ΧΡΗΣΗ ΔΟΡΥΦΟΡΙΚΩΝ ΣΤΟΙΧΕΙΩΝ ΓΙΑ ΤΟΝ ΕΛΕΓΧΟ ΤΗΣ ΑΣΤΙΚΗΣ ΕΠΕΚΤΑΣΗΣ ΣΤΗΝ ΠΕΡΙΟΧΗ ΤΗΣ HURGHADA, ΣΤΗΝ ΑΙΓΥΠΤΟ

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Abstract

The tourist activities in Egypt are, in some cases, associated with unplanned and uncontrolled expanding in urban areas. Such expanding has added around 12000 km2 as a new urban area during the last twenty years in Egypt. Hurghada is one of these tourist areas at the Red Sea coast of Egypt. Data of Landsat 5 TM of 1987, Landsat 7 ETM+ of 2000 and ASTER of 2005 were used to examine the scope and speed of urban expansion over 18 years before and after tourist development of Hurghada. In this context, five change detection techniques (qualitative and quantitative) were tested to detect areas of change. Three land use/land cover maps with 10 classes are produced. The results showed that urban area expanded from 7.93 km2 in 1987 to 28.65 km2 in 2000 with an average rate of 1.6 km2/year, and to 39.60 km2 in 2005 with an average rate of 2.2 km2/year. The study also, subjected to detect changes in the position and nature of coastline as a result of land filling which threatens the coral reefs and biodiversity in shallow shore water. The landfill areas formed from 1987 to 2000 are 3.2 km2 with an average rate of 0.25 km2/year and from 2000 to 2005 are 1.3 km2 with an average rate of 0.3 km2/year.

USING SATELLITE IMAGERY FOR MONITORING URBAN EXPANSION OF HURGHADA AREA, RED SEA COAST, EGYPT

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Περίληψη

Οι τουριστικές δραστηριότητες στην Αίγυπτο συνοδεύονται συνήθως από μια μη σχεδιασμένη και ανεξέλεγκτη επέκταση στις αστικές περιοχές. Αυτή η επέκταση έχει προσθέσει περίπου 12000 τετ. χλμ. ως μια νέα αστική περιοχή κατά τη διάρκεια των τελευταίων είκοσι ετών στην Αίγυπτο. Η Hurghada είναι μια από αυτές τις τουριστικές περιοχές στις ακτές της Ερυθράς Θάλασσας στην Αίγυπτο. Στοιχεία από τους δορυφόρους Landsat 5 TM του 1987, Landsat 7 ETM+ του 2000 και ASTER του 2005 χρησιμοποιήθηκαν για να εξετάσουν το πεδίο και την ταχύτητα της αστικής επέκτασης για περισσότερο από 18 έτη πριν και μετά την τουριστική ανάπτυξη της Hurghada. Σε αυτό το πλαίσιο, πέντε τεχνικές ανίχνευσης αλλαγής εξετάστηκαν για να ανιχνεύσουν τους τομείς της αλλαγής. Τρεις χάρτες του land use/land cover με 10 κατηγορίες κατασκευάσθηκαν. Τα αποτελέσματα έδειξαν ότι η αστική περιοχή επεκτάθηκε από 7,93 τετ. χλμ. το 1987 σε 28,65 τετ. χλμ. το 2000 με μέσο όρο 1,6 τετ. χλμ./έτος και σε 39,60 τετ. χλμ. το 2005 με μέσο όρο 2,2 τετ. χλμ./έτος. Η μελέτη επίσης, έχει αντικείμενο να ανιχνεύσει τις αλλαγές της θέσης και της φύσης της ακτής ως αποτέλεσμα επέκτασης της ξηράς που απειλεί τους κοραλλιογενείς υφάλους και τη βιοποικιλότητα στα ρηχά ύδατα των ακτών. Οι περιοχές επέκτασης της ξηράς που διαμορφώθηκαν από το 1987 ως το 2000 είναι 3,2 τετ. χλμ. με μέσο όρο 0,25 τετ. χλμ./έτος και από το 2000 ως το 2005 είναι 1,3 τετ. χλμ. με μέσο όρο 0,3 τετ. χλμ./έτος.

Λέξεις κλειδιά: ανίχνευση αλλαγής, Hurghada, αστική επέκταση.

Key words: change detection, Hurghada, urban expansion.

