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Using GIS and Remote Sensing Satellite Data to mapping and monitoring Shatt Al-Arab Estuary and nearby coastline Southern Iraq

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ABSTRACT

Four Satellite Images for Shatt Al-Arab outer-bar region acquired from Landsat (MSS, TM, ETM+ and OLI) for the years 1973, 1990,2006, 2013 respectively. Furthermore it utilized from the QuickBird images 2006 for more detail analysis and integrated in a GIS (Geographical Information System) to perform spatio-temporal analysis of shoreline changes, coastal accretion and erosion, and coastline position for the Maraqat Abadan. Maraqat Abadan tidal coastal area and position changed markedly from 1973 to 2013 in the span of forty years. The objectives of present study are to analyze and assess the magnitude and direction of erosion or deposition for the Maraqat Abadan tidal flats and its relationship with movements of Shatt Al-Arab estuary over time period from the 1971-2013, and to predict the future shoreline changes to assist decision makers making sustainable management strategies to protect our maritime areas.False color composite comprised from the infrared, red and green spectral bands of the Landsat images enabled the visual interpretation and manual digitization for mapping the position and trend of shoreline near Maraqat Abadan. During this period the area increased with advance of the coastline at the rate of 136 m per year for the satellite images and 102 m for the nautical charts. The causes of this accretion in coastline mostly for the human factors, due to the construction of several large irrigation projects and dams by riparian countries (Iraq, Turkey, Iran and Syria),which led to a clear change in the movement and distribution of sediments and the deviation of the entrance of the Shatt al-Arab to the right side. Furthermore the establishment of the groins or sheet piles near the marine coast contributed to protect Iranian coast and trapping sediments from the Iraqi coast. This circumstance may influence on our maritime/political boundary, because of Shatt Al-Arab River between Iraq and Islamic republic of Iran conditioned to so-called Thalweg line.

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Introduction

A Coastline/Shoreline defined as the boundary when the sea surface contact the land body. [14, 32]. Among linear features in the earth's surface, the coastline area displaying a dynamic nature [33 in 61].The coastal areas are always physically and ecologically being change. It changed due to natural and human factors. The primary natural factors are comprise (waves, currents, tides and winds), as well as other factors such sand sources and sinks, changes in relative sea level, geomorphological characteristics of the coast. The human anthropogenic factors that changed coast are construction of artificial structures, mining of beach sand, offshore dredging or building of dams or rivers [51]. Consequently monitoring of coastline changes benefits to appreciate the coastal responses to these factors. Shoreline position is one of the primary geo-indicators for monitoring coastal changes as the shoreline is sensitive to natural processes (e.g., regional tectonic processes, fluvial processes, water quality, sea level and sediment supply) and anthropogenic alteration (e.g., construction of coastal structures, construction of river dams, and mining of coastal materials) [47].

A long term natural advance of shoreline position inferred a decrease in wave energy, an increase in sediment supply, or a low relative sea level. On the contrary, a natural retreat of shoreline position indicates an increase in wave energy, a decrease in sediment supply, a rise in sea level, or a combination of those causes [47].

The Coastline mapping and change detection are important for safe navigation, resource management, environmental protection, and sustainable coastal development and planning [24]. Following the coastline change is more than to investigate the potential relationship between the spatial-temporal patterns of sea-level rise and those of coastline changes, it is possible to provide essential information for government administrators and coastal managers to make scientific and rational policies for land use planning and sustainable development of coastal zones [50,56]. Remote sensing and geographical information system (GIS) techniques have been using widely to evaluate changes incoastal shorelines [16, 31,8,13,53,48,40,57, 20, 35, 2018; 39, 27]. These utilized from thecapability of repeatedsynoptic viewingof satellite data and the various options in multispectral bands and high resolution data [25]as well as the numerous services provided by geographic information system i.e. (analysis, stores, manipulation and visualization) for monitoring and mapping coastal/shore areas, than datacollected by conventional techniques[28]. The optical imaging sensors are essential technology in coastal mapping through their availability and easy to interpretation. Moreover,absorption of infrared wavelength area by water and its strong reflection by vegetation and soil make such images best combination for mapping the spatial distribution of land and water. These characteristics of water, vegetation and soil make the use of the images that include visible and infrared bands mostly used for coastline mapping [23 in 8].

Some of studies considered the tidal height as a proxy to evaluate coastal change detection, and therefore, the accuracy of shoreline position resulting from a satellite images based on the range of tidal height at the satellite flyover time [62]. Otherwise, there is attempt to use satellite images obtained matching tidal height and under clear atmospheric condition [64]. For the tidal-induced water level fluctuation, there are studies conducted for reduced such impact. [17, 64, 49, 63]. The image processing techniques differs according the nature of the coast, accuracy and scale required, and availability of the imagery series data and software and program as well as image processing techniques(Table.1).

There are several studies for change detection of coastal areas that connected satellite images with high water level [64, 54, 42, 43, 51,18, 2013; 21]. The primary and vital step in the shoreline change detection is the selection of suitable feature that can be considered as shoreline proxy or indicator that can represent the current position and can be as reference for monitoring the change in different periods. [14, 46]. These proxy shorelines are consist of two types: a visible and distinguishable line in coastal imagery known as High Water Line (HWL) or intersection of a tidal datum with coastal profile (such MHW, MLW, etc.) [14].

