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Detection of land use/cover change in Egyptian Nile Delta using remote sensing

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A B S T R A C T

The present study aims to assess the changes of different land use/land cover classes for Nile Delta of Egypt during the period from 1987 to 2015, to evaluate the impact of land cover change and urban sprawl, before, during and after the 25th of January 2011 using remote sensing and GIS techniques, as a result to unplanned urban sprawl which was done by people during the lack of general security of Egyptian revolution. The results indicated that there was a regular trend characterized in most classes and that the change in different land use/land cover classes ranged between increase and decrease areas. A continuous increase in agricultural, urban, fish farms and natural vegetation areas and a continuous decrease in water bodies and sand areas were detected in the studied area. The agricultural area recorded the highest increase during the period from 1987 to 2000 (305296.1 ha.) while it increased by 170578.1 ha., during the period from 2000 to 2015. However, in urban area, the highest increase was recorded during the period from 2000 to 2015 followed by the period 1987–2000 with mean values of 97940.8 and 53112.6 ha., respectively. The analysis of the results showed that most of Egyptian Delta governorates have been significantly affected by the different classes of land use/land cover change due to agriculture activities, urban growth as a result of human activities dynamic impact.

1. Introduction

Egyptian Nile Delta is one of the oldest agricultural areas in the world as it is under continuous cultivation since thousands of years. The estimated cultivated area in the Delta was 1,828,840 ha. that representing 63.0% of Egyptian cultivated area (Shalaby, 2012). The total estimated agricultural land in Egypt is 3.5 million ha. (3.5% of the total area of Egypt) as the rest is desert land (Khalil et al., 2014). Agriculture was the core of many sustainable development polices in the country. During the last two decades, the government was targeted to increase the agricultural production and its quality through increasing the agricultural area Shalaby and Ali, 2010) and application of good agricultural practices. Now a days, one of the most global serious problems that threaten food security within the region, if left untreated, is land degradation (Khalil et al., 2014). Such changes are usually caused by human activities (e.g., deforestation, urbanization, agriculture intensification, overgrazing) (Lambin, 1997). These human-induced changes can cause declines in natural resources and can affect food supply in these areas resulting in serious socio-political consequences (Turner et al., 2007).

However, the inventory of cultivated area which conducted by traditional surveying methods is become difficult and inaccurate way due to urban encroachment on cultivated land (Khalil et al., 2014). Therefore, there is need for precision and up-to-date land use/land cover data for any sustainable development programs where it serves as main input criteria (Deng et al., 2005).

Remote sensing is very successful tools in agricultural field where digital data availability, for two decades minimum, in multiple wavebands of the spectrum and their large ground coverage makes it superior to field-based study (Khalil et al., 2014). Also, GIS technology provides a flexible tool for storing, analyzing and displaying digital data required for detection change and developing database. Satellite imagery has been used to monitor discrete land cover types via spectral classification or to evaluate land surface biophysical characteristics linear relationships with spectral reflectance or indices (Weng, 2001). Change detection is the process of determining and/or describing changes in land cover/use

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characteristics based on co-registered multi-temporal remote sensing data. The basic premise in using remote sensing data for land cover change detection is that the process can identify change between two or more dates that is uncharacteristic of normal variation (Shalaby, 2012).

The present investigation aimed to assess the changes of land use/cover classes in Egyptian Nile Delta feature classes using remote sensing data in order to determine type as well as the conversion rate among different land use/land cover types in the studied area.

2. Materials and methods

2.1. Study area

The Nile Delta is formed in Northern Egypt where the Nile River spreads out and drains into the Mediterranean Sea (Shalaby, 2012). The Nile Delta is located between longitudes 29° 37′ 52″ E and 32° 55′ 49″ E and latitudes 29° 37′ 49″ N and 31° 41′ 2″ N., NASA (1987–2015). It extends over an area of 240 km^2 (416,7007 ha) on the Mediterranean coast, (El-Asmar and Hereher, 2010). The Nile Delta is Egypt's economic and financial heart, it includes the richest farmland in Egypt. It is occupied by the most populated governorates in Egypt, whereas around 50% of the population live in the Nile Delta, (Haars et al., 2016). In addition, the Nile Delta consists of 11 governorates: Qalyobia, Gharbia, Monofiya, Sharkia, Port Said, Ismailia, Dakahliea, Damietta, Kafr El-Sheikh, El-Bohaira and Alexandria (Fig. 1).

