Original Research

Major Impacts from Anthropogenic Activities on Landscape Carrying Capacity of Kuwaiti Coast

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Received: 27 April 2013
Accepted: 29 June 2013

Abstract

The metamorphosis from land cover to land use for urban, industrial, and other socio-economic developments in Kuwait has remarkably evolved the "coastal morphological landscape (CML)" such that the impact has decreased carrying capacity. Information on carrying capacity is vital for decision makers to take immediate steps in preserving the coast. Mitigation and control measures are essentially required to lower human interference and to increase carrying capacity. It is noted that among 12 existing anthropogenic activities commanding the impact on carrying capacity of CML, only 3 were positive, significant, irreversible, direct and indirect, and long term; whereas others were negative, significant, irreversible, direct and indirect, and long term. It was found that all 12 categories of ongoing and future projects would have negative impacts ranging from high (severe) to very high (chronic) levels on carrying capacity of CML, evaluated as significant, irreversible, direct and indirect and long term. The study lists preventive measures that can reduce negative impact to achieve considerable levels of sustainability.

Keywords: indicators, irreversible, diagraph, damage control measures, no-go-project, residual impacts

Introduction

Coastal environment is an interface between land and marine water. Economic development and competing demands have caused over-exploitation, modification of coastal land cover (LC) to land use (LU), and reclaimed natural landscape. Physical changes over a specific area, which are caused by the anthropogenic effects of economic and social factors, initially lead to deformation of the nature of that area [1], thus affecting the coastal morphological landscape (CML) and carrying capacity. Human pressure threatens to destroy coastal habitats and, consequently, their carrying capacity that allows for many essential functions [2]. The scale of human impacts on the natural environment, however, is now considerably larger than at any point of history [3].

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Our study deals with the impact of CML on mainland shoreline of the coast of Kuwait, which is about 325 km, or about 500 km if all nine islands (Failaka, Bubiyan, Miskan, Warba, Auha, Umm Al-Maradim, Umm Al-Namil, Kubbar, and Qaruh) are included. The mainland coast is categorized into undisturbed and disturbed by anthropogenic activities. Both possess different variables showing the ability to carry the human needs and withstand ecological process termed as carrying capacity. They inter-act and intra-act, resulting in various impacts on natural resources.

The concept of carrying capacity relates 'resource use to environmental support' [4] and is often used to understand interactions among them. Another approach to carrying capacity is related to the "fitness" of development within an environmental system and this approach is based on environmental loading [5, 6], termed the 'intensity of development.' It is understood as stated by Zacarias et al. [7]

despite the severe limitations associated with the carrying capacity concept; it remains a useful concept for environmental management, especially in providing insights about the interaction of human activities with the environment. Landscape impact assessment is normally a required element of an environmental impact assessment (EIA) and it describes the likely impact of changes to the landscape from the type of activity being evaluated [8], and the landscape-change-ecology vulnerability.

The main objectives of our study are:

- determine and identify the main human factors affecting natural carrying capacity of the CML
- to perform rapid impact evaluation on coastal landscape morphology based on previous information and from expert opinion – for carrying capacity due to disturbance in CML indicators
- suggest and list mitigation and control measures.

This study is limited to the above objectives and is not extended to quantitative assessment of carrying capacity of coastal landscape. Quantitative assessment requires broad studies connecting various aspects of the environment. However, the subjective concept of carrying capacity is considered to understand human factors changing the natural coastal landscape.

Materials and Methodology

Reconnaissance Survey and Ground Truthing

As part of baseline studies, for the coastal information to be depicted and demonstrated on a map (Figs. 1-3), reconnaissance survey and ground truthing were performed to verify the facts collected (from secondary and collateral information, visual data interpretation from ground and aerial photographs, sketches, satellite images, and aerial video survey) as a part of the investigation to identify the topographic and landscape features.

Mapping of Coastal Developments

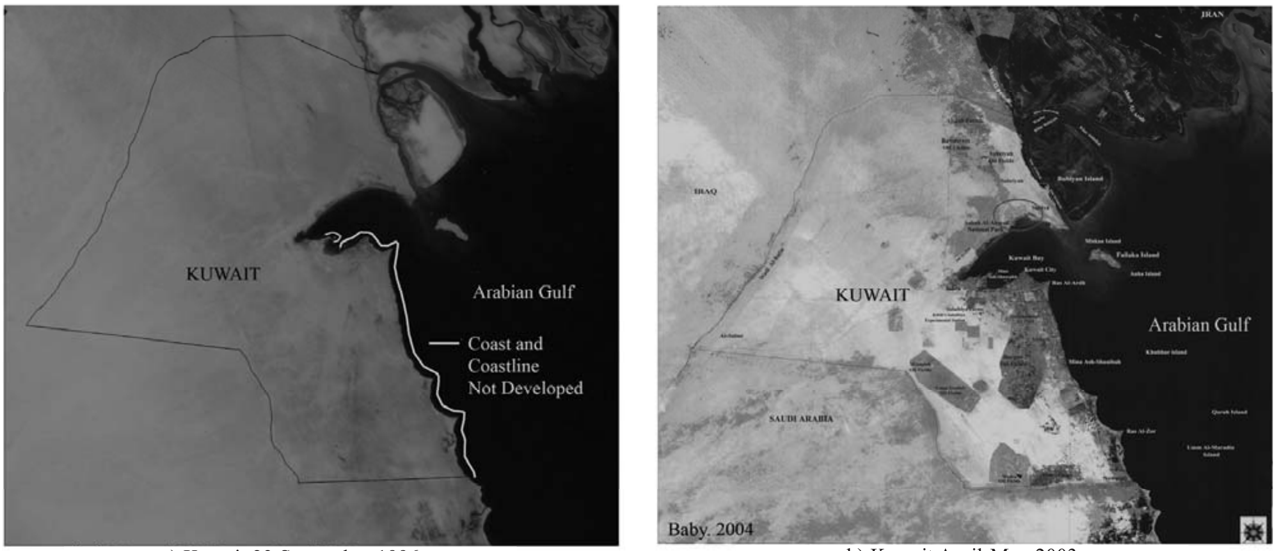
The first step was to map the coastal areas for the following:

a. major socio-economic development
b. built-up area at 6 governorates
c. ongoing and future development
d. existing and proposed conservation areas
e. important land use and conservation areas along the coast obtained from Kuwait Master Plan

