical position of the shoreline could vary anywhere between centimeters and tens of meters, depending on the beach slope, tidal range, and prevailing wave/weather conditions. Over a longer, engineering time scale, such as 100 years, the position of the shoreline has the potential to vary by hundreds of meters or more [20]. The shoreline is a time-dependent phenomenon that may exhibit substantial short-term variability [21], and this needs to be carefully considered when determining a single shoreline position.

## 2. OBJECTIVES OF THE RESEARCH

It is important to be able to detect shoreline position in costal zones with relatively high accuracy. Remotely sensed data with some techniques are useful for this purpose. This paper aims to study various methods of shoreline detection using remotely sensed data and evaluating the performance of these methods.

## 3. STUDY AREA AND SATELLITE DATA

### 3.1 Study Area

The study area is RAS EL-HEKMA which fall on the Mediterranean Sea at northwest of Egypt. This coastal zone has been conceded as promising area for the future tourism investment during the coming 20 years. It has received many human activates in last years. The study area is located between Dabaa in Kilo 170 by way of the northwest coast to Matrouh at km 220, along 50 km on Mediterranean Sea. This coastal zone is located in northwest of Egypt from 31° 6` N to 31° 15` N in latitude and 27° 41` E to 27° 53` E in longitude. Fig. 1 illustrates study area.

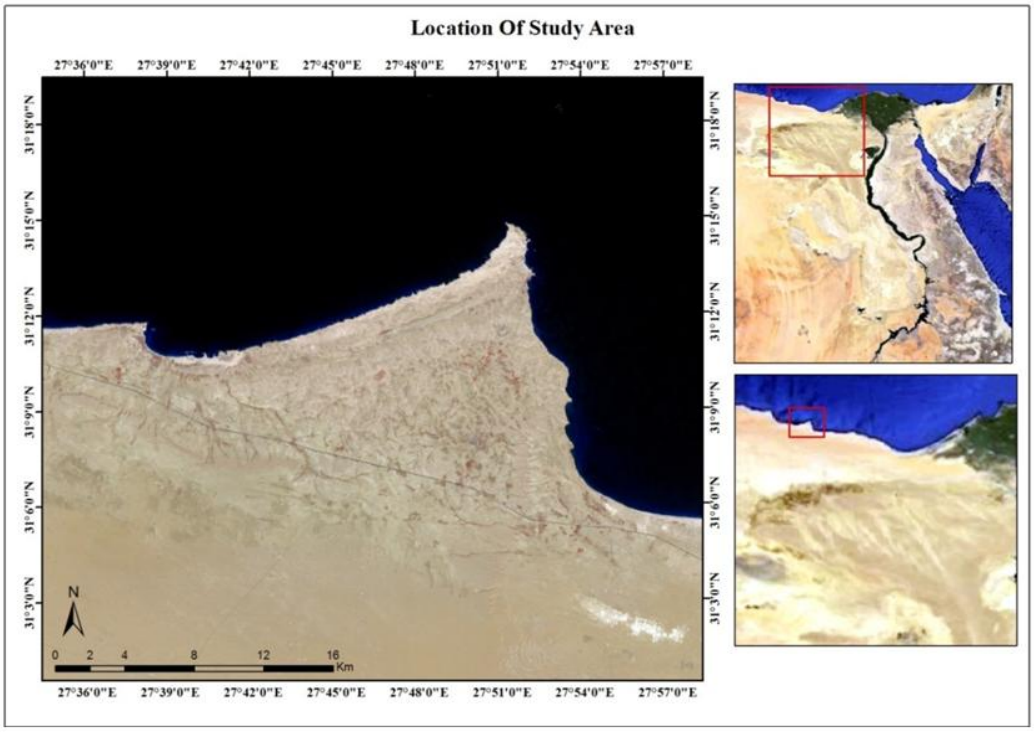


**Fig. 1. Location map of the study area. Ras El-Hekma, North West of Egypt**

## 3.2 Satellite Data

### 3.2.1 Data sources

In this study two images are acquired, one from Landsat8 and the second one from Pleiades 1B. These images are used to examine the different methods to extract shoreline.

Landst 8 consists of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. The ultra-blue Band 1 is useful for coastal and aerosol studies. Band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 meters. The main characteristics of lansdsat8 are reported in Table 1.

**Table 1. LANDSAT 8 satellite sensor specifications**

| Band name | Bandwidth (μm) | Resolution (m) |
|---|---|---|
| Band 1 Coastal | 0.43 - 0.45 | 30 |
| Band 2 Blue | 0.45 - 0.51 | 30 |
| Band 3 Green | 0.53 - 0.59 | 30 |
| Band 4 Red | 0.63 - 0.67 | 30 |
| Band 5 NIR | 0.85 - 0.88 | 30 |
| Band 6 SWIR 1 | 1.57 - 1.65 | 30 |
| Band 7 SWIR 2 | 2.11 - 2.29 | 30 |
| Band 8 Pan | 0.50 - 0.68 | 15 |
| Band 9 Cirrus | 1.36 - 1.38 | 30 |
| Band 10 TIRS 1 | 10.6 - 11.19 | 30 (100) |
| Band 11 TIRS 2 | 11.5 - 12.51 | 30 (100) |

** TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product*

Pleiades consists of four spectral bands plus panchromatic band, with a spatial resolution of 2 meters for multispectral Bands (blue, green, red and near IR), and panchromatic band with 50 cm spatial resolution. It designed for civil and military users; the Pleiades system is especially suited for emergency response and change detection. The main characteristics of Pleiades1B sensors are reported in Table 2.

**Table 2. Pleiades satellite sensor specifications**

| Band name | Bandwidth (μm) | Resolution (m) |
|---|---|---|
| Panchromatic | 0.47 - 0.83 | 50 cm |
| Blue | 0.43 – 0.55 | 2m |
| Green | 0.50 – 0.62 | 2m |
| Red | 0.59 – 0.71 | 2m |
| Near infrared (NIR) | 0.74 – 0.94 | 2m |

## 4. METHODOLOGY

The overall methodology adopted to accomplish the purposes of this paper is illustrated in the following Fig. 2.

## 4.1 Shoreline Detection Methods

In this paper six methods of shoreline detection are studied and evaluated. Each method is discussed individually as follows.

### 4.1.1 On-screen digitizing method

Extraction of shoreline by digitizing is easy method and costless. That method is a common one used to extract shoreline by digitization of a shoreline from an available geoinformation. The problem of this procedure is that it is carried out manually and involves the personal assessment, characteristics and experiences of an operator.in this method the shoreline has been drawn as a line at intersection between water and lands by the operator manually that increasing image resolution and operator skills, Increasing accuracy of shoreline extracted and vise versa. The following Fig. 2 illustrates the methodology adopted to extract shoreline from Landsat OLI_TIRS 2015 image by on-screen digitizing method.

In this method the shoreline is manually extracted. After possessing is done on image the scale is selected as 1:10000 as possible for the user. The new vector layer is created and shoreline is drawn from the raster data by tracing.

### 4.1.2 Thresholding band ratio method

This method is a combination of two methods threshold histogram method and band ratio method. The following chart describes thresholding band ratio method methodology adopted to extract shoreline from Landsat OLI_TIRS 2015 image.

As shown in Fig. 3 First, the histogram thresholding on band 5 has been used for separating land from water. The lower values (<N) will represent water and the higher values will represent land .The threshold values have been chosen such that all water pixels were classified as water and most of the land pixels were classified as land. A few land pixels have mistakenly been assigned to water but not vice versa. Therefore a binary image (1) has been

created. B2/B4 and B2/B5 ratios are greater than 1 for water covered areas and less than 1 for areas covered with land [2]. By Applying these ratios binary image (2) was produced [22]. Then the two images are multiplied to obtain final binary image (3).finally, last stage is converting raster binary image to vector in order to extract the shoreline.

