The Egyptian Journal of Remote Sensing and Space Sciences (2016) **19**, 23–36

HOSTED BY

ELSEVIER

National Authority for Remote Sensing and Space Sciences

The Egyptian Journal of Remote Sensing and Space Sciences

www.elsevier.com/locate/ejrs
www.sciencedirect.com

RESEARCH PAPER

Applying post classification change detection technique to monitor an Egyptian coastal zone (Abu Qir Bay)

Mamdouh M. El-Hattab

Institute of Environmental Studies and Research, University of Sadat City, Egypt

Received 4 January 2015; revised 21 January 2016; accepted 18 February 2016
Available online 7 March 2016

KEYWORDS

Post classification;
Change detection;
Coastal zone management;
Coastal changes;
Egypt

Abstract Land cover changes considered as one of the important global phenomena exerting perhaps one of the most significant effects on the environment than any other factor. It is, therefore, vital that accurate data on land cover changes are made available to facilitate the understanding of the link between land cover changes and environmental changes to allow planners to make effective decisions. In this paper, the post classification approach was used to detect and assess land cover changes of one of the important coastal zones in Egypt, Abu Qir Bay zone, based on the comparative analysis of independently produced classification images of the same area at different dates. In addition to satellite images, socioeconomic data were used with the aid of land use model EGSLR to indicate relation between land cover and land use changes. Results indicated that changes in different land covers reflected the changes in occupation status in specific zones. For example, in the south of Idku Lake zone, it was observed that the occupation of settlers changed from being unskilled workers to fishermen based on the expansion of the area of fish farms. Change rates increased dramatically in the period from 2004 to 2013 as remarkable negative changes were found especially in fruits and palm trees (i.e. loss of about 66 km^2 of land having fruits and palm trees) due to industrialization in the coastal area. Also, a rapid urbanization was monitored along the coastline of Abu Qir Bay zone due to the political conditions in Egypt (25th of January Revolution) within this period and which resulted to the temporary absence of monitoring systems to regulate urbanization.

1. Introduction

With the overpopulation change in the Nile Delta, human activities in the region, like the establishment of new industrial projects, usually result in significant and rapid changes in different land covers. These rapid changes could create disastrous physical, biological and socio-economic problems. The reliable knowledge about how the land cover in such areas actually

E-mail address: mmelhattab@gmail.com
Peer review under responsibility of National Authority for Remote Sensing and Space Sciences.

http://dx.doi.org/10.1016/j.ejrs.2016.02.002
1110-9823

respond to environmental changes and human actions are prerequisite to making effective decisions in response to these environmental problems. Lack of such knowledge is a major impediment to the design of sustainable development strategies. Most recent studies have conducted to detect, monitor and assess these environmental changes in a number of regions in Egypt (El-Hattab, 2015a,b; El-Askary et al., 2014; Aymen et al., 2014). However, the traditional monitoring systems for assessing land cover changes, such as sampling methods and geographical surveys, are no longer sufficient (Rokni et al., 2015). Recent techniques of studying such changes depend on identifying differences in the state of objects or phenomena by observing them at different dates (Lu et al., 2004; Abdul Jabbar, 2008; Berberoglu and Akin, 2009; Chen et al., 2012). This detection process frequently employs the following two basic approaches:

(1) The *post classification approach* which is the comparative analysis of independently produced classifications for different dates (Alagu Raja et al., 2013).
(2) The *pixel-to-pixel approach* (Nemmour and Chibani, 2004; Hussain et al., 2013) which is a simultaneous analysis of multispectral images.

This study primarily used the post classification approach for detecting, monitoring and assessing land cover changes of one of the coastal zones in the north of Egypt, Abu Qir Bay zone. The zone is a coastal region that extends between longitudes 30°00′ and 33°30′ to the East and latitudes of 31°10′ and 31°30′ to the North. It is one of the important coastal areas in Egypt due to its location and socio-economic importance. Its coast extends along 47 km between Rosetta promontory and Abu Qir head, deepening landward for more than 27 km along its longest axis. It represents an ideal arc-shape embayment among the Mediterranean bays on the Egyptian northern coast, and is considered as one of the highly dynamic areas on the Nile Delta.

2. Data used

The data used in this study were collected from different sources. It consisted mainly of images from LANDSAT satellite covering the area of study in different dates, topographic maps, socioeconomic data, and field survey measures. Each of these types of data described briefly in the next section.

2.1. Satellite images

Three LANDSAT multispectral satellite images were used (WRS_PATH = 177 Starting Row = 038; Reference Datum = "WGS84", Reference Ellipsoid = "WGS84" Map Projection = "UTM", Projection = UTM, Zone Number = 36). They are acquired in different dates but still at the same month and conditions (for change detection reasons); 30 August 2000, 9 August 2004, and 31 August 2013. The spatial resolution of used images is 30 meters. Fig. 1 represents one of those used satellite images. Those three dates chosen to examine the changes and its rates are after and before 25th January, revolution in Egypt to measure the effect of human activities during these periods as well as the effect of the temporary absence of monitoring systems anticipated during these periods.

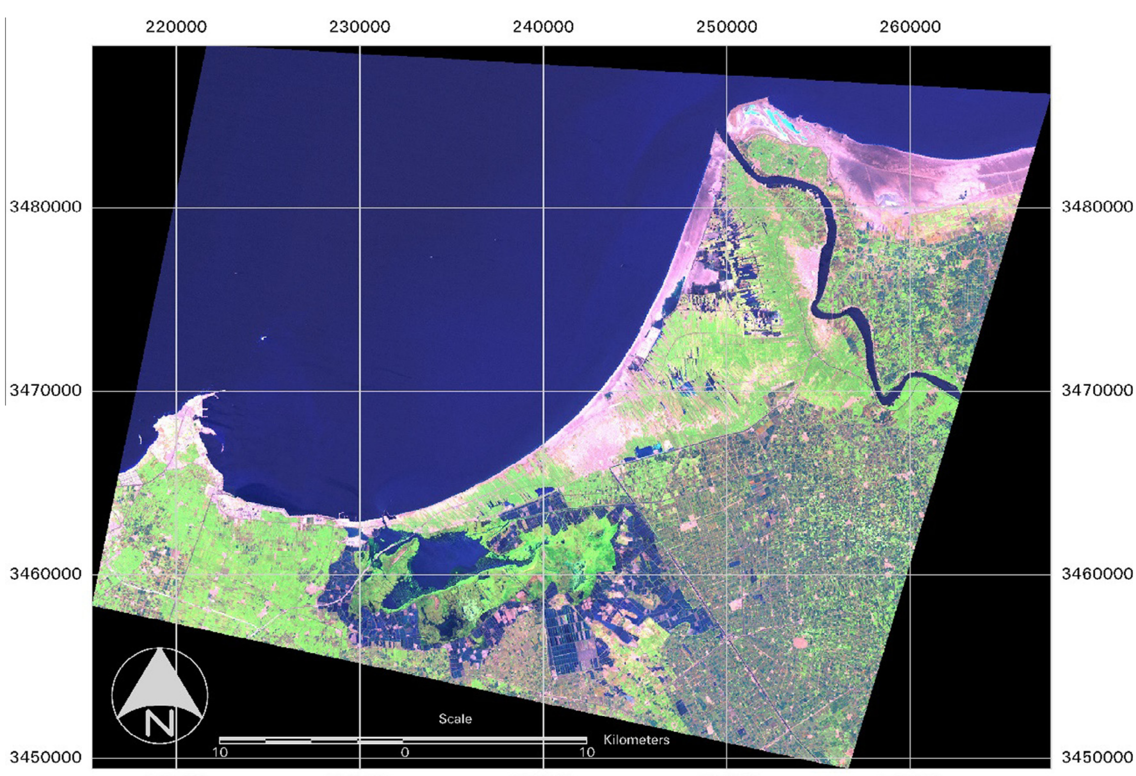

Figure 1 False color composite image of the study area, (year 2004).

2.2. Topographic maps

Six topographic maps were used in this study. The Egyptian General Survey Authority (EGSA) under the project of United States Agency produced these maps for International Development (Numbers 263-0132). Maps complied from aerial photographs were taken in 1991 and the field verification and completion was done in 1993. The scale of those topographic maps is 1:50,000. The six maps covered the following locations in the northern coastal zone; Kafr El-Dawar, Damanhour, Dessouk, Abu Qir, Rosetta, and Edfina.

