

Land Use /Land Cover Change Detection Analysis for Eastern Nile Delta Fringes, Egypt

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Abstract

Egypt has turned its attention to develop many new areas for agricultural development, such as the fringes of the Nile Valley, the eastern, western fringes of the Nile Delta, and also to the desert areas. In this research, integration of GIS and remote sensing (RS&GIS) were used in the South Eastern Nile delta region to follow the change in land use/cover and to assess the change in the agricultural lands in the desert areas. Three satellite images for years 1992, 2002, 2015 were used to produce the land use/cover maps using the maximum likelihood method by selecting five classes for land cover as (Agricultural, water, desert, and urban). The results of the accuracy assessment were evaluated as 85%, 86.2%, and 87.5% for the years 1992, 2002, and 2015. The change detection maps were produced between (1992-2002), (2002-2015) and (1992-2015). To follow up the increase in reclaimed areas that previously planned for reclamation by the National Water Resources Plans. More change detection statistics were performed. The results showed an increase in the area of agricultural lands within the desert regions, with values that are aligned with the areas proposed in the previous national water plans. The area of reclamation lands of the existing reclamation projects started before 1992 increased by 17527.6 (feddan) from the year 1992 to 2015 compared to 115436 feddan for the reclamation lands planned by the Land master plan from (1992 to 2017) for the same period of years. Finally, we can consider the integration between GIS and remote sensing data as an important and powerful tool for accurately detection land use/land cover changes over the study area. Also, these tools were considered very useful for the planning of sustainable management for water resource plans.

Keywords: Geographical Information Systems (GIS), Remote Sensing (RS), Land-use/ cover, change detection, the South Eastern Nile delta region.

DOI: 10.7176/JEES/10-10-07

Publication date:October 31st 2020

1- Introduction

The continuous growth of population increases dramatically in Egypt, especially in the last century. Most of this increase concentrated in the Nile Delta Region, Therefore, successive governments have paid great attention to the problem of overpopulation and its extent related to the continuous demand for the agricultural sector with increasing agricultural production. Therefore, Egypt has turned its attention to develop many new areas for development, such as the fringes of the Nile Valley and the eastern and western fringes of the Nile Delta, and also to the desert areas. During 1997 to 2017, increasing in land reclamation areas was 3.4 million faddan for different areas of Egypt (Abdel Salam et al., 2004). These development projects require continuous monitoring to avoid large-scale environmental deterioration (Abu Zeid, 1991) depending on the National Water Plans during the period from 1997 to 2017 demonstrated by the Ministry of Water Resources and Irrigation (MWRI).

In this research, the South Eastern Nile delta region was chosen to follow the change in land use/cover and to assess the change in the agricultural lands in the desert areas located southeast of the Nile Delta fringes. So the changes in the agricultural expansion especially must be quantified and detected to help in the process of sustainable management of water resources. The area of the South-Eastern Nile delta changed drastically in the last 30 years. Since 1980, the area of the South-Eastern Nile delta changed as a result of extensive reclamation of desert areas and relatively large enterprises (large scale projects) cultivated with surface water from the Ismailia Canal. In addition to the private farms surrounding the Ismailia Canal and other areas irrigated conjunctively (Abdel Salam et al., 2004). Many factors have a great effect on the rapid and dynamic change in the study area, such as a) continuous increase of reclamation land by increasing the cultivation areas .b) the changing of irrigation source from groundwater to surface water or conjunctive use. c) The rapid growth of urban areas over the existing cultivation areas. d) Changing the areas of sand dunes and barren desert to urbanization or cultivation areas (Abo El Magd, 2011). Many previous studies have attempted to assess and detect the land use/cover change in different areas in the Eastern Delta region. Abdulaziz A. M. et al., 2009 used a hybrid classification approach to asset and monitor land use/cover changes associated with the agricultural and urban expansion in the Eastern Nile Delta especially in the desert fringes by classifying Landsat images. Three land cover maps were obtained for years 1984, 1990, 2003. These maps are used to create changes detection maps by post-classification and some statistics for the obtained land use maps. The results presented an increase in the agricultural area by 14% over the study period. Also, the urban areas increased by 21,300 hectares during the period from 1990-2003. Also, Abo EL Magd, 2011 Applied the data of remote sensing through the period (1990-2008) for Eastern Nile Delta Region, the author

categorized the study area according to land cover and water resources.

