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Using Remote Sensing Techniques to Assess the Changes in the Rate of Urban Green Spaces in Egypt: A Case Study of Greater Cairo

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Abstract:

Urban Green Spaces (UGS) are highly valued by landscape and urban planners for their positive impact on city quality of life. More than half of Cairo's population has less than 0.5 m2/person, which is a staggering ratio that is considerably below the city's average of 1.7 m2. Egypt has a per capita UGS ratio of 3.1 m2, compared to 11.8 m2 in Paris and 26.7 m2 in London. The National Organization for Urban Harmony (NOUH) created a guideline to assist Egyptian urban planners in improving the qualified ratio of UGS per capita. The purpose of this research is to assess the impact of the NOUH guideline on the Greater Cairo (GC) region and Cairo city districts between 2010 and 2019 using free-easy access data such as Landsat and LandScan datasets. In Cairo, UGS increased by 942 hectares at a 34.6 percent pace, from 2724 ha in 2010 to 3666 ha in 2019. In GC region, the number of people living in unqualified rate districts has increased from 36.4 percent in 2010 to 87.5 percent in 2019. The new districts maintained the region's greatest per capita UGS rate (41.6 m2/capita).

Keywords:

Urban Green Spaces, Landsat, LandScan, Greater Cairo, Remote Sensing, GIS

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1- Introduction:

Urban Green Spaces (UGS) are quite worthwhile within urban surroundings. They are highly recognized by landscape and urban designers for their impact on the quality of life of the population in cities(Kafafy and Al-Betawi, 2011). Moreover, Limiting urban growth and preserving UGS are top priorities for urban planners in developing countries (Wang et al., 2021). Green areas in public places may enhance air quality, minimize the heat island effect and pollution, and help animals and plants survive and develop (Ji and Ding, 2021). UGS is defined in land-use planning as open space areas dedicated to parks as well as other green spaces containing plant life and other types of natural environment (WHO - World Health Organization, 2017). In the current concept of UGS, there is no agreed upon standard. Public parks, private gardens, forests, and children's play places may all be included in one of these definitions (WHO - World Health Organization, 2016). For example, Coles and Grayson (2004) defined UGS as: public green spaces located in urban areas, majorly covered by vegetation, which are effectively used for active or passive entertainment, or indirectly used by morality because of their positive influence on the urban environment, suitable for citizens, serving the diverse needs of the residents, and therefore improving the quality of life in cities or urban areas (Coles and Grayson, 2004).

Different studies' considerations of UGS often include public parks and gardens, public space planting inside city centers, and commercial, industrial, and residential regions (Coles and Grayson, 2004). Other public open spaces, sports pitches, street trees, and recreational facilities such as golf courses, private and semi-private gardens and other residential open space, roof gardens, urban agriculture, commercial forests, vegetated waste land, and any other place where there is a natural surface or where trees are growing are also included (WHO - World Health Organization, 2016). Generally, UGSs are considered to be green areas within the general conception of open space. These include public parks and gardens, natural green spaces, playgrounds, amenity green spaces, greenways, and others (Kafafy and Al-Betawi, 2011). Other definition was that UGSs are those open public or private green spaces in urban areas that are mainly covered by vegetation (Alsonny et al., 2022). All of the above elements will greatly affect the proper definition of UGSs in this study (Coles and Grayson, 2004). As a result, this article takes the World Health Organization's (WHO) definition of "all urban land covered by vegetation of any kind" (WHO - World Health Organization, 2017) into account.

Egyptian UGS per person is much below the global norm and requirements, which range from 20 to 40 m2 per person in developed countries and 12 to 18 m2 per person in developing countries, according to El-Zafarany (2004). Contrarily, the most optimistic estimates of Cairo's per capita green space do not exceed 2 m2, despite the fact that this is still considered low. However, this is somewhat misleading because more than half of Cairo's population only have 0.5 m2/person, which is an incredible figure and far beyond the city's average of 1.7 m2/person, which more than 70% of the city's population has less than. According to the Cairo government, 925,841 people, or 12.14 percent of the city's population, have less than 0.1 m2/person (El-Zafarany, 2004).

One of the most significant difficulties facing cities today is identifying the most effective methods, concepts, and regulations for creating new UGSs while also preserving the existing ones. These difficulties are particularly acute in developing countries like Egypt, where it could be identified that the amount of green space per person is relatively low (Kafafy and Al-Betawi, 2011) when compared to the 9 m2/capita recommended by the World Health Organization, and that the quality of life in the areas provided is commonly poor (Keleg et al., 2021). Greater Cairo (GC) is Egypt's most populous metropolitan area, growing from 6.77 million people in 1976 to 20.58 million people in 2016 (Salem et al., 2020a). Despite being the largest and most important urban region in the Middle East and Africa, the GC has an extremely low per capita ratio of UGS. The per capita green space is 3.1 m2, compared to 11.8 m2 in Paris, 26.7 m2 in London, and 31.9 m2 in Tokyo (5.5 m2 per capita). So, in order to enhance the quality of life, the future vision and strategic directions for GC aim to increase the ratio of UGS per capita in GC while minimizing the infrastructure required to construct and maintain such green spaces (General Organization for Physical Planning (GOPP), 2012).

