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Original Article/Research

Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt

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Abstract

Urban growth is a worldwide phenomenon but the rate of urbanization is very fast in developing country like Egypt. It is mainly driven by unorganized expansion, increased immigration, rapidly increasing population. In this context, land use and land cover change are considered one of the central components in current strategies for managing natural resources and monitoring environmental changes. In Egypt, urban growth has brought serious losses of agricultural land and water bodies. Urban growth is responsible for a variety of urban environmental issues like decreased air quality, increased runoff and subsequent flooding, increased local temperature, deterioration of water quality, etc. Egypt possessed a number of fast growing cities. Mansoura and Talkha cities in Daqahlia governorate are expanding rapidly with varying growth rates and patterns. In this context, geospatial technologies and remote sensing methodology provide essential tools which can be applied in the analysis of land use change detection. This paper is an attempt to assess the land use change detection by using GIS in Mansoura and Talkha from 1985 to 2010. Change detection analysis shows that built-up area has been increased from 28 to 255 km^2 by more than 30% and agricultural land reduced by 33%. Future prediction is done by using the Markov chain analysis. Information on urban growth, land use and land cover change study is very useful to local government and urban planners for the betterment of future plans of sustainable development of the city.

Keywords: Land use/cover; Urban growth; Monitoring; Remote sensing; GIS; Egypt

1. Introduction

Land use and land cover change, as one of the main driving forces of global environmental change, is central to the sustainable development debate. Land use/land cover change has been reviewed from different perspectives in order to identify the drivers of land use/land cover change, their process and consequences. Urban growth, particularly the movement of residential and commercial land to rural areas at the periphery of metropolitan areas, has long been considered a sign of regional economic vitality.

The rapid changes of land use and cover than ever before, particularly in developing nations, are often characterized by rampant urban sprawling, land degradation, or the transformation of agricultural land to shrimp farming ensuing enormous cost to the environment (Sankhala and Singh, 2014). This kind of changes profoundly affects local

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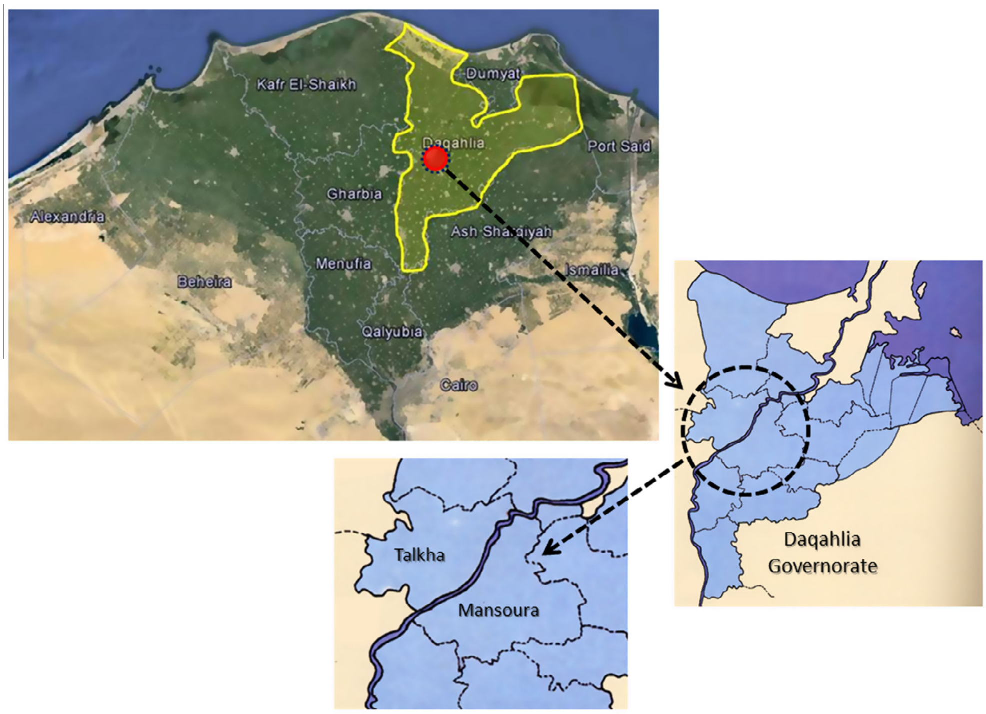

