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Effect of Land Use Change on Agricultural Soils in Northern Nile Delta of Egypt Using Remote Sensing and GIS

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Abstract: Egypt Nile delta has very limited area of fertile soils which threatening by urban sprawl. Assessment of thebuilt-up areastretch effect on agricultural lands of the Egyptian Northern Nile delta has been detected by using Landsat TM, Landsat ETM$^+$ and Landsat OLI satellite images (1984, 2002 and 2016 respectively). Monitoring of urban sprawl was applied by visual interpretation viasupervised classification, on-screen digitizing and change detection techniques.The urban thematic layerand the land capability map using GISmade it possible to highlight the hazards of urban growth on the soils that have high capability. The obtained results showed that theoverallincrease of urban area amounted to 28 Km^2 (210% of the built-up area) during the study from1984 to 2016. The built-up areagrowththroughout the 1984 – 2016 was on the expense of the soils that have good capability with amount of 18 km^2(4 % of the good capability soil area). While the soils with fair capability lost 9 km^2(4 % of the fair capability soil area). The built-up area growth over the noncapable soils (barren land) wasvery large during the 1984 and 2002 period, where it has been amounted to 11 km^2 was converted to urban. The urban sprawlpattern has been changed during the period from 2002 to 2016, where very partial area amounted to (1km^2) of the non capable soils (barren land) was changed to built-up area. It could be summarized that the urban sprawl represents one of themainsoil loss and degradation processesin theNile delta.

Key words: Urban sprawl · Land cover changes · GIS · Remote Sensing · Land use policy

INTRODUCTION

Using GIS and RS for updating the urban database leads to detect the latest changesthatrestusually on the effect and impact of urban changes and the social and economic improvement [1].

Urban expansion is an unavoidable procedure because ofthe rapid population growth and economic development. Increase of built-up areas, which generally occurs on expense of agricultural land, may lead to very badramification. The impact ofincrease in population density possesses with time leads to increasing pressure on soils already populated and affected a reduction in soil per capita from (0.12 ha) to (0.06 ha) in 1950 to 1990 respectively [2] and in 2009 reached to 0.04 ha. Therefore, it's very essential to define the trend and the rate of land cover change for the development decision making in order to found rational land use policy [3]. Therefore, the remote sensing data temporal changes play the main role in the analyzing and monitoring of land use/land cover (LULC) changes. An up-to-date and accurate land use/land cover change data is very important to understand both the human effects and the environmental consequences of these changes [4]. Therefore, information about LULC is important for any kind of natural resource management. The accurate information about LULC changes of an area is important to understand the relationship between human and natural resources for better support of decision maker [5]. There is a continuous need for accurate and up-to-date LULC information for any kind of sustainable development that LULC serves as one of the main input criteria. As a result, various research workers for decision-making activities acknowledged the importance of mapping exact LULC and its change as well as updating it through time.

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Unplanned urban expansion causes to loss inagricultural land, leading to essential changes in agricultural area characteristics. Urban planning and monitoring temporal changes occurred can be achieved using different time series data remotely sensed data [6]. Change detection can be defined as the process of defining and/or illustratingtemporal changes in the LULC area using multi-temporal imagery. The basic principle behind using remote sensing data for detecting the change of LULC is that it can identify thechangeoccurred between two or more dates. Numerous studies have showed the problem of accurately monitoring of LULC change in a wide variety of environments [7, 8, 3, 9].Several studies have assessed the changes in LULC in arid and semi-arid regions [10, 11, 12, 13, 14, 15]. These studies concluded that urban growthgenerallyhappenson expense of the fertile agricultural lands.There are differentmethods available to be used to detect and assess differences such as image differencing and ratios or correlation and thes echanges could be attributed [16, 17, 18, 19, 20]. Simple change detection is not generallynecessary. Material about the initial and final status of land cover or land use types (“from-to” analysis) is usually essential [21]. Comparisons of post-classification resultant thematic maps are considered one of the simple change detection techniques whichare utilized to assess the variouskinds of land use change. The success degree mainly depends on the accuracy of the classified maps. Generally, regional changes (e.g. widespread logging, main urban development) could be assessed and mapped simply. While in evolutionary changes (e.g. degradation, colonization or erosion), the boundaries might not be obvious and class-labels ambiguous [21, 22, 3].

Aim of studyisassessment of the urban sprawl hazard and itseffecton the area of the agriculture land in northern part of Nile Deltaof Egypt using program of remote sensing and GISduring the period 1984-2016.

MATERIALS AND METHODS

Study Area: The area of study is found between 31° 12’ 57” and 31° 33’ 07” North and 30° 57’ 55” and 31° 14’ 59” East in the north of Nile Delta, it covers about 637 km^2 (157341.96fed.), Map (1). The study area climate is arid and semi-arid Mediterranean type, characterized by very little precipitations. Precipitations on the study area were onlyone hundred to two hundred millimeter throughout the year and most of this falls within the winter months. The northern Nile delta shows its highest temperatures in summer months, averaging 32-48°C. Winter temperature is typically within 10°-19°C, with cooler temperatures and a rare precipitation. The northern Nile delta region come back to be quite wet throughout the winter months. In keeping with the aridity index classes [23], the Nile delta is located under arid and semi-arid climate.

In the summer, main crops are rice, cotton and maize. Main crops in the winter are clover and wheat.

Materials

Soil Map: Soil map of Egypt is the major item that were collected and transformed to digital format according to [24].

Topographic Map: Topographic map was created at scale 1: 50, 000 which covering the study area, produced by the Egyptian General Survey Authority (EGSA) were transformed to a digital format.

Satellite Data: Various kinds of multispectral satellite sensors were used for tracking and mapping the changes occurred in the land use.These sensors include Landsat TM (1984), Landsat ETM$^+$ (2002) and Landsat 8 (2016).

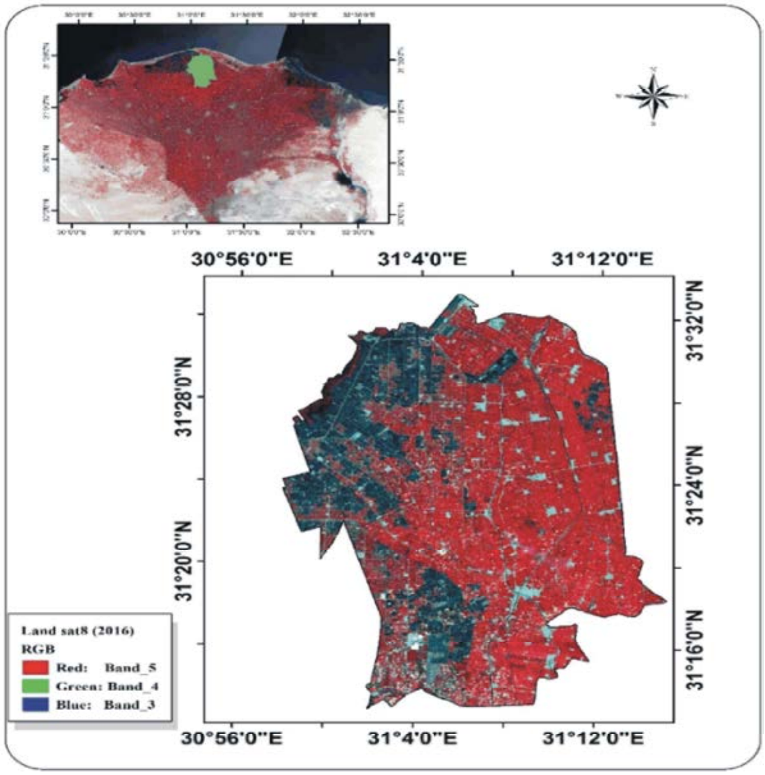
Methods

Image Processing and Software: Image processing procedures were applied using the ENVI 5.1 software and ArcGIS 10.2 Software. Image processing could be categorized into Image pre-processing, as well as geometric corrections; image enhancement for upgrading pixel readings and data improvement; image classification for clustering spectral content of the image into definite classes [25].