To solve and improve the previous situation of UGSs in Egypt, the National Organization for Urban Harmony (NOUH) developed the 4th Guideline-Urban Harmony Standards and criteria for open areas and UGS as part of its role in directing and controlling urban development in order to create an appropriate urban environment (National Organization for Urban Harmony (NOUH), 2010). The purpose of this guideline is to give local government officials, such as licensing officials, project approvers, and other decision makers, the reference bases and processes they need to review and approve detailed plans at the governorate, city, and neighborhood levels, as well as to evaluate the effectiveness of already-existing and future UGSs. Additionally, this guideline contributes to the provision of scientific concepts and criteria for urban planners and designers of open spaces and UGSs, including for those who specializes in the field. It may be used as a scientific reference for challenges relating to UGSs in Egypt, such as their major causes, which can be addressed in order to improve the system of UGSs on a national basis. As a consequence of the NOUH guideline, minimum UGSs must be provided in the city in order for the per capita ratio of the city's population to not be less than the minimum mentioned in the following Table 1:

Table 1 Planning Rates for UGSs in Egypt

City Types	*The Rate of UGS in the Cities in the Nile Valley*	
	Minimum Official Rate m^2/Capita	*Proposed Official Rate m^2/Capita*
Existing Cities	*7*	*10*
New Cities	*15*	*20*

The comparison of images from multiple years provides an analysis of changes that have happened in a particular location over a specific period of time, which assists in monitoring land-use differences and detecting urban growth patterns. This may be achieved expertly through the integration of Geographic information systems (GIS) tools and remote sensing data, Although this integration are cost-effective and technologically advanced, they are effective techniques for studying and assessing urban growth (Roy and Kasemi, 2021). Because of that, data gathering on UGS is frequently accomplished by remote sensing (Vidal et al., 2022). Remotely sensed satellite images, as a free-easy access data provide a high resolution data sources for any location throughout the world (Hamdy et al., 2020) (Stroppiana et al., 2014) (Hamdy and Zhao, 2016), whilst GIS techniques aid in spatial analysis and the development of improved processed images in urban planning applications (Hamdy et al., 2014).

This study presents an approach for monitoring and assessing changes in UGSs that makes use of freely available and easily accessible data. Most of the earth's locations are covered by Landsat images, which give continuous enough data for the monitoring method to be effective. Moreover, Landsat imagery is appropriate for analyzing urban growth (Koroso et al., 2021). For each study year, the most recent and accessible Landsat imagery data were downloaded using the USGS Earth Explorer tool, which can be found at http://earthexplorer.usgs.gov/ (USGS, 2019). The Landsat 8 OLI/TIRS file for the year 2019 was utilized, and the Landsat 7 ETM+ file for the year 2010 was utilized. The downloaded data were checked to ensure that they were taken during a half-month period of the year when there was almost no cloud cover.

In order to classify Landsat images, researchers use spectral classification methods, which may be further divided into two categories: unsupervised classification and supervised classification

(Hedayati et al., 2022). Unsupervised classification is performed by grouping satellite images into multiple classes. This method is fast and it does not need training samples, but the supervised classification is much more accurate (Li et al., 2014). The supervised classification method relies on the selection of sample groups for each class (Hedayati et al., 2022). In order to determine the class type of an image's pixels, the spectral characteristics of each pixel are tested against those of the training samples. Using Landsat TM and ETM+ images, it has been shown that the maximum likelihood classification approach (Li et al., 2014) produces the best accuracy when used in conjunction with the supervised classification process (Sisodia et al., 2014). LULC mapping usually depends on the usage of this approach to classify data (Hussain et al., 2022). Both classification methods are referred to the classification accuracy evaluation process, which is an essential step in assessing the validity of maps generated from RS data (Stehman, 1996).

Regarding Landsat classification accuracy assessment, KAPPA validation is a well-known approach that quantifies how well the pixels sampled tested to the ground truth Landsat classes (Rwanga and Ndambuki, 2017). Therefore, using 500 randomly chosen sample points, the classification approach was tested for accuracy using the kappa coefficient. The error matrix is the most popular approach to show classification accuracy (Gadrani et al., 2018). A legitimate sample set of pixels in the study area taken from a valid reference classification such as Google Earth is commonly used to assess accuracy (Stehman, 1996). To achieve acceptable accuracy, these samples are recommended to be more than 50 per class (Faisal et al., 2021). The kappa coefficient ranges between 0 to 1, with 1 being the most accurate. A kappa value of 0.75-1 indicates excellent accuracy, 0.4-0.75 suggests moderate accuracy, and less than 0.40 indicates poor accuracy (Kalkhan et al., 1997).

The LandScan population grids are freely available online from 2000 to 2019 for researchers and students to identify the most densely inhabited places (Francisca et al., 2020) (Rose et al., 2020). These were acquired from the LandScanTM Project at Oak Ridge National Laboratory (“Home | LandScanTM,” n.d.). With the best census counts for every country and four main geographic input data sets, namely land cover, roads, slopes, and night time lights, that are critical indicators of population distribution (Levin and Zhang, 2017). For researchers from all around the world and from a wide range of scientific fields, e.g., remote sensing experts, geosciences, and urban planners, The LandScan dataset is many times larger than other worldwide population datasets that have been updated annually since 2000. Therefore, it can be used to analyze the trends in demography and the geographical distribution of the population according to urbanization, suburbanization, or urban sprawl (Calka and Bielecka, 2019).

This study has two goals. The first goal is to assess past and present UGS statues in the GC region in order to detect the impact of the 4th Guideline-Urban Harmony Standards and Criteria for Open Areas and Green Spaces in 2010, which was initiated by the National Organization for Urban Harmony (NOUH) to work on improving the requirements of Egyptian cities' UGSs. The second objective is to analyze the role of using free, easy-access data sources for identifying UGSs using Landsat and population distribution using LandScan datasets to achieve the first goal of providing an effective procedure for urban planners and decision makers in developing countries to remotely monitor the UGS suitability ratio.