As noticed, although these are the most recent available maps in Egypt, yet they expected to be different from reality, as they need critical updates, as they were collected some time ago. For that reason the maps are used only in annotation of the satellite image results, i.e. nomination of the different locations. Unfortunately, the six maps could not be used in the validation of the final classified maps as they were produced in older dates than the date of acquisition of the satellite images.

2.3. Field surveys

During several field visits paid to the study area, the various environmental problems facing the study area, like coastal erosion, water logging, and decrease of the number of palm trees, were observed. The data needed to undertake both image classification and accuracy assessment processes were obtained through different field visits. All field surveys were achieved through the standard remote sensing field survey way, using common tools used in such trips like DGPS, topographic maps, printout satellite image, and digital camera. The survey depends on identifying the exact position of clear areas representing each land cover, those areas are called training areas. Those training areas were used in both classification of satellite images and accuracy assessment.

2.4. Socioeconomic data

In order to obtain the effects of changes on the communities, and how it affect the land use changes, a most recent socioeconomic tabular data used. The source of the tabular data is Central Agency for Public Mobilization and Statistics (CAPMAS) based on the latest Egyptian census operation in 2006. The EGSLR model, as web mapping tool that created by author and others in 2014 to model the different scenarios of sea level rise on the Nile Delta coastal zone was used as a source of socioeconomic data maps and to verify the satellite image change detection results. Three socioeconomic maps were created using EGSLR tool, representing; family distribution, population, and occupational status (Figs. 2–4), those maps were used in explaining the land use changes accordingly to the changes in different land covers.

3. Methodology

The methodology followed two main processes; the first involved the use of digital image processing and the analysis of satellite image to produce a land cover thematic map (like

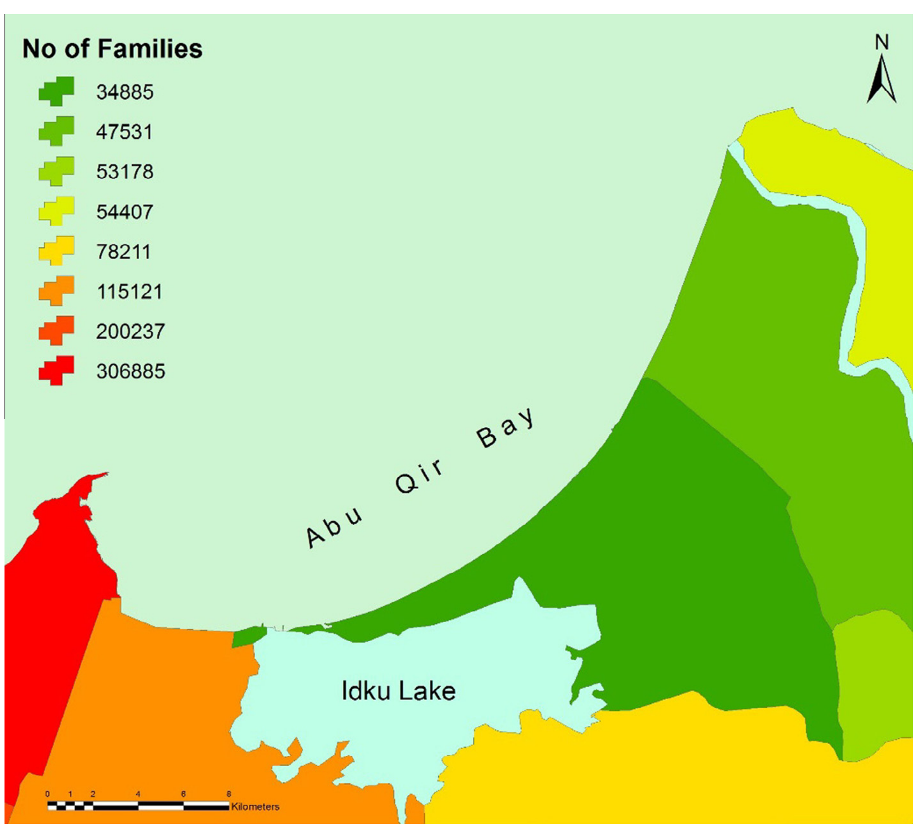

Figure 2 Family distribution in the study area.

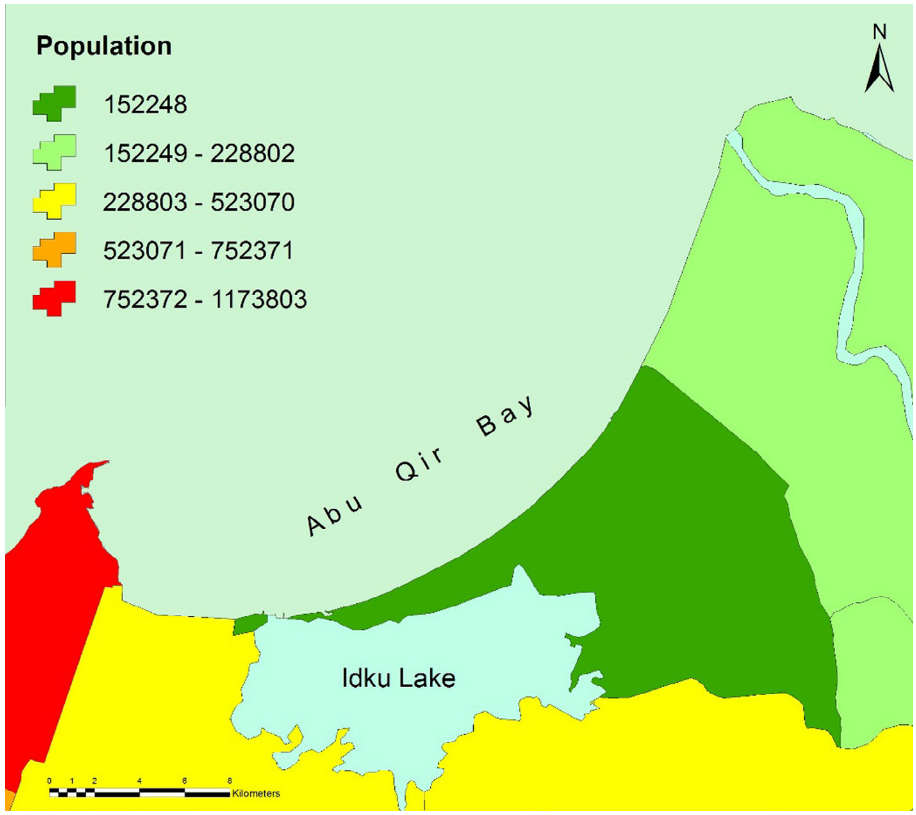

Figure 3 Population distribution in the study area.

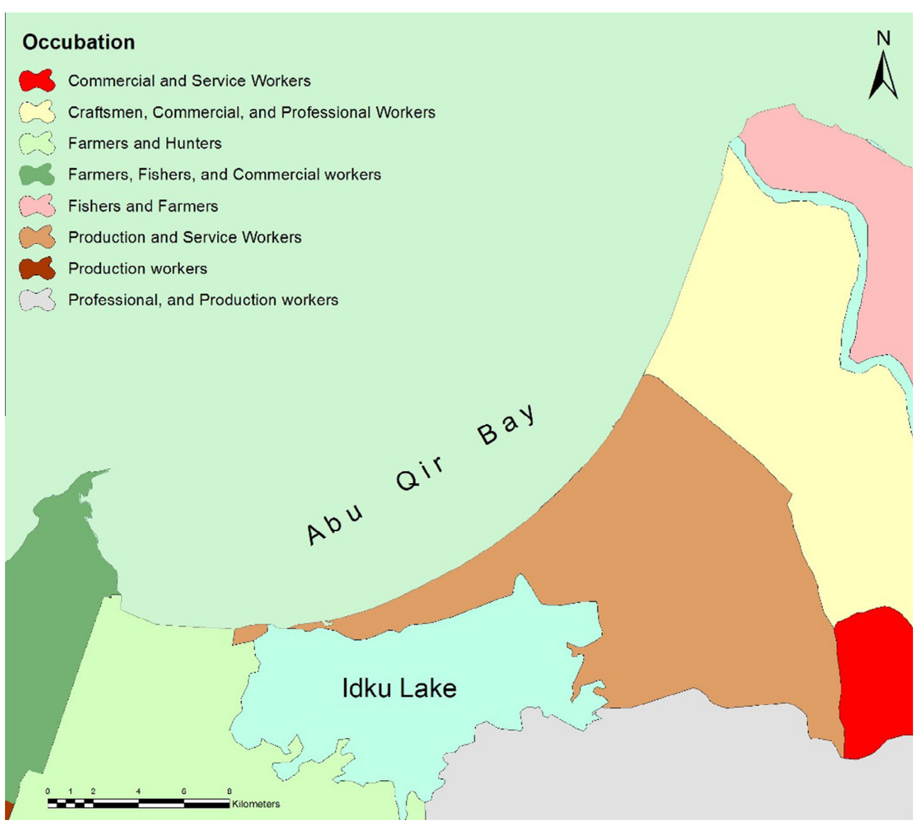

Figure 4 Occubational status in the study area.

