# Quantifying Urban Growth in Dubai Emirate: A Geoinformatics Approach

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**Summary:**

With the rapid pace of urbanisation in coastal-desert areas, like Dubai, the fundamental changes in land cover can have significant impacts on the fragile ecosystems within this environment. Thus, it is essential to quantify historic land cover changes, evaluate the impacts of such changes and use this to define sustainable strategies for future development. The present project uses remote sensing and GIS techniques to investigate the magnitude of urban growth and pattern of development in Dubai Emirate from 1972-2011. We have revealed phenomenal rates of urban growth. In addition to this growth, a substantial increase in the terrestrial area of the emirate was revealed through construction of offshore islands.

**Keywords**: Urban Growth, Landsat, Coast, Desert, Dubai, Environmental Assessment.

## 1- Introduction:

Urbanisation is a major consumer of natural resources such as land, water and energy, and results in large amounts of pollution and waste. A number of researchers have assessed the consumption rate of natural resources and associated environmental impacts resulting from the large industrial cities in the world (Yuan, 2008; Gillies *et al.*, 2003).

Over the last few decades Dubai Emirate has witnessed a great economic revival resulting in massive urbanisation that turned the desert into residential, commercial, sports and tourism projects. In addition, the offshore was developed with artificial islands, such as Palm Jumairah, Palm Deira and the World Islands. These huge constructions have raised many debates amongst environmental researchers and activists. They argue that artificial islands threaten the marine ecosystems due to increased pollution and the absence of polices to protect the environment has increased the risk (Aspinall, 2004; Chen & Heligman, 1994; Salahuddin, 2005).

Therefore, spatio-temporal monitoring of urban growth must be established in order to get a better insight on the environmental impacts of urbanisation. Fortunately, remote sensing and GIS technologies offer a cost effective approach which is potentially more efficient than conventional techniques such as surveying and manual mapping and can provide an accurate means of quantifying and monitoring urban growth. However, previous researchers studying urban growth in arid environments using remotely-sensed data have faced considerable challenges in discriminating urban areas from bare soil and desert areas using multispectral imagery (Yin *et al.*, 2005; Wu *et al.*, 2003).
In this research, we evaluated that use of remote sensing and GIS for quantifying urban growth in Dubai Emirate between 1972 and 2011. The purpose of this spatial-temporal analysis was to shed light on urban growth patterns and the direction of this growth in order to assist policy makers, urban planners and environmental scientists.

## 2- Study area:

Dubai is the second largest Emirate after Abu Dhabi in terms of population and area, and is one of seven emirates forming the United Arab Emirates (Abu Dhabi, Dubai, Sharjah, Ajman, Ras Al Khaimah, Fujairah and Umm al-Quwain). It lies on the latitude 25° 26' 97" North and longitude 55° 30' 95" East, extending from the Arabian Gulf to the North, Abu Dhabi Emirate to the South West, Sharjah to the North East and Oman to South East (figure 1). The total area of the emirate is 3885 km2 excluding Hatta which is an exclave city that has no boundary with Dubai Emirate (2008 Dubai municipality boundary; Dubai DOF, 2009). Dubai Creek runs from the Arabian Gulf from the North to the South which divides the city into Deira to the East and Bur Dubai to the West.