2.2. Data collection

Three different types of Landsat images (Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI TIRS) were obtained from the USGS earth explorer website. Landsat 5 TM images, consist of seven spectral bands with wavelengths of 0.45 µm to 2.35 µm and the spatial resolution of 30 m for Bands 1 to 5 and 7, meanwhile spatial resolution for band 6 (thermal infrared) is 120 m. Landsat 7 ETM+, consist of eight bands with wavelengths of 0.45 µm to 2.35 µm and spatial resolution for bands 1,2,3,4,5,7 are 30 but bands 6 and 8 are 60 and15m respectively. Landsat 8 OLI TIRS, consists of eleven bands with a spatial resolution of 30 m for Bands 1–7, and 9 have a spatial resolution of 30 m, bands 10 and 11(thermal bands) (TIRS) has 100 m, meanwhile band 8 (panchromatic) has spatial resolution of 15 m. To achieve the study objectives three different dates for the images were used 14/7/1987, 11/7/2000 and 5/7/2015, respectively.

2.3. Image preprocessing

Digital image preprocessing was manipulated by the used software. The scenes were selected to be geometrically corrected by using EVNVI 5.1 software, calibrated and removed from their drop-outs. After that, the atmospheric correction was done for visible, near-infrared and shortwave infrared data in all different types of Landsat images. Atmospheric analysis of subtraction method (dark-object) model was used to correct the atmosphere effect on reflected data according to Chavez (1996) by using EVNVI 5.1 software.

2.4. Image processing

Image processing was carried out using ENVI 5.1 software. An unsupervised classification was performed using the iterative self-organizing data analysis (ISODATA) algorithms in order to identify the classes that could be found in the study area, ISODATA unsupervised classification calculates class means evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. The supervised classification was conducted based on the support vector machine technique by selected sigmoid model in ENVI 5.1 software according to Srivastava and Bhambhu (2009). The different Landsat images in the study area were classified into nine different classes from land use/land cover (agricultural, urban, water bodies, fish farm, natural vegetation, sabkha, salt, bare soil and sand).

2.4.1. Post classification change detection

Comparison change detection was done after classifying the rectified images separately from three time periods (1987, 2000 and 2015). Each date of imagery was classified using support vector machine technique. The classified images were exported to the ArcGIS 10.2 software for vectorization, calculation and comparison of areas among the different dates, to identify various changes occurring in increase or decrease of land use/land cover.