#### 4.1.3 Classification technique

Classification technique to detect a position of land/water boundary "shoreline" was introduced by [23]. Mainly this technique based on calcification image into two classes only water and land. Hard or soft classification is available. The boundary detected between these two classes defined as shoreline. In this study the hard classification image was used and the image was classified into two classes, land and water. The Border line between the two classes was vectored to detect the shoreline. This shore line was compared with actual shoreline which detected from high resolution image (0.50 m) to evaluate this method. The following Fig. 4 illustrates the methodology of classification method adopted to extract shoreline from Landsat OLI_TIRS 2015 image.

#### 4.1.4 Normalized difference water index (NDWI) method

McFeeters in [24] proposed Normalized Difference Water Index (NDWI) to detect Water surfaces in wetlands and to allow for the measurement of water surface extent [16]. Although this index was generated for using with Landsat (MSS) image data, it has been successfully used with other sensor systems. The NDWI index is calculated by Equation (1):

$$NDWI = \left(\frac{NIRInfrared - Green}{NIRInfrared + Green}\right) \quad (1)$$

Where Band 3 is Landsat 8 (OLI) green light reflectance and Band 5 is the Landsat 8 (OLI) near-infrared (NIR) reflectance. Fig. 5 refers to the steps which have been followed to extract shoreline using NDWI method.