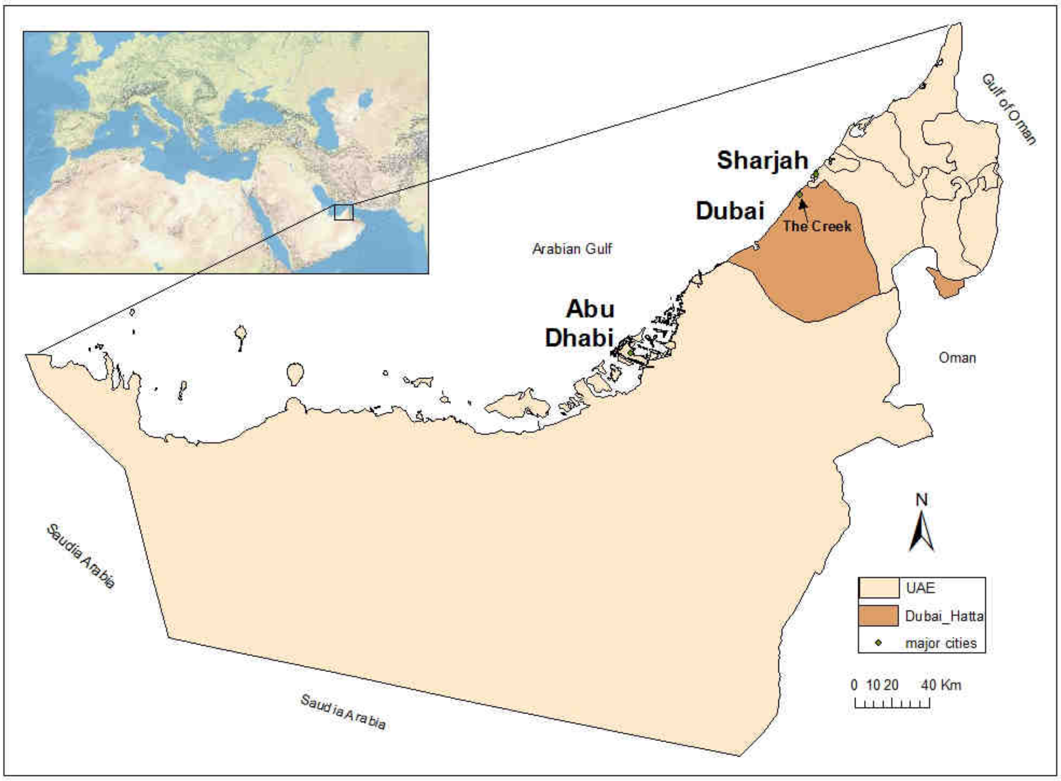


**Figure 1.** Location of the study area excluding Hatta

## 3- Data used:

A time series of Landsat images were acquired covering the years 1972-2011 as seen in Table 1. The images were cloud free and were chosen to be as close as possible to the same Julian day, in order to minimise the effects of variations in solar geometry. Two scenes of Landsat MSS needed to be mosaicked to cover the study area for each of the years 1972, 1976 and 1980, while individual TM and ETM+ scenes provided complete coverage for each of the subsequent years. Other datasets used in the study are also listed in table 1.

**Table 1**: data used in the study

| *Data type* | *format* | *Spatial Resolution* | *acquired date YYYY/MM/DD* |
|---|---|---|---|
| *Landsat (MSS)* | *Raster* | *60 m* | *1972/11/11* |
| *Landsat (MSS)* | *Raster* | *60 m* | *1972/11/11* |
| *Landsat (MSS)* | *Raster* | *60 m* | *1976/08/06* |

| | | | |
|---|---|---|---|
| *Landsat (MSS)* | *Raster* | *60 m* | *1976/08/06* |
| *Landsat (MSS)* | *Raster* | *60 m* | *1980/08/25* |
| *Landsat (MSS)* | *Raster* | *60 m* | *1980/08/25* |
| *Landsat (TM)* | *Raster* | *30 m* | *1985/02/11* |
| *Landsat (TM)* | *Raster* | *30 m* | *1990/08/28* |
| *Landsat (TM)* | *Raster* | *30 m* | *1998/10/13* |
| *Landsat (ETM+)* | *Raster* | *30 m* | *2000/08/23* |
| *Landsat (ETM+)* | *Raster* | *30 m* | *2003/08/16* |
| *Landsat (ETM+)* | *Raster* | *30 m* | *2005/07/20* |
| *Landsat (ETM+)* | *Raster* | *30 m* | *2008/08/29* |
| *Landsat (ETM+)* | *Raster* | *30 m* | *2010/08/19* |
| *Landsat (ETM+)* | *Raster* | *30 m* | *2011/08/22* |
| *DubaiSat-1* | *Raster* | *5m* | *2011/07* |
| *IKONOS* | *Raster* | *1m (fused)* | *2001, 2005* |
| *Aerial photo* | *Raster* | *1: 50,000* | *1991* |
| *Roads* | *Vector* | *-* | *2011* |
| *Dubai boundary* | *Vector* | *-* | *2008* |

## 4- Methodology:

The study involved three main steps. The first step was to prepare and preprocess the Landsat imagery by applying atmospheric correction and image to map/image registration. The second step was to classify the TM and ETM+ images into different land cover types. Third step was to assess the accuracy of classification using high resolution images.