Riad, P. et al. (2020), Used different landsat datasets from 1970 to 2018 to study how the urban expansion affects the agricultural area in four cities (Luxor, Cairo in Egypt, and Aqaba and Amman in Jordan). The authors had applied the spectral Angle Mapper and the Maximum Likelihood Algorithm to perform landcover classification and post-classification comparison for change detection. The images were processed by using different ERDAS IMAGINE 2014 tools and open-source approaches implemented in QGIS. Other previous studies have addressed the methodology of monitoring land use map and detect the change between the produced land use maps among these studies El-Kawy et al., 2011, Berberoglu, S., & Akin, A. 2009, Hegazy, I. R., & Kaloop, M. R. 2015. The objective of this study is to monitor the rate of increase in the reclamation lands by increasing the agricultural areas as it is considered one of the main factors that have a great effect on the rapid and dynamic change in the study area. Observing and quantifying the changes of the land cover for the classified land use maps between 1992, 2002, and 2015. by integration of remote sensing data and GIS (RS&GIS) considered important and powerful tools for accurately detection land use/land cover changes over large areas.

2- Materials and Methodology

2-1 Location of Study Area

The area presented in this study covers part of the Eastern Nile delta Region located between 31° 00' and 32° 00' E longitude and 30° 00' and 30° 31' N latitude. The study area is bounded by the Damietta branch to the west, to the East by Suez Canal, to the north by Lake EL Manzala, and to the south by Cairo-Suez desert Road. It occupies part of the flood plain in the North West direction. Another portion of the study area occupies by a high land desert area located north and south Ismailia canal. Where is considered the natural extension of flood plain towards the east Abdulaziz, A. M. (2007) .The study area is characterized by an arid to semi-arid climatic conditions. The climate is dry, hot, and rainless in the summer. But it is mild with some precipitations in the winter with mean, monthly temperature ranges from about 12,c in winter to 27,c in summer. The Eastern Nile Delta region covered an area of approximately 14,000 km², it is characterized by different topographic features. The ground elevations have a gentle slope to the east direction. It is characterized by extensive and rapid development projects since 1980 depending on the conjunctive use of surface water and groundwater Figure 1.

2-2 Datasets

In this study, three Landsat images are used for the years 1992, 2002, and 2015, Table 1. These images were downloaded and composited together to monitor the change in the special and temporal patterns of the high desert land area located north and south of Ismailia canal Eastern Nile Delta Fringes. The three Landsat images were downloaded from the USGS website <https://earthexplorer.usgs.gov/> Landsat data are available at the website for free download. The three images were mostly cloud free. The acquisition date for the used images was selected in the summer period (August and September) to maintain the intensity of crops, where active and green agricultural fields are existing (Ismael, A. M, 2007). This clarity in agricultural lands greatly helps in the classification process between the agriculture class and the bare soil or urban areas. Figure 2. The Landsat images already had a geographic special reference as the Universal Transverse Mercator (UTM) projection system and projection as (zone: 36N, datum: WGS-84) with cell size (30m x 30m) represents the image spatial resolution.

Table .1 Satellite data sets characterization for the study area

Platform(Sensor)	Acquisition Date	Path/Row	No. of bands
Landsat 5 TM+ C1 Level-1	26/09/1992	176/039	7
Landsat 7 ETM+ C1 Level-1	01/09/2002	176/039	7
Landsat 8 OLI/TIRS C1 Level-1	14/08/2015	176/039	11

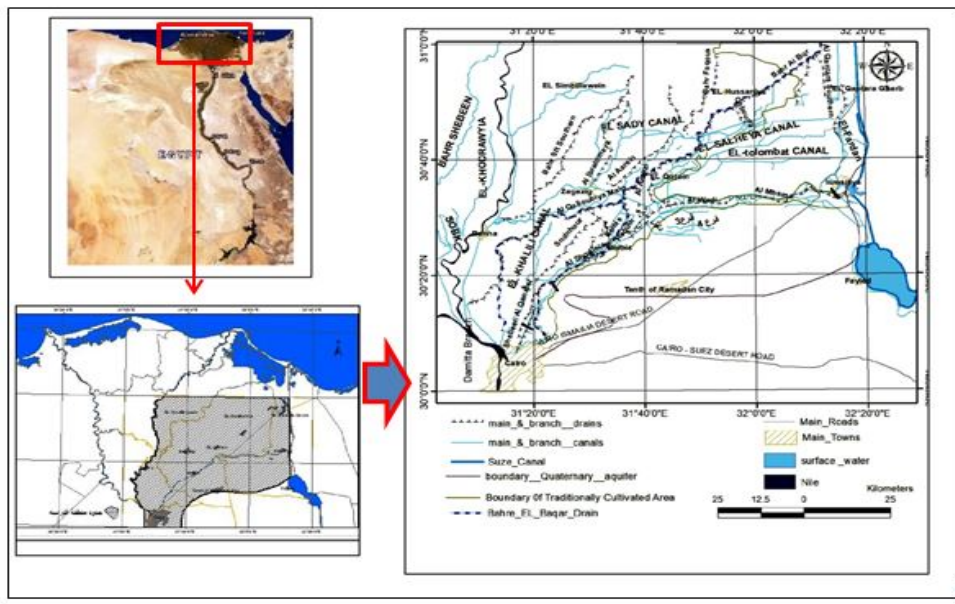


Figure 1. Location map of the study area

In this research different softwares were adopted to complete our classification and change detection analysis required to achieve the objective of the research. Arc GIS version 10.3 was used for pre-processing and for performing the classification processes, Google Earth program for extracted the data corresponding to the ground truth referenced points required for the Accuracy Assessment process. finally Microsoft Excel Worksheet for representing the results in the form of charts and tables also for creating and tabulating the Error matrix to calculate the required values for assessing the accuracy of our classification.

