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Impacts of Accelerated Coastal Developments on the Eastern Coast of Qatar, Case study: *Umm Saeed Coastal Area*

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ABSTRACT

This research concerns the coastal ecosystems along coastal area between Doha and Umm Saeed area (Qatar); a region where development is increasingly intensified and where the population is expanding. This research proposal aims to tackle environmental change and coastal regulation issues in the eastern coast region by establishing a sound scientific foundation, through earth observation data acquisition of both satellite imageries and discrete sampling data. Water quality assessments were conducted in a monthly basis from November 2013 to March 2014, from six sites representing the study area. Some important water quality properties were analyzed; e.g. temperature (37.9-40.3 ^{o}C), salinity (48.4-50.5 psi), pH (8.6 to 8.8), transparency (4 m> 6.5m), total suspended matter (2-7 mg/l), total suspended solids (2.2 and 3.5 mg/l) and total dissolved solids (45.3 - 47.4 mg/l) and nutrients (7 - 41 µg/l, for phosphates, 10 and 70 µg/l for nitrates, 5 - 21 µg/l for nitrites, 900-1680 µg/l for silicates and 10-70 µg/l for ammonia). Organic carbon was below the detection limit and biodegradable matter measured was in the range of 0.3 - 6.9 mg O^2/l within the study area.

Thus, water has been classified as oligotrophic-mesotrophic type, with some sites/dates was eutrophic due to their nutrient rich status. Levels of chlorophyll were moderate to high (0.6-8.3 µg/l). Results were used to feed in an integrated diagnosis for the study area which provides a holistic understanding of Qatar coastal system. Analyses of the satellite imageries (for 2006 and 2013) helped to classify the Qatari coast and habitats (e.g. mangroves, inter-tidal flats, salt marsh, etc.), and help in detection the change process within the study area during the period from 2006 to 2014. Results of this research are good baseline piece of information for any future CZMP for the area in specific and for the Qatari coast in general.

1. INTRODUCTION

Coastal and marine ecosystems are vital for the provision of goods and services, including food, energy, water, construction materials, recreational opportunities, transportation corridors and more holistically, climate regulation.

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From an anthropogenic perspective, Tinch and Mathieu (2011) subdivided key services into four main categories: Regulating services (e.g. climate and flood control, water quality and soil maintenance), Provisioning services (e.g. food, fuel, medicine and water), Cultural services (e.g. educational, recreational and spiritual) and Supporting services (e.g. species' nursery grounds, nutrient recycling, soil formation).

The 'natural capital' generally helps sustain and support human activities and biodiversity, but as humanity encroaches on the coastal zone, the integrity of such natural capital often suffers and ecosystem management is therefore essential.

The dynamic nature of most coastal areas is basically attributed to various earth surface processes that control the formation of various landforms that constitute many of such areas (Abou El-Magd & Hermas, 2010; Ahmed *et al*., 2010). These earth surface processes include both coastal and hydrodynamic aeolian processes (Allen, 1997). The coastal hydrodynamic processes produce several coastal landforms (e.g. sand beaches, coastal plains, salt marshes, wetlands, water bodies, etc). The coastal hydrodynamic processes produce several coastal landforms (e.g. sand beaches, coastal plains, salt marshes, wetlands, water bodies, etc). The aeolian processes, however produce several varieties of sand dunes (e.g. barchans sand dune, longitudinal sand dunes, and the star dunes) (Masselink and Hughes, 2003).

The excessive increase in population, civilization generally in Qatar and the accompanied developments during the last few decades accelerated the demand for other developmental projects; either planned or unplanned; to exist Qatar is currently experiencing unparalleled economic and population expansion and there is a need to ensure a harmonious balance between economic growth, social development and environmental protection as detailed in the Qatar National Development Strategy (2011-2016). The excessive increase in population, civilization and the accompanied developments during the last few decades accelerated the demand of extensive developmental projects; either planned or unplanned; to exist. Coastal biodiversity is widely threatened by such increasing population, and consequential pressures associated with rapid urbanization can impact fragile coastal environments. Furthermore, while international shipping and trade have introduced invasive species that threaten indigenous species, overfishing is impacting every level of the marine food chain. Therefore, it is imperative that some forms of coastal and marine spatial planning is instigated to identify any potential conflict between coastal users (industry, fishing, residential, protected biodiversity, etc.) but before that is possible, baseline data of the coastal and marine biomes must be established.