Coastal areas have become a prime natural resource and CML in Kuwait that has changed considerably through alteration of topography or reclamation interpretable from satellite images from Landsat of 1966 and 2003 (Fig. 1 taken from manuscript of authors Saji Baby and Mohammad A. Al-Sarawi – 'Visual Interpretation of Pictorial Data and Reconnaissance Survey to Extract Information on Kuwait's Coastal Landscape' accepted for publishing in 'Indian Journal of Geo-Marine Science' from the National Institute of Science Communication and Information Resources) and 2012-13 (from GoogleEarth online). GEOMATICA image processing software was used to process the raw data obtained from the Landsat satellite. These images supported in assessing the coastal morphological landscape changes occurred within a period of the last 40 to 50 years and was interpreted through visual interpretation.

Figs. 2 and 3 from Baby [9], illustrated below, provide coastal information to appraise the impacts on carrying capacity. The map below shows coastal land-use areas mapped for various major activities (Fig. 2a) and built-up areas (Fig. 2b) for 6 governorates. Land use along the coastal edge includes oil refineries, power stations, a desalination plant, petrochemical industries, coastal roads, transportation, commercial, residential areas, recreational, hospitality industries, beach houses, waterfront projects, coastal protective structures harbors, and ports.

Appraisal of the impacts (direct and indirect) of project on landscape – carrying capacity of CML is well thought-



a) Kuwait 23 September 1996 b) Kuwait April-May 2003

Fig. 1. Landsat Images of 1966 and 2003.

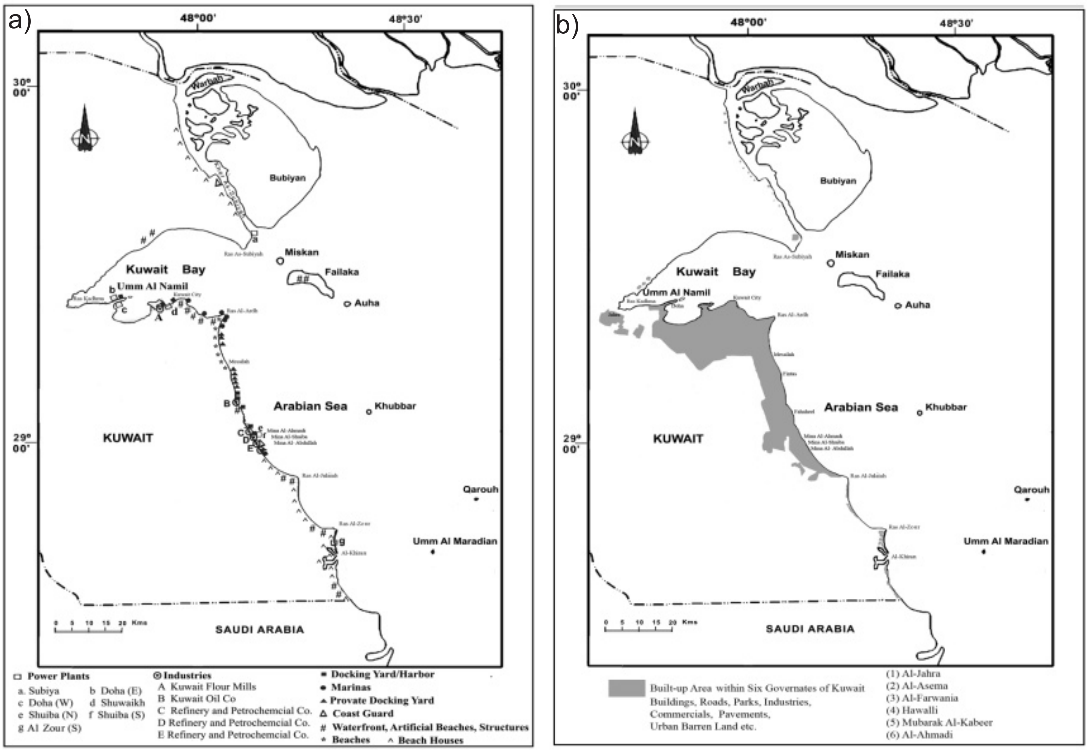


Fig. 2. Existing major coastal edge developments and built-up area.
(a) Major socio-economic developments (b) Built-up area at 6 governorates

out in view of existing major coastal edge developments and built-up areas (Fig. 2), and ongoing and future major projects (Fig. 3a) such as railways (interacting with the coast), bridges (crossing Kuwait Bay and to Bubiyan), new Bubiyan mega port (Mubarak Al-Kabir Port), coastal townships (at Jahra and Al-Khiran), developments in Failaka Island, and occupying coastal areas for tourism. A review of impacts is conditional on Kuwait Master Plan (Fig. 3c). The residual impacts were derived by taking into account the list of 14 mitigation and control measures (Table 2) including the steps undertaken by Kuwait by declaring coastal protected areas such as Sabah Al-Ahmed National Park, bird migratory/habitat location, proposed marine conservation areas, and national recreation areas (Fig. 3b).

