Original Research Article

Monitoring urban expansion directions in 6th October City, Egypt using Remote Sensing and Geographic Information System Analysis

ABSTRACT:

Urban expansion is a universal trend primarily determined by the over population growth chiefly in developing countries like Egypt. Pattern and boundary of urban expansion could be observed and modeled on a spatial and temporal dimension. GIS and remote sensing data along with other thematic maps were used to analyze the urban expansion and directions in five dates in one of the biggest new cities in Egypt. Five Landsat (TM), (ETM) and (OLI) images, acquired in 1990, 2000, 2005, 2010 and 2015 were rectified, classified, analyzed and compared using ENVI and Arc GIS. The classified images were compared to locate the directions of urban expansion in 6th October City during four periods: (1990-2000), (2000-2005), (2005-2010), (2010-2015). Observing the change detection in the urban expansion was led to firstly, directions of urban expansion and secondly with a structural sign of the boundaries, size, and extension of urban expansion itself. Results indicated that the southern direction of the urban increase was predominant in (1990-2000) 2.31 km$^2$. While the northern direction of the urban increase was predominant in (2000-2005) 1.42 km$^2$. However, the eastern direction of the urban increase was the predominant in two periods (2005-2010) and (2010-2015), recorded 1.2 km$^2$ and 2.22 km$^2$ from the total of urban area respectively. This study will have a high potentiality in understanding the present and predicting of the future expansion scenario. This will further help in preparation of effective planning and administration strategies for both controlled and systematic urban expansion at regional as well as local level.

Keywords: urban expansion, urban growth directions, urban change, urban development, Monitoring, Landsat TM, Remote sensing, GIS, Egypt.

1. Introduction:

Urban expansion is a universal trend which consequence of the population ’ growth as well as economy and infrastructure projects. There is an obvious dissimilarity between urban expansion and sprawl, where the urban expansion may have a planned appearance as a planned physical extension in consequence to the population ’ growth; however, the urban sprawl often appears complex and unrestrained [1]. Torrens and Lata defined the urban sprawl as urban leapfrog as due to badly planned, large-scale housing, commercial and industrial in available land, which earlier not used for urban objectives [2]- [3]. Although the 6th October City is one of the new cities, which has advanced
schemes, it didn't follow that schemes and thus showed random urban expansions [4]. Optimal land use planning presents the right direction for urban expansion and thus preserves 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 evaluation the urban expansion are 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]-[8]-[9]. Mapping expansion of urban areas is one of the most valuable and successful applications of remote sensing. As urban areas are expanding quickly, 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 usefulness encouraged the using of remote sensing over many regions in the world. Urbanization expansion at Washington DC area was studied using Landsat MSS and TM images between 1973 and 1996 [10].

Aerial photographs and IKONOS images applied to study the urban direction of Al-Ain City, UAE between 1976 and 2000 [11]. Urbanization change detection was observed for Minnesota, USA area using TM images obtained between 1986 and 2002 [12]. In Egypt, SPOT images obtained between 1987 and 1995 were operated to map urban sprawl at Tanta and El-Mahala Al-Kobra cities [13]. In addition, the total built up area of the Greater Cairo was decided 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 is to utilize remote sensing technique for mapping urban expansions in the 6th October City, from 1990 to 2015 concentration on the directions and size of the urbanization. Analyzing the direction and driving forces of urban expansion are another goal of this study.

2. Materials and method:

2.1. Study area:

6th October City is the first new cities which transpired as a way to solve urban problems, to exploit unused resources, deconstructing the concentration of the population in AL-Wadi, EL-Delta, and the capital, also facing rapid urbanization, and population ' attractions in consequence of migration. In order to face all these challenges, the solution remains to be the establishing 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 areas problems [4]. 6th October city is one of the new cities, situated in the South-west of the Greater Cairo desert margin, about 32 km² from Cairo governorate, at the intersection of a longitude (30°, 45') in the east and latitude (30°) to the north, as revealed in Fig (1). It is also located within Giza administrative borders. 6th October has a unique geographical location near to the greater Cairo region, which is the main urban gathering and the foremost resource of population and workforce in Egypt.