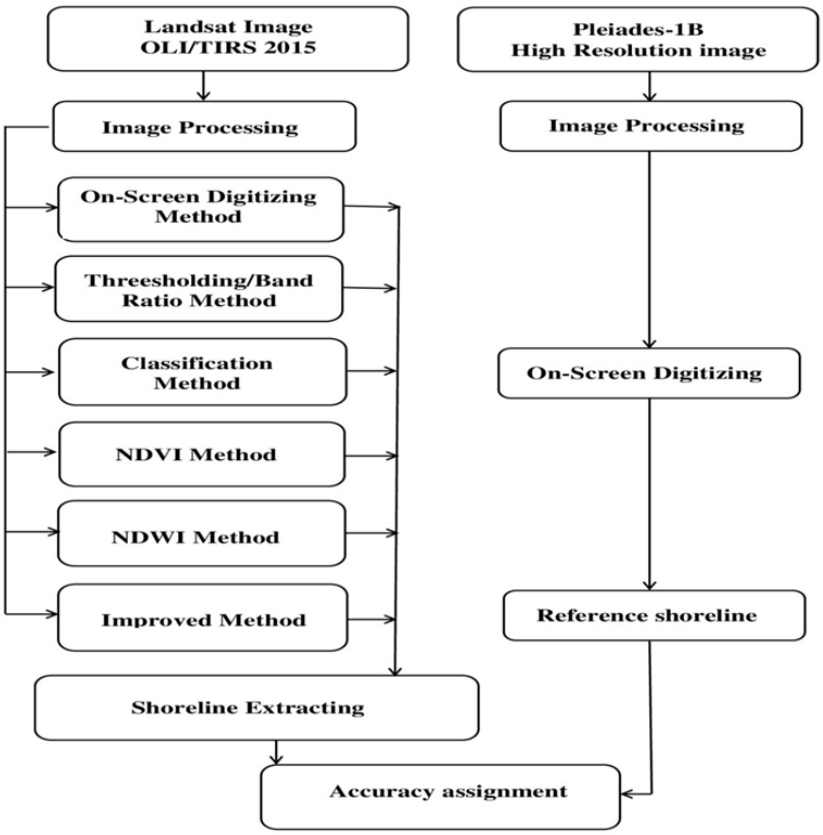


**Fig. 2. Flowchart of overall methodology adopted to evaluate the performance of the shoreline extracting methods**

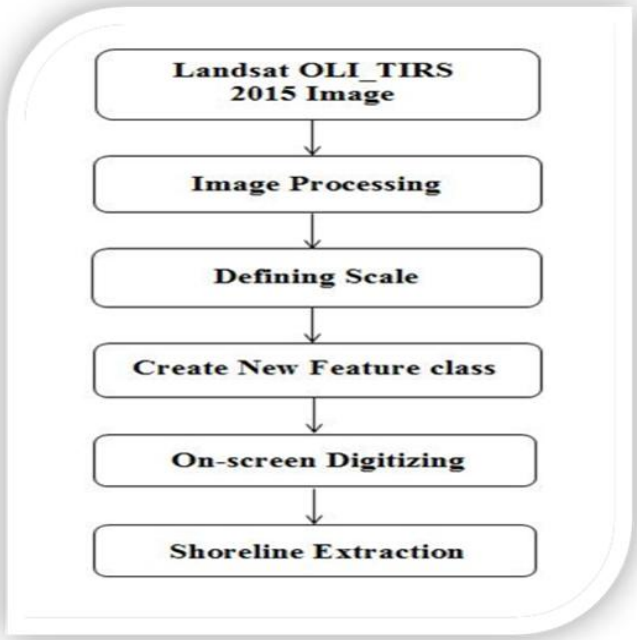


**Fig. 3. Methodology to extract shoreline using on-screen digitizing method**

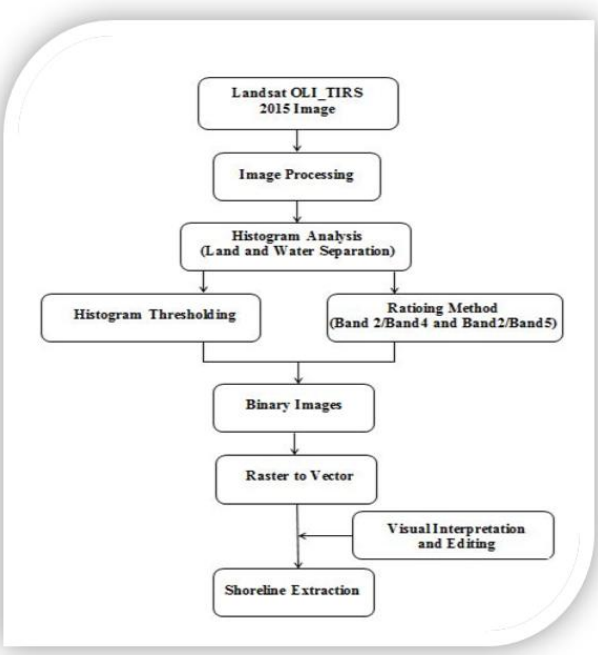


**Fig. 4. Methodology to extract shoreline using thresholding band ratio method**

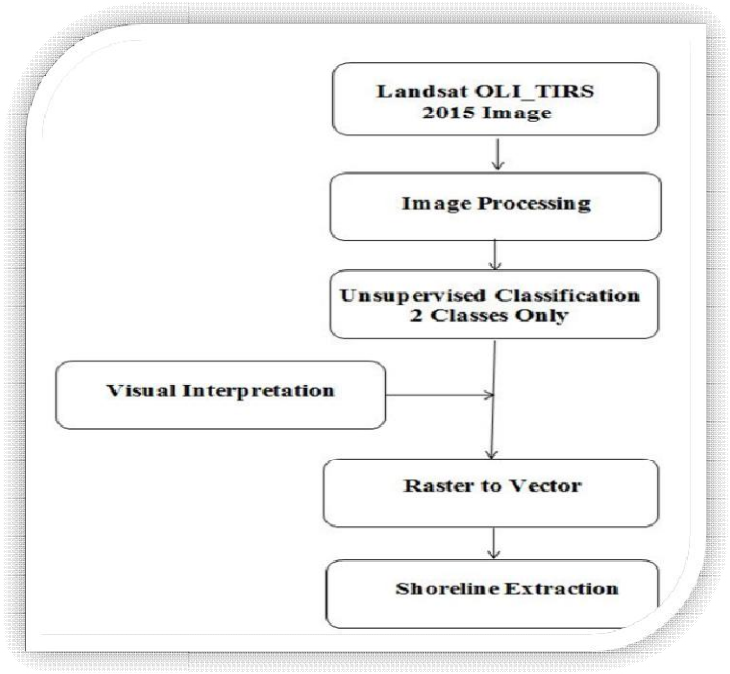


**Fig. 5. Methodology to extract shoreline using classification method**

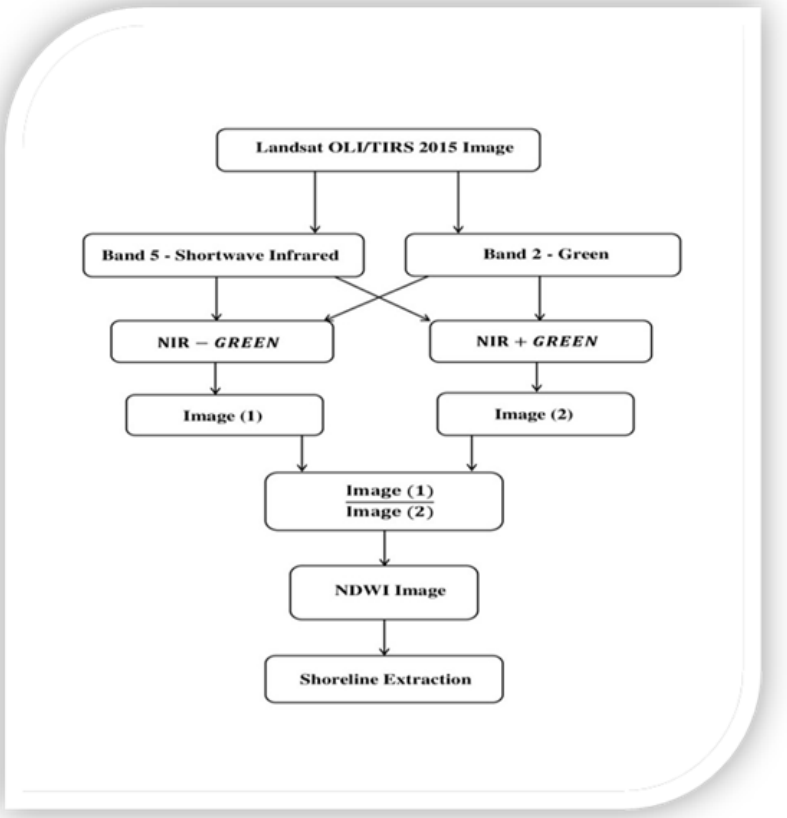


**Fig. 6. Methodology to extract shoreline using NDWI method**

#### 4.1.5 Normalized difference vegetation index (NDVI) method

The normalized difference Vegetation index (NDVI) is derived using similar principles to the Normalized Difference water Index (NDWI). In the NDVI the two bands which used is red and near-infra-red (NIR), presence of vegetation and soil features is enhanced while presence of water features is restrained because of the different ways in which these features reflect these wavelengths [24].

The NDVI is calculated by Equation (2):

$$NDVI = \left(\frac{NIRInfrared-Red}{NIRInfrared+Red}\right) \quad (2)$$

Where Band 4 in Landsat 8 (OLI) is red light reflectance and Band 5 in the Landsat 8 (OLI) is near-infrared (NIR) reflectance. Fig. 6 refers to the methodology which has been followed to extract shoreline using NDVI method. As shown in the methodology three images have been created. Frist image by differentiate between two bands, second by combining two bands and third by dividing two images 1 and 2 after that third image is created then the shoreline can be detected.

#### 4.1.6 Improved method

Hongxu Ma [20], introduces the improved method in order to improve the accuracy of detecting water edges. he depends on combining Normalized Difference Water Index (NDWI) method and Normalized Difference Vegetation Index (NDVI) method to create improved method. The methodology of improved method which used to extract shoreline from Landsat OLI_TIRS 2015 image is illustrated in Fig. 8. In the improved method first, NDWI and NDVI values is calculated. The threshold values can be defined either by man machine interpretation way. Then determined threshold value is used to extract water features. The extracted water features with optimum threshold values are defined as A (NDWI) and A (NDVI). The over-extracted water features with values higher than the threshold values are defined as O (NDWI) and O (NDVI). Then the calculation is carried out according to equation (3).

$$(O\ (NDVI) \cup A\ (NDWI)) \cap O\ (NDWI) \quad (3)$$

Arriving to this step raster to vector is applied and the shoreline has been detected.

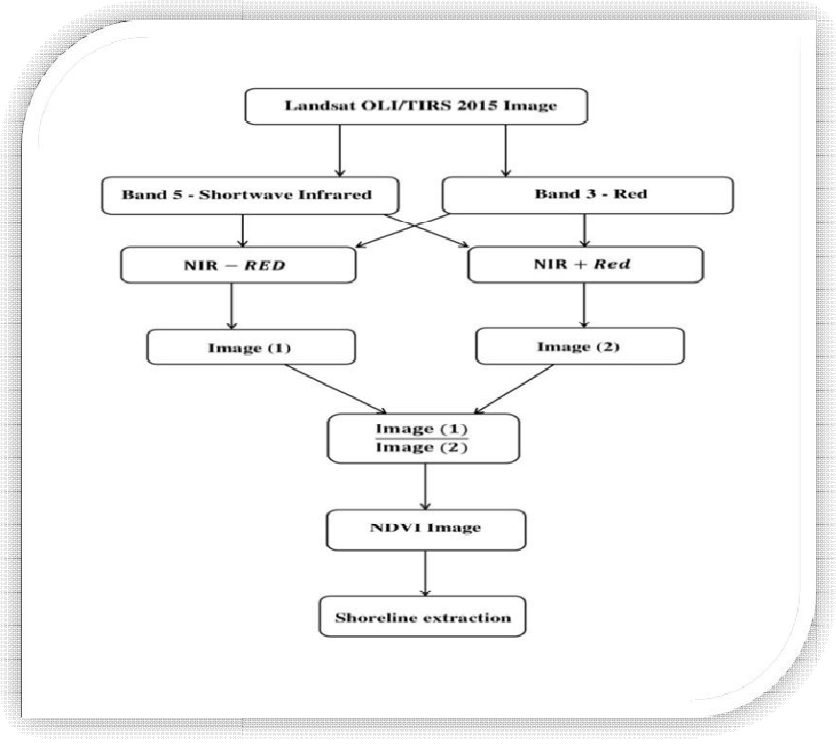


**Fig. 7. Methodology to extract shoreline using NDVI method**

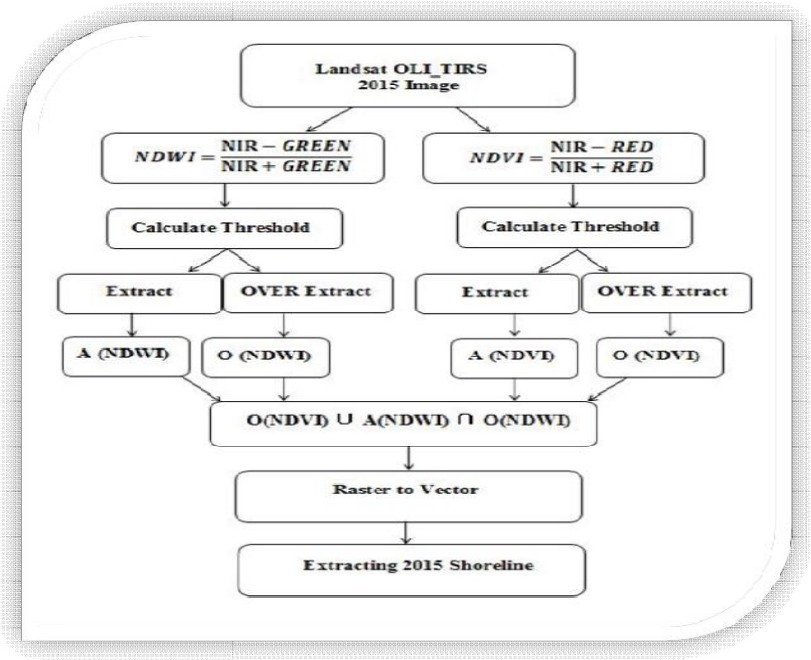


**Fig. 8. Methodology to extract shoreline using improved method**

## 4.2 Evaluation Criteria

In order to evaluate six shoreline extraction methods four statistical measures were calculated to represent the degree of matching between extracted and the actual shoreline, 1) The mean which calculated by (equation 4), 2) RMSE (root mean square error) which calculated by (equation 5), as following:

$$\text{mean } (\bar{X}) = \frac{1}{n}\sum_{i=1}^{n}|Xi| \quad (4)$$

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Xi - \bar{X})^2} \quad (5)$$

Another two evaluation criteria are, 3) the percentage of the extracted shoreline within 1 pixel distance of the actual shoreline and, 4) D90%-the shifting distance within which 90% of the shoreline are included. In order to applying this statistical measures the shifting distances between actual shoreline and extracted one are calculated by transact method or baseline approach which was proposed first by [25]. In this study first a baseline is proposed parallel to the shoreline offshore. Then about 172 Transacts with a spacing of 300 m apart are generated perpendicular to this baseline, and it should intersect with actual shoreline and all extracted shorelines. For the ith transact, the shifting distance between actual and extracted shorelines are calculated as (xi) as shown in Fig. 9.