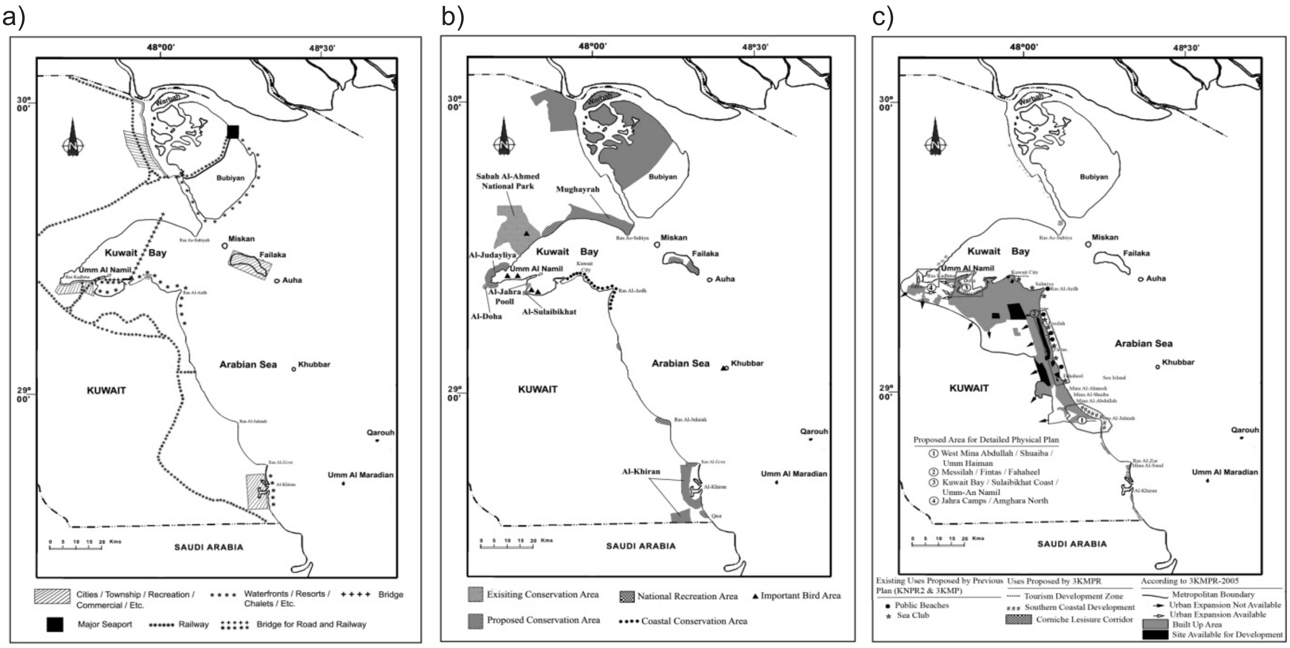


Fig. 3. Major activities interacting with coastal edge.
(a) Ongoing and future development (b) Existing and proposed conservation area (c) Kuwait Master Plan.

Mapping of Occupied, Not-occupied and Sensitive Coastal Areas

The map (Fig. 4, From manuscript of authors Saji Baby and Mohammad A. Al-Sarawi – 'Visual Interpretation of Pictorial Data and Reconnaissance Survey to Extract Information on Kuwait's Coastal Landscape' accepted for publishing in 'Indian Journal of Geo-Marine Science' from the National Institute of Science Communication and Information Resources) was prepared from information on coastal morphology [9-13] and visual interpretation of visual data. In the map (Fig. 4), the coastal area are classified into 6 broad categories (Fig. 4) for occupied, not-occupied, and sensitive.

1. Built-up(a): which consists of land use such as urban and commercial buildings; industries, refineries, power stations, desalination, and petro-chemical; ports and harbors; waterfront projects and beaches; coastal protective structures; government establishments and buildings; utility and supply line infrastructures; hospitality industries; and entertainment.
2. Built-up(b): which consists of land use such as beach houses; resorts and motels; small jetties; utilities; and illegal structures.
3. Less interfered: the shore where for a long distance no major man-made structures were noticed

Fig. 4. Coastal Map for Occupied (LU) and Not Occupied Area (LC).

Table 1. Impact types and grading.

• A (+ve) sign placed in a box indicates a "beneficial"/"positive" impact, while a (-ve) sign indicates an "adverse"/ "negative" impact
• The likely intensity of the impact is graded on a simple scale of 1 to 4, namely; 1 = slight; 2 = moderate; 3 = appreciable; 4 = high/severe and 5 = very high/chronic
• Significance level: S = significant and InS = insignificant
• R = reversible and IR = irreversible
• ST = short term and LT = long term
• D = direct and ID = indirect
• M&C = land use mobilization and construction
• O&M = land use operation and maintenance
• The absence of any notation in a box signifies that no impact is envisaged.

4. Built-up(a) and Sensitive: cover those coasts that are sensitive and have land use of Built-up(a).
5. Built-up(b) and Sensitive: covers those coasts that are sensitive and have land use of Built-up(b).
6. Less Interfered and Sensitive: covers those coasts that are not interfered with directly by human built-up or reclamation activities.

Impact Evaluation for Carrying Capacity due to Disturbance in CML Indicators

In this section impact evaluation for carrying capacity due to change in natural CML indicators has been performed based on:

a) the understanding of the existing and future environmental settings for the coastal areas (Figs. 1 and 2).
b) coastal areas for occupied and not-occupied coastal areas and classified for sensitivity based on natural morphology (Fig. 4).
c) impact type and grading (Table 1)
d) six CML indicators (Table 2) listed from expert opinion through questionnaire.
e) 12 major anthropogenic coastal activities, existing and future (Table 2) listed from expert opinion through questionnaire.

