Observing and Monitoring the Urban Expansion of Makkah al-Mukarramah Using the Remote Sensing and GIS

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Abstract: This study aims at surveying and recording land cover changes as well as urban changes in the city of Makkah al-Mukarramah throughout the period between 1992 and 2016. To achieve this purpose, the study relies on the inductive approach to monitor the urban developments, population growth and land uses through the structural schemes of Makkah al-Mukarramah along with the official reports issued from the Secretariat of Holy Makkah Municipality, the High Commission for the Development of Makkah al-Mukarramah and scientific research. It also endorses spatial analysis as its approach to extract digital data from satellite imagery to survey the temporal changes to the land covers in Makkah al-Mukarramah. These digital data, along with the final output map compositions, have been processed through the employment of two specific mapping software: **ArcGIS v10.3** and **ERDAS IMAGINE v14**.

The study at hand reached the conclusion that most of the urban developments in the city, particularly the housing and commercial developments, is centered around the Holy Mosque and in the neighboring districts in a way that demonstrates the influence of the mountainous terrain on the urban sprawling of the city across the narrow valleys to the flat urban outskirts. The study has further shed light on the changes that affected the percentage of land covers in the city throughout the period of the study. Urban use[1] of land covers in the city rose significantly from **12%** of its total area in **1992** to **22.13%** in **2016**. On the contrary, ratio of undeveloped lands to the total area has plummeted from **42.7%** in **1992** to **35.36%** in **2016**. This fall is due to the rise in the urban exploitation of lands and the urban growth towards the low-lying areas in the outskirts of the city, particularly the lands that circle regional highways and ring roads. With regards to the mountainous areas, it fell in ratio to the total area of the city from **41%** in **1992** to **39.2%** in **2016** thanks to the development projects which necessitated removing and flattening some of the rocky areas near parts of the most important sites in the holy city. Whereas the ratio of green spaces to the total area of the city has oscillated from one image to another, it hit a percentage of **3.83%** in **1992** falling to **3.27%** in **2016**. In fact, this fluctuation stems from the variance of months that passed between the satellite imagery collection. The researchers, who conducted this study, seek to highlight the significance of employing GIS and remote sensing technologies in executing subsequent studies that are concerned with planning and predicting land cover changes and land uses in the city of Makkah al-Mukarramah.

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[1] Urban land uses subsume: housing, commerce, providing services (religious, educational, administrative, entertainment and security), building roads, establishing commercial malls and industrial utilities.

Introduction:

A city is considered a social[2], economic[3], political[4], cultural and urban[5] unit, which dynamically grows and flourishes in a particular spatial space while operating and interconnecting in a special way that characterizes one city from another.

The city of Makkah al-Mukarramah is regarded one of the cities that receive special attention from the Saudi government for its religious and regional eminence, which helped the city achieve record developmental leaps in short periods of time. Consequently, the city has witnessed a population boom and a spatial expansion towards its outskirts, resulting in an increase and a quality shift in its districts. Great iconic projects followed, such as: Al-Harameen rail project, Al-Haram al-Sharif expansion project, Makkah slum developments, and completion of the structural road network and prospective ring roads projects, leading to great changes in the urban morphology of the city. Hence comes the need to conduct this study, in order to monitor and record the temporal and spatial changes witnessed in the city in terms of urban development and population growth along with changes in land use throughout the period between **1992** and **2016**.

Object of Study, its Aims and its Importance:

Significant developments taking place in the City of Makkah in the previous years have led to an acceleration in urban changes, which created the need for this study. Accordingly, the present study sought to observe the dynamism of the fast-urban changes occurring in the city of Makkah al-Mukarramah via establishing a geographic information system that is based on analyzing and extrapolating satellite imagery data to achieve the following objectives:

1. monitoring and recording urban change features in the city of Makkah al-Mukarramah through undertaking a comparative study of the following elements in consecutive periods of time:
    1. Urban expansion of Makkah al-Mukarramah and its patterns.
    2. Incongruity of land covers distributions in the city of Makkah al-Mukarramah.
2. shedding light on the contributing factors to the acceleration of urban change and land covers change in the holy city.
3. Producing modern digital maps that track change in land cover in the city of Makkah al-Mukarramah.
4. observing the incongruity in the land covers distributions in Makkah al-Mukarramah in the period of the study.

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[2] Population represent the socio-cultural aspects.
[3] It represents the nature and types of economic activities carried out by the population.
[4] The administrative and legislative authorities in a city.
[5] Urban fabric or urban elements.

To fulfil these objectives, the present study sought answers to the following questions:

1. What are the major changes in the urban morphology of the city of Makkah al-Mukarramah throughout the period between **1992** and **2016**?

2. Does any variance in the ration of land covers distributions take place in the city of Makkah al-Mukarramah between **1992** and **2016**?

3. What are the contributing factors to the urban changes and land cover changes in the city between the years of **1992** and **2016**?

The significance of this study stems from the attention it draws towards the need for developmental or planning decision-makers to rely on the spatial technologies embedded in GIS and remote sensing in obtaining, cataloguing and analyzing any piece of information. This would save time and effort as well as ensure speed and accuracy in providing data, so that an (urban) planning decision is reality-based and built on solid foundations especially in case of fast-growing cities such as Makkah al-Mukarramah[6] which require constant information updates and changes follow-up.

Study Methodology:

This study seeks to survey and record the changes, which occurred to the land cover of Makkah Al Mukarramah, as well as the urban changes therein in the period spanning 1992-2016. To that end, the study adopts several approaches:

1. Deductive Approach:

This approach is utilized to study the urban and demographic changes and land use in the city, through city charts and governmental reports issued by the Holy Capital Secretariat, High Commission for the Development of Makkah al-Mukarramah and academic research.

2. Approach to Spatial Analysis:

The study adopts this approach in order to extract the digital data supplied by satellite images and use them to record the temporal changes of land covers in the studied area. Also, relevant information was collected from various bibliographic resources. Digital data was processed and final outputs were designed using ArcGIS v10.3 and ERDAS IMAGINE v14.

Area of the Study (the City of Makkah Al Mukarramah):

The city of Makkah Al Mukarramah is located in a latitude of $20°$, 21^0 N and a longitude of $39^0 45'$, $40^0 00'$ E. It has also an elevation of approximately 300 meters above the sea level. Given its God-given positive attributes, distinction and eminence, the city of Makkah Al Mukarramah is a major center of attraction for population, urban development and economic activities. Moreover, since the city is the spatial space where all of these activities take place, this study is dedicated to detect the urban changes in Makkah Al Mukarramah with its established administrative borders (figure no. 1) throughout the extended period

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[6] The city of Makkah al-Mukarramah has been witnessing rapid growth, particularly in the last two decades. Its population in 2010 grew by a percentage of 73% in comparison with their numbers in 1992. Its total area has been also increasing so a lot of new districts have appeared towards the outer districts of the city.