2- Case Study:

Egypt is divided into 29 governorates. The Greater Cairo includes the Cairo Governorate's urban mass as well as parts of the governorates of Giza and Qalyubia, and also some new urban areas (specifically, Sheikh Zayed, the 6th of October, the 15th of May, Shorouk, New Cairo, Obour, and Badr) (General Organization for Physical Planning (GOPP), 2012) shown in Figure 1. This region is home to over 22% of Egypt's inhabitants (Alla et al., 2021). The GC, Africa's first megacity, with a population of more than 17 million people (Eldakdoky and Elkhateeb, 2021). It is estimated that a substantial chunk of the GC is made up of extremely productive and arid desert land surrounding the Nile River (Osman et al., 2019). This region is made up of three parts: the main agglomeration, the new urban area, and the peri-urban area (PUA). PUAs may be found to the north and west of the main agglomeration (Salem et al., 2020b). The GC has a variety of urban districts, comprising formal and informal slums, as well as upper and lower class residential neighborhoods. Furthermore, one-third of the GC's urban population lives in illegal and informal slums

(Osman et al., 2019).

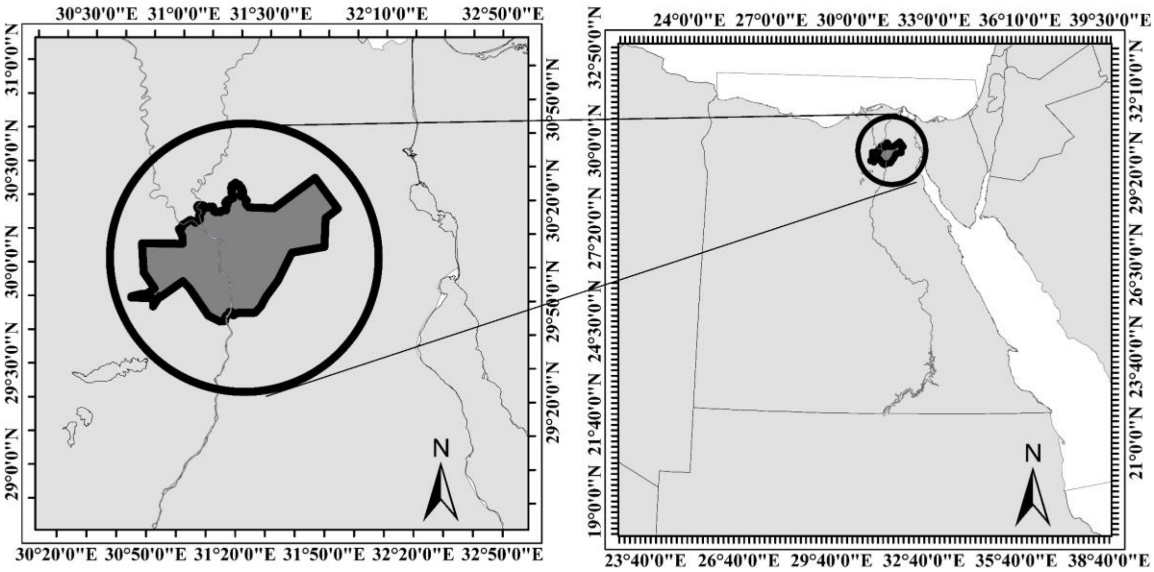


Figure 1 Location of Case study (GC).

3- Methods:

This section of the research demonstrates the methodologies used to achieve the article's stated aims. The approach has been divided into three sections, the first one provide the data source that will use in article analyses, the second section will illustrate the methodology to extract the land use of case study area including UGSs using Landsat images, and the final section discuss how to estimate the population using raster data sources.

3-1- Data Sources

Assessing the growth of UGSs requires data sources to conduct analyses of the changes that occurred from 2010 to 2019. This article relies on free-easy access data to provide the necessary data sources that can assist urban planners in monitoring the changes in UGSs, such as Landsat satellite images to create land use classifications and LandScan raster maps to estimate the population during this period of time, the details and sources of used data was mentioned in in Table 2. Error! Not a valid bookmark self-reference.

Table 2. Summary of used data sources.

Category	*Details*		*Source*
Landsat	Year 2010	7 ETM+ , Date Acquired: 4 October	United States Geological Survey, Downloaded from earth explorer tool at https://earthexplorer.usgs.gov/
	Year 2019	8 OLI/TIRS, Date Acquired: 19 September	
LandScan	Year 2010	Global population distribution data. At approximately 1 km (30″ X 30″) spatial resolution	OAK Ridge National Laboratory https://landscan.ornl.gov/
	Year 2019		

3-2- Supervised Classification

Using Landsat TM data, maps of UGSs were created in this study in order to examine in depth the spatial distribution of UGS in the GC region. In this research, we present an application for assessing changes in UGSs by using free-easy access data. For the year 2019, the Landsat 8 OLI/TIRS file was utilized, whereas the Landsat 7 ETM+ file was used for the year 2010. A supervised classification was carried out using the Maximum Likelihood Classification approach, which has been shown to generate the highest accuracy with Landsat TM and ETM+ images (Sisodia et al., 2014). The land uses were divided into four major categories: desert, green, urban, and water.

