

Conference Paper

Techniques, Tools and Methods to Determine Coastal Morphologic Evolution & Management for ‘Coasts in Crisis’ in ‘The State of Kuwait’

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ABSTRACT

The coastal and marine resources had sustained the local inhabitants for thousands of years. As with years the concern about coastal morphological change in Kuwait has led to the “Coasts in Crises”. Adoption of a number of preventative measures can assist in maintaining the status quo and sustain the natural coastal morphological environment. The change in coastal landscape morphology can be documented by various techniques. The paper cites the integration of techniques, tools and methods for such studies which is being proposed and applied to determine and manage coasts in crisis due to morphological changes in Kuwait. The historic data assessment, analysis of remotely sensed data, geographical information system, vector analysis, fractal analysis, real time/aerial video monitoring, modeling, statistical analysis and data management supports in detecting, monitoring and studying the overall trends in coastal development and its impact. The recent development of new remote sensing sensors and software applications has transformed some of these techniques into powerful methods and tools for studying the degree of changes in coastal morphology. This paper depicts about the techniques that would aid in developing management strategies to combat the coastal deterioration of Kuwait.

Key words: Remote sensing, fractals, coastline, change detection, vector analysis, RIAM, SWOT, AHP.

1. Introduction

The coastal and marine resources have sustained the local inhabitants for thousands of years. With years the concern about coastal morphological change and modification in Kuwait has increased and this led to the “Coasts in Crises”. Like any other place the fragile coastal zone is suffering from human activities and natural processes which play an important role in shaping the morphology of coast. Kuwait’s shoreline (mainland and nine islands) which is about 500 km is under pressure of booming unmanaged over-development, recent increase in attraction towards the development in all sectors- urbanization, industrialization, tourism and entertainment. As Kuwait’s economy transforms with oil based industries, the country also faces a number of environmental challenges, especially in the regions of coastal ecosystems, causing significant changes in the morphology, directly or induced. The changed morphology has intensified pressure on coastal natural landform resources and vice-versa. There is an unanswered question on sustainability and carrying capacity of the coastal morphology. Adoption of a number of preventative measures can assist in maintaining the status quo and sustain the natural coastal morphological environment.

The proposed techniques, tools and methods cited in the succeeding section would help in determining and managing coasts in crisis due to landscape morphological changes and evolution in Kuwait. These techniques would help to conduct an intensive and extensive

research which would answer the unanswered questions erupted from unwisely exploitation of coast and improper coastal protection measures. Apart from the human activities, natural processes play an important role in shaping the morphology of the coast. These changes are significant, slow and occur during a long period of time. If these changes are studied on space-time basis with proper techniques, and the outcomes presented in a proper way the '*facts, problems and causes*' will be more clear for decision makers, of coastal management, and to take proper measures for coastal protection. The outcome from this techniques, tools and methods will also throw light on the severity of the problems, and the need to implement protective measures, to achieve sustainable development for the future generation.

2. Objectives

The objective of this paper is to introduce the different techniques, tools and methods that are being applied by the author for extensive research with a goal to develop an integrated analysis of shoreline changes, which will help guide coastal-degradation, deterioration and risk mitigation along the Kuwait shorelines. It would help in developing coastal management strategies to protect the sensitive and vulnerable coast and control encroachment of coast. The specific objectives which can be attained by following the techniques, tools and methods mentioned in this paper. They are as follows:

- Historical shoreline change and evolutionary trend
- Identifying and mapping the eroding/accreting/ stable coastal areas.
- Identifying and inventorying coastal land use land cover (LULC) change.
- Assess coastal sand encroachment.
- Identify coastal ecological / habitat change.
- Identifying, quantifying and evaluating - carrying capacity for the coastal morphology
- Assess anthropogenic development in coastal zone (to understand the manner in which coastal zone are influenced by human interaction).
- Identify causes and zoning of coastal morphological and environmental settings.
- Identify coastal sensitive areas.

3. Study Area

The application of the techniques, tools and methods proposed for The State of Kuwait which is located in the Middle East, and occupies an area approximately 17,800 km², extending between 28° 30' N and 30° 05' N of latitudes and 46° 3' E and 48° 35' E of longitudes^[1]. Kuwait (Fig. 1) is surrounded by Arabian Gulf (east), Iraq (north and west) and Saudi Arabia (south and west). The main shoreline of the coast of Kuwait is about 325 kilometers long and the the total shoreline including all the nine islands is about 500 kilometers in length^[2].

3.1 Literature Review

Coastlines and beaches in particular, are dynamic fast-changing systems due to human and natural interference. Literature review says there is a tremendous change in the coast geomorphology of Kuwait (1960s-2009). Massive construction and development on the costal areas of Kuwait during the last decade with improper Environmental Impact Assessment strategy has consequently resulted in major drawbacks in sustainability.