The likely impacts of the anthropogenic activities (LU), i.e. change from LC to LU, have been assessed with context to major coastal morphological landscape feature vulnerably levels. Within the defined study circle, the likely impacts of the various anthropogenic LU that would change the natural CML features have been assessed in terms of "Beneficial" or "Adverse" effects, their likely intensity, duration, and extent. Based on the assessment a summarized table (Table 2) on the finding and mitigation method is given for convenience of understanding and for easy reference. Table 2, presented herewith, which highlights the likely impacts to be received by the various CML elements, from the various human LU activities considered the intensity of the impact and its duration. The notations used in preparing Table 2 are essentially as follows:

Table 2. Impact evaluation for carrying capacity due to disturbances in CML indicators.

S. N.	Change in natural CML Indicators	Due to major direct anthropogenic (LU) activities near coastal areas (existing and future)	Existing coastal land use/future coastal expansion and land use	Presumed Phases	Impact (Type and Magnitude) on natural CML thereby evaluating the impact on Carrying Capacity	Mitigation and control solutions	Residual Impact on Carrying Capacity of natural CML	Reasons
	01	02	03	04	05	06	07	08
01	1. Change in near onshore topography, geomorphology, landscape, relief features, and vegetation. 2. Change in near offshore coastal marine ecology, marine geomorphology, sea bed relief. 3. Change in coastline shape. 4. Depletion and extinction of coastal land cover (LC). 5. Depletion and extinction of vital non renewable natural coastal morphological landscape. 6. Availability of land for development	Commercial and Residential Township	Existing	O & M	-ve; 3; S; IR; D; & ID; LT	1. Transparent EIA studies, EMP plan developed and implementation. 2. Proper scientific and engineering studies. 3. Proper classification of coastal land cover (LC) for land use (LU). 4. Developing away from coast with proper setback distance. 5. Maintain the natural CML beauty and aesthetics. 6. Reconsidering Kuwait Master Plan and proposed future development. 7. Proper coastal land management system. 8. Integrated coastal zone management. 9. Damage control measures and management 10. No man and protected zone declared. 11. Coastal conservation area and national parks. 12. Public awareness program. 13. Strict statutory, rules, regulations and implementation. 14. Building of coastal management strategies	-ve; 2; S; IR; D & ID; LT	1. Attraction, migration and population settlement along coastal areas. 2. Unscientific method and not proper engineering practice in coastal land use including all the constructions. 3. Coastline change due to erosion, accretion and reclamation. 4. Illegal construction, alteration of coastal land. 5. Coastal land degradation. 6. Encroachment and deficit of coastal land. 7. Costal disposal of solid waste including construction and demolition waste. 8. Coastal disposal of liquid waste. 9. Disturbances to ecosystem Change or extinction of natural habitat. 10. Different types of pollution (direct and indirect impacts), oil spill, contamination and vulnerability.
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for +ve; 5; S; IR; D & ID; LT	
				O & M	-ve; 4; SIR; D & ID; LT			
02		Refineries, Desalination Plants, Power Stations,	Existing	O & M	-ve; 4; S; IR; D & ID; LT		-ve; 3; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for +ve; 4; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D & ID; ST			
03		Harbors, Port, and Marina	Existing	O & M	-ve; 3; S; IR; D & ID; LT		-ve 2; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		+ve; 2; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D & ID; LT		+ve; 1; S; IR; D & ID; LT	
04		Industries and factories	Existing	O & M	-ve; 3; S; IR; D & ID; LT		-ve; 1; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for +ve; 4; S; IR; D & ID; LT	
				O & M	-ve; 3; S; R; D & ID; LT			
05		Dredging, dumping, and reclamation.	Existing	O & M	-ve; 4; S; IR; D & ID; LT		-ve; 3; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		+ve; 2; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D & ID; LT		+ve; 1; S; IR; D & ID; LT	
06		Beach sand mining	**Existing**	**O & M**	**-ve; 5; S; IR; D & ID; LT**		-ve; 2; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for +ve; 4; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D & ID; LT			
07		Beach Houses	**Existing**	**O & M**	**-ve; 5; S; IR; D & ID; LT**		-ve; 2; SIR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for +ve; 4; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D & ID; LT			
08		Waterfront projects, and recreation	Existing	O & M	+ve; 3; S; R; D & ID; LT		+ve 4; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		+ve; 3; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D & ID; LT		+ve; 1; S; IR; D & ID; LT	
09		Artificial Beaches, Recreation and Real Estates (Lagoons)	Existing	O & M	+ve; 3; S; R; D & ID; LT		+ve; 4; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for +ve; 4; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D & ID; LT			
10		Road and Transportation	Existing	O & M	-ve; 1; S; IR; D & ID; LT		+ve 3; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for	
				O & M	-ve; 4; S; IR; D & ID; LT		+ve; 4; S; IR; D & ID; LT	
11		Bridges, Railways, and Associated Roads	Ongoing and Future	M &C	-ve; 5; S; IR; D & ID; LT		Provision for +ve; 4; S; IR; D & ID; LT	
				O & M	-ve; 4; S; IR; D; & ID; LT			
12		Coastal protective and defensive structures and nourishment	Existing	O & M	+ve; 2; S; R; D & ID; ST		+ve; 3; S; IR; D & ID; LT	
			Ongoing and Future	M &C	-ve; 4; S; IR; D & ID; LT		+ve; 3; S; IR; D & ID; LT	
				O & M	-ve; 4; S; R; D & ID; LT		+ve; 2; S; IR; D & ID; LT	

Table 1 reflects two assumed conditions:

- it refers to the conditions in the study area that is within the impact circle (unless an asterisk mark is placed in the box to signify that the impacts originates from outside or originates within, but extends beyond the study area
- it refers to the likely impacts that could, after adoption of all proposed control measures as residual.

