**International Journal of Development, Vol.2, No.(1) (2013): 21-36**
**ISSN: 2314-5536** **e-ISSN: 2314-5544 (Online)**
**www. ijd.byethost13.com** **e-mail: fas_ijd@yahoo.com**

# Monitoring and prediction of urban growth using GIS techniques: A case study of Dohuk City Kurdistan Region of Iraq

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## ABSTRACT

Everyday, Engineers and planners use GIS technology to research, develop, implement and monitor the progress of their plans. GIS provides planners surveyors, and engineers with the tools they need to design and map their neighborhoods and cities. Planners have the technical expertise, political understanding, and good understanding to transform a vision of tomorrow into a strategic action plan for today, and they use GIS to facilitate the decision-making process.

The growth of urban cities have been take uncontrolled policies ,which leads the planners to us information technologies such as GIS technology and remote sensing data to monitor this type or growth and to study the future expectation.

This paper aims to observe and predict the urban growth of Dohuk City using the twin techniques of GIS and Satellite images. Data have been derived from high resolution satellite imagery and filed survey .the outcome of this work shows that the area of Dohuk has expanded through the period from 2003-2012 with a rapid growth.

The main purpose of this paper is to use high resolution imagery for detecting urban growth changes occurred in residential areas of Dohuk city during the last ten years.

The database are designed and developed to support application modules namely built up area, green and recreational areas. Finally, change process of Dohuk city residential areas over the last ten years was determined using GIS overlay analysis and its relation with population growth was studied. In this period, urban growth of residential areas have expanded rapidly because of many reasons such as; the demographic migration from the villages and rural areas adjacent to the city center as well as migration from areas of central and southern Iraq, because of the stable security situation and moderation climate in addition to providing business and investment opportunities in addition to the fact that the city is considered as trade free zone with neighboring countries.

**Key words:** Urban growth; Satellite imagery; GIS; Monitoring;

## INTRODUCTION

Urban growth represents specific response to environmental, economic, and demographic conditions. Urban Growth is a major problem in the course of the urban development of the developing countries in the 21st century, most of the urban growth is considered to be the expansion of low density accompanied by a series of environmental and socio-economic issues. Across developing countries there is not growing awareness of, and concern about urban growth, which has different background from the cities of China, Europe

and North America. Land development has been out of control and the construction land has kept expanding blindly, especially in the marginal areas of some metropolises.

Nowadays urban areas experience fast growth due to enormous population growth, rapid industrialization, economic development and specific economic policies adopted by governments and immigration of people from villages to cities. Accelerated urban growth is usually associated with and driven by the population concentration in an area. The extent of urbanization or its growth drives the change in land use/cover pattern (Kumar et al., 2008). Urban growth is simply the growth of a major city or cities. Most cities will cite areas where they want the growth to be by setting boundaries, and/or control rate of growth (Jamaliah , 2004).Or it is an urban area or community in which the population of the area increases. In those cases where there is a growth in population in an urban area some factors need to be taken into consideration, how it will benefit my community, how will it hurt my community and will extra services or businesses be needed to meet the demands of the growth within the area (www.answers.askkids.com). Based on growth, there have been four city types identified:

1. Low-growth cities with modest rates of infilling.
2. High-growth cities with rapid, fragmented development.
3. Expansive-growth cities with extensive dispersion at low population.
4. Frantic-growth cities with extraordinary land conversion rates at high population densities (Schneider and Woodcock, 2008).

Factors which affect on the urban growth can be determined by industrial; migration; agricultural; technological; and commercial factors .Unplanned of urban expansions may caused problems in term of Irregular Planning of Urban Growth, Environmental, Transportation, and Pollution Problems.

In this research, an attempt has been made to apply a good method to monitor and predict urban growth for the study area. The researches used the multi-temporal high resolution satellite images to carry out the image geometric correction, image classification and features extraction. The built-up areas of three different years were extracted from the classified images so that the dynamic changes and the characteristics of urban expansion could be recognized, and then the built up area was regarded as one of indicators. GIS technique by using ArcGIS 9.3 from ESRI was applied to collect, process, analyses and layout the built up area. The final results of analysis were visualized as thematic layers. The Accurate extracted information on the extent of urban growth is of great interest for the municipalities of growing urban and suburban areas for diverse purposes such as urban planning, water and land resource allocation, etc. Urban authorities and municipal management, marketing analysis, service corporations are required to devote more time, attention and effort to manage the use of land and other resources in order to accommodate the expanding population or other urban land uses (Al-Awadhi and Azaz, 2003).