Pre-Processing of Satellite Image

Geometric Correction: Landsat image geometric correction that used in the present study was achieved by using ENVI 5.1 and ArcGIS 10.4 software [26, 27]

Image Processing: Image processing and enhancement are two ways to change and alert the original raw data to bring out visual details. In order to make use of image processing software, the data have to be in the form of digital raster data. The used Landsat TM data is already in digital raster format. With these picture elements (Pixels) a variety mathematical operations can be performed [27].



Map 1: Study area on land sat 8 image

Satellite Image Classification: Image classification could be defined as theautomatically process of classifying all the image pixels into land cover classes [28]. Supervised image classification technique is a user-controlledprocess in which pixels are given to classes according to pre-determined training sites acquired previously from field data, maps and aerial photographs [29].

Image Enhancement and Visual Interpretation: The visual interpretationprocess and image enhancement attempts to improve the matchingcapabilities of the computer and the human mind. The human mind is very good at the spatial interpretation and is clever of finding different features in the satellite image [30].

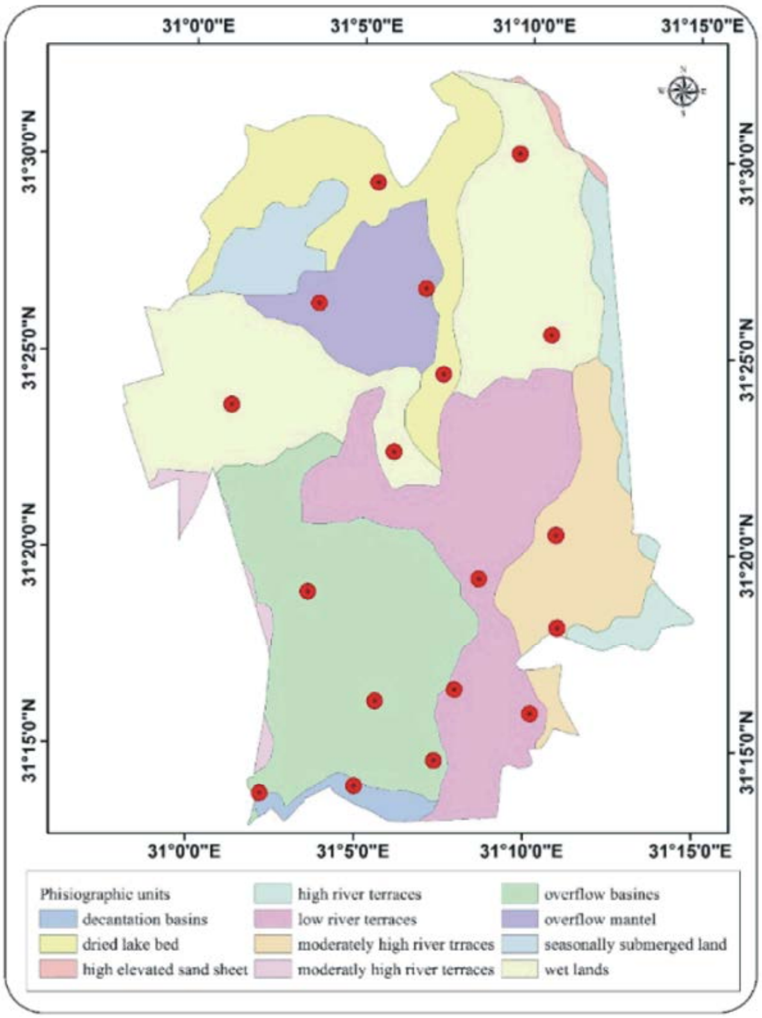
Fieldwork and Laboratory Analysis: Soil samples were collected from 18 soil profiles chosen carefully based on the soil physiographic map (2), in the studied area.The soil profiles morphologically described in the field, according to the system outlined by [31]. Water samples were collected from irrigation, drainage and water table sources closed to the soil profiles locations. Soils and water samples were analyzedas follows:

Physical Analyses: Particle size distribution was determined according to [33]. Bulk density was determined by [32].

Chemical Analyses: Soil Electric conductivity (EC), soluble cations and anions, CaCO3, organic matter (OM), pH, Gypsum content and sodium adsorption Ratio (SAR), were determined according to [33]. Available N, P and K were determined by [32], available Fe, Mn, Zn and Cu were extracted by using DTPA and determined by Atomic Absorption according to [33].Cation exchange capacity (CEC), was determined using ammonium acetate (NH4 OAC) pH 7.0, according to [33].

Land Capability Map: The obtained of land capability map was using ALES-arid software that has an extension in ArcGIS. Due to urban sprawl leads to calculate the losted area from different land capability classes by overlaying the urban land cover class with the soil capability map.

Urban Sprawl Detection: Irrespective of the change detection used technique, success of change detection process from images can rely on each the character of the