Figure 1. Location of study area of Mansoura and Talkha cities.

and/or regional environment, which would eventually affect the global environment. Human induced changes in land cover for instance, influence the global carbon cycle, and contribute to the increase in atmospheric CO (Alves and Skole, 1996). It is therefore indispensable to examine the changes in land use/cover, so that its effect on terrestrial ecosystem can be discerned, and sustainable land use planning can be formulated (Muttitanon and Tripathi, 2005).

In Egypt, unprecedented population growth coupled with unplanned developmental activities has led to urbanization, which lacks infrastructure facilities. This also has posed serious implications on the resource base of the region. The urbanization takes place either in radial direction around a well-established city or linearly along the highways. This dispersed development along highways, or surrounding the city and in rural countryside is often referred as sprawl. Some of the causes of the sprawl include – population growth, economy and proximity to resources and basic amenities.

National ministry of agriculture estimated that due to urban growth on agricultural lands, the agricultural land loss during the period 1980–2000, of not exceeding 25,000 feddan (26.25 thousand acres) yearly (Belal and Moghanm, 2011). Daqahlia governorate in the middle of the Nile Delta is one of the major agricultural governorates. Its agricultural lands are estimated by 650 thousand acres that puts it in the third place after Ash-Sharqiyah and Beheira governorates in terms of acreage where its agricultural lands represent 8% of the agricultural lands in the country (ESIS, 2014). Due to urban growth, its loss of agricultural land is estimated to be more than 25% during the period 1980–2010.

Urban growth monitoring is the process of studding the differences in the state of an object or phenomenon by remotely observing it at different times. Monitoring results from anthropogenic forces are the result of human modification of the environment (Pilon et al., 1988). In Egypt, remote sensing and its applications have emerged as early as this technology was invented (El-Baz et al., 1979); the growth monitoring has become a major application of remote sensing data and Geographic Information System (GIS). Growth monitoring is the process of determining and/or describing changes in land-cover and land-use properties based on co-registered multi-temporal remote sensing data. The basic premise in using remote sensing data for change detection is that the process can identify change between two or more dates that is uncharacteristic of normal variation. Numerous researchers have addressed the problem of accurately monitoring land-cover and land-use change in a wide variety of environments (Shalaby and Tateishi, 2007). Usually land uses and urban growth in remote sensing involves the analysis of two registered, aerial or satellite multi-spectral bands from the same geographical area obtained at two different times. Such an analysis aims at identifying changes that have occurred in the same geographical area between the two times considered (Radke et al., 2005).

Satellite remote sensing is a potentially powerful means of monitoring land-use change at high temporal resolution and lower costs than those associated with the use of traditional methods (El-Raey et al., 1995). Remote sensing data is very useful because of its synoptic view, repetitive coverage and real time data acquisition. The digital data in the form of satellite imageries, therefore, enable to accurately compute various