of time between **1992** and **2016**. All the data, descriptive information based on satellite imagery and the tabled information for the study area have been analyzed, accordingly.
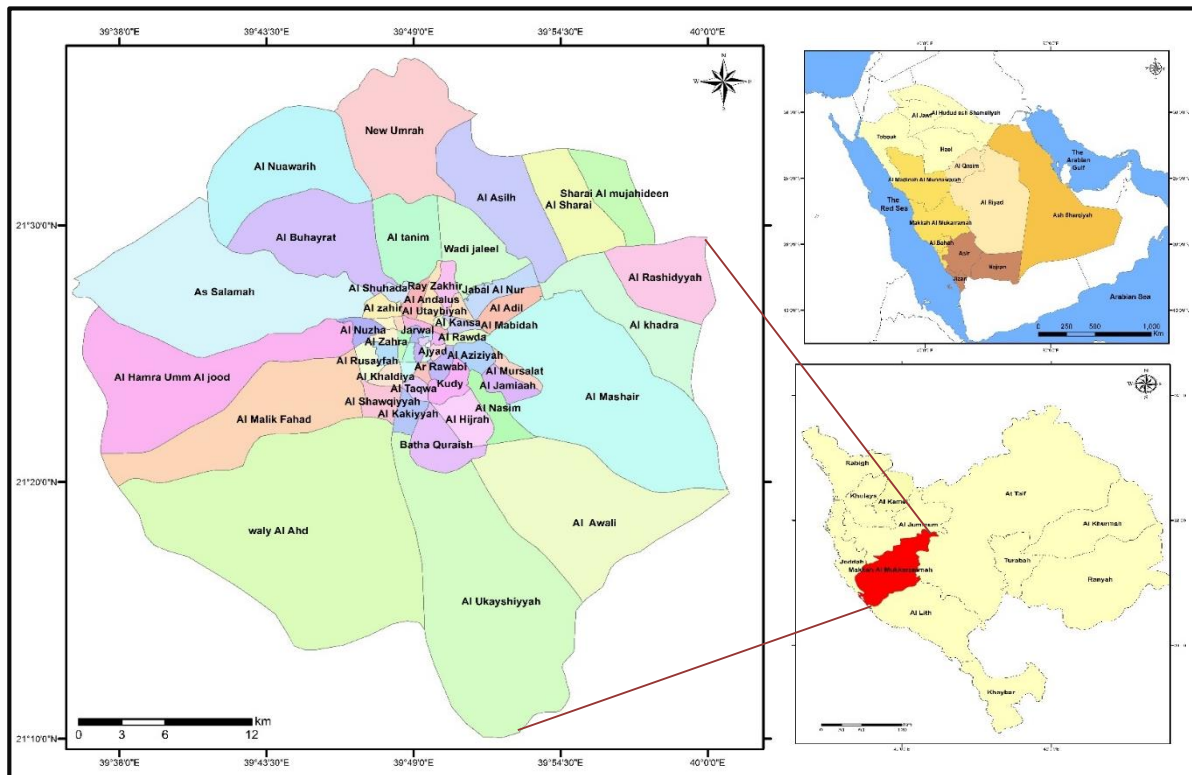

Figure 1: Location of the Study Area: Makkah Al Mukarramah

Source: These maps are prepared by the researcher in consultation of the maps drawn by the General Authority for Military Surveying, Riyadh, 1421 A.H., Holy Capital Secretariat, and General Administration of Information Technology.

Literature Review;

Most of the changes that affect cities through the passage of time materialize in the urban morphological change, which includes changes in population composition changes, total area or land covers. Thus, geographic studies tracking this change have been multiplying and continuing. These studies could be categorized according to the following themes:

3. **Studies of Urban Growth in Cities:**

A growing body of literature has grappled with urban growth in many global cities, which includes the research undertaken by **W. Huang et al** (**2008**) entitled "Detection and prediction of land use change in Beijing based on remote sensing and GIS". This particular study detected the urban expansion as well as the spatial and temporal changes in the city of Beijing spanning between **1984** and **2005**. It has highlighted the density of urban expansion in the city of Beijing towards the outskirts throughout that period and the concentrated urban core to the East of Beijing, up to its west. The researchers have been capable of examining the correlation between the population, gross domestic income and the urban land area, applying a regressive linear model to predict the future size and urban developmental patterns of Beijing.

In the Arab World, Lutfi Kamal Azzar (**2009**) investigated the urban development of Alexandria via establishing a geographic information system, which is based on satellite imagery data collected by Landsat between **1984** and **1993** to identify the most important characteristics and demographic features of urban development in the city. The study concluded that the city has witnessed an exponential urban growth throughout the study period, which is projected to double in the coming years leading to the loss of agricultural lands in the south and south-east of the city.

Eissa al-Shaer (**1993**), **at the local level of the Saudi cities**, used satellite imagery to detect the urban expansion of al-Riyadh city, whereas Muhammad al-Khuzami (**2000**) relied on remote sensing and satellite imagery analysis technologies to monitor the urban development in al-Dariyya in the period spanning **1987-1997** along with al-Asmari's study (**2008**) on the human factors influencing the urban growth of the city of Jeddah in the period spanning **1980-2005**.

Pertaining to the city of **Makkah Al Mukarramah**, a considerable amount of studies has been published, which includes: Abdel Baqi's study (**1983**) on the origins of Makkah Al Mukarramah, the extents of its urban expansion throughout different temporal stages and the three-section division of Makkah. In Abdel Baqi's division, the City is comprised of: the central area overlooking the Haram, which used to support high density population eventually plummeting during the Haram expansion projects and the demolition of many buildings, a medium-density population area and the modern districts area which is less densely populated. Al-Mazra (**1984**) investigated in his study the influence of the ecological factures on the urban growth of the city of Makkah, while Abdel Baqi (**1986**) focused on identifying the features of the ancient and modern urban growth of Makkah Al Mukarramah. In the body of research on Makkah, al-Seriany's two research studies (**1986**) stand out, in which one has been dedicated to the urban growth of Makkah with a special emphasis in the relationship between the reality of urban growth in the city and the Western theories of city growth along with the similarities and differences between ancient Makkah, modern Makkah and the projected future of Makkah. Al-Seriany's second study further investigated land schemes and its distribution in Makkah, highlighting the influence of these schemes on increasing the populated land areas and its extension along the highways. That resulted in a growing demand on services and utilities especially with the emergence of peripheral schemes which were out of touch with the center, leading to an imbalanced urban growth that distorted the fabric of the city surrounding al-Haram al-Sharif. Al-Sharif (**2002**) attempted to study the urban change in Makkah Al Mukarramah, in which he divided the modern urban environment of the city into three areas: the traditional area, the transitional stage area, the modern growth area. Eventually, al-Zahri (**2004**) tried to calculate the total area of the urban development spaces in Makkah Al Mukarramah in quarter a decade, depending on the maps of **1880/1947/1989** in a geographic information system.

Furthermore, al-Wizinani (**2010**) sought to monitor the change and urban growth in the maps of Southern Makkah Al Mukarramah in the period spanning **1970-2007**. On his part, al-Jabari (**2013**) tracked

the urban development of the city throughout history, the accompanying changes to this growth, its leading factors and its consequent problems.

4. **Studies of land use changes in cities:**

Many studies have been undertaken in relation to land use in cities; nevertheless, the focus of most these studies on investigating change in densely green and modern areas is problematic, as in: **R. Jensen** (**1981**) who studied the American district of Boulder, **T. Fung** (**1992**) who studied the city of Hong Kong, **Yichun Xie** (**2007**) who detected the temporal and spatial changes in land use in the Chinese city of Beijing in the period spanning **1990-2000** and **Nasar** (**2015**) who observed the urban expansion and land use change in the Pakistani city of Lahore in the period spanning **2000-2014**.

In the Arab World, al-Askari (**2009**) employed the technologies of remote sensing and GIS in studying regional land use change in Iraqi Hawizeh Marshes between the years of **1973** and **2004**.That study has succeeded in setting up a geographic information database to detect land cover change and its causes. Ashour (**2005**), on his part, focused on studying the ecological and human characteristics along with land use patterns hand in hand with concentrating on the role of remote sensing and GIS in identifying directions for urban expansion in the city of Misrata. Yehia and Ahmed's study (**2013**) of land use change and land cover change near al-Mosul Dam Lake in the period spanning **1984-2009** is among the recent research which employed the supervised classification system and urban change manual calculations in analyzing land use and land cover changes in ERDAS IMAGINE. The study came to the conclusion that climactic changes led to a deterioration in the ecological and functional potentials of the agricultural lands along with the human factor, which negatively impacted the environment in this area.