According to a land use map classification accuracy assessment for the 2010 and 2019 land use maps, a total of 500 random sampling points were dispersed among the categorized classes in order to evaluate classification accuracy. The results were compared to the actual land cover classifications of the city as depicted on Google Earth. These coefficients were derived based on the error matrices that were generated, and they are one of the variables that are often employed in error matrix analyses for accuracy validation and reliability evaluation. The Kappa values demonstrate that the classifications were accurate. It was calculated that the kappa coefficient was 0.973 in 2001 and that it was 0.968

in 2019. As a result, all of the land use categories were deemed quite accurate. The classification maps can be shown in b for 2019.

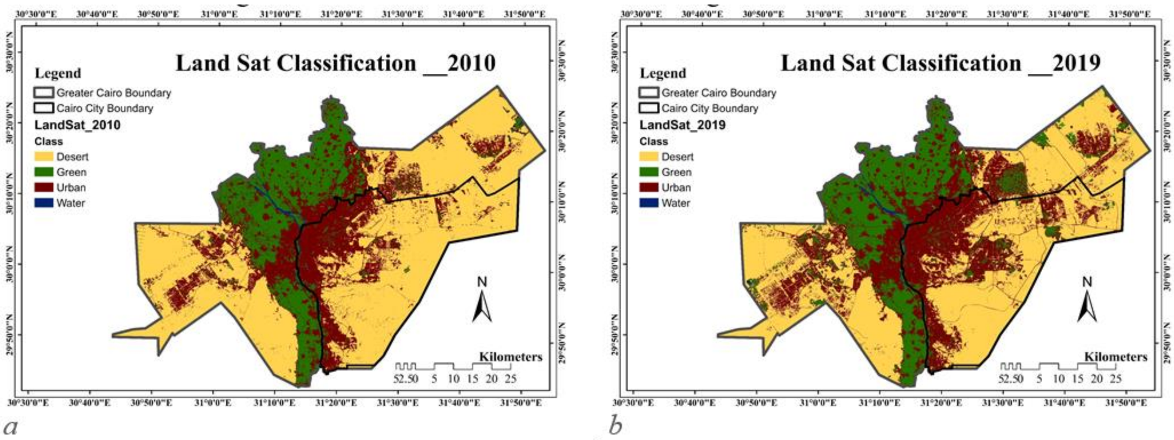
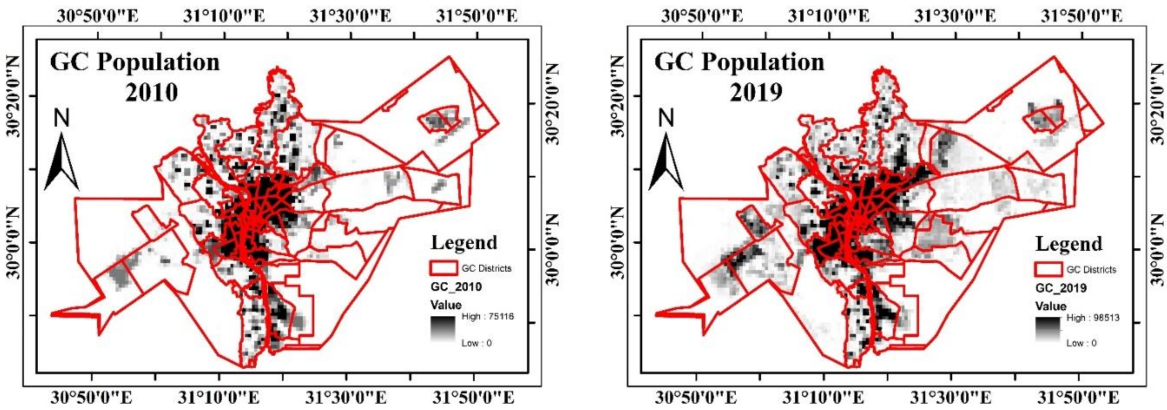


Figure 2 Land use classification for GC region at 2010 and 2019.

3-3- Identifying The Population at Case Study.

In this article, we use the LandScan data set as a valid open-source data source to analyze the amount of the population lives at case study area. This data set provides the spatial distribution of the population for all of the world, and we use the case study area's boundary as a splitter to extract only the population distribution for GC, which is the focus of this article. The most recent available LandScan imagery files for each study year were downloaded from the OAK Ridge national laboratory website available at (https://landscan.ornl.gov/). Figure 3 depicts the final raster map for population, in which each cell value corresponds to the number of people living in that cell.

In this article, we use the LandScan data set as an accurate open-source data source to estimate the proportion of the population that is inhabited in the GC region. This data set contains the spatial population distribution for the entire globe, and we use the case study area's district boundaries as a divider to select only the population distribution for GC, which is the topic of the article. The most recent accessible LandScan imaging files for each research year (2010 and 2019) were downloaded from the OAK Ridge national laboratory website (https://landscan.ornl.gov/). Figure 3 (a, b) illustrates the final raster map for population, in which each cell value represents the number of people living in that cell.



a b

Figure 3 Distribution of population on GC.

4- Results:

A two-part classification system, GC region and Cairo City, has been introduced. Existing Districts (72 Districts) and new Districts make up the GC region (14 Districts). A significant tract of green space had been encroached upon by urbanization. The categorization of land cover in 2010 was compared to the classification in 2019. The most important factor for the loss in UGS was the conversion to urban areas, according to the results of a direct comparison following classification. These findings revealed that urbanization is the most important process affecting other land uses and vacant space consumption in the study area district dividing.

The study area was divided into two categories: exiting districts (which included the 72 District) and new districts (comprising 14 District). As stated in Table 3, each district was assigned a unique code, such as Abdeen code (01 (E) for exiting districts and 6-Oct-01code (73 (N) for new districts.

Table 3 The study area districts coding.