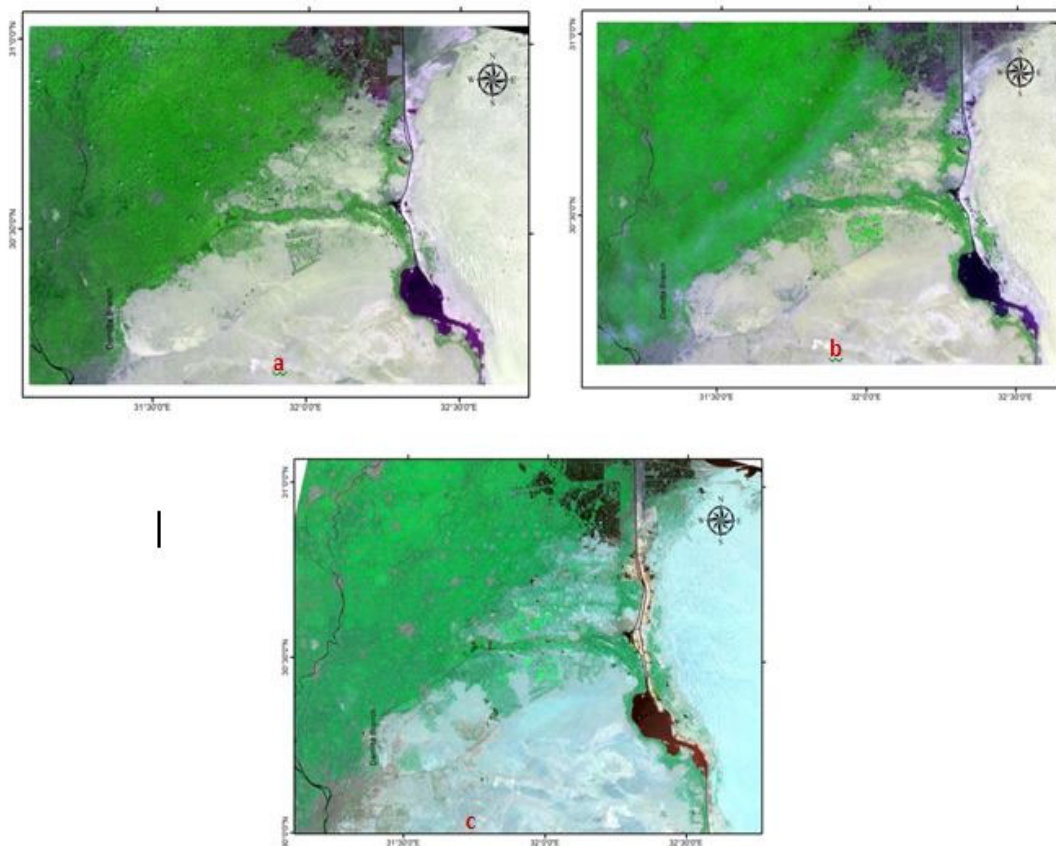


Figure 2. The selected Landsat images with band combinations for the years a) 1992 (RGB 2, 4, 1), b) 2002(RGB 3, 4, 1), and c) 2015 (RGB 6, 3, 2).

3- Image classification

This study describes the assessment of land use/land cover classification processes which adopted the pixels classification based method. This method involves multivariable spectral classification. Abburu and Golla (2015) referred to classify satellite image as a combination of the value of image pixel into valid or useful groups. according to Singh, Abhishek, et al. (2020) Image classification is the process of land use detection by the way of labeling each pixel by a class label. Depending on the interconnection between the computer and the analyst during classification. the image classification process contains supervised and unsupervised. With the Spatial Analyst extension in the ArcGIS, there are a group of tools in the Multivariate toolset to achieve supervised and unsupervised classification in the supervised classification previous information about the area under classification is required. (ArcGIS10.3, help).