1. Introduction

The study area is situated at the Eastern Desert of Egypt and at about 550 km from Cairo (Figure 1). It stretches for about 60 km along the western shoreline of the Red Sea between El-Gouna resort to the north and Sahl Hashish area to the south . It encompasses an area of about 750 km2 and is bounded by latitudes 27° 03'-27° 25' N and longitudes 33° 35'-33° 55' E. Geologically, the study area comprises Precambrian basement rocks including metagabbros, Older Granites, Dokhan Volcanics, Hammamat sediments, Younger Granites and post-granite dykes as well as Cenozoic Tertiary and Quaternary deposits (EGSMA, 2005). The study area is considered now as a major tourism destination for international and local visitors as it hosts three tourist centers, El-Gouna, Hurghada and Sahl Hashish. Hurghada acts as a town and a tourist center and is characterized by special geographic, geologic and geomorphologic features and attracted the investors to construct various economic development activities. Indeed, theses activities transformed Hurghada rapidly from primitive fishing village in 1920s to the first destination resort on the Egyptian Red Sea coast. As well as El-Gouna resort was constructed at the middle of 1990s at 20 km north of Hurghada over the old Graeco-Roman port called Myos Hormos.

No doubt, the increasing and booming of the coastal tourism in the study area are expected to lead to increase in urbanization. This reason initiates the objective of this work to detect and evaluate the urban expansion of Hurghada area, using multi-spectral, multi-temporal satellite data. In addition, discuss the pattern and the forces driving it.

Although land use and land cover changes can be monitored by traditional inventories and survey, satellite remote sensing provides greater amounts of information on the geographic distribution of land use and changes, along with advantages of the cost and time savings for regional size areas (Yuan et al., 2005). The timely and spatially explicit characteristics of remotely sensed data not only provide a means for exploring and testing hypotheses and models about urban areas, but also for constructing new theories that can help in the formation of policy in anticipation of the problems that accompany urbanization processes (Rashed et al., 2005).

Relevant growth processes in urban and suburban areas can be detected and analyzed by application of change detection techniques (Jürgens, 2001). Some researchers refer to change detection as monitoring process and defined monitoring as the regular examination and recording of a time-variant process of phenomena, such as land use changes (Shair and Nasr, 1999).

2. Change detection techniques

Numerous methods for change detection were discussed by several researchers for many years. Consequently, different approaches have been developed. Lu et al. (2004) reviewed previous studies about change detection techniques and summarized these techniques into two main types: 1) those detecting binary change/no-change information, and 2) those detecting detailed "from-to" change.

Moufaddal (2005) divided change detection techniques into two major groups: 1) qualitative techniques, which outline only area of changes, without giving any figures or estimates on the type and volume of change (e.g. image differencing, image ratioing, image overlay and PCA), and 2) quantitative techniques, which provide estimates on type, volume and rate of change such as post-classification comparison and direct multidate classification.

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3. Data used

To start a remote sensing approach to determine urban growth, one need at least two images of different dates. One should be a very up-to-date image, showing the most recent situation, and one should be an older image showing a reference situation from which growth determined (Jürgens, 2001).

In the present study, Landsat Thematic Mapper (Landsat 5 TM), which acquired on 14 August 1987, Landsat Enhanced Thematic Mapper Plus (Landsat 7 ETM+), which acquired on 10 September 2000 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), which acquired on 27 November 2005, were selected as the basis for image analysis and land cover classification. The three images data cover a time period of 18 years, TM-1987 used as reference situation and ASTER-2005 used as up-to-date situation of Hurghada area. In addition to the remote sensing datasets, several data sources were utilized. These data sources include aerial photographs, topographic maps, administrative maps, tourist maps, land use maps and demographic data. These raster datasets were basically used as reference materials for determining the locations and densities for training and ground truth points.

4. Pre-classification processing

Of the various requirements of pre-processing for change detection, multi-temporal image registration and radiometric and atmospheric corrections are the most important (Lu et al., 2004). The major task of pre-processing of images is geometric registration (Ji et al., 2001), that is a critical pre-request for change detection (Moufaddal, 2005).