Exiting Cities						New Cities	
No.	District Name	No.2	District Name3	No.4	District Name5	No.6	District Name7
01 (E)	Abdeen	25 (E)	Alqahera-DB	49 (E)	Embaba-Center	73 (N)	6-Oct-01
02 (E)	Al-Agoza	26 (E)	Al-Qanater Al-Khairea	50 (E)	Faisal	74 (N)	6-Oct-02
03 (E)	Al-Ahram	27 (E)	Al-Saf	51 (E)	Hadaq Al-Quba	75 (N)	10th Ramadan-1
04 (E)	Al-Ayaat	28 (E)	Al-Sahel	52 (E)	Helwan	76 (N)	10th Ramadan-2
05 (E)	Al-Azbakia	29 (E)	Al-Saieda Zainab	53 (E)	Kerdasa	77 (N)	10th Ramadan-DB
06 (E)	Al-Badrashan	30 (E)	Al-Salam	54 (E)	Mansheat Naser	78 (N)	15th May
07 (E)	Al-Basateen	31 (E)	Al-Sharabia	55 (E)	Mashtol Al-Souq	79 (N)	Al-Obour
08 (E)	Al-Darb Al-Ahmar	32 (E)	Al-Tal Al-Kabeer	56 (E)	Masr Al-Gadeda	80 (N)	Al-Obour-DB
09 (E)	Al-Doky	33 (E)	Al-Tal Al-Kabeer-DB	57 (E)	Masr Al-Qadema	81 (N)	Al-Shekh Zaid
10 (E)	AlGamalia	34 (E)	Al-Tebeen	58 (E)	Menya Al-Qamh	82 (N)	Al-Shrouq
11 (E)	Al-Geza	35 (E)	Al-Waily	59 (E)	Naser City-1	83 (N)	Badr
12 (E)	Al-Geza-Center	36 (E)	Al-Waraq	60 (E)	Naser City-2	84 (N)	New Cairo-1
13 (E)	Al-Geza-DB-1	37 (E)	Al-Zaher	61 (E)	Oseem	85 (N)	New Cairo-2
14 (E)	Al-Geza-DB-2	38 (E)	Al-Zaiton	62 (E)	Qaha	86 (N)	New Cairo-3
15 (E)	Al-Hawamdya	39 (E)	Al-Zamalek	63 (E)	Qaleoub		
16 (E)	Al-Khalefa	40 (E)	Al-Zawia Al-Hamraa	64 (E)	Qalub		
17 (E)	Al-Khanka	41 (E)	Ashmoun	65 (E)	Qasr Al-nile		
18 (E)	Al-Khosos	42 (E)	Bab El-Sherya	66 (E)	Rod Al-Farag		
19 (E)	Al-Maady	43 (E)	Banha	67 (E)	Shebeen Al-Qanater		
20 (E)	Al-Marg	44 (E)	Belbees	68 (E)	Shoubra		
21 (E)	Al-Mataria	45 (E)	Bolaq El-Dakror	69 (E)	Shoubra Al-Khima-1		
22 (E)	Al-Mosky	46 (E)	Boulaq	70 (E)	Shoubra Al-Khima-2		
23 (E)	Al-Nozha	47 (E)	Ein Shams	71 (E)	Torah		
24 (E)	Al-Omrania	48 (E)	Embaba	72 (E)	Toukh		

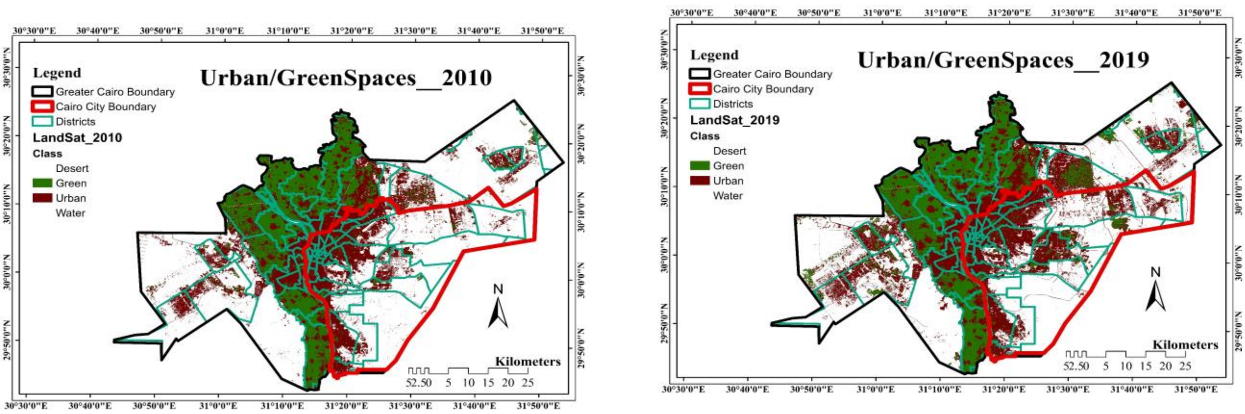
4-1- Population Distribution during Land Use

As shown in Table 4 and Figure 4 (a,b), Greater Cairo's population reached 22.6 million in 2019, a growth of 5.1 million over 2010, when the population was 17.5 million, or 29.1 percent. The city of Cairo's population reached 8.3 million in 2019, an increase of 0.6 million, or 8%, over 2010, when it was 7.7 million. Between 2010 and 2019, the GC region's UGS increased by 13,129 hectares at a rate of 16.7 percent. This rise includes both existing districts (3845 ha) at 5.2 percent and new districts (9284 ha) at a relatively high rate of 231.8 percent. In Cairo city, UGS grew by 942 hectares at a rate of 34.6 percent, from (2724 ha) in 2010 to (3666 ha) in 2019. The estimated urban growth was compared between 2010 and 2019, when the GC region's urban areas increased by (23449 hectares) at a rate of 22.5 percent. Whereas urban areas in existing districts accounted for 5.9 percent (5197 ha), urban areas in new districts accounted for 62.4 percent (18252 ha).