The maximum likelihood classification tool which works in the same way as the interactive supervised classification method in the ARC GIS program was used to perform the classification. The maximum likelihood rule is the greatest popular supervised classification method used for the satellite images analysis (BOLSTAD and Lillesand, 1991)

Generally, the supervised classification method basically relies on the user's accuracy and experience (Esam et al, 2012). The classification was performed on the three Landsat images using a signature file. Although the spectral analysis shows the clear difference between agricultural lands, whether cultivated or harvested areas and the urban areas, however, the harvested areas, and urban classes are very similar to each other during the classification processes. To avoid this interference during the classification process, the agricultural lands were divided (Due to the difference in color) into two separate classes (cultivated, harvested), but both of them were considered as agricultural lands in the classification accuracy calculations and change detection analysis. So five different classes are chosen and classified according to the existing land features of the study. The classification process produced the five classes as cultivated, harvested, water, desert, and urban areas. Using ARC GIS version 10.3 a maximum likelihood classification tool was used to perform the classification on Landsat (1992, 2002, and 2015) to identify the land cover changes in the selected study area.

4- The Classification accuracy Assessment

Classification accuracy is defined as the measure of proximity of the results of the classification to the true values extracted from the reference maps. Also, the sample number of each class and the quality degree of the reference maps have a great effect on the certainty of the classification (Esam et al, 2012). To perform the accuracy assessment 80 points were chosen to represent the reference points (checkpoints) corresponding to reference maps (Google Earth maps and satellite imagery for the year (1992, 2002, and 2015) these checkpoints were chosen randomly according to the land use classes used for the image classification. 20 points were chosen to represent the classification class as the classification have four classes. The classification and reference data were extracted for the selected eighty checkpoints to perform the interpolation and the analysis of the data to build the error matrix. Excel software was used to build the error matrix and computing the Kappa coefficient for classification. According to Olofsson, Pontus, et al. (2014) the error matrix defined as a quite cross-tabulation of the labels of the classes resulted from the remotely sensed data classification opposed to the sample sites reference data. This matrix organizes the data obtained from the simple random sampling points (reference data) and the corresponding data from the classification. The main objective of the error matrix is to calculate the producer's accuracy, user's accuracy, the total accuracy, the overall accuracy, and finally the Kappa coefficient value to determine the degree of confidence of our classification. In the classification process, the classifier gives some omission errors due to the failure of recognizing some class pixels, the evaluation of these errors is called by the producer's accuracy. But the measure of other errors (commission errors) related to these pixels from other classes that the classifier has recognized to the same class is called the user's accuracy (Ammeish.et al, 2016). The error matrix expresses the degree of accuracy between checkpoints and the value resulting from the classification of the same image. This method is considered one of the essential and popular methods for detecting the overall classification using producer accuracy, user accuracy, and kappa coefficient (Zaidi S.M., et al., 2017).

5- Change detection

Change detection is a common technique of remote sensing where a comparison between imagery for an area at different times takes place giving the change in the image feature (Esam et al, 2012). Many authors had adopted digital change detection techniques. Various techniques for remotely sensed data and change detection methodologies have been advanced and still newer techniques are arising (Hussain et al., 2013). Ban, Y., & Yousif, O. (2016) presented various methods for the change detection process for both synthetic aperture radar (SAR) and optical images; they reviewed different conditions of the change detection process as pre-processing of data, generation of change detection, and different change detection algorithms.

This work aimed to detect and calculate the amount of change from different classified land use maps during the period from 1992 to 2015 especially monitoring the change in the agricultural areas by subtracting the classified

image for years 1922, 2002, 2015 from each other. the main development in the study area associated with the agricultural expansion especially the area of south Eastern Nile Delta located north and south of Ismailia canal, this area had a rapid expansion in the agricultural projects since 1980 to now.

6- Results and Discussion

The image classification performed for the study area represented a part of the Eastern Nile delta Region, presented three land use /cover maps for three different dates 1992, 2002, and 2015 as shown in Figure 3. Five different classes are chosen and classified according to the existing land features of the study. The classification process produced the five classes (cultivated, harvested, water, desert, and urban areas. Before performing the classification processes each class was sampled by many polygons to create the training sample file in the three satellite images. There was a difficulty to distinguish between some agricultural and urban areas because they have similar infrared spectral colors this was the reason to isolate the class for agricultural into two classes (cultivated & harvested) to decrease the interference between the areas agricultural and urban areas during the classification. It can be seen that the total classified area was (8953 km²) (2,130,891 feddan). The results showed a great difference between the three classified images, especially between the agricultural and desert areas. In 1992 land use map, there was more than 485,928 feddan for desert areas as 22.8% of the total area. This area was decreased in 2002 and 2015 to 404,094 and 295,045 feddan as 18% and 13 % respectively. This decrease in the desert land was faced by an increase in the agricultural area in 1992, the agricultural land covered (1,475,658.6 feddan) as 69.2% of the total area. While it covered about (1,658,676.8 feddan) as 77.8 % of the total area in 2015. It was noticed that the agricultural land has increased from the year 1992 to 2015 by (183,018 feddan) by a percentage as 8.6% this increase in the agricultural land was subjected to the extensive reclamation projects in the area since 1980 to 2015 related to the management plans and strategies applied to Eastern Nile delta. Also, the results showed that there is an increase in the urban areas during the period between years 1992 to 2002 by 5.4% but recorded a decrease by a value of 3.4% from 2002 to 2015. also, the areas covered with water recorded an increase of 0.5% from 1992 to 2002 this is maybe due to the construction of new canals in addition to the appearance of some logging areas in lands near the Ismailia canal. While a decrease in these areas is appeared by 1.9% from 2002 to 2015. All areas and percentage values of classified images are shown in Table 2.