The cities of Kurdistan Region of Iraq have been developing rapidly after reform and opening-up since 2003, urban growth has emerged in some cities (such as Dohuk City). Land development has been out of control and the construction land has kept expanding blindly, especially in the marginal areas of some metropolises.

Satellite images have been used to study urban growth the world over, very few studies have employed these methods to examine the growth of Iraqi cities. Duhok is perhaps one of the most important cities in the northern part of Iraq and, thus, was selected for this study. Duhok city -capital of Duhok Governorate in the north of Iraq- has experienced a rapid urban

growth over the last decade due to accelerated economic growth and many other reasons. There are natural features that affect the growth of Duhok city such as mountains that surround the city from north, south and east.

The aim of this study is to monitor, analyze and predict the size and trend of urban growth in a part of Duhok city using satellite images and GIS from period between 2004 and 2010 and population censuses of Iraq. By applying classification methods to satellite images, four main types of land use were extracted; built-up, green area, agricultural lands and encroachments. Then, the area coverage for all the land use types at different points in time were measured and coupled with population data. The results demonstrate that, over the six years of study period, development in the northern-west part of Duhok –Masik Quarter- cannot be characterized as sprawl. In some places, however, one can see evidence of sprawl due to encroachments. There is also a transformation from agricultural land use into land for housing, roads and other activities. Furthermore, the ratio of green space is very low considering the available built-up areas. It's advisable that future plans for the city give serious consideration to the preservation and increasing of green space and, when possible, eliminate encroachments for compensation. The results emphasize the potential of using satellite images and GIS in monitoring urban growth where these technologies can save time, effort, and money comparing with traditional approaches.

## MATERIALS AND METHODS

### Study Area

Duhok city is the Capital of Dohuk Province, which is one of Kurdistan cities. (Fig. 1). It is located in the North West of Iraq, at 585 m above mean sea-level and about 470km north of Baghdad, at the latitude of (36° 51' 43.45" N) and longitude (42° 59' 50.30" E) in the center of the city.

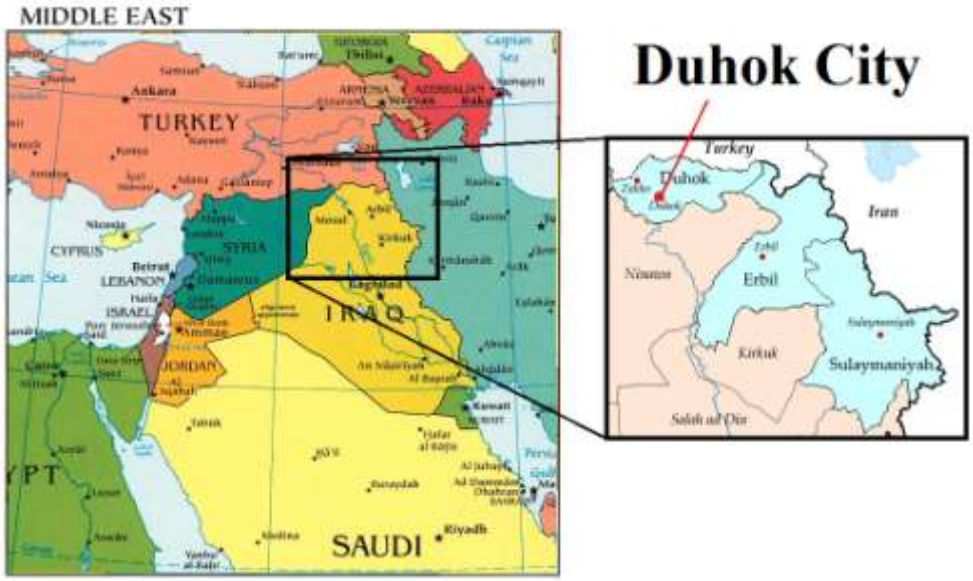



**Fig. (1). Location of Duhok city**

The territory area is about 60 km². Duhok city has a strategic location being near the tri-junction of the borders of Iraq, Turkey and Syria in the north-west of Iraqi Kurdistan region. It lies between two mountain ranges namely the Bekhair range from north to north-east and the Zawa range in the south. Duhok is a multi culture and multi religion city with a population of approximately 295000 inhabitants in 2010 (Directorate of statistics in Duhok city). Ethnically the majority of the populations are Kurds, with minority groups of Assyrians, Chaldeans, Arabs and Armenians. The population records show an unprecedented growth during the last two decades due to the rural-urban migration and returning refugees and many other reasons.