Among all the vertical levels that are used in the shoreline change detection, HWL is very common as it is easily interpretable in photos [14]. After determination, shoreline can be extracted by manual digitization or some automated techniques in GIS [43,3]. Furthermore, the shoreline movement, erosion and accretion rates can be calculated and its future trends can be predicted [19, 52].

The objectives of present study are toanalyze and assess the magnitude and direction of erosion or deposition for the Maraqat Abadan tidal flats and its relationship with movements of Shatt Al-Arab estuary over time period from the 1971-2013, and to predict the future shoreline changes to assist decision makers making sustainable management strategies to protect our maritime areas. This study highlightsthe coastal monitoring and analyzing the shoreline change using remote sensing and GIS techniques with the confirmationof using satellite images acquired at same tidal height for improving mapping efficiency and accuracy.

Table 1. Shoreline Change Detection Studies throughout the World

References	Source of Tidal height (Software, Model, Website, historical Tide gauge)	Satellite Images Time series	Shoreline Extract	Study Area	Tidal range	Change Factors Induced
[64]	https://tidesandcurrents.noaa.gov/	TM-ETM+	- Edge filter algorithm- - Tasselled cap -Unsupervised classification	west-centralFlorida coast	High tide	Hurrican
[41]	South China Branch of State Oceanic Administration (Neilingding)	MSS-TM-ETM+-SPOT	- Classification - Slicing - Digitizing	Pearl River Estuary, China	Low tide	Sedimentation and Man-made structures
[49]	Tide Model Driver and the Oregon State University Tidal Inversion Software	TM - ETM+	- NDWI	Tidal Flat China	High tide Low tide	sea level rise
[40]	Institute of Marine Geology and Geophysis (IMGG) on Hondau Station	MSS-TM-ETM+ ALOS 1975-2009	- Band rationing - Threshold technique	Estuary area of the Red river system, Vietnam	High tide Low tide	Sedimentation and Erosion by Red River andThai Binh
[51]	Tamil Nadu Port	MSS, TM, ETM+ and OLI 1978-2014	- Layer Stacking, - digitization USGS DSAS End Point Rate	Tamil Nadu, India Bay of Bengal	High Tide	Wave action
[63]	https://www.co-ops.nos.noaa.gov/ GPS Surveying Rockport station	TM-ETM+ OLI LIDAR	- Thresholding of MNDWI -Water frequency index (WFI)	Texas Coastal Area Intertidal area	High tide Low tide	Hurricane Sea Level Variation

Study Area

1- Location and Geographical Description

Geographically, Shatt Al-Arab Estuary located at the northwestern part of the Arabian/ Persian Gulf. The study are lies between 30˚5'0"–29˚50'10" North latitude and 48˚30'00"-48˚50'00" East longitude. The area bounded to the west by Khor Abdallah, and the east by the estuary of Bahmshiras shown in (Figure 1).Tectonically, the area located on the unstable shelf, particularly in the Mesopotamian zone, Zubair Subzone [15,9]

Shatt Al-Arb River originated from the confluence Tigris and Euphrates Rivers at Qurnah City 70 Km north of Basrah Governorate. Downstream of Qurnah, Shatt Al-Arab River flowssouthwestern for 204 Km shared between Iran and Iraq before drain in Arabian/Persian Gulf formed Delta. Besides to the Euphrates and Tigris Rivers, the Karkheh and the Karun sub-basins contribute water to the Shatt al Arab. Both the Karkheh and the Karun Rivers originate in the central zone of the Zagros Mountains in Iran and discharge into the Shatt al Arab [26]