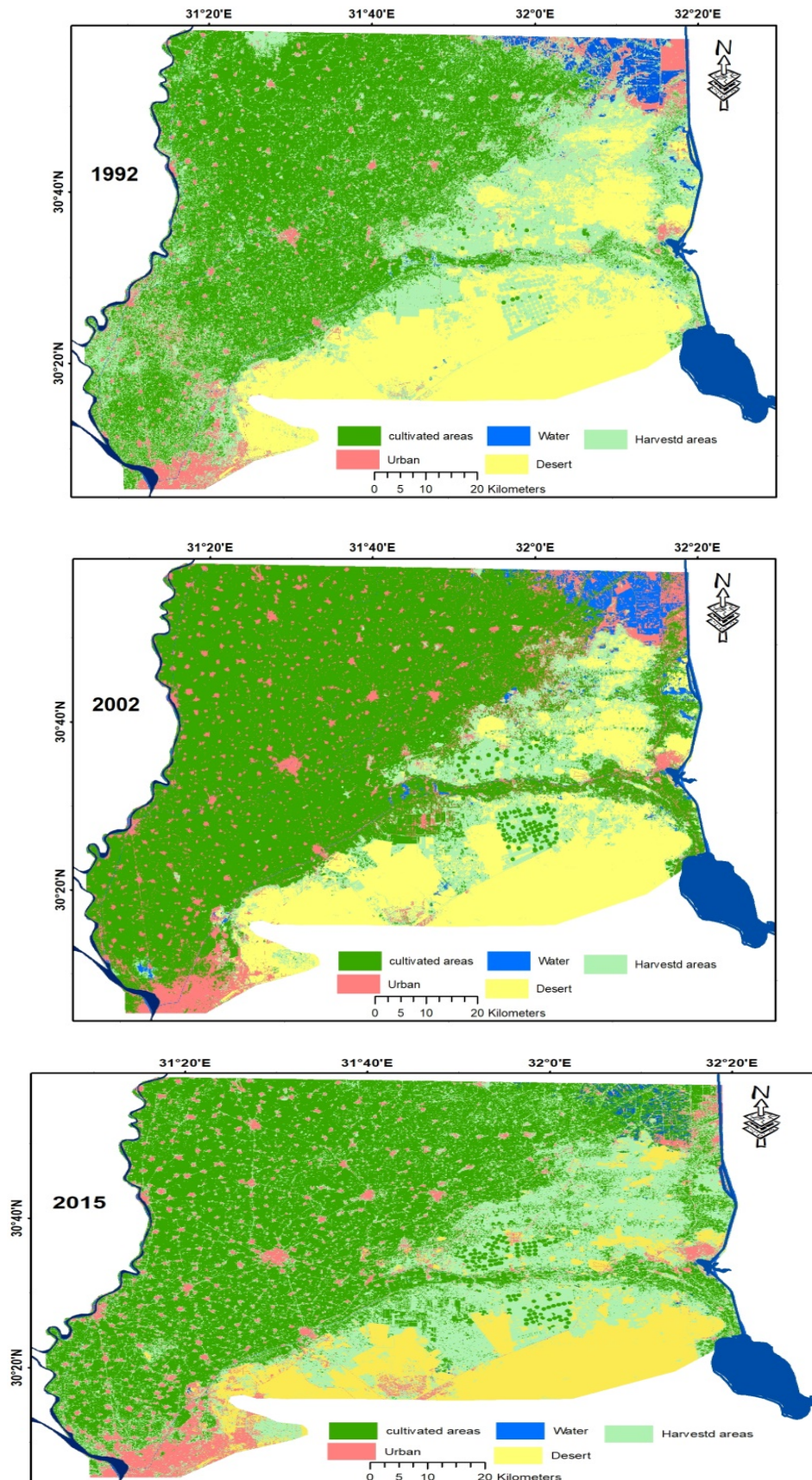


Figure 3. Land use maps produced by the classification processes for the years 1992, 2002, and 2015
Also, the areas covered with water recorded an increase of 0.5% from 1992 to 2002 this is maybe due to the construction of new canals in addition to the appearance of some logging areas in lands near the Ismailia canal.