Locally in the Kingdom of Saudi Arabia, there is a study by al-Anaqri's (**1989**) whose aims included investigating the change in land use in the city of Unaizah in the period spanning **1976-1983**. Another research by al-Gekhaidab (**1994**) tracked land use change in the city of Hufuf in the years between **1977** and **1977**. Al-Shaer (**1993**) undertook a study of the urban expansion in the city of Riyadh in the period spanning **1950-1989**. Al-Ghamidi has also undertaken many studies that concentrate on the changes affecting the city of Makkah Al Mukarramah: the first in **2001** in which he chose a group of automatic methods to discover land cover changes in Makkah Al Mukarramah while integrating the satellite sensor digital data (**SPOT XS**) in two different periods, highlighting the possibility of detecting change, its type and its extent in urban environments through using unsupervised classification of the principal components analysis output; and the second in collaboration with al-Najar (**2002**) which depended on satellite data in tracking the urban expansion in the city of Makkah in the period spanning **1978-2000**; and the third was conducted to classify land use in Makkah Al Mukarramah via processing compacted data from the thematic mapper of **Landsat 5** and the panchromatic sensor of **IRC 1C Pan** (Indian Remote Sensing Satellite). These data have been processed and the resulting imagery integrated in one imagery, which has been exposed to

unsupervised classification then a supervised classification. That research produced a map for land use in the city of Makkah that is **98%** accurate in land covers while being **84%** accurate in land use.

Data Processing Procedures:

Satellite digital data has been processed using two software: **ArcGIS v10.3** and **ERDAS IMAGINE v14**. The most important steps in examining, processing and analyzing the satellite-based digital data are as follows:

5. **Data Collection Phase**

The study adopted a research methodology that is based on integrating GIS and remote sensing, where satellite imagery for the city of Makkah Al Mukarramah, covering the suggested study period (table 1) as exemplified in the years (**1992, 2003, 2010, 2016**), has been obtained from the United States Geological Society (**USGS**) whereas the **2010** Landsat imagery has been obtained from **Global Land Cover Facility** website (**GLCF**).

- **Image Processing:**

The goal of satellite image processing is determining populated areas and to distinguish various land uses during the period represented by said data. To achieve this, the following steps are followed:

- Combining imagery bands using the "Layer Stack" tool, in order to get 7 bands from the Landsat 5 imagery for 1990, 8 bands from the imagery taken on 2003 and 2010 and 11 bands from the 2016 imagery.

Table (1): Satellite Imagery Used by the Study

Imagery	Sensor	Date
Landsat 8	OLI	16/02/2016 – 23/02/2016
Landsat 7	ETM	22/01/2010
Landsat 7	ETM	19/01/2003
Landsat 5	TM	27/08/1990

- Creating a mosaic for the Landsat 8 imagery by the OLI sensor for 2016, which did not cover the full studied area.

- Cutting at the borders of the studied area, using the "Create Subset Image" tool in the ERSAS IMAGINE 2014 program.

- Enhancing radiation in the imagery using the "Rescale" tool, found in the "Radiometric" tools in the same program.

- Spatial enhancement of the Landsat OLI, ETM imagery through combining the band of every image with the panchromatic band number 8.
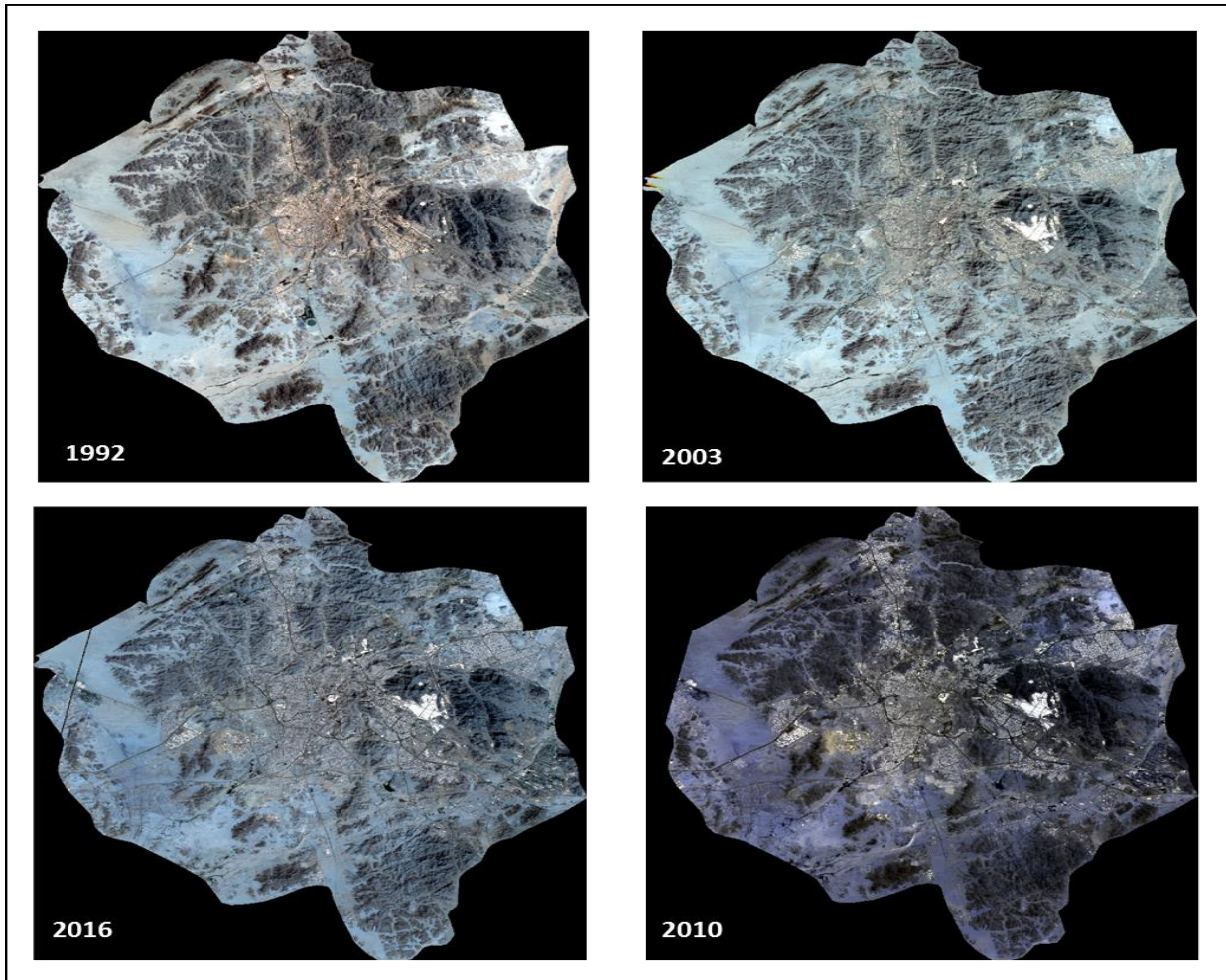
Figure 2: Landsat imagery used in the study after cutting around the studied area of Makkah Al Mukarramah

Source: 1992-2003-2010 imagery were obtained from the United States Geological Survey (USGS) website. 2010 Landsat imagery were obtained from the Global Land Cover Facility website.

- **Supervised Classification of Imagery**:

    Because the researcher is well-acquainted with the studied area, she used supervised classification of imagery, through taking spectral signatures of the urban population, soil, rocks and plants of the different parts of the image. Supervised classification requires signatures of the reflection coefficient in certain areas of the imagery, to use it in representing the categories of classification. The classification aims to divide the imagery into a number of categories or classifications. The study categorized the land cover of the studied area to the following covers: urban use, soil, mountains and cliffs and plants.

- **Data Analysis:**

    After the data processing and satellite imagery analysis stage, all results were input in Arc GIS V.10.3 software. Then data was converted from "raster" to "vector", in order to work on the GIS software to calculate area and finalize the digital maps.