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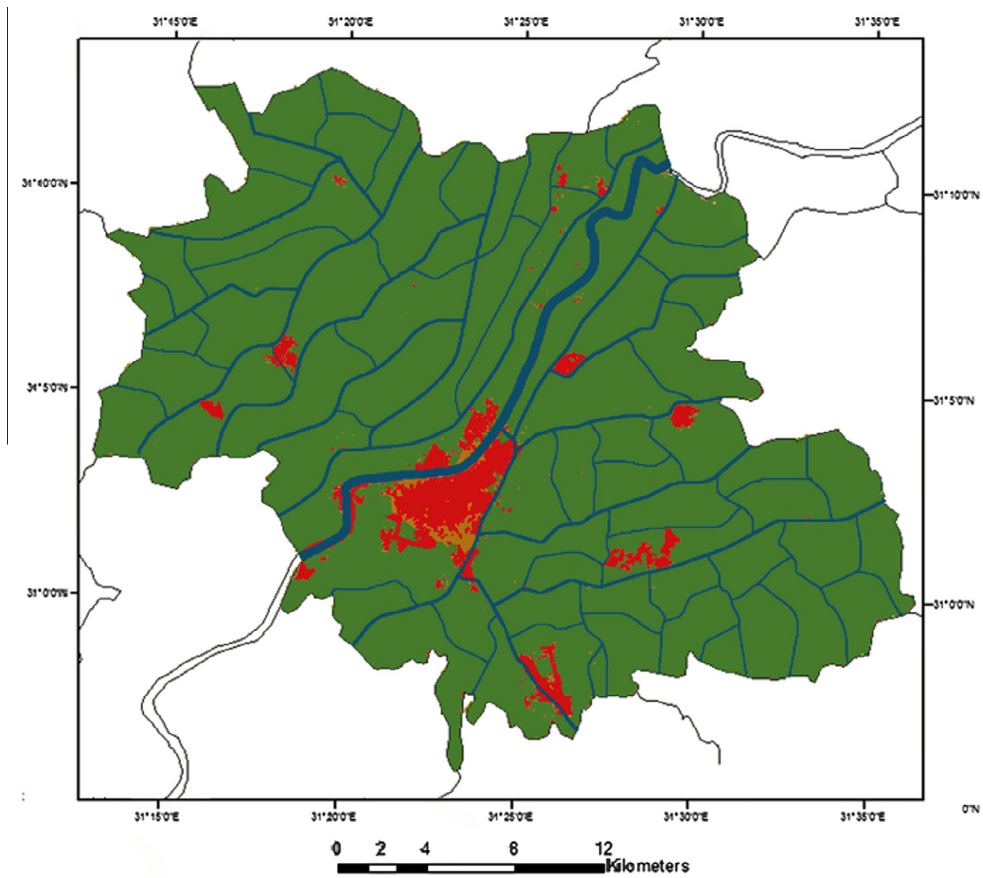

Figure 2. Mansoura and Talkha land use maps in 1985.

land cover/land use categories and help in maintaining the spatial data infrastructure which is very essential for monitoring urban expansion and land use studies (Mukherjee, 1987).

A GIS is a decision support system that can facilitate urban planning. The use of GIS modeling has become quite prevalent within the field of urban sprawl research. Some research on urban sprawl uses GIS as a tool in understanding the effects of urban sprawl on the natural environment. GIS reveals spatial patterns of urban sprawl by measuring distances of new urban growth areas from town centers and roads for example (Gar-On Yeh and Xia, 2001). Because urban development is irreversible, GIS simulates future land development (Lee et al., 1998).

The aims of the this study are to produce a land use/land cover map for two of the important cities in Daqahlia governorate that experienced a fast increase of urban population in the recent decades (Mansoura and Talkha cities) at different years in order to detect changes that have taken place particularly in the built-up land and subsequently to analyze the urban sprawl of the different time periods and to predict the urban area growth in the same over a given period (2010–2035).

2. Description of study area

Daqahlia governorate is located at the North East of Nile Delta in Egypt. Geographically, it is located between longitudes 30° and 32° E and latitudes 30°50′ and 31°50′ N. The Governorate is bordered by the governorate of Dumyat to north and Ash-Sharqiyah to south, while is aligned by Manzala lack in the east and the governorates of Kafr El-Shaikh, Gharbia and Menufia in the west (see Fig. 1). Mansoura (the capital of Daqahlia governorate) and Talkha are the most important cities in Daqahlia governorate; the area of investigation covers 670 km^2 (159,541 feddan). Regionally, the studied area is located in the central Daqahlia governorate and has been chosen because of the fast rate of urbanization and little studies were made on it. Urban growth is one of the main problems that reduces the limited highly fertile land in these cities. In this context, Mansoura and Talkha are experiencing various urban environmental problems. For sustainability of urban systems a balanced land use/land cover is to be planned.