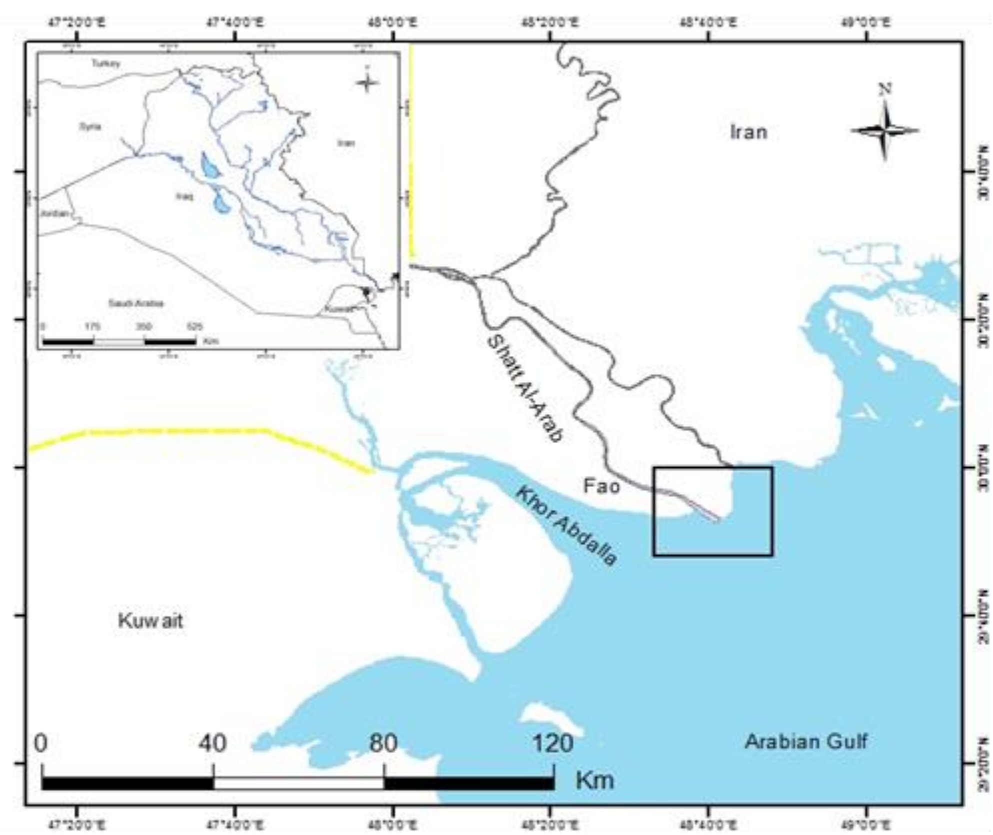

Figure 1. Location of study area

2- Hydrologic Setting

In order to understand the natural hydrologic system of Shat Al-Arab River, researchers have investigated the hydrological system of Shatt Al-Arab from its (Discharge and catchment characteristics) and the tidal effect, and Sediment budget. All this characteristics have been differed started from the past quarter 20thcentury.

Generally the hydrological regime of Shatt Al-Arab depends on the hydrology of the (Tigris, Euphrates, and Karun) also to water of Arabian Gulf. In other words the rate of water level changes in Shatt Al-Arab drainage basin, firstly is influenced by the river regime, and secondly the daily alteration of the water by the tide in the Gulf. It is important to consider these variables as distinctive character of the fluvial level system of Shatt Al-Arab.

There are number of important tributaries considered as the source of water and sediments of Shatt Al-Arab River. These tributaries are represented by the rivers (Tigris, Euphrates, and Karun). In addition to marshes regions that border Shatt Al-Arab from the upper section, which are represented by Hammar Lake that drains its water at Qurmat Ali into the east of Shatt al-Arab. Presently this tributary is considered as a branch [45]. As well as, Al-Huwaiza Marsh that flow via Al-Swaib waterway that discharge its water into Shatt Al-Arab River (5 km south of Qurna city) [4].

The hydrological studies point out that the water discharge of Shatt Al-Arab decreased dramatically than it was in the past quarter 20th century, when it reach to 1500 m^3 (Hussein et al, 1991) and continued to decline to (724-815 m^3) in the late nineties of the last century [11], reach after the 21st century to low value between 50-70 m^3[5, 2]. The present situation of the river hydrological system is completely different. Since 2010, Shatt Al-Arab River depends mainly on the freshwater flow from the Tigris River [5].Nowadays, Shatt Al-Arab water supply decreased, because of construction of large-scale hydropower and reservoirs dams and most important water diversions in the upstream basins in Turkey, Syria, Iran and Iraq.

The variation of water level inthisprocess is about 2m between two sequential tides [36].As well as, Shatt Al-Arab is affected by the tidal phenomena. It is mixedtype ranging from (diurnal to semi-diurnal) but the semi- diurnal is thedominant type which it characterized by unequal range as well as time, i.e.occurrence of two tides and two ebbs in one day [12].The Tidal range varies along Shatt Al-Arab course. It reaches 3m at Fao city and 1 m at Al-Ma`aqal, while it decreases away towardsQurna [1]. Thus, according to Davies`s [22 in 30] classification 1980 of tide ranges

[30] the region may be considered as a microtidal in type, which variesbetween 2-0 m, [1]. The maximum difference between high and low water levels may approach 1.7m in summer and 1.5m in winter [6]. Velocity of tide and ebb currents in Shatt Al-Arab estuary ismoderate to high. However, the tidal currents take a period of about 40minute in spring tide state after occurrence of upper level of Shatt Al-Arabwater, whereas in neap tide state where the water is in lower level, it takesperiod of about one hour after occurrence of upper level too. On the otherhand the ebb currents take period of 30 minute after occurrence of lowerlevel of Shatt Al-Arab water in spring tide state, whereas in neap tide stateit takes a period of one hour after occurrence of lower level too [44].

