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Automatic Coastline Extraction Using Satellite Images

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Abstract: *Information about coastlines and their changes is critical in many coastal zone applications such as tidal inundation, sea level rise, coastal geomorphology, sustainable coastal development, coastal environmental management, and protection. Digitizing a feature such as the coastline from satellite images is a time-consuming operation besides introducing errors. This paper examines a procedure based on a combination of edge detection method, satellite images infrared bands, and GIS tools for automatic extraction of part of Mediterranean coastline in Egypt side. In this procedure : The images where pre-processed ,images segmentation and edge detection were applied on reflectance infrared bands and bands ratio to produce coastlines edges raster images , and finally the coastline vector maps where produced after converting raster to vector layers . The accuracy of this technique mainly depend on image resolution and it was estimated as 1.25 pixels (pixel size=30 m). This methodology consider as coast effective and demonstrate the applicability to extract a long distance of coastline in a rapid manner and moderate accuracy.*

Keywords: *Coastline extraction, TM & ETM+ sensors, Edge detection ,GIS*

I. Introduction

Following the definition of the European Environment Agency (EEA), a coastline is a 'line that separates a land surface from an ocean or a sea' and constitutes one of the most important linear characteristics of the Earth's surface. [1]

Coastal zone monitoring is an important task in sustainable development and environmental protection. For coastal zone monitoring, coastline extraction in various times is a fundamental work. It is highly dynamic environment with many physical processes, such as tidal inundation, sea level rise and coastal geomorphology. The horizontal position of the land-water interface is constantly changing with time as the water level moves up and down. Water level of the sea fluctuates due to short-term effects of tides as well as long-term relative sea level changes. It is also, affected by wind, atmospheric pressure, river discharge, beach changes, and steric effects due to changing salinity and temperature of the water body.

From 1807 to 1927, all coastline maps have been generated through ground surveying. In 1927 the full potential of aerial photography to complement the coastline maps was recognized. From 1927 to 1980, aerial photographs were known as the sole source for coastal mapping. However, the number of aerial photographs required for coastline mapping, even at a regional scale, is large [2]. Collecting, rectifying, analysing and transferring the information from photographs to map are costly and time consuming. In addition to cost, using black and white photographs creates several other problems. First, the contrast between the land and water in the spectral range of panchromatic photographs is minimal, particularly for the turbid or muddy water of coastal region, and the interpretation of the coastline is difficult [3].Second, the photographs and the resultant maps are in a non-digital format, reducing the versatility of the data set. Labor intensive digitization is required to transfer the information to a digital format, and this process introduces additional costs and errors. The geometric complexity and fragmented patterns of coastlines compounds these problems. In addition to the above, other possible limitations are: (1) the lack of timely coverage, (2) the lack of geometrical accuracy unless Ortho-rectified, (3) the expense of the analytical equipment, (4) the intensive nature of the procedure [4], and (5) the need for skilled personnel. In addition to high costs and difficulties, generation of coastline maps has fallen sadly out of date. From 1972 the Landsat and other remote sensing satellites provide digital imagery in infrared spectral bands where the land-water interface is well defined. Hence remote sensing imagery and image processing techniques provide a possible solution to some of the problems of generating and updating the coastline maps [5].

Remote sensing plays an important role for spatial data acquisition from economical perspective [6]. Optical images are simple to interpret and easily obtainable. Furthermore, absorption of infrared wavelength region by water and its strong reflectance by vegetation and soil make such images an ideal combination for mapping the spatial distribution of land and water. These characteristics of water, vegetation and soil make the use of the images that contain visible and infrared bands widely used for coastline mapping [7]. Coastline extraction for part of Mediterranean sea using TM , ETM+ and LANDSAT_8 imagery is the main aim of this paper. Furthermore, an automatic approach for coastline extraction from LandSat imagery has been examined and presented

II. Study Area

The study site of this investigation is Egyptian coast zone on Mediterranean Sea. The extent coast zone is located between latitude 29.89°N to 31.48 °N and longitude 31.03°E to 31.67 °E .The length of the coastline for this area is about 180 km (fig1). The digital images used in this research are: 7 Landsat images in different time. The following Table shows the used Land sat images.