Discussion and Analysis:

Because the present is an extension of the past, the study surveyed and monitored the change that took place in the land cover of Makkah Al Mukarramah in the period spanning 1992-2016, studying the patterns of land use and factors influencing it in the Holy Capital. Through the supervised classification of satellite imagery, the study reached the following results:

✓ Through comparing the classification of satellite imagery of the studied area for 1992, 2003, 2010 and 2016, a qualitative and quantitative change was detected of land use in that period spanning approximately a quarter of a century. We contend that the change was limited to a rise in a certain use of land, such as the transformation of some green or mountain areas into concrete structures and roads. Change also occurred in terms of a decrease, like empty lands transformed into roads, buildings or asphalt parking lots. Makkah Al Mukarramah went through many changes, which resulted in changes in land use throughout the past 24 years. Through tracing the most prominent changes on the land use of the map of the Holy City, we notice the following:

- A steady rise in urban use[7] in the Holy City, which is primarily related to the rise in city population year after year. This is the result of the population growth, internal migration and international migration to the city (Figure 3-4, Table 2). The population of the city used to be 965,697 inhabitants, occupying 12% of the city area in 1992. Their number rose to 1,292,638 inhabitants in 2004, as urban use covered 15,32% of the city area. Such use rose to 19,45% in 2010, then to 22,13% in 2016.

We argue that Makkah Al Mukarramah witnessed an urban growth across history, which greatly rose with the beginning of the Saudi era and the flow of petroleum revenues with their broad influences on economic and social activities and the residential and demographic structure of the city. The city expanded, urbanism boomed, neighborhoods flourished and the composition and structure of the city changed. Migration to the city rose remarkably and it became a commercial and cultural hub, beside its religious status. The city was transformed from a small metropolitan area into a sprawling millionaire city, with multiple functions and activities. 1391 A.H. is considered the real beginning of adopting the scientific and schematic method in developing the city. In that period, bylaws and systems of planning urbanity in the city, through establishing municipalities and secretariats with their different institutions responsible for managing construction and urbanism. Security, stability, and expansions of Al-Haram Al- Sharif[8] had a great impact on the development and growth of the city, especially with the introduction of means of transportation in 1927. Roads expanded and residents started to inhabit external areas, so the city sprawled, witnessing great urban leaps that restructured its urban

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[7] Urban use includes residential and commercial uses, services (religious, educational, administrative, health, entertainment, security), roads, malls and industrial facilities.
[8] Expansions started in 1955 (1375 A. H.) and went on for 20 years, in consecutive phases.
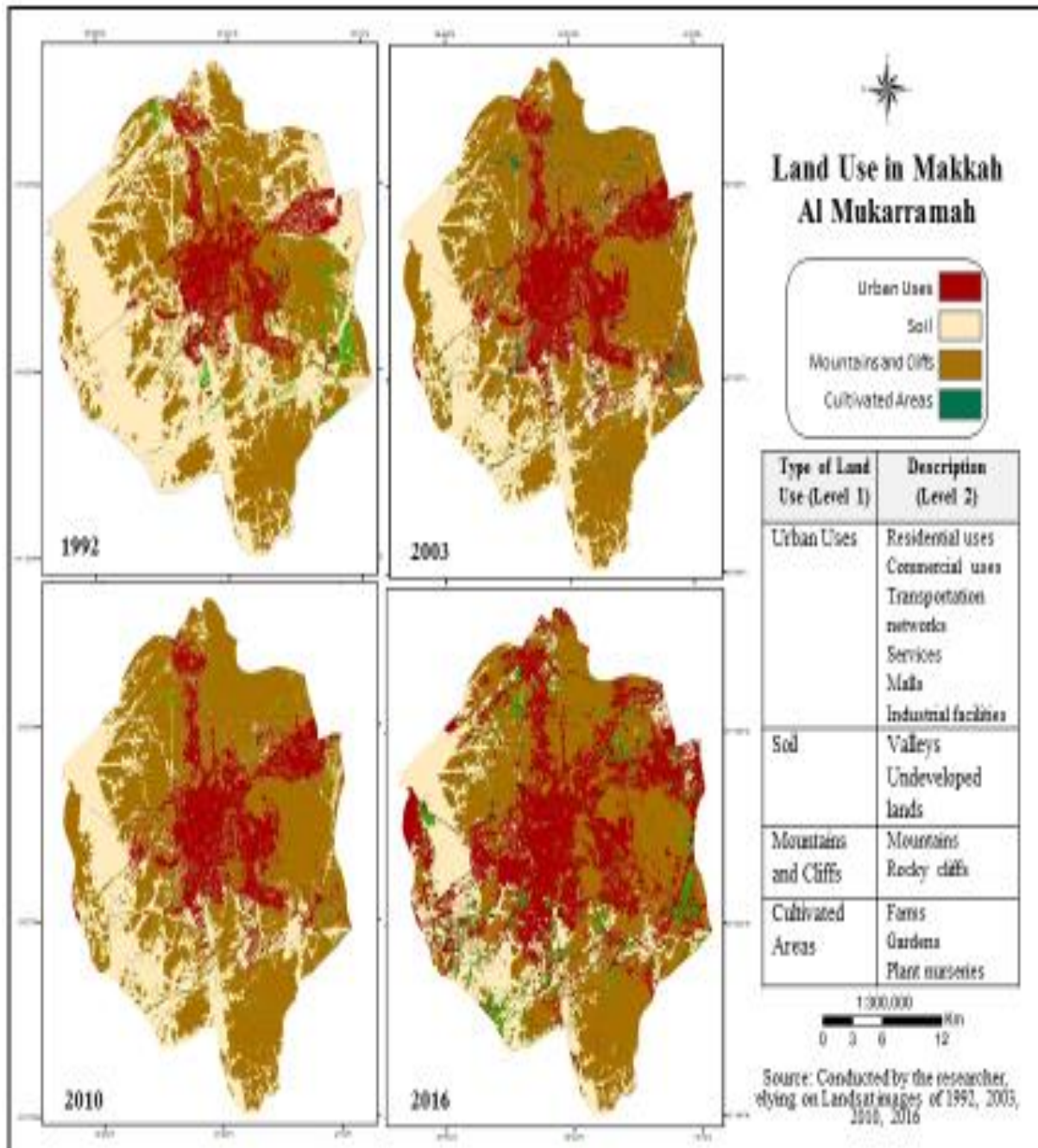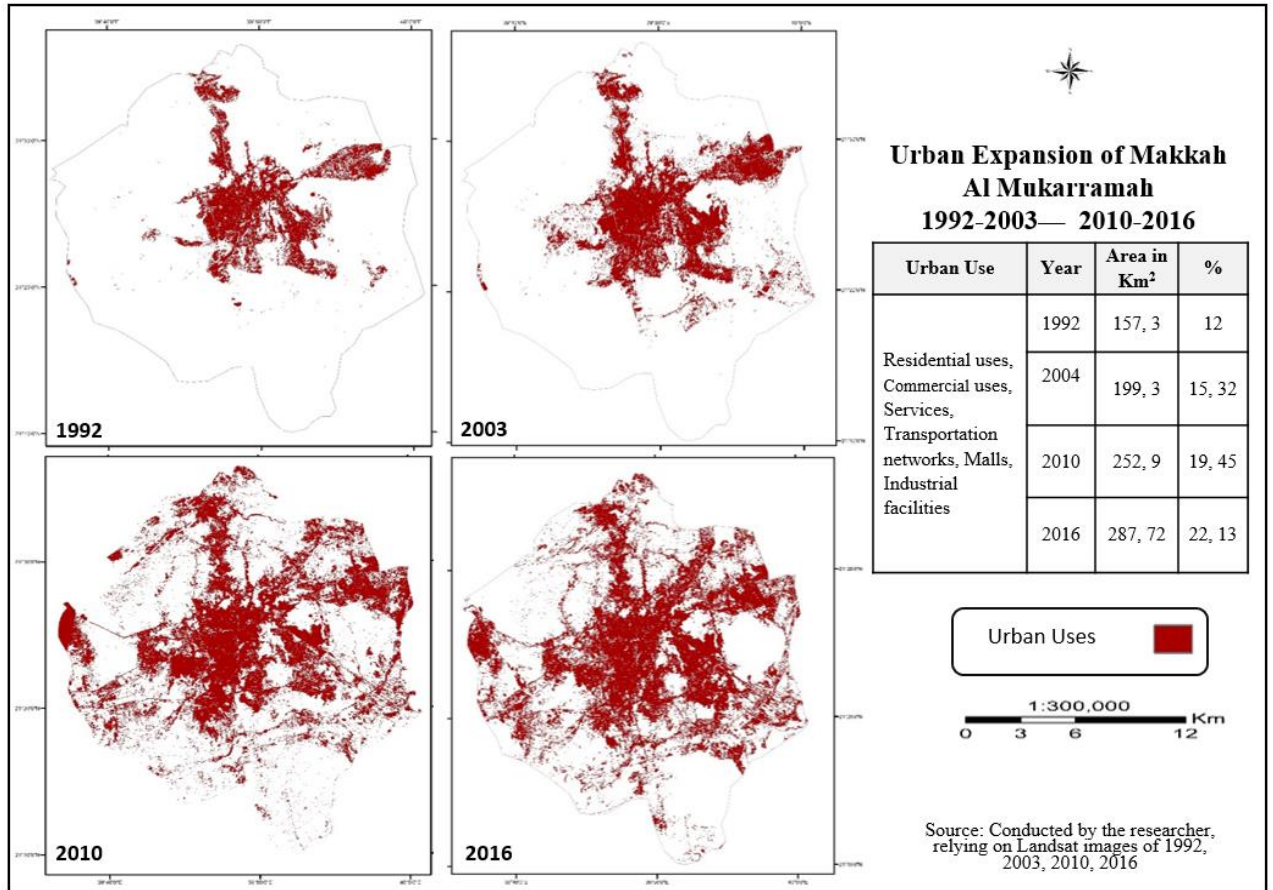
Figure 3: Land Use in Makkah Al Mukarramah