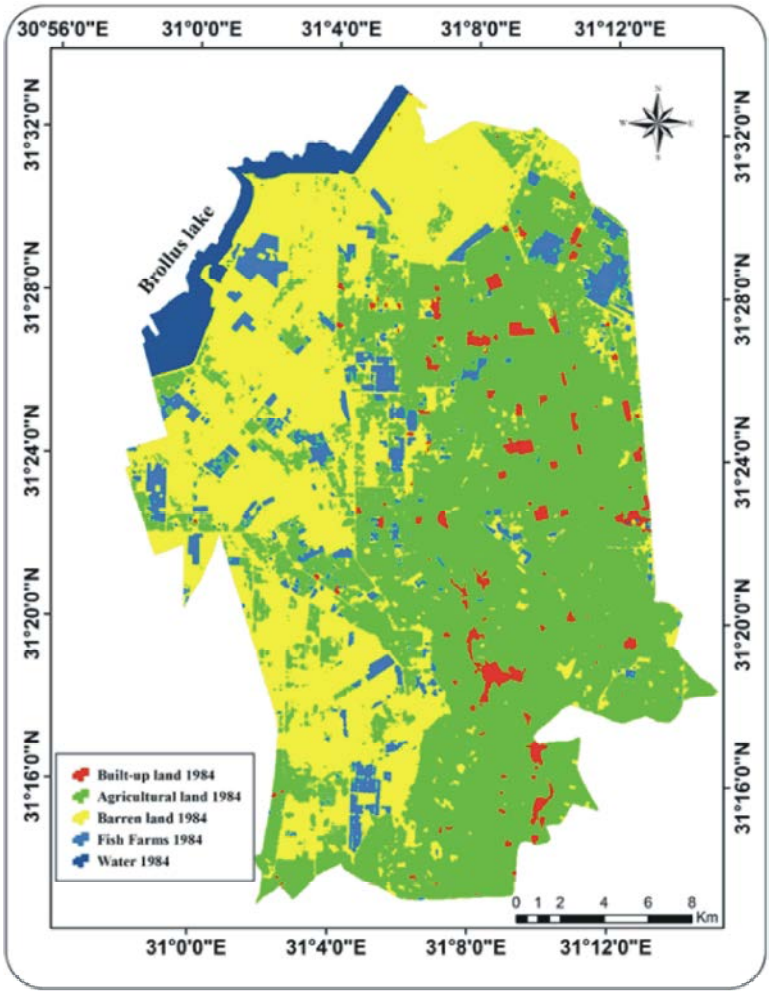


Map 2: Distribution of soil profiles locations

change concerned and also success of the classification procedures. So whether the character of the change in a specific scene is either abruptly or gradually in the collected images then change should be comparatively simple to be detected [34].Within the studied area, field measurements and observation showed that the land cover change between the three dates was each obvious and gradual. Post-classification and other change detection techniques were used during this study. Post-classification is that the most evident technique for change detection, which needs to compare several images that resulted from classification. Post-classification results was verified to be the foremost effective technique, where it rely on the data, which resulted from two dates are on an individual basis classified. The built-up class was detected after the satellite images post-classification processes, then cross-tabulation analysis was applied to check the spatial distribution of land use in (1984, 2002 and 2016) and so impact of urban sprawl on the different varieties of the soil capability, ArcGIS 10.4.1 was used for this operate.

RESULTS AND DISCUSSION

Land Use/ Land Cover (LULC) Map: An up to date land use/ land cover map was produced based on the supervised classification (i.e. maximum likelihood classifier) for multispectral Landsat image dated 2016. In order to improve the accuracy of the classification, ancillary data and field observation were incorporated into the classification results using Arc GIS environment. The overall accuracy obtained was 94.42 %. Five main classes were detected in the study area; urban area, agricultural land, barren land, fish farms and water (EL-Brollus Lake).



Map 3: LULC Map for the study area in 1984

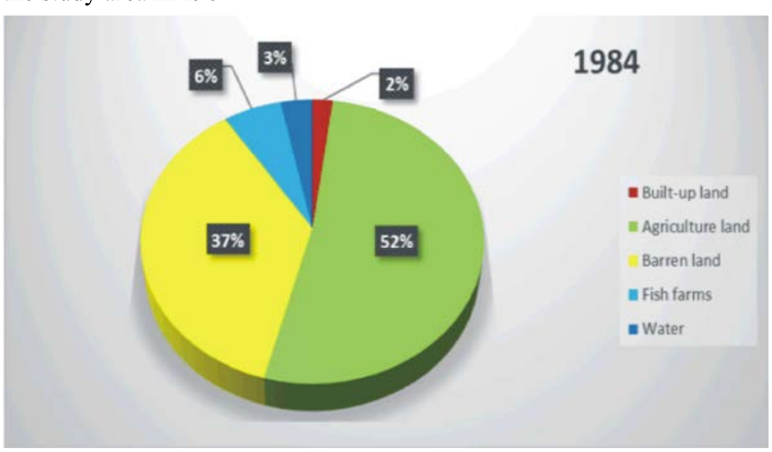


Fig. 1: LULC classes in 1984

The main class represented in the study area was the agricultural land, which dominates the whole area except the western parts. It is mostly a cultivated land; occupying 111683.7 feds. (74%). Fish farms represent the second dominant class in the study area exhibiting 27045.2 feds. (18%). In the third place, the built-up land that has been distributed in the whole study area, occupying 9715.5 feds. (6%). Barren land represents the least dominant class in LULC, amounting 752.3 feds. (0.5%). Roads were found embedded in the whole study area with a total length of 1006.1 km. Irrigation and drainage canals were found in association, with the agricultural land that amounted to 852.8 km Fig. (1) Map (3).

Change Detection in Land Use Classes: The spatial-temporal changes in land use classes were assessed over a 32 years period from 1984 to 2016 in El-Hamul district, Kafr El-Sheikh Governorate. In Egypt, the urban expansion on account of the agricultural land is considered one of the main causes of land degradation and loss; particularly in the Nile Delta region where the most fertile soils are found. In most of the Egyptian Governorates, the built-up areas are continuously growing at the expensive the agricultural land.

LULC During Years of Study: In 1984, areas of LULC classes were 55445.0 feds, 78943.4 fed., 9095.2 feds. and 3138.1 fed. for agricultural land, barren land, fish farms and built-up land, respectively. A significant difference was observed within LULC classes during 1984. LULC classes could be ordered as follow; agricultural land (52%)> barren land (37%) > fish farms (6%) > built-up land (2%) considering the areas in 1984 as shown in Map 3 and Fig. 1.

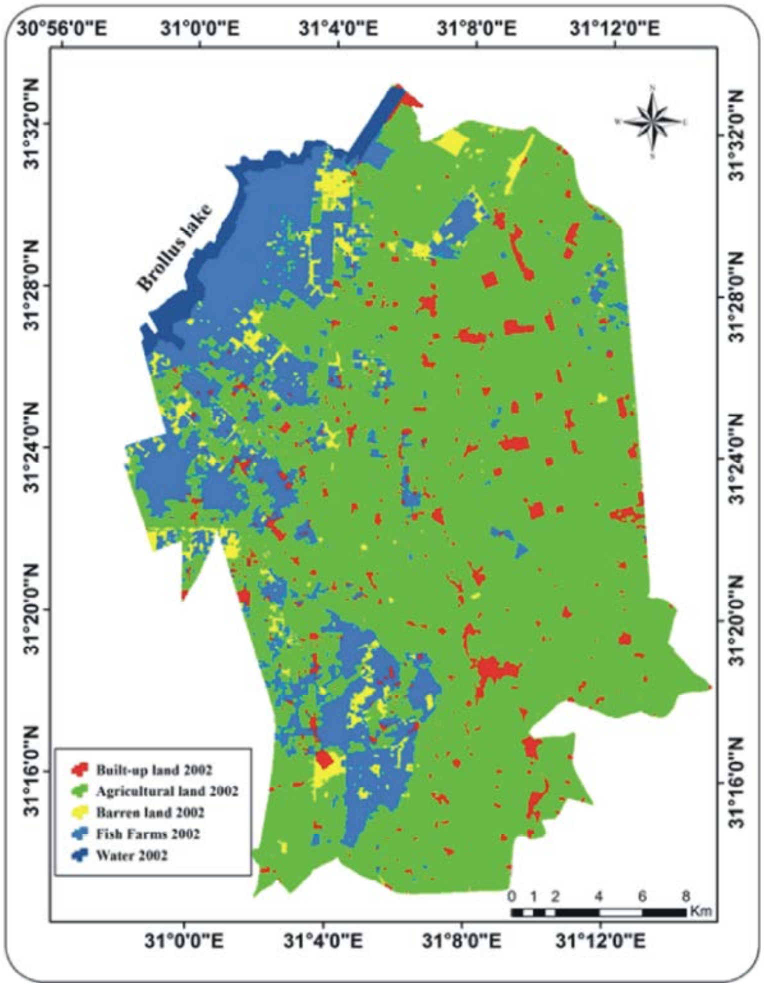
In 2002, areas of LULC classes were 109111.9, 27104.1, 6756.4 and 5548.0 fed. for agricultural land, fish farms, built-up and barren land, respectively. Order of LULC classes in 2002 showed some differences compared to 1984, where the area of the fish farms has been increased more than the urbanized areas and the barren land classes. In 2002, LULC classes could be ordered as follow; agricultural land (72 %)> fish farms (18 %) > built-up land (4%) > barren land (4%). The areas of residential and barren lands recorded similar areas; 6756.4 and 5548.0 fed, respectively. (Map 4, Fig. 2)

In 2016, areas of LULC classes were 111683.7 fed. agriculture, 27045.2 fed. fish farms, 9715.5 fed. for built up land and 752.3 fed. barren land. LULC classes in 2016 showed the same order of 2002 while the areas and percentage of each class were changed. LULC classes could be ordered as follow; agricultural land (74 %)> fish farms (18 %) > built-up land (6%) > barren land (0.5 %).