3. Data and methodology

The present study involves the collection of topographic sheets from Survey of Egypt and city map from relevant authorities. The required satellite imagery for the study area is to be downloaded from the USGS Earth Explorer. Processing the imagery and image interpretation for the development of land use/land cover maps is in done in ERDAS Imagine software. The obtained maps are studied

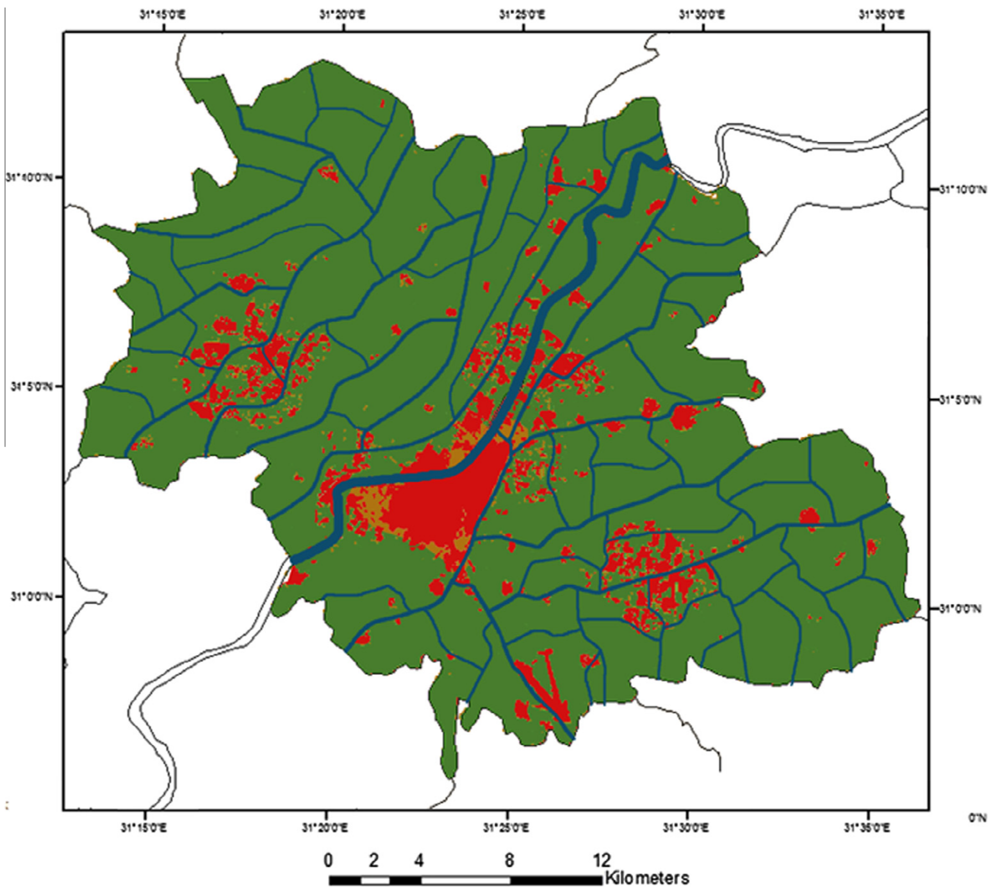

Figure 3. Mansoura and Talkha land use maps in 2000.

and analyzed to detect the change in urban sprawl. Future prediction is done based on past data.

3.1. Image preprocessing

Digital image processing was manipulated by the software used. The scenes were selected to be geometrically corrected, calibrated, and removed from their dropouts. These data were stratified into 'zones', where land cover types within a zone have similar spectral properties. Other image enhancement techniques like histogram equalization are also performed on each image for improving the quality of the image. With the help of Survey of Egypt topographic-sheets of 1:50,000 and city plan map obtained from Daqahlia governorate headquarter, the study area has been delineated. The data of ground truth were adapted for each single classifier produced by its spectral signatures for producing series of classification maps.

