

Monitoring Urban Expansion Directions in 6th October City (Egypt) Using Remote Sensing and Geographic Information System Analysis

**Mona Saad Ramadan^{1*}, Hala Adel Effat¹, Efrag Azab Pasha²
and Magdy Shafiq Saqr³**

¹*Division of Environmental Studies and Land Use, Department of Urban Planning, National Authority for Remote Sensing and Space Sciences (NARSS), Cairo, Egypt.*

²*Department of Geography and Geographic Information System, Faculty of Arts, Banha University, Banha, Egypt.*

³*Department of Urban Geography and Geographic Information System, Faculty of Arts, Mansoura University, Mansoura, Egypt.*

Authors' contributions

This work was carried out in collaboration between all authors. Author MSR designed the study and wrote the first draft of the manuscript. Author HAE performed literature review, statistical analysis and arranged the structure of the whole paper. Authors EAP and MSS revised the whole paper. All authors read and approved the final manuscript.

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ABSTRACT

Urban expansion is a universal trend primarily determined by the over population growth, particularly in developing countries like Egypt. Pattern and boundary of urban expansion could be observed and modeled on a spatial and temporal dimension. In the present study, GIS and remote sensing data along with other thematic maps were used to analyze the urban expansion and directions in the past 25 years for 6th October city which is one of the biggest new cities in Egypt. Five Landsat images, acquired in 1990, 2000, 2005, 2010 and 2015 were calibrated, classified and compared using ENVI 5.1. and Arc GIS 10.2. software. The classified images were analyzed to

*Corresponding author: E-mail: mona7974@live.com;

locate the directions of urban expansion in 6th October City during four periods 1990-2000, 2000-2005, 2005-2010 and 2010-2015. Change detection results showed the areas and directions of urban expansion. Results indicated that the southern direction of the urban expansion was predominant during the period 1990-2000 (2.31 km²), while the northern direction was predominant during 2000-2005 (1.42 km²). However, the eastern direction of the urban increase was predominant in two sequent periods; 2005-2010 and 2010-2015 recording 1.2 km² and 2.22 km², respectively. This study supports the future urban planning strategies through assessing the spatiotemporal changes and directions of urban expansion.

Keywords: Monitoring urban expansion; urban growth directions; remote sensing; GIS; 6th October City.

1. INTRODUCTION

Urban expansion is a universal phenomenon which is a consequence of the population growth as well as economic and infrastructure projects. There is an obvious difference between urban expansion and sprawl, where the urban expansion may have a planned appearance as a planned physical extension in consequence of the population growth, however the urban sprawl often appears complex and unrestrained [1]. Torrens [2] and Lata [3] defined the urban sprawl as urban leapfrog due to the non-good planning, large-scale housing, commercial and industrial in the available land, which earlier were not used for urban objectives. Although the 6th October City is one of the new cities, which has advanced schemes, it didn't follow that scheme and showed random urban expansions [4]. Optimal land use planning presents the right direction for urban expansion and thus conserve natural resources to guarantee the needs and rights of the population [5]. Therefore, accurate mapping of urban environments and monitoring urban expansion became an urgent necessity at the universal level [6].

The usual surveying and mapping method to evaluate the urban expansion is expensive and also time-consuming, hence statistical techniques along with remote sensing and GIS have been used as an alternative for usual studies of urban expansion [7-9]. Mapping the expansion of urban areas is one of the most valuable and successful applications of remote sensing. As urban areas are rapidly expanding, the updated routine surveying is not accurate, time and work consuming, expensive and boring. Alternatively, satellite remote sensing could deliver periodic, large coverage, less costly and precise mapping. This encouraged the usage of remote sensing over many regions in the world.

Urbanization expansion of Washington DC area was studied using Landsat MSS and TM images

between 1973 and 1996 [10]. Aerial photographs and IKONOS images were used to study the urban direction of Al-Ain City, UAE between 1976 and 2000 [11]. Urbanization change detection was observed in Minnesota, USA area using TM images obtained between 1986 and 2002 [12]. In Egypt, SPOT images were obtained between 1987 and 1995 to map urban sprawl of Tanta and El-Mahala Al-Kobra cities [13]. In addition, the total built up area of the Greater Cairo was obtained using Landsat TM (1986) and ETM+ (1999), it revealed a net increase of urban areas from 344.4 km² in 1986 to 460.4 km² in 1999 with a total expansion area of 116 km² in 13 years [14].