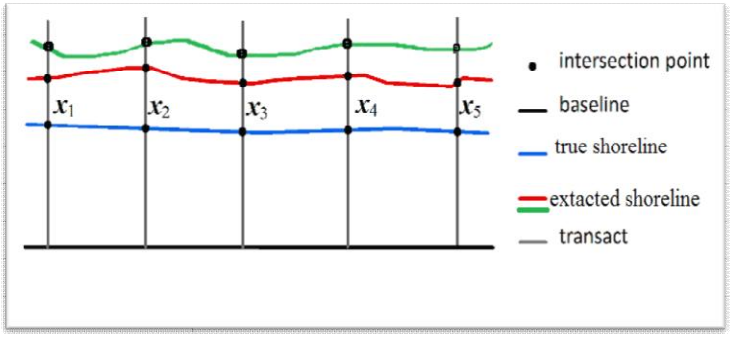


**Fig. 9. Illustration of the baseline approach for accuracy assessment. $X_{1,2,...}$ represents the Shifting distances between actual shoreline and extracted shoreline**

## 5. RESULTS AND DISCUSSION

The different methods of shoreline extraction are examined to detect which ones are better. First, Landsat8 2015 image is used by evaluated methods to extract shorelines and then these extracted shorelines are compared with reference 2015 shoreline which detected by high resolution image Pleiades B1. All shorelines are overlying together and the distance between a reference shoreline and other extracted shorelines are detected and the previous evaluation criteria are applied. The extracted shorelines by digitized, thresholding band ratio, classification, NDWI, NDVI and improved methods are compared with the reference shoreline and illustrated in Figs. 9, 10, 11, 12, 13, and 14 respectively. This comparison is to showthe deference between actual and extracted shoreline. The non-perfect overlap between the extracted and actual shoreline generated shifting distance which was considered as an indicator of the accuracy of the result. At each transect the shifting distance between actual and extracted shorelines are calculated and is drown as shown in charts 1, 2, 3, 4, 5 and 6.

As shown in the chart1 the maximum shifting distance is 148.23 m which occurred in transect No. 9 and the minimum is 0.315 m at transect No. 42. The mean of shifting distance is calculated and equal 12.78 m. the RMSE value obtained is 16.15 m, about half the value of the pixel size (30 m) of TM images, and 93.65% of the shoreline segments lie within 1 pixel distance of the true shoreline. The fourth evaluation criteria D90% is 26.06 m, which 90% of shifting distances between extracted and true shoreline is lying in.

As a result of Chart 2 in the previous chart the maximum shifting distance is 59.38 m which occurred in transect No. 94 and the minimum is 0.60 m at transect No. 13. The mean of shifting distance is calculated and equal 18.69 m. the RMSE value obtained is 11.82 m, about One third the value of the pixel size (30 m) of TM images and 84.12% of the shoreline segments lie within 1 pixel distance of the true shoreline. The fourth evaluation criteria D90% is 33.01 m, which 90% of shifting distances between extracted and true shoreline is ling in.

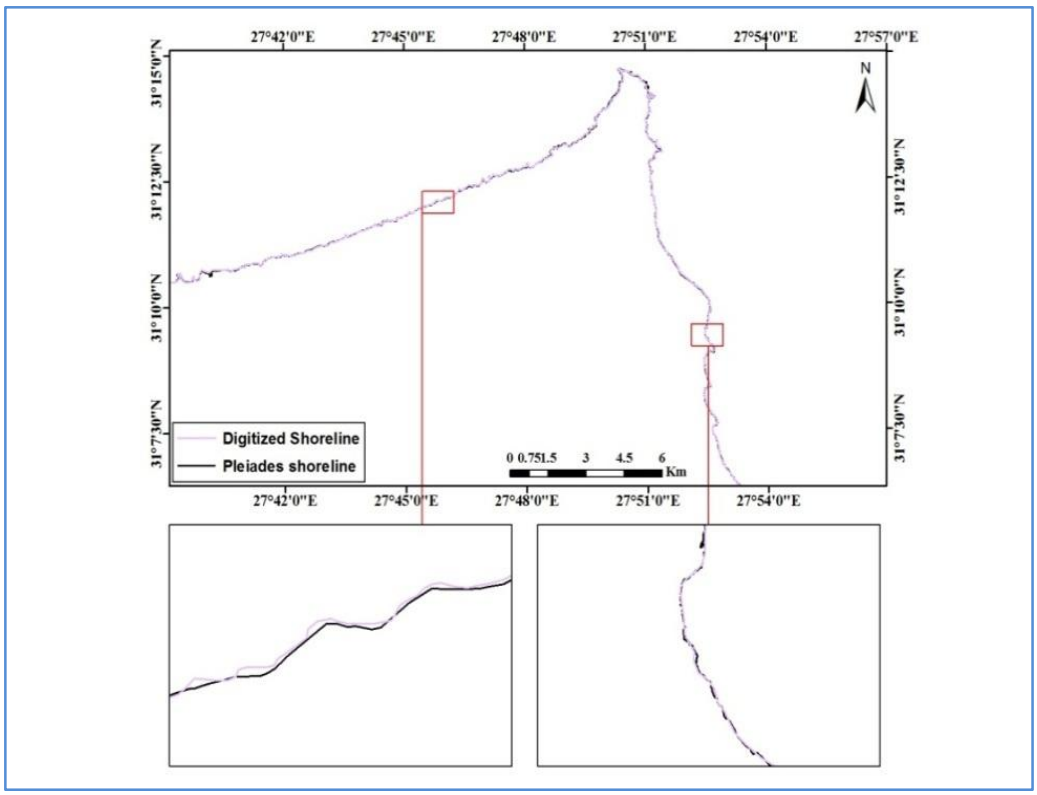


**Fig. 10. Actual and extracted shoreline 2015 by digitizing method**

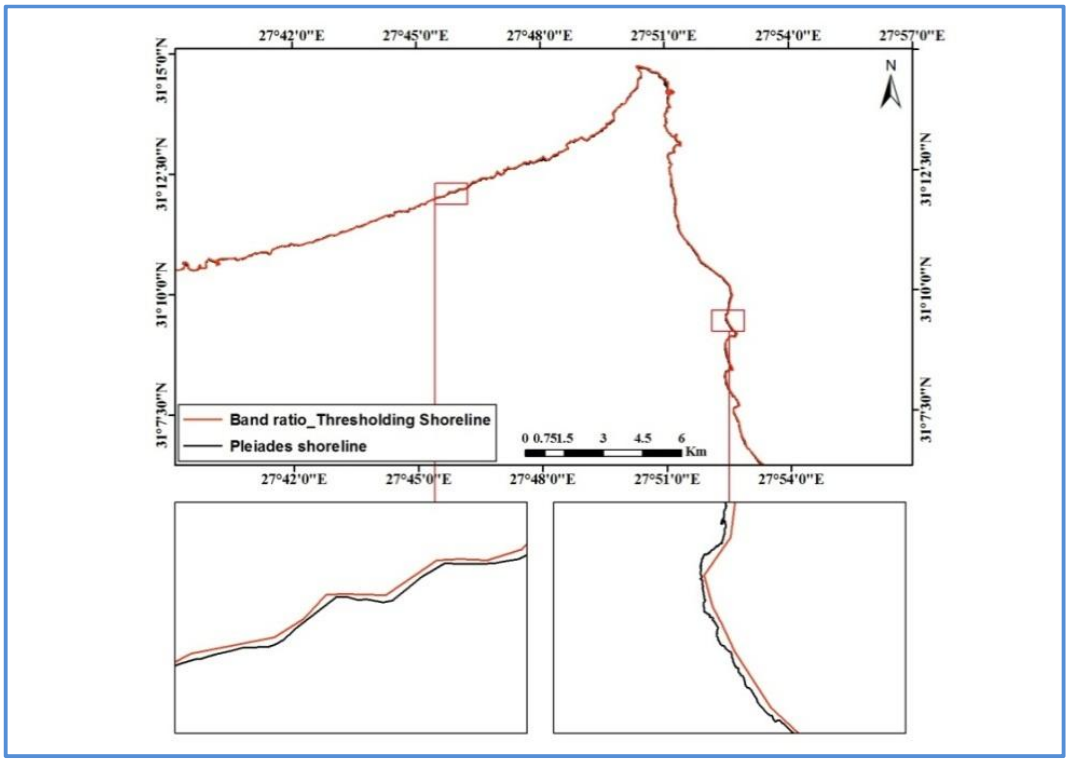


**Fig. 11. Actual and extracted shoreline 2015 by thresholding band ratio method**

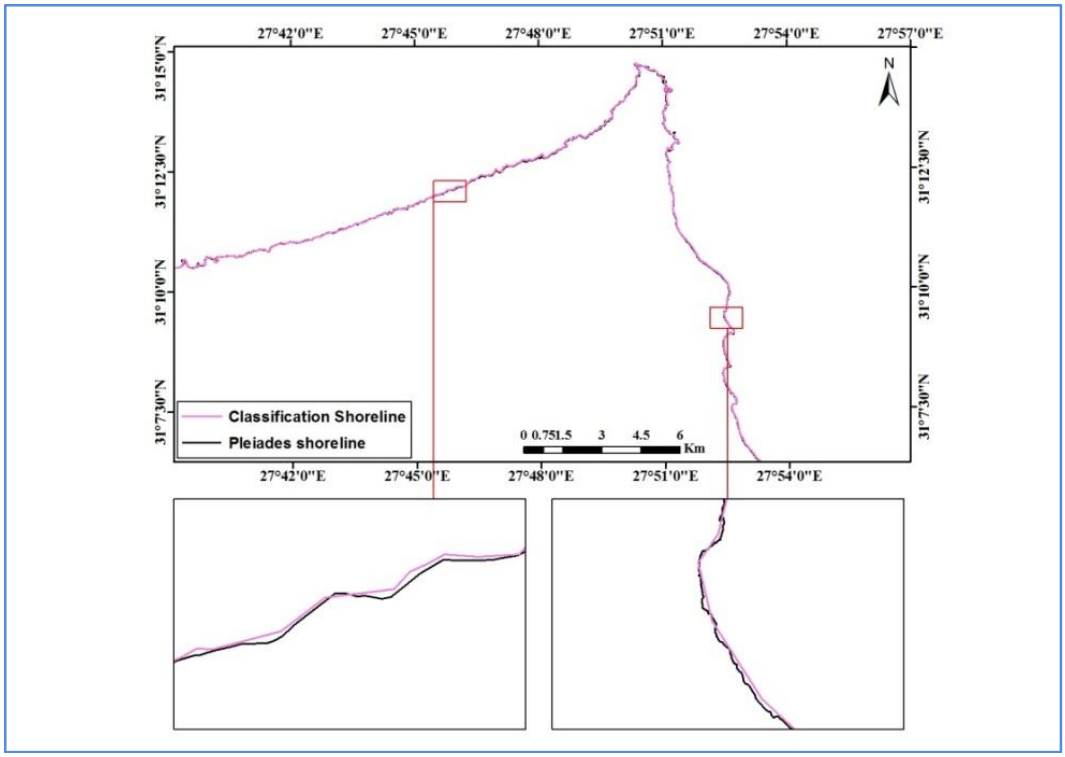


**Fig. 12. Actual and extracted shoreline 2015 by classification method**

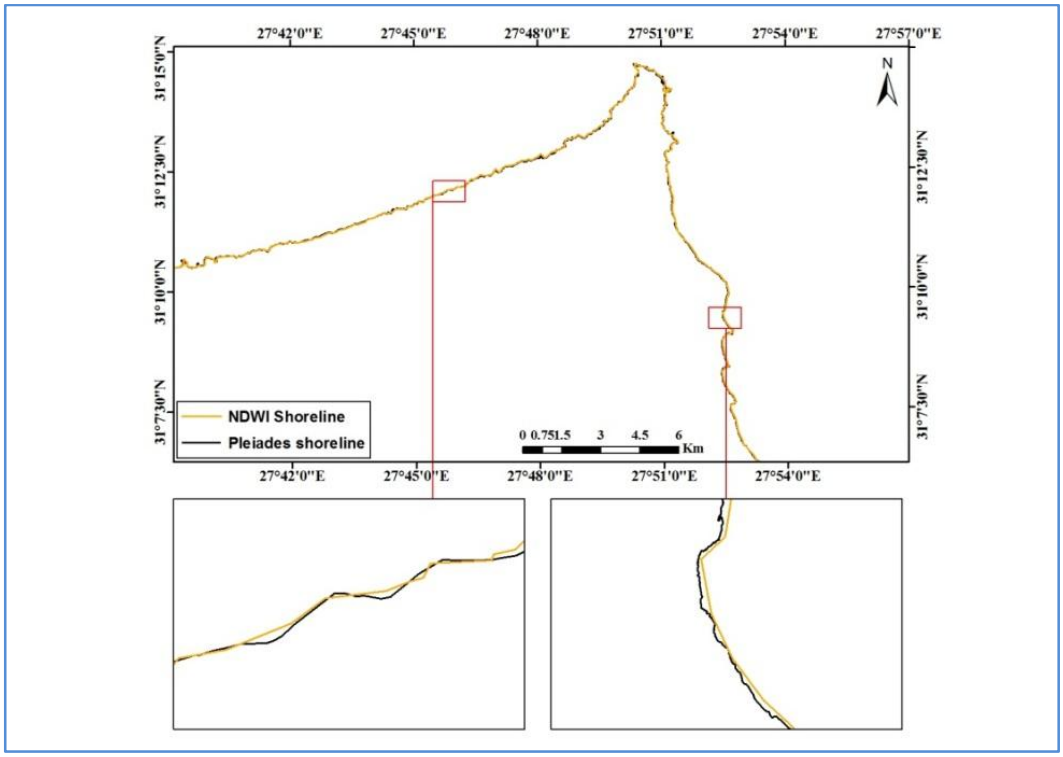


**Fig. 13. Actual and extracted shoreline 2015 by NDWI method**

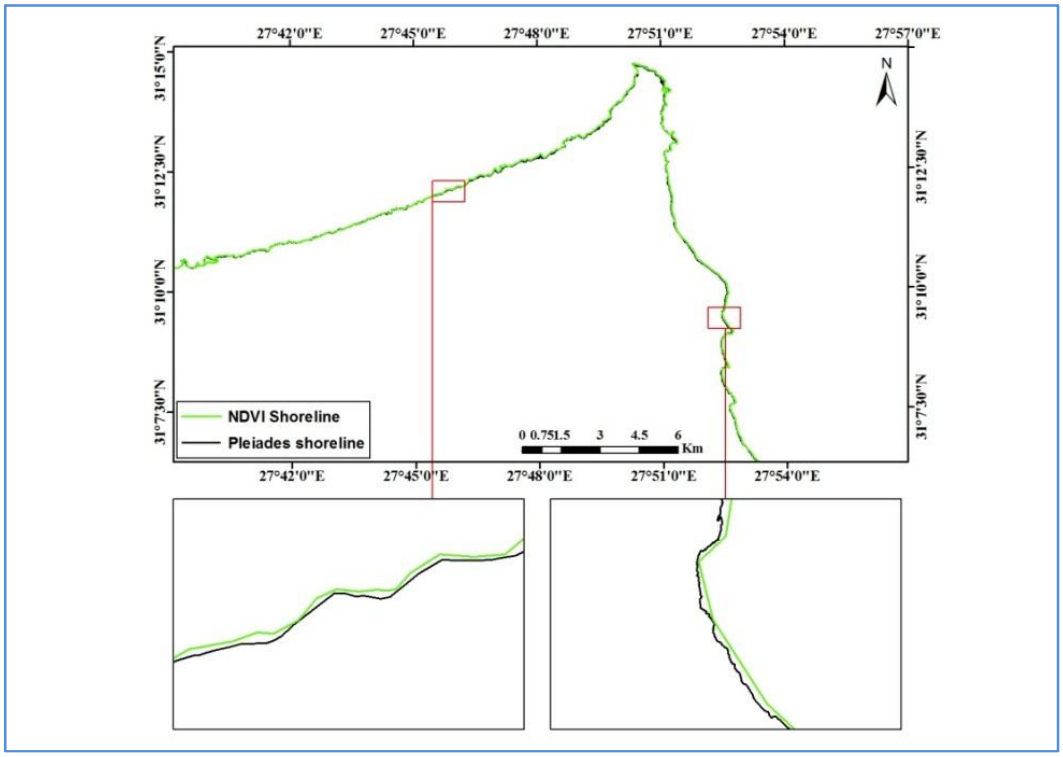


**Fig. 14. Actual and extracted shoreline 2015 by NDVI method**

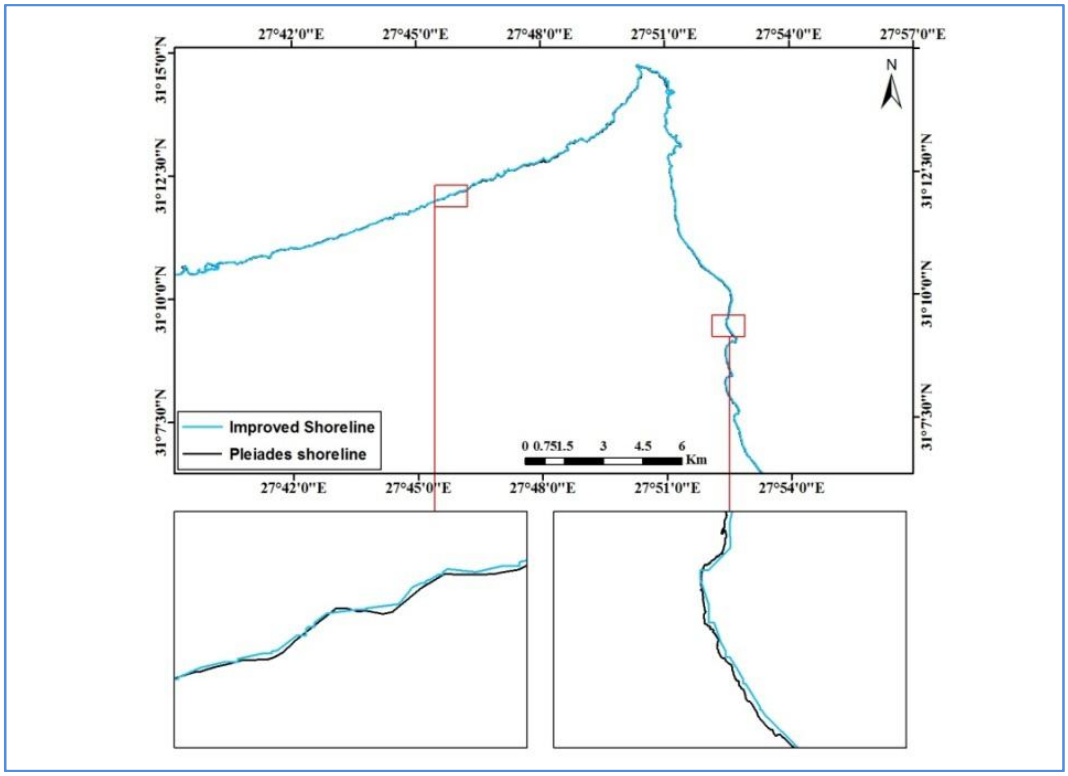


**Fig. 15. Actual and extracted shoreline 2015 by improved method**

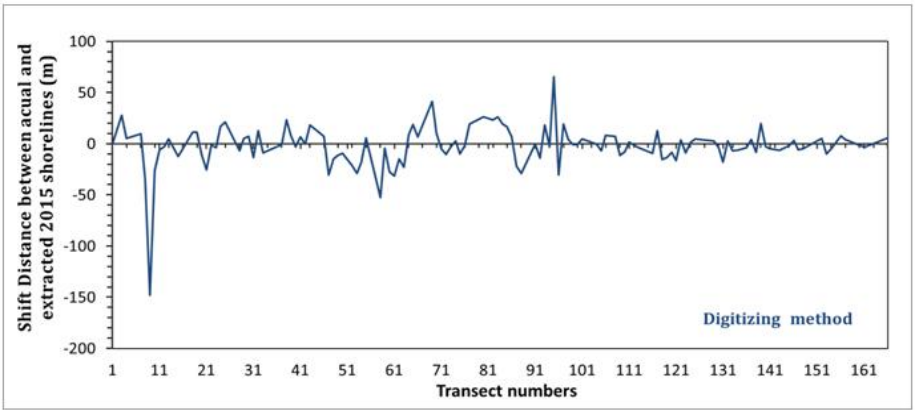


**Chart 1. Shifting distance between actual and extracted shorelines at year 2015 by digitizing method**

As a result of Chart 5 in the previous chart the maximum shifting distance is 52.60 m which occurred in transect No. 62 and the minimum is 0.040 m at transect No. 92. The mean of shifting