While a decrease is appeared by 1.9% from 2002 to 2015. All areas and percentage values of classified images are shown in Table 2 and Figure 4.

Before evaluating the change detection between the satellite images the accuracy of the three land-use maps resulted from the classification should be checked. The accuracy assessment method adopted in this research was the generating of the error matrix by comparing the truth values of sampling points by the classified images for each class type. for each land-use map, an error matrix was produced as shown in Table 3. as (user's and producer's accuracy) for each separate land class, overall accuracy, and overall Kappa (κ).the results showed that the user's accuracies were 69%, 89%, and 67% for 1992, 2002, and 2015 respectively. While the results presented the value of producer's accuracies as 91%, 89%, and 100% for the same years .the overall accuracies evaluated as 85%, 86.2%, and 87.5% for the same years respectively. Finally, the classification was evaluated for each year by the value of overall Kappa (κ) coefficient values as 0.794, 0.815, and 0.832 for 1992, 2002, and 2015 respectively. According to (Borana and Yadav,2017) the degree of agreement depending on the value of overall Kappa (κ) was evaluated as substantial for the year 1992 and Almost Perfect for the years 2002 and 2015.

Table 2. Land use/cover statistics resulted from the classification process

class Name	year 1990			year 2002			year 2015		
	Area (km ²)	Area (feddan)	% of total area	Area (km ²)	Area (feddan)	% of total area	Area (km ²)	Area (feddan)	% of total area
Agricultural area *	6200.25	1475658.6	69.25	6036.148	1436603.2	67.42	6969.23	1658676.8	77.83
Urban area	481.25	114536.5	5.38	943.7412	224610.4	10.54	643.0786	153052.7	7.182
Desert	2041.72	485928.56	22.8	1697.876	404094.4	18.96	1239.688	295045.85	13.84
Water	230.12	54768.006	2.57	275.4982	65568.567	3.08	101.3318	24116.967	1.13
Total	8953.32	2130891.6	100	8953.263	2130876.6	100	8953.329	2130892.3	100

(*) the two classes (cultivated & harvested) are merged into one class as agricultural

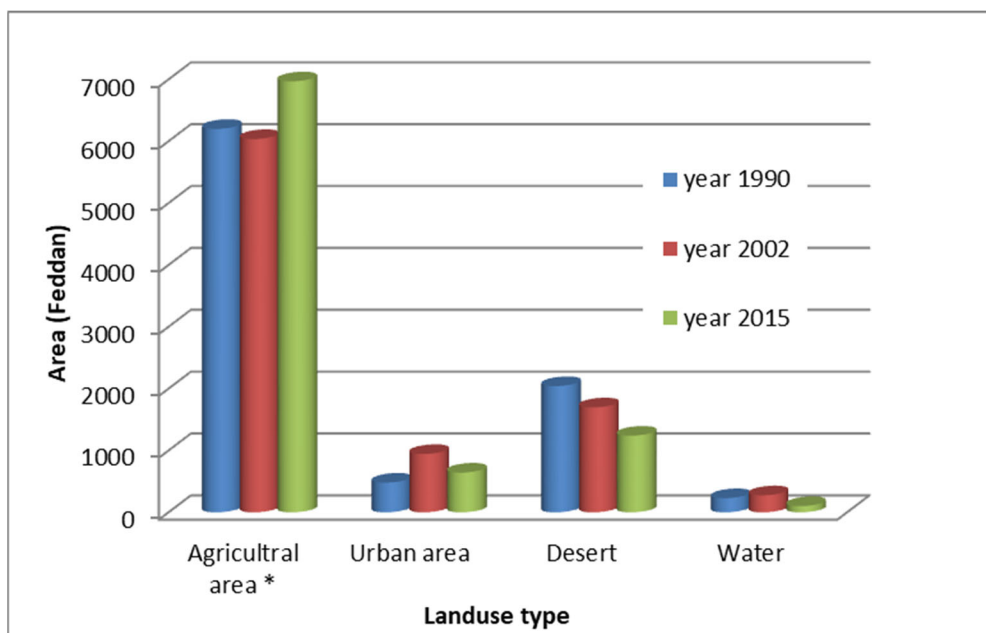


Figure 4. Chart showing Land use/Cover maps for the years 1992, 2002, and 2015.

Table 3. Classification accuracy statistics and Error matrices for the classified images (1992, 2002, and 2015).

