GIS APPROACH FOR ASSESSMENT OF HUMAN FOOTPRINT AND LAND MANAGEMENT: AN EXAMPLE IN THE UNITED ARAB EMIRATES

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ABSTRACT:

The main objective of this study was to build a spatial GIS database for land management on the AL Sammalyah Island. Twenty GIS layers were created to populate the database. GIS overlay analysis was applied to five major land cover types between 1999 and 2005. The study drew the attention on the fact that real increase took place in most important land cover types namely mangrove, palm trees, and buildings registering more than 336%, 130%, and 300% increase in six years. Finally, building the GIS database was a real success; managers of the island started to use it to do measurements and generate statistics for land management, consequently reliability and flexibility of the remote sensing and GIS products were demonstrated.
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1. INTRODUCTION

Remote sensing and GIS are promising new time and cost effective techniques to image remotely arid and hyper arid lands. (Mulders and Girard, 1993; Ustin and Xiao, 2001). With the use of ancillary field data and the calibration of remote sensing inputs, data integration within a GIS can enhance the extraction of information from satellite imagery and improve the accuracy of a variety of outputs (Jenssen *et al.*, 1990; Salami *et al.*, 1999). This has led to a synergistic approach in spatial data handling (Jenesen, 2000; Suga *et al.*, 1994).

All large operational GIS are built on the foundation of a geographic database. After people, the database is arguably the most important part of a GIS because of the costs of collection and maintenance, and because the database forms the basis of all queries, analysis, and decision making (Ayeni and Ikwuemesi, 2002; Chen, 2002; Periera *et al.*, 2002; Suga *et al.*, 1994; Travaglia *et al.*, 2001). A database can be thought of as an integrated set of data on a particular subject. Geographic databases are simply databases containing geographic data for a particular area and subject. In recent years geographic databases have become increasingly large and complex. For example, AirPhoto USA's US National Image Mosaic is 25 terabytes (TB) in size, EarthSat's global Landsat mosaic at 15 m resolution is 6.5 TB, and Ordnance Survey of Great Britain has approximately 450 million vector features in its MasterMap database covering all of Britain (Longley *et al.*, 2005).

In the United Arab Emirates, where deserts compose more than 97 percent of its land, an extensive development works have been and continue to be undertaken in the country, thanks to investments generated from oil exports (Alhameli and Alshehhi, 2004). This development is manifested in the rapid change in landscape, settlements, and infrastructure (CER, 2000; DER, 2004). During the last decade, many studies were conducted to highlight the rates and extent of change in the UAE, including change analyses studies using satellite and archived data (Essa *et al.*, 2005; Starbuck and Tamayo, 2006; Sohl, 1999; Yagoub, 2004). Transformation of islands into high value land indicates that islands in the UAE will become a focus for many investors. This will generate opportunities and challenges and there is a need to create spatial databases that can be used to address problems associated with the reality (DER, 2004).

Remote sensing and geographical information systems (GIS) are applied to a study area at the fringes of Abu Dhabi capital city with the following objectives:
1.1. To build a spatial GIS database for optimal land resources management on AL Sammalyah Island.
1.2. To evaluate and visualize change rates and extent of main land cover types between 1999 and 2005.
1.3. To demonstrate the flexibility and reliability of remote sensing and GIS technologies in providing essential, updated information for resources mapping and management particularly for developing countries.

2. STUDY AREA

AL Sammalyah is located at approximately 24° 26′10″N - 24° 28′56″N and 54° 29′22″E - 54° 34′12″E (Figure1). Situated in the Arabian Gulf, about 12 km north east of Abu Dhabi Island is characterized by its rich ecosystems and marine life. The Island covers an area about 14.7 square kilometres. Its geomorphology is characterized by a flat desert surface with small artificial sandy hills and dispersed coastal S*abkhat* especially in the low lands along the shoreline. The island is characterized by its hyper arid climate; the mean annual rainfall is just below 50mm, while the mean monthly temperature exceeds 30ºC. Soil texture is dominated by sand, with high salt content reaching 31.5% Total Soluble Salts (TSS) on the surface, being mostly Chloride soluble salts giving a white color to the soils of the island**,** which produces high brightness levels on satellite imagery operating in the visible portion of the EMR, however the very narrow mangrove soils surrounding the island have dark color because of high content of organic carbon content**.** The Island is a natural reserve containing high biodiversity, particularly mangroves *(Avicenna marina)* (CER, 2000), (DER, 2004).

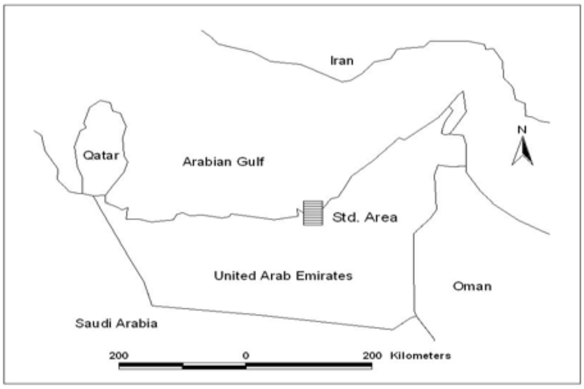


Figure 1: The location of the study area.

3. DATA & MATERIALS

A multi-temporal dataset of remote sensing data was acquired for the study area. It was composed of aerial photographs from 1985, 1999, 2005, and 2006. The software used includes ESRI ArcGIS v9.1 software for vector processing, and ERDAS Imagine 8.4 for image processing. The hardware used includes PC Pentium IV 3.2 GH speed, and HP color LaserJet printers. The selection of data used in this study was largely governed by availability and accessibility of archived data especially at the MSD archives; the selection of hardware, and software was governed by the UAEU geology department's facilities.

4. METHODOLOGY

1. Aerial photographs are scanned at a resolution of 600dpi. The nearest neighbour method of grey-level interpolation is applied. An image-to-image registration is used to register other datasets using the corrected 2000-aerial photograph as a master image.
2. Five land cover types representing the 1999 and 2005 dates are created namely: Roads; Water constructions; Vegetation; Buildings; and Barren land, using heads up on-screen digitizing.
3. Evaluation and visualization of the change between past and present to assess the vigour of human footprint manifested by construction and rehabilitation activities on the island is achieved using GIS overlay analysis.
4. Designing, building and populating the GIS database with respect to the following general steps:
   i. Data sources selected for entities and attributes are user requirements identified through field visits, discussions and scientific reports.
   ii. ArcGIS version 9.1 geodatabase structure is adopted for the design and building of the database
   iii. Shapefiles created by digitizing using ArcGIS 9.1 under Edit session, and then converted to the database using geoprocessing tools available in ArcGIS.
   iv. All data are projected to UTM, zone 40N, Nahrawan Datum.

5. RESULTS

5.1 Imageries datasets

All aerial photographs were processed and integrated into the database. The dataset was registered to Nahrwan_1967 coordinate system, Universal Transverse Mercator projection, zone 40. A minimum of 10 ground control points (GCPs) was collected for each photograph and a second degree polynomial transformation was used to project them. The total RMS was less than 0.4 pixels. The resulting aerial photographs were resampled using ERDAS Imagine Map Interpreter Function and a unique pixel resolution of 2 meters was achieved for the whole dataset. The 1999 and 2005 aerial photographs were used to create GIS layers for main land cover types. The layers were then used to evaluate the change during this active period, furthermore they were used to populate the spatial database produced for the island.

5.2 GIS Layers

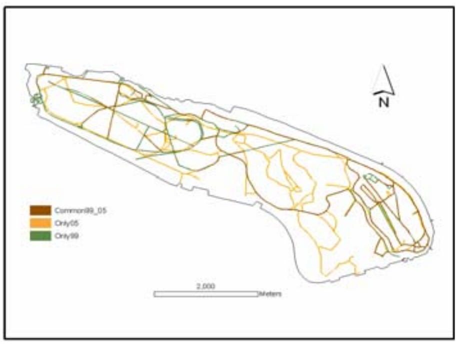
Ten GIS vector layers (feature classes in the database) representing five land cover types for each of 1999 and 2005 were created (Table 1). These feature classes were chosen as they reflect most of the engineering and rehabilitation and greening works carried out on the island. Thus analyzing those parameters is a key factor to evaluate the level of development and to assess the vigour of human footprint on the study area during the research period.

Land cover classes (visual Interpretation of large scale aerial photographs) of 1999 and 2005	
1	Transportation: Roads / Footpaths/ tracks and Roundabouts Transportation: Roads / Footpaths/ tracks and Roundabouts
2	Water constructions: bodies / Water channels
3	Vegetation: Shrubs & grass / Palm trees / Mangroves
4	Buildings
5	Barren land

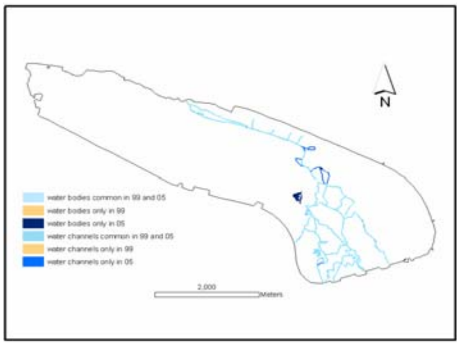
Table 1: Vector GIS layers considered for representing and studying land cover classes for 1999 and 2005.