Conservation and sustainable use of marine and coastal resources is one of the main objectives of the Integrated Coastal Zone Management Plan for the State of Qatar. The first step in "Planning" is the problem definition, which relies mainly on collection of relevant data and information to enable planners fully understanding what issues they will plan for. Therefore, quality of a plan depends significantly on effective and efficient assessment of problems and issues. Qatar, as a continuously developing country with a growing population and large oil and gas reservoirs, is facing an important need for wise and highly efficient management aspects of natural resources (such as; land and water). Major development plans along the eastern coastal zone of Qatar are already in progress but coastal resources management that are sensitive to environmental changes and its associated distributaries requires a comprehensive assessment of land sea interaction, biological resources quality and pollution levels. Understanding how environmental changes, such as industrial development intensification, pollution and climate, affect the availability and quality of coastal water in marine environments requires an integrating approach.

Minerals; for example, are among the main economic resources in Qatar. Minerals are known to use sand dunes as their good "host". Therefore, detailed knowledge about the major sand fields in Qatar (i.e. morphology, type and mineralogy) is required not only to trace the existent mineral sources but also to monitor and respond adequately to their adverse impacts (e.g. threats on buildings and agriculture).

This research is looking for using remote sensing as an efficient EO source of data which provide valuable information about the surface expression of the regional geomorphologic and coastal features at Qatar western coast. The present study employed remote sensing data integrated with field surveys and laboratory measurements to examine the distribution, type and geo-morphological features and the coastal zone cover at SE of Qatar. The water and sediment quality are also among the aims of this research to evaluate the eater status at this coast.

Results of this study would serve as base line information to the national planners and decision makers that ensure their better understanding of the coastal zone management. In turn, this might help in planning of such area at minimum risks or reduced harms of the environment.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study area of focus is situated halfway along the North East coast of Qatar (Fig. 1). The coastal zone of the study area (Mesaiied) is low to moderate relief with a slightly undulating surface and several scattered features. Most of the geo environmental features are filled with aeolian sand deposits. The central part is formed by a plateau covered with limestone and colluvial soils. Calcareous beach sands are principally along the present coast-line, but they also occur at the edge of or within the scattered sabkha in the study area whose outlining areas were previously covered by the Quaternary Sea. Al Wakra is located approximately 10 km south of the Doha city and 15 km north to the proposed project location. Originally, a small fishing and pearling village, Al Wakra has evolved into a small town with a population of 30,000 (MOI, 2012).

Historical remote sensing data show that this lagoon was not presents prior to 1977, and that it formed sometime between then and 1995. The sedimentary character and time of formation of the barrier spits and tar piles is consistent with a hypothesis that they have been formed as a result of beach scraping in response to the oil and tar deposition. The scraping of the rock/sand into a semi-continuous long-shore feature (the barrier spit) would have effectively created the lagoon behind.

With a population of 120,000, Mesaiied has the status of a municipality and is managed by Mesaieed Industrial City Management, a subsidiary of Qatar Petroleum (the national oil and gas company responsible for exploration, production and export of hydrocarbons in Qatar). It is a self contained town with modern amenities such as schools, shopping areas, entertainment parks, sport clubs etc. Mesaieed Port was primarily established for the export of petroleum products (primarily from the Dukhan Oilfields located on the west coast of Qatar).

2.2 Field and laboratory data

Field and laboratory data were used in combination with EO data to provide detailed description of the coastline of the study area.