Year 1992	Agricultural	urban	desert	water	Total	User's accuracy	producer's accuracy
Agricultural	20	3	3	3	29	0.69	0.91
urban	2	8	0	0	10	0.8	0.67
desert	0	1	24	0	25	0.96	0.89
water	0	0	0	16	16	1	0.84
Total	22	12	27	19	80		
Overall Accuracy	85						
Kappa coeff	0.7940						
Year 2002	Agriculture	urban	desert	water	Total	User's accuracy	producer's accuracy
Agricultural	17	0	1	1	19	0.89	0.89
urban	2	13	1	4	20	0.65	0.87
desert	0	1	24	0	25	0.96	0.92
water	0	1	0	15	16	0.94	0.75
Total	19	15	26	20	80		
Overall Accuracy	86.2						
Kappa coeff	0.815						
Year 2015	Agricultural	urban	desert	water	Total	User's accuracy	producer's accuracy
Agricultural	20	2	1	7	30	0.67	1.00
urban	0	15	0	0	15	1.00	0.88
desert	0	0	22	0	22	1.00	0.96
water	0	0	0	13	13	1.00	0.65
Total	20	17	23	20	80		
Overall Accuracy	87.5						
Kappa coeff	0.832						

After checking the accuracy of classification the land-use raster datasets were converted into polygon features to extract the areas of each class to a separate shapefile. the study concerned the agricultural expansion with more interest so, In this study, the desert fringes of the Southern Eastern Nile delta region was chosen to evaluate quantitatively the change of the Agricultural development and its relation with the water national plans for desert reclamation in the study area by monitoring and mapping the change in the land cover during the period (1992-2015). The results of the change detection maps as presented in Table 4 and Figure 5 that showed an increase in the agricultural areas accompanied by decreasing in the desert areas during the period 1992-2015. The results showed an increase in the agricultural area by 8.6%, this increase was related to the decrease of the desert area by 8.9% .the results were concentrated on the agricultural class changes by producing the Agricultural area change detection maps for the study area between (1992-2002), (2002-2015) and (1992-2015), respectively

Table 4. The land cover change in feddan between the year 1990 and 2015

class Name	year 1990 (feddan)	year 2015 (feddan)	total change	% change
Agricultural area	1475658.554	1658676.757	183018.203	8.588805948
Urban area	114536.501	153052.7003	38516.1993	1.807515082
Desert	485928.5647	295045.8539	-190882.711	-8.95787708
Water	54768.00642	24116.96687	-30651.0395	-1.43841338

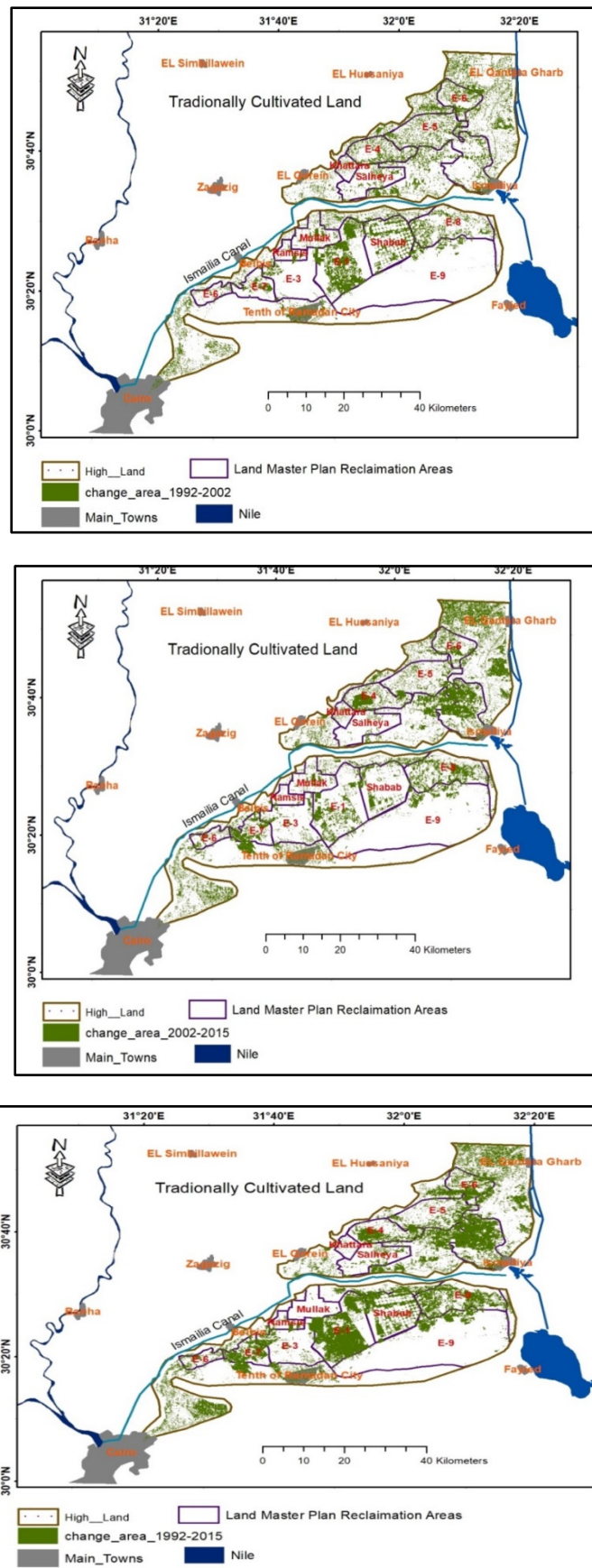


Figure 7. Change detection of Agricultural development in Land master plan areas and the existing large scale projects during the period ((1992-2002), (2002-2015) and (1992-2015), respectively

Table 6. the amount of change in agricultural area for the High land including the development areas for land use subarea (A, B) during the period 1992-2015.