In the present study landsat 7 ETM+ was co-registered to the base topographic maps with scale 1:50,000 (i.e. image to map registration) using the Universal Transverse Mercator Projection (UTM) Zone 36 North with a world Geodetic System (WGS) 84 datum. Image to map registration was done using 25 ground control points (GCPs) at a root mean square (RMS) error of less than 0.7 pixels. Landsat 5 TM and ASTER images were co-registered to the corrected landsat 7 ETM+ at RMS errors of ~ 0.3 pixels and < 0.4 pixels, respectively. No clouds or haze are visible over the study area in any of images. Three subset scenes of 1111 by 1388 pixels covering the study area were extracted from the full scenes.

5. Data processing and identification of changes

In the present study, some selected approaches were applied to detect and monitoring Hurghada urban expansion. For qualitative techniques (Moufaddal, 2005), the image differencing, image ratioing, image overlay and multidate principal component analysis (PCA) were used, whereas for quantitative techniques, the post-classification comparison was selected.

5.1 Image differencing

Image differencing is the most widely used change detection technique (Moufaddal, 2005). The process simply subtracts one digital image, pixel by pixel from another, to generate a third image composed of the numerical differences between pairs of pixels (Sunar, 1998; Dewidar, 2002; Moufaddal, 2005). The difference in the areas of no change will be very small, and areas of change will reveal larger positive or negative values (Lillesand and Kiefer, 2000).

In the present study, image differencing routine was carried out using ENVI software to extract difference map representing the differences between the initial state and final state images. Many tests were carried out on the different bands of the three images (TM, ETM+ and ASTER) and these tests showed that difference maps of band 7 of 1987 and 2000 and band 3N of 2005 displayed the urban growth and shoreline shifts.

5.2 Image ratioing

Image ratioing is a powerful technique for extracting spectral information from multi-spectral imagery (Dewidar and Frihy, 2003). When one spectral band divided by another, an image with relative intensities will produce (ENVI, 2004). Ratios for areas of no change tend toward one and areas of change will have higher or lower ratio values (Lillesand and Kiefer, 2000; Shair and Nasr, 1999).

In the present study, ratios of band 4 of 1987 and 2000 and band 2 of 2005 gave the best results and highlight the changes in urban growth, vegetation and seagrass.

5.3 Image overlay

Image overlay is the simplest way to produce a change map from comparison of a single band of data from two dates (Sunar, 1988). Moufaddal (2005) added that is straightforward way of comparing historical data and provides a qualitative changes between two dates. Lu et al. (2004) concluded that image overlay can be implemented by inserting one band from date 1 as red, the same band from date 2 as green and the same band from date 3 as blue, if available.

In this study, the change images were produced by inserting the older band in green display and the younger one, is to overlay it, in red display according to Howarth and Boasson (1983). Overlay trials of band 5 and band 7 of 1987 and 2000 and band 3N of 2005 highlight the urban growth and shoreline development.

5.4 Multidate principal component analysis (PCA)

Principal component analysis (also referred to as PCA) has proven to be significant value in the analysis of remotely sensed digital data (Jensen, 1986). The transformation of the raw remote sensor data using PCA can result in principal component images that are often more interpretable than the original data (Byrne et al., 1980). PCA may be used to compress the information content of a number of bands of imagery (e.g. seven thematic mapper bands) into just two or three transformed principal component images (Jensen, 1986).

In the present study, the three datasets were subjected to PCA to create a number of principal components (PCs). Visual inspection of the PCA color composites, which produced from these components, indicated that the composite containing the first three PCs were the most informative and produced more colorful color composite images than spectral color composites. Each composite was composed from the first three PCs of the file contains temporal change between two dates and highlight clearly the volume of urbanization in the study area.

5.5 Post-classification comparison

Remotely sensed datasets provide useful thematic information. Extracting this thematic information from the dataset is accomplished through image classification. Its overall objective is to automatically categorize all pixels in the multi-spectral dataset into land cover classes. Computer-based interpretation of this dataset is referred to as quantitative analysis because of its ability to identify pixels upon their numerical properties and owing to its ability for counting pixels for area estimated (Richards, 1999). Computer-assisted classification of remote sensing data can be partitioned into two general approaches: supervised and unsupervised. Supervised one will be discussed here.

Lillesand and Kiefer (2000) summarized that the typical supervised classification has three basic steps: 1) training stage, 2) classification stage, and 3) output stage. Importantly, training data must be representative, homogenous and complete for land cover classes that will be mapped in the output map.