Figure 4: Changes of Urban Land Use in Makkah Al Mukarramah

Table 2: Land Cover Area (km²) for 1992/2003/2010/2016

Year	Land Cover Area (km²)									
	Urban Use		Soil		Mountains and Cliffs		Green Areas		Total	
	Area	%	Area	%	Area	%	Area	%	Area	%
1992	157.3	12	555.93	42.77	537.3	41.4	49.85	3.83	1300.2	100
2003	199.3	15.32	532.9	40.90	536.62	41.28	31.38	2.5	1300.2	100
2010	252.9	19.45	472.6	36.35	535.20	41.17	39.50	3.03	1300.2	100
2016	287.72	22.13	460.14	35.36	510.12	39.24	42.22	3.27	1300.2	100

Source: Conducted by the researched, relying on Landsat imagery 1992, 2010, 2003, 2016

morphology. This resulted in a complete transformation of its urban features[9]. These changes were classified to four phases, as follows:

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[9] The urban growth of the city began with a phase of the striped extensions outside the urban block, followed by the phenomena of growth leap in almost all parts of the city, and final phase was the stage of filling and completion of the spaces in between.

The First Period: 1391 – 1401 A.H. (1971 – 1981)

This was the period of economic prosperity. Number of pilgrims travelling to Makkah increased to 2.5 million pilgrims. This influenced the movement of urbanization in the city, as the number of residents doubled[10]. The most significant feature of this period was the growth and expansion directions towards the East and North. With respect to the urban design, the grid pattern was dominant during that time and replaced the traditional compact pattern. This period also witnessed a change in urbanization plan and a trend of new high buildings, as in Ajyad district (See Figure 5).

The Second Period, 1401 – 1411 A.H. (1981 – 1991 A.D.)

witnessed the largest expansion of the Holy Mosque of Makkah in history. Massive demolition of buildings in the central area resulted in a real-estate market boom, especially on the main roads linking Makkah to other cities in the Kingdom. The tunnels constructed helped facilitate the traffic among different districts of the city. This situation led to the prevalence of irregular and distant urban patterns, which were different compared to the pattern adopted around the Holy Mosque.

The Third Period, 1411 – 1421 A.H. (1991 – 2001 A.D.),

Makkah entered a stage of urban balance where the quantitative urban prosperity reached an end and the qualitative approach to improve the urban environment was adopted. Areas of urban growth at that period were almost in a state of completion and conclusion of urban growth extensions from previous periods. This was the rule with exception for new trends for growth in western, south-western, southern and south-eastern areas. In these areas, new districts were planned in south-west of Makkah (Al-Khalidiyah) and in the south (Batha Quraysh). This urban growth included extensions around Makkah-Jeddah highway and Al-Laith road. It also extended to the north to reach the urban extensions south to the third ring road (Al-Subhani, Al-Misfalah and Al-

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In this phase, new neighborhoods such as Al-Rusaifah and Al-Hijra emerged. The planned neighborhoods of [10] the southeast part of the city appeared outside the traditional boundaries of Makkah, especially after the construction of the tunnels that ended the natural barriers between the Haram and Al-Masha'ir areas. In result, this growth of the residential areas around the University of Umm al-Qura's area formed one of the fastest growth factors in the region. In addition, new trends of urban growth have begun to emerge eastwards (Al-Shara'i') and towards the north, especially with the city's routes (Al-Tanim scheme and the industrial zone) and Al-Sail (Al-Ghassalah and Jabal al-Nour). Furthermore, the city were extended south along Ajyad Street /Jabal Thur until it met with Kudy Street (Rawabi Ajyad and Pilgrims' Parking Lot) and continued to grow east to Al-Badr scheme .and Muzdalifah Street
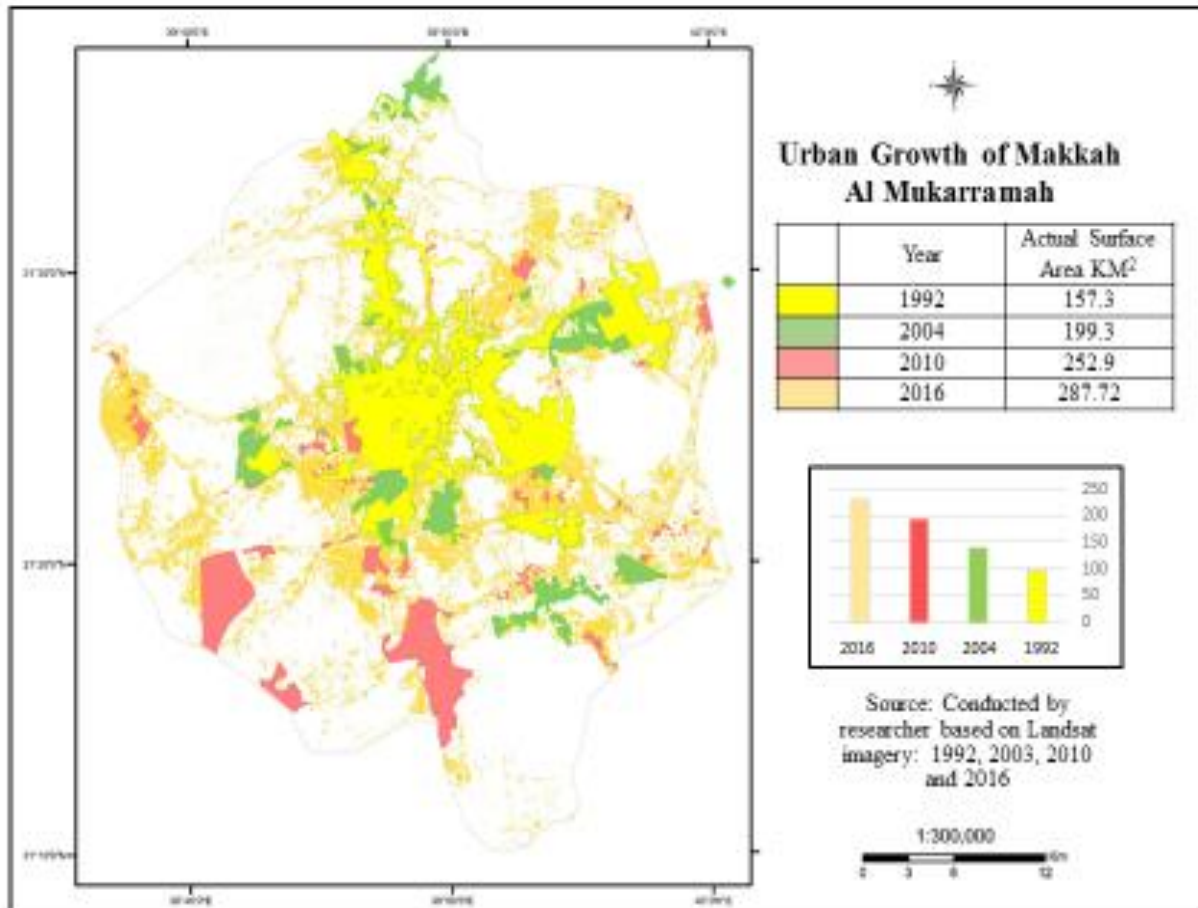
Figure 5: Periods of Urban Growth of Makkah Al Mukarramah