The main objective of the current study was to utilize remote sensing/GIS techniques for mapping urban expansions in 6th October City, during the period 1990-2015. It also focused on identifying the directions and the urbanization area.

2. MATERIALS AND METHODS

2.1 Study Area

6th October City is the first new city that constructed as a way to solve urban problems, to exploit unused resources, deconstructing the population density in AlWadi-EIDelta and the capital, also to face the rapid urbanization, and to attract migration. In order to face all these challenges, the solution remains to be the establishment of new cities, according to presidential decree no. 249 dated 06.04.1976 to allocate the land which located between kilometer 48 and kilometer 68 at the Cairo / Ismailia Desert Road. Other new cities were established in Egypt subsequently as the 10th of Ramadan City, Sadat, Al- Aamriya, AL-Amal, Al-Shourouk, and Al-Obour city. Therefore, the new cities became a foundation stone of development, opening new horizons, also the treatment of the existing urban area problems. 6th

October city is one of the new cities, situated in the South-west of the Greater Cairo desert margin, about 32 km from Cairo governorate, at the intersection of a longitude (30°, 45') in the east and latitude (30°, 00') to the north (Fig. 1). It is also located within Giza administrative borders and has a unique geographical location near to the greater Cairo region, which is the main urban gathering and the foremost resource of the population and workforce in Egypt [4].

2.2 Study Approach

The methodology adopted to assess spatiotemporal changes in the urbanized areas and to identify the directions of urban expansion, based on the processing of space-borne multitemporal Landsat images, is shown in Fig. 2. The detailed explanation for this methodology is explained in the next paragraphs;

2.2.1 Satellite data acquisition

To achieve the goals of this study, five Landsat satellite images with spatial resolution 30 meters were freely obtained from the United States Geological Survey (USGS) databases [15] for the following years 1990, 2000, 2005, 2010 and 2015 (Table 1).

2.2.2 Image processing

All the data were originally geo-referenced to the UTM-WGS84 AREA 36N projection system,

rectified, and cropped to the study area. The data pre-processing was performed using Environment for Visualizing Images (ENVI) software package (Version 5.1) [16,17]. “Layer stacking” was applied to images bands for each year. As all the images were completely cloudless, so no “Atmospheric corrections” were made. The satellite images were all taken in the same climatic season, which means similarities of climatic factors, they were obtained in the spring except 2015 image which was taken in the winter but also cloudless. After the images were prepared, they are ready to use. Two images were containing a Scan Line Corrector, ETM+2005 and ETM+2010 which requires removing distortions (noise) by using “Replace Bad Value” a tool in ENVI 5.1. Then “subset” was applied to the study area by using 6th October City boundary shape file (Fig. 3).

Table 1. A technical description of the Landsat TM, ETM+ and OLI images used in this study

Date	Sensor	Path/Row
6 April 1990	Landsat-5 TM	176/39
15 March 2000	Landsat-7 ETM+	176/39
9 March 2005	Landsat-7 ETM+	176/39
23 May 2010	Landsat-7 ETM+	176/39
20 January 2015	Landsat-8 OLI	176/39

