



Scientia Research Library

ISSN 2348-0424
USA CODEN: JETRB4

Journal of Engineering And Technology Research,
2022, 10 (2):1-14

<http://www.scientiaresearchlibrary.com/archive.php>

Implementation of GIS & Remote sensing to support urban development analysis Case study : Makkah city, KSA

Hesham Bagnied^{1*}, Tarek A. El-Damaty²

¹Department of Civil Engineering, Faculty of Engineering and Islamic Architecture, Umm Al-Qura University, Makkah, Saudi Arabia

²Department of Civil Engineering, Faculty of Engineering and Islamic Architecture, Umm Al-Qura University, Makkah, Saudi Arabia

Email: *heshamaab@yahoo.com tdamaty@hotmail.com

ABSTRACT

Makkah city has experienced substantial urban growth over the last few decades, transforming from rural to urban communities due to rapid economic growth. The purpose of this study is to monitor and analysis the Population growth, Urban expansion, Topography and land use classification of Makkah city for last 20 years, from 2000 to 2020. 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. Makkah city is located in the west of the Kingdom of Saudi Arabia, about 400 km from Medina in the southwest direction, and about 75 km from the city of Taif in the eastern direction, and 72 km from the city of Jeddah and the Red Sea coast and the closest ports to it is the Jeddah Islamic Port, and the nearest Airports Its international airport is King Abdul-Aziz International Airport. 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. The Data used in this study are census data from 2000 to 2020, as well as Landsat data for the years of 2000, 2010 and 2020 along with Remote Sensing (RS) and Geographic Information System (GIS) techniques. Digital data, along with the final output map compositions, have been processed through mapping software: ArcGIS v10.3 and ERDAS IMAGINE v14. The results in this paper smart growth rate in Makkah city by (2.453%) in 2020 and (2%) in 2010, which guarantees development for future land use/land cover planning in Makkah City. In 2000 the population was 1,294,000 and in 2010 increased to 1,578,722 by overall rate of increase by (22%) then in 2020 jumps to 2,017,793 by (27.81%) that means the population have increased almost the double from 2000 to 2020. The Area of Makkah city have increased in 2020 to 465 km² compare to 2010 was 388 km² & in 2000 was 366 km². This is due to the increase of number of districts in Makkah city from 60 in 2010 to 101 in 2020 by rate of increase about (68.3 %) from the number of districts. The researcher uses a map scale of 1:300,000 and the items to classify was Mountains (blue), urban (green), desert (red) and roads (black). The conclusion was as

we expected the mountains and deserts have decreased and the urban & roads have increased this because of the increase of population during the 20 years.

Keywords: Satellite imagery, Urban analysis, Land Use classification , Topography map, Population Growth, Makkah city.

INTRODUCTION

The Holy City of Makkah is the administrative capital of Makkah Region, and the spiritual center for more than one-fifth of the global population who shares the aspiration to come to Makkah to complete the Hajj journey. The city is located at 277 meters above sea level, lying in a valley region within a mountainous corridor on the Western slopes of the Sarawat Mountains. Makkah's geographic location and topographic characters played a strong role in shaping the city's urbanization, as the surrounding mountains historically constrained development growth, and concentrated it around the Haram area. Most recently, development has extended across the mountains, due to increasing population levels, and made access to it possible through the improved road networks and modern methods of transportation. Equally impactful as a driver of growth over the years, Makkah has experienced a massive increase in the number of pilgrims performing Hajj and Umrah. The smart growth rate in Makkah city in 2010 was (2%) and in 2020 is (2.453%) and is expected to jump by 2030 to (3.2%) which guarantees development for future land use/land cover planning in Makkah City. Intense growth took place to the Southeast, South, and Southwest of the city along newly enhanced major roads. This signaled a shift in the development patterns, as well as substantial changes in building typologies and urban form, due

to the development of high-rise buildings, dedicated to housing pilgrims around the Haram and elsewhere across the city. A series of neighborhood renewal operations also began to take place in the areas surrounding the Haram, as older buildings were demolished and replaced with newer and taller buildings [1]. Makkah city In 2000 the population was 1,294,000 and in 2010 increased to 1,578,722 by overall rate of increase by (22%) then in 2020 jumps to 2,017,793 by (27.81%) and in 2030 is expected to be 3,038,873. That means the population have increased almost the double from 2000 to 2020. The main objectives of this study are: a) study urban expansion of Makkah city in the last 20 years, b) study the topography on urban analysis, and c) study the Land use classification in this period [2]

STUDY AREA

Makkah city is located in the west of the Kingdom of Saudi Arabia, about 400 km from Medina in the southwest direction, and about 75 km from the city of Taif in the eastern direction, and 72 km from the city of Jeddah and the Red Sea coast, and the closest ports to it is the Jeddah Islamic Port, and the nearest Airports Its international airport is King Abdul-Aziz International Airport [3]. The study area of Mecca is located in the central part of the western region of the Kingdom of Saudi Arabia at an elevation of 277 meters above sea level, and approximately 80 km inland from the Red Sea with geographical coordinates lat (21°15' to 21°37') N and long (39°47' to 39°59') E, as shown in **Figure 1**.