The total annually dissolved load that Shatt Al-Arab drains to theGulf is about 30 million ton. The annual suspended load of Shatt Al-Arabnorth to the confluence with Karun River is about 22 million ton [1]. Whereas it is about 20 million ton downstream the confluence and9.5 million ton at Fao [11]. The bed load is too low to beconsidered in Shatt Al-Arab, it is between 85 thousands ton/year [11].Shatt Al-Arab formed delta described as tide dominated affected slightly with waves[7] according to Gallawy's classification 1975 [29].The sediment of the Shatt al-Arab in the (Delta)mainly consists of 60% silt, 25% clay and 15% sand.The remarkable feature is deposited in main course of Shatt Al-Arab near Out Bar region was characterized by the longitudinal sediment bars.The Coriolis phenomena occurred in Shatt Al-Arab estuary thereforeit caused transportation and redistribution of the sediment load besidesits erosion effects on the Iraqi's coast [7]. The water circulation in the Arabian Gulf seems to be counter clockwise, passing northwesterly along the Iranian coast and recession water southeasterly along the Arabian coast (Emery, 1956).

Sea level has increased globally in recent decades as a result of global warming that impact consequently on the increased temperature and droughts that related primarily to the greenhouse effect because increasing concentrations of carbon dioxide, methane and nitrous oxide generated by human activities [37]. As estimated by Alothman et al. (2014) the relative of sea level for northern Arabian/Persian gulf included the outlet of Shatt Al-Arab recorded about 2.2 ± 0.5 mm/year over the period 1979–2007.

Material and Method

1- Data Source

In this study, Landsat MSS (Multispectral Scanner), TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus) and OLI (Operational Land Imager) datasets acquired from (USGS) website [60] for 1973 to 2013 were used to demarcate the shoreline changes along Maraqat Abadan. Table 2 indicates the data sources used for the coastlinechange detection. The datasets were obtained predominantly from June to July in order to acquire cloud free images, as well as, the highest tide in spring occurred predominately in summer season [10]. Itwere acquired in the same tidal height with 3 m near the station tide (Shatt A-Arab Out Bar). The tide level obtained using the admiraltytotal tide software (ver.1) [58] (Figure. 2), with cross checking website Sailwx (https://www.sailwx.info/tides/tidemap.phtml). High resolution data of Quick-Bird satellite with the spatial resolution 0.6 m (Table.2). Multi-date admiralty charts available in Marine Science Center Remote Sensing Lab.for the time periods (1971, 1986, 2004, 2008) (Table 3).

2- Image Processing

As the satellite images have been processed to level L1 T level. So the geometric rectifications are not required. All image data were projected to WGS84 datum UTM Zone 39N. The atmospheric correction is not applied as the vegetation and any other indices are not conducted in present study. The Landsat satellite images obtained were taken as an input for spectral preprocessing. Using layer stacking method, the individual bands of the satellite data were converted into a False Color Composite image using ERDAS Imagine ver.14 for displaying best contrast between land-water boundary in the satellite image and thus shoreline position was identified and demarcated.

3- Shoreline Extraction

The shoreline vectors have been created using ArcGIS ver. 10.1 (Arc-Map Interface) for two source of data used in study (Satellite Images and Admiralty Charts). These vector layers created as (Point, Polyline and Polygon). For satellite images high water line boundary was regarded as the shoreline proxy and demarcated using visual interpretation andscreen digitization method. As concerned the admiralty charts, it was scanned and converted to tiff file format then added to Arc-Map for georeferencing. It once georeferenced to the same coordinate system WGS 84-

UTM Zone 39N. Then, it created shapefiles polygons for the zero-line areas that reflect the low water tide and demarcated these areas using manual screen digitization. The UTM coordinates (x and y) for each end points in shoreline were used to calculate m EPR for both x and y locations of each point.

The position of these shapefiles calculated to find the accretion rate that caused the change in coastline of Abadan tidal flats. Average shift in meters was calculated and using duration ofoccurrence of change over the span time and for all time of data used in study using the formula: Rate of accretion meter/ year= distance f shifts/ total time period (span) (Figure-3).

Table 2. Specifications of the spatial data used in the study

Satellite Name	**Sensor Type**	**Path Row**	**Date Acquisition**	**Spatial Resolution (m)**	**Local Time**	**Tidal height (m)**
LANDSAT 1	MSS	177_39	1973-07-26 6:45:24 AM	60	6:45:24 AM	3 m
LANDSAT 5	TM	165_39	1990-06-20 6:36:02 AM	30	6:36:02 AM	3 m
LANDSAT 7	ETM+	165_39	2006-07-10 7:33:08 AM	30	7:33:08 AM	3 m
LANDSAT 8	OLI	165_39	2013-07-21 7:17:40 AM	30	7:17:40 AM	3 m
Digital Globe	Quick-Bird	29N_48E	2006-05-07	0.6	Unknown	Low tide

Table 3. List of Admiralty chart used in study

Name of Charts	**ID**	Year of Charts
Khawr Abd Allah and Approaches to Shatt Al-Arab	1235	2008
KhorAbdallah and Approaches to Shatt Al-Arab	1235	2004
Kuwait 1	Kuwait 1	1986
Entrance to Shatt Al-Arab	3842	1971