### 4.1 Data preparation and pre-processing:

In order to quantify urban growth and other land covers as accurately as possible, all images were preprocessed prior to classification to remove radiometric and geometric distortions.

1- The Landsat images were atmospherically corrected using Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) module within ENVI so that they were brought together to the same reference spectral characteristics (Song *et al.*, 2001). As a result, all digital numbers (DNs) in the raw, MSS, TM and ETM+ data were converted to surface reflectance values.
2- Landsat bands were stacked together (excluding thermal bands because it has coarse spatial resolution, 120m) in order to use a wide range of the wavelengths to detect land cover types in subsequent stages.
3- The two scenes for each year of 1972, 1976 and 1980 were mosaicked together to cover the study area.
4- Landsat images were co-registered precisely with existing map data using a WGS 84 datum/ Dubai Local Transverse Mercator (DLTM) projection (GIS center, 2006). To do this 57 ground control points (GCP's) were collected from road intersections represented in existing vector maps and these were distributed well around the images to provide maximum accuracy (Jensen, 2005). After that, registered Landsat images were used to co-register other Landsat images.
5- The Landsat images were then clipped to the Dubai administrative boundary.

### 4.2 Classification

A modified first level Anderson classification schema (Anderson *et al.*, 1976) was adopted after the extensive study of the spectral clusters inherent within the imagery to include four separable land cover classes that were of value for addressing the aim of the project: Built up, Sand, Water and Vegetated areas.

A hybrid method of classification using unsupervised and supervised algorithms was adopted in this study. Serra *et al.* (2003) demonstrated that using this combined method with Landsat data is more accurate than using a single method. In the present study, unsupervised classification was used to aid the selection of the training signatures (classes) needed for the subsequent supervised classification for each image, as this provided the most effective spectral separability of different land covers. Using unsupervised classification in this way can reduce the time required for manual selection of adequate training classes and can reduce the subjectivity of the process (King *et al.*, 1989). Therefore, this hybrid approach attempts to combine the advantages of both methods and overcome their limitations.

### 4.3 Classification Accuracy Assessment:

Accuracy assessment was undertaken for the classifications of Landsat images acquired in the four years for which reference data were available. For each of these years, a total of 60 stratified random samples (image and reference pairs) were collected for each class in order to produce a confusion matrix and calculate kappa coefficient, overall accuracy, producer and user accuracies (Card, 1982). The reference samples classes were identified through manual interpretation of a Dubai Sat-1 image for year 2011, IKONOS images for 2005 and 2000 and aerial photography for 1990.

## 5- Results and Discussion

Across the four years tested for classification accuracy, overall accuracy ranged 89-93% and Kappa coefficient 0.8-0.9. The consistency of these results demonstrated the transferability of the classification technique across Landsat image time series and the high levels of accuracy indicated that the land cover maps produced were sufficiently reliable for subsequent analysis and interpretation.

The time series of land cover maps revealed a dramatic increase in the urban area of 561km2 over 39 years, which represents an average annual growth rate of 10.03%. However, as can be seen in Figure 2 the majority of this growth occurred after 2000, with the period 2003-2005 experiencing a peak annual growth rate of 13.02%. Furthermore, it appears that there has been a rapid decrease in the rate of urban growth recently.

Over the whole study period the total area of Dubai Emirate increased by 68km$^2$ due offshore reclamation projects in the Arabian Gulf which took place mainly after 2000. Vegetated areas within the emirate increased substantially from 0.85km$^2$ in 1972 to 41.31km$^2$ in 2011, due to government policy to increase the green spaces in Dubai (Al Marashi & Bhinder, 2008). Inland water increased from 3.88km$^2$ to 18.30km$^2$ where the increase was due to Creek dredging, ports formation and recreational water bodies.