Changedetection During 1984 - 2002: A significant increase was recorded in the total areas of agricultural areas and fish farms, while a slight increase was detected in the built-up areas during the period of 1984-2002. The agricultural land area increased from 78943.4 Fed. in 1984 to 109111.9 fed. in 2002, with a difference 30168.4 fed. Map (6). The built-up land area increased from 3138.1 feds. in 1984 to 6756.4 fed. in 2016, with a difference + 3618.3 fed. as well as the area of fish farms showed an increase from 9095.2 feds. in 1984 to 27104.1 fed. in 2002 with a difference 18008.9fed. Despite the agricultural area showed the highest increase during 1984-2002, it was found that the urbanized areas expanded by 115.3 % at the where are that the agricultural land increased by 38.2 %. The increase recorded in agricultural land, fish farm and urban area were synchronized with a decrease in barren land and water bodies. The significant decrease was observed in the barren land area in comparison with the water, which showed a very slight decrease during 1984-2002. The barren land area decreased from 55445.0 to 5548.0 feds. with a difference of 49897.0 fed., as shown in Fig. (5).

Changes During 2002 - 2016: A significant increase was recorded in the agricultural areas and built-up areas during the period of 2002 - 2016. The agricultural land area increased from 109111.9 fed. in 2002 to 111683.7 fed. in 2016, with a difference 2571.8 fed. map (7). Furthermore, the built-up land area increased from 6756.4 feds. in 2002 to 9715.5 fed. in 2016, with an increase of 2959.1 fed. Despite the agricultural area and the built-up land showed a near increase during 2002-2016, it was found that the built-up land expanded by 43.8 % at the same time that the agricultural land increased by 2.4 %. The increase that was recorded in agricultural land and urban area were synchronized with a decrease in abarren land, fish farm and water. The highest decrease was shown in the barren land area followed by the fish farms and water. The fish farms showed relatively similarity of total increase during 2002-2016. The barren land decreased from 5548.0 feds. in 2002 to 752.3 fed. in 2016, with a significant difference 4795.7 fed. In addition, the fish farms decreased from 27104.1 feds. in 2002 to 27045.2 fed. in 2016, with a slight difference 58.8 fed. as shown in Fig. (6) and Table (2).

Overall Changes During the Study Period (1984-2016): The overall changes in LULC classes during the whole period of study (1984 to 2016) are shown in Figure (7) and Table (3). It was noticed an increas in the area of built-up land, agricultural land and fish farms by 6577.4, 32740.2 and 17950.0 feds. respectively. This increase synchronized with a decrease in the total area of



Map 4: LULC Map for the study area in 2002

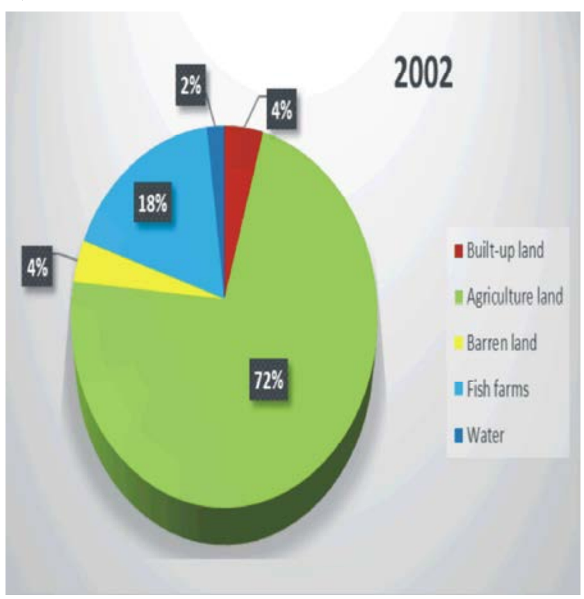
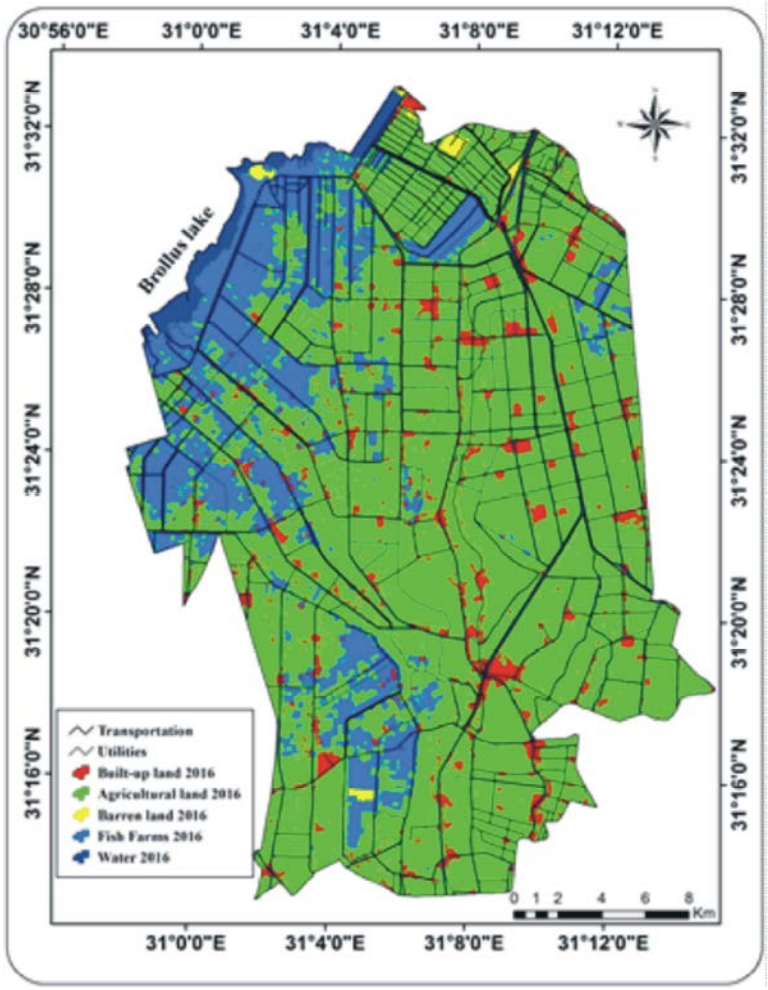