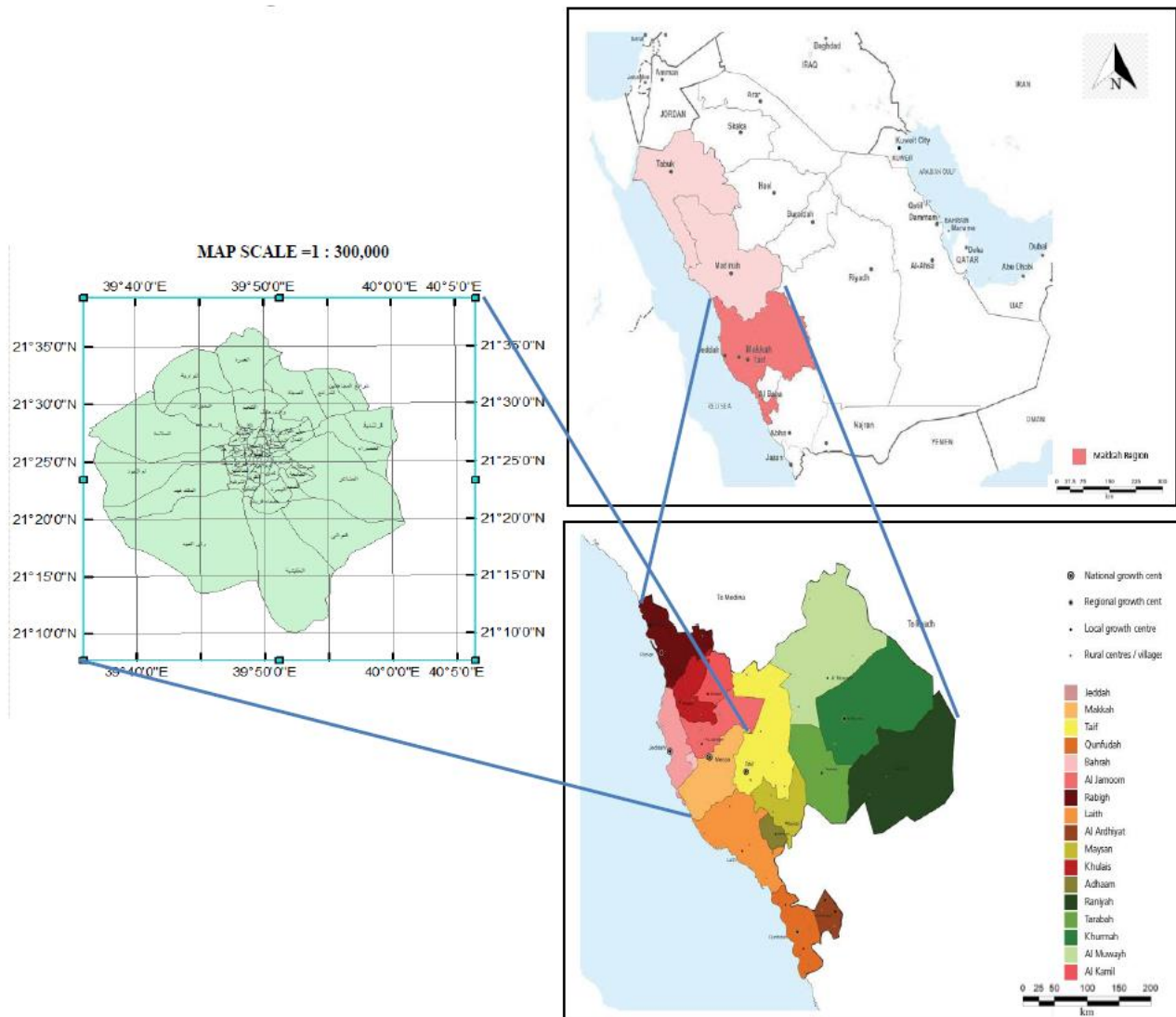


Figure 1: Location of Makkah city, Saudi Arabia.

MATERIALS AND METHODS

Population Data

Population data used in this research according to the population census approved by the General Authority for Statistics & Makkah city profile (Ministry of municipal and rural affairs). The Makkah Region is the most populated region in KSA, hosting more than a quarter of the population of the Kingdom. It has a population of 6,915,006, (according to the 2010 Census). Jeddah Governorate has the most significant share of the total population of the region at 50.3%, followed by Makkah with 24.2%, and by the third largest city, Taif, with 14.1%. The number of Saudi population in the region is estimated to be 4.55 million and 3,340 non-Saudis, which is one of the highest ratios in the Kingdom [1]. The population in Makkah city was 1,294,000 in 2000. In 2010, the population of the city was 1,578,722 people, in 2020 the population reached 2,017,793, the population of Makkah city is expected to reach 3,038,873 people in 2030. Table 1 shows the absolute evolution of Makkah’s city population in the last 20 years.