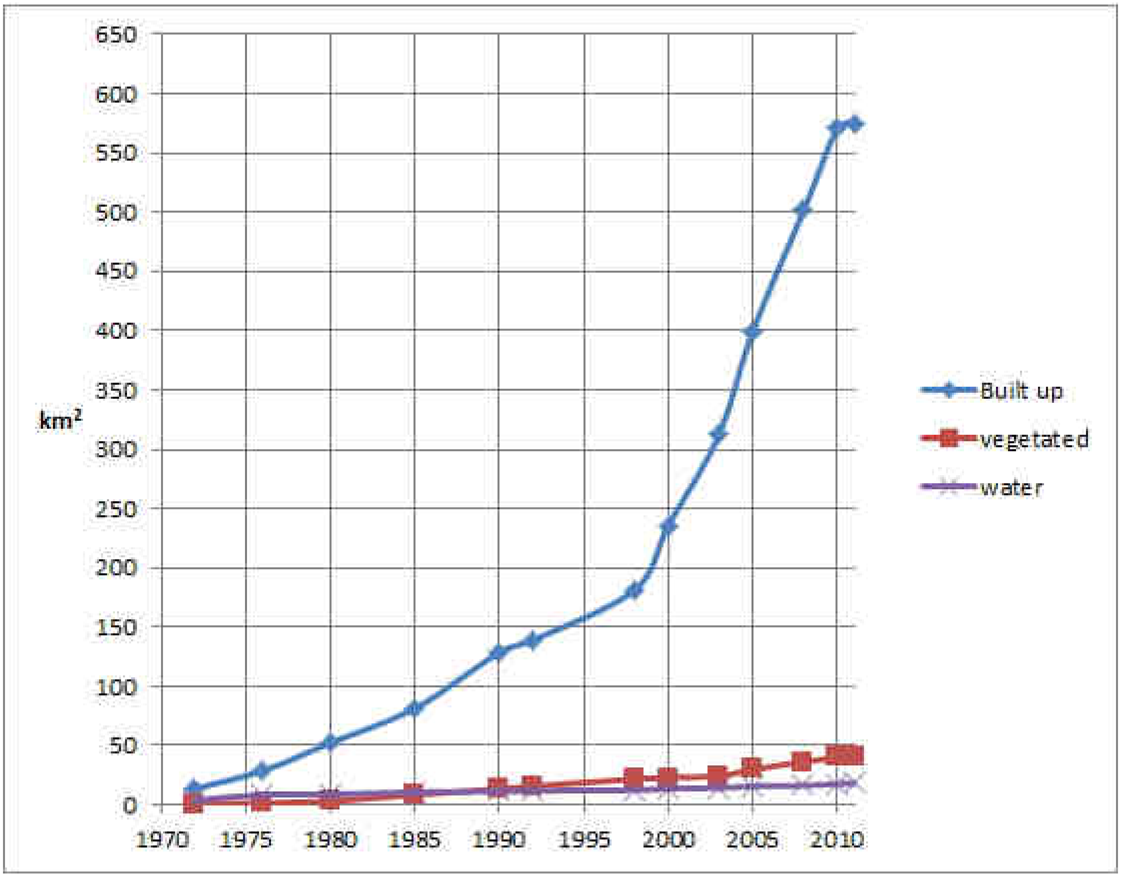


**Figure 2** The trend of land cover changes in Dubai in 39 years

The patterns of urban growth for the study period are shown in Figure 3. Between 1972 and 1990 most of the built up areas are concentrated around Dubai Creek. During the 1990's the built up areas expanded to the East of Dubai towards Sharjah Emirate and along the gulf coast, for real estate purposes. By 2011, the urban sprawl had expanded primarily towards the West coast where Palm Jumairah Island was built with Jebel Ali Palm Island still under development. Moreover, urban growth intensified towards Sharjah in the North East and around Jebel Ali port to the West. More built up areas were developed to the west and southern west of the Emirate where a new airport was developed (Al Maktoum International Airport).