Zhong et al., 2014), while the second dealt with the change detection analysis of the multi-date satellite images using the post classification approach (like El-Hattab, 2015a).

The first process consisted of a number of steps. The first step (*Image pre-processing*) involved specifying the sub-areas to be studied and the geometric correction of the images used. The second step (*Image processing*) involved both unsupervised and supervised classification and the accuracy assessment. The third step (*Post processing*) was to prepare the output of the final maps which resulted from the classification process (like smoothing). Both statistical and visual data were then prepared and interpreted.

3.1. Image pre-processing

Typical pre-processing operations include applying the geometric correction technique that helps to bring the digital images into registration with the Earth's surface (i.e. georeferencing). Through this technique, visual identification of identical points (i.e. ground control points (GCPs)), including those that were collected during field surveys using Differential Global Positioning System (DGPS), was done on both the image and the topographic map. Afterward, the satellite images were geometrically corrected using the polynomial transformation process and the Universal Transverse Mercator (UTM) projection system. The overall root mean square (RMS) error value of the final images produced ranged from 0.2 to 0.6 pixel, which was an acceptable error value for the current study.

3.2. Images classification

The hybrid classification algorithm that represents unsupervised classification followed by a supervised classification was applied to extract land cover and land use classes.

3.2.1. Classification scheme

The CORINE standard classification scheme was used in the present study (with minor modifications like palm trees). This scheme is established to provide a practical system for the description and monitoring of habitat types for national, regional and local nature inventory, as giving standard names for each land cover is needed to harmonize all results of classification all over the world. Also, it aimed at gathering information relating to the environment on certain priority topics such as land cover, coastal erosion, biotopes, etc. (Centre for Ecology and Hydrology, 2002; György Büttner, 2014).

3.2.2. Unsupervised classification

ISODATA algorithm as a function in ERDAS IMAGINE software was used to carry out the unsupervised classification of the area under investigation. ERDAS is a remote sensing application with raster graphics editor abilities designed for geospatial applications by ERDAS Inc. The ISODATA algorithm uses spectral distance as in the sequential method, but iteratively classifies the pixels, redefines the criteria for each class, and then re-classifies the pixels again so that the spectral distance patterns in the data gradually emerge. Through this

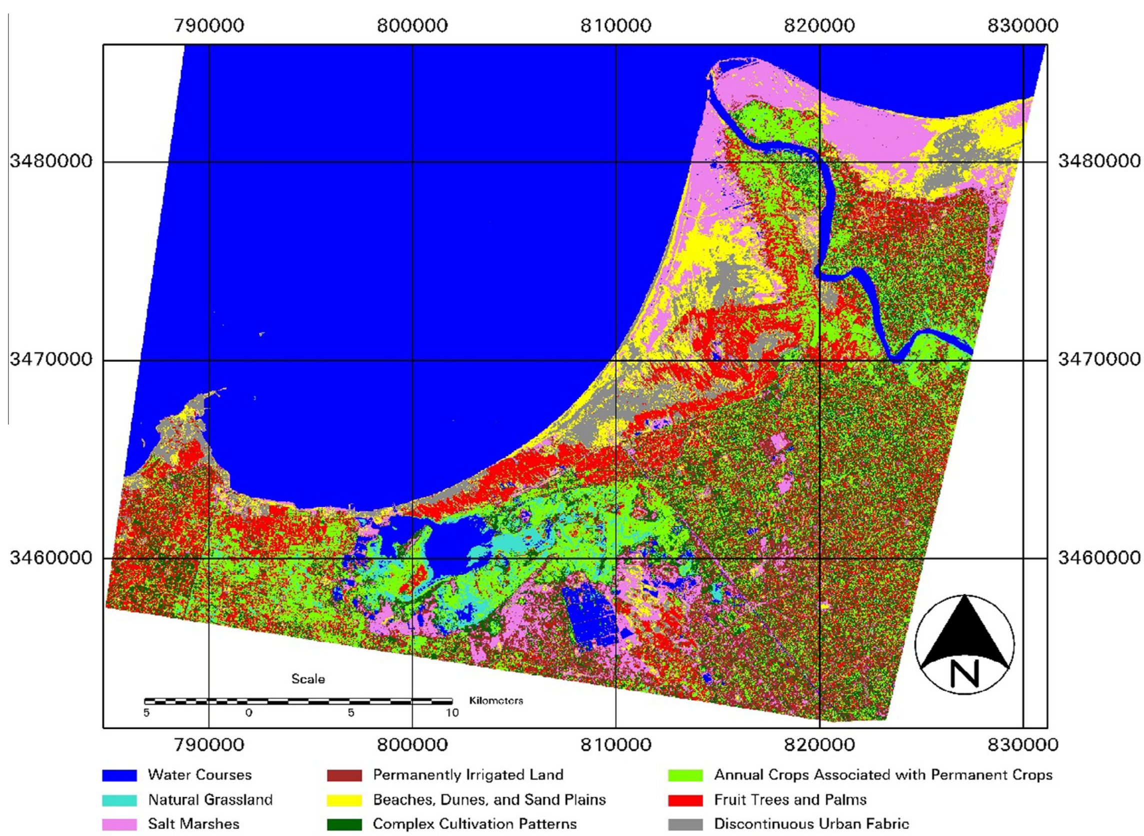

Figure 5 Corine land cover supervised classification image of the study area (LANDSAT, year 2000).

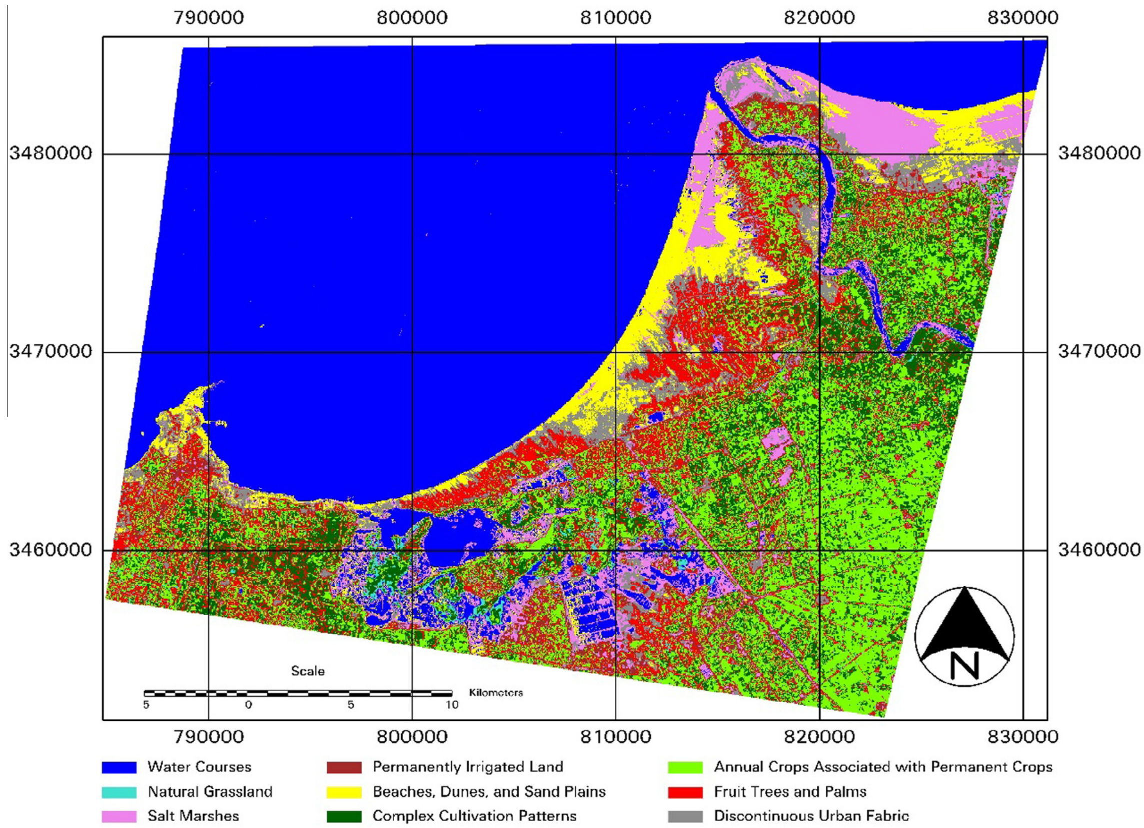

Figure 6 Corine land cover supervised classification image of the study area (LANDSAT, year 2004).