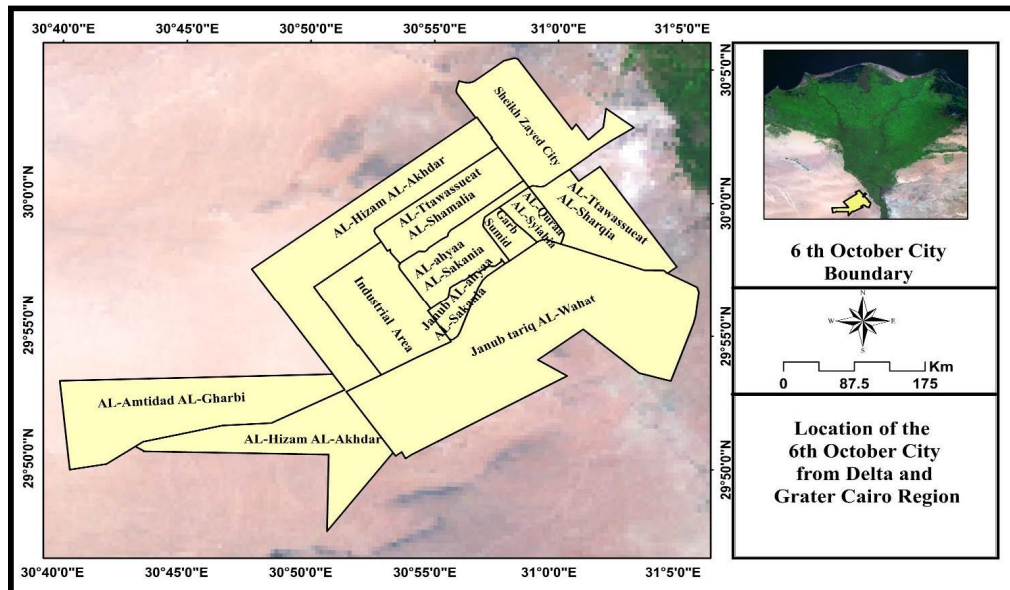


Fig. 1. Location of the 6th October City from Delta and Greater Cairo region

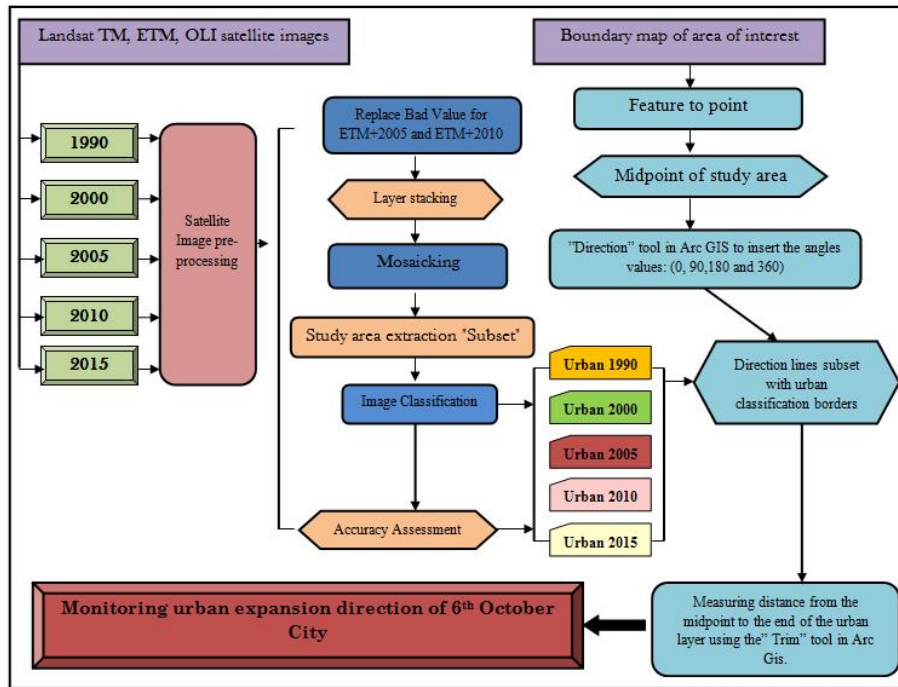


Fig. 2. Study approach

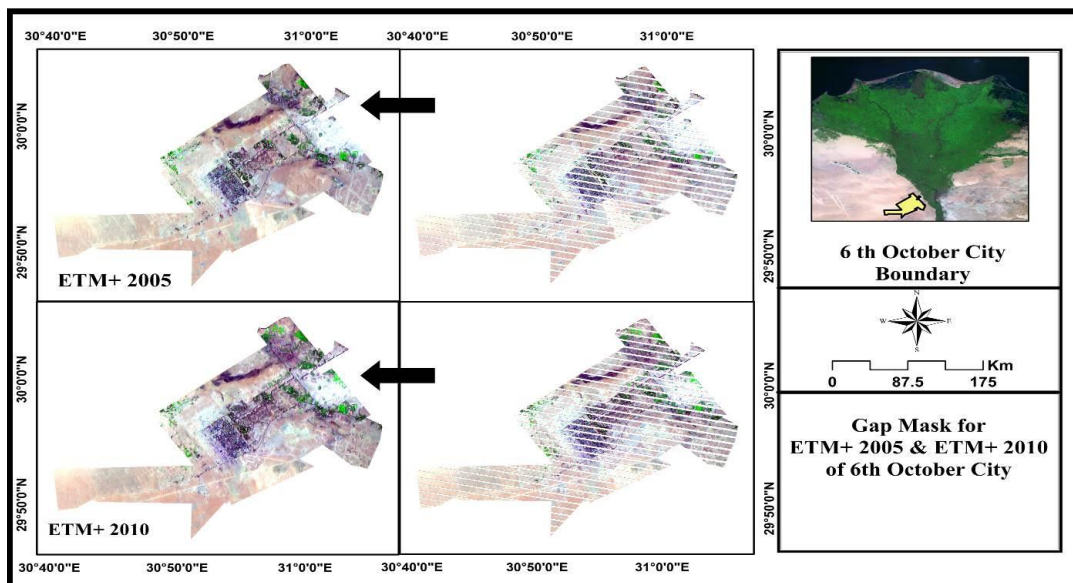


Fig. 3. Gap mask for ETM+2005 and ETM+2010 of the 6th October city

2.2.3 Image classification

The "supervised classification" was applied using ENVI 5.1 for the classification process to spectral bands excluding the thermal band. At least 100 training sites (signatures) were chosen to represent the urban class. The "maximum

likelihood" and "minimum distance" classifier were applied to the clustering process. These classifiers were selected because they showed the best results in the urban layer classification in contrast of the results obtained from "Parallelepiped Classification" and "Mahalanobis Distance Classification". "Minimum distance"

classifier showed the best results for urban layer classification in 2005 and 2010 images, which contained a Scan Line Corrector. However, "maximum likelihood" classifier showed the best results in other studied years (i.e. 1990, 2000, 2015). After classification, a major 3 × 3 filters were applied to remove anomalous pixels from the matrix then urban layer were extracted from the other layers and transformed from raster to vector using "Raster to vector" tool in ENVI. The urban area was, then, extracted from the classification for further analyses and assessment.

2.2.4 Accuracy assessment