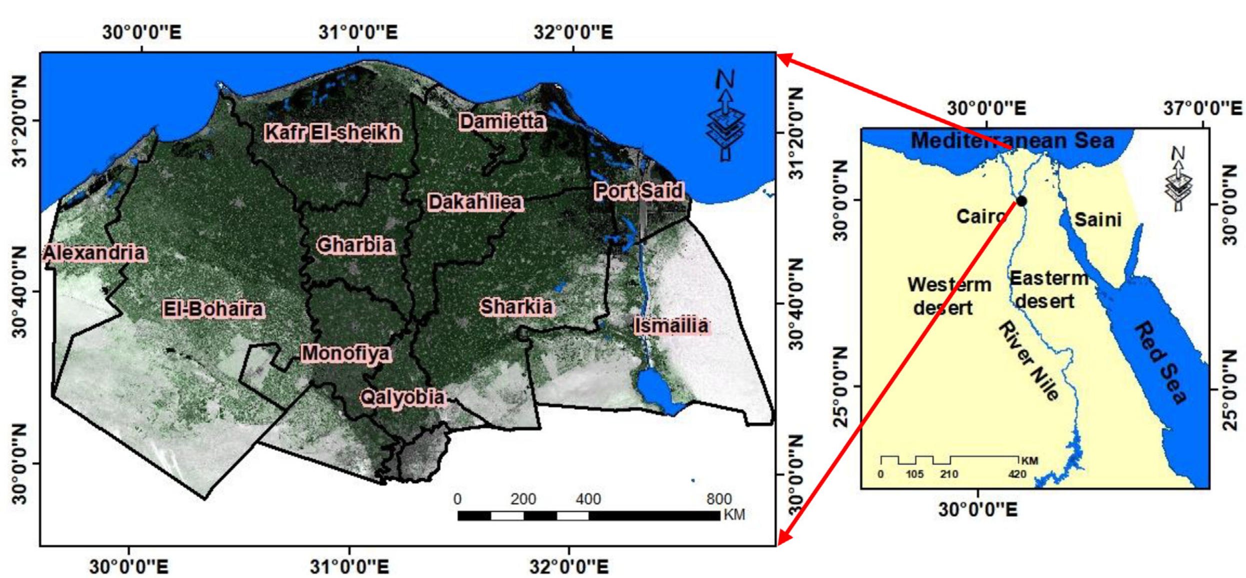

Fig. 1. Location map of the study area.

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2.5. Statistical analysis

The significance of determined differences between calculated means values was done using "SPSS software ver. 20" according to Steel and Torrie (1980). Statistical significance was computed based on F-test and Duncan-test for threshold of significance at 5.0% probability level.

3. Results and discussion

3.1. Land use/land cover change detection in Nile Delta

The obtained classified images, after pre-processing and supervised classification indicated the different land use and land cover patterns in the studied area (Fig. 2). The change of different land use/land cover classes in the studied areas during the period from 1987 to 2015 were increased and decreased as a response to different activities such as urban sprawl and lands reclamation (Table 2 and Fig. 2). The major impact of human induced on land degradation in investigated areas was urban sprawl. The results showed a regular trend characterized the change in all land use land cover classes.

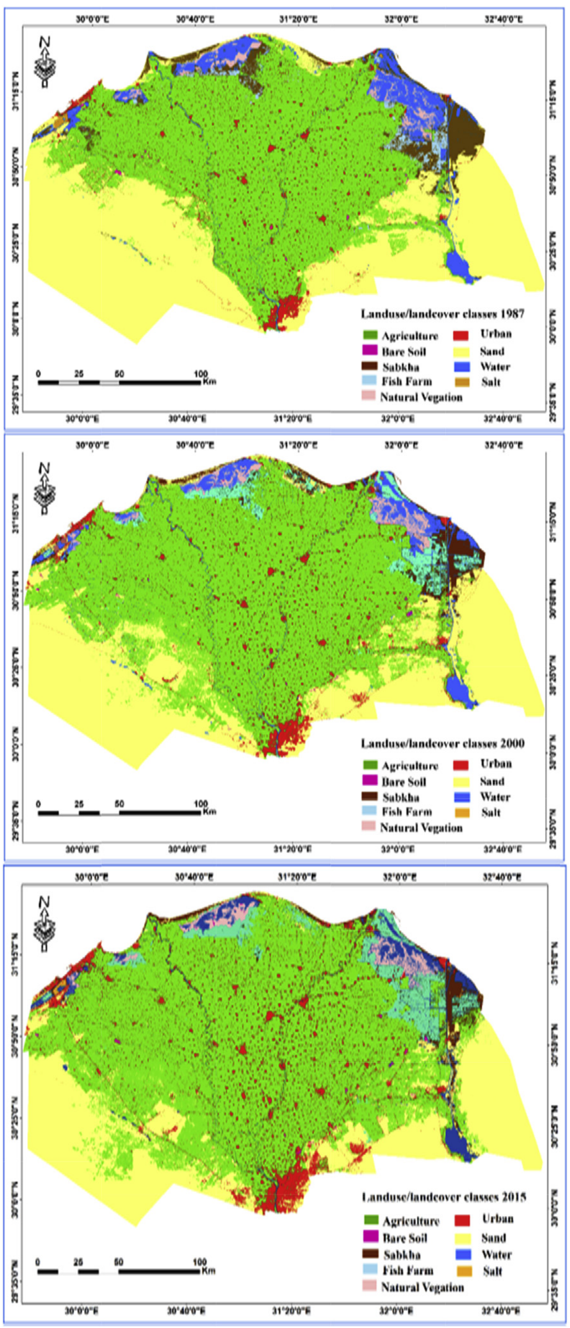

Fig. 2. Land use/land cover map for the studied area in 1987, 2000 and 2015.