Table 1. Absolute evolution of Makkah's city population in the last 20 years (General Authority for Statistics).

Year	Population	Growth Rate	Growth
2000	1,294,000	2.48%	28,256
2005	1,325,622	2.95%	38,012
2010	1,578,722	2%	46,139
2015	1,795,849	3.08%	53,702
2020	2,017,793	2.453%	37,218

The Mathematical equations used to determine population calculations in **Table 2:**

$$\text{Difference in population} = [\text{post population} - \text{previous population}] \quad (1)$$

$$\text{Overall rate of increase} = \left[\frac{\text{Difference in population}}{\text{Previous population}} \times 100 \right] \quad (2)$$

$$\text{Ratio of population increase annually} = [A = P \cdot E^{R \cdot T}] \quad (3)$$

Where, A= post population, P= previous population, E= 2.718, R= growth rate, T= duration time

$$\text{The population percentage in proportion to whole KSA (\%)} = \left[\frac{\text{Previous population}}{\text{KSA Population}} \times 100 \right] \quad (4)$$

Table 2. Mathematical equations used to determine population calculations) by researcher





Population calculations of Makkah city, KSA in (2000-2010-2020)						
Date	Population	Population difference	Overall rate of increase (%)	Ratio of population increase annually (%) Growth rate (R)	The population percentage in proportion to whole KSA (%)	KSA population
2000	1,294,000	-	-	-	6.2%	20.85 M
2010	1,578,722	284,722	22%	2%	5.81%	27.14 M

2020	2,017,793	439,071	27.81%	2.453%	5.76%	35.01 M

Urban expansion

Makkah city has experienced substantial urban growth over the last few decades, transforming from rural to urban communities due to rapid economic growth. The researcher used the United States Geological Surveying (USGS) website (www.earthexplorer.usgs.gov). By using features and tools in this website the researcher drew a polygon in different duration years in 2000, 2010 and 2020 around the boundaries of Makkah city .Also, he calculated the area and perimeter using ArcGIS. The results, That the Area of Makkah city have increased in 2020 to 465 km² compare to 2010 was 388 km² & in 2000 was 366 km². This is due to the increase of number of districts in Makkah city from 60 in 2010 to 101 in 2020 by rate of increase about (68.3 %) from the number of districts. **Table 3** describes the area and parameter of Makkah city in 2000, 2010 ,2020 AND 2021. **Figure 2** shows the urban expansion in Makkah city in 2000, 2010, 2020 and 2021.

Table 3 The area and parameter of Makkah city in 2000, 2010 ,2020 and 2021.

DATE	AREA [COMPUTED FROM table attribute GIS]	PRAMITER [COMPUTED FROM table attribute GIS]	N.O OF DISTRICTS [ACCORDING TO RESEARCHERS]	COLOR
2000	366 KM ²	122 KM	-	
2010	388 KM ²	136 KM	60	
2020	465 KM ²	156 KM	101	
2021	477 KM ²	167 KM	110	