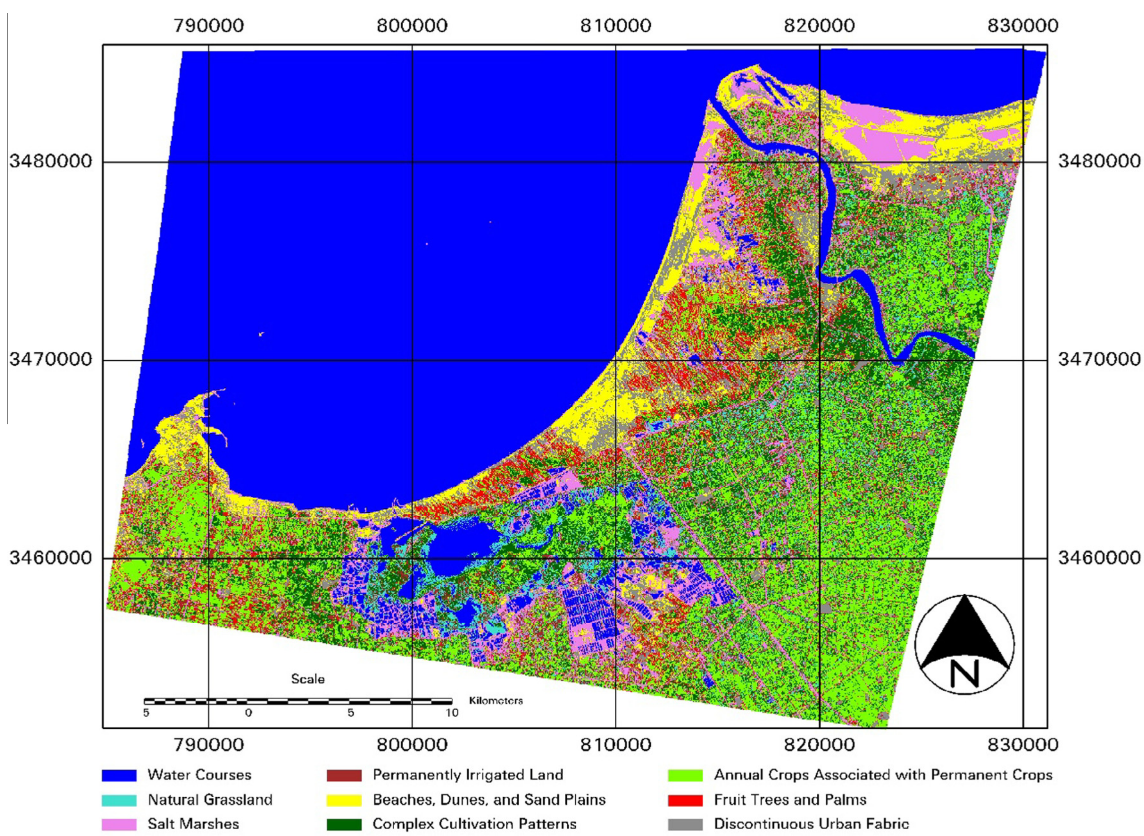

Figure 7 Corine land cover supervised classification image of the study area (LANDSAT, year 2013).

Table 1 Changes occurred between years 2000 and 2004 (in km^2).

Class name	2000 area (km^2)	2004 area (km^2)	Change in area (km^2)	Change % from original Area
Water courses	576.60	572.34	−4.26	**−0.74%**
Natural grassland	23.21	15.02	−8.19	**−35.30%**
Salt marshes	80.70	63.97	−16.73	**−20.73%**
Permanently irrigated land	75.85	49.04	−26.81	**−35.34%**
Beaches, dunes, and sand plains	52.73	52.02	−0.71	**−1.34%**
Complex cultivation patterns	95.89	117.05	21.16	**22.07%**
Annual crops associated with permanent crops	145.07	188.88	43.81	**30.20%**
Fruit trees and palms	133.31	109.89	−23.42	**−17.57%**
Discontinuous urban fabric	52.25	47.67	−4.58	**−8.77%**

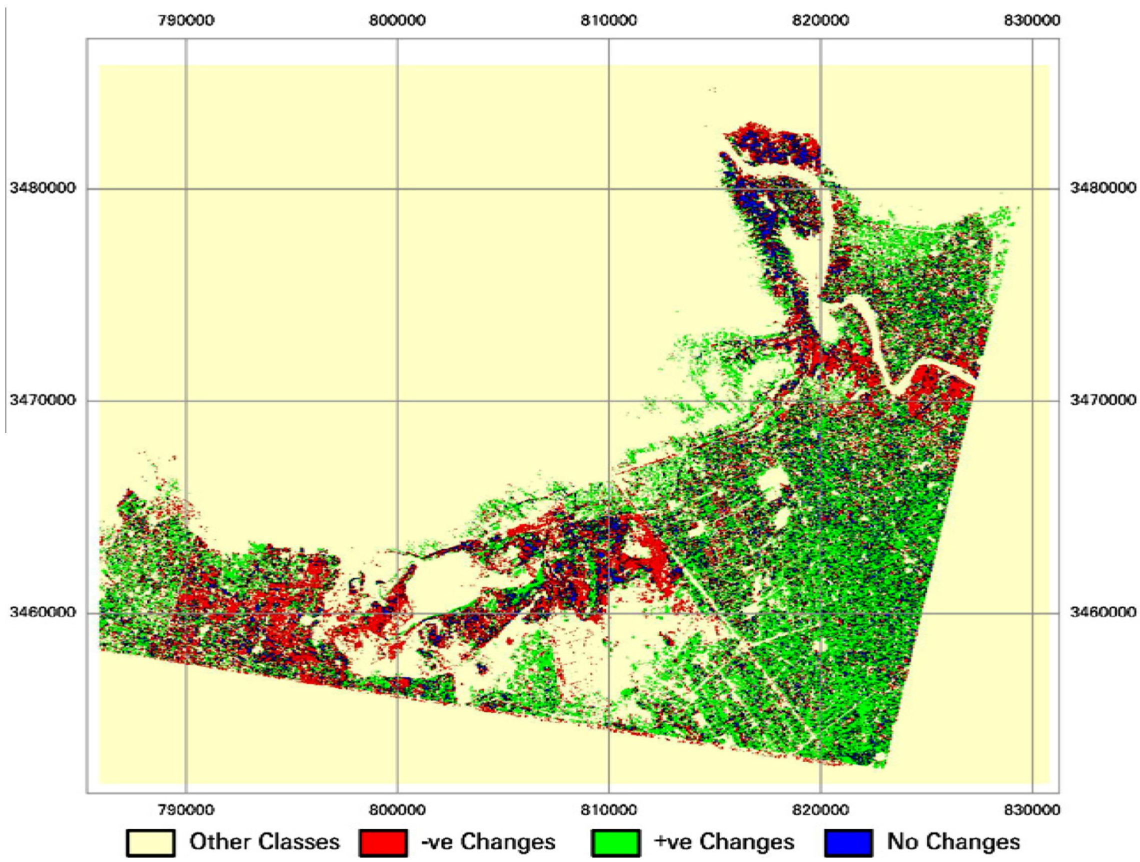

Figure 8 Changes in "annual crops associated with permanent crops" class, between 2000 and 2004.

process, the convergence threshold was set to 0.99 to produce 100 classes using 50 different iterations. All the 100 classes correlated based on their extracted spectral signature to produce only nine separate land cover classes.