No attempts have been made to determine the sum of the entire plus and minus numbers pertaining to each CML element, since such an exercise is not useful in most cases as the impacts are not additive nor do beneficial ones cancel out the adverse ones in the complex CML environmental situation. The study evaluates the impact on geomorphologic aspects and carrying capacity during land use mobilization and construction (M&C), and operation and maintenance (O&M) phase separately for activities along the coastal areas. The expected coastal morphological landscape impacts (CMLI) and impact evaluation on carrying capacity are described in Table 2.

The human impacts on carrying capacity inherent in the CML were evaluated with opinion gathered from experts. Information from various coastal projects (as stated in the following paragraphs) on environmental impact assessment (EIA) submitted to Kuwait Environmental Public Authority (K-EPA) and a published paper related to the coast in the State of Kuwait were referred. The information helped in deciding the type, magnitude, and residual impacts on carrying capacity of CML. In all the projects cited in the subsequent paragraph, the impacts were evaluated with analytical and measurement methods; modeling; opinion gathered from experts (Scientists, Professors, and Coastal Engineers); and response obtained from questionnaire (list of questions to frame columns 1, 2, 5, 6, 7, and 8) distributed to stakeholders and environmental non-governmental organizations (NGOs). However, irrespective of that again in this study, experts were invited for panel discussion to get consensus on impact types and grading. The 'Questionnaire' supported the scope and impact identification [14, 15], whereas 'Expert's opinion' was applied in helping to fulfill the insufficiency and uncertainty of information [16]. The concept of indicator group [17] was adopted to assess the impacts.

The EIA projects (referred) undertaken that are interacting with coastal areas of Kuwait Bay (mainly Shuwaikh, Doha, Subiya and Sabriyah), Failaka, and the Arabian Gulf such as:

1. Kuwait rapid transit and railroad systems [18]
2. Bridge from Shuwaikh to Doha know as Doha Link [19]

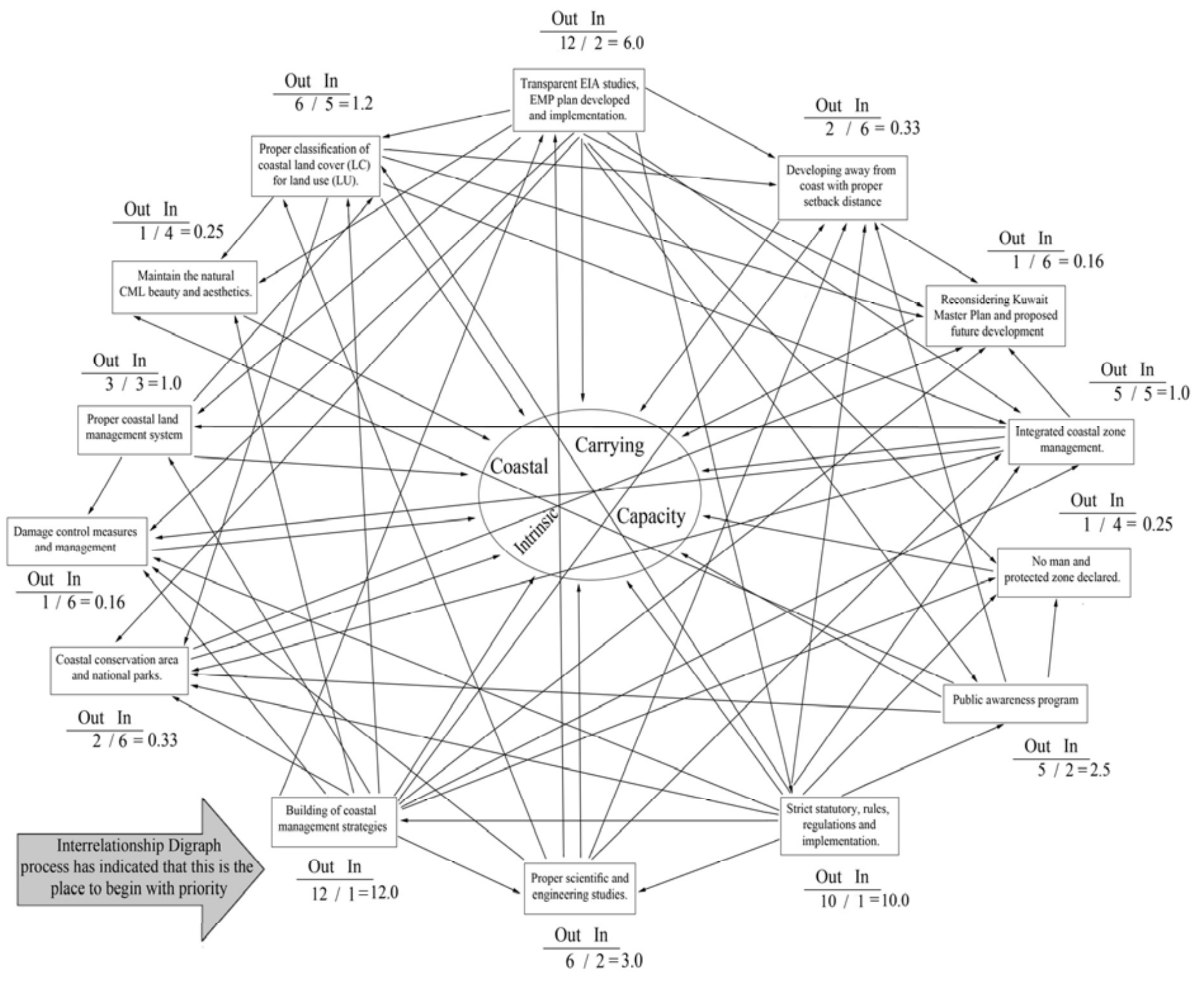


Fig. 5. Interrelationship Diagraph for mitigation and control measures.