3.2. Classification of images

The pre-processed images are then classified by both un-supervised, supervised classification methods. In un-supervised classification method the ISODATA clustering algorithm which is built in the ERDAS Imagine will classify according to the number of classes required and the digital number of the pixels available. In the supervised classification technique the maximum likely hood algorithm will classify the image based on the training sets (signatures) provided by the user based on his field knowledge. The training data given by the user guides the software as to what types of pixels are to be selected for certain land cover type. The un-supervised classified image has been used for reference and for understanding about the distribution of pixels with different digital numbers. The classification finally gives the land use/land cover image of the area. Four land cover classes namely agricultural land, built up area, barren land and water bodies are identified in the study area.

3.3. Land use and land cover

There is no doubt that human activities have profoundly changed land cover in the two cities during the past three decades. Land is one of the most important natural resources. All agricultural, animal productions depend on the productivity of the land. The entire eco-system of the land, which comprises of soil, water and plant, meets the community demand for food, energy and other needs of livelihood. Viewing the Earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. In situations of rapid

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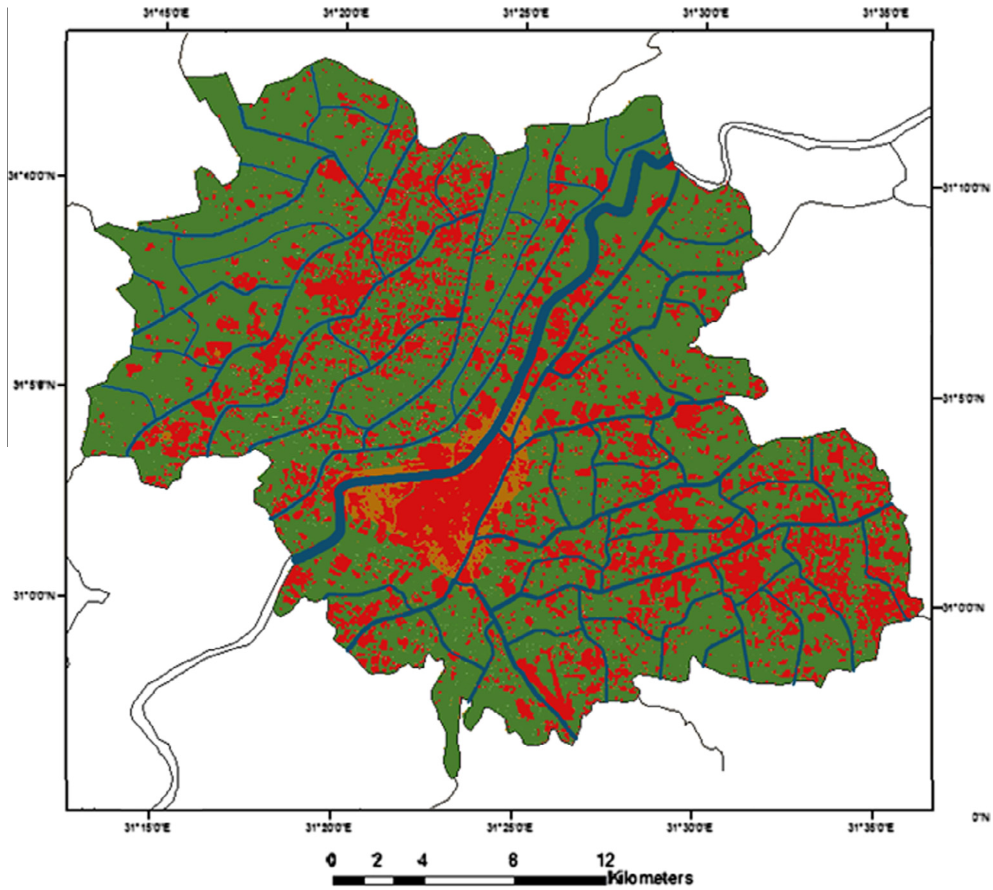

Figure 4. Mansoura and Talkha land use maps in 2010.

Table 1
Change detection in Mansoura and Talkha cities.