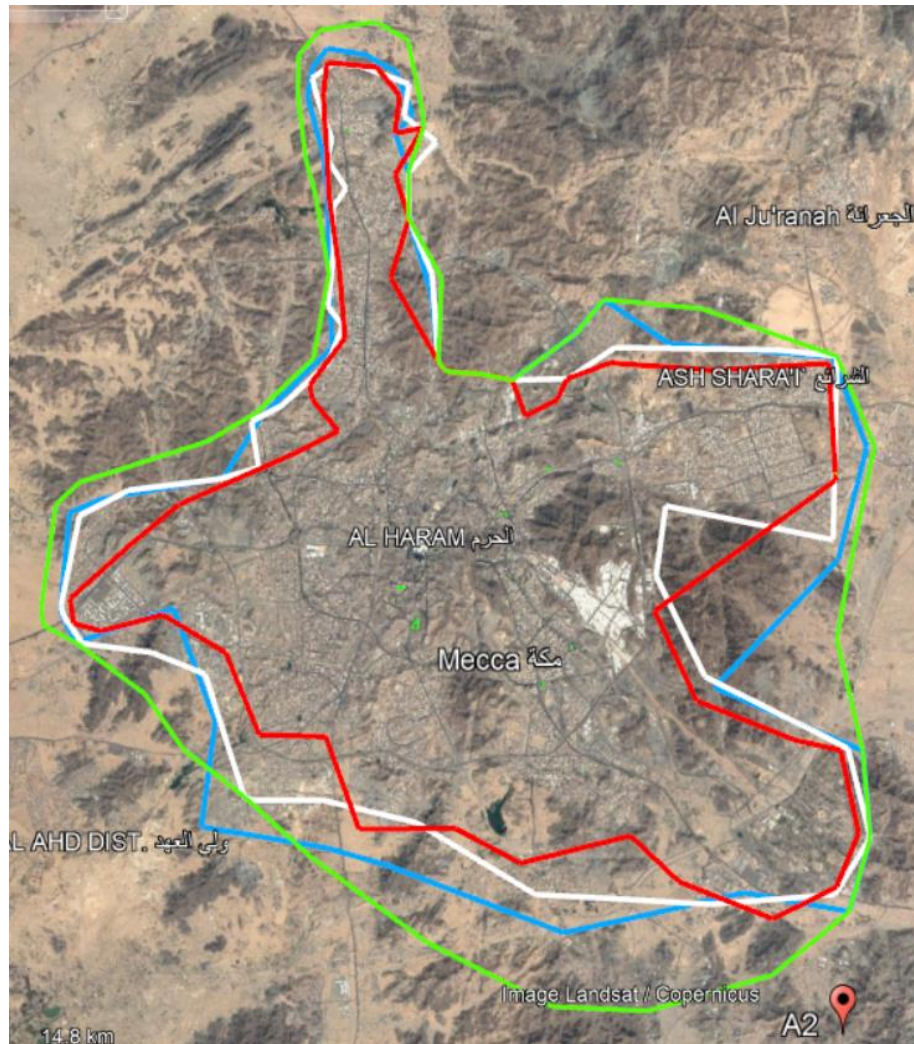
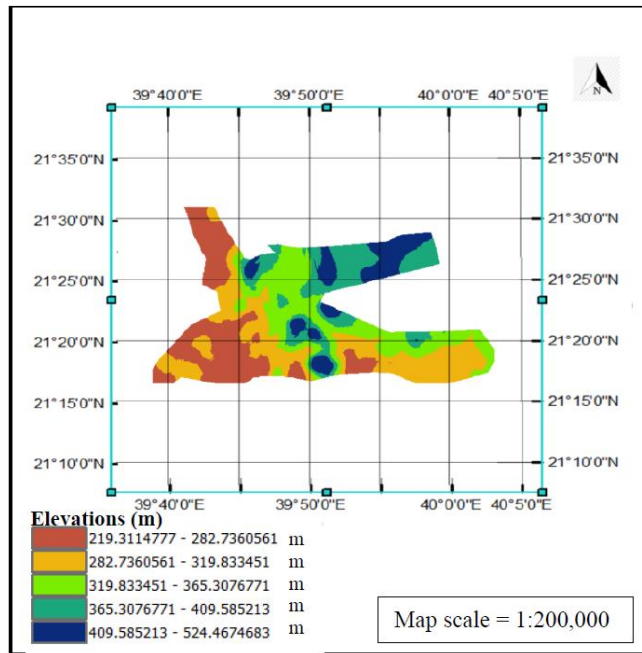


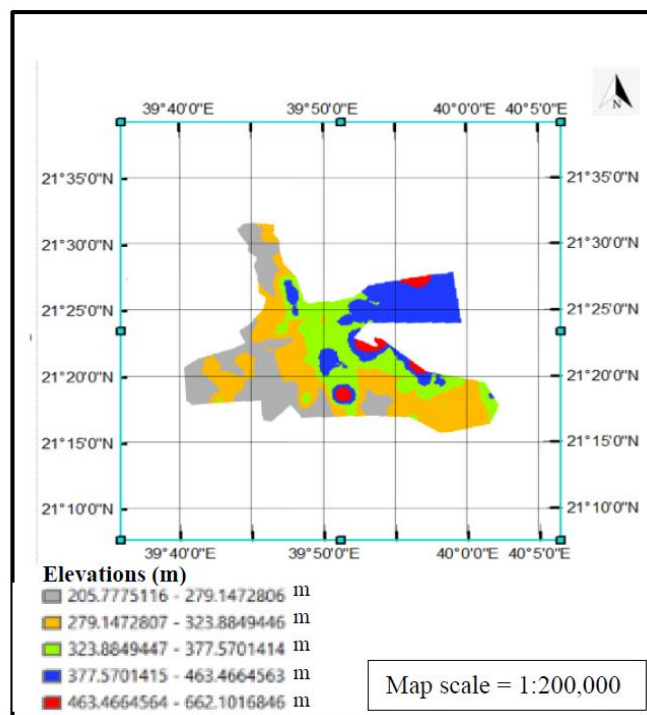
Figure 2 The urban expansion in Makkah city in 2000, 2010, 2020 and 2021.