Fig. 2: LULC classes in 2002



Map 5: LULC Map for the study area in 2016

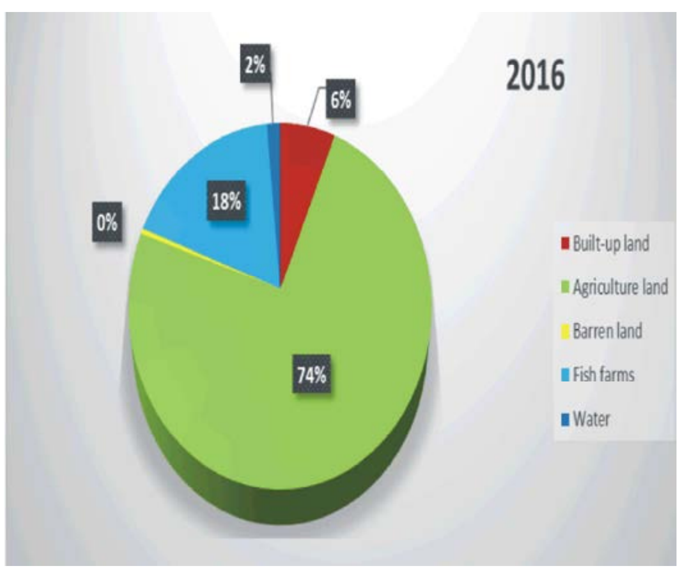


Fig. 3: LULC classes in 2016

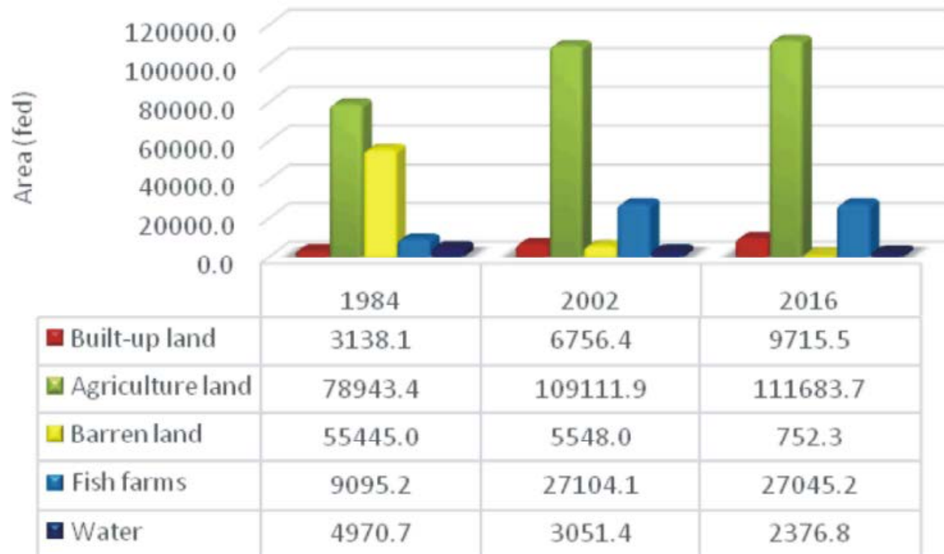


Fig. 4: The LULC area during years of study

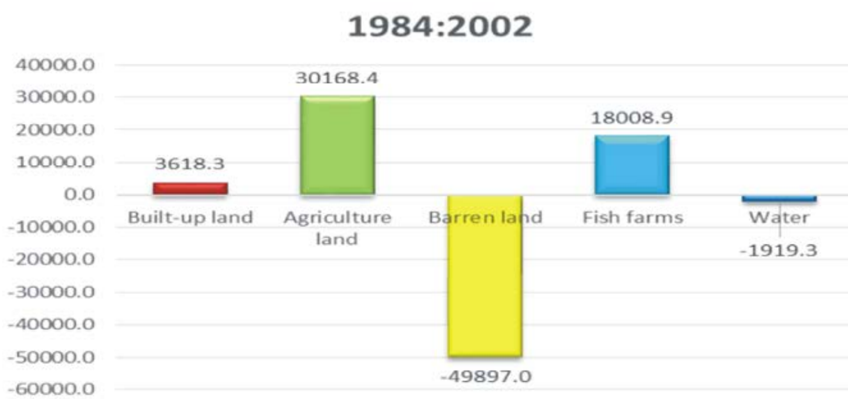


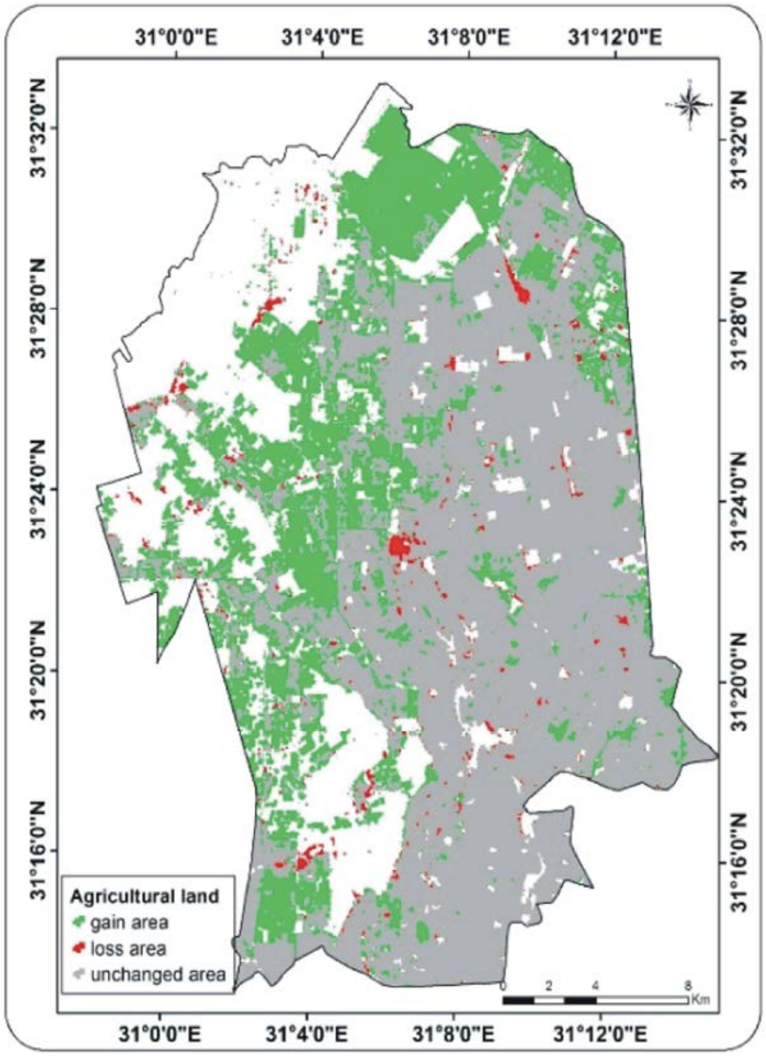
Fig. 5: Area changes of LULC classes from 1984 to 2002

Table 1: Change detection between 1984-2002 years

	1984	2002		
	Fed.	Fed.	Change of area (Fed.)	%
Built-up land	3138.1	6756.4	3618.3	115.3
Agricultural land	78943.4	109111.9	30168.4	38.2
Barren land	55445.0	5548.0	-49897.0	-90.0
Fish farm	9095.2	27104.1	18008.9	198.0
EL-Brollus lake	4970.7	3051.4	-1919.3	-38.6

able (2): Change detection between 2002-2016 years

	2002	2016		
	Fed.	Fed.	Change of area (fed.)	%
Built-up land	6756.4	9715.5	2959.1	43.8
Agricultural land	109111.9	111683.7	2571.8	2.4
Barren land	5548.0	752.3	-4795.7	-86.4
Fish farm	27104.1	27045.2	-58.8	-0.2
EL-Brollus lake	3051.4	2376.8	-674.6	-22.1