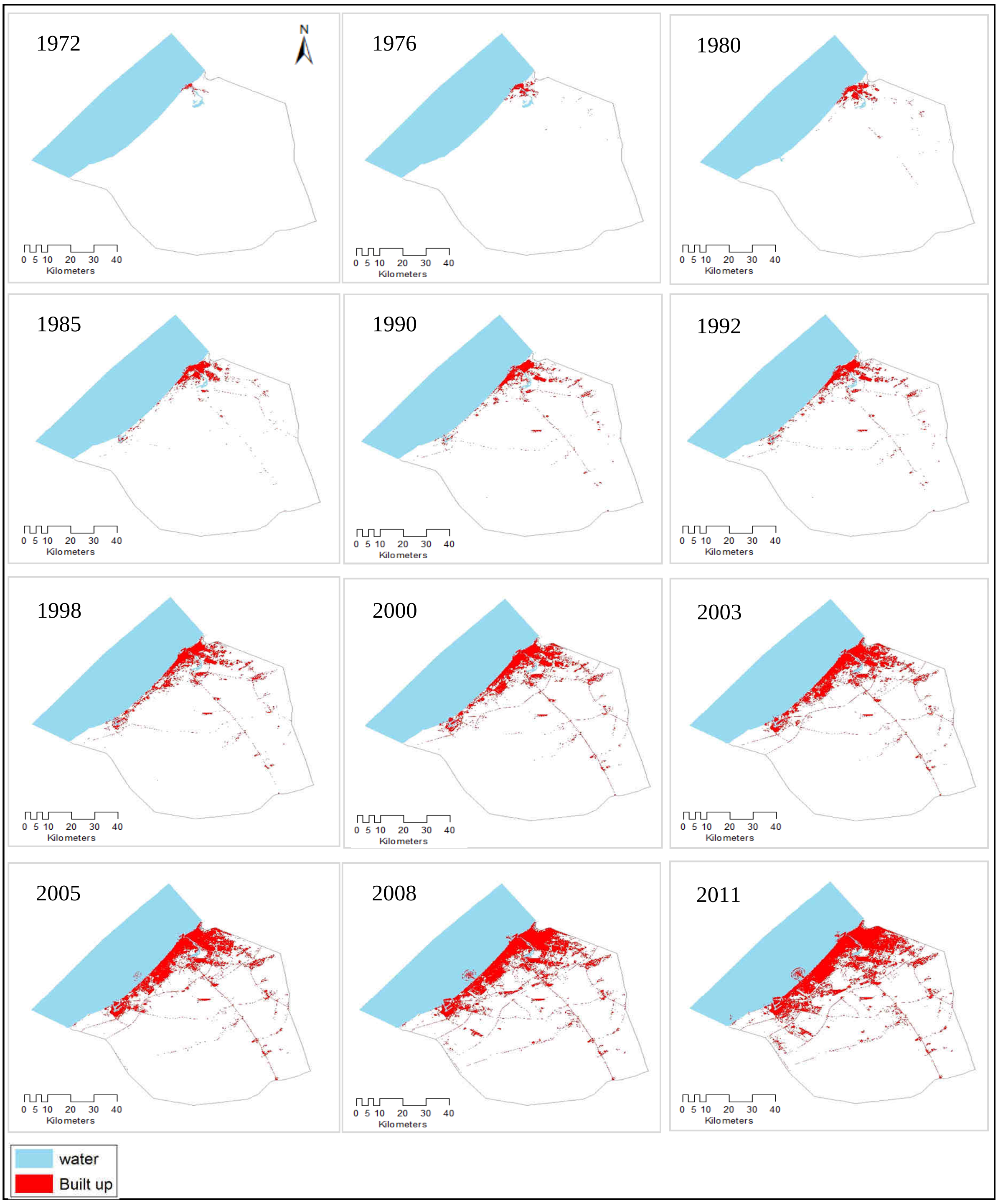


**Figure 3**. Urban change in Dubai Emirate

The study also shows a massive change in Dubai's coastal zone between 2000 and 2010 (Figure 4). More than 11km$^2$ of marine environment was converted to build up areas (artificial islands) while approximately 57km$^2$ were converted to sand where three islands are still under construction.