2.3 Field surveys:

Six Sampling sites were selected (Fig. 1) to cover a large sector of the investigated area and represent various coastal features with different human activities such as industrial projects and touristic activities. Water samples were collected in polyethylene bottles and frozen prior to later analyses at the laboratory. Samples were collected monthly from November 2013 to March 2014 to monitor the accelerated development in the study area. Walk over

site visits were conducted by trained coastal morphologists. A description of the coastal morphology based upon the data and observations were then described.

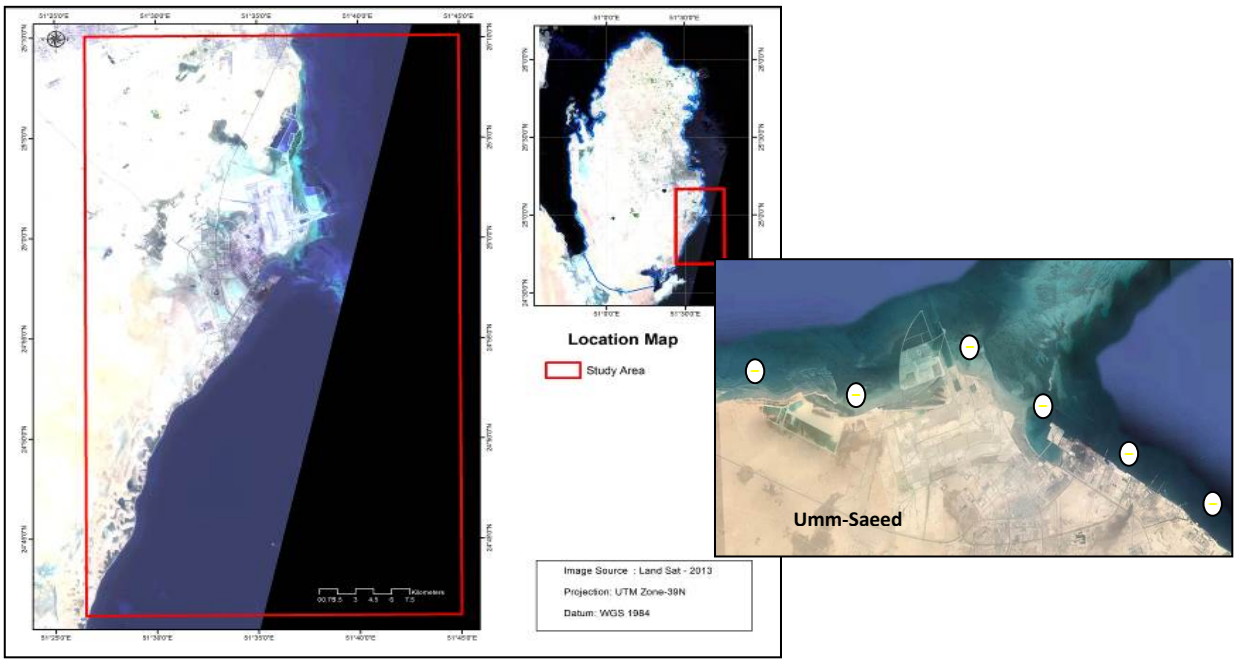

Fig. 1: A Satellite Image of Qatar in 2013 showing the study area and the sampling sites covering Umm Saeed coastal water (indicated as white circles)

Some measurements were conducted *in situ* using a multi sensors probe and other different instruments; such as water temperature (water thermometer), pH (pH Scan 2), salinity (Salinometer -ATAGO S/Mill, Model 8908), and dissolved oxygen (oxygen meter-Model 9071 JENWAY).

2.4 Laboratory measurements

Collected water samples were analyzed to determine chlorophyll and nutrients (nitrates, ammonia, phosphates and silicates) following the methods described in Parsons *et al*. (1984) and concentrations estimated; in micromoles per liter using the spectrophotometer; each at its specific wavelength. Laboratory investigations included grain size analysis, X-ray diffraction and laboratory measurements of spectral reflectance. Values (range of concentration) of total suspended matter, total dissolved solid and Organic carbon was taken from internal reports of the Ministry of Environment (MoE, 2010).