Result and discussion

Satellite data and nautical admiralty maps for 40 years were compared quantitatively to delineate shoreline positions in both tide level (High, Low). Depositional/ progradingshoreline are observed at the Abadan tidal flats.(Table 4) summaries rates of the Maraqat Abadan tidal flats changes as average of the erosion and accretion values on generated transects for the two sets of data Satellite images and nautical charts. The end point rate values represents the movement of the Abadan tidal flats toward the gulf (accretion rate). The position of Maraqat Abadan started moving forward toward the gulf from year 1973with distance 2416 m from year 1973 to 1990 with the advance rate about 142m per $yr^{-1}$for 17 time span(Figure. 3).The sediment supply near the mouth of Shatt Al-Arab that drained in Delta and estuary may indicate growth of the Abadan shoreline in this period. The discharge of Shatt Al-Arab River with its tributary Karun was in high level as mentioned by the hydrological studies[36].Since the last 1980s and beginning of 1990 past century, Shatt Al-Arabsediment supplyreached 22 million ton of suspended load [1].

Over the period of 1990 to 2006 for 16 years the advance rate of Abadan tidal flats constantly increased but with low rate was 139m yr^{-1} (Figure. 3). The Shatt Al-Arab river discharge decreasesintensely where the discharges became (724 m3-815 m^3). Thus because the construction of irrigation water storage dams and flood control projects in the riparian countries (Turkey, Syria Iraq and Iran) of the Mesopotamian rivers basin (Altinbilek, 2004; 38]. Accordingly the sediment supply drained in Shatt Al-Arab mouth declines which it evaluated to 9.5 million ton [11].

Table 4. End point rate for Abadan Maraqat from satellite images time series

Date of Satellite imagery	Time Spans yrs.	Rate ($m.year^{-1}$)	End Point Position (Distance, m)
1973-1990	17	142	2416
1990-2006	16	139	2234
2006-2013	7	115	810
Total	40		5460
Rate ($m.year^{-1}$)		136.5	136.5

Despite the deposition process is noticed along the Iranian shoreline (Abadan Maraqat), Iran government establishedsea protection structures like groynes or sheet piles etc. causes trapping sediments along the protection structures thus reduces the sediment supply to the Iraqis' shoreline. The high resolution satellite image Quick-Bird 2006 showed set of sheet pile to protect the coastline from the erosion processes and for trapping sediments purposes(Figure.4).

The period of the 2006 to 2013 for 7 years the rate of shoreline advance gradually decreased southwest from the Shatt Al-Arab mouth compared with past times pans. The rate of end point reaches 115m yr^{-1} over a distance (810 m). Recently the discharge and accordingly sediment supply were in the lowest level. In 2008 the Iranian government forwarded Karun River to the

Bahmshirwaterway, which helped recover the vegetation and agricultural fields in this area [34]. Also the Euphrates River cut-off its water and diverted to Marshes. So the freshwater flow of Shatt Al-Arab depends mostly on Tigris River[5].All the distance for the whole time series reached about 5 Km and rate of movement with (136.5 $m.yr^{-1}$). This impact to deflection of the entrance of Shatt Al-Arab estuary for the right direction.The right direction of the Abadan shoreline may attributed to effect of water circulation occurred in the northern part of Arabian/Persian Gulf, as mentioned in studies (Emery, 1956; 7, 10].

The historical nautical charts for years (1971, 1986, 2004 and 2008) representthe Lowest Astronomical Tide (LAT)showed changes through their areas and positions(Table. 5). The intertidal zone for Maraqat Abadan showed variation in its area and direction in the period from1971 to 2010. (Figure. 5).

Table 5 Area of the intertidal zones fromNautical Admiralty Charts used in study

Name of Charts	Chart ID	Chart Date	Area Km2	Rate of Advance
Entrance to Shatt Al-Arab	3842	1971	46. 37	0
Kuwait 1	Kuwait 1	1986	132.81	0.58
Khor Abdallah and Approaches to Shatt Al-Arab	1235	2004	82.57	3.03
Khawr Abd Allah and Approaches to Shatt Al-Arab	1235	2008	83.38	3.8
Average		37yr		102.7 $m\ yr^{-1}$

The total distance of Maraqat Abadan advanced progressively about 3.8 km i.e.(2 nautical mile).It is noteworthy, the Iraqi territorial sea extends to distance not exceeding 12 nautical milesmeasured from baselines that represents lowest water level as referenced in United Nations Convention on the Law of the Sea(UNCLOS)[59]. While the rate of intertidal advance about (102.7 $m\ yr^{-1}$).The advance of shoreline position may be attributed toa decrease in wave energy, an increase in sediment supply, or a low relative sea level or combination those causes[47].On the other hand, the shifts of the position baseline may generate some critical consequences related to maritime boundary between the neighboringcountries. Since the baseline subjected to change spatially and temporarily which require redraw and calculate the new baseline which effect maritime boundaries[55].

Conclusion

It has been found that the coastline of Abadan is very dynamic accumulative coastal environment. It is a changeable region facing several natural and anthropogenic factors that increase the deposition process, for the last four decades. The coastline in this area showed advancing in position and direction in different water level (high, low) tide, using historical time series Landsat data and Nautical chartsintegrated in a geographic information system (GIS). Both natural and anthropogenic factors contributed for increasing the extent of the Abadan coastal area. This situation may influence on our maritime/political boundary or territorial waters. The study demonstrates the applicability and usefulness of historical Landsat data for change detection studies of the coastal environment with conformation that the satellite images should be at same tidal height for the accuracy change detection outputs.