3. Bridge across Kuwaiti Bay to Subiya 'Sheikh Jaber Al Ahmed Al Sabah Causeway' [20]
4. Dredging activities in existing Failaka Port [21]
5. Project interacting with eastern coast of Arabian Gulf such as marine facilities upgrading project in Ahmadi [22]
6. Mubark-Al-Hassawi private marina to be built up at Messila Beach [23].

Other referred works and literature are 'sand quarry mining' from coastal areas northwest of Kuwait Bay [24] and 'Rapid Impact Assessment Matrix (RIAM)' applied by Baby and El-Sammak [25] to study permanence, reversibility, and cumulative potential impact of construction of new marina and to enhance the beaching area for shore-zone development. The study considered the 'environmental management plan' developed by Baby [26] and guidelines of EPA [27] to mitigate the negative impacts.

Development of Interrelation Digraph

Fourteen imperative solutions (mitigation and control measures) (Table 2) are recommended to reduce the impact from 12 major activities on carrying capacity of CML. After identifying the 14 solutions that would help combat the deterioration of CML and improving landscape capacity, it was difficult to know where to begin the process for successful implementation of mitigation and control measures and experts had different opinions on more than one occasion. In order to compromise the differences and to determine particular steps to start, an interrelationship digraph tool was used to aid the experts (panel discussion).

After identifying the solutions that would improve the impact on carrying capacity of CML and protect CML, assembled experts helped to construct an "interrelationship digraph" (Fig. 5) in a systematic manner. The procedure specified by Benbow and Kubiak [28] was used for constructing the digraph. The procedure began with comparison of each potential solution – with every other potential solution. For each comparison it was asked, "Is there a relationship between these two solutions?" If it was determined that there is a relationship between the two, a straight line was drawn between them. Next, it was asked, "Which of these two solutions would 'drive' the other?" For it, an arrow was drawn to the line, pointing AWAY from the solution that would be the "driver," TOWARD the solution that it 'drives'. The steps were repeated for comparing each potential solution with every other potential solution-determining whether or not a relationship existed, and if there was, which solution would 'drive' the other solution. A good way to proceed was to arrange the concerns in an approximate circular pattern. The concerns are placed in the 12 o'clock pattern and 12 is made the first concern. It is then compared with the concern in the next concern in the position. Thus, it is moved clockwise and selects another concern to compare with the first concern. This process is repeated until all possible combinations of concerns have been compared by the team.

The resulting digraph (Fig. 5) reflects the collective judgment of the expert team. After all the relationships have been examined, the number of arrows going both out of and into each potential solution is counted. This information is recorded in the form of a fraction near each potential solution. Generally, the potential solution with the most arrows out is the place to begin. This action will have the largest positive impact, and will go farthest in ensuring the success of mitigation and control in the plan. However, in order to balance the counter-effect of the other factors (incoming arrows), ratio was calculated between outgoing arrows versus incoming arrows. An item with the highest number of output arrows is the driver or the key step, but the efficiency depended upon the highest ratio. The input arrow signifies that the item is controlled by other factors from which the arrow originates.

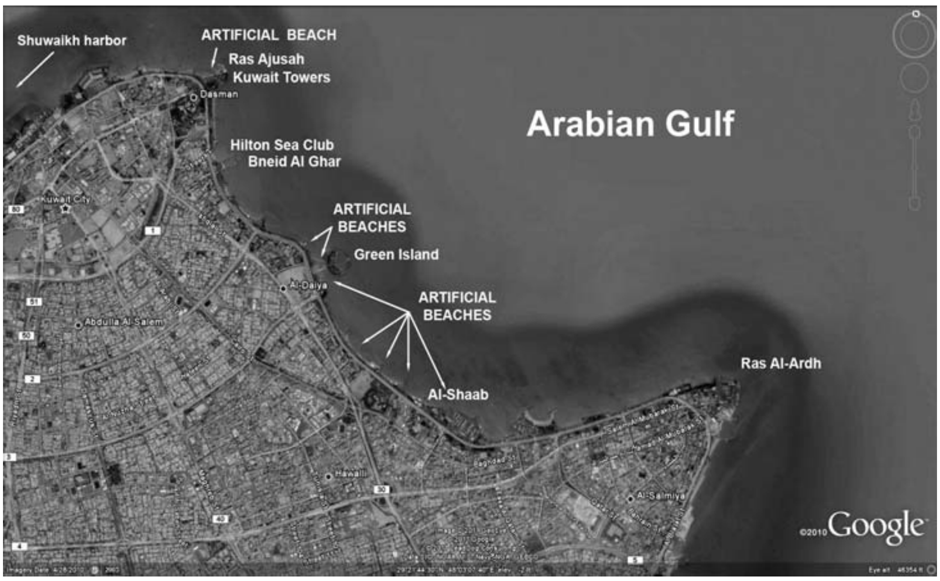


Fig. 6. Waterfront Projects (Image courtesy: Google Earth, 2010).