2.5 Earth observation data

Two satellite imageries were used covering the study are for 2006 and 2013 to monitor the coastal morpho-dynamics and the coastal changes. Images have been radiometrically and geometrically preprocessed and various enhancement methods (i.e. classification, accuracy assessment, contrast stretching, color composition, and principal component analyses) have been applied to define adequately the existent thematic layers using ERDAS IMAGINE Ver. 2013. The coastline of the study area included headlands, bays, two coastal lagoons and a wide (~1 km), gently sloping, intertidal zone. The shoreline is generally orientated in a NNW-SSE direction, with the primary geomorphic features identified along the coastline indicating that the net littoral drift is southerly directed (consistent with the predominant wave and wind direction). Image analyses results were validated by field observations and GPS data. Field ground trothing included one hundred and forty measurements of spectral reflectance

for various sediment exposures representing main sand types in the studied parts of Qatar.

Other maps (e.g. topographic map, bathymetry map, land use map, etc.) were also used to provide information about the current thematic layers at the study area. The Arc GIS Ver. 10.1were used for mapping the resulting layers.

2. 6 Bathymetric map

With the bathymetric survey and the measurements conducted with the Echo-sounder (PLASTIMO. ECHOTEST II), and Geographical Positioning system GPS (GPS Model 320, MAGELLAN, a set of bathymetric data was generated including the coordinates of each location (X, Y) and the bottom depth (Z). GPS readings and bathymetric measurements have been done along a path approximately parallel to the coastline. A final output results from bathymetric survey compiled with the available row data, which could be detected from bathymetric map of the study area conducted in a previous survey conducted in 1999, to construct the bathymetric map of the study area (Fig. 2).

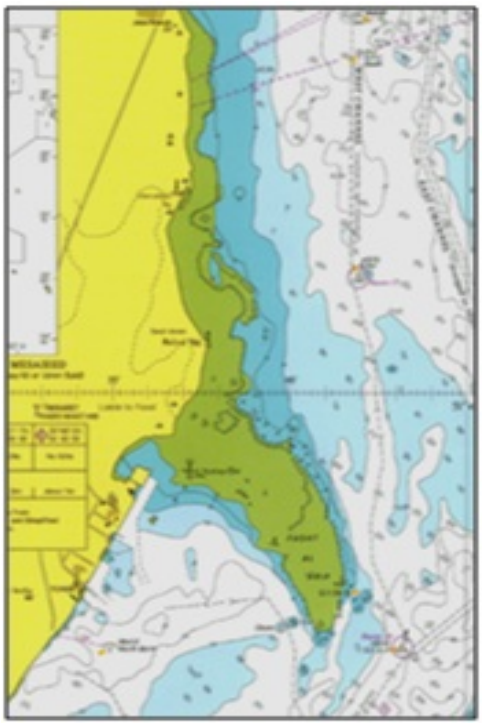

Fig. 2: A Bathymetric map of the coastal area of Um-Saeed, Qatar

3. RESULTS AND DISCUSSION

3.1 Water Quality characters

Temperature ranged from 37.9-40.3^{o}C and salinity varied from 48.4 to 50.5psi, with some values were above the Qatar standards for salinity are due to the shallow water depth and the high evaporation. The pH values within the study area ranged from 8.6 to 8.8 (Table 1).

Table 1: Concentration ranges of some water quality parameters measured as minimum and maximum values of water samples collected from the six sampling sites

Nutrient	Chlorophyll mg/L	Organic compounds µg/L	T. Suspended Matters (µg/L)	T. Suspended Solids (µg/L)	Transp. (m)
Concentration Range	0.6 - 8.3	0.3 - 6.9	2 - 7	2.2-3.5	4 - 6.5