Map 6: Change of agricultural land area between years 1984: 2002

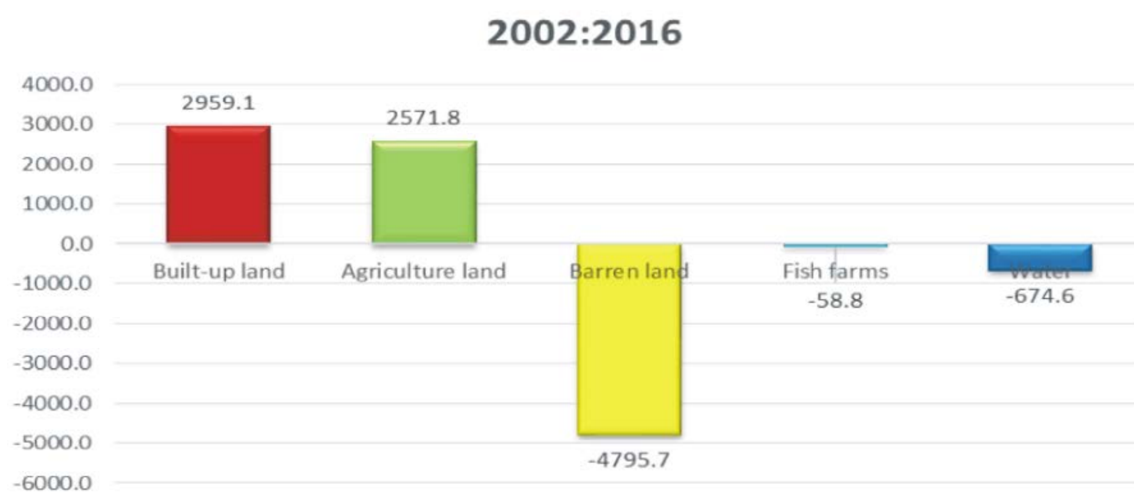
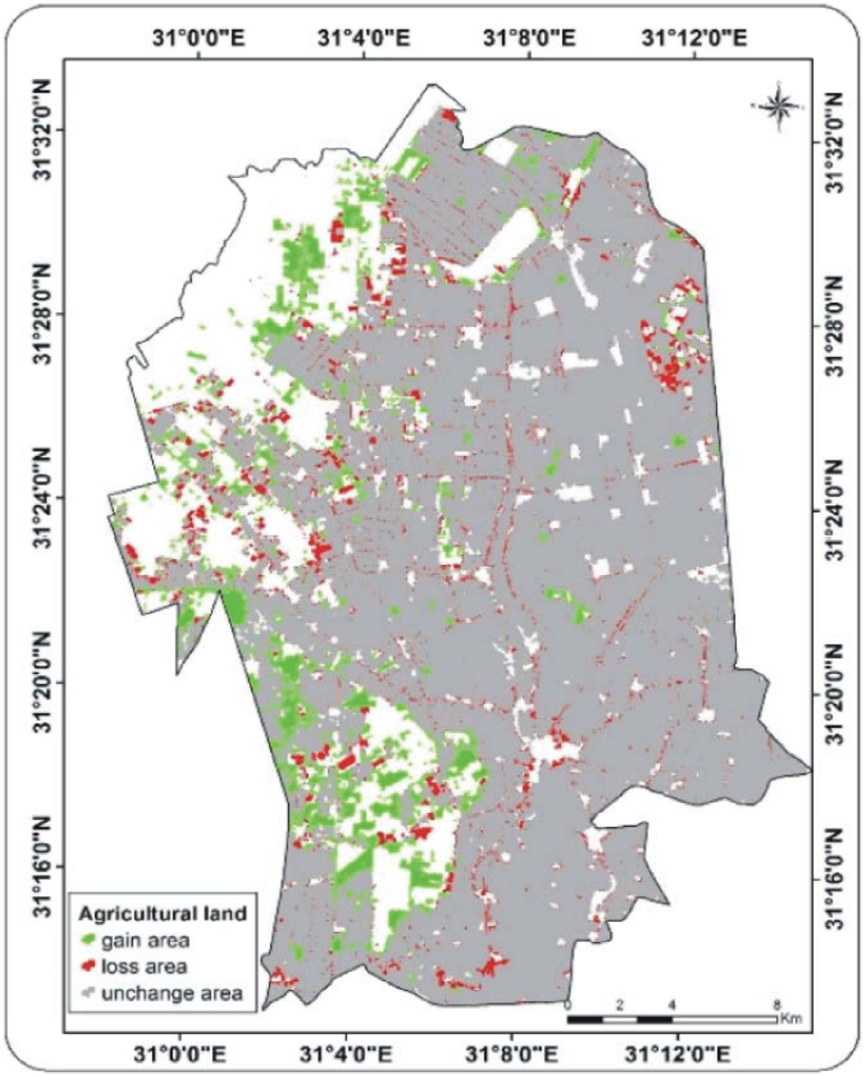


Fig. 6: Area changes of LULC classes from 2002 to 2016



Map 7: Change of agricultural land area between years 2002: 2016

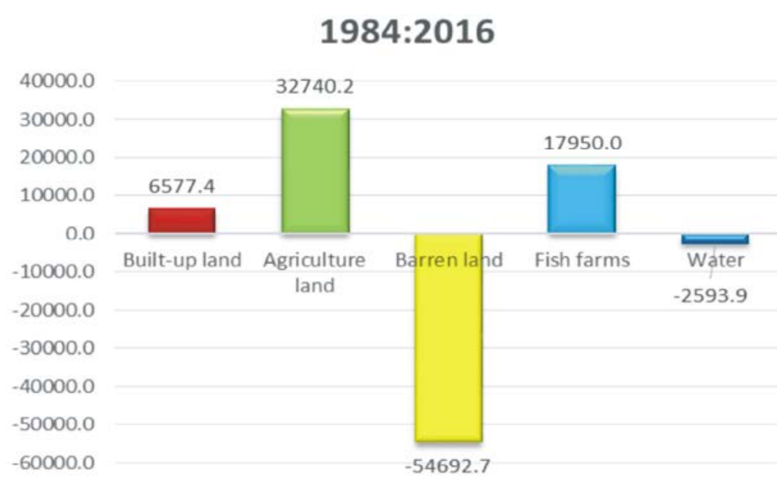
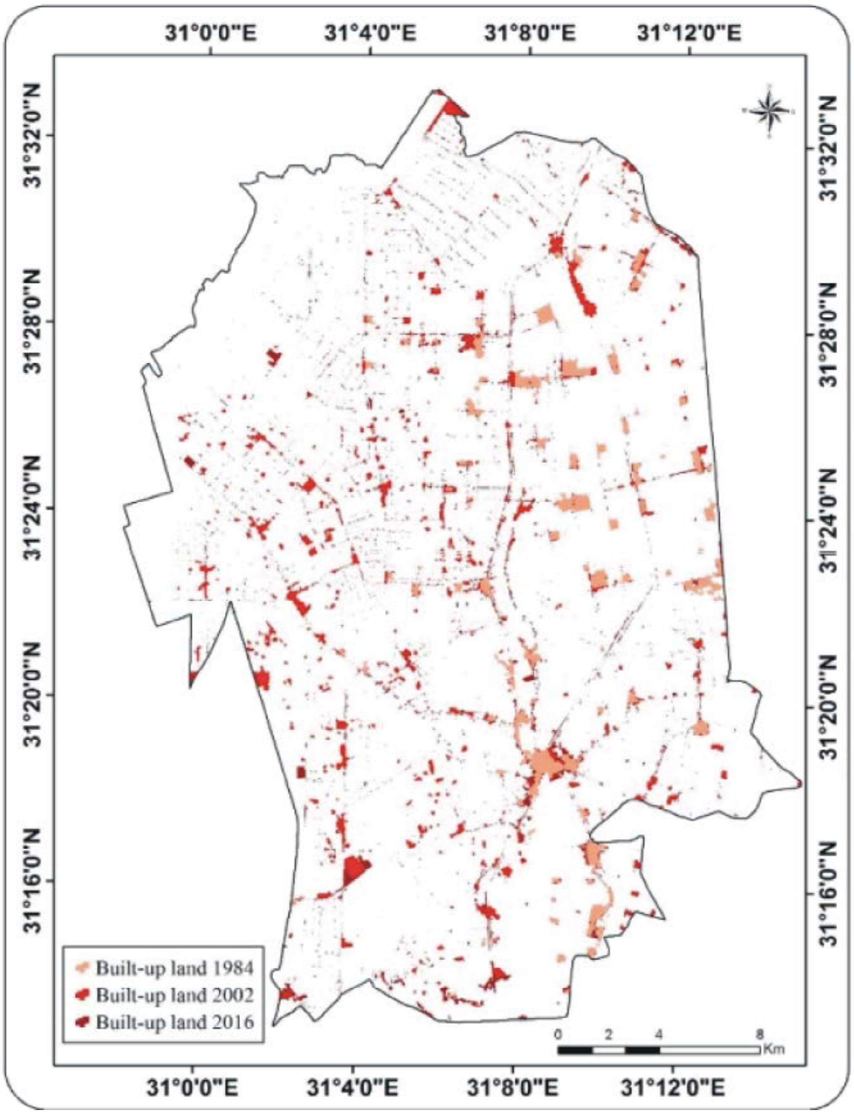