Results and Discussion

The study shows significant change in coastal morphology, thereby decreasing the carrying capacity. From impact evaluation on CML indicators from various anthropogenic activities along the shore it is noted that among the12 existing activities commanding the impact on carrying capacity only three showed positive, significant, irreversible, direct and indirect, and long-term on CML, whereas others were evaluated to be negative, significant, irreversible, direct and indirect, and long term. The positive ones can be explained as stated below:

The positive effect was seen because the three activities (referred in Table 2) have helped in mitigating the negative impacts (direct and indirect) to a greater extent caused due to coastal urbanization and industrialization along these areas. Once, most of these coastal areas were uninhabited before the 1960s (Fig. 1a) and was undisturbed by humans. For over 30 years starting from the mid-1970s and what was observed from a 2003 image (Fig. 1b), was rapid development and changes to the present paradise. The coastal development occurred unscientifically and unplanned.

The Waterfront Projects from Kuwait Water Tower to Ras-al Ard (Fig. 6) in a stretch of 20 km was attained through various coastal defensive management programs, techniques, and coastal structures. A well-managed 12 km-long nourished beach along the northern part of the southern section was developed from 1984-86. Evaluation of the stability of artificial beaches especially along the waterfront projects also suggests that the artificial beaches have rapidly adjusted to an equilibrium platform and profile. Wherever required, the beach nourishment program has helped replace and build up the net losses of eroded sand. The study considered the review of coastal process measurement (waves, wind, longshore currents) and beach profile measurements in order to monitor the morphological changes, and the grain size distribution along each profile [29]. Sediment budget and beach profiling monitoring program revealed the stability and sustainability of the projects, adding confidence to the coastal developer and coastal management. The changes in observed beach profiles were acceptable and did not show significant sediment erosion with time. The grain size distribution studies have shown that the artificial beaches along the 'Waterfront Projects' are stable and is a value added coast restoration program. The stability of artificial beaches in Kuwait is fortified through coastal protective and defensive structures and nourishment.

Water quality and biological sampling and analysis study represented normal composition in the coastal ecosystem [30] with some exceptional cases causing uncontrolled sewage outlet. The studies suggest that concentrations of pollutants were not affected by waterfront project construction or related activities.

Even though artificial beaches are constructed from the sand source from the desert areas that would change the composition of the native sands of the shore, it proved to be an important step in preserving the morpho-ecological components of the coast. Not only does the 'Waterfront Project' and beach nourishment stabilize the foreshore and backshore areas but also promote aesthetic buildup in this shore environment, an increase in marine habitat and growth. Through these wise programs, the socio-economy of Kuwait was elevated. This was a positive approach for all inhabitants, visitors, and tourists. This is the place where you will find most people of Kuwait in the late afternoons.

Among the negative ones two are showing very high or chronic impact on carrying capacity. The first is sand mining along the east coast of Kuwait Bay (Fig. 7) for road construction, in which blue line cutting transects a, b, c, d, and e from the coastline, indicates the extend of tidal flats that covers the coastal area where the activities of sand mining take place. The second is beach houses (Figs. 2a and 3), which have disturbed the coast morphology through illegal actions such as illegal dumping of waste,

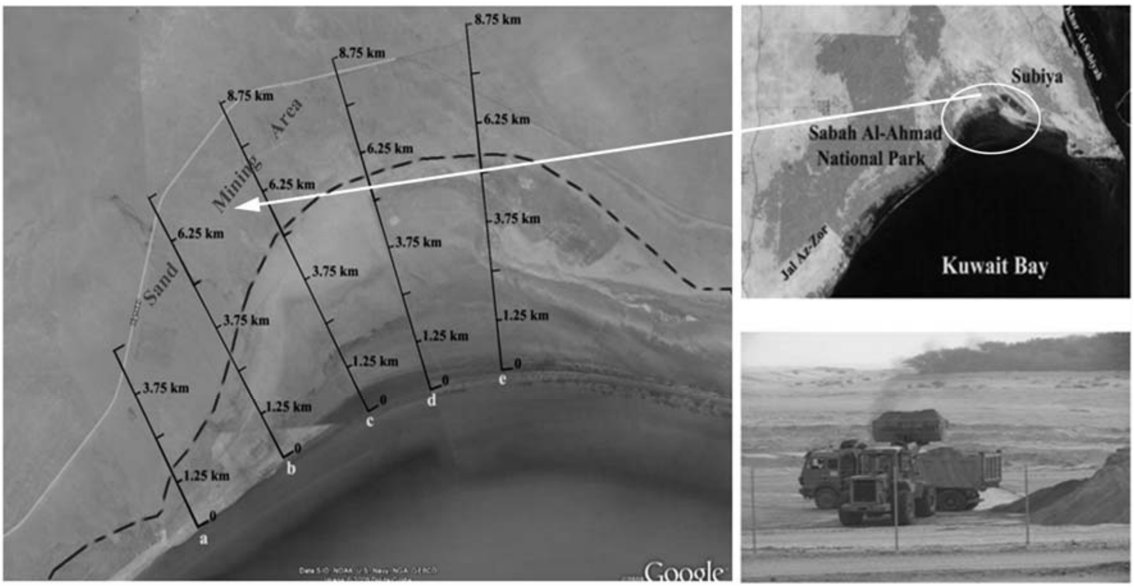


Fig. 7. Sand mining areas along Kuwait Bay (Image courtesy: Google Earth, 2009).

Fig. 8. Morphological landscape changes at Al-Khiran (Courtesy: Google Earth, 2011).

construction, coastal off-track vehicle driving along the sandy shores, prompting and promoting real estate, influencing policies, etc.