As for agriculture activities the cultivated areas were significantly increased continuously during the period from 1987 to 2015 where the recorded rate of changes was 16.5% and 7.9% during 1987–2000 & 2000–2015, respectively. The total rate of change recorded for the period from 1987 to 2015 was 25.8% (Table 2). These results could be attributed to agriculture expansion of desert land reclamation. These findings confirmed those obtained by Shalaby and Ali, 2010. In addition, land cover change was located around the Northern lakes as many sabkha and salt marches were turned into agricultural areas cultivated with halophilic crops.

Concerning urban area, the year of 2015 recorded the highest value followed by the year of 2000 and 1987. The rate of urban ration was increased in the period 1987–2000 by 34.8% from the study area, while increased in the period 2000–2015 by 47.6%. The total change rate in the period from 1987 to 2015 by 99.0% (Table 1). These results could be attributed to the urban sprawl, which causes loss of agricultural land, these obtained results are in agreement with those obtained by each of Shalaby (2012) who found that the study area has undergone a very severe land cover change as a result of urban sprawl as the main causes of urban sprawl are the fast population growth and the internal migration.

The opposite trend was observed with water bodies' where the largest area was detected in the year 1987 and decreased the years in 2000 and 2015. The change detection results showed a decrease in waterlogged areas as the decrease rate was −15.2% in 1987–2000 and in the next period 2000–2015 the rate of decrease in the overall area reached −14.4%. The total change for the period from 1987 to 2015 was −57698.3 ha. with a rate of decrease by −27.4%.

Regarding fish farms, the largest number was recorded in the year 2015 while the numbers were lower in 2000 and 1987. It was observed that the change in fish farms area increased by 71745.0 ha during the period 1987–2000, with a rate of 145.9%, while it increased by 59475.6 ha during the period 2000–2015, with a rate of 49.2%. The total change during the period from 1987 to 2015 was 131220.6 ha. recording increasing rate of 266.8%.

Concerning the natural vegetation area, the results indicated that the year of 2015 recorded the largest area followed by the years 2000 and 1987. The results of change detection showed that the natural vegetation area was increased during the period 1987–2000 where the increasing rate was 21.6% while it increased by 3.4% during the period 2000–2015. The total change for the period from 1987 to 2015was 13165.7 ha. with increasing rate 25.8%.

As for the sabkha, a continuous decrease was detected from 1987 to 2015. The decreasing rate recorded −39.1%, and −34.9% for the periods from 1987 to 2000 and from 2000 to 2015, respectively, with a total change rate of −60.3% for the whole period from 1987 to 2015.

Salts and bare soils exhibited different patterns of change. As for salts, the area was decreased in 2000 compared to the area in 1987 with change rate of −34.7% whereas it increased in 2015 compared to 2000 recording change rate 1.1%. However, Salts area in 2015 remained lower compared to that in 1987. The total rate of change during the period from 1987 to 2015 was −34.0%. As for bare soils, the area was decreased in 2000 compared to 1987 with change rate of −13.4%. In 2015 the bare soils area was increased compared to the area in 2000 and 1987. The recorded change rate was 60.4% during the period from 2000 to 2015 whereas the total change rate during the whole period of study was 38.8%. The sand area

Table 1
Change rate of different land use/land cover classes in the studied area during the period from 1987 to 2015.

Classes	Total area (ha.)			1987–2000		2000–2015		1987–2015	
	1987	2000	2015	Change	Rate (%)	Change (ha)	Rate (%)	Change (ha)	Rate (%)
Agriculture	1845957.2[c]	2151253.3[b]	2321831.4[a]	305296.1	16.5	170578.1	7.9	475874.2	25.8
Urban	152505.6[c]	205618.2[b]	303559.0[a]	53112.6	34.8	97940.8	47.6	151053.4	99.0
Water bodies	210955.9[a]	178988.9[b]	153257.6[c]	−31967.0	−15.2	−25731.3	−14.4	−57698.3	−27.4
Fish farms	49177.0[c]	120922.0[b]	180397.6[a]	71745.0	145.9	59475.6	49.2	131220.6	266.8
N. Vegetation	51070.8[c]	62101.1[b]	64236.5[a]	11030.3	21.6	2135.4	3.4	13165.7	25.8
Sabkha	194571.3[a]	118348.8[b]	77153.9[c]	−76222.5	−39.1	−41194.9	−34.9	−117417.4	−60.3
Salts	4731.8[a]	3091.3[c]	3124.5[b]	−1640.5	−34.7	33.2	1.1	−1607.3	−34.0
Bare Soil	5218.3[b]	4516.8[c]	7243.7[a]	−701.5	−13.4	2726.9	60.4	2025.4	38.8
Sand	1660313.8[a]	1328833.9[b]	1056202.8[c]	−331479.9	−20.0	−272631.1	−20.5	−604111.0	−36.4

Where N. = Natural.