Map unit	Area 1985			Area 2000			Area 2010		
	km^2	Feddan	%	km^2	Feddan	%	km^2	Feddan	%
Agriculture	610	145,254	*91.04*	588	140,015	*87.76*	382	90,963	*57.01*
Built up	28	6667	*4.18*	47	11,192	*6.98*	243	57,863	*36.26*
Barren land	3	714	*0.48*	6	1428	*0.96*	19	4524	*2.83*
Water	29	6906	*4.3*	29	6906	*4.3*	26	6191	*3.9*
Total area	670	159,541	*100*	670	159,541	*100*	670	159,541	*100*

and often undocumented and unrecorded land use change, observations of the Earth from space provide objective information of human activities and utilization of the landscape. The classified images provide all the information to understand the land use and land cover of the study area.

3.4. Change detection analysis

Change detection analyses describe and quantify differences between images of the same scene at different times. The classified images of the three dates can be used to calculate the area of different land covers and observe the changes that are taking place in the span of data. This analysis is very much helpful to identify various changes occurring in different classes of land use like increase in urban built-up area or decrease in agricultural land and so on.

4. Results and discussion

4.1. Land use/land cover images

The classified images obtained after pre-processing and supervised classification which are showing the land use and land cover of the study area are given in Figs. 2–4. These images provide the information about the land use pattern of the study area. The red color represents the

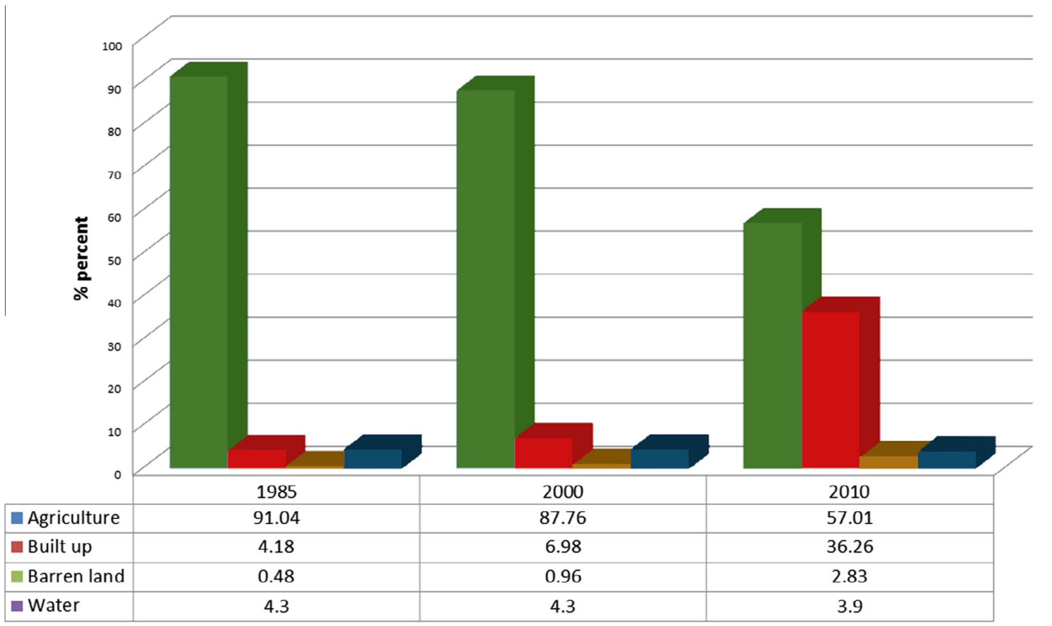

Figure 5. Land cover for Mansoura and Talkha in 1985, 2000 and 2010.

Table 2
Urban growth rate in Mansoura and Talkha cities.

Map unit	Change area 1985/2000		Change area 2000/2010		Change rate %	
	km^2	Feddan	km^2	Feddan	1985/2000	2000/2010
Agriculture	−22	−5239	−206	−49,053	−3.28	−30.74
Built up	+19	+4525	+196	+46,671	+2.83	+29.25
Barren land	+3	+714	+13	+3096	+0.45	+1.94
Water	0	0	−3	−714	0	−0.45

Table 3
Post classification matrix of study area from 1985 to 2000.