distance is calculated and equal to 11.06 m. the RMSE value obtained is 9.54 m, about One third the value of the pixel size (30 m) of TM images and 94.44% of the shoreline segments lie within 1 pixel distance of the true shoreline. The fourth evaluation criteria D90% is 22.35 m, which 90% of shifting distances between extracted and true shoreline is ling in.

As a result of Chart 4 in the previous chart the maximum shifting distance is 166.93 m which occurred in transect No. 9 and the minimum is 0.53 m at transect No. 111. The mean of shifting distance is calculated and equal to 17.63 m. the RMSE value obtained is 22.70 m and 90.48% of the shoreline segments lie within 1 pixel distance

of the true shoreline. The fourth evaluation criteria D90% is 29.70 m, which 90% of shifting distances between extracted and true shoreline is ling in.

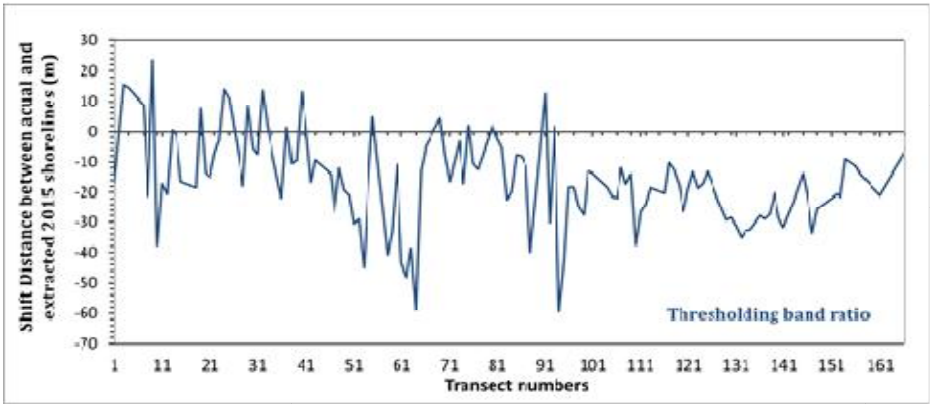


**Chart 2. Error in positions of shoreline between actual and extracted shorelines at year 2015 by thresholding band ratio method**