Table 2 shows accuracy of the classification considering the overall accuracy and the kappa coefficient (KC) [18,19]. It was done by referencing and assessing 50 randomly generated points of each year for urban layers. Afterward, an accuracy assessment and kappa coefficient were calculated using "Confusion Matrix" using "Ground Truth ROIs" tool in ENVI for each of the classified images of the five years [20,21].

Table 2. Accuracy assessment results

Year	Overall accuracy (%)	Kappa coefficient
1990	87.1	0.81
2000	87.62	0.82
2005	85.32	0.79
2010	85.24	0.78
2015	87.97	0.85

2.2.5 GIS analysis and layers

After the urban layer was extracted for each year, the layers were transformed from raster to vector. Afterward, the border of the city was converted to point from "feature to point" tool in Arc catalog to get the midpoint of the city. The output obtained from the previous step was saved as a "Geodatabase" in addition to the created features of the directions. Further, the main directions were drawn (North, South, East, and West) as a feature class, from the midpoint. To re-correct, the drawn directions tool in Arc GIS "Direction" was applied by inserting the angles values (0, 90, 180 and 360). The direction lines were subset as a consequence of the urban borders, followed by measuring the distance of urban layer in each direction for each year from the midpoint to the end of the urban layer using the "Trim" tool at advanced editing bar in Arc Map.

3. RESULTS AND DISCUSSION

3.1 Urban Area Change Detection

In 1990, the city urban area occupied 3.6 km² (5.6%) which increased by 8.1 km² in 2000 to reach 11.7 km² as revealed in Fig. 4 and Table 3. However, urban area has decreased to 13 km² in 2005. In the periods 2005-2010 and 2010-2015, the urban areas were gradually increased by 2.9 km² (24.84%) and 3.9 km² (30.93%), respectively.