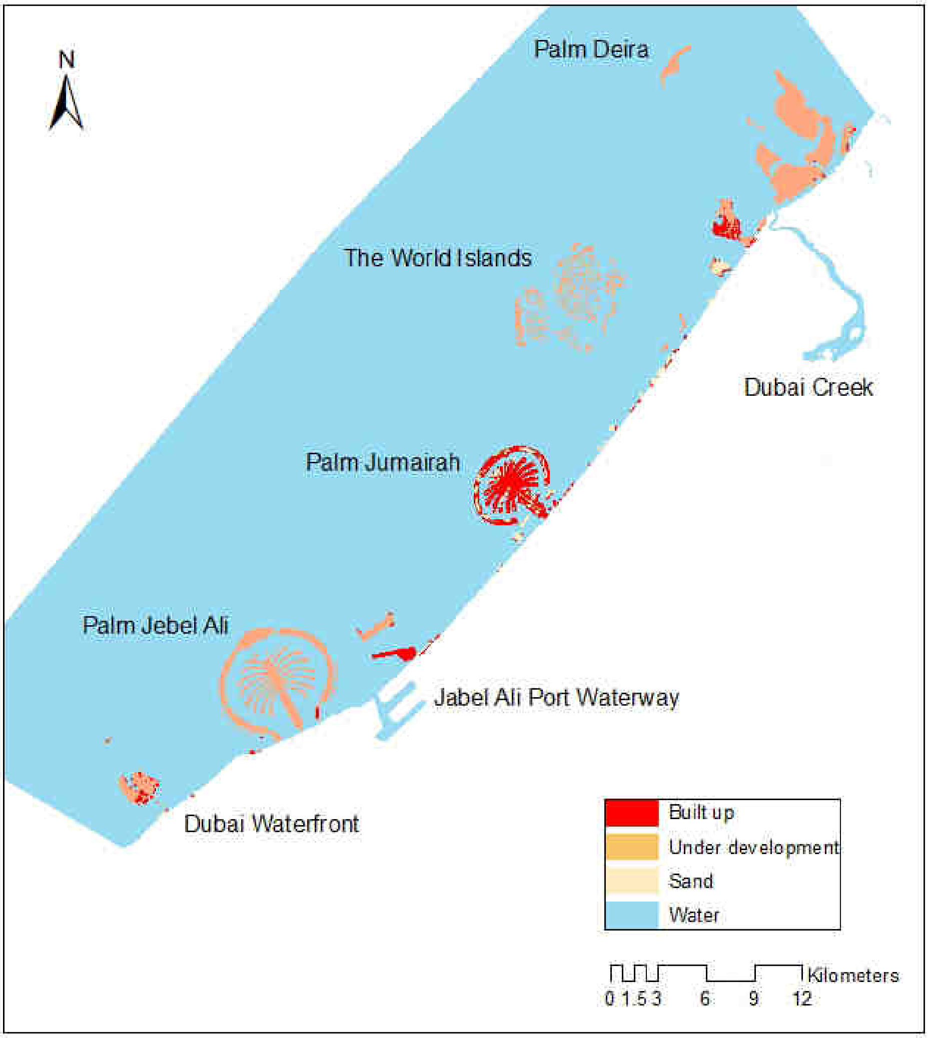


**Figure 4.** Coastal change in Dubai between 2000 and 2011

## 6- Concluding Remarks

This study has quantified the rapid process of urbanisation in Dubai emirate, with an average increase of 31km$^2$ per year between 2000 and 2011. This study also monitored the change of coastal zone in the emirate which showed a massive change in the form of the coastline, resulting in a substantial increase in the terrestrial area of the emirate. The causes of the observed changes are attributed to the strategic decisions of the government to diversify of the economy of the emirate to avoid over-reliance on the fragile petroleum industry, by building new infrastructure, increasing the population and developing tourism.

Without remote sensing it is difficult if not impossible to document such large scale changes in landuse, as other sources of information are restricted or non-existant. Therefore, geoinformatics tools can play a vital role in understanding urban change and if fused with environmental data this can help to determine the effect of urbanisation on the environment. This will form the focus of our subsequent work, aimed at providing the basis for developing coherent guidelines and to promote sustainable development in this region.

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