Future Work

With the beginning of the 21thcentury, different types of the remote sensors, platforms and techniques are available. As far as the sensor type is concerned, Synthetic Aperture Radar (SAR) sensors (ALOS, Sentinel-1), characterized by the socalled “all-weather” and “all-day” working capabilities. These techniques are became effective tool for mapping the coastal area. Through their polarimetry and interferometry characteristics can provide more detail about the surface and subsurface (underwater topography) of coastal zones. So, a further study for change detection of the present study area based on new generation of SAR data can be conducted.

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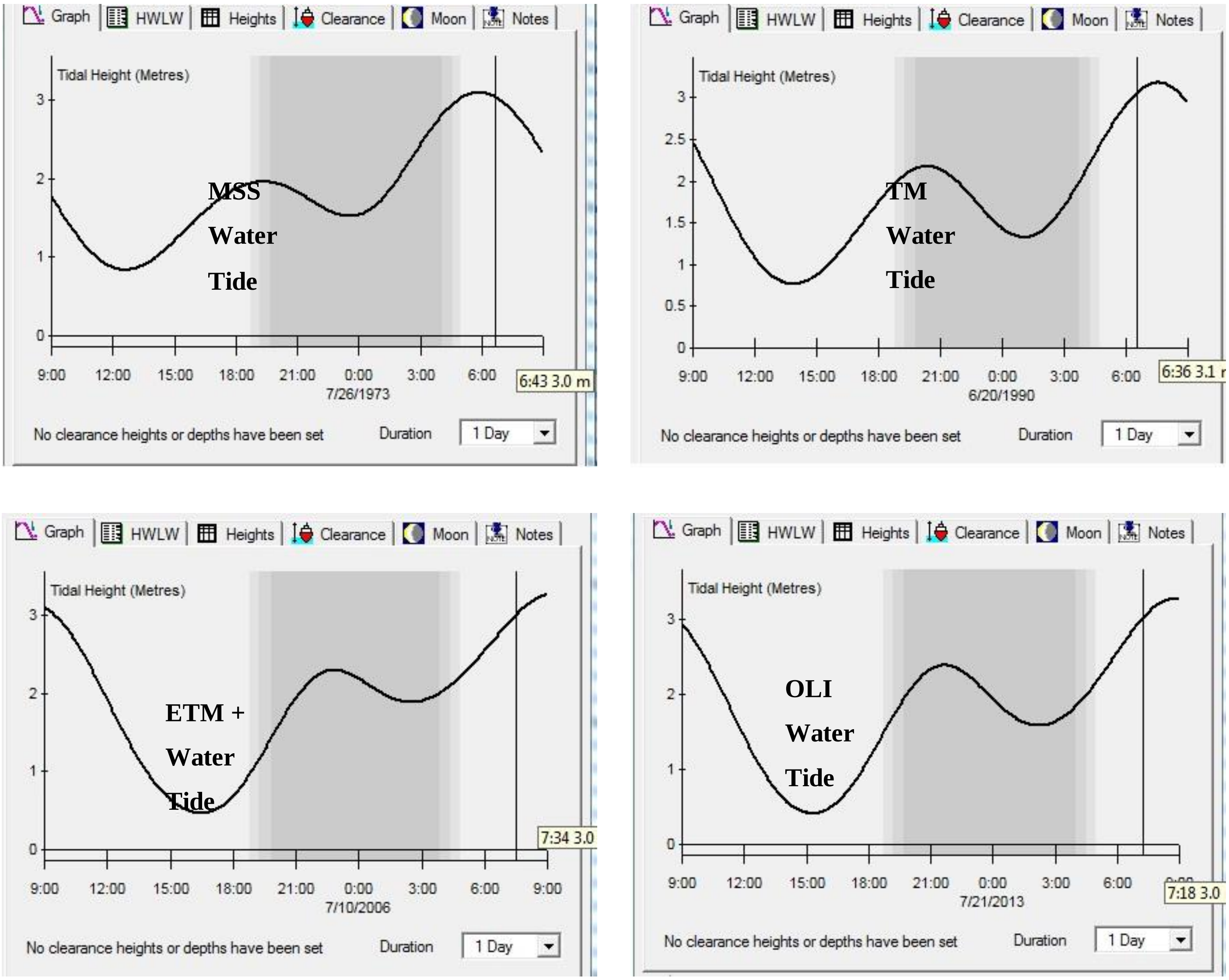

Figure 2. Total Tide software Water Tide Level for Landsat Images used in study (MSS, TM, ETM+, OLI)