Topography of Area

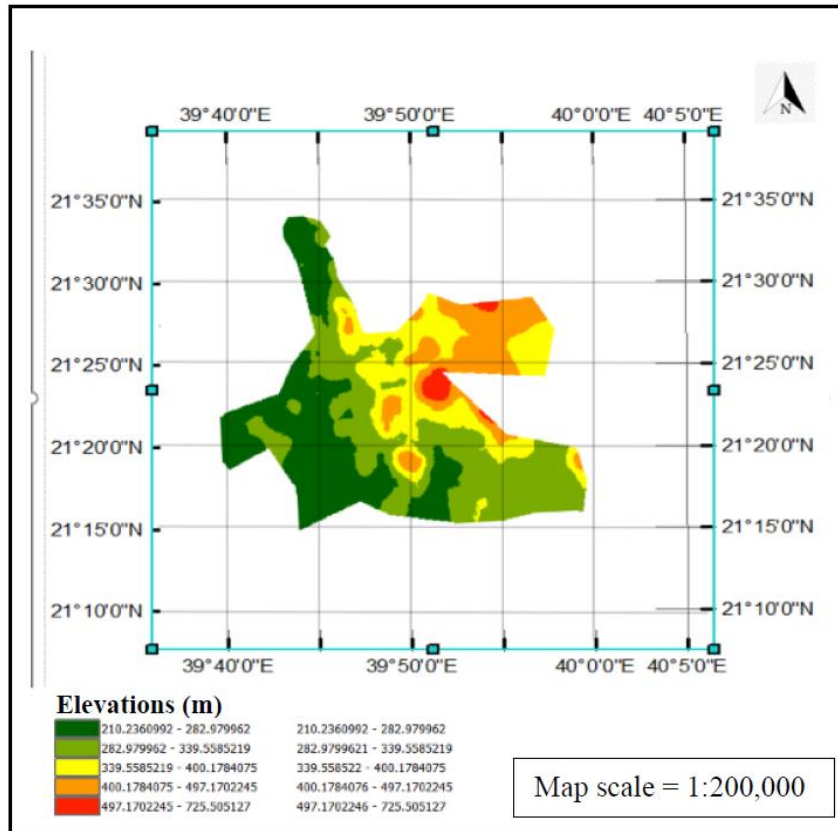
The height of Makkah Al-Mukarramah is between 250 and 350 meters above sea level from west to east, including the holy sites. Makkah Al-Mukarramah is distinguished by its different terrain, where the hills and mountains are scattered from the slopes of the people of Makkah Al-Mukarramah as urban areas for their dwellings **Figure 3** shows Topography of Makkah city in last 20 years. As expected in 2020, the highest elevation was detected, which is 725.5 meters. The highest level was observed in 2010, which is 662.1 meters. In 2000, the highest level was detected, which is 524.46 meters. We note that the year 2020 is the highest level with a difference of 63.4 meters from 2010 and a difference of 200 meters from 2000 and this is the result of the increase in population and construction facilities during this period. See **Table 4**



(A)



(B)



(C)

Figure 3. Topography of Makkah city in (a) 2000, (b) 2010, and (c) 2020

Table 4. Maximum and minimum elevation comparison in 2020, 2010 and 2000.

DATE	MIN. ELEVATION (m)	MAX. ELEVATION (m)	DIFFERENCE	PERCENTAGE Of increment (%)
2000	219.31 m	524.46 m	305.15 m	-
2010	279.14 m	662.1 m	382.96 m	20.31%
2020	210.9 m	725.5 m	514.6 m	25.6%

Analysis

This section attempted to make the methodology to be used to analyze and monitor the land use/land cover dynamics in Makkah City, in KSA in 2000, 2010 and 2020, using the integration of a prediction model with Landsat images and GIS spatial analysis techniques. using ERDAS Imagine 2014 and ArcGIS 10.3. Details of the process are presented in subsequent sections.

Landsat images

Satellite images of Makkah city were downloaded from the United States Geological Surveying (USGS) website (www.earthexplorer.usgs.gov). These images are for different periods of time by Landsat 5, 7, and 8 satellites. Also the researcher uses the google earth pro to help him in land use classification. The resolution of the grid cell size used is 30 m and different sensors of satellite

images TM, ETM+, OLI/TIRS. See Table 5.

Table 5. Landsat images data of Makkah city in 2000, 2010, 2020 and 2021.