The construction along the coast has created tremendous problems, especially along the middle and southern coast in terms of pollution and change in coastal topography. In the middle section along Kuwait Bay, most of the constructions occurred within the intertidal flat and has caused a decrease in longshore currents, which have increased the amount of siltation within these areas. The thickness of soft mud has increased by 30-35%, reaching an average thickness of 5-7m in some locations. The major problems affecting the southern coast is mainly from the private summer beach houses, and residential areas where people have expanded their properties into the upper tidal flat beyond the high tide waterline. The other is from the projects, such as real estates and artificial lagoons (Fig. 8), at Al-Khiran that have caused topographic impacts that are not limited to the project area but the impacts would sprawl, changing the topography of the adjoining area too with passage of time and thus decreasing the carrying capacity.

Al-Sarawi et al. [31] studied major impacts of private beach houses on beach stability and listed more than 486 illegal activities that occur within 45km of shoreline. These private activities included boat ramps, groin, jetties, and shadow sites, all of which have been built within the tidal flat and have caused increased sediment accumulation on the southern sides of these structures, leaving the northern sides exposed to more wave action resulting in beach erosion and great losses to the properties.

All 12 categories of ongoing and future projects (Table 2) would have negative impacts ranging from high (severe) to very high (chronic) levels. The impacts on carrying capacity on CML are evaluated as significant, irreversible, direct and indirect, and long-term in nature. Particularly the roads, bridges, railways and port (Fig. 3a) interfering with the coastal morphology of Kuwait Bay, Subiya, and Sabiya and Bubiyan Island (Fig. 9).

The existing, activities and projects have permanently changed the CML. The natural morphological terrain and beaches are stolen. However, the carrying capacity can be improved and enhanced with better environmental impact assessment (EIA), i.e. transparent and authentic. An EIA can be characterized as a preventive environmental policy, management tool [32], and should be considered as a decision-maker tool [33]. EIA should not be limited to the studies but should extend to the implementation or execution of a project-specific environmental management plan (EMP) constructed during the EIA process. For ongoing and future projects, EIA studies should be undertaken with various alternatives and options considered with 'no-go project.' Having doors open for a 'no-go-project option' would pro-

Fig. 9. Morphological landscape changes from bridges connecting Sabiya and Bubiyan Coast (Courtesy: Google Earth, 2011).

tect and preserve the vital and sensitive natural CML that is on the verge of extinction. Apart from the above, all the other mitigation and control measures mentioned in Table 2 is the important driving force toward the preservation of CMLs. These preventive and protective measures would answer and provide solutions to all the reasons and causes (Table 2) that deteriorate CML with due consideration of the significance of the impacts. The proper preventive measures undertaken and the negative impact can be reduced to considerable residual levels.

The outcome showed that the highest number of outgoing arrows was from 'Building of coastal management strategies' with 12, followed by 'Strict statutory, rules, regulations and implementation' with 10. The ratios between outgoing versus ingoing arrows also had same values, i.e. 12 for former and 10 for later. The Interrelationship Diagraph constructed for mitigation and control measures clearly indicated that 'Building of coastal management strategies' with a ratio of 12 is the place to begin. This action will have the largest positive impact and will go farthest in ensuring the success of the mitigation and control measures, to protect the intrinsic morphological landscape carrying capacity from metamorphosis of land cover to land use at the coastal interface. This is followed by 'Strict statutory, rules, regulations, and implementation' with ration of 10. It is interesting to note that the solution 'Transparent EIA studies, EMP plan developed and implementation' provides scientific control over the 'Strict statutory, rules, regulations and implementation' solution.

Conclusions

1. It is noted that among the 12 existing activities commanding the impact on carrying capacity only three showed positive, significant, irreversible, direct and indirect, and long-term on CML whereas others were evaluated to be negative, significant, irreversible, direct and indirect, and long-term.
2. All 12 categories of ongoing and future projects would have negative impacts ranging from high (severe) to very high (chronic) levels. The impacts on carrying capacity on CML are evaluated as significant, irreversible, direct and indirect, and long-term in nature. Particularly the roads, bridges, railways, port and industries interfering with the coastal morphology of Kuwait Bay, Subiya, and Sabiya and Bubiyan Island.
3. 'Waterfront Projects' from Kuwait Water Tower to Ras-al Ard proved to be successful in enhancing the coast interfered with by human activities, but it cannot help in attaining the lost natural morphology and associated ecosystem.
4. Evaluation of the stability of artificial beaches suggests that the artificial beaches have rapidly adjusted to an equilibrium platform and profile.
5. Construction along the coast has created tremendous morphological landscape deterioration, especially along the middle and southern coasts.
6. Projects such as real estate and artificial lagoons at Al-Khiran that have caused topographic impacts is not limited to the project area but the impacts would sprawl to the adjoining areas.

The following recommendations given below would help in protecting the natural CML and the capability of the carrying capacity:

1. For ongoing and future projects, EIA studies should be undertaken with various alternatives and options consideration with "no-go project."
2. Considering the current scenario of coastal areas of Kuwait, it is highly recommended to stop further coastal land use for development apart from exceptional cases.
3. The coastal area of the northern half of Kuwait starting from Sulaibikhat Bay until the Iraq border including the islands of Bubiyan and Warba should be left untouched and protected.
4. Illegal coastal land used should be considered a violation and defended with legal actions. Encroachment and urban sprawl toward coasts should be brought to a halt.
5. The study suggests that developed areas also should not go for further saturation and the development should be controlled in various fronts.
6. The interrelationship diagraph constructed for mitigation and control measures clearly indicated that building of coastal management strategies is the place to begin. It also pointed toward an interesting solution: transparent EIA studies, EMP plan development and implementation provides scientific control over the solution, and strict statutory, rules, regulations and implementation.

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