In the present study depending on the prior knowledge of the study area, which gathered through a combination of reference data and ground data collected during fieldwork, ten pre-defined cover classes were designed as basement rocks, Miocene rocks, sabkha deposits, alluvial deposits, wadi (dry valley) deposits, green land (mangroves, farmlands and golf courses), urban (built-up, tourist activities, roads, airport runways), reef flat, coral reef and sea water.

The three images of 1987, 2000 and 2005 were subjected to the maximum likelihood classifier independently using the training classes of each date. The early attempts of the classification process of each image showed that a considerable confusion occurs between some spectrally similar classes, e.g. confusions between urban area and other classes. Therefore, it was hypothesized that subdividing each multidate dataset into two sections (land and water) by masking and then performing a maximum likelihood classifier on each section independently would resolve a major part of confusion and would improve accuracy of change maps.

After that, supervised classification using maximum likelihood classifier was performed independently on both sections (land and water) of the three datasets of 1987, 2000 and 2005. Six different land use/land cover maps of the three land sections and three water sections were created, indeed with satisfactory accuracy. The classified images of land and water sections were collected using GIS analysis function to produce the land use/land cover maps of the 1987 date, the 2000 date and the 2005 date.

6. Post-classification processing

Once classification process was completed, a post-classification filtering using majority function 3x3 pixel size, was performed to reduce the noise in the classified images. After that, the classified maps were carefully scrutinized to detect the obvious misclassification by comparing results with the source images, through a careful, section by section examination of satellite imageries. On-screen editing of regions of pixels obviously misclassified was performed. The post-classification manual editing stage requires labor-intensive work and most time-consuming.

Once post-processing manual editing stage was completed, accurate land use/land cover maps of the 1987 (Figure 1), of the 2000 (Figure 2) and of the 2005 (Figure 3) were obtained. In addition, urban areas and green land were extracted from each classified image and overlaid onto false color composite of 1987 to show the urban growth through 18-year period (Figure 4). The overall accuracies for the classification maps of 1987, 2000 and 2005 images were 94.89%, 95.96% and 91.29% respectively. Also, kappa coefficients for 1987, 2000 and 2005 were 0.92, 0.93 and 0.86, respectively. Finally, a comparison between the three classification maps was carried out on a pixel-by-pixel basis.

7. Hurghada urban growth and factors driving it

The outcomes of this study comprised two components: thematic maps and the statistical data. The thematic maps include 1) land use/land cover maps of the three dates and 2) change detection map. The results of the three classification maps are summarized in table (1) and the areas of all classes are represented in figure (5). From table (1) it could be concluded that the urban area of Hurghada area expanded from 7.93 km2 (in 1987) to 28.65 km2 (in 2000) with an average rate of 1.6 km2/year and to 39.6 km2 (in 2005) with an average rate of 2.2 km2/year. The overall rate of the entire period (1987-2005) was 1.75 km2/year. The green land expanded from 0.38 km2 (in 1987) to 3.63 (in 2000) with an average rate of 0.25 km2/year and to 4.3 km2 (in 2005) with an average rate of 0.14 km2/year. The changes during the time periods 1987-2000, 2000-2005 and 1987-2005 are represented in figure (6). Figure (6) demonstrates the greatest changes occurred in urban and green land classes and indicates the interference of the human in environment.

One of the principal aims of this study is to shed light on the forces that are affecting on the urban expansion. Ji et al. (2001) and Xiao et al. (2006) stated that urban expansion is governed by geographical and socio-economical factors, such as population growth, policy and economic development. The relationship between population growth and growth in urban area was examined. Table (2) shows the relative change and annual urban growth rate during the 18-year period from 1987 to 2005. The annual urban growth rate (AGR) was calculated according to the formula adopted by Xiao et al. (2006):

$$AGR = UAn+i - UAi/nUAr \qquad (1)$$

where UAr is the reference urban area; UAn+i and UAi the urban area or built-up area at time i+n and i, respectively, and n is the interval of the calculating period (in years).