Between 2010 and 2019, the UGSs rats/capita share in GC region declined (-4.3 m2/capita) by 9.6 percent, with the UGSs rats/capita share being 44.8 m2/capita in 2010 and 40.5 m2/capita in 2019. This drop is attributed to a (5.2 m2/capita) 11.4 percent fall in the UGSs rats/capita share in the Existing Districts, where the UGSs rats/capita share was 45.5 m2/capita and reduced to 40.3 m2/capita. Despite a 16.5 percent rise in the per capita share in the New Districts (5.9 m2/capita), where the per capita share was 35.7 m2/capita and increased to 41.6 m2/capita. While the UGSs rats/capita share in Cairo city increased by 25.7 percent (0.9 m2/capita), while the UGSs rats/capita share was 3.5 m2/capita in 2010 and jumped to 4.4 m2/capita in 2019.

Table 4 The Districts Statistics including the population and UGS for GC region and Cairo city.

Districts Statistics	GC region			Cairo City
	Existing Districts	New Districts	Total / Average	
Population 2010 (Million)	16.4	1.1	17.5	7.7
Population 2019 (Million)	19.4	3.2	22.6	8.3
Changing in Population (Million) (2010-2019)	3.0	2.1	5.1	0.6
Changing in Population % _ (2010-2019)	18.3%	190.9%	29.1%	8%
UGS in 2010 (ha)	74428	4006	78434	2724
UGS in 2019 (ha)	78273	13290	91563	3666
Changing in UGS (ha) (2010-2019)	3845	9284	13129	942
Changing in UGS %_ (2010-2019)	5.2%	231.8%	16.7%	34.6%
Urban Area in 2010 (ha)	74918	29252	104170	32859
Urban Area in 2019 (ha)	80115	47504	127619	35759
Changing in Urban Area (ha) (2010-2019)	5197	18252	23449	2900
Changing in Urban Area % (2010-2019)	6.9%	62.4%	22.5%	8.8%
UGS 2010 m^2/capita	45.5	35.7	44.8	3.5
UGS 2019 m^2/capita	40.3	41.6	40.5	4.4
Changing in UGS m^2/capita (2010-2019)	-5.2	+5.9	-4.3	+0.9
Changing in UGS % (2010-2019)	-11.4%	+16.5%	-9.6%	+25.7%



a *b*

Figure 4 Distribution of Urban Areas and UGS at All Districts in 2010 and 2019.

4-2- Urban Green Spaces Rates

In the GC region, the official minimum rate of UGS is 7 m2/capita for existing districts and (15 m2/capita) for new districts. These rates have been updated to include a minimum of 10 m2/capita for existing districts and 20 m2/capita for new districts. In 2010, the number of districts having a high rate in the GC region was Al-Tal Al-Kabeer (32E), with existing districts having an extremely high rate of 27190 m2/capita. In addition, the new district Al-

Obour-DB (80N) have the highest rate with a rate of 202. However, the Al-Tal Al-Kabeer (32E) district remained among the existing districts with a high rate in 2019, with a rate of 10801 m2/capita. Furthermore, the New District 10th Ramadan-DB (77N) have a rate of 97 m2/capita. In terms of Cairo city Districts with a high rate, Alqahera-DB District (25E) was only in 2010 with a rate of 553 m2/capita, and it was also in 2019 with a rate of 105 m2/capita. In 2010, the number of districts having a low rate in the GC region was 10 districts. Whereas the number of Existing Districts was 9 districts, with a rate of 0 m2/capita, and the number of New Districts was one district, with a rate of 4 m2/capita. This number fell to (7 districts) in 2019 as a result of (6) Existing Districts at a rate of 0 m2/capita and only one New District at a rate of 10 m2/capita. Districts in Cairo city with a low rate were Al-Azbakia District (05E) in (2010) and Bab El-Sherya district (42E) in (2010 - 2019), both with a rate of 0 m2/capita.

The GC region has 48 districts that did not meet the official rate in 2010 as shown in Table 5, Figure 5, and Error! Reference source not found.. These districts are grouped into 43 existing districts and 5 new districts. In 2019, the number of districts was reduced to 41, with 38 existing districts and two new districts. While the number of locations in Cairo that did not meet the official rate was 29 in 2010, it has since fallen to 26 in 2019. These findings suggest a small decrease in the number of districts failing to meet the stated rate. In terms of the number of districts in the GC region that met the minimum official rate in 2010, there are three, all of which are existing districts. In 2019, the number of districts rose to eight, with seven existing districts and one new district added. These findings show a considerable rise in the number of districts meeting the official rate, particularly in the existing districts. The number of districts in the GC region that met the proposed official rate in 2010 is 35, including 26 existing districts and 9 new districts. In 2019, the number of districts grew to 37, with 29 existing districts and 11 new districts. In Cairo, the number of areas that achieved the proposed official rate increased from 5 in 2010 to 6 in 2019. These findings show a slight increase in the number of districts achieving the proposed official rate.