Source: Conducted by the researcher based on Landsat imagery: 1992, 2003, 2010 and 2016.

Muhammadiyah),in addition to (north-south) strip growth linking these extensions to the strip extension around Jeddah highway. In this period, there was the completion of urbanization of many districts including Al-'Awali, Al-Shara'i, Al-Misfalah and Al-Nawariya, which were constructed in the previous period. The urban design for this period was not different from the previous one except for the domination of housing communities in areas planned for residential use. The **Fourth Period**,1421−1437 A.H. 2001−2016 A.D.),is considered an extension of the third period. The fourth period witnessed the completion of urban growth extension from the previous periods, except for the growth in western and south-western areas, where there were the housing communities in Wali Al-Ahd,Al-Takhassusi and Al-Rabia districts.The city also witnessed launching many large-scale development projects which led to demolition of approximately 26,000 building by the end of 2016. This is expected to result in rarefaction of too many old districts in the city (Al-Riyadh Newspaper, 1436 A.H.) In turn, this made urbanization of the city an ongoing process: continuous demolition and building processes to pave the way for development and renewal.

- The location of Makkah and its religious importance had an impact on the city's population; the population growth was influenced by natural increase and migration.[11] Studying the rise of the Makkah population (Table 3) and comparing three population censuses in 1992, 2004 and 2010 A.D, we observe a rise. In 2004 A.D., there is an increase in population of 33% in a period of 12 years (1992 − 2004 A.D.), while in 2010 A.D., the population increase was 73%. This gradual decrease of population growth in Makkah reached 4.8% in 1992, 3.5% in 2000 and then 2.5% in 2010. It is expected that this population growth gradual decrease will continue to reach 2% in 2050. These decreases are reasonable in light of social development of the population, Saudization of workforce and, in turn, the decrease in migration to the city.

Table (3) Makkah Al Mukarramah Population and Future Population Growth Rates

Year (A.D.)	Population	Annual Increase (%)	Growth Rate (%)
1971	301,000	/	/
1974	369,395	7.57	
1983	566,460	5.93	4.86[1]
1992	965,697	7.83	5.48[1]
2000	1,275,000	4.00	3.53[1]
2004	1,292,638	0.35	2.55[1]
2010	1,534,731	3.12	0.044[2]
2016	1,819,776	3.10	0.029[2]
2020	2,345,000	7.22	2.70[2]
2030	3,012,500	2.89	2.50[2]
2040	3,780,000	2.55	2.30[2]
2050	4,629,495	2.25	2[2]

Source: Extracted from the Final Report of Structural Planning 1999 A.D., Makkah Region Development Authority. Population of 1971 was extracted from estimates by Robert Mathew Co and the annual increase was calculated by the researcher. Sources for growth rates are as follows:

1– Updated Structural Planning for Makkah1450, Vol.1: Current Situation and Updated Information

2– Estimates by the researcher.

- Through close investigation of the urban pattern and expansion in Makkah for the 1992/ 2016 A.D. imagery, it is observed that most urban uses in the city, especially residential and commercial purposes, were focused around the Holy Mosque and neighboring districts. The effect of

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[11] Due to sanctity of Makkah and benefits for residents in there, large numbers of Muslims decided to stay and live there, either for religious reasons; living near the Holy Mosque and devotion to worshipping, or for some other purposes as religious education or trade especially in seasons of pilgrimage and minor pilgrimage.

topographic terrain features[12] in the form of urban expansion is significant. Such urban expansion extended through narrow valleys and towards the outskirts over major corridors[13] as follows:

1. Northern-eastern corridor on as Sayl – Al Ta'if road, in districts of Al-Shara'i', Shara'i Al-Mujahidin, Al-Usaylah, Al-Rashidiya and Al-Khadra' (Illustration no. 6)

2. Northern corridor on the sides of the road to Al-Madina Al-Munawara, in districts of Wadi Al-Jalil, Al-Tan'eem, Al-Nawariya and Al-Umra.

3. Southern-western corridor on the sides of Al-Laith road in districts of Al-Shawqia, Al-Ka'kiya and Wali Al-Ahd.

4. Southern-eastern corridor on the sides of Al-Ta'if road in districts of Al-Azizia, Al-'Awali and Al-Husseiniya.

5. Western corridor on the road to Jeddah towards Al-Hamra' area, Umm Al-Jud, King Fahd Housing and Al-Salamah.

Further investigation of 2010 imagery shows that the urban expansion in this period was a process to complete the urban growth extensions from previous periods in districts in south of the City (Al-'Awali and Al-Husseiniya), east of the City (Al-Shara'i', Al-Rashidiya, Al-Usaylah and Al-Khadra'), north of the City (Al-Nawariya, Al-Umra and Al-Salamah). The growth also included districts in south-west of the City (Wali Al-Ahd, Al-Khalidiyah, Al-Shawqia and Al-Rabia), west of the City (Al-Takhassusi, Al-Hamra' and Umm Al-Jud) and south of the City (Al-Subhani, Al-Misfalah and Al-Muhammadiyah).

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[12] Mountains were natural obstacles before the urban expansion in Makkah. Some of the mountains close to the Holy Mosque were removed and some other piedmonts were used for housing purposes. However, there are still some mountains which form huge spaces without urbanization inside urban design of the city; for example, Mount Thubair, Mount Al–Tariqy, Mount Al–Ahdab, Mount Khandamah, Mount Thawr and Mount Al–Nour.