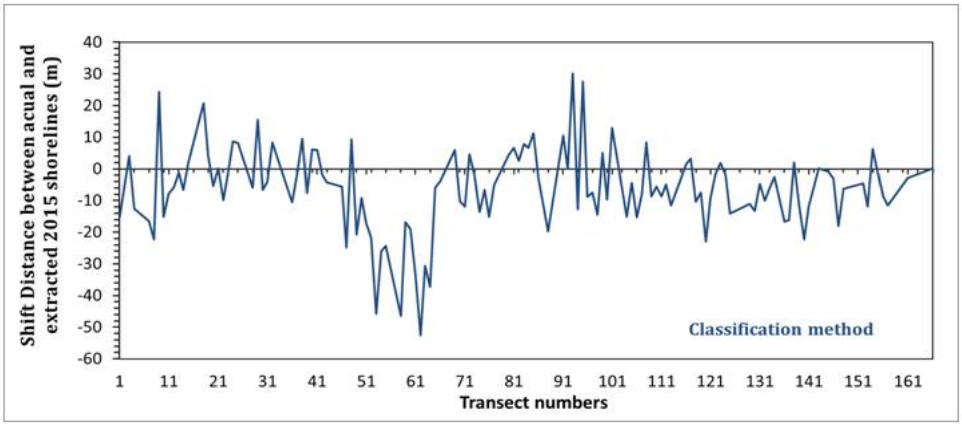


**Chart 3. Error in positions of shoreline between actual and extracted shorelines at year 2015 by classification method**

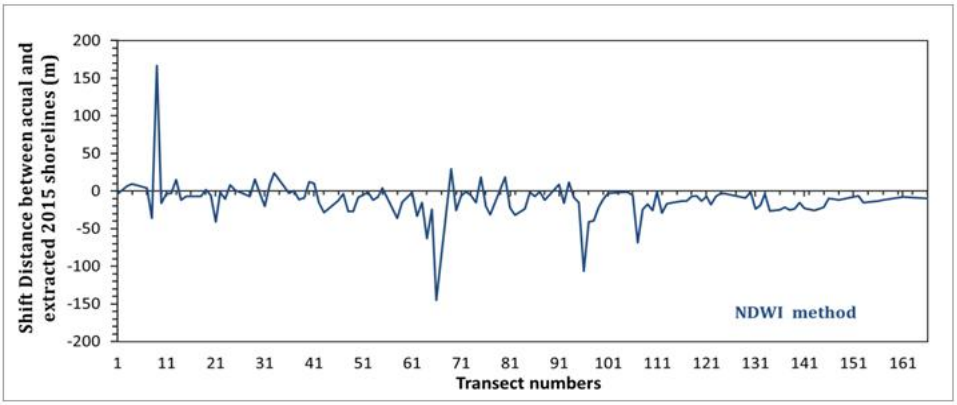


**Chart 4. Error in positions of shoreline between actual and extracted shorelines at year 2015 by normalized difference water index method**

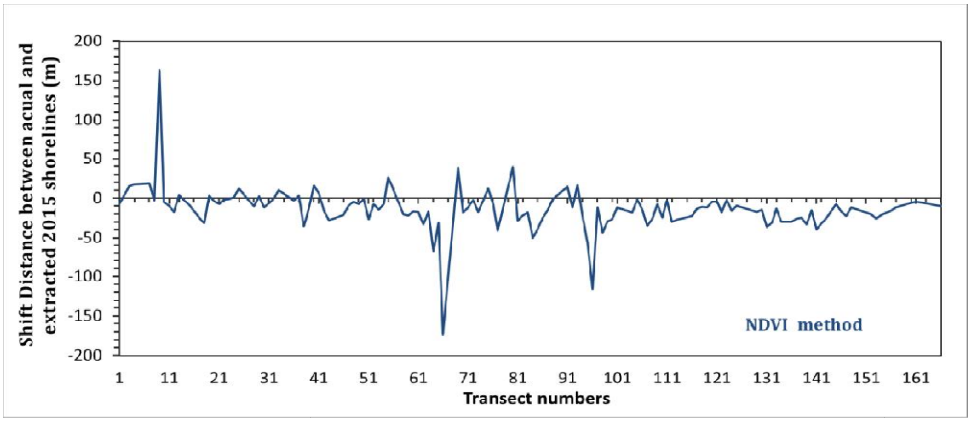


**Chart 5. Error in positions of shoreline between actual and extracted shorelines at year 2015 by normalized difference vegetation index method**

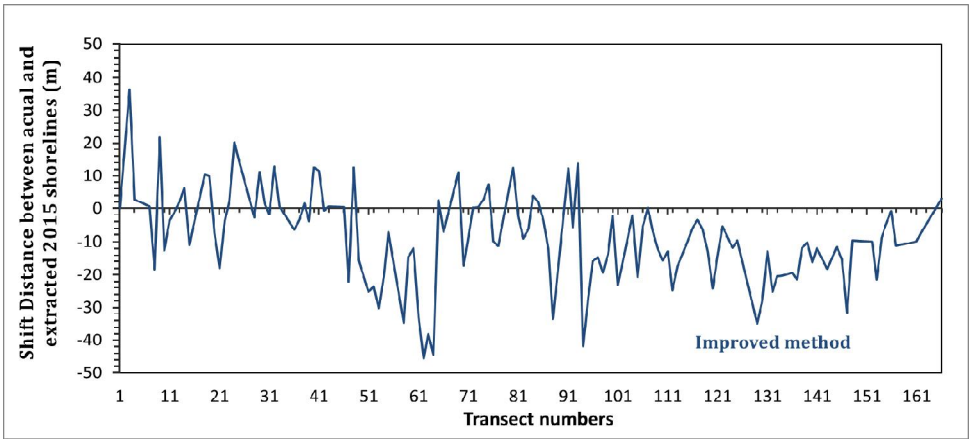


**Chart 6. Error in positions of shoreline between actual and extracted shorelines at year 2015 by improved method**

As a result of Chart 5 in the previous chart the maximum shifting distance is 173.45 m which occurred in transect No. 66 and the minimum is 0.48 m at transect No. 32. The mean of shifting distance is calculated and equal to 20.41 m. the RMSE value obtained is 24.13 m and 84.92% of the shoreline segments lie within 1 pixel distance of the true shoreline. The fourth evaluation criteria D90% is 36.20 m, which 90% of shifting distances between extracted and true shoreline is ling in.

As a result of Chart 6 in the previous chart the maximum shifting distance is 45.73 m which occurred in transect No. 62 and the minimum is 0.05 m at transect No. 1. The mean of shifting distance is calculated and equal to 12.96 m. the RMSE value obtained is 10.27 m, about One third the value of the pixel size (30 m) of TM images and 91.21% of the shoreline segments lie within 1 pixel distance of the true shoreline. The fourth evaluation criteria D90% is 25.19 m, which 90% of shifting distances between extracted and true shoreline is ling in.

## 6. ACCURACY ASSESSMENT FOR EXTRACTION METHODS

In order to evaluate six shoreline extraction methods four statistical measures were calculated to represent the degree of matching between extracted and the actual shoreline 1) The mean, 2) RMSE (root mean square error), 3) the percentage of the extracted shoreline within 1 pixel distance of the actual shoreline and 4) D90%-the distance within which 90% of the shoreline are included. The statistical measure Results of every six methods are discussed and illustrated in the following Table 3.

**Table 3. Closeness of the extracted shoreline to the true shoreline indicated by Mean, RMSE, D90% in meter and within 1 pixel criteria**

| Methods | Accuracy measures | | | |
|---|---|---|---|---|
| | Mean | RMSE | 90% within (m) D90% | Within 1 pixel% |
| Digitizing method | 12.78 | 16.15 | 26.06 | 93.65 |
| Thresholding band ratio | 11.06 | 9.54 | 22.35 | 94.44 |
| Classification method | 12.69 | 11.82 | 26.01 | 92.12 |
| NDWI method | 17.63 | 22.70 | 29.70 | 90.48 |
| NDVI method | 20.41 | 24.13 | 36.20 | 84.92 |
| Improved method | 12.96 | 10.27 | 25.19 | 91.21 |

The Results are discussed graphically as in following Chart 7.