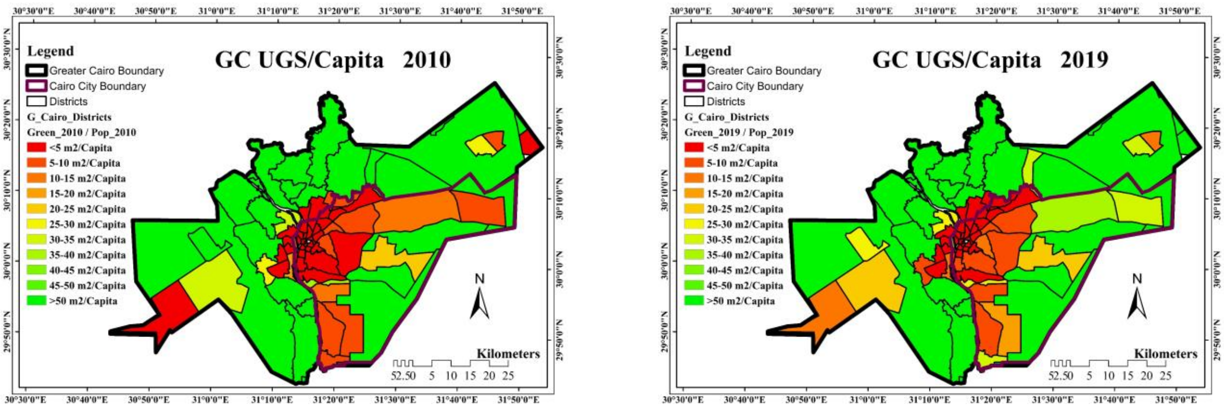


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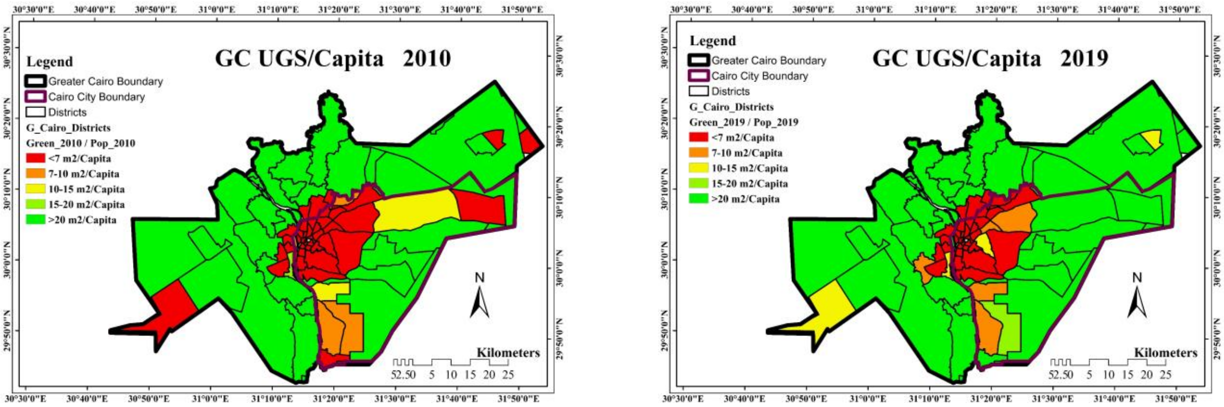
Figure 5 UGSs Per Capita at Districts of GC region at 2010 and 2019.

Table 5 The districts statistics related to NOUH guideline rats.

Districts Statistics	GC region			Cairo City
	Existing Districts	New Districts	Total / Average	
Min Official Rate for UGS (m^2/capita)- 2010	7	15	---	---
Proposed Official Rate for UGS (m^2/capita)	10	20	---	---
Higher Rate District (m^2/capita) (2010) (Number of Districts) (Existing/New)	27190 32(E)	202 80(N)	---	553 25(E)
Lower Rate District (m^2/capita) (2010) (Number of Districts) (Existing/New)	0 05(E), 13(E), 33(E), 42(E) 27(E), 43(E), 50(E), 58(E), 62(E)	4 74(N)	---	0 05(E), 42(E)
Higher Rate District (m^2/capita) (2019) (Number of Districts) (Existing/New)	10801 32(E)	97 77(E)	---	105 25(E)

Lower Rate District (m²/capita) (2019) (Number of Districts) (Existing/New)	0 42(E), 27(E), 43(E), 50(E), 58(E), 62(E)	10 74(E)	---	0 42(E)
Districts not Achieved the min Official Rate 2010 (Count)	43	5	48	29
Districts Achieved the min Official Rate 2010 (Count)	3	0	3	2
Districts Achieved the Proposed Official Rate 2010 (Count)	26	9	35	5
Districts not Achieved the Official Rate 2019 (Count)	39	2	41	26
Districts Achieved the min Official Rate 2019 (Count)	7	1	8	4
Districts Achieved the Proposed Official Rate 2019 (Count)	26	11	37	6
Total Number of Districts (Number of Districts)	72	14	86	36



A *b*

Figure 6 UGSs Per Capita at Districts of GC region at 2010 and 2019 Based on the Official Rates.

4-3- Qualified and Unqualified Urban Areas

In 2010, the GC region's overqualified UGS rate was 5.8 million people. They are divided into 5.4 million in the existing districts (32.2%) and 0.4 million in the new districts (36.4%). In 2019, the GC region's population living above the qualifying rate increased to 9.2 million (existing districts 6.4 million, or 33 percent) and new districts 2.8 million, or 87.5 percent). In addition, the number of people living in Cairo's overqualified rate grew to 1.5 million (15.8 percent) in 2019 from 1.1 million (18 percent) in 2010. Other cities also had a considerable increase in the number of people living at the over-qualified rate, with 7.7 million (84.2 percent) in 2019 compared to 4.7 million (82 percent) in 2010.