Table 3. The increase in urban layer of 6th October city from 1990 to 2015

Years	Urban area (km ²)	Urban area % of the city	Increase (km ²)
Before - 1990	3.6	5.6	-
1990-2000	11.7	18.28	8.1
2000 - 2005	13	20.31	1.3
2005 - 2010	15.9	24.84	2.9
2010 - 2015	19.8	30.93	3.9

3.2 Direction of Urban Expansion

Table 4 and Figs. 5, 6 illustrate that the dominant direction of the urban extension is the southern direction for (1990-2000) which contributed 2.31 km² (30%) of the total urban area in the city. In the period (2000-2005), the northern direction was predominant, which contributed 1.42 km² (19%) from the total urban. However, the eastern direction was the predominant direction for the periods (2005-2010) and (2010-2015), which recorded 1.2 km² and 2.22 km² respectively.

3.3 Causes of Dominant Urban Expansion Direction

The southern direction was the main direction in (1990-2000) as a reason of the deficiency in services, facilities and the infrastructure networks in the city. As a result, the population started to move to the main district of "AL-Ahiaa AL-Skanya" because of its commercial center, which serves the districts around it, and also as a result of the low costs and economic residential units.

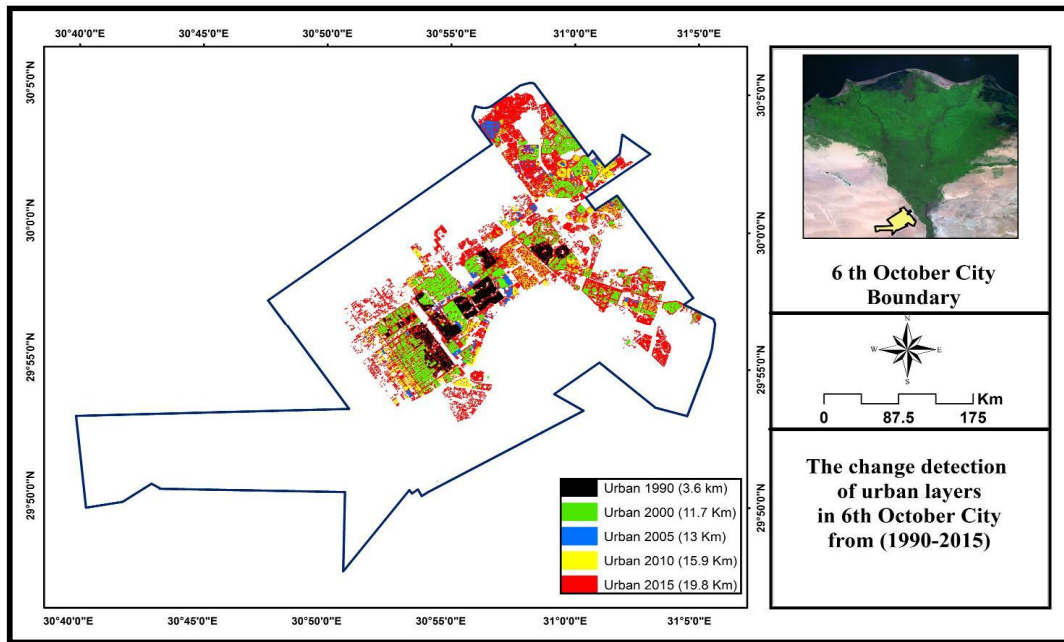


Fig. 4. Images classification for urban layers from (1990-2015)

Table 4. The urban distance along the expansion directions of 6th October city from 1990 to 2015

Directions	1990-2000		2000-2005		2005-2010		2010-2015	
	Km ²	%	Km ²	%	Km ²	%	Km ²	%
North	1.42	19	0.37	33	0.52	18	0.65	15
East	2.22	29	0.35	31	1.2	41	2.22	49
South	2.31	30	0.25	22	0.85	29	1.43	32
West	1.73	32	0.16	14	0.36	12	0.18	4
Total	7.68	100	1.12	100	2.93	100	4.49	100