[13] On the other hand, roads and tunnels played a very crucial role in urban expansion and extension to areas distant from the Holy Mosque. They facilitated connecting the city distant areas especially after construction of the ring roads; three ring roads are already constructed (the 1st, 2nd and 3rd ring roads) while the 4th and 5th are still under construction.
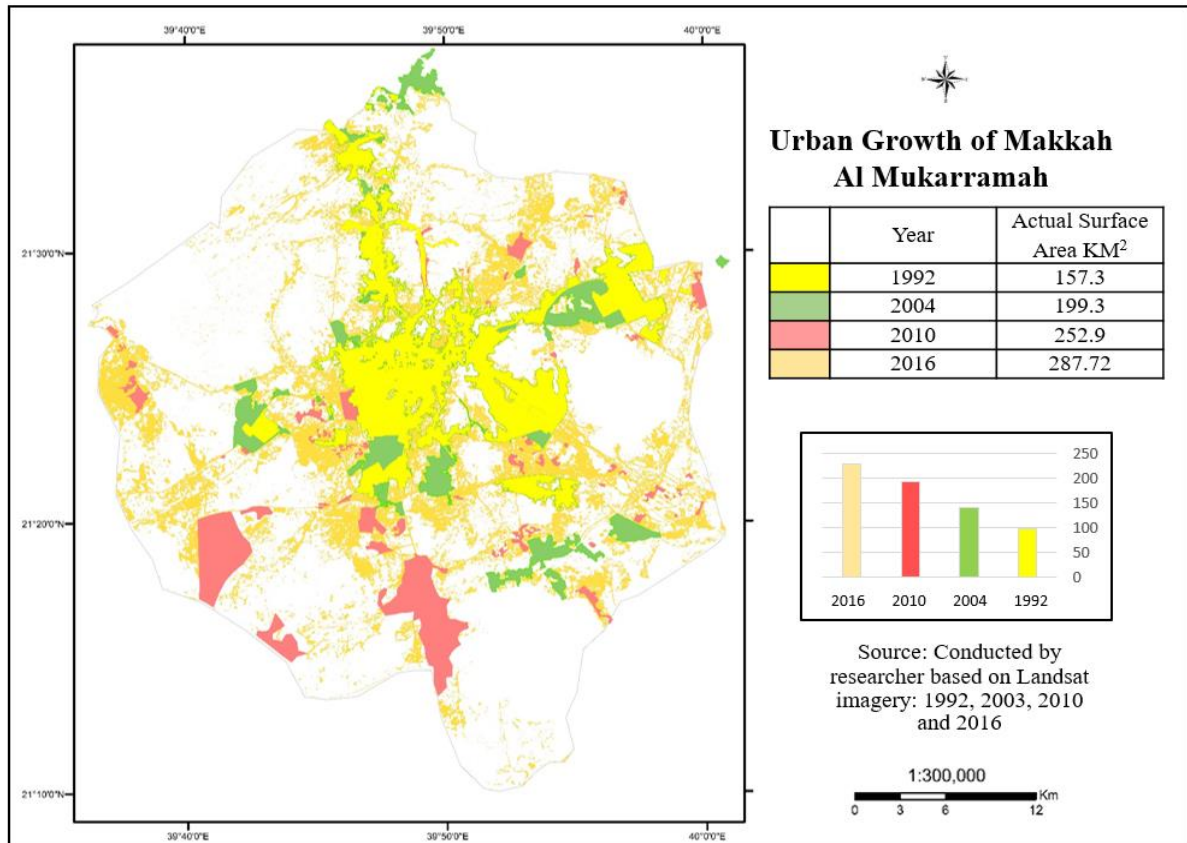
Figure 6: Urban expansion in Makkah Al Mukarramah (1992 – 2016)

In the last years, Holy City witnessed launching many huge development projects. It was necessary for this development to have removal, land clearing and reclamation of some mountain areas in some of the important areas in the Holy City. The result was expansion of the City urban scope (see Illustration no. 7) Demolition of thousands of land properties was caused by projects as "King Abdullah bin Abdul Aziz's Expansion of the Holy Mosque," development of ancient slum areas and completing the ring roads around the City. Thus, there appeared a rapid building and construction movement to occupy many undeveloped lands with housing communities at outskirts of the City.

1. Up to 1992, undeveloped lands and valley streams represented 42.7% of the City area. This percent gradually decreased to 35.36% due to urban use of lands and urban expansion towards the City outskirts, especially the lands located on the sides of regional transport and ring roads.

2. The mountain covers the largest space of the City area (41%). This space was decreased to 39.2% of the City area in 2016. This was due to the sequence of development projects in the Holy City (see Illustration no. 7). For this purpose, it was required to have process of removal, land clearing and reclamation of some mountain areas in some important locations in the Holy City.

3. The green space in the City was not the same all the time. It was different from some imagery to the other. In 1992 A.D., the green space was 3.83% while it declined to 2.5% in 2003 A.D., then a slight increase in 2010 and 2016 up to 3.03% and 3.27% respectively. The reason beyond this

instability was that the satellite imageries were taken in different months of the years. Consequently, there was a time gap between periods on rainfall in the area and sensing for imageries.
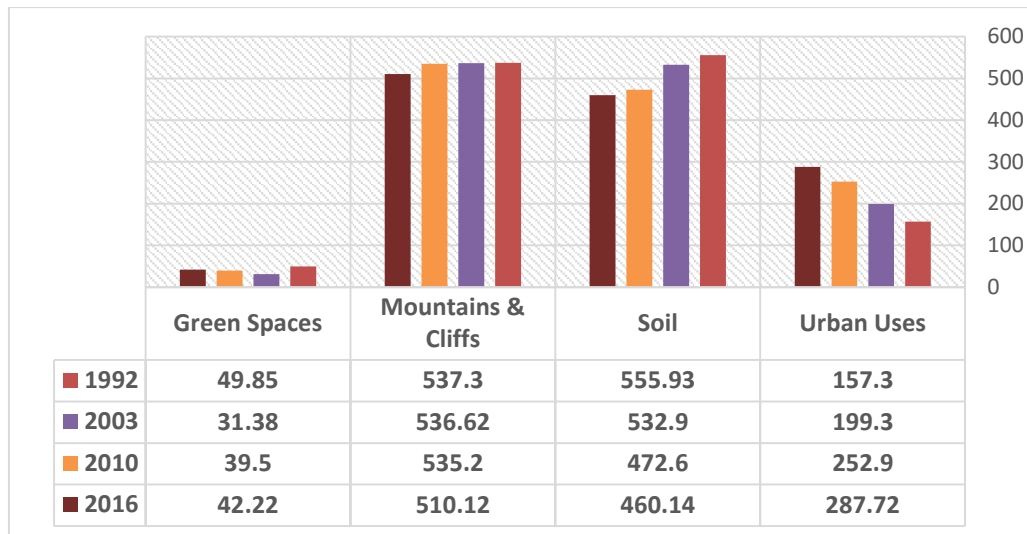

	Green Spaces	Mountains & Cliffs	Soil	Urban Uses
1992	49.85	537.3	555.93	157.3
2003	31.38	536.62	532.9	199.3
2010	39.5	535.2	472.6	252.9
2016	42.22	510.12	460.14	287.72

Figure 7: Change in Land Use in Makkah Al Mukarramah (km^2)

Source: Prepared by the researcher based on data of satellite imageries.

In order to identify the most influential elements on the urban growth of Makkah, the Multiple Regression Analysis (Table 4) was used to study the influence of variables of population growth, the state budget and number of pilgrims (independent variables) on the urban growth of the Holy City (dependent variable). The study shows a strong correlation (0.986) between the dependent variable and independent variables (population growth, the state budget). These independent variables justify 97% of the change with respect to the urban uses in Makkah. By checking the significance of the numbers in (Table 5) and by comparing the significance of the regression coefficient at the significance level of 5%, the value of the level of significance (0.00) is less than the level of significance 0.05(P=.00 < .05). This confirms the correlation between increasing the growth of urban uses and population in the city of Mecca and the rise of the state budget (Figure 8). This showed the positive impact of the increase in the state general budget on the breakthrough in the real estate economics and urbanization in the city. In addition, the impact of increase in population and increase the numbers of pilgrimages, that resulted in high demand on housing, which in turn led to a boom in the building and urbanization movement to meet the demands of the City residents and visitors for minor and major pilgrimages (Umra and Hajj). Consequently, the spatial expansion of the Holy City increased and in result, there was a loss of some agricultural and green spaces around the city. The pattern of land use in the City changed then into housing communities and much of the mountain areas were removed and planned as lands for urban uses. It is expected that the urban space of Makkah to be on ongoing expansion in the following years due to the government's aspirations to increase the number of pilgrims visiting the City to achieve the Kingdom's vision for 2030. This vision targets an increase up to 10

million pilgrims a year. This will in turn result in increasing need for more lands for planning and construction for housing of the City residents and visitors to the Holy Mosque.