In 2010 as shown in Table 6, 1.1 million people in the GC area were classified as qualified. They are divided into one million in the existing districts (6.1 percent of the total population) and 0.1 million in the new districts (9.1 percent of the population). In 2019, the population of the GC region living at the qualifying rate climbed to 2 million (existing districts 1.9 million, or 9.8 percent) and new districts 0.1 million, or 3.1 percent). As long as there were 0.1 million qualified residents in Cairo city, that number stayed the same. In other cities, the number of qualified residents grew significantly, from 1 million (90.9%) in 2010 to 1.9 million (95%) in 2019.

Table 6 The statues of UGS qualified rates.

	Existing Districts	*New Districts*	*Total*	*Cairo City*	*Other Cities*
Population lives in Over Qualified Rate 2010 (Million)	*5.4 (32.9%)*	*0.4 (36.4%)*	*5.8*	*1.1 (18.0%)*	*4.7 (82.0%)*
Population lives in Qualified Rate 2010 (Million)	*1.0 (6.1%)*	*0.1 (9.1%)*	*1.1*	*0.1 (9.1%)*	*1.0 (90.9%)*
Population lives in Unqualified Rate	*10.0*	*0.6*	*10.6*	*6.6*	*4.0*

2010 (Million)	*(61.0%)*	*(54.5%)*		*(62.3%)*	*(37.7%)*
Population lives in Over Qualified Rate 2019 (Million)	*6.4 (33.0%)*	*2.8 (87.5%)*	*9.2*	*1.5 (15.8%)*	*7.7 (84.2%)*
Population lives in Qualified Rate 2019 (Million)	*1.9 (9.8%)*	*0.1 (3.1%)*	*2.0*	*0.1 (5.0%)*	*1.9 (95.0%)*
Population lives in Unqualified Rate 2019 (Million)	*11.1 (57.2%)*	*0.3 (9.4%)*	*11.4*	*6.8 (59.7%)*	*4.6 (40.3%)*

In 2010, 10.6 million people in the GC region lived in unqualified rate districts. They are divided into ten million in existing districts (61 percent of the population) and 0.6 million in new districts (54.5% of the population). In 2019, the number of people living in unqualified rate districts in the GC Region increased to 11.4 million (existing districts: 11.1 million, or 57.2 percent) (new districts: 0.3 million, or 9.4 percent). In addition, the number of people living in Cairo city at an unqualified rate has grown to 6.8 million (59.7 percent) in 2019 from 6.6 million (62.3 percent) in 2010. Other cities have also seen a growth in the number of persons living in unqualified rate districts, like their number increased to 4.6 million (40.3 percent) in 2019 from 4 million (37.7 percent) in 2010.

According to previous studies, the new districts in the GC region (2010-2019) have the greatest share of the people living in overqualified districts. Whereas it was 36.4 percent in 2010, it is now 87.5 percent in 2019.Also, there was no change in the new districts' population (0.1 million) who lived at a qualifying rate districts between 2010 and 2019, where their proportion of the population was 9.1 percent in 2010 and 5 percent in 2019. In terms of the people living at an unqualified rate districts, the existing districts with the greatest percentage were in the GC region, where their number was 10 million (61 percent) in 2010 and climbed to 11.1 million (57.2 percent) in 2019. In the city of New Cairo, the percentage was the greatest population lives at an unqualified rate districts, as the number of people living at an unqualified rate districts in 2010 was 6.6 million, or 62.3 percent, while it was one million, or 59.75 percent, in 2019.

5- Conclusion:

The lack of urban green spaces and the per capita share in developing countries, particularly Egypt, and the availability of great efforts from the government to improve this situation by issuing a NOUH guideline for all those involved in urban planning to increase knowledge about green spaces and raise the share of the population, provided the research with a clear objective to study the ratios of green spaces in one of the most important regions in Egypt, which is Greater Cairo. Moreover, this article compared the situation of UGS before applying the NOUH guideline in 2010 and after the application in 2019. It was clear from this comparison that the per capita share of UGS decreased by 11.4 percent in existing districts while it increased by 16.5 percent in new districts, where it was easier to respond to new regulations that were recommended by the NOUH guideline.

The comparison also showed that the per capita share of UGS at the level of the GC region in general declined by 9.6 percent, but at the level of Cairo city, the rate of rise was great, reaching 25.7 percent, despite the major changes. The new districts remained with the highest rate of per capita UGS (41.6 m2/capita) in the percentages of increase or decrease for each significantly, which explains the high cumulative crossover between the new districts and agricultural and rural areas surrounding the region.

The research depended on the supply of a scientific approach based on free-easy access data such as Landsat and LandScan, as well as the use of a hybrid of remote sensing and geographic information systems techniques. This methodology provides researchers, urban planners, decision makers, and anyone else involved in city planning and management with a chance to monitor changes in land uses, particularly urban green spaces, with an analysis of the per capita share of them, which is particularly important in developing countries where resources are limited in providing data for this monitoring.

Future research will be required to confirm the validity of the kinds of findings that may be derived from this work. Because of the availability of high-resolution cost data and the availability of a large fund for fieldwork, it will be possible to distinguish between different types of urban green areas and improve the accuracy of Landsat and LandScan images. Possibly, in the future, this assumption will be addressed through research. Moreover, if there are high resolution satellite images the urban planner can used our methodology to monitoring the changes in urban green areas regularly in addition can use some prediction models to predict the future situation of urban green areas.

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