5.3 Change analysis

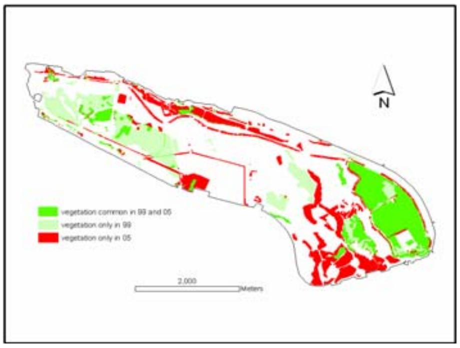
GIS overlay analysis method for detecting and visualizing changes between the two dates was applied. Roads buffers; Water constructions; Vegetation; Buildings; and Barren land layers were mapped, also areas and lengths were measured hence producing a qualitative (Figure 2) and a quantitative (Table 2) estimation of the change.



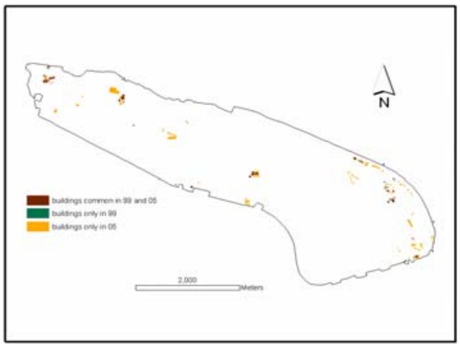
(a) Roads Network: Main roads / Footpaths/ Tracks and Roundabouts dynamics



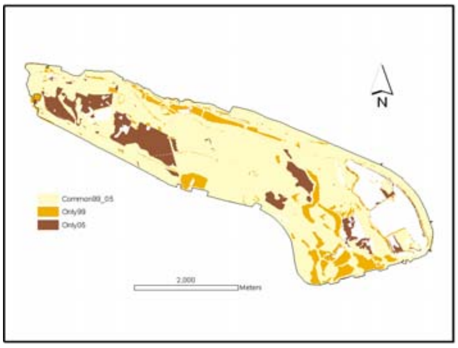
(b) Water construction dynamics



(c) Vegetation: Shrubs & grass / Palm trees / Mangroves dynamics



(d) Buildings construction dynamics



(e) Barren land dynamics

Figure 2. Overlay analysis mapping results of the change analysis between 1999 and 2005 for five major land cover classes: (a) Roads buffers dynamics; (b) Water construction dynamics; (c) Vegetation dynamics; (d) Buildings construction dynamics and; (e) Barren lands dynamics.

Class name	1999	2005	Change	% Net Change
Roads Network	53.49	63.82	10.33	+19.31
Water Channels(km)	21.1	23.2	2.1	+10
Vegetation(ha)	352.3	355.7	3.4	+1%
Buildings (ha)	2.31	9.66	7.35	+318
Barren land (ha)	1045	1025	20	-1.4

Table 2. Land cover change analysis statistics in the study area (1999 - 2005).

5.4 The Geo-Database

As a result, the Al Sammalyah database integrates 20 GIS vector and raster layers encompassing various types of features on the surface of the Island (Table 3). The building of the actual GIS database is essential for sustainable development and management of the island in the long term.

	GIS Layer
	The image dataset
1.	B/W Aerial photograph, 1985
2.	Color Aerial photograph, 1999
3.	Color Aerial photograph, 2005
4.	Color Aerial photograph, 2006
	The 2005 change analysis input layers
5.	Roads Network –second date
6.	Water constructions –second date
7.	Vegetation –second date
8.	Buildings –second date
9.	Barren Land –second date
	The 1999 change analysis input layers
10.	Roads Network –first date
11.	Water constructions –first date
12.	Vegetation –first date
13.	Buildings –first date
14.	Barren Land –first date
	The Overlay output layers
15.	Roads change analysis
16.	Water change analysis
17.	Vegetation analysis
18.	Buildings change analysis
19.	Barren land change analysis
	The TIN layer
20.	Al Sammalyah TIN layer

Table 3. Al Sammalyah GIS Database layers

6. DISCUSSION

6.1. GIS layers creation and Database building

The building of the actual Al Sammalyah database is essential for sustainable development and management of the island in the long term. Large scale aerial photographs were scanned, corrected, processed, interpreted and converted to ArcGIS geodatabase format. An integrated geodatabase of 20 GIS vector and raster layers encompassing various types of features on the surface of the Island (Table 3), is now in the hands of decision makers of the island for the best management of its land resources. The history of each unit of the total 1475 hectares of the island can be studied and analyzed back to the mid eighties. Information can be extracted about the dimensions or extent of any of the main land cover types e.g. extent of mangrove, or building of new site seeing constructions for tourists and visitors, engineering works, etc. Another important point to learn about the database of the island is its open structure nature, in the sense that it is possible to add new data or GIS layers for any feature class of the island at any time (e.g. soil layer, water table layer, salt distribution layer, land suitability layer, etc.). Land suitability maps are of particular importance, as they will help in assisting and directing managers in their greening and construction efforts for sustainable development of the island in the long run.

The importance of building GIS spatial databases gains its importance in the region especially with growing attention given to islands that resulted in building artificial islands such as Palm and World islands built in Dubai. Definitely, the associated high cost of these artificial islands greatly justifies the implementation of GIS spatial databases to manage and sustain the development on these islands.

6.2. Evaluation and visualization of the change

Change maps shown in Figure 2 together with statistical analysis presented in Table 2 confirm the following:

- An increase in the buildings surface of more than 300% in six years, totaling an area of about 10 hectares in 2005, representing 0.7% of the total island area.
- Results of the change analysis indicate good progress in the level of greening of the island, especially in the increase of the salt-tolerant mangrove plantation during the study period:
  - Mangrove testifies the most significant land cover type area increase.
  - Palm trees show an increase of more than 130% in six years.
  - Grass is a new land cover type introduced in a later stage. Indicating that the island has reached an advanced stage in its urbanization and development.

Engineering works and urbanization were demonstrated by the increase in built up areas and roads network infrastructure, while rehabilitation and human fingerprints were demonstrated by the increase in water constructions, manifested by either artificial water bodies for hosting migrant birds or by the construction of water channels for land reclamation and irrigation. This is confirmed by the high expansion rate of Mangrove vegetated areas to reach more than 11% of the total area of the island in 2005.

6.3. Flexibility and reliability of Remote Sensing and Geographical Information Systems

Demonstrating the flexibility and accuracy of remote sensing and GIS technologies in providing essential and updated information for resources mapping and management is one of the objectives of this study. This is of paramount importance undertaken to convince high ranking administrators of the importance of using RS/GIS technologies in management and decision making process. Since most developing countries' governments have a preference towards rapid solutions with low maintenance cost in the long run. These governments are welling to provide a one-time don with the expectation to see quick and concrete results. Investing this one-time money don to build a digital, accurate and comprehensive geo-database to manage land resources is a well thought-out and a great achievement. This geo-database will have the potentiality for archiving, retrieval, querying and processing, visualization and disseminating of results amongst decision makers and the public.

Furthermore, building the GIS database was a real success; managers of the island started to use it to do measurements and generate statistics about main land cover types like mangrove and palm trees plantation. Visualization is another product being used to print maps and generate reports for important meetings to justify funding and persuade superiors. The open structure nature of the GIS database makes it possible to expand and add more layers deemed necessary to the database in the future. The reliability and flexibility of the remote sensing and GIS products are demonstrated by assisting and directing managers in their efforts for the sustainable development of the island in the long run.

7. CONCLUSION

This study is part of a big project conducted primarily on the island to first, quantify rates of change and levels of development using GIS and remote sensing; second build a spatial geodatabase to integrate and store all spatial data available. The geodatabase contains 20 GIS layers showing the evolution of the island landscape in time, in addition to the actual status of the island as of 2005, 2006. The geodatabase provides opportunities for quick and timeless maintenance, and provide a basis for the construction and publication of the Island SDSS.

On the island large-scale reclamation started in the early 1990s and has increased very rapidly since then. Urbanization and the spread of water bodies was testimony to the development of the island for enhancing scientific research and developing the ecosystem. Further, results provided convincing evidences of modernism, but also conservation, greening, and desert watering which were successfully achieved on the Island. The successful engineering and reclamation works conducted proved that dedication and wise decisions can make differences in enhancing local environmental conditions.

The production of an integrated geospatial database for land management was the first in the UAE. It is believed that other institutes will follow as past experiences proved that such study example was usually followed by other public institutes in the country as well as in other Gulf States. The spread of artificially built islands in the UAE as well as in the region such as Palm and World islands in Dubai justifies the implementation of such GIS spatial databases to help in the management of tourism and economic development on these islands.

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