3.2.3. Supervised classification

The maximum likelihood classifier used to carry out supervised classification. The spectral signature library that was produced through the training stage, both in the laboratory and field, was fed into the maximum likelihood classifier to classify the satellite images. CORINE classification scheme was used during this stage, as well as CORINE Land Cover (CLC) nomenclature (György Büttner, 2014).

3.3. Change detection assessment

Changes occurring on the earth's surface can be attributed to either natural or anthropogenic forces. Natural changes are related to both seasonal and annual variations in climatic conditions, and are often reflected by variations in natural land cover. The impacts of human-induced changes are not necessarily restricted to areas where intentional modification of the landscape has taken place. The change detection procedures assume that a change in surface cover or surface material will produce a corresponding change in the reflectance of the study area. Many change detection techniques have developed recently; the most commonly used are image

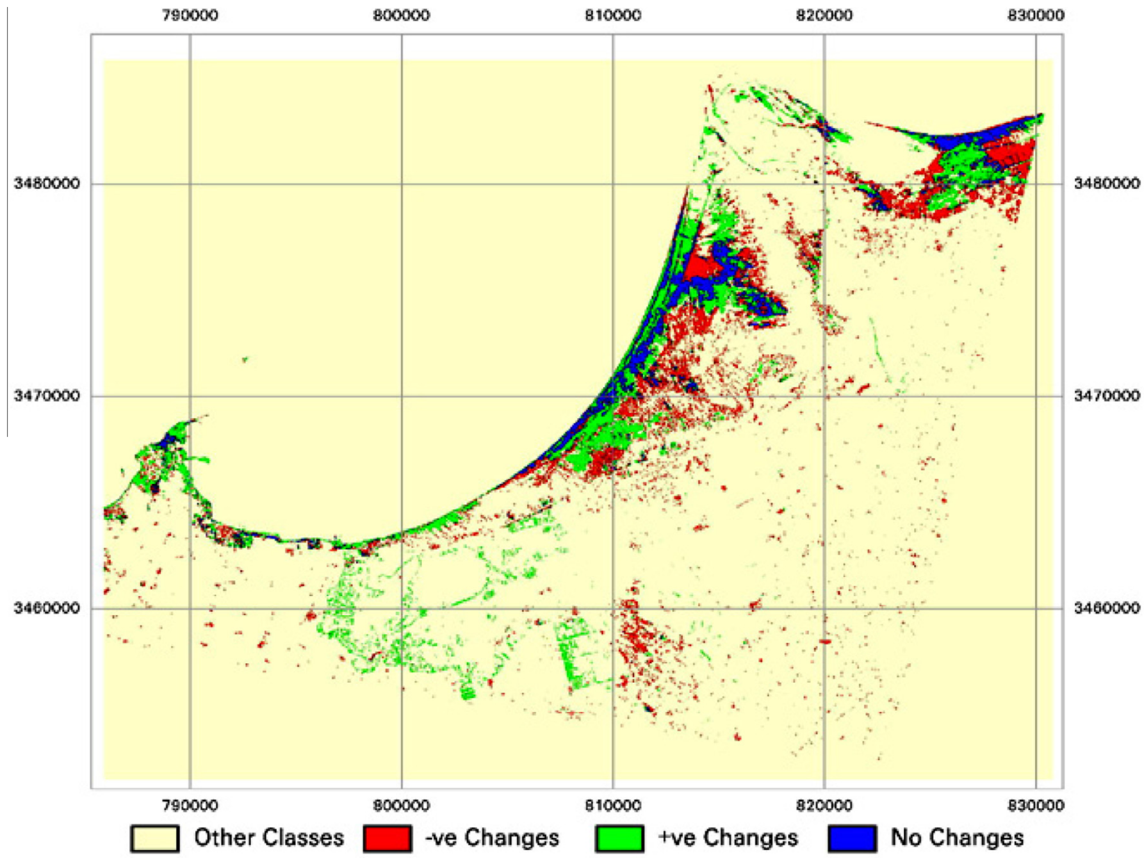

Figure 9 Changes in ''beaches, dunes, and sand plains'' class, between 2000 and 2004.

Table 2 Cross tabulation results between 2000 and 2004 Scenes (in area km^2).

2000 classes	2004 classes								
	Water courses	Natural grassland	Salt marshes	Per. irreg. land	Beaches, dunes, sand plains	Complex cultivation pattern	Ann. crops	Fruit trees and palms	Discontinuous urban fabric
Water courses	548.78	0.32	6.97	0.72	1.99	0.38	0.82	0.53	0.68
Natural grassland	3.27	1.65	2.45	1.17	0.63	5.95	5.07	2.52	0.53
Salt marshes	8.05	1.01	31.68	6.29	11.41	1.83	4.68	4.77	10.69
Per. irreg. land	2.52	1.58	5.93	9.39	0.73	12.05	28.65	11.29	2.35
Beaches, dunes, and sand plains	1.75	0.58	7.67	2.82	17.36	0.52	1.40	6.63	13.88
Complex cultivation pattern	3.02	2.62	3.40	6.37	0.63	23.36	41.56	12.38	1.03
Ann. crops	3.24	3.61	3.36	10.21	0.73	44.61	54.35	22.64	1.05
Fruit trees and palms	0.68	2.65	1.03	9.06	0.41	26.90	48.92	39.92	2.45
Discontinuous urban fabric	0.73	0.98	1.13	2.96	18.04	1.15	3.19	9.11	14.92

differencing, principal component analysis and post-classification comparison (Lu et al., 2004). The post-classification change detection technique was chosen for use in this study, because it does not only give the size and distribution of changed areas (either negative or positive), but it also gives the percentages of other land cover classes that share in the change in each land cover class individually. The change detection technique used has a number of consequent steps and sub-steps. First, the images representing all dates studied were supervised and classified using maximum likelihood classifier algorithm, CORINE classification scheme was then used to nominate land cover classes, and finally, the classification accuracy was calculated for all resulted classification images. Second, the changes of the three date ranges (2000–2004, 2004–2013, and 2000–2013) for the classified images calculated using the cross tabulation technique.

Table 3 Changes occurred between years 2004 and 2013 (in km^2).

Class name	2004 area	2013 area	Change in area (km^2)	Change % from original area
Water courses	572.336	580.3695	8.0335	+1.4%
Natural grassland	15.02	39.4443	24.4243	+62.6%
Salt marshes	63.9664	79.5402	15.5738	+24.3%
Permanently irrigated land	49.0412	62.5815	13.5403	+27.69%
Beaches, dunes, and sand plains	52.02	60.5439	8.5239	+16.3%
Complex cultivation patterns	117.0492	114.6294	−2.4198	−2.06%
Annual crops associated with permanent crops	188.8788	189.5211	0.6423	+0.34
Fruit trees and palms	109.89	43.1982	−66.6918	−60.7%
Discontinuous urban fabric	47.668	58.7799	11.1119	+23.6%

Finally, a simple technique was used to visualize the changes in each land cover class.

After that, all change detection results were combined with the socioeconomic data to access the effects of those changes on man's behavior and how could that new behavior reflect on changes in land uses. That verification step has achieved by EGSLR model, through modeling the changes pattern and expect the future figure.

4. Results and discussion

Results obtained from the classification, change detection, and modeling processes are illustrated and discussed in the present section.

A hundred signatures were obtained by combining signatures from both ISODATA and field survey. Those signatures were compared, and then the similar ones were merged. As a result, only nine separable land cover classes have obtained; these were as follows:

1. Water courses
2. Natural grassland
3. Salt marshes
4. Permanently irrigated land
5. Beaches, dunes, and sand plains
6. Complex cultivation patterns
7. Annual and permanent crops
8. Fruit and palm trees
9. Discontinuous urban fabric

Figs. 5–7 illustrate the supervised classification images of years 2000, 2004, and 2013 respectively.

4.1. Water courses

This class included all water bodies types (fresh, brackish, and saline) present in the region. This class contained mainly the Mediterranean sea water, lake Idku, river Nile, Ghallyoun lagoon (north of Rosetta Promontory), and some wet lands disseminated in the region indicating the flooded agriculture fields.