Table 2
Change of agriculture area in Nile delta Governorates during the period from 1987 to 2015.

Governorates	Total agriculture area (ha.)			Change area (ha.)		
	1987	2000	2015	1987–2000	2000–2015	1987–2015
Qalyubia	86522.1[a]	82807.8[b]	79876.6[c]	−3714.3	−2931.2	−6645.5
Sharkia	321081.4[c]	349970.3[b]	368534.2[a]	28888.9	18563.9	47452.8
Monofiya	150623.3[c]	171976.7[b]	178129.1[a]	21353.4	6152.4	27505.8
Gharbia	179430.8[a]	178254.6[b]	170290.5[c]	−1176.2	−7964.1	−9140.3
Ismailia	47494.4[c]	71995.8[b]	118968.3[a]	24501.4	46972.5	71473.9
Port Said	1345.4[b]	389.1[c]	12178.0[a]	−956.3	11788.9	10832.6
Damietta	51097.2[a]	48545.1[b]	44533.1[c]	−2552.1	−4012.0	−6564.1
Dakahliea	297819.1[a]	297530.8[b]	280072.8[c]	−288.3	−17458.0	−17746.3
Kafr Elsheikh	227518.2[c]	242621.9[b]	248798.1[a]	15103.7	6176.2	21279.9
El−Behera	411355.0[c]	576440.0[b]	680634.2[a]	165,085	104194.2	269279.2
Alexandria	36365.9[c]	73887.4[b]	75811.1[a]	37521.5	1923.7	39445.2
Total	1810652.8[c]	2094419.5[b]	2257826.0[a]	283766.7	163406.5	447173.2

followed the same change pattern that was recorded for both water bodies and sabkha area where it decreased continuously from 1987 to 2015 and recorded a total change rate of −36.4%.

These results could be attributed to the evaporation due to high temperature besides converting some water bodies to agricultural lands and fish farms decreased the overall area of water bodies. Regard with to fish farms, this increase that occurred could be referred to the intensive reclamation of sabkha areas and converting these sabkha to fish farming activities. As for the sabkha, these results could be mainly due to the agricultural expansion and increased urban, which occurred during this period. Concerning with salts, this is due to converting some salts to agricultural lands and, increased urban and increased fish farms. Regarding with sand, this is due to the continuous human activities in the studied area which grow towards reclamation of more agricultural lands and increased urban. These results are in agreement with those obtained by Shalaby (2012) who found that the study area has undergone a very severe land cover change, for the water bodies. Also, the Egyptian government adopted policies aimed at self-sufficiency in food production, e.g. extension of cultivated land (1.2 percent per year) and maximization of production of the existing agricultural land. The principal purpose was and still is to overcome Egypt's overwhelmingly unfavorable population to agricultural land ratio, Shalaby and Tateishi (2007).

3.2. Change detection in Nile Delta governorates during the period of 1987 up to 2015

This part monitors the land use/land cover change in the Nile Delta governorates during the study period from (1987–2015) by using change detection analysis, has been done for agriculture, urban, water bodies and sand feature classes through three periods; the first period from 1987 to 2000, the second from 2000 to 2015 and the third period was for the overall period from 1987 to 2015. As for changes in agricultural area, the eleven Nile Delta governorates showed three different patterns. The first pattern included six governorates (Sharkia, Monofiya, Ismailia, Kafr El-Sheikh, El-Behera and Alexandria) where the cultivated area recorded continuous increase from 1987 to 2015. In these governorates, the cultivated area represented 66.0, 72.0 and 74.0% of the total area cultivated in 1987, 2000 and 2015, respectively. The change percent recorded 24.5% and 12.4% for the periods from 1987 to 2000 and 2000 to 2015, respectively (Table 2). Four other governorates represented the second pattern (Qalyubia, Gharbia, Damietta and Dakahliea) where the agriculture area was continuously decreased during the whole period of study. The area cultivated in these governorates, in 2015, represented 26.0% of the total cultivated area in Nile Delta compared to 29.0% and 34.0% in 2000 and 1987 recording degraded percent of 1.4%, 8.2% and 9.9% for the period from 1987 to 2000, 2000 to 2015 and for whole period from 1987 to 2015, respectively. The third pattern was represented by Port Said governorates where the cultivated area was decreased by 71.1% during the period from 1987 to 2000 and increased there after by 3029.8% from 2000 to 2015. Change detection for the whole period of study exhibited that El-Behera governorates had the highest change in cultivated area whereas Damietta governorates exhibited the lowest change. These obtained results can be attributed to the ongoing human activates in the studied area which is moving mainly towards desert reclamation. However, although the continuous efforts to increase the agricultural area though desert reclamation, the loss of highly productive and fertile soils in the Nile Delta is still on going.