![Location of the 6th October City from Delta and Grater Cairo region.](image)

Figure (1): Location of the 6th October City from Delta and Grater Cairo region.

2.2. Study Approach:
Figure 2 below graphically explains how the research was carried out to accomplish the main objective.

2.3. Satellite Data and Processing:

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 online [15] for the following years 1990, 2000, 2005, 2010, and 2015 covering the temporal scenes, table (1).
Table (1): A technical description of the Landsat TM, ETM+ and OLI images used in this study

<table>
<thead>
<tr>
<th>Date</th>
<th>Sensor</th>
<th>Path/Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 April 1990</td>
<td>Landsat-5 TM</td>
<td>176/39</td>
</tr>
<tr>
<td>15 March 2000</td>
<td>Landsat-7 ETM+</td>
<td>176/39</td>
</tr>
<tr>
<td>9 March 2005</td>
<td>Landsat-7 ETM+</td>
<td>176/39</td>
</tr>
<tr>
<td>23 May 2010</td>
<td>Landsat-7 ETM+</td>
<td>176/39</td>
</tr>
<tr>
<td>20 January 2015</td>
<td>Landsat-8 OLI</td>
<td>176/39</td>
</tr>
</tbody>
</table>

2.3.1. Image Processing:

All the data were originally geo-referenced to the UTM-WGS84 AREA 36N projection system, and rectified, and cropped to the study area Fig (1). 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 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 at the spring except 2015 image which was taken in the winter but also cloudless. After the images were prepared, hence, the images are prepared to use and so to extract the data from them. 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).

Figure (3): Gap mask for ETM+2005 and ETM+2010 of the 6th October City.
2.3.2. 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 for the clustering process. After classification, a major 3 × 3 filters was applied to remove anomalous pixels from the matrix Fig (4).

2.3.3. Accuracy Assessment:

The accuracy of the urban classification images was assessed using accuracy assessment 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].

Table (2): Accuracy Assessment results

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Overall Accuracy (%)</th>
<th>Kappa Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>87.1</td>
<td>0.81</td>
</tr>
<tr>
<td>2000</td>
<td>87.62</td>
<td>0.82</td>
</tr>
<tr>
<td>2005</td>
<td>85.32</td>
<td>0.79</td>
</tr>
<tr>
<td>2010</td>
<td>85.24</td>
<td>0.78</td>
</tr>
<tr>
<td>2015</td>
<td>87.97</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Figure (4): Images classification for urban layers from (1990-2015).
2.3.4. 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" a tool in Arc catalog to decided the midpoint of the city. The output obtained from the preceding step has to put as a “Geodatabase” besides the created features of the directions. Then drawing main directions (North, South, East, and West) as a feature class, from the midpoint. To re-correct the drawn directions "Direction” a tool in Arc GIS 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 per 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 area of the city was only (3.6 km$^2$), which representing (5.6 %) from the current urban area as revealed in Table (3) and the figure (4). In the period 1990-2000, which lasted 10 years, the urban area reached 11.7 km$^2$; there was an increase by 8.1 km$^2$ comparing to before 1990 which was the highest growth percentage of all periods. However, urban area has decreased to (1.3 km$^2$) in the period (2000-2005) which lasted (5 years). For (2005-2010), (2010-2015) the urban areas were gradually increased by (2.9 km$^2$), (3.9 km$^2$) respectively, this two period represents (24.84%), (30.93 %) from the total urban area.

<table>
<thead>
<tr>
<th>Years</th>
<th>Urban area (km$^2$)</th>
<th>Urban area % of the city</th>
<th>Increase (km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before -1990</td>
<td>3.6</td>
<td>5.6</td>
<td>-</td>
</tr>
<tr>
<td>1990-2000</td>
<td>11.7</td>
<td>18.28</td>
<td>8.1</td>
</tr>
<tr>
<td>2000-2005</td>
<td>13</td>
<td>20.31</td>
<td>1.3</td>
</tr>
<tr>
<td>2005-2010</td>
<td>15.9</td>
<td>24.84</td>
<td>2.9</td>
</tr>
<tr>
<td>2010-2015</td>
<td>19.8</td>
<td>30.93</td>
<td>3.9</td>
</tr>
</tbody>
</table>
3.2. Direction of urban expansion

Table (4) and fig (5, 6) illustrate that the dominant direction of the urban extension is the southern direction for (1990-2000). It contributed 2.31 km$^2$ (30%) of the total urban area in the city. In the period (2000-2005), the northern direction was the predominant direction, which contributed 1.42 km$^2$ (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 km$^2$ and 2.22 km$^2$ of the urban area respectively.