4.2. Natural grassland

This class represented the naturally grown short vegetation, like aquatic plants floating on the river Nile and Lake Idku, in addition to the scattered grass in agricultural fields.

4.3. Salt marshes

The salt marshes class was represented frequently in the area studied. It existing near a number of forms like the drains and canals on banks, dry sabkhas, and the poorly maintained portions of the fish farms located in the south of the study area (i.e. the southern part of Lake Idku).

4.4. Permanently irrigated land

This class represented exposed agricultural lands and plowed fields that are vegetated all over the year and irrigated mainly by river Nile's water. Hence, it could contain also a complex irrigation system.

Table 4 Cross tabulation results between 2004 and 2013 scenes (in area km^2).

2004 classes	2013 classes								
	Water courses	Natural grassland	Salt marshes	Per. irreg. land	Beaches	Com. cultivation	Ann. crops	Fruit trees and palms	Discontinuous urban fabric
Water courses	554.09	4.09	8.99	0.98	1.64	0.72	0.50	0.10	0.87
Natural grassland	0.97	2.23	1.56	1.99	0.55	2.09	3.53	1.38	0.72
Salt marshes	11.37	3.47	24.37	3.45	12.84	1.45	1.73	0.73	4.53
Per. irreg. land	1.16	2.95	9.15	8.39	2.20	4.86	9.51	4.79	6.02
Beaches, dunes, sandplains	4.52	0.99	7.97	0.82	23.19	0.23	0.33	0.89	13.06
Comp. cultivation pattern	0.80	9.18	4.16	11.99	0.56	19.71	47.34	3.97	1.32
Ann. crops	1.03	11.77	9.91	19.24	1.36	45.87	86.39	9.86	3.42
Fruit trees and palms	0.70	3.71	7.24	12.67	5.04	19.29	34.15	18.03	8.99
Dis. urban fabric	1.35	0.79	5.72	2.23	13.13	0.53	1.53	2.87	19.49

4.5. Beaches, dunes, and sand plains

This class which is represented in one ecosystem (i.e. the coastal zone) has three different forms. All the three features were present mainly along the coastal area, except for the coastal dunes that were clearly noticed especially around Rosetta city.

4.6. Complex cultivation patterns

This class was represented by the cultivation areas of different types of species existing very close to one another. This is because the majority of farmers owned small size lands, and they do not follow specific agriculture plans (each one plants a different crop), thus producing mixed signatures and making the classification process difficult. Some water floating plants have also identified under this class due to the similarity of its spectral characters of this class.

4.7. Annual and permanent crops

The annual and the permanent crops class is spread over large areas in the region and it exists all over the year.

4.8. Fruit and palm trees

The study area is one of the famous and important areas of growing palm trees in Egypt. Based on this fact, the name of this class was slightly modified from the original one in the CORINE classification scheme by adding the word "palm" to the word "fruit" and "trees" to suit the nature of the study area. The study area is not only famous for its palm trees, but with banana, guava, and orange. Palm trees could be identified easily from fruit trees according to its special color and pattern. Palm trees appear in pale red in false color composite, while regular fruit trees take the dark red color. In terms of their arrangement pattern, palm trees take a radiation pattern.

4.9. Discontinuous urban fabric

The discontinuous urban fabric represented both Rosetta and Idku cities, in addition to small towns like Kafr El-Dawar. It was also clearly noticeable that there are a large number of small villages that are scattered all over the agricultural lands in the region studied as they appeared as small and medium scattered areas on the satellite images.

4.10. Accuracy assessment

Both training areas (which were created earlier during the training stage of supervised classification) and those points that were selected randomly (equalize random) by the software were assessed. The number of the random points for each class is equal to 90 (equal to n (n + 1) where n is the number of classes). At the position of each of those completely random points, a polygon of dimensions 9 * 9 pixels was created, and then the class type was examined. The overall classification accuracy for the classification of 2000, 2004, and 2013 sce-

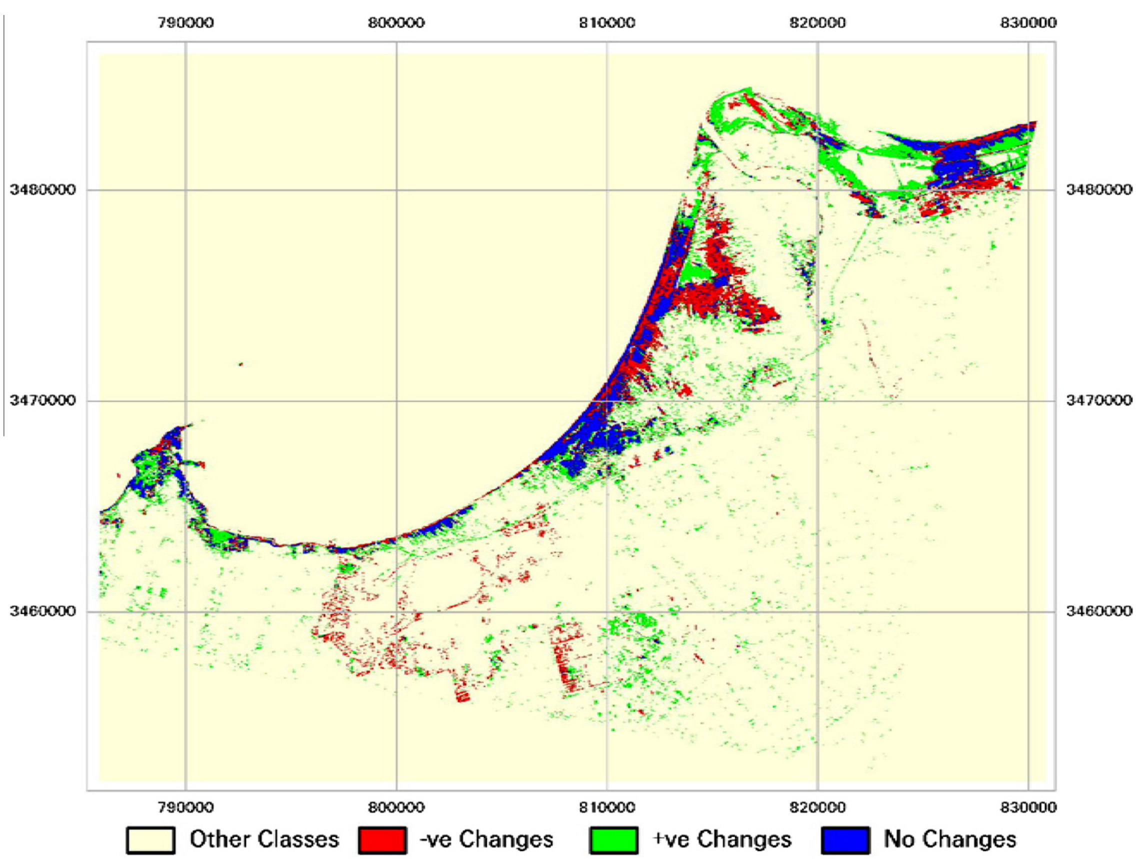

Figure 10 Changes in "beaches, dunes, and sand plains" class.

nes were equal to 96.2%, 97.15%, and 98.4%, respectively, and this was found acceptable for accuracy assessment.

4.11. Change detection results

As mentioned earlier, the change detection analysis started from the most recent images to the older ones. Thus, the images used divided the period span of the study from 2000 to 2013 into the following three periods of change:

4.11.1. Changes between 2000 and 2004

By applying the cross tabulation technique on classified images of the years 2000 and 2004, statistical results were obtained showing the land cover changes that occurred within the period from 2000 to 2004 (Table 1). To visualize the changes that occurred in that period, a simple technique (El-Hattab, 2015a) was used to create a final change image for each land cover class, representing the areas of change, either positive or negative, in addition to the areas that showed no change. Examples of the final nine change detection images of each land cover class are shown in Figs. 8 and 9.

The results of the cross-tabulation analysis are illustrated in Table 2. Those changes indicate that there is a loss in several land covers like natural grassland (about 8 km^2) as it changed to cultivated lands. This is highly likely due to the young farmers' decision to try to invest in relatively low-priced, yet quality areas for agricultural purposes.

Another loss appeared in the salt marsh areas (about 16 km^2) as it changed to water courses (i.e. fish farms) as some farmers seem to prefer to invest in rearing fish that give higher profit returns rather than produce agriculture products. In addition, salt marshes also changed to urban areas in other scattered places due to random building constructions.