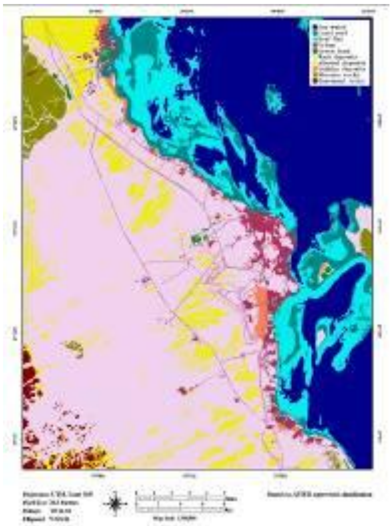
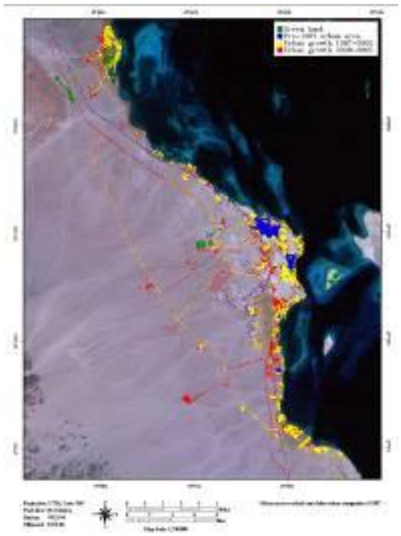


Figure 3. Land use/land cover map of 2005 of Hurghada area.



Hurghada area Figure 4. The urban growth of through 18-year period (1987-2005).

Table (2) shows that, relatively, the urban area increased ~ 400% from 1987 to 2005, with the greatest increase occurring from 1987 to 2000 about 261%. The annual urban growth rate was 20% from (1987 to 2000) and 27.5% (from 2000 to 2005) and 22.2% for the entire period (from 1987 to 2005). This comprises to an annual population growth rate of approximately 14.3% from 1987 to 2005.

The population data (Table 3) which collected from CAPMAS (1980-2005) about Hurghada during 25 years from 1980 to 2005 shows that the correlation between population growth and urban change appears strong (Figure 7). This is clearly appeared in figure (8) which demonstrates the strongly correlates with the population growth and urban area in a nearly linear form. So, it can be concluded that the population growth is the major dominant factor driving urbanization of Hurghada; therefore the urban area was increased ~ 5 times from 1987 to 2005 with corresponding growth of population more than 3.5 times.

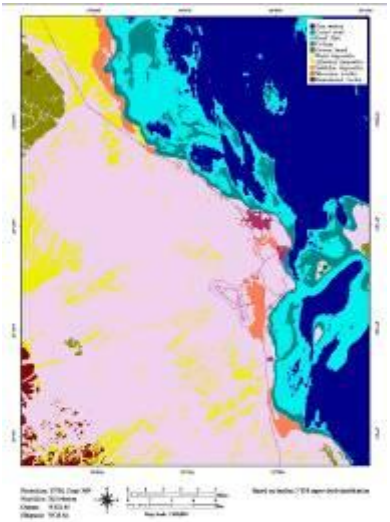


Figure 1. Land use/land cover map of 1987 of Hurghada area.

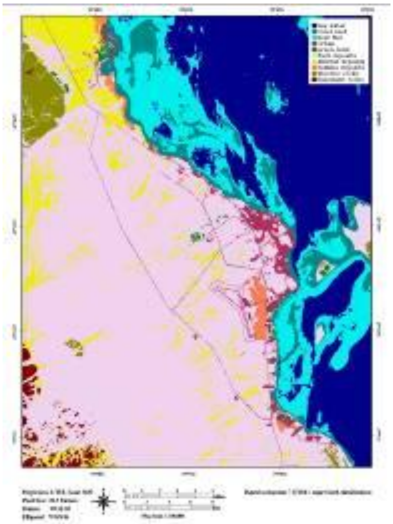


Figure 2. Land use/land cover map of 2000 of Hurghada area.

Table 1. Summary of results of the supervised classification for 1987, 2000 and 2005 images of Hurghada.

Year / Class	LULC-1987		LULC-2000		LULC-2005		Area changed (Km^2)		
	Cover %	Area (Km^2)	Cover %	Area (Km^2)	Cover %	Area (Km^2)	1987-2000	2000-2005	1987-2005
Sea water	24.41	305.81	24.74	310.07	25.98	325.41	+4.26	+15.34	+19.6
Reef flat	4.79	59.94	4.71	59.00	5.04	63.11	-0.94	+4.11	+3.17
Coral reef	10.97	137.53	10.49	131.44	8.96	112.24	-6.09	-19.2	-25.29
Urban	0.63	7.93	2.29	28.65	3.16	39.60	+20.72	+10.95	+31.67
Green land	0.03	0.38	0.93	3.63	0.34	4.30	+3.25	+0.67	+3.92
Wadi deposits	47.26	591.90	47.75	598.61	45.89	574.80	+6.71	-23.81	-17.1
Alluvial deposits	7.34	91.93	5.97	74.42	6.93	86.76	-17.51	+12.34	-5.17
Sabkha deposits	1.71	21.46	0.93	11.53	0.68	8.55	-9.93	-2.98	-12.91
Miocene rocks	1.99	24.95	1.95	24.52	2.09	26.18	-0.43	+1.66	+1.23
Basement rocks	0.93	11.62	0.94	11.73	0.99	12.46	+0.11	+0.73	+0.84
Total	100	1253.5	100	1253.5	100	1253.5	* LULC = Land use/Land cover		

On the other hand, the intrinsic beauty and diversity of natural resources of Hurghada attract the foreign investments to this area. No doubt, these tourist activities play an important role in promoting the urban development. In addition, the government policy aims to improve roads network and infrastructure of Hurghada, such factors show a complex relationship with urban growth and increase the migration rate from all the territory to this area for the new employment opportunities.

Table 2. Relative change and annual urban growth rate of Hurghada from 1987 to 2005.

Period	Relative change of urban area	Annual urban growth rate
1987-2000	261%	20.0%
2000-2005	138%	27.6%
1987-2005	400%	22.2%

Table 3. Population and urban area of Hurghada from 1980 to 2005.

Year	Population*	Urban area (km^2)	
1980	12472	3.10•	* Population after CAPMAS (1980-2005) • After El-Bana (2002)
1987	23010	7.93	
1990	25458	8.50•	
2000	64363	28.65	
2005	82050	39.60	

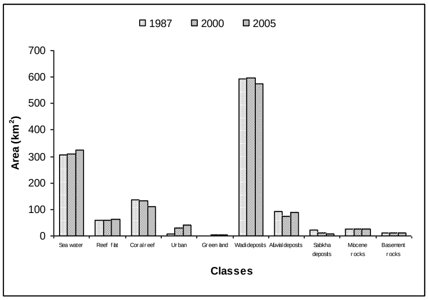


Figure 5. Showing the area of each class in the classified maps of 1987, 2000 and 2005 images.

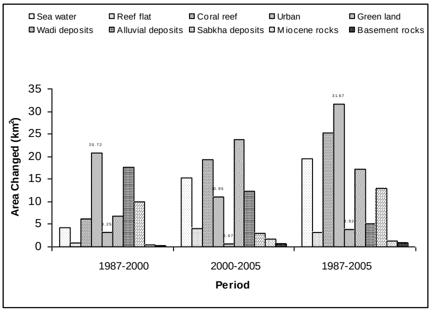


Figure 6. Representing the changed area in the three periods of study, 1987-2000. 2000-2005 and 1987-

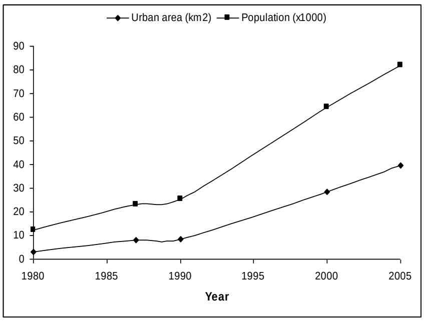


Figure 7. Graphical representation of the growth of population and urban area of Hurghada area from 1980 to 2005.

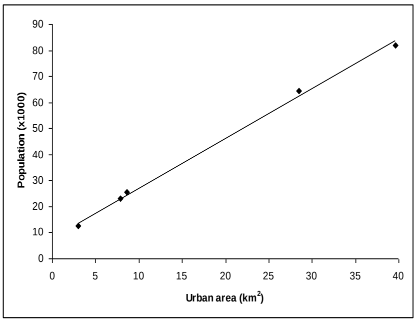


Figure 8. The correlation between population growth and urban expansion appears particularly strong for Hurghada area.

8. Change pattern analysis

Urban expansion takes places in substantially, different forms, it can be orderly-properly laid out in simple geometric forms or it can be disorderly (Angel et al., 2005). By reviewing the produced classification images and change detection map, it can be concluded that the urban region is largely broadened and the urban growth can be identified in one of three models; infill, expansion and outlying (Wilson et al., 2003).