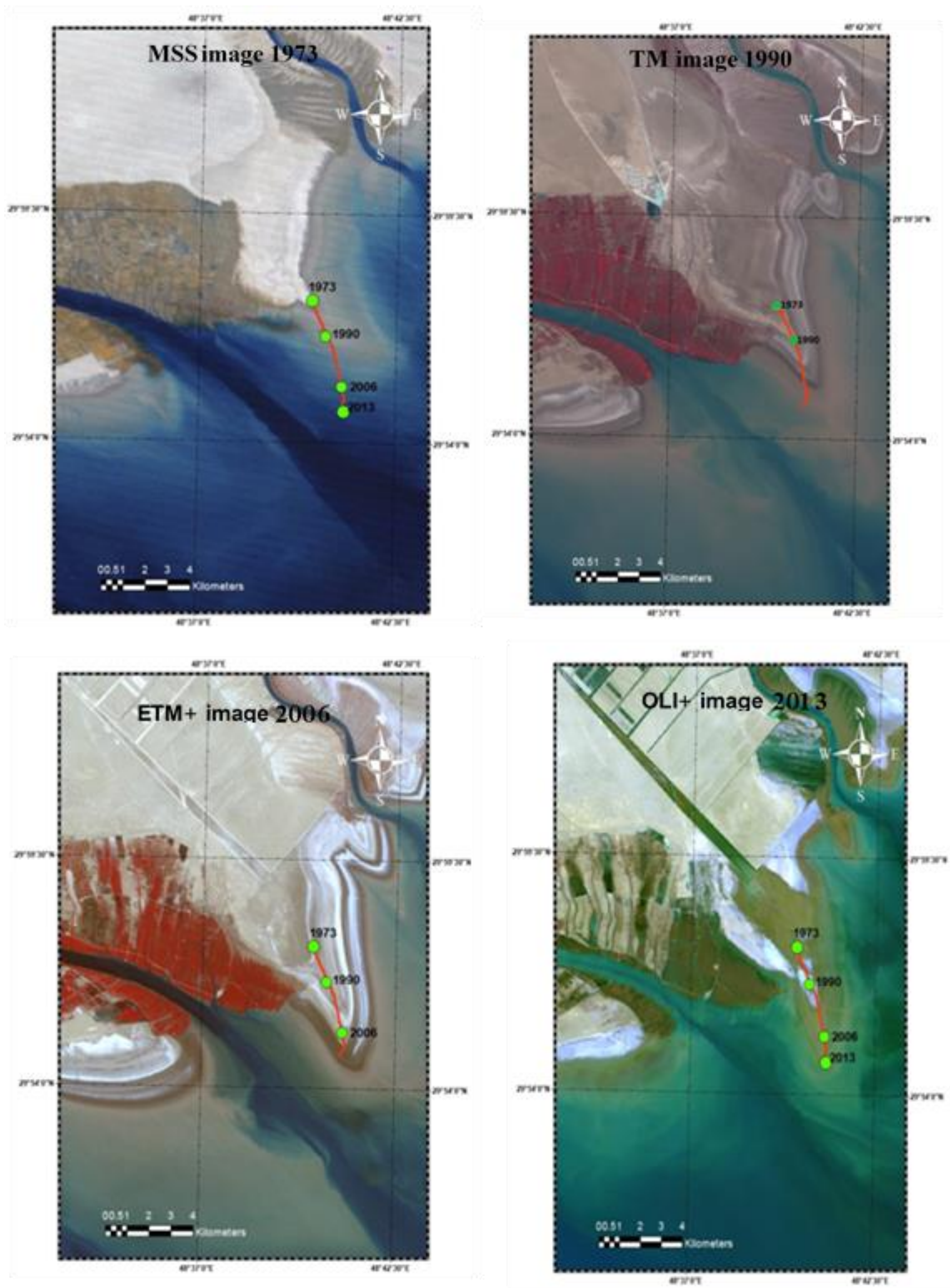

Figure 3. Shoreline direction and change detectionSatellite Image

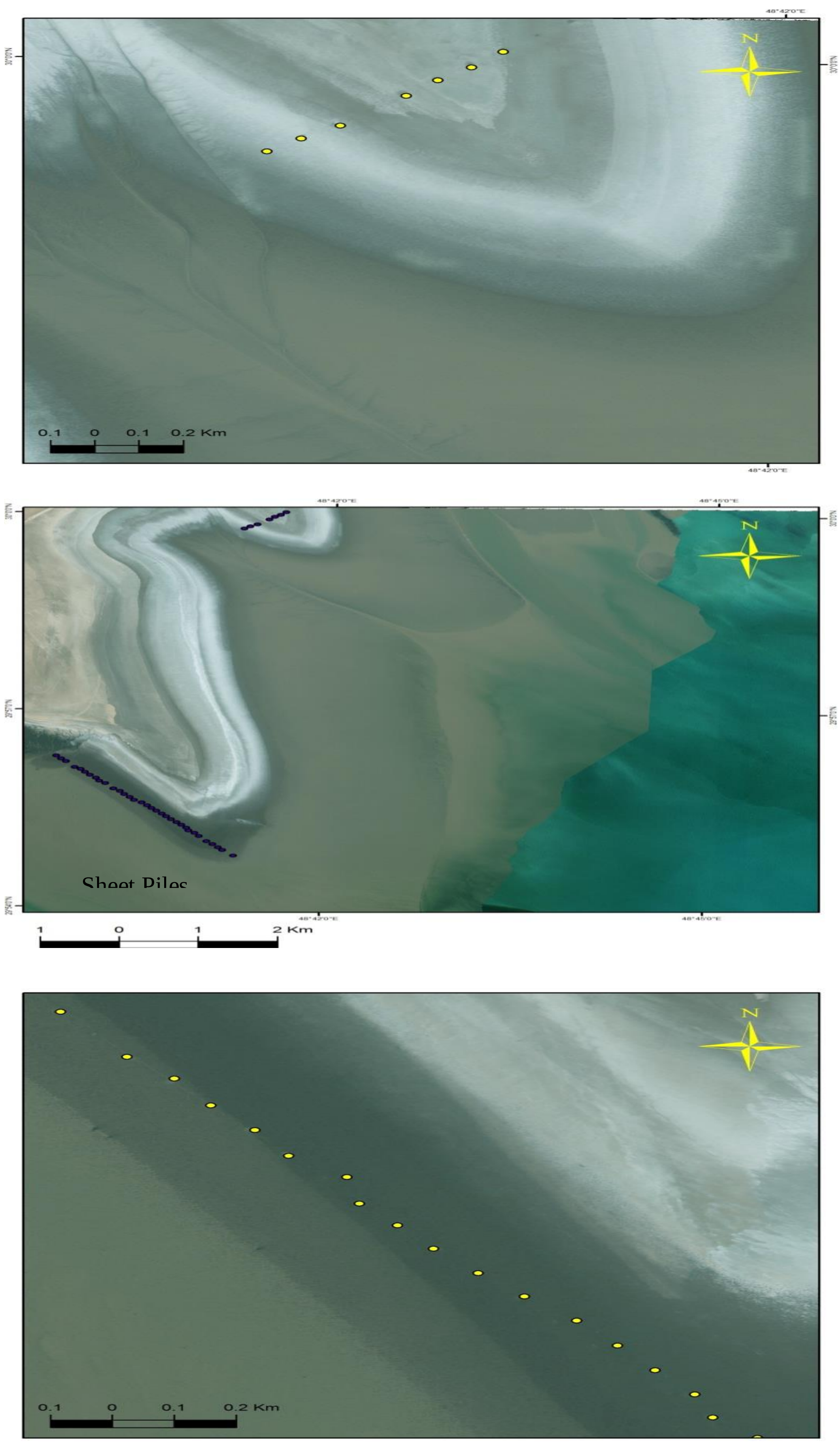

Figure 4. Sheet pile or groins for stabilization the shoreline of