**Fig. (2). North-West View of Duhok**

The majority of Duhok population is concentrated in the north-eastern part of the city (Fig. 2). However, recent development and population growth took place in the western part of the city as well. Urban growth of the city of Duhok is somehow based on the model of Ernest Burgess, a theory that divides the city into five concentric zones; central business district (CBD), zone of transition, zone of working class, zone of better residence and commuter zone. Moreover, urban growth in Duhok city has been appeared recently in the east as well as in the west; on the other hand, the growth of the city is restricted at the north and south by the mountain ranges. For this research, Masik quarter is selected as a study area due to the rapid urban growth that has been occurred there in the last few years, along with the possibility of future expansion of the city of Duhok in the area and nearby.

Masik district (Fig. 3) is located in the north-west of the city of Duhok at the latitude (36° 52’ 25.73” N) and longitude (42° 56’ 40.13” E) on the plains that lies between northern and southern mountain ranges. The territory of the area is about 6 km² which is around 600 hectares. A noticeable growth occurred the last few years. The population of Masik district in 2010 is more than 15,000 inhabitants, where in 2004 it was not exceeding 1,000. Masik lands where used only for agricultural Purposes till 90s, afterwards, agricultural uses were gradually becoming less and less that in 2006 it was completely swept away.

**Fig. (3). Satellite image of Duhok showing study area (Masik District)**

## Data sources and Methodology

A selection of multi-resolution and multi-temporal images was used for this study. The specific satellite images used were from years of 2004, 2007 and 2010. The time interval between images for analyzing urban growth is three years each, which could be helpful to detect urban land change detection and growth of city. Another reason for selecting these images was their availability; unfortunately we did not have any access to images after 2010.

In this research, ESRI® ArcGIS™ 9.3 is the selected GIS software. Initially, all satellite images were rectified and georeferenced to the UTM Coordinate System and UTM Projection based upon well distributed ground control points obtained from Google Earth software. Geometric correction was resulted in RMSE (Root Mean Square Error) between 1.0. and 1.5 m. The standard image processing techniques, such as image extraction, rectification, restoration and classification have been used for analysis of the satellite images. After that, visual interpretation and ground truth observations were applied to classify, then digitizing techniques were used to extract the built-up, encroachments, green space and agricultural areas.

As any GIS project, the initial steps of GIS work are those of acquisition, data entry, data processing, data analysis, querying, data presentation should be implemented.

## Data Preparation and Data Collection

The first Satellite image (IKONOS with 1.0 resolution) of 2004 was obtained from the internet using map downloader software which is “Universal Maps Downloader”. The software provides maps from several map servers such as Google Satellite Maps and Microsoft VirtualEarth Satellite Maps. Images are acquired from this software by giving the coordinates of target map and defining the desired zoom level. The images, then, are saved in the personal computer as small images. Then you can combine them into one big image map by using a tool “map combiner” that comes with the software. The output big image is in BMP format. It can later be converted to other formats using some image tools. In this case, top and bottom latitudes with right and left longitudes of Masik district are given, along with defining the zoom level to a satisfactory precision. Afterwards, the image is converted to TIF image extension so as to be suitable for ArcGIS product software with ArcMap application software.

Satellite image of 2007 is the second image (QuickBird with 0.6 m resolution), and has been achieved from the Center of Guidance and Information in Duhok City. The map of Masik district is cropped and the image is prepared as a TIF format that is ready to be added into ArcMap.

