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MONITORING URBANIZATION GROWTH IN CAIRO CITY

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ABSTRACT

In the present study, high resolution remotely sensed data (<60-m resolution) has been used to locate and track changes in urban land cover in Cairo, Egypt. Landsat (TM) images for July months of the years 1985, 1990, 1995, and 2000 have been analyzed to identify the growth of urban region at Cairo. The population growth in Cairo City during the period 1985 to 2000 and its expected rates up to 2035 have been taken into consideration. The results of the study revealed that, a real extent of urban lands of Cairo City could be monitored accurately by using a high resolution Landsat satellite images. Among the main findings is the increase of urban area of Cairo from 267.38 Km^2 to 548.13 Km^2 through the period from 1985 to 2000 with percentage annual ratio estimates 7%. A significant correlation between the rate of increase of Cairo urbanized area, $\Delta U_{A,}$ and the rate of population growth, ΔP_A, has been found in the simple form, $\Delta U_A = 40.85 - 100.6\ \Delta P_A$. Therefore, if the rates of population growth and human activities in Cairo City continued, the urban area will reach to be 1193.85 km^2 by the year 2035. In addition to serious local climate changes will prevail.

KEY WORDS: Urbanization, human activities, high resolution, landsat images, air pollution.

1. INTODUCTION

1.1 Background of Urbanization

Urban climatology has a long history. The scientific literature on the subject dates back at least to 1833, when Luke Howard published his famous book on London's climate, Howard, [1]. After a long time period, in particular during the last 35-40 years, the science of urban climatology has been spread rapidly as reflected in several publications. However, the goals of research in urban climatology are to improve the understanding of the physical, radiative, thermal, chemical and moisture

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characteristics of the cities. The process of urbanization involves the construction of buildings, roads, underground drainage system, and factories which radically transforms the radiative, thermal, moisture and aerodynamic characteristics of the pre-existing landscape, and thus creates of its urban climate.

The urban climatology could be used as the basis for weather prediction and urban planning. The World Meteorological Organization (WMO) emphasizes research towards understanding the interaction between the urban area and the atmosphere, especially in the tropical and subtropical regions, WMO, [2].

People are attracted to urban areas because they offer a host of socio-economic and cultural opportunities. Growth of cities introduces a profound modification of climate by human activities. The extent of urban climate change varies from city to city, according to the site and size of a city, land use pattern, structure and density of buildings, traffic, and industry and other urban activities. Many studies show that many large cities have experienced significant changes in cloudiness, precipitation, radiation and energy balance, temperature, air quality and visibility e.g. (Georgii, [3], Arnfield, [4], Landsberg, [5], Holz [6], Handerson and Robinson, [7] Givoni, [8], Tapper, [9], Barradas, [10], Gallo and Owen, [11], Robaa, [12] and Lawrence, et al., [13]).

1.2 Nature of the Urbanization Problems in Cairo City

Egypt has one of the largest populations in the Middle East. Several papers examined the determinants and consequences of population growth in Egypt in the recent, past, and the near future (e.g. Entwisle, et al., [14], Sayed et al., [15] and El-Zanaty, et al., [16]). The population of Egypt has duplicated several times during the last century. The scenarios estimate that, it will increase from about 64 million currently to 103 million in 2035, World Bank, [17].

The capital of Egypt, city of Cairo, lies south of Delta in the Nile basin. Cairo is considered as one of the world’s 15 largest cities in population growth. This huge increase of population is followed by rapid increase in traffic density and the industrial activity. Also, the urbanization and industrialization have increased very rapidly in Cairo, particularly in the second half of the last century causing an increase in the pollution of its atmosphere. This in turn has an effective role in intensifying the problem of contaminating our environment with various impurities and environmental hazards, Robaa, [12].

Climatologically, Cairo follows the subtropical climatic region. It is characterized by the presence of Mokattem hills to its east and south east, then desert areas extending in the west and east directions. Among the outstanding weather events are the dust and sandstorms frequently blow in transitional seasons. In spring season, hot desert depressions are known as the Khamsin depressions. They are always associated with strong hot southernly wind often laden with dust and sand increasing the atmospheric pollution.