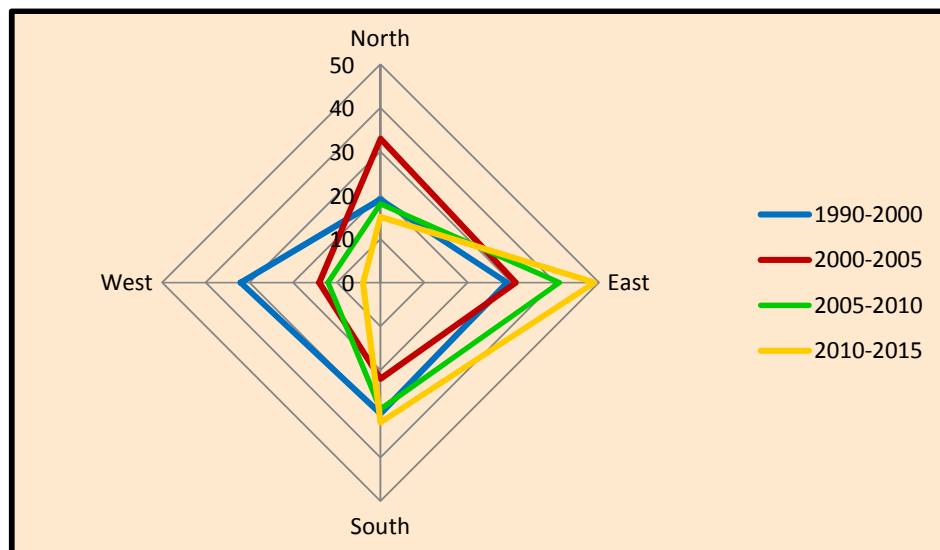


Fig. 5. The dominant direction in each period

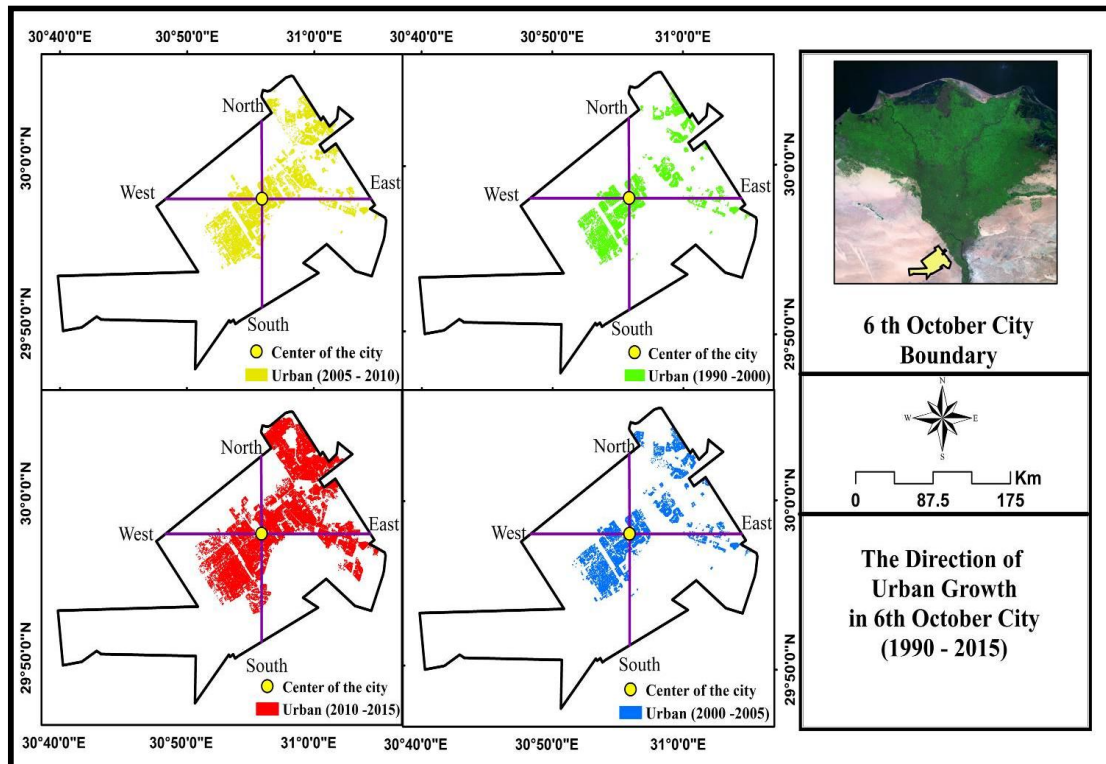


Fig. 6. The direction of urban expansion in 6th October city (1990 -2015)

In (2000-2005), the dominant expansion was the northern direction which is attributed to several factors. Firstly, this direction represents an economic area as it contains the second main private university in Egypt. This university had a direct influence on the influx of migrations from different Egyptian governorates in addition to other Arab countries. Secondly, the establishment of Smart Village in 2001 which includes a grouping of IT companies, institutions, agencies and government ministries that are related to the IT industry. Examples of such establishments are the Ministry of Communications and Information Technology, IT Institute and the Egyptian telecommunications companies (Orange, Vodafone, Etisalat). This industrial renaissance had an impact on attracting investors and businessmen to the city. This has resulted in an increase in the urban expansion in this direction during this period.

The trend of urban expansion in (2005-2010) was the eastern direction due to the development of the transportation network between Giza and 6th October City during this period, such as the 26th of July axis, Masr-Alexandria Desert Road, and the Ring Road. Accordingly, there were a

settlement and reconstruction near to this transportation network, in addition to the existence of 6th October University, which situated in the east of the city. Also, the subsequent founding of educational services and facilities, which has an influence on the reconstruction of other urban areas such as first district (El-Motamez), AL-Tawassueat AL-Sharqia district and AL-Quraa AL-Syahia district. Moreover, the investor's trend through this period was towards the new construction style "villas", this is called Gated Communities (Compounds). They are closed residential complexes located in Sheikh Zayed city and the north-east of the city that included luxury housing, such as Palm Hills and Eskan El-Golf which were constructed by investors to attract share capital and businessmen of the city.

The continuation of the dominant eastern direction in (2010 - 2015) was arisen from the multiplicity of revolutions at the local and Arab levels famous as the Arab Spring, which broke out in the Arab world in late 2010 and early 2011, such as the Tunisian Revolution, the Egyptian Revolution, and the Syrian Revolution. These revolutions had a negative and positive influence