The last 2010 satellite image (QuickBird with 0.6 m resolution) is attained from internet as well. This time Google Earth software is used for getting such an image. Simply you can navigate to the place you want to download; next you should click on historical imagery button in the toolbar above and use the time slider to move between acquisition dates. Subsequently you can use file>save>save image to save the current view as an image file to your computer's hard drive as jpeg image extension. When you save an image, a Save dialog box appears and you can locate a folder on your computer to save the image to, just as you would for any document you might save. Images can be saved in various resolutions such as low, medium, high and premium resolution. Satellite image of Masik has been saved in the finest resolution available i.e. premium. The resolution of the image is 4800 x 3225 pixels. However, this is not a good resolution comparing to the other images, but it is the best one at hand. Later, this image can be converted to TIF format the same way as the first image.

**Data Entry**

This step encompasses the way images are entered into ArcGIS, including creation of geodatabase needed to complete the required work. The operations of creating personal geodatabase and raster image spatial referencing are made using ESRI® ArcGIS with ArcCatalog™ 9.3.

**Data processing**

This step includes the following operations:

**(a)** Operations of georeferencing and image rectification; together with

**(b)** Process of digitizing and data extraction.

**(a) The operations of georeferencing and image rectification**

They are made using ESRI® ArcGIS with ArcMap™ 9.3. In order to use these types of raster data in conjunction with other spatial data, it is often needed to georeference it to a map coordinate system (Figs. 4-6). When you georeference or orthorectify raster, you define how the data is situated in map coordinates. This process includes assigning a coordinate system that associate the data with a specific location on earth. This transformation of raster data allows it to be viewed, queried and analyzed with other geographic data.

Different steps for georeferencing a raster image can be applied using in ArcMap, the researches applied the georefernced technique based on selected GCPs, and these points are listed in (Table 2). Six GCPs are used for each image to applied the georeferencing based on UTM projection with zone 38 N. the RMS errors were rounded between 1-1.5 m.

**Fig. (4). Satellite image to be georeference with ArcMap**

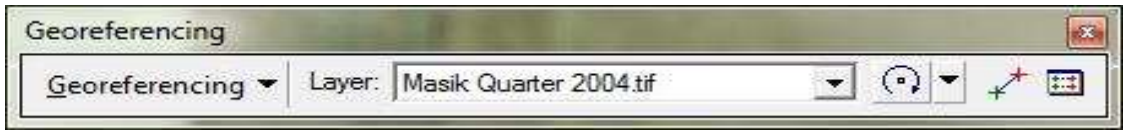



**Figure (5) Georeferencing toolbar**

**Fig. (6). Adding control points**

**Table (2). List of Selected Ground Control Points (GCPs)**

| Ground Control Points (GCP) | Satellite Image | Latitude (°)(‘)(“) | Longitude (°)(‘)(“) | Easting (m) | Northing (m) |
|---|---|---|---|---|---|
| **1** | Masik 2004 | 36° 52’ 47.03” N | 42° 55’ 34.73” E | 315190 | 4083538 |
| **2** | Masik 2004 | 36° 51’ 40.33” N | 42° 55’ 55.94” E | 315671 | 4081471 |
| **3** | Masik 2004 | 36° 52’ 42.93” N | 42° 57’ 59.04” E | 318760 | 4083335 |
| **4** | Masik 2004 | 36° 51’ 41.44” N | 42° 57’ 57.35” E | 318678 | 4081441 |
| **5** | Masik 2004 | 36° 52’ 19.30” N | 42° 55’ 59.25” E | 315779 | 4082670 |
| **6** | Masik 2004 | 36° 52’ 01.74” N | 42° 57’ 03.12” E | 317350 | 4082095 |
| **1** | Masik 2007 | 36° 52’ 52.78” N | 42° 55’ 49.00” E | 315547 | 4083708 |
| **2** | Masik 2007 | 36° 52’ 10.17” N | 42° 55’ 49.04” E | 315520 | 4082395 |
| **3** | Masik 2007 | 36° 52’ 27.92” N | 42° 57’ 36.64” E | 318196 | 4082884 |
| **4** | Masik 2007 | 36° 52’ 09.41” N | 42° 57’ 23.34” E | 317854 | 4082321 |
| **5** | Masik 2007 | 36° 52’ 49.13” N | 42° 56’ 50.94” E | 317078 | 4083562 |
| **6** | Masik 2007 | 36° 52’ 05.75” N | 42° 56’ 35.67” E | 316671 | 4082233 |
| **1** | Masik 2010 | 36° 52’ 52.78” N | 42° 55’ 49.00” E | 315547 | 4083708 |
| **2** | Masik 2010 | 36° 52’ 10.17” N | 42° 55’ 49.04” E | 315520 | 4082395 |
| **3** | Masik 2010 | 36° 52’ 27.92” N | 42° 57’ 36.64” E | 318196 | 4082884 |
| **4** | Masik 2010 | 36° 52’ 09.41” N | 42° 57’ 23.34” E | 317854 | 4082321 |
| **5** | Masik 2010 | 36° 52’ 49.13” N | 42° 56’ 50.94” E | 317078 | 4083562 |
| **6** | Masik 2010 | 36° 52’ 05.75” N | 42° 56’ 35.67” E | 316671 | 4082233 |