Cairo area consists of several industrial and urban areas. There are two main big neighboring industrial areas. Shubra El-Kheima to the north and Helwan to the south of Cairo. During the last two decades, new industrial cities have been established around the Cairo City. Such as 10th Ramadan, 6th October, and 15th May etc. Therefore, it is extraordinary difficult to locate and track changes in urban cover classes at the global scale using traditional techniques. The usage of remote sensing data to detect urbanization in Egypt is very scarce. Recently, the remote sensing technique has been used for urban planning e.g Imhoff et. al., [18], Golla and Owen, [11] and Florian and Klaus, [19]. There are several studies used to delineate urban areas using a thresholding technique that eliminates ephemeral light sources e.g Imhoff et al., [20], and [18]. Unfortunately, this method is neither sufficient nor suitable for monitoring the urban sprawl particularly with respect to urban area of Cairo since Cairo City has many urban random regions that have not any source of light at all. The aim of this study has been directed to investigate the extent of urban lands of Cairo using thematic mapper Landsat 5 and Landsat 7 data, with resolusion <60 m.

2. DATA

The Landsat mission utilizes a series of satellites to remotely sense the Earth's surface from a height of 705 kilometers. The resulted images are artificial representations created from digital data. The urbanization using the Landsat sensor data (<60-m resolution) has been investigated. Four selected Thematic Mapper (TM) scenes in bands 572 including Cairo City through the years 1985, 1990, 1995 and 2000 have been used to monitor urban sprawl of the understudy area. The scene was (176 path and 39 row) over 6166 x 6166 TM 30 m pixels (across track) covering approximately 185 x 185 Km^2 or 34225 Km^2 (whereas the area of Cairo equals 1400 Km^2 approximately). The used geographic bounds were N 31^o 10$^/$ 20.71$^{//}$, E 30^o 26$^/$ 19.21$^{//}$ [upper left corner] and N 29^o 38$^/$ 40.38$^{//}$, E 31^o 57$^/$ 59.07$^{//}$ [lower right corner]. Therefore, Cairo area and most of the Nile delta region of Egypt are covered. These data are obtained from the archive of the European Space Agency (ESA).

The data of Cairo population through the period from 1985 to 2000 has been obtained from the Egyptian Central Agency for Public Mobilization and Statistics (ECAPMAS). Moreover, the predicted population growth from 2000 to 2035 is also taken in the consideration.

3. IMAGE PROCESSENING AND METHODOLOGY

3.1 The Landsat

Landsat 5 was launched on 1 March1984 and followed by Landsat 7, launched on 15 April 1999 on a Delta II-7920-10 from Vandenburg Air Force Base (VAFB) and placed into a 705 km frozen circular orbit. The orbit of Landsat 7 was sun-synchronous with an inclination of 98.2 degrees and a descending node at 10:00 (± 15 min) AM local solar time. This orbit gives the spacecraft full Earth coverage and allows it to pass over any point on the Earth every 16 days. The ground track of the spacecraft follows the standard World-Wide Reference System (WRS) used by Landsat 5. Landsat 7 is a three-axis stabilized platform carrying a single nadir-pointed instrument and the Enhanced Thematic Mapper Plus (ETM+). Both Lansats have approximately the same features except the resolution of band 6. Whereas Lansat 5 has 120 meter resolution and Landsat 7 has 60 meter.

Landsat Thematic Mapper (TM) scenes cover Cairo. The Thematic Mapper is a mechanical scanning device that has improved spectral, spatial, and radiometric characteristics of the widely available satellite imagery. A TM scene covers an area 185 km^2 on a side with picture elements 30 meters wide. Landsat TM detects spectral radiation in 7 bands of different wavelength regions. The wavelength interval of each band is shown in Table (1). Where Bands 1,2,3,4,5, and 7 record reflected energy, and Band 6 records emitted thermal (heat) energy.

Urban areas in Egypt were not accurately determined yet by using Landsat images. This obstruction inspired the authors to examine a technical method to estimate the urban area in Cairo using Landsat images.

Table 1. The wavelength interval of each band of Landsat 7 scenes.

Bands	Color of the spectrum Band	Wavelength (microns)	Resolution (meters)
Band 1	Visible Blue	0.45 to 0.52	30
Band 2	Visible Green	0.52 to 0.60	30
Band 3	Visible Red	0.63 to 0.69	30
Band 4	Near Infrared	0.76 to 0.90	30
Band 5	Mid Infrared	1.55 to 1.75	30
Band 6	Thermal Infrared	10.4 to 12.5	60
Band 7	Mid Infrared	2.08 to 2.35	30
Pan.	Panchromatic	0.52 to 0.90	15

3.2 Methodology

A mosaic was generated from four TM scenes for the composite of bands 572 acquired over the Cairo city in July of the years, 1985, 1990, 1995 and 2000. These satellite mosaics were co-registered and the images were processed to enhance spectral variations between cultivated land and urban areas and to minimize spectral variations related to atmospheric interferences. Four color composites were generated from the four digital mosaics, and were used to identify the location and timing of urban progression in Cairo city.