Hurghada in 1987 comprised essentially from two areas: Ad-Dahhar area (old city) and the Harbor area (As-Saqqalah area), from these two nucleuses the town began to expand. In the first stage, the expansion model was the dominant, which characterized by a non-developed pixel being converted to developed and surrounded by no more than 40% existing developed pixels (Wilson et al., 2003). Expansion type development has called also urban fringe development (Heimlich and Anderson, 2001). The expansion occurred at fringe of the urbanized area of 1987, as well as, expanded along corridors (road networks) resulting an elongate city shape.

In the same time, outlying growth is represented, which characterized by a change from non-developed to developed land cover occurring beyond existing developed areas (Wilson et al., 2003). This type of growth has been called development beyond the urban fringe (Heimlich and Anderson, 2001). This type is divided into the following three classes: isolated, linear branch and clustered branch. The isolated growth is characterized by one or several non-developed pixels some distance from an existing developed area being developed. This type is represented in El-Ahhya area, which acts as a new community began during 1990's at the north of the main town, and El-Gouna resort is the obvious example for this model at 20 km north of Hurghada.

According to the dramatic increase of the tourist and recreational activities during 1990's at Hurghada area, the urban area expanded in a linear fashion parallel to the Red Sea coast from the most north area (El-Gouna) until the most south area (Sahl Hashish area). It is clearly appeared to see how the pristine coastline of Hurghada area in 1987 transformed into concrete strip of tourist hotels and recreational facilities during the 18-year period until the year 2005. In addition, Hurghada airport, sewage station, recycling factory and El-Gouna's farmlands are examples of clustered branch growth in the west direction of the town.

As a result of the improvement of the infrastructures in the Hurghada town, the infill growth was developed. The infill growth is characterized by a non-developed pixels being converted to urban use and surrounded at least by 40% existing developed pixels (Wilson et al., 2003). The presence of facilities such as sewer, water, and roads helped in developing areas of As-Salam and Al-Hadabah within the town, and some of the inner-urban areas during the 18 years from 1987 to 2005.

9. Landfill detection

Dredging and land-filling of backshore and fringing reef areas are considered as one of the most negative activity accompanying the urbanization process. The shoreline was pristine in the 1987 image and since that time uncontrolled tourist development has already caused damage in shore reefs. Investors tend to fill out parts of the reef flat in order to create inexpensive land to be exploited for establishing artificial beaches, marinas, …etc. According to the estimates of Medio et al. (1997), 64 of 75 resorts surveyed in Hurghada had carried out some forms of land-filling. Dewidar (2002) estimated the total area subjected to land-filling in the vicinity of Hurghada over 13-year period from 1984 to 1997 is 2 km2.

Moufaddal (2005) estimated the total area which subjected to either land-filling and dredging in the coastal strip from north of Hurghada to south of Safaga over 16-year period from 1984 to 2000 is about 6.55 km2. Of this area, 3.65 km2 as landfill and 2.9 km2 as dredging area.

The present study estimated the landfill along the coastline from El-Gouna at the north of Hurghada to Sahl Hashish area at the south by comparing the three classification maps (Figures 1, 2 and3). The results illustrated that the extra land gained during the 18-year period from 1987 to 2005 was 4.5 km2 with an average rate 0.25 km2/year. The greatest increase occurring from 1987 to 2000 was about 3.2 km2 with an average rate 0.25 km2/year and the new land gained from 2000 to 2005 was 1.5 km2 with an average rate 0.3 km2/year.

10. Conclusions

From the above mentioned analysis, the use of remote sensing technology for urban expansion monitoring in Hurghada area has been a success in terms of achieving its original goals, because the changes with time are very well documented in remote sensing imagery data. The obtained results reflected the rapid development of urbanization of Hurghada area during the last 18 years. Ministry of Housing, Utilities and Urban Development expected that the area of Hurghada will be 150 km2 and its population will be 175000 in the year 2020. Really, this continuous urban expansion needs up-to-date and accurate monitoring at regular intervals of time. In addition, legislative measures are needed to be adopted to regulate this expansion.

Bibliography

Angel S., S. C. Sheppard and D. L. Civco, 2005: The dynamics of global urban expansion. Transport and Urban Development Depart., The World Bank, Washington DC, USA.