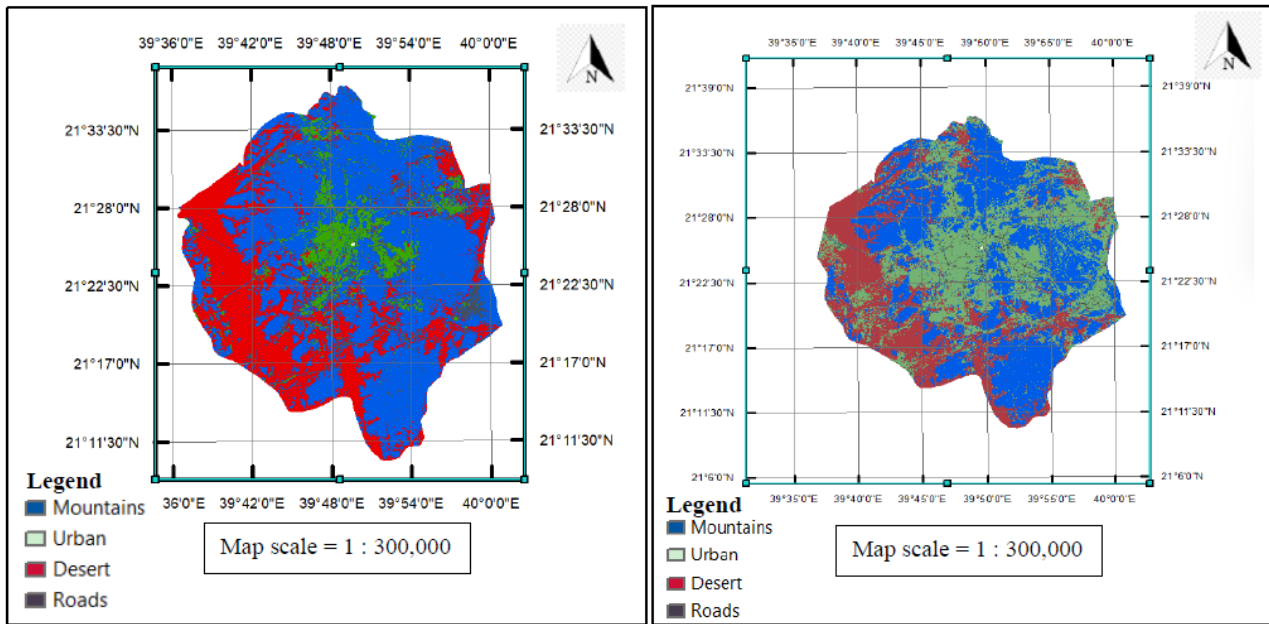
N.O	SATELLITE NAME	ACQUISITION DATA DATE	GRID CELL SIZE	ELLIPSOID	SENSOR IDENTIFIER	REFERENCE
1	LANDSAT-5	(20-2-2000)	[30m]	WGS84	TM	WWW.USGS.GOV
2	LANDSAT-7	(12-12-2010)	[30m]	WGS84	ETM+	WWW.USGS.GOV
3	LANDSAT-8	(28-7-2020)	[30m]	WGS84	OLI/TIRS	WWW.USGS.GOV
4	GOOGLE EARTH PRO V9.14	(11-7-2021)	[15cm-15m]	WGS84	-	WWW.GOOGLE.EARTH.COM

Image processing

After downloading the satellite images they should be processed using Erdas program. Because they are captured and there are many factors affect the image quality such as : wind, dust and sun rays to improve the quality of satellite images such as geometric correction, radiometric correction, enhancement, classification. Many techniques are used to improve it by searching the researcher can use various tools to make the best quality of the Landsat image.

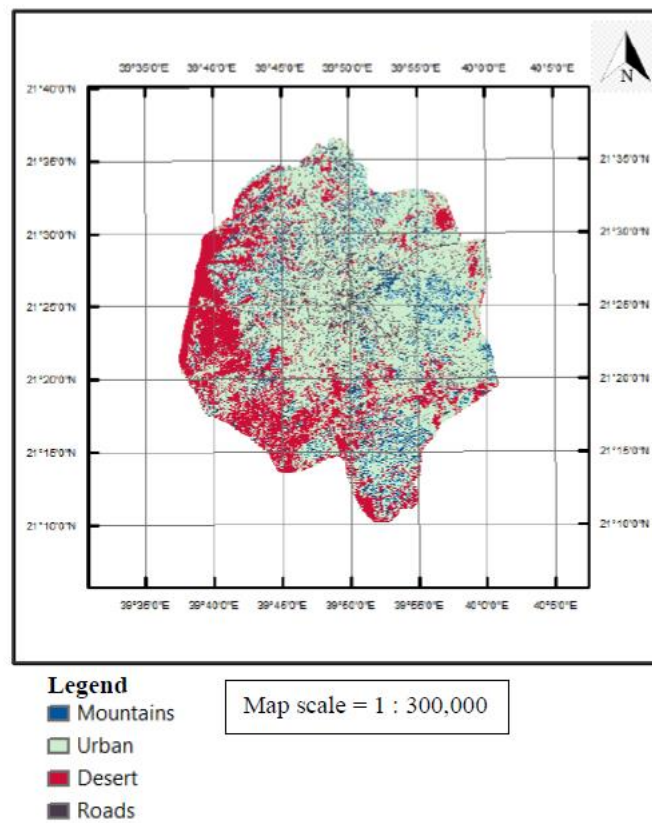
Image classification

The technique used in image classification is the supervised classification. which are used according to several criteria, conditions and use cases. In the process of classification, land use and (LU) were detected. The Landsat images are cropped in the shape file of Makkah to insure the area to be work on it. They were classified into three main categories, namely, The researcher uses a map scale of 1:300,000 and the items to classify was Mountains (blue), urban (green), desert (red) and roads (black). as shown in Figure 4.



(a)

(b)



(c)

Figure 4. Land use classification of Makkah city in (a) 2000, (b) 2010, (c) 2020.

In **Table 6**. The land use scheme is illustrated to classify the land in Makkah city that contains small rocks, mountains and residential, commercial services, transportation communications. Also including white and yellow sand, roads and networks and streets.

Table 6. The land use scheme is illustrated to classify the land in Makkah city.