Another form of change was noticed in the irrigated land area (27 km^2) as they changed by having other types of agricultural products. Perhaps this is because farmers are trying to grow products that yield higher profits for them.

Finally, a critical change in the palm trees' area (lost 4 km^2) which changed into agricultural lands and urban areas. Probably this is due to the low prices of palm trees' areas which are usually turned by farmers/settlers into agricultural lands that grow more profitable crops or used for building random constructions.

Changes also indicate an increase in other land covers like complex cultivation areas (21 km^2) and annual and permanent crops' areas (43 km^2) which seem to have replaced other types of agriculture mainly for economic reasons.

4.11.2. Changes between 2004 and 2013

Following the same procedure described in the previous section, supervised classification images of 2004 and 2013 were compared and statistical results were obtained. By comparing the statistics, changes were calculated and are represented in Table 3.

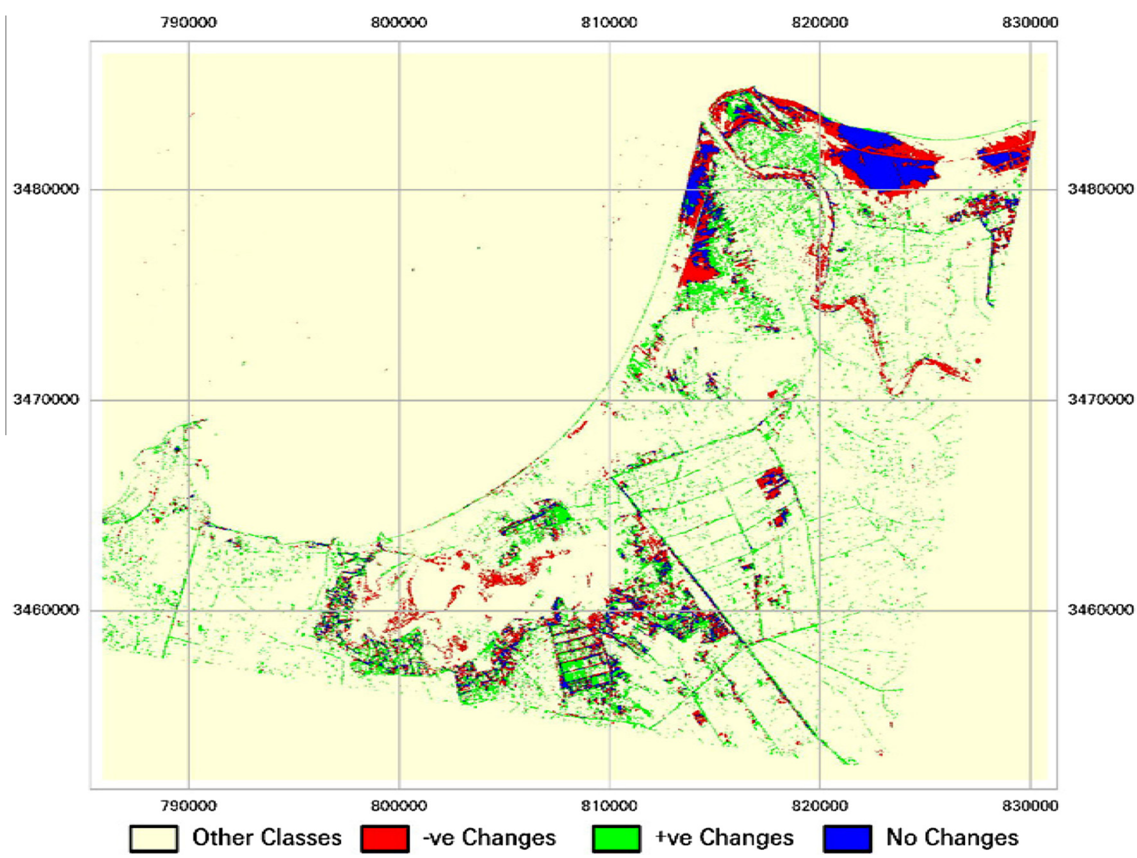

Figure 11 Changes in "salt marshes" class.

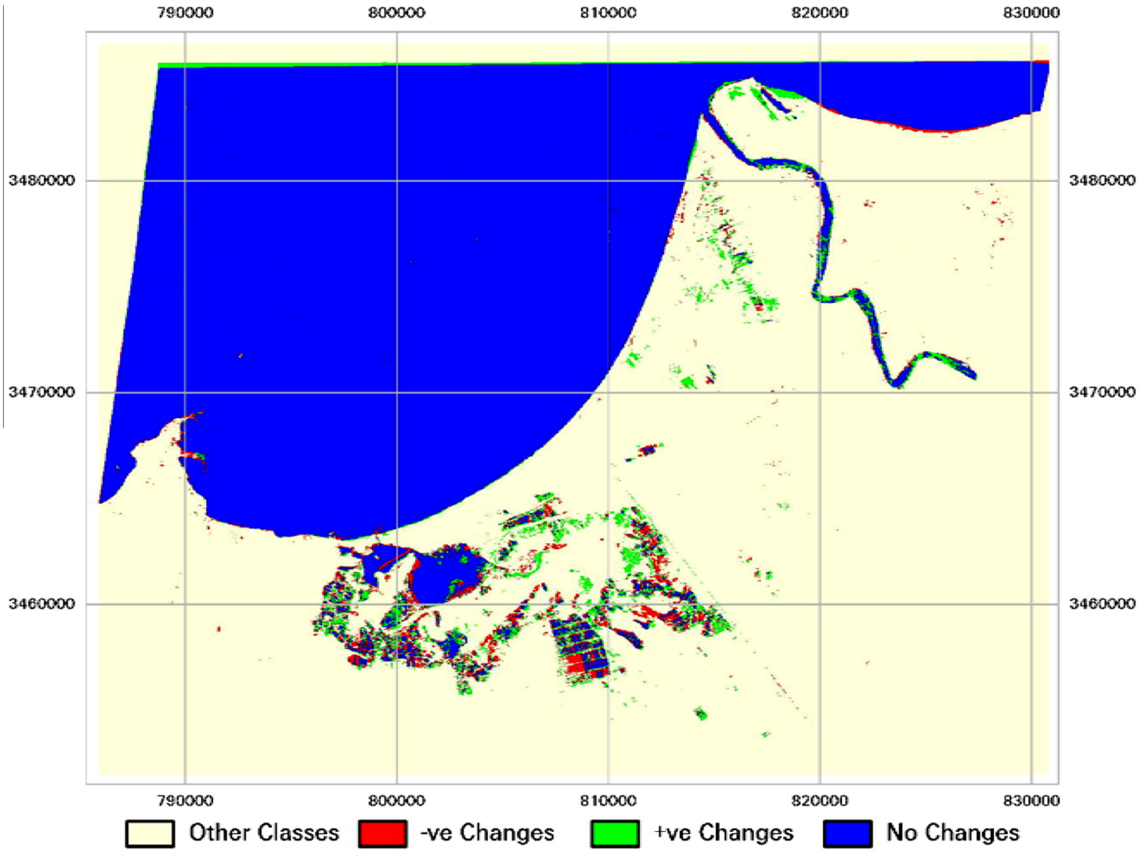

Figure 12 Changes in "water courses" class.

Results of the cross-tabulation analysis for the nine land cover classes for both years are illustrated in Table 4. A final change image for each land cover class was created using the same simple technique that was used earlier. Three examples of change detection images are shown in Figs. 10–12.

During this period, remarkable negative changes were identified especially in fruits and palm trees area (loss of about 66 km^2) due to rapid urbanization and industrialization along the coastline, and thus the occupational status changed from farmers to production and professional workers.

4.11.3. Changes between 2000 and 2013

After applying the change detection techniques for the first period (between years 2000 and 2004) and for the second period (years 2004 and 2013), the extracted results were used to obtain tables that show the rate of changes that occurred through the whole study period (13 years).

The total changes are summarized in Tables 5 and 6. The two tables show the percentage of changes in each land cover type. The most remarkable change is witnessed in the expansion of both types of vegetation over the palm and fruit trees. The more plausible explanation for this change is that most farmers during that period found that the price of the palm trees and their products are very low compared with other agriculture products, so they cut the palm trees and replaced them with other crops that yield more profit to them. Also, some areas of trees were converted into urban areas to serve the new industrial projects in the region (e.g. liquid gas project), and it is noticed from occupation map which indicates that people in this area have changed their occupation from farmers to professional and production workers.