Transparency data indicated a good status of the water and ranged from 4 m to > 6.5 m. Concentrations of the total suspended matter ranged between 2 and 7 mg/l. This is much complying with the Qatar Standards (MoE, 2010) for ambient marine waters (30 mg/l). The total suspended solids ranged between 2.2 and 3.5 mg/l and were well below the Qatar standard of 30 mg/l, while the total dissolved solids ranged between 45.3 - 47.4 mg/l. Organic carbon was below the detection limit and biodegradable matter measured was in the range of 0.3 - 6.9 mg O_2/l within the study area. There was a clear gradient of decreasing concentration from the coast and seawards during the outgoing tide, especially along the sampling sites. This indicates that the major source of the biodegradable material is the southern coast and the Umm al Houl mangrove area. Lagoons and mangrove sediments are known to naturally accumulate organic matter and certain other compounds such as sulphide due to the sheltered conditions and low energy physical environment. Organic matter is normally suspended from the sediment in the bottom sediments and discharged to the sea during outgoing tide. Oxygen condition was good mostly at all stations were in a range (3.9 - 9.8 mg/l.) coincided well within Qatar standard (>4 mg/l).

Nutrients levels (Table 2) along the study area were extremely high particularly with regards to phosphate and ammonia and to some extent nitrate. Concentrations of phosphate within the study area were in the range <7-41µg/l, mostly complies with Qatar marine ambient water quality standards (30µg/l for phosphate).

Table 2: Nutrient concentration ranges (as µg/L), standard errors (SD) and of water description comparing with the water quality standards. The percentage indicated the % of samples of which nutrient concentration exceed the standard level.

Nutrient	Concentration Range µg/L	SE	Standard limit*	% exceeding the limit	remarks
Phosphate (P-PO4)	7 - 41	±0.00 - ±0.4	30	13%	Oligotrophic water
Nitrite (N-NO2)	5 - 21	±0.3 - ±0.8	35	0%	Oligotrophic water
Nitrate(N- NO3)	10 - 70	±0.2 - ±0.7	100	0%	Oligotrophic water
Silicate(Si-SiO3)	330 - 1680	±0.01 - ±0.04	900	20%	Mostly oligotrophic water Some samples are eutrophic
Ammonia (N-NH4)	10 - 170		15	80%	Mesotrophic to eutrophic water

*source: Ministry of Environment, 2002: Qatar Water Quality standards

Based on that, bout 60% of the samples could be classified as typical of oligotrophic (nutrient poor) water, while most of the remaining samples could be classified as mesotrophic to eutrophic with high to very high phosphate concentrations.

Concentrations of ammonia nitrogen ranged between < 10 and 170µg/l. Only 20 % of the samples complied with the Qatar ambient water quality standard (15µg/l). Most of the samples had moderate or high concentrations and could be classified as being mesotrophic or eutrophic in terms of ammonia nitrogen concentration. There are strong indications that the source of elevated ammonia concentrations is the southern lagoon (located adjacent to the study site) and Umm Al Houl lagoon and mangrove area (COWI, 2011). There is a clear gradient of decreasing concentration of ammonium nitrogen from the coast and seawards during the outgoing tide, especially along the sampling transects in the vicinity of the southern lagoon. Ammonia is apparently released from the anaerobic sediments of the lagoons/mangrove area which are rich in organic matter and chemically reduced nutrients and discharged to the sea during

outgoing tide. The elevated phosphate levels are also expected to originate from releases from lagoon sediments (Richlen, *et al*., (2010).

Concentrations of other determined nutrients were almost with low concentrations and were below the Qatar marine ambient water quality standards (Table 1). For example; Nitrate concentration ranged from < 10 to 70 µg/l. This range led to describe water as very low to low in nitrates which corresponds to oligotrophic water. Similar finding was with nitrite which ranged from < 5 - 21 µg/l. Silicate concentrations ranged between 330 and 1680 µg/l. with almost 80% of samples complies with Qatar water quality standards (900 µg/l).

The present study determined nutrient levels during July 2011 in five sites at the southern part of the QENFB, just north of Fasht Al Arif and found that nutrients were extremely high particularly that for phosphate, ammonia and nitrate. No indications of any ecological effects of the permanent high nutrient levels (e.g. high chlorophyll or/and phytoplankton blooms).