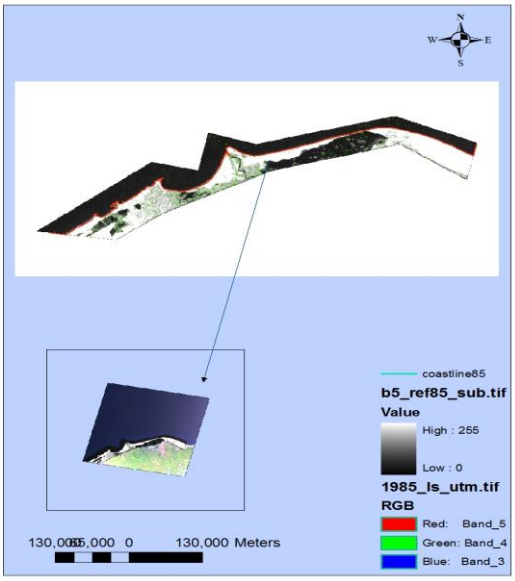

Figure1: Study area

Table 1:Landsat Images

Image	Type	Acquasation_Date
1	Landsat-5	1984-09-11
2	Landsat-5	1985 06 26
3	Landsat-7 ETM+	2001-02-22
4	Landsat-7 ETM+	2002-06-17
5	Landsat-7 ETM+	2005-03-05
6	Landsat-7 ETM+	2011-02-18
7	Landsat-8	2013-06-23

III. Methodology

Various methods for coastline extraction from optical imagery have been developed. Coastline can even be extracted from a single band image, since the reflectance of water is nearly equal to zero in reflective infrared bands, and reflectance of absolute majority of land covers is greater than water. Experience has shown that of the six reflective TM bands, short-infrared band 5 and near-infrared band 4 are the best for extracting the land-water interface [8]. Band 5 exhibits a strong contrast between land and water features due to the high degree of absorption of mid-infrared energy by water (even turbid water) and strong reflectance of mid infrared by vegetation and natural features in this range. The dynamic and complex land-water interaction in coastal zone of wetlands makes the discrimination of land-water features less certain, [9]. In this procedure the following steps have been carried out, and were described in flowchart (fig2).

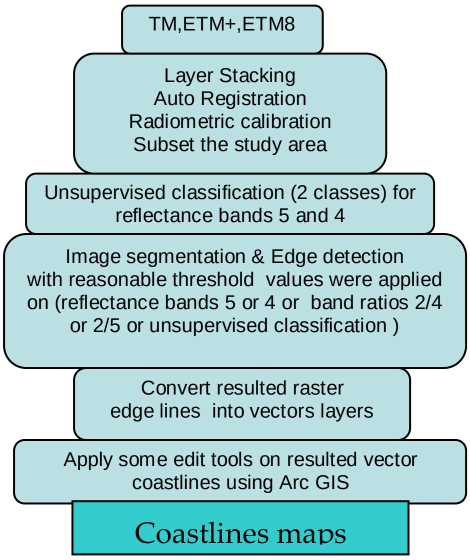

Figure 2: Flowchart of procedures for extracting coastlines from landsat images

- Applying layers stacking **-** Auto registration **-** Radiometric calibration (using ENVI 4.7) then subset the images to the study areas (fig 1).
- Performing Unsupervised classification on some reflectance band5 or 4 (for ETM images) with only 2 classes: black colour for water and irrigated vegetation fields, while white colour for soil and buildings and un- irrigated areas (fig 3).

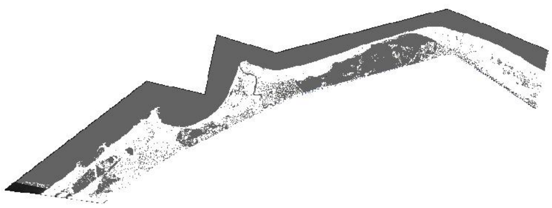

Figure.3: classified _B5ref_2002

- Applying image segmentation and edge detection on reflectance band 5 or 4 or reflectance band ratios 2/4 or 2/5 or classified reflectance band 5 or 4 for all tested images with different dates for coastlines detection. The resulted raster image for edge detection including coastline was produced as shown below (fig 4).