Image processing was done using the software package of the European Space Agency (ESA). The following processing steps were adopted:

1- Selection of appropriate Landsat data according to the following specifications:

i. Minimal cloud coverage

ii. Similar acquisition date

iii. High overall quality

2- Selection of appropriate Landsat wavelengths (TM bands 5, 7 and 2) taking into consideration that, the images in the band 572 have a Maximum spectral difference between vegetation and urban areas and characterized by less susceptible to atmospheric contributions.

3- Generation of TM mosaic

A mosaic was generated from four TM scenes acquired in the dates of (5/7/1985, 3/7/1990, 7/7/1995, and 2/7/2000).The scenes acquired at different dates were normalized to the scenes with the least atmospheric contribution.

4- Generation of color mosaics

A color composite was generated from the 1985, 1990, 1995, 2000 TM mosaic. The TM mosaic was assigned the bands of 572 color. Qualitative interpretation of colors on the digital mosaic has been made. The urban areas on this mosaic are greenish grey compared to the agricultural areas green color (See Fig. 1). Thus, on these 1990/1985, 1995/1990 and 2000/1995 mosaics, urban areas that have existed since 1985 defined the sprawl greygreen areas.

5- The color of the composites bands 572 images was interpolated. The greenish grey regions represent the urban areas (See Fig.1). Therefore, the real urban area of Cairo in Km^2, U_A, could be determined from the following equation;

$$U_A = m a_{Gg} \sum_{i=1}^{n} \sum_{J=1}^{m} a_{i,j} \tag{1}$$

Where, m is the map's scale factor (1mm^2 : 1.184256 Km^2) a_{Gg} is the infinitesimal greenish grey area in the Landsat images, (a_{Gg}=1 mm^2). $a_{i,j}$ is the number of the infinitesimal areas of, a_{Gg}, in the image of concerned area of Cairo, Where i=1, 2,….n. and j= 1, 2,…..m. (See Fig. 2).

6- The technique of correlation analysis has been used to study the relationship between the population growth and urban sprawl in Cairo through the period from 1985 to 2035.

4. RESULTS AND CONCLUSION

The population growth in Egypt and its capital, Cairo City, has been increased several times during the period of study (1985-2000). The results revealed that, the rate of population growth during the period from 1985 to 2035 ranges between 0.94 to 1.24 millions per year in Egypt and 0.200 to 0.234 millions per year in Cairo city (Table 2, Fig.4 and Fig.6).

Generally, the urban sprawl in Cairo sharply increased following the population growth. Particularly, in Cairo, during the last two decades the human activities became incredible and random, resulting in several random areas in and around Cairo without any urbanization planning (See Table 2 and Fig. 5).

Table 2. The estimated and predicted population growth with the corresponding sprawl urban area of Cairo through 65 years (1965 to 2030).

Years	Population (In millions)		Urban Area (Km^2)
	Egypt	Cairo	
1985	46.5	12.9	267.38
1990	52.3	14.1	350.90
1995	58.1	15.1	454.54
2000	63.9	16.2	548.13
2005	69.9	17.3	630.55
2010	76.1	18.3	723.12
2015	82.1	19.3	815.65
2020	87.9	20.4	910.23
2025	93.2	21.4	1009.75
2030	98.1	22.5	1095.33
3035	102.8	23.5	1201.16

The grid point technique has been used based on the color of urban areas (greenish grey) of bands 572 (Table 1) Landsat imagery for Cairo during the period (1985-2000). It was found that the growth of urban area increases with the time during the study period. The mean rate is 16.70, 20.73 and 18.72 Km^2 per year for the period from 1985 to 2000 (See Table2 and Fig.6). The analysis of Landsat imagery illustrates that the trend of the urban growth is shown mainly in the northern east part and also towards the southern west of Cairo during the period of study (See Fig.3.a, b, c and d).