Fig. 7: Area changes of LULC classes from 1984 to 2016

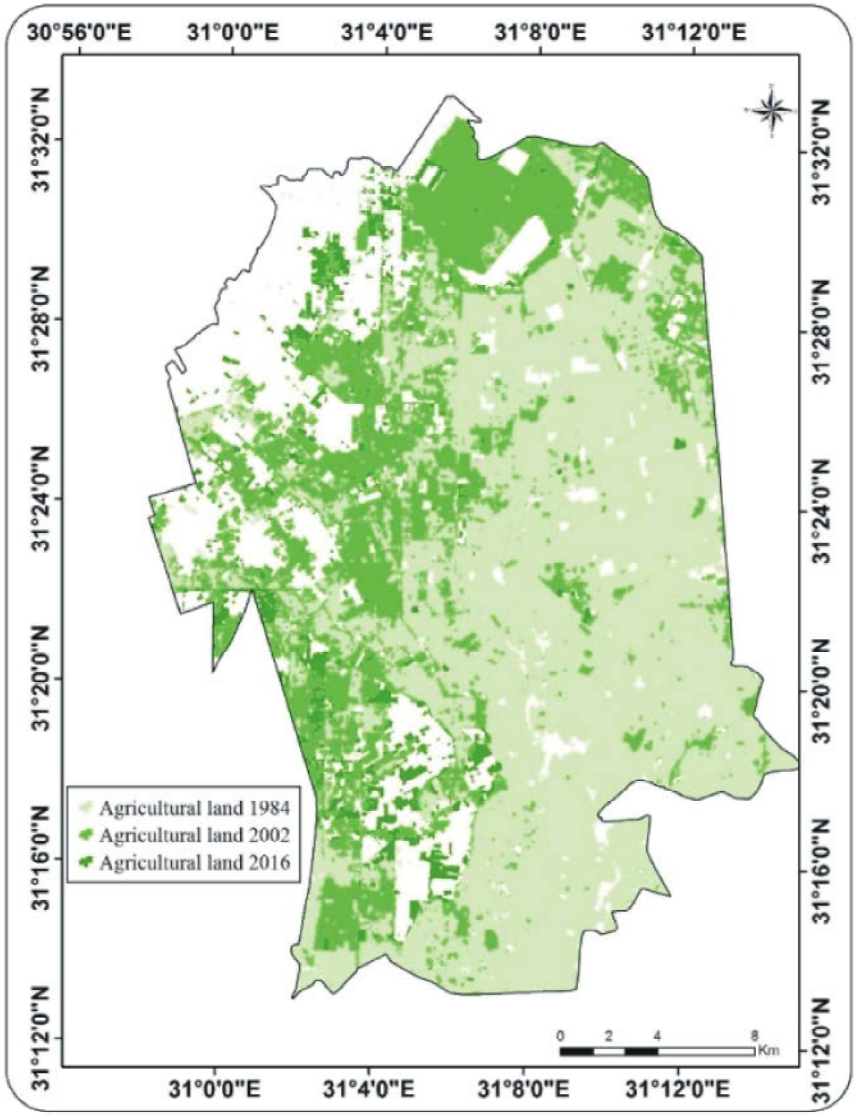
Table 3: Change detection between 1984 to2016 years

	First period (1984-2002)		Second period (2002-2016)		Total change (1984-2016)	
	%	Rate (fed/year)	%	Rate (fed/year)	%	Rate(fed/year)
Built-up land	115.3	201.0	43.8	211.4	209.6	205.5
Agricultural land	38.2	1676.0	2.4	183.7	41.5	1023.1
Barren land	-90.0	-2772.1	-86.4	-342.6	-98.6	-1709.1
Fish farm	198.0	1000.5	-0.2	-4.2	197.4	560.9
EL-Brollus lake	-38.6	-106.6	-22.1	-48.2	-52.2	-81.1



Map (8: Built-up area changes during the period of study (1984-2016)

barren land by 54692.7 feds. as shown in Fig. (7) and Map (8), (9) and(10). The annual rate of built-up land slightly increased from the first period to the second period by 201 fed/year to 211.4 fed/year respectively. While the agricultural land annual rate highly decreased from 1676 fed/year in the first period to 183.7 fed/year in the second period. The fish farms recorded an increasing annual rate in the first period by 1000.5 fed/year, but in the second period, it recorded a decreasing rate of4.2 fed/year. The annual rate of EL-Brollus Lake drying decreased from 106.6 fed/year to 48.2 fed/year in the first and second periods respectively.



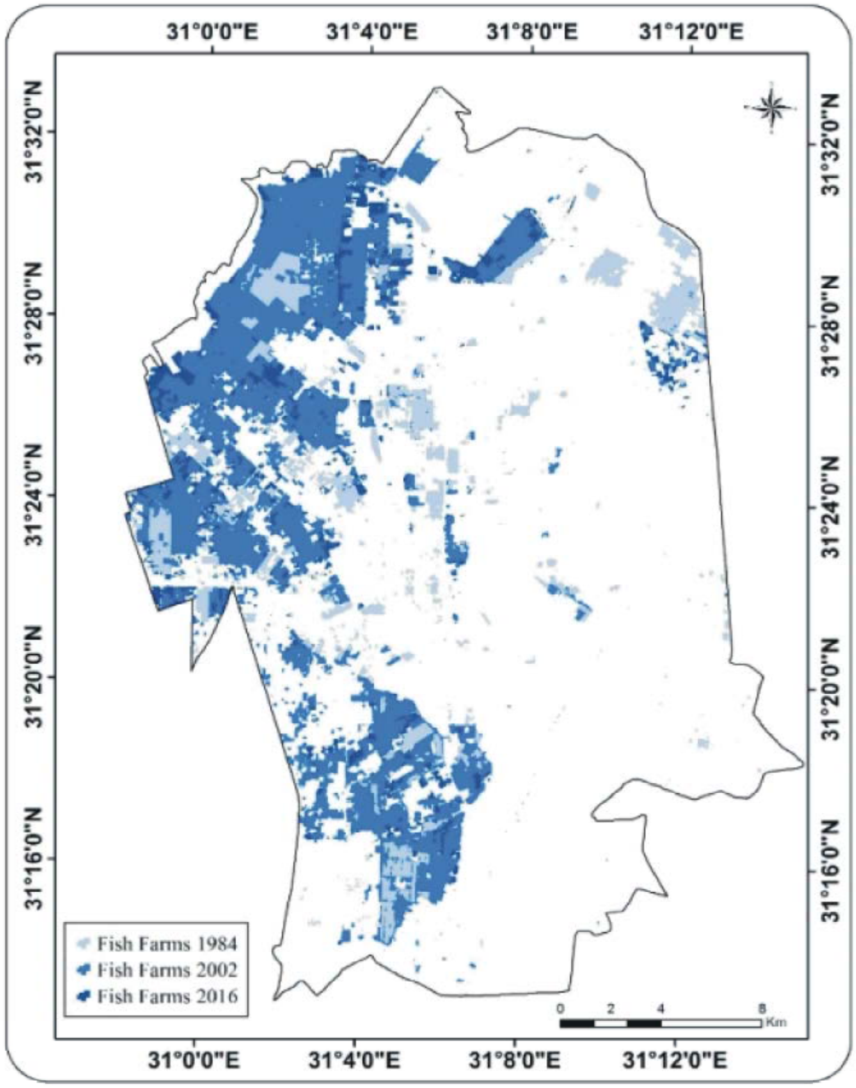
Map 9: Agricultural land area changes during the period of study

Table 4: Land capability classes with change detection area between 1984 to2016 years

Land capability class	Area 1984 (feddan)	(km2)	Area 2002 (feddan)	(km2)	Area 2016 (feddan)	(km2)
C2	98182	412	95947	403	93833	394
C3	50286	211	48912	205	48070	202
Total	148468	623	144859	608	141903	596

Generally, it was found that the annual rate of agricultural land growth is greater than the rate of built-up land sprawl during the period of study. Despite that, the built-up area was increased by 209.6 %, while the agricultural land was increased by 41.5 %.

The increase in the urban areas occurred at theexpense of barren land by 3701.0 feds. and on agricultural land by 2630.1 feds. Barren land area decreased because it changed into the built-up land, agricultural land and fish farms by 3701.0, 31325.4 and 19825.3 fed respectively. Some of fish farms area changed to agricultural land by 5005.6 feds. Part of EL-Brollus Lake was dried and changed into fish farms.



Map 10: Change of fish farms area during the period of study (1984-2016)

Chang Detection of Land Capability: Studied area was classified into two capability classes, which are Good (C2) and Fair (C3) as shown in Figure (8). Land capability indices ranged between (46.4 to 68.9%). Good soils represent the largest area about 66 % of the studied area, where fair and poor soils represent about 34%. According to ALES Arid, the study area was classified into two capability classes:

Fig. 8 showed that soils with theGood land capability (C2): Soils in this class have one slight limitation, which requires good ongoing management practices or slightly restrict the range of crops or both. These soils are deep, well-drained, moderately affected with alkalinity and low to moderate electric conductivity (ECe). Accordingly, these soils need slightly good management practices to improve its current situation. This class is representing most of thestudy area, about 100316 fed. (66 % of total area).

Soils with thefair land capability (C3): Soils in this class (Fig. 8) have more than slight limitations and more than moderate limitations that require moderately intensive management practices or moderately restrict the range of crops or both. Soils in this class represent the second place of thearea (34% of the total area) after soils with good capability. Therefore, the current capability of this soil map unit can be changed to be good with moderately intensive management practices. This class is covering about 51288 fed.

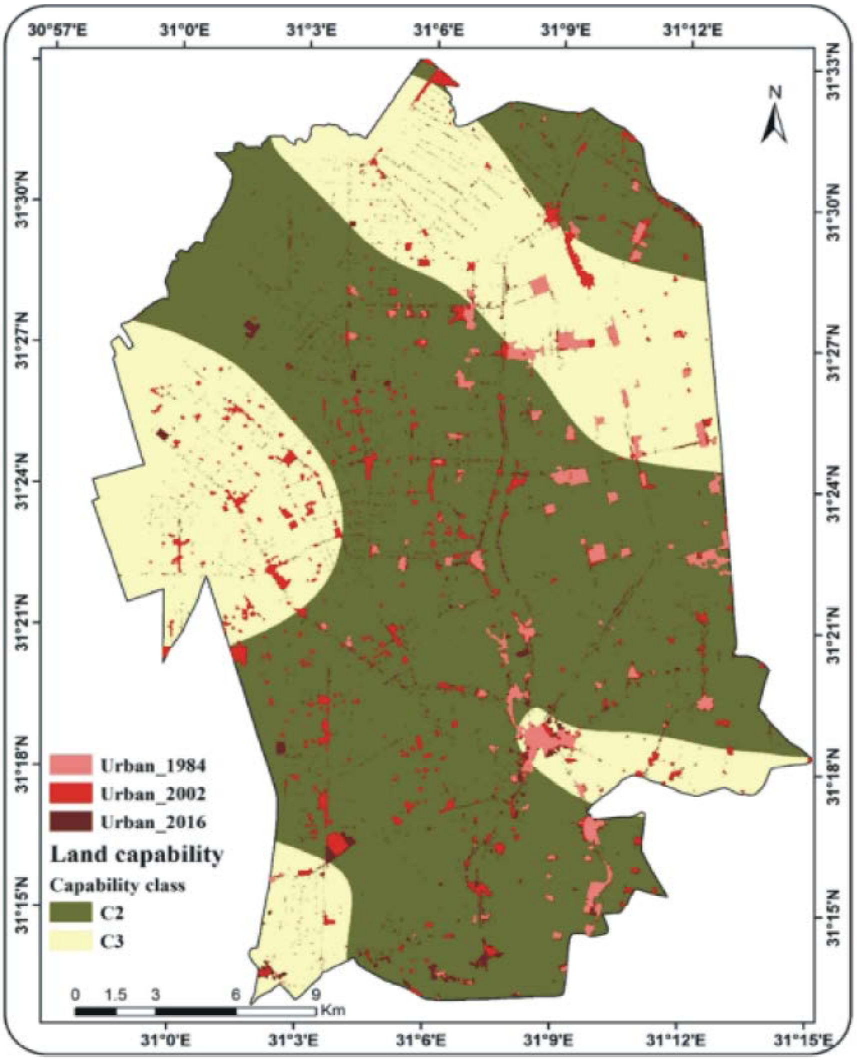


Fig. 8: Land capability classes with change detection between 1984 to2016 years

CONCLUSION

Visual interpretation and post-classification technique were a powerful way of extract urban areas precisely. The studied area has subjected to an exceptionally serious land cover change because of urbanization that resulted from quick and continuous growth of population. A significant increase in built-up areas occurred on the expense of the most fertile soils in the study area. GIS gave a worthy data about the how and influence of urban sprawl, through the integration between the urban sprawl map that resulted from post-classification and the soil capability database.

Fast population growth and the economic development are considered the fundamental reasons of urban encroachment. In the northern of Nile delta, urban growth is considered one of the main land degradation forms. This downside has to be seriously planned, through multi-dimensional fields together with socioeconomic, to keep up the valuable and restricted agricultural land and so increase food production.

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