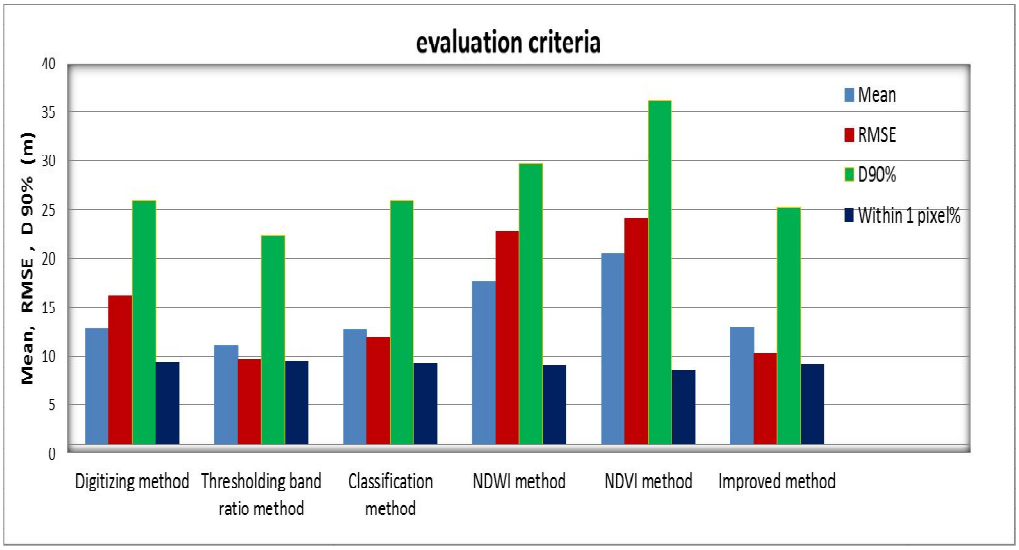


**Chart 7. Results of evaluation criteria for all methods**

## 7. CONCLUSIONS

The main aim of this paper is to examine different methods used to extract shoreline from Landsat images. The individual comparison has been done for six methods of extracting shoreline. The results showed the thresholding band ratio method is the most method closed to the true shoreline where the mean value is 11.04 m, RMSE is 9.54 m about one third the value of the pixel size (30 m) of landsat8 image, and 94.44% of the shoreline segments lie within 1 pixel distance of the true shoreline. The fourth evaluation criteria D90% is 22.35 m, which 90% of shifting distances between extracted and true shoreline is ling in. Improved, classification, and digitizing methods are convergent in accuracy. NDVI and NDWI methods are the worst methods among six methods.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Winarso G, Budhiman S. The potential application of remote sensing data for coastal study. Proc. 22nd Asian Conference on Remote Sensing, Singapore; 2001. Available:http://www.crisp.nus.edu.sg/~acrs2001
2. Alesheikh AA, Ghorbanali A, Nouri N. Coastline change detection using remote sensing. Int. J. Environ. Sci. Tech. 2007;4(1):61-66.
3. McKenna J, O'Hagan AM, Macleod M, Power J, Cooper A. Obsolete maps and

coastal management: Case studies from northwest Ireland. Coastal Management. 2003;31:229–246.

4. Zuzek PJ, Nairn RB, Thieme SJ. Spatial and temporal considerations for calculating shoreline change rates in the Great Lakes Basin. Journal of Coastal Research. 2003;38:125–146.
5. Ryu J, Won J, Min K. Waterline extraction from Landsat TM data in a tidal flat: A case study in Gosmo Bay. Korea Remote Sense Environ. 2002;83:442–456.
6. Loos E, Niemann K. Shoreline feature extraction from remotely sensed imagery. Geoscience and remote sensing symposium. IGARSS'02. IEEE Int. 2002;6:3417–3419.
7. Boak EH, Turner IL. Shoreline definition and detection: A review. Journal of Coastal Research, Number. 2005;214:688-703.

   DOI: http://dx.doi.org/10.2112/03-0071.1
8. Yamano H, Shimazaki H, Matsunaga T, Ishoda A, McClennen C, Yokoki H, Fujita K, Osawa Y, Kayanne H. Evaluation of various satellite sensors for waterline extraction in a coral reef environment: Majuro Atoll, Marshall Islands. Geomorphology. 2006;82(3–4):398–411.
9. Anders F, Byrnes M. Accuracy of shoreline change rates as determined from maps and aerial photographs. Shore Beach. 1991;59:17–26.
10. Byrnes M, McBride R, Penland S, Hiland M, Westphal K. Historical changes in shoreline position along the Mississippi Sound barrier islands. Coastal depositional systems in the Gulf of Mexico: quaternary framework and environmental issues. Gulf Coast SSEPM Foundation. 1991;43–55.
11. AL-Mansoori S, AL-Marzouqi F. Coastline extraction using satellite imagery and image processing techniques. International Journal of Current Engineering and Technology. 2016;6(4).
12. Du Z, Linghu B, Ling F, Li W, Tian W, Wang H, Gui Y, Sun B, Zhang X. Estimating surface water area changes using time-series Landsat data in the qingjiang river basin, China. J. Appl. Remote Sens. 2012;6.

    DOI:10.1117/1.JRS.6.063609.
13. Muslim AM, Ismail KI, Khalil IB, Razman N, Zain K. Detection of shoreline changes at kualaterengganu, Malaysia From multi-temporal satellite sensor imagery". Conference: 34th International Symposium on Remote Sensing of Environment, At Sydney, Australia; 2011.
14. McFeeters SK. The use of the normalized difference water index (NDWI) in the delineation of open water features. International Journal of Remote Sensing. 1996;17:1425-1432.

    DOI:http://dx.doi.org/10.1080/01431169608948714.
15. Xu H. Modification of normalized difference water index (NDWI) to enhance open water features in remotely sensed imagery. International Journal of Remote Sensing. 2006;27(14):3025–3033.
16. Hongxu M, Shenglian G, Yanlai Z. Detection of water area change based on remote sensing images "GRMSE 2013, Part I, CCIS. 2013;398:626–636.

    2013 © Springer-Verlag Berlin Heidelberg 2013.
17. Selvanayagam K. Shoreline change monitoring in coastal India, using remote sensing and GIS Tools. Enzine Articles.com, 29 Aug 2008.

    Available:http://ezinearticles.com/?ShoreLine-Change-Monitoring-in-Coastal-India,-Using-Remote-Sensing-and-GIS-Tools&id=1154397
18. LIST JH, FARRIS AS. Large-scale shoreline response to storms and fair weather Proceedings of the Coastal Sediments" '99(Long Island, New York). 1999;1324–1337.
19. Smith GL, Zarillo GA. Calculating long-term shoreline recession rates using aerial photographic and beach profiling techniques. Journal of Coastal Research, 1990;6(1):111–120.
20. Komar PD. Beach processes and sedimentation. Upper Saddle River, New Jersey: Prentice Hall Inc. 1998;544.
21. Morton RA. Accurate shoreline mapping: past, present, and future. Proceedings of the Coastal Sediments '91 (Seattle, Washington). 1991;997–1010.
22. Niya AK, Alesheikh AA, Soltanpor M, Kheirkhahzarkesh MM. Shoreline change mapping using remote sensing and GIS.

Int. J. Remote Sens. Appl. 2013;3:102–107.

23. Muslim AM. Shoreline mapping using satellite sensor imagery. [Thesis for Doctor of Philosophy]. (Faculty of Engineering Science and Mathematics, School of Geography). 2004;212.
24. McFeeters SK. The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. Int. J. Remote Sens. 1996;17:1425–1432.
25. Dolan R, Hayden B, Heywood J. New photogrammetric method for determining shoreline erosion. Coast Eng. 1978;2:21–39.

*© 2017 El Kafrawy et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.*

*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*http://sciencedomain.org/review-history/20986*