TEMPORAL CHANGES IN MANGROVE COVER BETWEEN 1972 AND 2001 ALONG THE SOUTH COAST OF THE ARABIAN GULF

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Abstract - The oil rich gulf countries are building new cities both onshore and on reclaimed offshore islands changing the region's mangrove cover. Temporal Landsat MSS images of 1972-1973 and Landsat ETM images of 1999-2001 were used to calculate percentage change in mangrove cover at ten sites using geometrically registered and radiometrically corrected historical Landsat images. Region masks were employed to isolate the unwanted area from the images. Normalized Vegetation Difference Index (NDVI) was used to detect mangroves using near-infrared and red bands which were computed from the satellite images. The change in mangrove cover is uneven, six sites showed varying degrees of reduction (2 – 100 %). However, at four sites area covered by mangroves actually increased despite urban development. Their destruction or growth is considered to be a good indicator of infrastructure development policies and practices in this region.

Key Words: Arabian Gulf, Remote Sensing, Mangroves, Infrastructure Development, Image Registration, Normalized Difference Vegetation Index (NDVI)

1. INTRODUCTION

Arabian Gulf countries like Bahrain, Qatar, Saudi Arabia and United Arab Emirates are developing vary large coastal infrastructure projects. This adversely impacts the coastal ecosystem and makes this coast vulnerable to both environmental and unforeseen geological disasters (Kumar, 2009). Due to reckless construction activities this region is facing progressive resource degradation. In a critical analysis of policy issues on environment and sustainable development in the oil rich gulf countries Spiess (2008) states, "*Policies that implicitly subsidize or support a wasteful and environmentally destructive use of resources are still pervasive (Elhadj, 2006), while noteworthy environmental improvements still face formidable political and institutional constraints to the adaptation of the necessary far reaching and multisectoral approach (El-Sayed, 2004; Brown et al. 2006)*". A footnote on page 245 in Spiess (2008) ranks the Gulf countries at the bottom in the 2005 Environmental Sustainability Index (ESI). This "*index benchmarks the ability of 146 nations to protect their environment over the next several decades by comparing five fundamental components of sustainability: Environmental Systems; Environmental Stresses; Human Vulnerability to Environmental Stresses; Societal Capacity to Respond to Environmental Changes; and Global Stewardship. While there was insufficient data for Qatar and Bahrain, Kuwait ranked 138, Saudi Arabia 136 and the UAE 110 (Yale center for Environmental Law and Policy/ Center for International Earth Science Information Network, 2005)*". Khan and Al-Homaid (2003) demonstrated massive losses of mangrove forests in Tarut Bay on the east coast of Saudi Arabia between 1973 and 1997. The present study further investigates changes in mangrove cover between 1972 and 2000/2001.

Mangroves occur as isolated patches of varying length and width along the western coast of the Arabian Gulf. They occur south of latitude 26^0N and are predominantly a monospecific community of *Avicenia marina* and rare *Rhizophora mucronata*. During the past few decades there has been a growing awareness of the importance of mangroves in protecting the coastline, preventing erosion and providing habitat for a wide variety of biota (Blasco, *et al.*, 1996; Ewel *et al.*, 1998). Mangrove forests protect coastal regions from erosion due to constant impact of tides, currents and storms. Recognizing the importance of mangrove forests many governments have adopted mangrove restoration and conservation programs (Ong, 1995). Strict legislation to protect mangroves is in place in many countries.
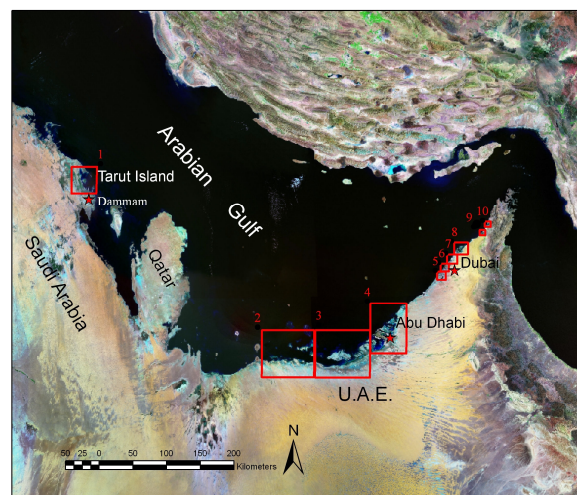

Figure 1: Location of study sites

3. MATERIALS AND METHODS

Satellite images and geographic information systems provide useful tools to detect and map the temporal variation in the coverage of mangroves (Riaza, *et al.*, 1998; Long and Skewes, 1996). Ten sites were selected to study temporal changes in geographic distribution of mangroves along the Arabian Gulf Coast (Figure 1). For this purpose Historical Landsat Multispectral Scanner (MSS) and Landsat Enhanced Thematic Mapper (ETM) data were used (Table 1). An important step, in the comparison of multispectral remotely sensed images, is the geometric registration (Richards, 1986). In this study image-to-image ground control points were used to geometrically register all of the Landsat ETM and MSS images to a UTM grid. In all cases 20 to 25 image control points were used and the geometric registration accuracy of better than one pixel (picture element) was obtained. The Landsat TM has a 30 meter spatial resolution whereas MSS data has 79 meter spatial resolution. In order to make the pixel size of both the data sets compatible the Landsat MSS data was resampled to 30 meter resolution. All the images were radiometrically corrected using dark-pixel subtraction (Crane 1971), also known as histogram minimum method (Chavez *et al.*, 1977). The most widely used technique

for detecting vegetation with remotely sensed images is the Normalized Difference Vegetation Index (NDVI). Studies using NDVI and other vegetation indices are varied and include those involved with local, regional, and global mapping of vegetation (Richardson and Evert, 1992). The Normalized Difference Vegetation Index (NDVI) is defined as: NDVI = (RIR-R) / (RIR+R); Where, RIR = Reflective Infrared band (MSS bands 6 and 7; TM band 4) and R = Red band (MSS band 5; TM band 3)

Location	Sensor	Acquisition date	Sensor	Acquisition date
1	MSS	98-01-1973	ETM	5/11/1999
2	MSS	30-11-1972	ETM	30-06-2001
3	MSS	30-11-1972	ETM	30-06-2001
4	MSS	22-01-1973	ETM	23-08-2000
5	MSS	22-01-1973	ETM	23-08-2000
6	MSS	22-01-1973	ETM	23-08-2000
7	MSS	22-01-1973	ETM	23-08-2000
8	MSS	22-01-1973	ETM	23-08-2000
9	MSS	22-01-1973	ETM	23-08-2000
10	MSS	22-01-1973	ETM	23-08-2000

Table 1. Temporal satellite image data used in the study

Since the mangroves grow along the coastline, the coastline boundary was used to mask the land areas from the Landsat images. This operation excluded the coastal vegetation comprising of palm trees, vegetable farms, halophytes and grassy recreational areas from the Landsat images. The vegetation associated with the mangroves such as halophytes and exposed algal mats could not be excluded. The masked Landsat images were used to create NDVI images. NDVI for Landsat MSS images was calculated using MSS bands 5(0.6-0.7 µm) and 7 (0.8-1.1 µm). NDVI for Landsat ETM images was calculated using bands 3(0.63-0.69 µm) and 4(0.76-0.90 µm).

Location	Acquisition Date	Area (Hectares)	Acquisition Date	Area (Hectares)	Temporal change	% Change
1	08-01-1973	622	5/11/1999	390	-232	-37
2	30-11-1972	2639	30-06-2001	2590	-49	-2
3	30-11-1972	4082	30-06-2001	3488	-540	-13
4	22-01-1973	4066	23-08-2000	4822	756	19
5	22-01-1973	648	23-08-2000	30	-618	-95
6	22-01-1973	84	23-08-2000	0	-84	-100
7	22-01-1973	212	23-08-2000	115	-97	-46
8	22-01-1973	1063	23-08-2000	1131	68	6
9	22-01-1973	100	23-08-2000	317	217	217
10	22-01-1973	182	23-08-2000	294	112	62

Table 2. Past 25-30 years temporal changes in the geographical area of mangroves for sites 1 through 10 in both numerical values in hectares and percentages.

4.   RESULTS AND DISCUSSION

In Landsat images the red band records the absorption of red wavelength by chlorophyll thus lower values indicate higher chlorophyll. Reflected Infrared (RIR) band records the reflection of IR wavelengths by the cell structures of leaves thus higher values of IR indicate more vigorous growth (Richardson and Evert, 1992). Values of NDVI images ranged from -1.0 to 1.0. Higher values indicate higher concentrations of vegetation, which in this study are mangrove stands. Lower values indicate non-vegetated regions like water bodies and bare soil. Thresholds of NDVI greater than 0.1, were applied to the NDVI images to classify the mangrove stands in the images. The threshold criteria, was determined from the false color composites of two visible and one near infrared bands. In this color composite vegetation appears in hues of red and can be easily differentiated from bare land, mud flats and water bodies along the coastal regions. The familiarity with the area and known locations of mangroves were also helpful in determining the threshold boundary.

5.   CONCLUSIONS

Temporal Landsat data provided a useful tool to study changes in mangrove cover at ten different sites along the west coast of the Arabian Gulf. The Normalized Vegetation Difference Index (NDVI) proved a useful tool to detect mangroves using near-infrared and red bands. Mangrove cover decreased at six sites but at four sites despite extensive construction activities, mangrove cover increased because mangroves were left undisturbed during development. The present study shows degradation of the coastal environments during the past forty years and suggests that there is need for careful planning to preserve the remaining mangrove forests which are vital to long term sustenance of not only for the regional flora and fauna but also for the quality of human life in the future.

6.   ACKNOWLEDGEMENTS

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