Chlorophyll is a measure of the biomass of phytoplankton. The levels of chlorophyll, at the six sites at the southern part of the study area were very low (range 0.08 - 0.52) and well below the Qatar water quality standards (1 µg/l). These results do not infer persistently elevated nutrient levels as no observations during the fieldwork indicated effects from the permanently high nutrient levels within the coastal water. This was further confirmed by the previously estimated low levels (Aljamali, *pers. Comm*.) of Chlorophyll-a (0.48 - 0.93 µg/l) estimated at close sites. One explanation for such low chlorophyll levels regardless the high nutrient levels is that water of the study area is micronutrients limited; i.e. scarce in micronutrients such as iron which limit the growth of phytoplankton (Burkholder *et al*., 2007).

3.2 Topography, Landscape and Landuse

With the use of VNIR spectral data and previous studies and data (e.g. Scott, 2008a &b) different ecological types have been identified; e.g. sabkha-derived salt-rich, quartz sand, and beach-derived calcareous sand and aeolian dune quartz. The limited coastal landscape of the study area typically consists of coastal/lagoon habitats (e.g. mangroves, inter-tidal flats, salt marsh etc.). The existing land use surrounding the study sites are illustrated in Fig. 3.

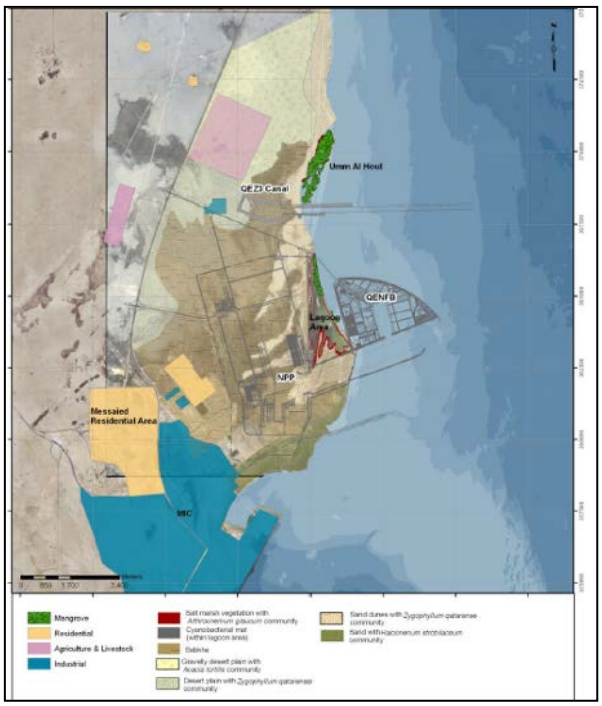

Fig. 3: Identified landscape and land use of study area and surroundings areas (COWI, 2011).

The following broad land use types are present within and surrounding the study area:

a) ***Vacant land***: At present these areas are not being used for any significant purpose;
b) ***Coastal areas***: Coastal areas include intertidal areas, low lying sand dunes, and lagoon areas. Some recreational activities such as driving, overnight camping, falconry etc. take place occasionally around the coastal lagoon area;
c) ***Industrial areas***: predominantly downstream oil and gas industries (such as petro- chemical complex, NGL etc), chemical production industries, and an aluminum smelter.
d) ***Residential areas***: A residential area exists nearby to study area.
e) ***Mangrove***: A large stand of dense and well established mangrove trees of the species *Avicennia marina* (Fig. 5A), occurs at Umm Al Houl, to the north of the NPP site.
f) ***Sabkha*** **:** Sabkha is devoid of vegetation (Fig. 5C), covers a large section of the NPP site. Sabkha is an Arabic name for a salt-flat ordinarily found nearby sand dunes. This is also the case for the sabkha at the NPP site, where several stretches of sand dunes representing previous coast lines intersect the Sabkhas are featureless, low-lying, flat and very saline areas of sand or silt formed just above the water-table where the sand is cemented together by evaporate salts from seasonal ponds. The sabkha has a crusty surface composed of a conglomerate of salt and gypsum (GEMS, 2008). Sabkha areas have high salt concentrations which render the habitat unsuitable for plant growth and they are distinguishable from other ecosystems in the total absence of higher plants except for the sabkha edges.