Maraqat Abadan. Quick-Bird Satellite Image 0.6 m

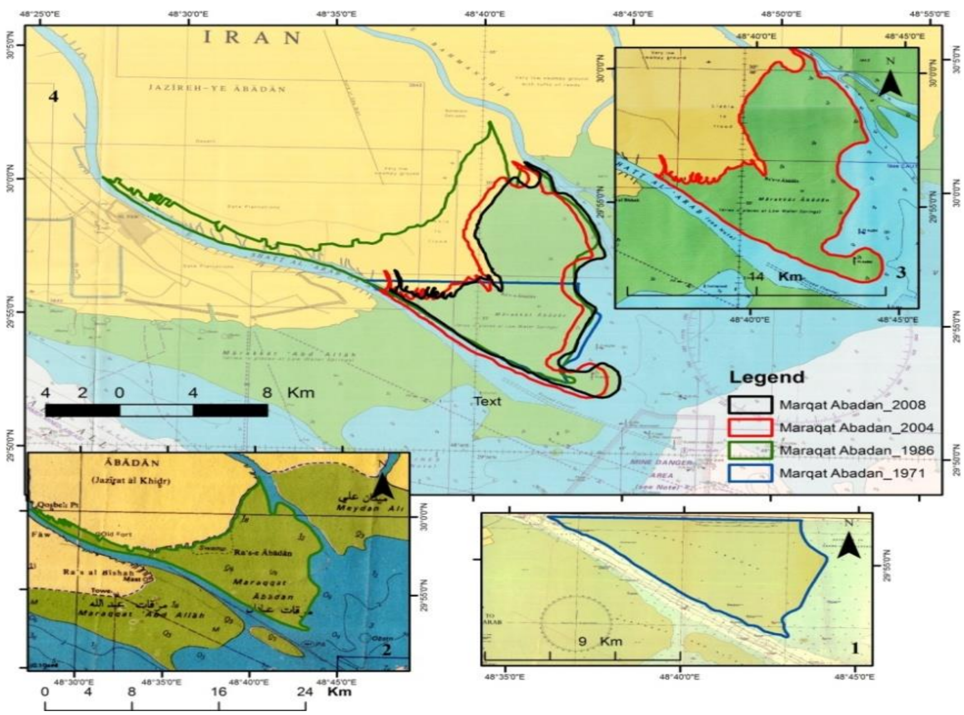

Figure 5. Baseline lines (zero line) and areas of the Abadan larvae from Admiral Maps by year, 1 (1971), 2 (1986), 3 (2004), 4 (2008)