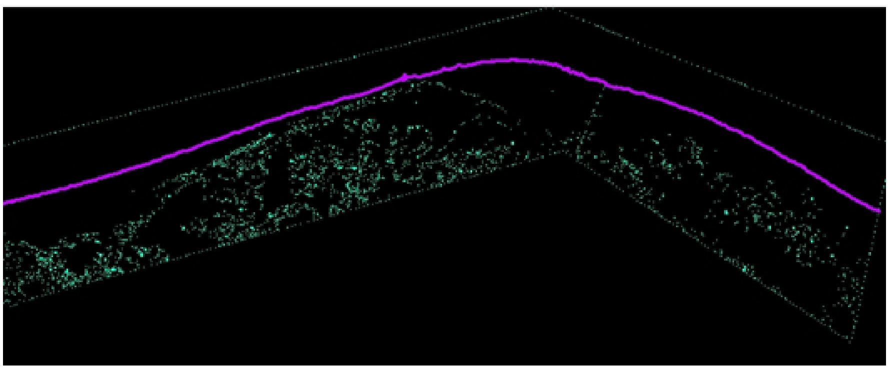

Figure.4: Raster image of edge lines for classified _B5ref_2013

- Converting raster edge lines into vector layers using ArcGIS Tool (fig 5)

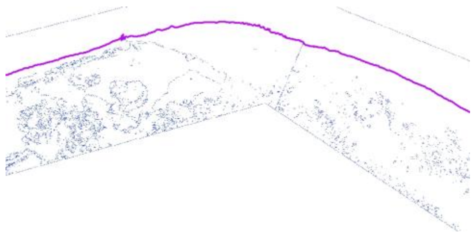

Figure.5: converted vector layer for classified _B5ref_2013

- Applying some edit tools (edit features, merge) for coastlines enhancing.
  The following figures demonstrate the automatic processing for the final coastlines layers production (classified or unclassified reflectance raster images + raster image for edge detected including coastlines + resulted vector coastline layers for different years) (fig 6,7)

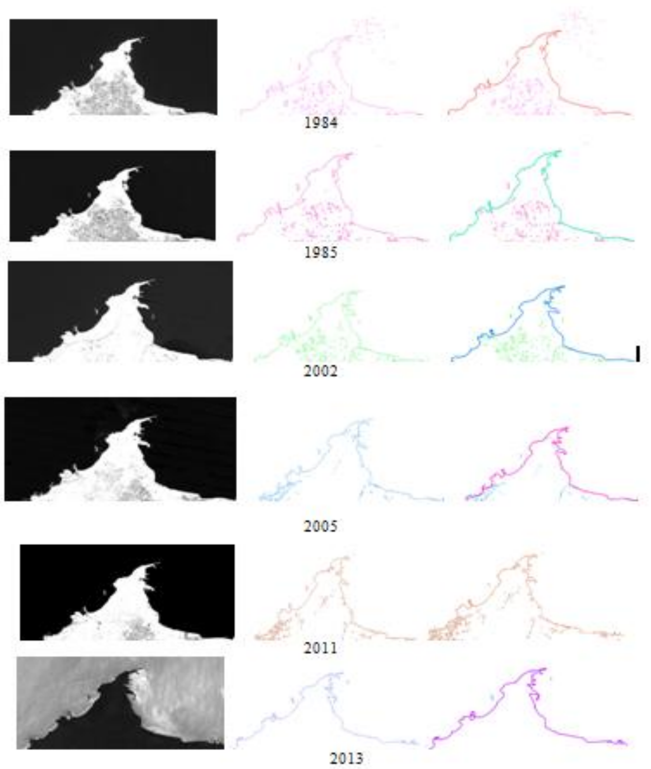

figure.6: infrared images + raster coastline edge detected+ resulted vector coastline layer for different years