Land cover class	Discription
Mountains	Mountains, small rocks
Urban	Including residential, commercial services, industrial, transportation communications.
Desert	Including white and yellow sand and dunes
Roads	Including roads and networks and streets

RESULTS AND DISCUSSION

Land use/land cover

Land use classification of Makkah city in 2000, 2010 and 2020. The researcher used Erdas program to classify the land of Makkah. He uses a map scale of 1:300,000 and the items to classify was Mountains (blue), urban (green), desert (red) and roads (black). The conclusion was as we expected the mountains and deserts have decreased and the urban & roads have increased this because of the increase of population during the 20 years. See Figure 5

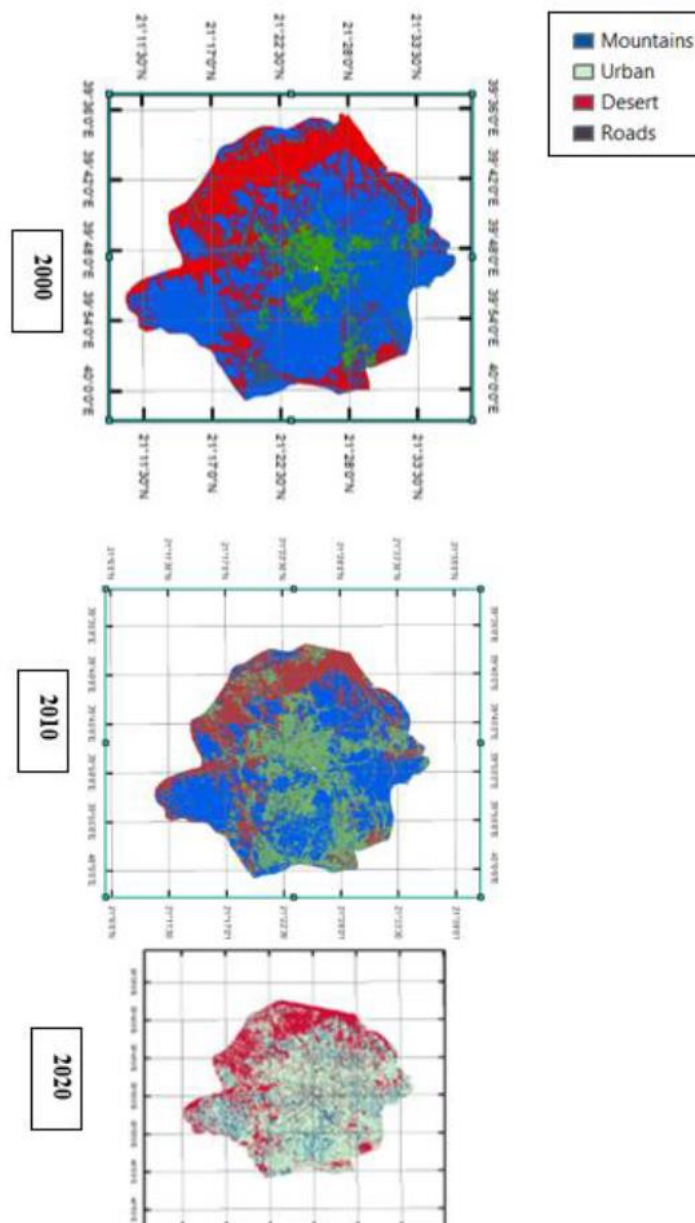


Figure 5. Land use classification of Makkah city last 20 years comparison

Population growth

The findings in this paper have found smart growth rate in Makkah city by (2.453%) in 2020 and (2%) in 2010, which guarantees development for future land use/land cover planning in Makkah City. In 2000 the population was 1,294,000 and in 2010 increased to 1,578,722 by overall rate of increase by (22%) then in 2020 jumps to 2,017,793 by (27.81%) that means the population have increased almost the double from 2000 to 2020. See chart 1

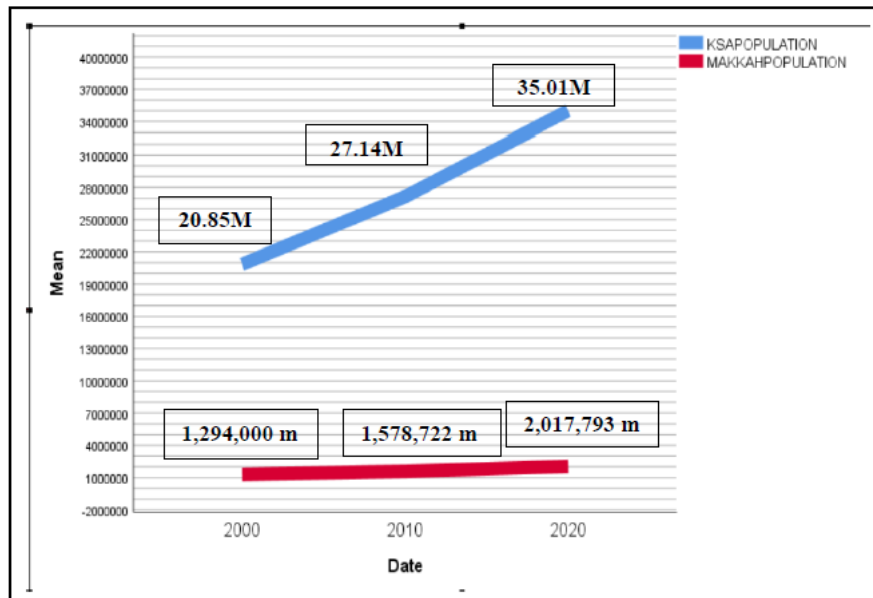


Chart [1]: Shows multiple lines of KSA population (blue) & Makkah population (red) (by spss).