Development Area	1992	2002	2015
Landuse	Area (Feddan)		
Shabab	18080.06458	27276.08064	31218.46422
Salheya	18783.02412	20861.02139	21453.39536
Mulak	17230.78267	14450.99146	17541.65029
Ramsis	3099.225132	3975.420321	4514.545307
Khattara	6310.96752	5329.029355	6303.576616
Total	Land use subarea(A)		
	63504.06403	71892.54317	81031.63179
Ramsis	1717.089067	4058.973756	7888.654252
Adleya	2786.136761	4746.144537	9232.524601
Desert Fringes Bilbeis	2421.057779	2218.950841	2888.642139
Manayff	12277.78406	18176.58612	29035.39685
Shabab (Youth Province)	6413.776242	26842.64589	38343.69885
South Cairo -Ismailia Desert Road	3091.924073	6378.191963	11600.30073
Khattara	12922.53204	13406.65813	21700.49513
Salheya North	28042.02512	34145.77518	54071.15862
Along Husseinia Canal	7319.611454	6803.697231	10347.48667
Total	Land use subarea(B)		
	76991.9366	116777.6236	185108.3579

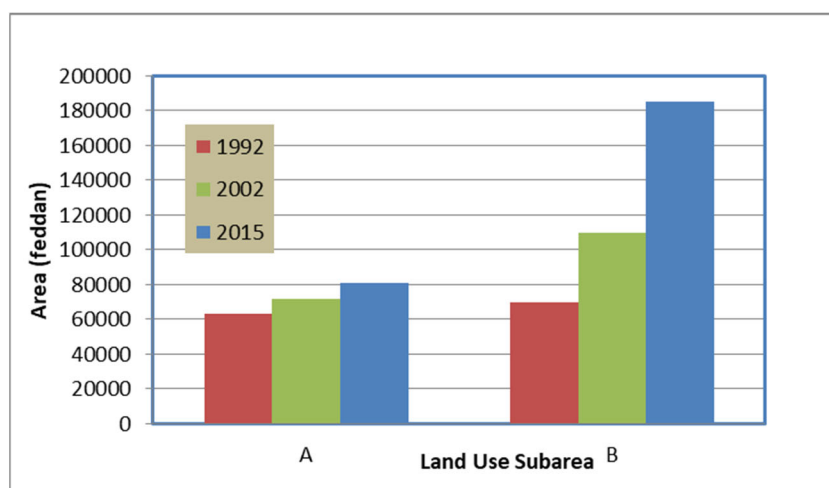


Figure (8) Graphical representation for the amount of Agricultural area increased for land use subarea (A, B) during the period 1992-2015.

7- Conclusions

It can be concluded from the research that the integration of GIS and remote sensing data as (RS&GIS) were considered important and powerful tools for accurately detection land use/land cover changes over large areas. The study used three satellite images for years 1992, 2002, 2015 to produce the land use maps by using the maximum likelihood classification processes including a signature file for the Eastern Nile delta region. The signature file was performed by selecting four classes according to the different land cover types existing in the study area. The selected classes of land cover were as (Agricultural, water, desert, and urban).the accuracy of the classification was performed. The results of the accuracy assessment were evaluated as 85%, 86.2%, and 87.5% for the years 1992, 2002, and 2015. Based on the results of the classification process, the change detection between three land use maps was performed and three change detection maps were produced for the study area between (1992-2002), (2002-2015) and (1992-2015). Detailed analysis for the results of change detection was achieved at the high land area located at the desert fringes. The area is divided into two sub-regions (A and B) representing the agricultural development areas that were planned for reclamation by the national water plans. The results showed remarkable active reclamation processes from year 1992 to 2015 especially for the development areas of the Land master plan included in sub-region (B). The reclamation areas which started before 1992 as the

development areas included in sub-region (A) increased by 175,27.6 feddan from year 1992 to 2015 compared to 115,436 feddan for the development areas of Land master plan included in sub-region (B) for the same period. The results of the research provided the study area with an acceptable and quantitative estimate for the development areas existing at the high land of the Eastern Nile delta desert fringes. This estimation can be useful for planning for sustainable plans for water resource management and future water projects.

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