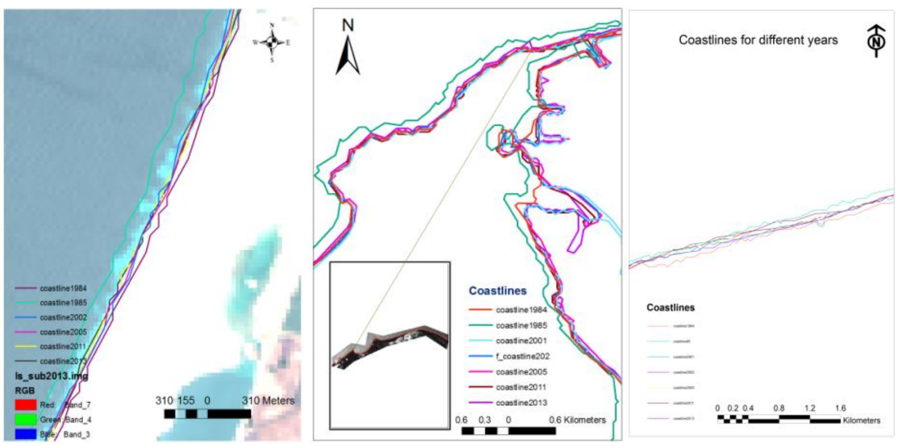

figure.7: resulted vector coastline layer for different years

IV. Results and Discussion

Many aspects have to be illustrated in this work , First: applying image segmentation was performed on different reflectance infrared bands:b4 (0.75 to 0.90 micron), b5(1.55 to 1.75 micron) , band ratio b2/b5 , b2/b4 , and classified b5 or b4) to test the most clear and perfect coastlines edge , and it was noticed that reflectance band 5 or classified b5 were the best for extracting the land-water interface line ,and also in some cases band 4 reflect water-land border better.

Second: Threshold value is important parameter in edge detection processing, because thresholds determine need a lot of experiments and visual comparison. For single band or multi layers, specifying a higher threshold will result in smaller number of edges and low noise. In this work the values were chosen between (0.01-0.05) in most images to guarantee delineate of all segments of coastlines and they usually have more noise but it can be distinguished from unwanted features as indicated in figure 8.

Third: To evaluate the accuracy of this approach, it is required to compare the extracted coastline which resulted from the reflected infrared band with the extracted coastline from a ground truth map. Because of the lack of a reliable ground truth map, an image driven reference data is utilized [10]. The ground truth image was provided via fusing the ETM+ multispectral bands with ETM+ panchromatic, and then collared with composite RGB 543 because this colour composite nicely depicts water-land interface. Furthermore, it is very similar to the true-colour composite of earth's surface. Also reference data of coastline was deduced from Principle component as reprehensive for ground truth image via visual interpretation (fig 9).