The correlation between the rates of increase of Cairo urbanized area, $\Delta U_{A,}$ and its rate of population growth, ΔP_A has been computed using the advanced computer statistical programs. The relation could be expressed as follows;

$$\Delta U_A = 40.85 - 100.6\, \Delta P_A \quad (R=0.964 \text{ and } E=0.0025) \tag{2}$$

Where, R, is the correlation coefficient and E, is the mean standard error.

Therefore, if the population growth and human activities in Cairo City continues with the same rate of the study period, the predicted urban area of Cairo will reach 1201.16 km^2 by the year 2035. This means that most of the area will be transformed to an urbanized area by year 2035. The continuous human activities and the incredible increase of the urban area of Cairo will be associated with a seriously and critical local climatic changes in the basic meteorological elements that control the climate such as the maximum and minimum temperature, wind speed, relative humidity, cloud amount, rainfall, Robaa, [12]. Moreover, the increase of the urban sprawl will lead to the increase of the concentration of atmospheric aerosols and pollutants in Cairo that will reach dangerous levels by the year 2035.

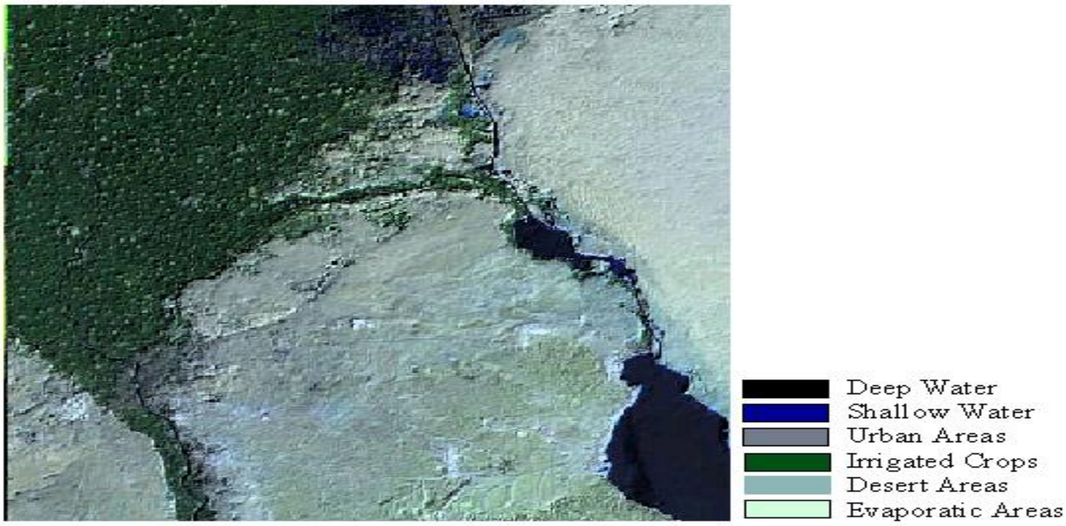

Fig. 1. The Landsat image on 2 Jul 2000 of the area including the Cairo City and its corresponding color interpretation index.

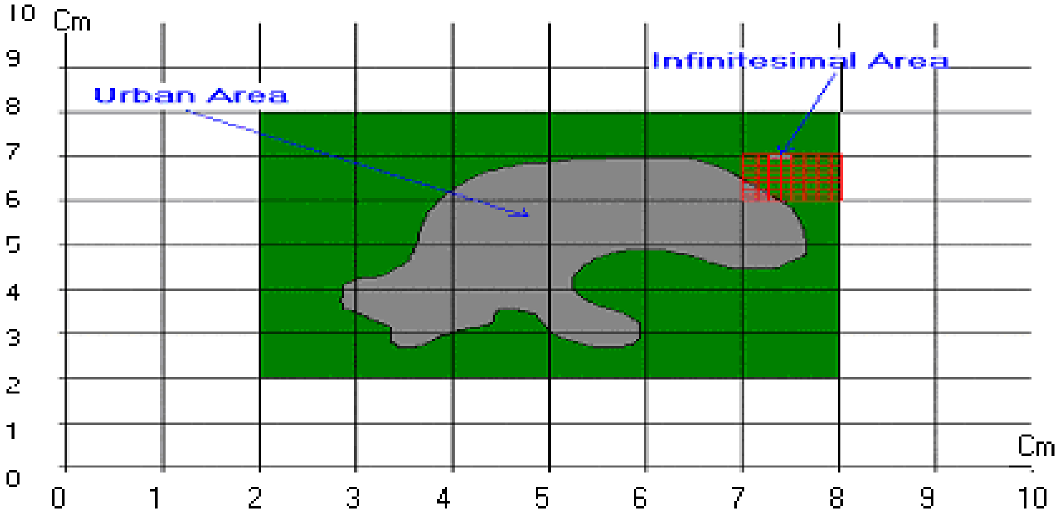

Fig. 2 The sketch of determination of urban area.

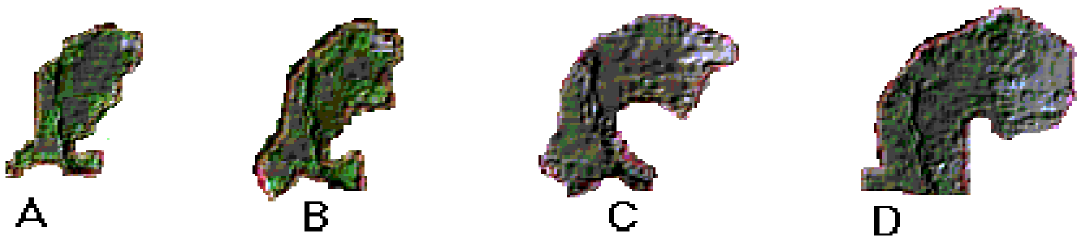

Fig. 3 The growth stages of urban sprawl area represented by A, B, C and D as obtained from the landsat images for the years 1985, 1990, 1995 and 2000 respectively.

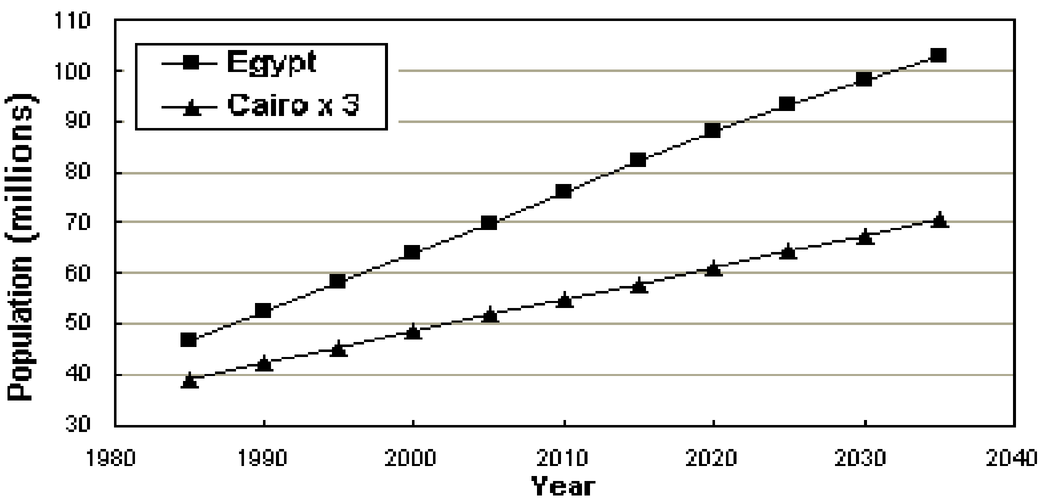

Fig. 4 The population growth in Egypt and Cairo City through the period from 1985 to 2035.

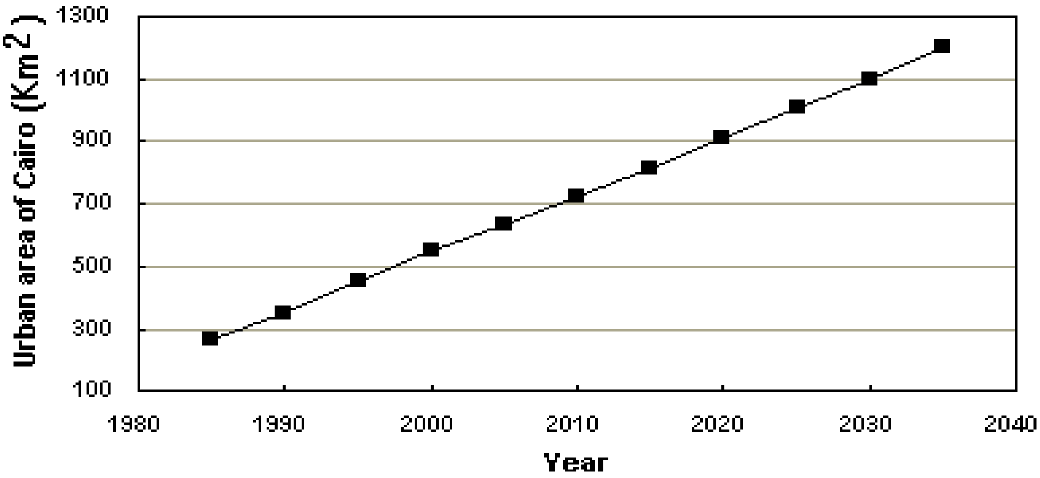

Fig. 5 The growth of urban area of Cairo City through the period from 1985 to 2035.

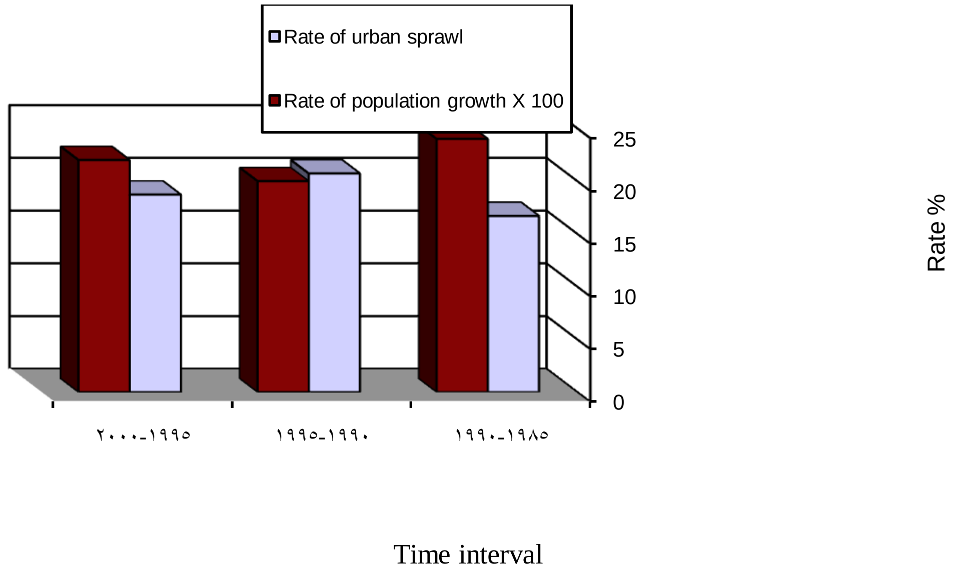

Fig. 6 The rate of population growth and the rate of urban sprawl at Cairo through the period intervals from 1985 to 2000.

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التعرف على التمدن فى مدينة القاهرة

تم استخدام تكنولوجيا الاستشعار عن بعد لتتبع مقدار التمدين والامتداد العمراني لمدينة القاهرة ، ولهذا الغرض تم استحداث تقنية مبتكرة لتحليل أربع صور للقمر الصناعي لاندسات مختارة لشهر يو ليو لأعوام 1985 و 1990 و 1995 و 2000، وأظهرت النتائج الكفاءة التحليلية لهذه التكنولوجيا فى تقدير المساحة الحضرية والامتداد العمرانى بدقة عالية وظهرت نتائج هامة منها أن مساحة القاهرة الحضرية قد زادت من حوالى 267 كم^2 عام 1985 إلى حوالى 548 كم^2 عام 2000م بمعدل زيادة مقداره 7 % سنويا، وأن الامتداد العمرانى لمدينة القاهرة خلال هذه الفترة تركز فى شمال شرق وجنوب غرب القاهرة وأن معدل الزيادة السنوية للمساحة الحضرية لمدينة القاهرة يرتبط ارتباطا قويا بمعدل الزيادة السنوية لعدد السكان وأنه إذا استمر النمو السكاني والانشطة الإنسانية بالقاهرة بالمعدل الحالى قد تصل المساحة الحضرية بها إلى حوالى 1200 كم2 من المجموع الكلى لمساحتها والتى تبلغ 1400كم^2 وذلك بحلول عام 2035 م مما سيكون له عظيم الأثر فى إحداث تغييرات مناخية محلية لجو القاهرة وزيادة معدلات التلوث بها.