Urban development

The Area of Makkah city have increased in 2020 to 465 km² compare to 2010 was 388 km² & in 2000 was 366 km². This is due to the increase of number of districts in Makkah city from 60 in 2010 to 101 in 2020 by rate of increase about (68.3 %) from the number of districts.

Topography of Makkah city

Makkah Al-Mukarramah is distinguished by its different topography, where the hills and mountains are scattered from the slopes of the people of Makkah Al-Mukarramah as urban areas for their homes. The height of Makkah Al-Mukarramah is between 250 and 350 meters above sea level from west to east, including the holy sites. in 2000 the average highest level reached 536.33 m meters, while in 2010 it reached 497.33 m meters, then in 2020 it reached 438.5 meters. We find that in 2020, the average level has decreased by a large difference from the dates 2010 and 2000, and this is the result of urban development, the demolition of mountains, and the construction of facilities.

REFERENCE

- [1] Makkah City Profile(2019).PDF
- [2] Al Jabri, N., & Alhazmi, R. (2017). Observing and monitoring the urban expansion of Makkah Al-Mukarramah using the remote sensing and GIS. *1* ,-125), 2(مجلة العلوم الهندسية و تكنولوجيا المعلومات) 103.
- [3] El-Damaty, T. A. E., & El-khrachy, I. (2014). Applying remote sensing and geographic information System For Geo-Environmental applications. *Journal of Engineering and Technology*, 2(1), 92-104.
- [4] Alqurashi, A. F., & Kumar, L. (2014). Land use and land cover change detection in the Saudi Arabian desert cities of Makkah and Al-Taif using satellite data. *Advances in Remote Sensing*, 3(03), 106.
- [5] Iman, A., Alhaddad, B., & Roca Cladera, J. (2016). Remote sensing efficiency for urban analysis

of MECCA and surrounds. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* (pp.905-910). International Society for Photogrammetry and Remote Sensing (ISPRS).

[6] Abdulrahman, Manal A. (2011). Spatial analysis of empty land in Makkah Al-Mukarramah using GIS.

[7] Abu Dhabi Urban Planning Council (no date). "Abu Dhabi Urban Street Design Manual" 1.0 Edition. Abu Dhabi Urban Planning Council.

[8] Al-Ahmadia K, Heppenstall A, See L, and Hogg J (2008). Modeling urban growth dynamics using cellular automata and GIS, Proceedings of the Third National GIS Symposium in Saudi Arabia, April 7 – 9, Al-Khobar, Saudi Arabia.

[9] Al-Gamdi, Saad Abo Ras (2006). Change Detection Using Digital Satellite Data Case study: The Holly City of Makkah and its Surroundings.

[10] Al-Joufie, Mohammed O. (2012). "Urban Growth and Transport in Jeddah". University of Twente.

[11] Al-Shehri, Noura Saad (2013). The effect of the topographical factor on the urban growth of the city of Makkah Al-Mukarramah, using the techniques of geographical information systems and remote sensing .

[12] Dawod, G. and MOHAMMED, W. (2009). Data management of different height systems within GPS/GIS integrated spatial technology, Middle East Spatial Technology Conference (MEST2009) , December 7-9, Kingdom of Bahrain.

[13] Feng, L. (2009). Applying remote sensing and GIS on monitoring and measuring urban sprawl. A case study of China, *Revista Internacional de Sostenibilisas, Tecnologia y Humanismo*, (4) 47-56.

[14] Al-Alola, S. S., Alogayell, H. M., Alkadi, I. I., Mohamed, S. A., & Ismail, I. Y. (2021). Recognition and Prediction of Land Dynamics and Its Associated Impacts in Al-Qurayyat City and along Al-Shamal Train Pathway in Saudi Arabia. *Sustainability*, 13(17), 9913.

[15] Alahmadi, M.; Atkinson, P.M. Three-Fold Urban Expansion in Saudi Arabia from 1992 to 2013 Observed Using Calibrated DMSP-OLS Night-Time Lights Imagery. *Remote Sens.* 2019, 11, 2266.

[16] Mustapha, M.R., San, L.H., Jafri, M.Z.M. & Syahreza, S., (2011), Land Cover Classification in Makkah Area using Frequency-based Contextual Classifier, In *International Conference on Environment Science and Engineering IPCBEE* (Vol. 8).