As for the second human activity, urban sprawl, it is clear that the urban area was increased in all Delta governorates through the overall period of study (Table 3). The total change percent recorded 36.2%, 51.0% and 105.6% through 1987–2000, 2000–2015 and 1987–2015. As for governorates, the largest urban sprawl was detected in Sharkia through 1987–2015 whereas. The smallest

Table 3
Change of urban area in Nile delta Governorates during the period from 1987 to 2015.

Governorates	Total area Urban (ha.)			Change area (ha.)		
	1987	2000	2015	1987–2000	2000–2015	1987–2015
Qalyubia	10176.7[c]	15521.9[b]	27469.6[a]	5345.2	11947.7	17292.9
Sharkia	19776.0[c]	31060.7[b]	45303.4[a]	11284.7	14242.7	25527.4
Monofiya	8703.4[c]	11816.7[b]	16465.3[a]	3113.3	4648.6	7761.9
Gharbia	13269.5[c]	14117.4[b]	22286.2[a]	847.9	8168.8	9016.7
Ismailia	3426.6[c]	13598.7[b]	18598.7[a]	10172.1	5000.0	15172.1
Port Said	677.3[c]	2392.9[b]	3189.3[a]	1715.6	796.4	2512.0
Damietta	3648.0[c]	6079.3[b]	8915.2[a]	2431.3	2835.9	5267.2
Dakahliea	19042.9[c]	23438.9[b]	34615.3[a]	4396.0	11176.4	15572.4
Kafr Elsheikh	13719.2[c]	15087.9[b]	20173.4[a]	1368.7	5085.5	6454.2
El-Behera	27377.2[c]	27877.2[b]	42696.3[a]	500.0	14819.1	15319.1
Alexandria	8642.9[c]	13990.9[b]	24445.2[a]	5348.0	10454.3	15802.3
Total	128459.7[c]	174982.5[b]	264157.9[a]	46522.8	89175.4	135698.2

area of urban sprawl detected through 1987–2015 was in Port Said represented 129.1 and 370.9%, respectively. However, change percent of urban sprawl followed a same trend in all over Delta governorates in the both studied periods (1987–2000 and 2000–2015), whereas the second period recorded the highest change rate followed by the first one except Ismailia and Port Said governorates. These findings can be attributed to urban sprawl as a result of rapid population growth as well as the internal migration on the expense of the highest fertile and productive agricultural soil in the Nile Delta. On other study carried out by Hegazy and Kaloop (2015) they found that Dakahliea governorate undergone a very severe land cover change as a result of urban sprawl, where they refer it to rapid population growth.

Water bodies were increased by 3.2% and 1.9% of the total area in five of eleven detected governorates through 1987–2000, 1987–2015, respectively while it decreased by 18.8% and 29.7% in the other six governorates, respectively. (Table 4). It was observed that water areas were decreased in the second period 2000–2015 in most of the governorates of the study area, except Ismailia governorate was increased. During the course of study, the highest change water area was recorded in Kafr Elsheikh, while the lowest change area was recorded in Monofiya by −40.7 and 2.7% respectively as shown in fig. (20–21). Water area reduction could be attributed to conversion of land cover, that is concentrated around the northern lakes, to agricultural land cultivated with halophilic crops, fish farms and urban areas (Shalaby, 2012).

Finally, sand area was decreased in all Delta governorate (Table 5). The total sand area was decreased by 19.7% and 34.5% from 1987 to 2000 and from 2000 to 2015, respectively. The total reduction in sand area through the study course was 36.0%. The

Table 4
Change of water bodies area in Nile delta Governorates during the period from 1987 to 2015.