**(b) Process of digitizing and data extraction**.

After the georeferencing of the three satellite image the digitizing operation were done. This step involves tracing features on the georeferenced satellite image by creating new lines and polygons in ArcMap.

## RESULTS AND DISCUSSION

After producing complete land use maps, the total coverage of different classes was determined. This information, along with the corresponding population figures from the Directorate of Statistics of Duhok, is presented in Tables (3 & 4).

**Table (3): Area of different land use types and population**

| Land Use Type/ (Hectare/km$^2$) | Date/year | | |
|---|---|---|---|
| | 2004 | 2007 | 2010 |
| Built-up | 6.72 / 0.067 | 22.5 / 0.24 | 90.52 / 0.96 |
| Encroachments/sprawl | 0.25 / 0.0025 | 1.69 / 0.016 | 5.6 / 0.056 |
| Green Space | 0 | 0.7 / 0.007 | 2.9 / 0.029 |
| Agriculture | 40.45 / 0.40 | 0 | 1.1 / 0.011 |
| Population (Person) | Less than 1,000 | 6,000 | 17,000 |

**Table (4): Percentage of urban as well as green space and population**

| Land Use Type | Date/year | | |
|---|---|---|---|
| | 2004 | 2007 | 2010 |
| Built-up | 14.17 % | 91 % | 90.91 % |
| Encroachments/sprawl | 0.52 % | 6.35 % | 5.29 % |
| Green Space | 0 | 2.63 % | 2.74 % |
| Agriculture | 85.3 % | 0 | 1.04 % |
| Population (Person) | Less than 1,000 | 6,000 | 17,000 |

Masik district has experienced a rapid urban growth during the study period. Satellite images of 2004, 2007 and 2010 together with the digitized maps are shown in figures (7, 8,9,10,11,12).

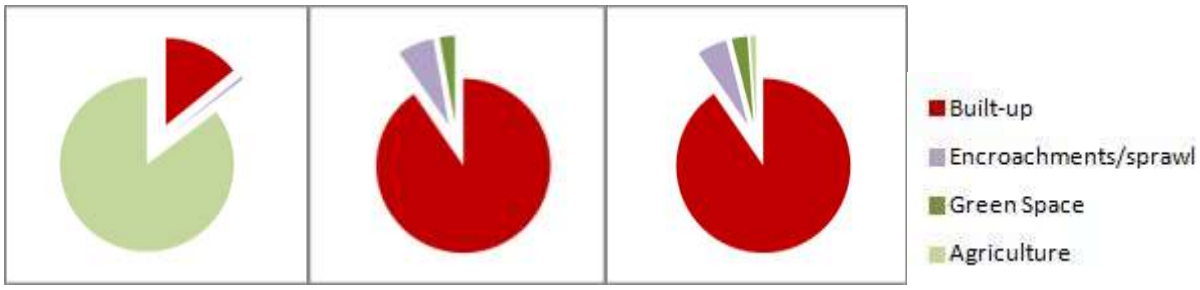
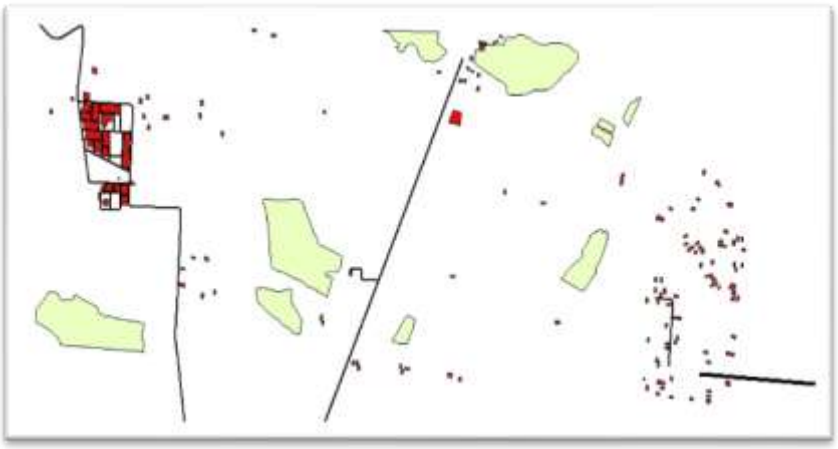