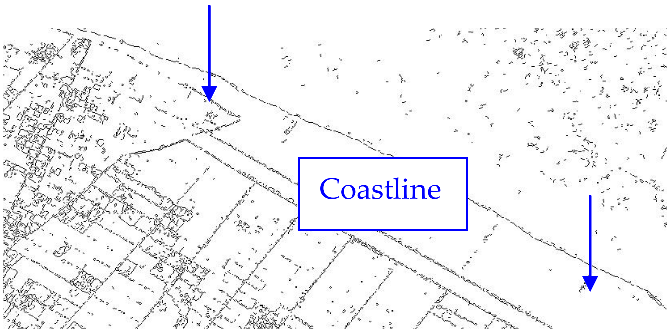

figure.8: edge detected (coastline) from infrared images

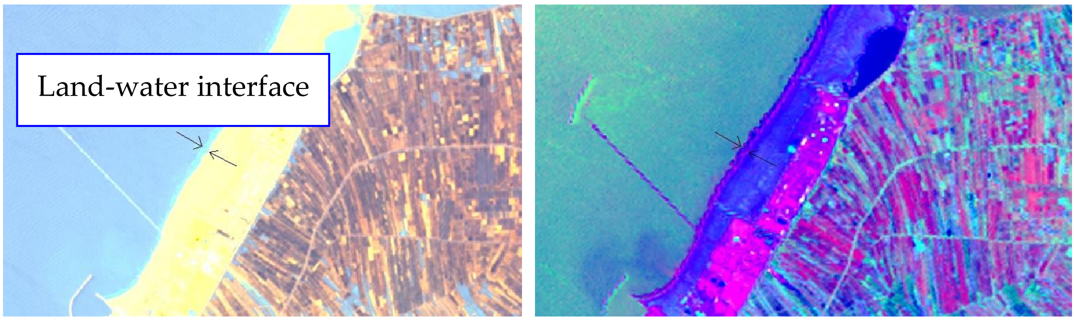

Figure 9: Fused ground truth & Principle component images (2013)

When applying Image segmentation on the resulted fused image, it must be taking into consideration to apply all layers of fused images to grantee all results are intersected to generate final results and also setting Euclidean Distance parameter and this mean for each pixel, its Euclidean Distance of all band values is used in performing segmentation.

It was clear from figure 9 the interface area between water and land, and obviously this area is shallow water and has lighter colour , and at the end of this area the coast line was extracted by applying image segmentation and edge detection followed by raster to vector conversion process (fig 10).

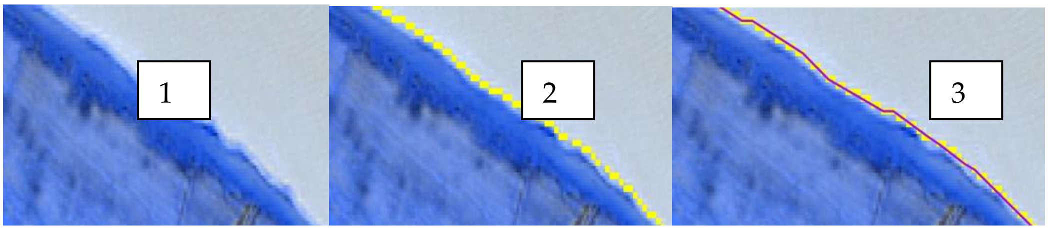

Figure 10: The three steps for automatically detected vector coastline.

The two edge coastlines resulted from the reflectance infrared band (30 m resolution) and the reference fused image (15 m resolution) showed accuracy about 1.25 pixels(pixel=30m)(fig11).

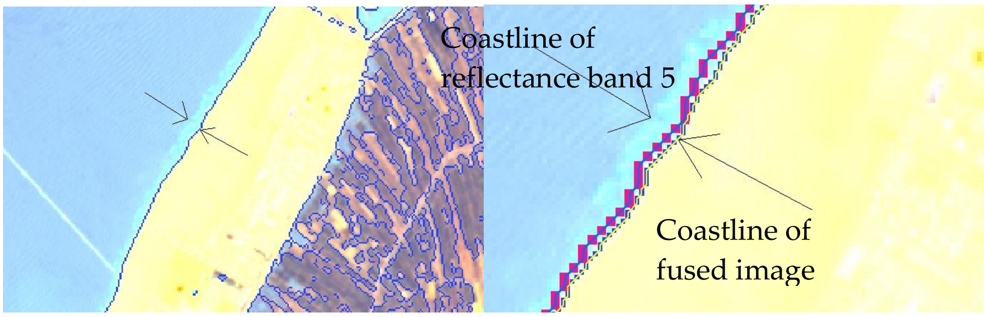

Figure 11: The resulted two edges coastline (reference and detected)

This result shows that medium resolution images (20 – 30 m/pixel) provide sufficient positional accuracy for certain applications of monitoring global coastline dynamics. Also the use of medium resolution images adds two principal advantages: (1) The availability of historic series (Landsat TM is operational from the beginning of the 1980 decade); and (2) they have a reduced cost compared to high resolution images. Finally, this methodology has a high potential for coastal change monitoring applications, as described above, in simple technique we can monitor the rapid change of coastlines through 1984 till 2013.

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