Al-Gadban *et al.* [4] and Neelamani and Baby [5] say there is a significant discharge of sediments from river Shatt Al-Arab flowing from Iraq and it is estimated that:

- Shatt Al-Arab pours about 20 billion cubic meter of nutrient rich water into the Gulf each year [6];
- about 0.1 cm / year to 1.0 cm/year of sediment accumulates in the lower part of this river [7]; and
- net annual sediment discharge entering the gulf is about 0.93 million tons [8].

The above studies have not documented anywhere the scenarios of the changing coastline due to the discharge with accurate mapping.

Different types of shoreline of Kuwait are discussed by Al Sarawi *et al.* [9]. Geomorphology and surface deposit of the coastal areas of Kuwait is described and mapped in El-Baz and Al-Sarawi [10], Al-Sarawi [11] and Al-Sarawi *et al.* [12]. White and El-Asmar [13] have stated that coastline change due to erosion and deposition is a major concern for coastal zone management.

Al-Yamani [14] have carried out a study to offer necessary recommendations for the strategic plan for the sustainable utilization of Kuwait's marine environment. They have identified new research programs for better marine management in the near future in Kuwait. Utilization of remote sensing and GIS of the marine environment is recommended as one of the essential research program.

Extensive literature review from different source have not indicated the application of all the techniques, tools and methods (Fig. 2) adopted in an integrated approach to assess the coastal status, identification of problems, and solution with developed coastal management strategies.

3.2 Proposed Techniques, Tools And Methods

The following techniques, tools and methods are proposed to identify the coastal area that is encroached the most and assess the future status of coast if such trend in coastal development occurs:

Data Collection, Questionnaires, Interviews and Analysis

Application of RIAM (Rapid Impact Assessment Matrix)

- Coastal demographic analysis
- SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis
- Application of AHP (Analytic Hierarchy Process)
2. Coastal development analysis: ground and aerial Survey.
3. Video (Helicopter) analysis and monitoring
4. Application of Remote Sensing and GIS,
5. Fractals analysis
6. Vector based shoreline analysis
7. Modeling: GIS, shoreline, coastal geomorphology
8. Zoning of coast and Segmentation of coastline
9. Statistical analysis
10. Ranking and rating methods

SWOT analysis originated in the 1960s [15] and is commonly used in the development of marketing plans and decision support [16,17, 18] is rarely used for any coastal morphological sustainability with few studies known [19,20]. In recent times the SWOT analysis has reached

wider fields of application, and it is commonly used to identify features and to solve conflicts of the territory.

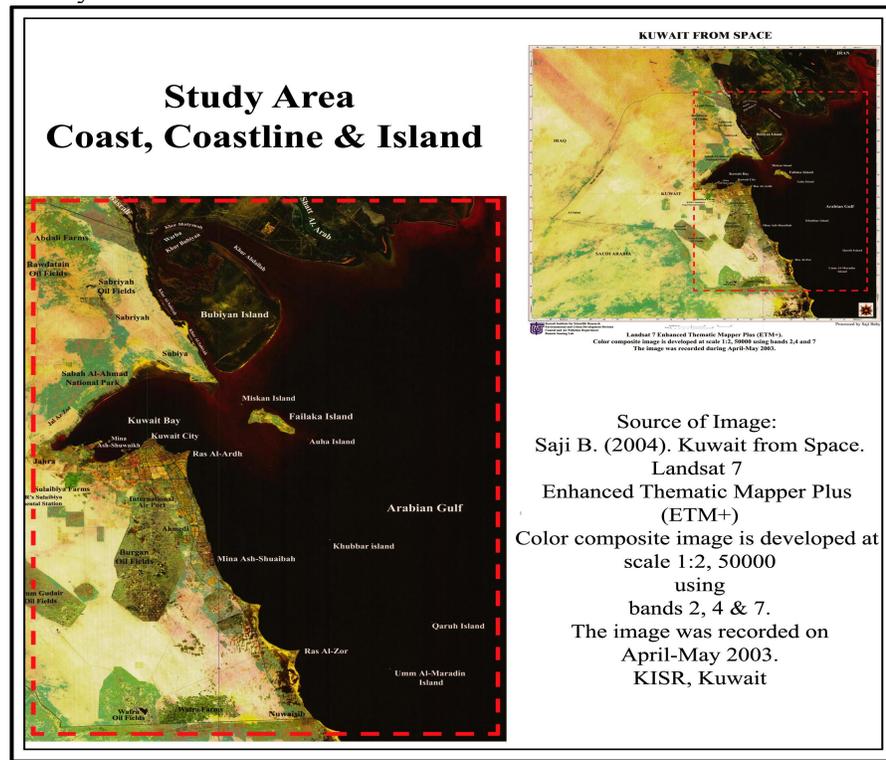


Fig. 1: Landsat image showing the Kuwait, Study Area and Coastal Coverage (Source: Baby, 2004).

SWOT integrated with AHP is rarely used for coastal morphological landscape (CML) to derive CMS to enhance sustainability of coastal environment. The decision analysis tool indicated in this paper, the Analytic Hierarchy Process (AHP), is a mathematical method for analyzing complex decision problems with multiple criteria. It was originally developed by Saaty^[21,22]. AHP can deal with qualitative attributes as well as quantitative ones. It has been found to be a useful decision-analysis technique and it has been applied in cases dealing with strategic planning. It can be combined with the Delphi technique when integrating interactive expert knowledge in decision analysis^[23].

The concept of the Rapid Impact Assessment Matrix (RIAM) to assess the human cause and development to rapidly changing coastal morphological landscape is a promising assessment tool to study the status of Kuwait coast and its vulnerability. RIAM is developed by DHI Water, Environment & Health to assist in the preparation of an environmental impact assessment (EIA). RIAM allows full transparency of the decisions made in an assessment study^[24]. The RIAM system is based on simple concepts and has been tested in a number of different conditions. It is a very powerful tool in connection with EIA's and was tested on various project studies^[25] where a multi-disciplinary team approach is used^[26]. It takes in data from different environmental, social and economic sectors associated with coastal zone to be analyzed against common important criteria within a common matrix, thus providing a rapid, clear assessment of the major impacts on the coasts. It depicts the scoring within a matrix that has been designed to allow subjective judgments to be quantitatively recorded for assessment of coastal morphological landscape changes of Kuwait in relation to various

developmental projects along the coast. This paper indicates the utility of RIAM to assess the coastal morphological landscape changes (CMLC) due to human interference and coastal developmental projects. Although the natural causes and processes like waves, tides, currents and storms; climatic and water level change and coastal vegetation have major role and significant in modifying the coastal morphology is considered slow and occur during a long period of time.

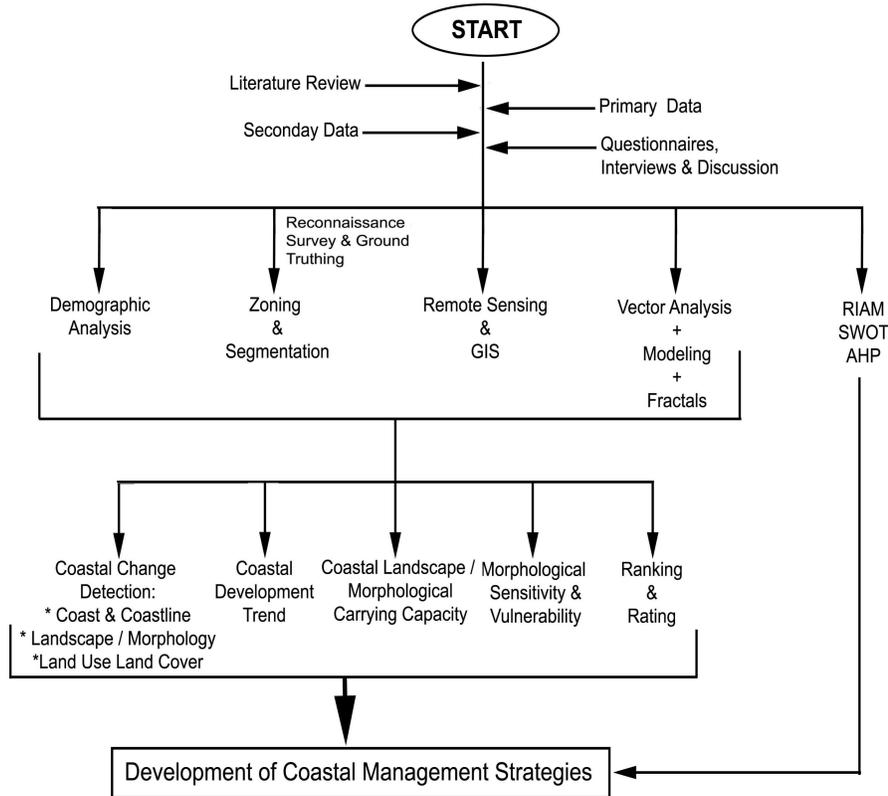


Fig. 2: Flow chart to study, depict coastal geomorphological changes and development of coastal management strategies

Coastal Landscape, Geomorphologic and coastline change may be understood through a comparative analysis of the spatial and temporal changes occurred in the coast of Kuwait through a long period of time through extracting information from remotely sensed data and integration of GIS. Remotely sensed data from space satellites such as LANDSAT, IRS, RADARSAT, IKONOS QuickBird, etc. can provide information and support to attain the objectives of the study. Neelamani and Baby^[27] had proposed a study of shoreline evolution for the coast of Kuwait to Kuwait Institute for Scientific Research. Neelamani and Baby^[27] had mentioned the complete application of remote sensing and GIS for the study.

Gleick^[28] have applied Fractal theory for coastline studies to derive information efficiently. This theory is not inherently based on graphic dumps, but rather on comparing the "roughness" of shapes. Through mathematical processes, the fractal dimension of shapes for coastline can be obtained. The fractal dimension is a measure of complexity of a statistically self-similar line that exhibits similar patterns at different scales. One of the first quantitative measures of coastline complexity was Mandelbrot's^[29] fractal-dimension analysis of the west coast of Britain. Fractal and Vector analysis will support detailed analysis of the changes occurred or occurring. The techniques will use mainly primary data, and information

extracted from remote sensing and overlay of images. Besides, secondary data of coast like population, land use, infrastructure, etc and analysis of historic maps to record the extent of changes occurred in the coastal change would be a vital part for the application of methodology. The historic shoreline data is to be segmented for analysis. The criteria used to segment the data should be developed within the analysis methods to provide consistent, accurate, and timely temporal shoreline change analysis results.

Zoning and segmentation is to break the coast and coastline into zone and segments depending on features, characteristics and morphology:

- This will help for study based on small units of coastal morphology, information extraction and analysis, final ranking and rating.
- In the later phase it will be integrated for the full stretch of Kuwait coast.

The methodology utilizes geomorphologic, applicable oceanographic and ecological characteristics as well as observed rates of changes. It has to take into consideration the socio-economic factors that have caused the change in coastal geomorphology. Long-term shoreline trend and short-term shoreline trend has to be a part of the study. Development of setback guidelines, rating and ranking for coastline is a priority for formulating and constructing coastal management strategies. The flow diagram (Fig. 2) shows the stepwise methods and complete flow for achieving the objectives cited in the paper:

3.3 Hypotheses And Expected Outcome

3.3.1 Hypotheses

The above techniques, tools and methods are proposed for the study on the basis of the following hypotheses:

- Developments, migration, increase in coastal land use is the main reason that is causing coastal change or alteration of geomorphology or coastline apart from the natural process.
- Unmanaged, non-scientific and non-technical use of coastal land will keep increasing in the next decade if it's not handled properly with adequate scientific research based information. This puts in more pressure on Kuwait's coastal area in general and marine resources in particular.
- With such trend of development it is expected in the near future there will not be any coastal area left untouched in Kuwait and no natural shore as an asset for the country.
- The mentioned techniques can highlight the problem, cause and solution in a more convincing manner in terms of more authentic scientific information.

3.3.2 Expected Outcomes

The techniques explained above are expected to explore the trend in coastline changes, vulnerable coast, sensitive coastline, coast at risk and come up with future prediction. It is expected to draw the interrelationship between human interference (development, construction, migration, etc.) and coastal geomorphologic and coastline changes, in particular with different aspects of geomorphologic changes of the coast of Kuwait. Additionally:

- *It is expected to prove that there is a vital link between the coastal land use and coastal change, alteration of geomorphology and change in coastline due to massive*

human activities occurring in a short period of time in the coastal region apart from normal natural process and agencies which occur over a large period of time.

- Provide proof on unmanaged use of coastal area for developmental purposes.
- Provide information about the most sensitive, vulnerable and deteriorated /deteriorating coast of Kuwait.
- Depict scenarios of coastal encroachment
- Recommend and suggest on the basis of the research findings for sustainable development of coasts in Kuwait.
- Development of coastal management strategies for Kuwait's geographical and socio-economical conditions
- This will serve a concrete support for national guidelines for coastal development.

4. Conclusion

To make a systematic classification of coastal zone, to perform objective based study and to find optimal solution, the integrated use of recent techniques and tools such as Geographic Information Systems (GIS), Image Processing Systems (IPS), Remote Sensing (RS) with Fractals Analysis and Data Management, Data Analysis and Modeling, seems to be a promising exercise and would address in depicting coastal geomorphologic evolution & Management for 'Coasts in Crisis' in The State of Kuwait". Such integrated studies considering all the techniques and tools have never been conducted for studying coastal morphological changes and the vulnerability of the coast for Kuwait. Kuwait does not have coastal management strategies developed for sustaining future based studies conducted from the techniques, tools and methods mentioned in this paper.

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