3. 3 Change Detection

Satellite images provided a solid basis for the assessment of the shoreline and estuary morphology over a long time span at a regional scale. Satellite images from 2006 to 2013 have been rectified and the coastline and major morphological features digitized (Fig. 4). In some instances, the shorelines could not be accurately discerned, due to the image quality and resolution. The results indicate little evidence of significant changes in the cross-shore coastline position, with most observed changes well within the accuracy of the applied methodology and image resolution. However, the formation of lagoons and the long-shore migration of accretion features such as barrier spit and near shore bars could be more readily identified and quantified. These interpretations, in conjunction with the observations from the walk over surveys, are detailed below.

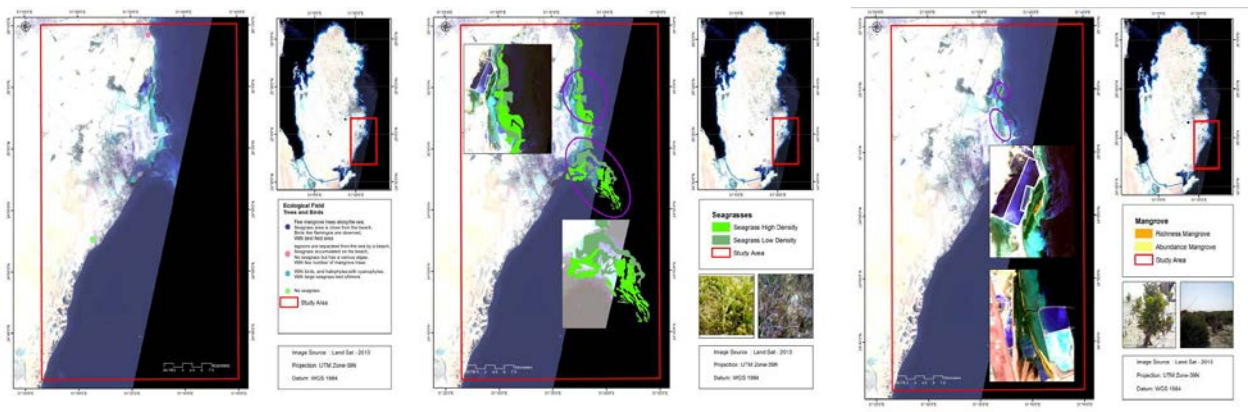

Fig. 4: Image analysis shows ecological features of the study area: birds and trees (left), sea grasses (middle) and mangroves (right)

a) **Mangroves**: As shown in Figs. 4 & 5A, amongst the above identified habitats, intertidal flats, along with the lagoon and mangrove areas were considered to be of highest ecological value. Other identified habitats are relatively common within Qatar, and are not considered to have high ecological value. The intertidal flats are important feeding areas for shore birds (Chalmers, 2008). The lagoon area supports extensive mangrove stands (*Avicennia marina*), is an important feeding and roosting area for shorebirds and is an important nursery area for juvenile fish (Steward, 2003). Mangrove areas are legally protected through an Emiri Decree in Qatar.

b) **Seagrass beds**: As shown in Figs. 4 & 5B, like other areas nearby and in Qatar, seagrass is an important nursery location for juvenile fish, prawns and a potential feeding ground for the endangered dugong. Dense seagrass beds are encountered within the QENFB study area. *Halodule uninervis* was the absolute dominating species observed, though some *Halophila stipulacea* was also present. *Halophila ovalis* was also found in the area, but only in very low densities. Offshore from the lagoon are extensive inter-tidal flats. The formation of longshore bars, similar to those observed farther north (discussed below), is hampered by the stabilizing effect of seagrass in near shore areas (Freon *et al*., 1993).