Governorates	Total area Water Bodies (ha.)			Change area (ha.)		
	1987	2000	2015	1987–2000	2000–2015	1987–2015
Qalyubia	1925.7[c]	2167.5[a]	2139.8[b]	241.8	−27.7	214.1
Sharkia	10054.8	6664.8[a]	4318.8[c]	−3390.0	−2346.0	−5736.0
Monofiya	2917.4[c]	3011.4[a]	2996.8[b]	94.0	−14.6	79.4
Gharbia	2795.1[c]	3193.9[a]	2914.1[b]	398.8	−279.8	119.0
Ismailia	26656.2[b]	25251.1[c]	29409.7[a]	−1405.1	4158.6	2753.5
Port Said	43145.4[a]	32932.5[b]	29822.5[c]	−10212.9	−3110.0	−13322.9
Damietta	15271.5[a]	11874.5[b]	8328.1[c]	−3397.0	−3546.4	−6943.4
Dakahliea	37878.1[a]	26314.4[b]	23630.6[c]	−11563.7	−2683.8	−14247.5
Kafr Elsheikh	43071.3[a]	33911.1[b]	25526.1[c]	−9160.2	−8385.0	−17545.2
El-Behera	12549.1[b]	17648.1[a]	8579.2[c]	5099.0	−9068.9	−3969.9
Alexandria	11648.0[c]	12550.2[a]	12512.2[b]	902.2	−38.0	864.2
Total	207912.6[a]	175519.5[b]	150177.9[c]	−32393.1	−25341.6	−57734.7

Table 5
Change of sand area in Nile delta Governorates during the period from 1987 to 2015.

Governorates	Total area Sand (ha.)			Change area (ha.)		
	1987	2000	2015	1987–2000	2000–2015	1987–2015
Qalyubia	19091.1[a]	17322.1[b]	7838.1[c]	−1769.0	−9484	−11253
Sharkia	141702.6[a]	111378.3[b]	75044.3[c]	−30324.3	−36334	−66658.3
Monofiya	54011.1[a]	29714.5[b]	18720.6[c]	−24296.6	−10993.9	−35290.5
Gharbia	12.0[a]	10.8[b]	0.8[c]	−1.2	−10	−11.2
Ismailia	476515.4[a]	443825.8[b]	384252.6[c]	−32689.6	−59573.2	−92262.8
Port Said	1696.5[a]	2060.2[b]	1159.4[c]	363.7	−900.8	−537.1
Damietta	2721.7[a]	595.8[b]	536.0[c]	−2125.9	−59.8	−2185.7
Dakahliea	17515.8[a]	9891.3[b]	4025.5[c]	−7624.5	−5865.8	−13490.3
Kafr Elsheikh	12532.3[a]	12055.2[b]	5626.4[c]	−477.1	−6428.8	−6905.9
El-Behera	668078.5[a]	510071.8[b]	396965.6[c]	−158006.7	−113106.2	−271112.9
Alexandria	147332.2[a]	101423.3[b]	92770.8[c]	−45908.9	−8652.5	−54561.4
Total	1541209.0[a]	728277.3[b]	986940.1[c]	−302860.1	−251409	−554269.1

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highest sand area was detected at El-Behera whereas the smallest area was detected at Gharbia. The change in sand area from 1987 to 2000 was highs compared to other governorates. This may be due mainly to the increase of agricultural land and the reclamation of more land in addition to the increase of urban sprawl.

4. Conclusion

It could be concluded that satellite data is a good and quick technique to monitor the changes in land use/land cover with low cost comparing to conventional surveying methods. The analysis of the results also showed that most of Egyptian Delta governorates have been significantly affected by the different categories of land cover such as agriculture, urban, water bodies and sand areas. Finally, this study showed that the study area has undergone a very severe land use/land cove change as a result of urban sprawl, the problem that need to be seriously studied, through multi-dimensional fields including socioeconomic, in order to preserve the precious and limited agricultural land and increase food production. Also, It is recommended that continuous remote sensing images collection, analysis interpretation and updating of images concerning urbanization in the Nile Delta is required to monitor the developments for quick response in decision making by appropriate authorities.

Conflict of interest

There is no conflict of interest.

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