	1985					
2000	Class	Agriculture	Built up	Barren land	Water	Total
	Agriculture	140,015	0	0	0	140,015
	Built up	4265	6667	260	0	11,192
	Barren land	974	0	454	0	1428
	Water	0	0	0	6906	6906
	Total area	145,254	6667	714	6906	159,541

Table 4
Post classification matrix of study area from 2000 to 2010.

	2000					
2010	Class	Agriculture	Built up	Barren land	Water	Total
	Agriculture	90,963	0	0	0	90,963
	Built up	45,577	11,192	1094	0	57,863
	Barren land	3475	0	334	715	4524
	Water	0	0	0	6191	6191
	Total area	140,015	11,192	1428	6906	159,541

urban built-up area, dark green color shows the agricultural area, blue color shows the water bodies and light brown color shows the barren land.

4.2. Classification accuracy assessment

Each of the land use and land cover map was compared to the reference data to assess the accuracy of the classification. The reference data were prepared by considering random sample points, the field knowledge and Google earth. During the field visits a hand held GPS (Global Positioning System) is used to identify the exact position of the place under consideration with latitude and longitude and its type by visual observation. The ground truth data so obtained was used to verify the classification accuracy. Over all classification accuracy of Mansoura city for the years 1985, 2000 and 2010 are 86.67%, 84% and 85.2% respectively. For Talkha city for the years 1985, 2000 and 2010 are 77%, 81% and 85% respectively.

4.3. Change detection analysis

The dominant causative factors of the different types of land degradation were identified in the field and also collected from the available technical reports. The main type of human induced land degradation in the investigated areas is urbanization. These degradation variables were assessed showing the changes that occurred during the period of 1985 and 2010 for human induced land degradation using multi-dates satellite images (Table 1 and Fig. 5).

It can be seen that the total investigated area was determined by 670 km^2 (159,541 feddan). In the year 1985, built up area covered 28 km^2 (6667 feddan) and barren land covered 3 km^2 (417 feddan), while the cultivated one covered 610 km^2 (145,254 feddan). In the year 2000, extra built

Table 5
Transitional probability matrix derived from the land use/land cover map of 2000–2010.

Class	Agriculture	Built up	Barren land	Water
Agriculture	0	0.9291	0.0708	0
Built up	0	1	0	0
Barren land	0	0.7661	0.2339	0
Water	0	0	1	0

Table 6
Land use statistic of the study area, 2010–2035.

Year	2010		2035		Change rate 2010–2035	
Land use type	Feddan	%	Feddan	%	Feddan	%
Agriculture	90,963	57.01	58,927	36.93	−32,036	−20.1
Built up	57,863	36.26	83,517	52.34	+25,654	+16.1
Barren land	4524	2.83	14,599	9.15	+10,075	+6.31
Water	6191	3.88	2498	1.58	−3693	−2.31
Total	159,541	100	159,541	100	0	0

up area covered 47 km^2 (11,192 feddan) as 7.02% of the total area and barren land was doubled, while the cultivated area decreased by 22 km^2 (5239 feddan) as 3.28% of the total area. In the year 2010, built up area is dramatically increased, more than 5 times, to cover 243 km^2 (57,863 feddan) as 36.3% of the total area, this is the case of barren land which increased more than 3 times to cover 19 km^2 (4524 feddan), while the cultivated area decreased intensely by 206 km^2 (49,053 feddan) as 30.7% of the total area. Water bodies decreased by 3 km^2 (714 feddan) as 0.45% of the total area (see Table 2).

4.4. Markov results

4.4.1. Post classification matrix

Cross tabulation is a means to determine quantities of conversions from a particular land cover to another land cover category at a later date. The change matrices based on post classification comparison were obtained and are shown in Tables 3 and 4.