**Fig. (7). Percentage charts for 2004-2007-2010**

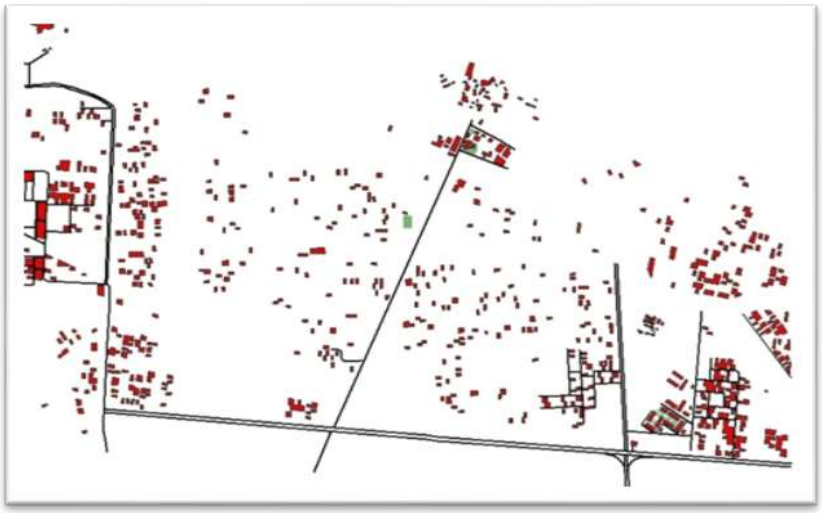

**Fig. (8). 2004 Satellite image and digitized layers**


**Fig. (9). 2007 Satellite image and digitized layers**

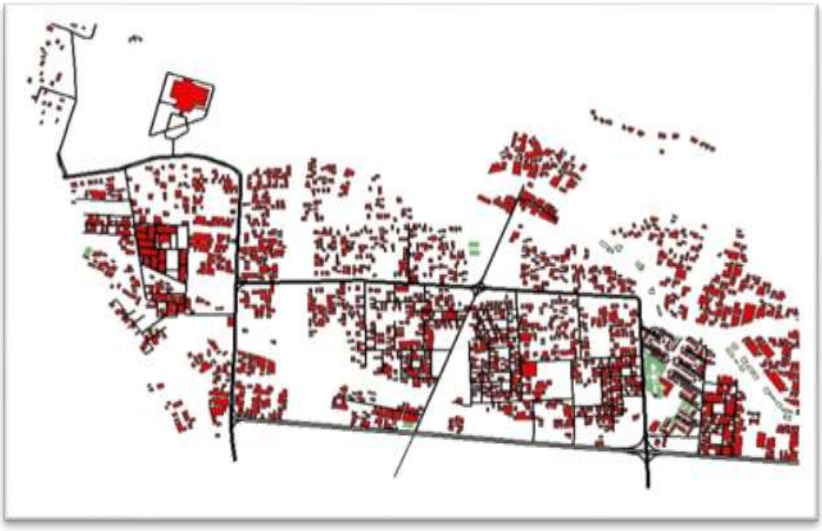

**Fig. (10). 2010 Satellite image and digitized layers**



2004



2007



2010

**Fig. (11). Built up, Agriculture, Green Space and Street Maps for 2004, 2007 and 2010**

According to the digitized maps produced by ArcGIS, the total built-up area of Masik district for 2004 was 6.72 hectares. This increased to 22.5 hectares by 2007 and finally reached 90.52 hectares in 2010. These figures represent about 234% growth in built-up area over the first pace, and 302% growth in the second pace. This has added about 83.8 hectares to the built-up area.