Byrne G. F., P. F. Crapper, and K. K. Mayo, 1980: Monitoring land-cover change by principal component analysis of multitemporal landsat data. Remote Sensing of Environment, 10, 175-184.

CAPMAS (Central Agency for Public Mobilization and Statistics), 1980-2005: Official censuses -for different years (1980-2005)- of Population, Housing and Buildings, Cairo, Egypt.

Dewidar Kh. M., 2002: Landfill detection in Hurghada, North Red Sea, Egypt, using Thematic Mapper images. Int. J. of Remote Sensing, 23, 939-948.

Dewidar Kh. M. and O. E. Frihy, 2003: Thematic Mapper analysis to identify geomorphologic and sediment texture of El Tineh plain, north-western coast of Sinai, Egypt. Int. J. of Remote Sensing, 24, 2377-2385.

EGSMA (Egyptian Geological Survey and Mining Authority), 2005: Geologic map of Hurghada quadrangle, Egypt, Scale 1:250,000.

El-Bana A. F., 2002: The urban change in Hurghada city in the quartet of the 20th century. M. Sc. Thesis, Fac. Art, Tanta Univ., Tanta, Egypt. (In Arabic).

ENVI, 2004: ENVI user's guide. Software package ver. 4.1. Research Systems Inc., USA.

Heimlich R. E. and W. D. Anderson, 2001: Development at the urban fringe and beyond: Impacts on agriculture and rural land. ERS Agricultural Economic Report No. 803, 88.

Howarth P. J. and E. Boasson, 1983: Landsat digital enhancements for change detection in urban environments. Remote Sensing of Environment, 13, 149-160.

Jensen J. R., 1986: Introductory digital image processing. Prentice-Hall, New Jersey.

Ji C. Y., Q. Liu, D. Sun, S. Wang, P. Lin, and X. Li, 2001: Monitoring urban expansion with remote sensing in China. Int. J. of Remote Sensing, 22, 1441-1455.

Jürgens C., 2001: Urban and suburban growth assessment with remote sensing. OICC 7th International Seminar on G.I.S. Applications in Planning and Sustainable Development Cairo - Egypt 13-15 Feb. 2001.

Lillesand T. and R. Kiefer, 2000: Remote sensing and image interpretation, 4th ed. John Wiley and Sons Inc.

Lu D., P. Mausel, E. Brondizio, and E. Moran, 2004: Change detection techniques. Int. J. Remote Sensing, 25, 2365-2407.

Medio D. M., P. Pearson, and R. F. Ormond, 1997: Effect of briefings on rates of damage to corals by divers. Biol. Conserv., 79, 91-95.

Moufaddal W. M. 2005: Use of satellite imagery as environmental impact assessment tool: A case study from the new Egyptian Red Sea coastal zone. Environmental Monitoring and Assessment, 107, 427-452.

Rashed T., J. R. Weeks, D. Stow and D. Fugate, 2005: Measuring temporal compositions of urban morphology through spectral mixture analysis: toward a soft approach to change analysis in crowded cities. Int. J. of Remote Sensing, 26, 699-718.

Richards J. A., 1999: Remote sensing digital image analysis. Springer-Verlag, Berlin.

Shair I. M. and A. H. Nasr, 1999: The use of satellite data to detect land-use change in Al Ain city, U.A.E. Egypt. J. Remote Sensing & Space Sci., 2, 107-116.

Sunar F., 1998: An analysis of changes in a multi-date set: a case study in the Ikitelli area, Istanbul, Turkey. Int. J. of Remote Sensing, 19, 225-235.

Wilson E. H, J. D. Hurd, D. L. Civco, M. P. Prisloe and C. Arnold, 2003: Development of a geospatial model to quantify, describe and map urban growth. Remote Sensing of Environment, 86, 275-285.

Xiao J., Y. Shen, J. Ge, R. Tateishi, C. Tang, Y. Liang, and Z. Huang, 2006: Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. Landscape and Urban Planning, 75, 69-80.

Yuan F., K. E. Sawaya, B. C. Loeffelholz, and M. E. Bauer, 2005: Land cover classification and change analysis of the twin cities (Minnesota) metropolitan area by multitemporal Landsat remote sensing. Remote Sensing of Environment, 98, 317-328.