The nature of the changes of different land cover classes can be examined in Tables 3 and 4. For example, built up area covered 6667 feddan in 1985 and 11,192 feddan in 2000, while the barren land covered an area of 714 feddan in 1985 and 1428 feddan in 2000. 140,015 feddan of the agricultural area which was vegetation in 1985 was still vegetation cover in 2000, but 4265 feddan had been converted to built up area use and 974 feddan had been converted to barren land by 2000. During the same period, 260 feddan of the barren lands had been converted to built-up area use by 2000. 2.83% was changed to built up area.

Similarly change of different land classes into another land class for the periods from 2000 to 2010 can be observed. By 2010, 45,577 feddan of agricultural lands and 1094 feddan of 1428 feddan that were barren in 2000 had been converted to built up area use. Moreover, between 2000 and 2010, 3475 feddan that were cultivatable have been converted to infertile land. During the same period, 715 feddan of water bodies had been converted to barren land to become a total infertile land is 4524 feddan. 29.25% was changed to built up area.

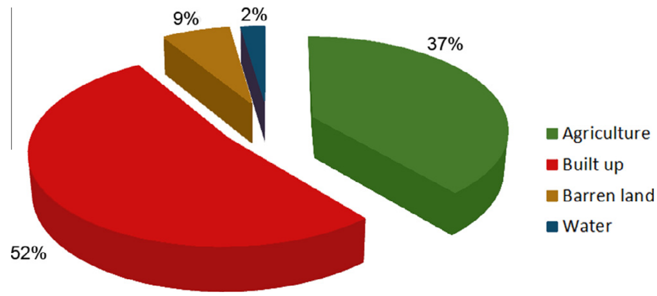

Figure 6. Predicted land cover for Mansoura and Talkha in 2035.

4.4.2. Transitional probability matrix and future land use statistic

Markov chain model is essentially a projection model that describes the probabilistic movements of an individual in a system comprised of discrete states. When applied to land use, Markov chains often specify both time and a finite set of states as discrete values. Transitions between the states of the system are recorded in the form of a transition matrix that records the probability of moving from one state to another (Clark, 1965). Applications of Markov chains to urban land use dynamics began to appear in the 1970s as an alternative to the use of large-scale urban simulations models for land use forecasting (Bell and Hinojosa, 1977).

Markov model result is a transition matrix which shows the probability of changes from each class of land cover or land use to each other class in the future. Table 5 is the probability transition matrix of different land cover types of the study area. In this research, 1985, 2000 and 2010 land cover maps to predict the 2035 land cover areas. Future Land Use statistic can be observed in Table 6 and Fig. 6.

5. Conclusion

In this work it is mainly highlighted the urban sprawl analysis of Mansoura and Talkha cities, Daqahlia, Egypt and their environs, using remote sensing and GIS techniques. The entropy method can be easily implemented using GIS to facilitate the measurement of urban sprawl. The main cause of urbanization is the rapid population growth. This problem needs to be seriously studied, through multi-dimensional fields in order to preserve the precious and limited agricultural lands. Based on this study, the analysis of the results leads to the following findings:

- In the year 1985, urbanized area covered 28 km^2 (6667 feddan), while in the year 2000, extra urbanized area covered 47 km^2 (11,192 feddan) as 6.98% of the total

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area, while the cultivated area decreased by 3.28% of the total area. In addition, the year 2010, urbanized area is dramatically increased, more than 5 times, to cover 243 km^2 (57,863 feddan) as 36026% of the total area, while the cultivated area decreased intensely by 30.75% of the total area.

- Actually, these two cities have no extended area to meet citizen demands therefore, no other choices to desertificate such very fertile land. The saturation is very critical since population growth is expected to double in less than 50 year.

At the last, it is observed that the urbanization in Mansoura and Talkha has increased about 32.08% from 1985 to 2010. Future prediction has been done by using the Markova chain analysis. It was observed that the future urban area may increase of about 16.09% in Mansoura and Talkha. The increased urbanization may have several impacts on infrastructure, energy use and economy of the country.

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