According to the statistical analysis, Figure (12) illustrates the population growth of Masik district has been growing from 2004 to 2010 by more than 17,000 inhabitants. The population showed a rapid growth from about 1,200 inhabitants in 2004 to 4,800 inhabitants in 2007 and then to 17,000 in 2010. Thus over the six years of study period population grew by 300% in the first pace, and by 254% in the second pace.

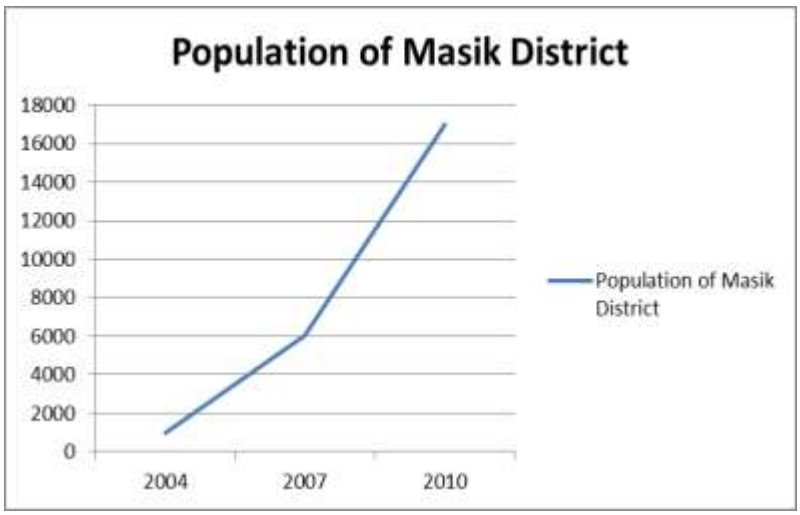



**Fig. (12). population of Masik District during study period**

As a total growth, the built-up area grew by 1247% over the entire period, while population grew by 1316%, just slightly higher than the growth of the built-up area.

With respect to green space, it is obvious that in 2004 there was no green space available. However, in 2007 about 0.7 hectares occurred which is a very small percentage, comparing to the available built-up area. Nonetheless, it has increased to about 2.9 hectares in 2010. Yet, it is still a very low percentage according to the built-up lands.

The census data indicate that the main phase of population growth as well as built-up area growth in Masik district occurred between 2007 and 2010. The main cause of this growth was the growth of the city of Duhok, which means the growth of the city has reached Masik district in 2004 and started growing very fast. Population census of Duhok give that the population of Masik in 2003 was zero. As stated before, growth direction of Duhok city is to the west due to the mountain ranges that surround the city from north, south and east. However, there is a space available in the east for growth, but it is very small comparing to the available space in the west.

According to Duhok Master Plan prepared by Duhok municipality and supported by a German Planning Company, population of Masik district is to be increased to 28,750 inhabitants in 2032. But the results of our study show that the population of Masik will be reached the number much earlier. One of the reasons behind this rapid growth is that;

• The growth of Duhok city is restricted at north and south by mountain ranges; and
• The location of Duhok University near the study area.

**Urban Growth Proposals**

As a result, we propose the following proposals;

- The growth of Masik should be kept the same way as occurred during study period. Also some encroachments have been occurred and should be stopped or eliminated for compensation.
- The ratio of green space is very low, and should be increased.
- Instead of the transformation of agricultural lands into built-up area, more green space should be created in the form of forests.
- Future expansion of Duhok city is expected to happen in the open space available to the west (Figs. 13 & 14). Thus, high-rise residential units should be constructed more than single dwelling units due to the small growth space available.
- Establishing a new sub-center for commercial purposes in the open space available to the west of study area. This may be helpful to decrease traffic problems in the center of Duhok (CBD), together with time consuming for the people in the area and nearby.


**Fig. (14). Space Available for Future Expansion**

**Fig. (13). Growth Directions of Duhok**

## Conclusions

- The development of urban areas in Masik cannot be characterized as sprawl; however, one can see evidence of sprawl due to encroachments.
- The ratio of green space is very low.
- Urban growth of the city of Duhok is somehow based on the model of Ernest Burgess.
- The elimination of agricultural lands by the year 2007. Anyhow, in 2010 a few plant nursery units have been built.
- Use of satellite images is the best way to analyze urban growth of cities

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