Table (4) multiple correlation coefficient

Dependent Variable	Independent Variables	Beta Coefficient	Correlation Coefficient	Coefficient of Determination (R^2)	(F) Value	Error Percentage	sig
Area of Urban Lands in Makkah	Population	0.000	0.986	0.971	523.813	0.00	0.00
	State Budget	0.078				0.012	0.00

Source: The table was prepared by the researcher using *SPSS*, version 20.

Table (5) Values of regression coefficients

Dependent Variable(y)	Independent Variables		
	b0	Population b1	State Budget b2
The value	-56.615	0.000	0.078
(T) Value	-6.133	13.388	6.583
Sig	0.000	0.000	0.000

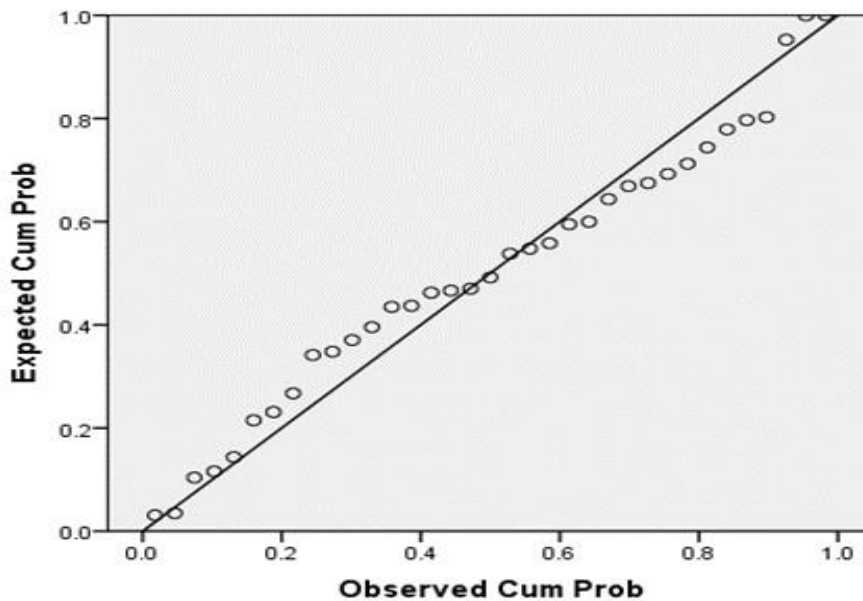Source: The table was prepared by the researcher using *SPSS*, version 20.

Figure 8: Normal p.p Plot of Regression Unstandardized Residual

Source: The table was prepared by the researcher using *SPSS*, version 20

The use of Multiple Regression Analysis in the study was to help predict future change in the dependent variable in light of influence by independent variables (see table 6).

Table 6: Estimates for Expected Urban Lands area in Makkah

Years	Expected Urban Growth Area
2016	287.72
2017	*293.66*
2018	*299.6*
2019	*305.54*
2020	*311.48*
2021	*317.42*
2022	*323.36*
2023	*329.3*
2024	*335.24*
2025	*341.18*

Source: The table was prepared by the researcher using **SPSS** version 20.

This was applied through the Multiple Regression Equation[14] to reach estimates of expected urban uses for Makkah in the following years . The area of urban lands is estimated to be 311.48 km^2 in 2020 A.D. and 341.18 km^2 in 2025 A.D. This is a great indicator for the decision-makers to consider the importance of planning to determine the trends for urban expansion and scheduling planning and preparation of these areas for housing of the city residents. Such areas have to be then supplied with (security, educational, health, entertainment, commercial, social and religious) services and necessary facilities of (highways, water supply networks, sanitation, sewerage, electricity and spillways).

In light of these results, the researcher drafted some recommendations, which could help make the best possible use of the study findings:

- The importance of using GIS and remote sensing to support and improve the decision-making process in municipalities and governmental bodies. This could be achieved through providing technologies appropriate for processing new data in terms of planning in a rapid and efficient manner.

- Necessity of providing updated, statistical, economic, social and demographic information about Makkah, as well as high-resolution satellite imageries for researchers to monitor the change in the land covers studied.

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[14] Multiple Regression Linear Equation $(Y) = (-56.615) + X_1(0.000) + X2(0.078) + 0.012$.

- Due to the deterioration of green spaces in the city, the study recommends that officials in charge of planning have to define some areas as vacant lands to be used for growing plants appropriate for the natural environmental circumstances of Makkah. It should be then prohibited to construct any buildings in these spaces, since they should act as a recreational park for residents of Makkah.

- Importance of conducting scientific studies in relation to planning and prediction of changes in land covers and uses of lands in Makkah Al Mukarramah.

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الملخص :

تسعى الدراسة إلى رصد وتسجيل تغير الغطاء الأرضي والتغيرات الحضرية في مدينة مكة المكرمة خلال الفترة بين عامي 1992-2016م ، ولتحقيق ذلك اعتمدت الدراسة على المنهج الاستقرائي لرصد التغيرات العمرانية والسكانية واستخدامات الارض من خلال المخططات الهيكلية لمدينة مكة المكرمة والتقارير الحكومية الصادرة عن أمانة العاصمة المقدسة والهيئة العليا لتطوير مكة المكرمة والأبحاث العلمية . كما اعتمدت الدراسة على منهج التحليل المكاني لاستخلاص البيانات الرقمية من صور الأقمار الصناعية لرصد التغير الزمني للغطاءات الأرضية بمكة المكرمة وقد تمت معالجة البيانات الرقمية ، ورسم المخرجات النهائية، باستخدام برنامجي ARC GIS V.10.3 ، وبرنامج ERDAS IMAGINE V.14

لقد خلصت الدراسة إلى أن معظم الاستخدامات الحضرية في المدينة خصوصاً الاستخدام السكني والتجاري تركز حول الحرم الشريف وفي الأحياء المتاخمة له ، مع وضوح تأثير التضاريس الجبلية على شكل الإنتشار الحضري الذي إمتد إشعاعياً عبر الأودية الضيقة باتجاه أطراف المدينة المنبسطة . أيضاً أظهرت الدراسة تغير نسب الغطاءات الأرضية بالمدينة خلال فترة الدراسة ، فقد زادت نسبة الاستخدام الحضري[15] للأرض في المدينة من 12% من مساحتها عام 1992م إلى 22.13% عام 2016م . بينما نقصت نسبة مساحة الأراضي البيضاء من 42.7% من مساحة المدينة عام 1992م ، إلى 35.36% عام2016م ، ويرجع ذلك لتزايد الاستخدام الحضري للأرض وزحف العمران تجاه المناطق المنبسطة في أطراف المدينة ، خصوصاً الأراضي الواقعة على جانبي طرق المواصلات الإقليمية والدائرية . أما المناطق الجبلية والتي كانت تغطي ما نسبته 41% من مساحة المدينة فقد تقلصت مساحتها إلى 39.2% عام 2016م بسبب مشاريع التطوير التي استلزمت ازالة وتسوية بعض المناطق الجبلية في بعض المواقع الهامة بالمدينة المقدسة . في حين تذبذبت نسبة مساحة المناطق الخضراء بالمدينة من مرئية لأخرى ، فقد بلغت نسبة المناطق الخضراء بالمدينة 3.83% عام 1992م ، بينما انخفضت النسبة إلى (3.27%) عام 2016م ويرجع سبب هذا التذبذب الى تباين شهور السنة التي التقطت فيها المرئيات الفضائية . ويأمل الباحثان أن تلقي هذه الدراسة الضوء على أهمية توظيف تقيني نظم المعلومات الجغرافية والإستشعار في عمل دراسات لاحقة تعنى بالتخطيط والتنبؤ بتغيرات الغطاء الأرضي واستخدامات الأرض في مدينة مكة المكرمة .

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15 - تشمل الإستخدامات الحضرية : الاستخدامات السكنية ، التجارية ، الخدمات (الدينية ، التعليمية ، الإدارية ، الصحية ، الترفيهية ، الأمنية) الطرق ، المجمعات التجارية والمرافق الصناعية .