Table 5 Changes occurred between years 2000 and 2013 (in percentages).

Class name	2000 area (%)	2004 area (%)	2013 area (%)
Water courses	46.67	47.07	47.24
Natural grassland	1.88	1.24	3.21
Salt marshes	6.53	5.26	6.47
Permanently irrigated land	6.14	4.03	5.09
Beaches, dunes, and sand plains	4.27	4.28	4.93
Complex cultivation patterns	7.76	9.63	9.33
Annual crops associated with permanent crops	11.74	15.53	15.43
Fruit trees and palms	10.79	9.04	3.52
Discontinuous urban fabric	4.23	3.92	4.78

In addition, some positive changes occurred in some land covers as in the case of natural grassland areas, which represent a middle phase of development between agricultural lands and urban areas, as farmers turn them into areas for building their houses (or to sale it as building area with much higher price). Some farmers, however, seem to neglect their agriculture land on purpose.

In addition, changes identified in the study area were not only changes of a specific land cover to another, but they were

Table 6 Changes occurred between years 2000 and 2013 (in km^2).

Class name	2000 area	2004 area	2013 area
Water courses	576.60	572.34	580.37
Natural grassland	23.21	15.02	39.44
Salt marshes	80.70	63.97	79.54
Permanently irrigated land	75.85	49.04	62.58
Beaches, dunes, and sand plains	52.73	52.02	60.54
Complex cultivation patterns	95.89	117.05	114.63
Annual crops associated with permanent crops	145.07	188.88	189.52
Fruit trees and palms	133.31	109.89	43.20
Discontinuous urban fabric	52.25	47.67	58.78

sometimes changes in its use. A good example of this is the change that occurred in the water courses class which changed from being a lake to being a fish farm especially in the southern parts of Lake Idku, where farmers found that a hectare of land give double profit when it is used as a fish farm rather than in agriculture.

Another noticeable change was also witnessed in the urban fabric class, which was almost stable or decreased a little during the years 2000–2004, but increased dramatically in the period from 2004 to 2013. This was most likely due to the political conditions in Egypt within this period and to the absence of monitoring systems after the 25th January revolution, 2011.

5. Conclusions

With the overpopulation change in the Nile Delta, human-induced changes have converted the uses of many land covers to new uses such as fish-farming, urban expansion and building internal and regional highways. The present study shows that satellite remote sensing based on land cover mapping is very effective for detecting coastal LULC changes. The high-resolution satellite images such as Landsat TM and ETM are excellent sources for providing accurate information about land covers' changes which are necessary for decision makers and planners. In terms of the techniques used in the study, it was found that the post-classification change detection technique was able to produce more accurate results than traditional change detection techniques. In addition, as land cover changes have a high correlation to land use changes, a modern model like EGSLR was of great benefit in monitoring change pattern and forecasting future change rates.

Using EGSLR tool and socioeconomic data indicates that there are changes in different land covers in the area of Abu Qir Bay zone reflecting the changes in occupation status of settlers in specific areas. For example, in south of Idku Lake zone, it was observed that the occupation of settlers changed from being unskilled workers to fishermen based on the expansion of the area of fish farms. Change rates also increased dramatically in the period from 2004 to 2013 as remarkable negative changes were found especially in fruits and palm trees (loss of about 66 km^2) due to the change in agricultural products produced by farmers to gain more profits as well as industrialization in the coastal area. Also, a rapid urbanization was monitored along the coastline of Abu Qir Bay zone due to the political conditions in Egypt (25th of January Revolution) within this period and which resulted from the temporary absence of monitoring systems to regulate urbanization.

6. Recommendations

(1) Based on the findings of this study proper land use management strategies within an umbrella of coastal zone management plans need to be established and implemented very soon. Those strategies help act to protect this important coastal zone from any misuse and to avoid its destruction on the long run due to human actions.
(2) Results indicate all the environmental stresses that lead to changes, it is recommended that Civil protection agency and Urban Planning agency should improve the monitoring, data collection, satellite images analysis and evaluation system.
(3) It is recommended to establish and improve a system to predict and warn against any disaster that may happen from new unplanned extension, and control illegal building without planning to avoid the negative effects of future risks.
(4) Decision makers should plan to establish a strategy to keep agricultural land from agricultural encroachment, specially near coastal cities.

Acknowledgment

The author acknowledges the SMART project for providing the field survey fund, and for assisting in the classification process through CORINE Land Cover classification scheme. In addition, the author also acknowledges the great efforts of all the scientific team members of SMART project for their valuable assistance.

References

Abdul Jabbar, M.F., 2008. Application of change detection techniques in Marsh areas, South Iraq. Iraqi Bull. Geol. Min. 4 (1), 105–115.

Alagu Raja, R.A., Anand, V., Senthil Kumar, A., Sandeep Maithani, V., Kumar, Abhai., 2013. Wavelet based post classification change detection technique for urban growth monitoring. J. Indian Soc. Remote Sens. 41 (1), 35–43.

Berberoglu, S., Akin, A., 2009. Assessing different remote sensing techniques to detect land use/cover changes in the eastern Mediterranean. Int. J. Appl. Earth Obs. Geoinf. 11, 46–53.

Centre for Ecology and Hydrology, 2002. Natural environment research council, european environment agency european topic centre on nature protection and biodiversity EUNIS habitat classification work programme. In: Dorian Moss, Cynthia E. Davies, (Ed.), Cross-references between the EUNIS Habitat Classification and the Nomenclature of CORINE Land Cover.

Chen, G., Hay, G.J., Carvalho, L.M.T., Wulder, M.A., 2012. Object-based change detection. Int. J. Remote Sens. 33 (14), 4434–4457.

El-Askary, H.M., Abd Mawla, S.H., Li, J., El-Hattab, M.M., El-Raey, M., 2014. Change detection of coral reef habitat using landsat-5 TM and landsat-7 ETM+ and landsat 8 OLI data in the Red Sea (Hurghada, Egypt). Int. J. Remote Sens. 35 (6), 2327–2346.

El-Hattab, M.M., 2015a. Change detection and restoration alternatives for the Egyptian lake maryut. Egypt. J. Remote Sens. Space Sci. 18, 9–16.
El-Hattab, M.M., 2015b. Improving coastal vulnerability index of the Nile Delta coastal zone, Egypt. J. Earth Sci. Clim. Change 6 (8), 293, Elsevier.
György Büttner, 2014. CORINE land cover and land cover change products. Chapter: Land Use and Land Cover Mapping in Europe, Volume 18 of the series Remote Sensing and Digital Image Processing pp. 55–74.
Hussain, M., Chen, D., Cheng, A., Wei, H., Stanley, D., 2013. Change detection from remotely sensed images: from pixel-based to object-based approaches. ISPRS J. Photogramm. Remote Sens. 80, 91–106
Lu, D., Mausel, P., Brondizio, E., Moran, E., 2004. Change detection techniques. Int. J. Remote Sens. 25 (12), 2365–2407.
Nemmour, H., Chibani, Y., 2004. Comparison between object- and pixel-level approaches for change detection in multispectral images by using neural networks. In: Proc. SPIE 5238. Image and Signal Processing for Remote Sensing.
Rokni, K., Ahmad, A., Solaimani, K., Hazini, S., 2015. A new approach for surface water change detection: integration of pixel level image fusion and image classification techniques. Int. J. Appl. Earth Obs. Geoinf. 34, 226–234.
Solyman, Aymen A., El-Hattab, Mamdouh M., Rifai, Rifai I., Fakhar, Waleed M.T., 2014. An integrated web mapping solution to assess the effect of SLR on the Northern coast of EGYPT – EGSLR. In: Bandrova et al. (Eds.), Thematic Cartography for the Society, Lecture Notes in Geoinformation and Cartography. Springer International Publishing, Switzerland. http://dx.doi.org/10.1007/978-3-319-08180-9_3.
Zhong, Bo, Ma, Peng, Nie, AiHua, Yang, AiXia, Yao, YanJuan, Lü, WenBo, Zhang, Hang, Liu, QinHuo, 2014. Land cover mapping using time series HJ-1/CCD data. Sci. China Earth Sci. 57 (8), 1790–1799.