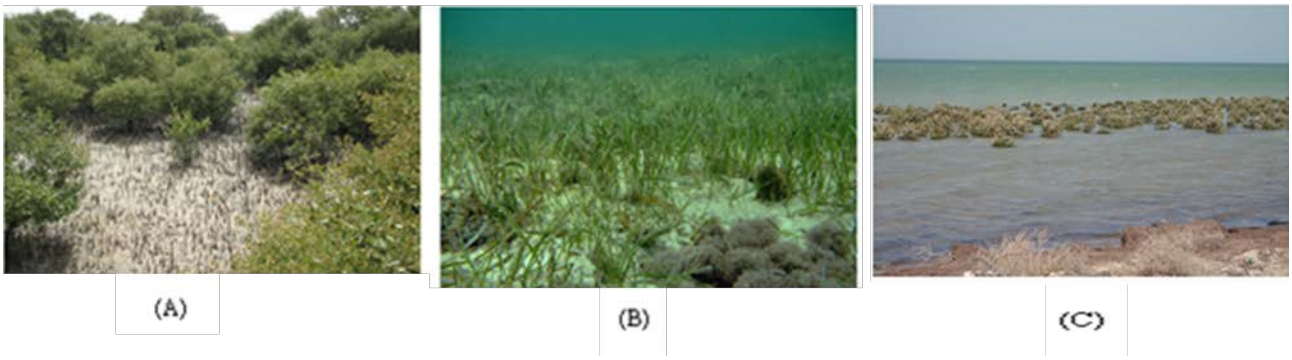

Fig. 5: Photos taken for the study area in March 2014 showing the various ecosystems ; mangroves (A), seagrass (B) and Sabkha (C)

Generally, the habitats identified within the study area do not exist in isolation. In particular seagrass beds, mangroves and coral reefs are known to be ecologically connected as interactions between these habitats or ecosystems takes place in the form of mutual and beneficial exchange of nutrients, organic matter, fish and crustaceans (Mazda *et al*., 1997).

These interactions between habitats can be divided into physical, chemical and biological interactions. For example, it has been recognized that mangroves and seagrass beds were important nursery areas for juvenile fishes. Fishes and crustaceans may during different life stages spend time in different habitats (Mazda *et al*., 1997). These organisms are therefore depend on the health and existence of these habitats to actually live through all life stages to be able to reproduce. A result of these interactions and the ecological connectivity among habitats is that impacts on one of the habitats results in an impact on the other (ATKINS, 2006).

With using the VNIR ground spectra along the study area suggested to be good with some limitation of the ground spectral reflectance study is the difficulty of covering large areas. The study also found that ground and laboratory spectral radiance are generally higher in reflectance than those of Landsat TM. This is due to several factors such as atmospheric conditions, the low

altitude or different scales (Ahmed *et al*., 2009). Whereas, for areas with huge size of sand dune, it is found that Landsat TM spectra has higher reflectance values than those field and laboratory measured (Ahmed, 2007). The study observed that there is a good correspondence or correlation of the wavelengths maximum sensitivity between the three spectral measurements i.e Lab, field and space-borne measurements.

4. CONCLUSION

Remote sensing and GIS analyses were used to determine the short term changes of an area along Qatar coast at Umm Saeed. Marine ecology and habitats were surveyed though image processing and field visits surveys (both transects and spot surveys) characterizing environment habitats exist Qatar coastal zone, and are not considered to have high ecological value. The lagoon area supports extensive mangrove stands (*Avicennia marina*) which is an important feeding and resting area for shorebirds and is an important nursery area for juvenile fish. Monitoring and analysis of the recent land cover/land use dynamics through the integration of remote sensing and GIS could provide base information for documenting changes along the shoreline, and urban surrounding the study area, digital elevation model to the area of study. Standard image enhancements, classifications, and change detection techniques will apply to determine changes between the used satellite images. The integration between results of satellite images and field observations and laboratory analyses have been proven as a powerful and cost effective approach for proposing the monitoring the impact of coastal development of the study area.

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