on the reconstruction and construction movement. The exploitation of the security chaos at the time of 25th January 2011 revolution was an example of the negative impacts of such revolutions. As a result, there were excesses in building without a commitment to the specifications of the construction of 6th October City in the absence of security and regulatory rules. The positive result is the influx of Arabs to Egypt specifically to the 6th October City which is famous as Arab city, because it contains all the Arab nationalities that came from different Arab countries for studying, escaping from wars in their homeland and for investment. The economic recovery has returned after a long recession during the Egyptian revolution, also the real estate market, because of the high rate of construction movement, has been recovered in the city.

4. CONCLUSION

Remote sensing and GIS have been proven as useful tools in urban studies, particularly prior the developed plans in order to prevent the random planning practises. The study further shows that remote sensing data could be processed to recognize and measure the spatial extents of urban development at the local level. The results show that the eastern direction was the predominant for the last 10 years (2005-2010) & (2010-2015) amounting 1.2 km², 2.22 km² respectively. This reflects a critical situation as the eastern direction is expected to dominate in the next years. Consequently, there will be full integration of the city with Greater Cairo, leading to an increase in the population burden and congestion which induce the urban encroachment on account of the agricultural land. This will hinder the achievement of the proposed objectives from the new cities planning, which mainly aimed at alleviating the overcrowding population and exit from the narrow valley to the desert. On the other hand, the presence of the industrial area in the west direction of 6th October city will be an obstacle against the urban expansion in this direction. Therefore, the continuous urban expansion should be oriented in the future plans to the suitable directions which are the north and the south of the city.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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