Table (4): The urban distance along the expansion directions of 6th October City from 1990 to 2015

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>Km$^2$</td>
<td>%</td>
<td>Km$^2$</td>
<td>%</td>
</tr>
<tr>
<td>North</td>
<td>1.42</td>
<td>19</td>
<td>0.37</td>
<td>33</td>
</tr>
<tr>
<td>East</td>
<td>2.22</td>
<td>29</td>
<td>0.35</td>
<td>31</td>
</tr>
<tr>
<td>South</td>
<td>2.31</td>
<td>30</td>
<td>0.25</td>
<td>22</td>
</tr>
<tr>
<td>West</td>
<td>1.73</td>
<td>32</td>
<td>0.16</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>7.68</td>
<td>100</td>
<td>1.12</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure (5): The dominant direction in each period.
3.3. Causes of dominant urban expansion direction

The southern direction was the main direction in (1990-2000) as reason of the deficient in services, facilities and the infrastructure networks in the city so the population started to go to the main city in this period; the district of "AL-Ahiaa AL-skanya" because of its commercial center, which serves the districts around it, and also, the low costs and economic residential units.

In (2000-2005) the dominant expansion was the northern direction which is attributed to several factors. Firstly, this period represents an economic area as it contains the second main private university in Egypt, which had a direct influence on the influx of migrations from different Egyptian governorates in addition to other Arab countries. Next factor, 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. For example, the Ministry of Communications and Information Technology, IT Institute, and the Egyptian telecommunications companies: Orange, Vodafone. This industrial renaissance has 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 as a reason for the development of the transportation network between Giza and 6th October city in that period such as the 26th of July axis, Masr-Alexandria Desert Road, and the Ring Road. Accordingly, there was a settlement and reconstruction near to this transportation network, besides the founding of a 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). As well as the investor's trend through this period towards the new construction style “villas”, this is called Gated Communities (Compounds). It is 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. It is set up by investors to attract share capital and businessmen of the city.

The Continuation of the dominance of the Eastern direction in (2010 - 2015) because of a 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 negative influence is exploitation the security chaos at the time of 25 January 2011 revolution so that there were excesses in building that there was no commitment to the specifications of the construction of the 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 the Arab city, thus it contains all the Arab nationalities that came to it from different Arab countries for studying, escaping from wars in their homeland and for investment. The economic recovery began again after a long recession during the Egyptian revolution, besides the recovery of the real estate market by reason of the high rate of construction movement again in the city.

4. Conclusion:
Remote sensing and GIS proved to be very useful tools in urban studies and urban directive consistent with the prior developed plans so that no random planning will occur. The study further shows that the remote sensing data acts as a good indicator to recognize and measure the spatial extents of urban development at the local level. It also shows that the remote sensing is an effectual tool to map and analyze urban expansion and to provide constructive information essential for planning, development and monitoring directions of urban expansion. The results show that the eastern direction was the predominant for the last 10 years (2005-2010), (2010-2015) in the city, which contributed about 1.2km$^2$, 2.22 km$^2$ respectively. It reflects a critical situation as the eastern direction continues to dominate in the next years. Subsequently, there will be full integration of the city with Greater Cairo, leading to an increase in the population ‘burden and the continued congestion and then encroachment into the agricultural land. It is opposite to the main objectives of the new cities idea, which appeared mainly to alleviate the overcrowding population and exit from the narrow valley to the desert and reconstruction it. The West direction has become non-existent because of the existence of the industrial area as a determinant of Western urban expansion. So continuous urban expansion should be oriented in the future plans to the suitable directions which are the north and the south of the city.
5. References:


