Bilad Alrafidain Journal for Engineering Science and Technology
https://dx.doi.org/10.56990/bajest/2024.030105
ISSN: 2957-9651
Pages: 59-71

Analysis of Urban Sprawl Using Geographical Information System (GIS) Techniques; A Case Study in Erbil City-Kurdistan of Iraq

Diyaree Kareem Hamajan[1]* ,Prof. Dr. Hussein D. Mohammed[2]
diyaree.kareem.h@spu.edu.iq , hussein.d.mohammed@spu.edu.iq
[1,2]City Planning Engineering Department, Technical College of Engineering, Sulaimani Polytechnic University

Abstract

Urban sprawl is one of the main threats in the city, and the present study focuses on the discussion and investigation of urban sprawl. Urban sprawl impacts the environment and agricultural fields in Erbil. The city has witnessed a remarkable rapid increase in population and urbanization at the expense of agricultural and pastoral lands, political, economic, and social factors. All these factors led to prevent the city from becoming green, which resulting in some issues like economic, social, and environmental. The most essential application of (GIS) technology is urban sprawl monitoring. It helps to determine the direction of expansion of urban areas, its pattern, and finding the most suitable sites for further urban development.

(GIS) spatial analysis covered the geo-processing application, which is the classification of maps of Erbil to detect the change detection (LULC) through two periods, 2010 to 2018. It is to discover how much the city has changed and improved over the selected years. The changes and developments that happened over the passing years illustrated in the figures and tables in the results and discussion sections. The purpose of this study is to recommend organized solutions for the unlimited growth of urbanization.

The results showed the Landsat and Satellite Images of Erbil city due years 2010 and 2018 using ArcGIS Pro. Geo-referencing and digitizing the maps of Erbil gave the spatial data surveying as a result for analyzing the changes and comparing them due to the specified years to see the differences that happened to the city. Furthermore, as a result, the vacant land area decreased by 33.20%, whereas the urban area increased by 15.86% from 2010 to 2018.

Keywords: Classification; Erbil; GIS; Urbanization; Urban Sprawl.

Article history: Received: 10/1/2024 Accepted :5/2/2024

Introduction

Urban sprawl is a term that describes the unplanned growth of towns and cities that focuses on empty spaces or areas of land that are not suitable for urban development. This causes a lack of improvement in the growing and diffusing of infrastructures and residents. Urban sprawl is a serious problem globally due to some factors, which are an increase in the number of populations, growth of finances, systems of transportation, and the strategies of using the land [9].

Urbanization is a global, social, and economic phenomenon with its effects reverberating the world [1]. The rapid industrialization and urban growth led to the significant loss of agricultural land. Rapid urbanization, especially in the developing world, remains a critical global challenge in the 21st century, significantly influencing human dimensions [10].

The definition of urban areas varies from a country to another, depending on factors like total population and the developmental stage of urbanization. Urbanization is the process by which many people are permanently concentrated in relatively small areas, giving rise to cities. A country is typically regarded as urbanized when more than 50% of its population resides in urban areas [7].

* Corresponding Author: diyaree.kareem.h@spu.edu.iq

ISSN: 2957-9651
Pages: 59-71

In developing countries, land use planning often falls short, resulting in the rapid loss of agricultural land, natural vegetation, and open land, with serious environmental repercussions. Changes in land use and land cover can disrupt the long-standing harmonious relationship between people and the environment [13]. Therefore, it is imperative to conduct a comprehensive analysis of the various parameters associated with land use and land cover changes in a given area. The combination of Satellite Remote Sensing (RS) and Geographic Information Systems (GIS) has emerged as a powerful approach for detecting land use and land cover (LULC) changes. These techniques have primarily focused on providing information about the changes in extent, location, and types of land use and land cover [8, 12, 14, 15]. In particular, (RS) remains an underutilized but potential source of urban information, offering consistent spatial coverage with many details and temporal frequency, including historical time series [5, 2].

This study aims to obtain benefits from using GIS raster analysis techniques due to the changes, developments, and improvements, upgrades of urbanization, and urban sprawl that had happened to the city of Erbil. Also, using it is helpful to show the problem that faced the city of Erbil and caused urban sprawl.

1. Literature Review and Analysis

The following researchers and studies discussed some examples about urban sprawl in different places, internationally, regionally, and locally:

- **Urban Sprawl Internationally:** A study has done in Japan and Germany about urban sprawl. According to the research, the relation between sprawl/mobility and infrastructure costs, where the saving effects are estimated for each region by comparing the most infrastructure-efficient and inefficient municipalities (interregional comparison). In addition, they made some policy suggestions for shifting residential urban development toward more infrastructure-efficient locations. They named some examples of different types of infrastructure like, the availability of roads, sewages, and schools. The study identifies a familiar mechanism between land-use patterns and the financial impact of patterns of land use and motorization for both case study regions. They found that the density of urban and housing significantly influences the extent of specific local sewage and local road infrastructures [6].

- **Urban Sprawl Regionally:** A study about Syria's non-formal settlement mentioned that other cities provided more than ten master plans to Syria's government to rebuild, organize, and revolute it, but Syria has been going through tough times due to the war. It caused Syria not to have enough money to implement all the various master plans. Any reason that people migrate from Syria to another city, urban sprawl happens, and each part of their population divided into different cities around the world, which is a way for the growth of population internationally [11].

- **Urban Sprawl Locally:** In the Soran district of Iraqi Kurdistan, an analysis done about urban sprawl due to (GIS) and (RS). Soran District has witnessed rapid growth in the last two decades because of its economic, commercial, and social attractions. The study took three periods within two decades. 1998, 2008, and 2018 used to study the growth and behavior of urban sprawl in Soran, where Soran district expanded rapidly in the 1990s into a large city. The results obtained using (GIS) and (RS) to evaluate the urban growth and sprawl patterns. These changes induced by upgrading many urban roads or constructing new road-linked structures [4].

2. Method and Materials

Study Area : The location of the study area is in the North of Iraq, where Erbil city is located and is the capital of the Kurdistan region as the largest city. It is one of those cities where urban sprawl has been threatening its urbanization and infrastructure. Also, analyzing the patterns of urban land use change within the study area and identifying the effects of urban sprawl on infrastructure change for the periods 2010 to 2018 for Erbil City, Kurdistan of Iraq. In addition to these, GIS techniques to identify the changes

ISSN: 2957-9651
Pages: 59-71

that occurred in the map of Erbil City for Years 2010 and 2018.

It is essential to discuss the neighborhoods that are distributed throughout Erbil City. The study area covered two neighborhoods of Erbil City. The first neighborhood is in an area with a low economic and social level (Poor Zone) along Cornish Roads. Meanwhile, the second neighborhood with a high social and economic level (Rich Zone) includes 32 Park, Italian Village, English Village, Dream City, Bakhtyari, and other Places. Rich zones are developed by having good services like water supply, electricity, and transportation, but poor zones do not have enough services. **Fig 1** shows the location of the study and **Fig 2** shows the location of both zones due to Erbil City's map. Furthermore, the area of Erbil city is more than 98,000 hectares regarding the selected boundaries, and each zone has taken an amount of it. Rich zones with high income take only 1,500 to 2,000 hectares of the city, while the poor zones take 3,500 to 4,000 hectares of the land. These summarize that the number of poor zones is much higher than the number of rich zones. This results from the sprawl that is happening in the city of Erbil.

Fig. 1 Study Area's Location on Iraq's Map

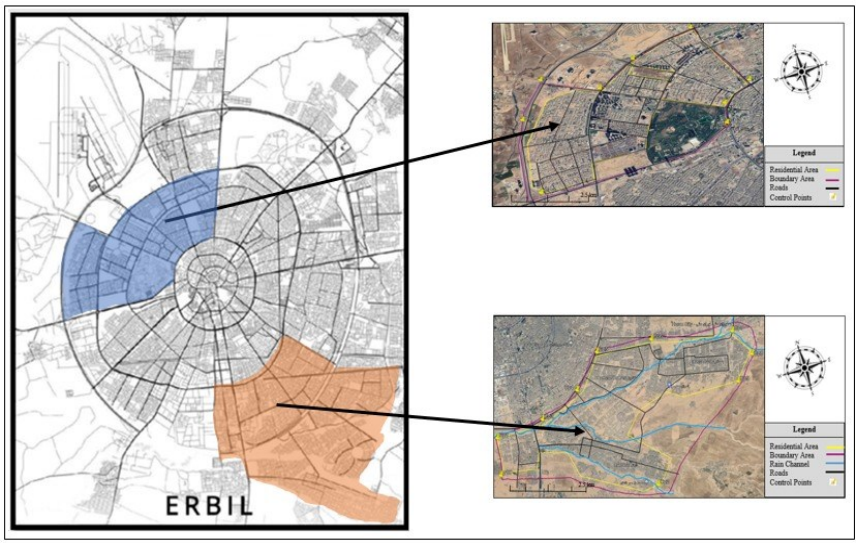

Fig. 2 Study Area's Location on Iraq's Map

ISSN: 2957-9651
Pages: 59-71

In addition to the location of the study area, this section covers the practical part that had done for this study and the material used. It achieved by several steps, starting from data capturing from different resources with different data formats such as satellite images, ground control points (GCPs) by GPS, and topographic maps, data storage and retrieval, data manipulation and analysis, and ending with visualizing and output of information about the urban sprawl of Erbil city. The development of satellite images can provide an exact area with data despite GIS. This results in using the required area to geo-referencing the raster data to a set of coordinates on the map. A map coordinate system defined by using a map projection, which is a method in which the bent surface of the earth portrayed on a flat surface. In this study, geo-referencing the raster data was done by adding GCPs gathered by GPS to define features' location using map coordinates and assigning the coordinate system of the map frame. **Table 1** lists the adopted image satellites used in the study.

Table 1 Properties of Satellite Images

#	Type of Data and Sensors	Description
1	Landsat 7 ETM+	30 m Spatial Resolution, 8 bands, 2010
2	Landsat 8 OLI	30 m Spatial Resolution, 9 bands, 2018
3	Quick bird Digital Globe Satellite Image	1m Spatial Resolution, tiff , 2010
4	Quick bird Digital Globe Satellite Image	1m Spatial Resolution, ecw.2018,
5	National Imagery and Map	Topographic Maps

ArcGIS Pro from ESRI is a powerful program and tool, such as geo-referencing, image processing, and displaying in 2D and 3D views, which helps planners evaluate and investigate information [3].

Geo-referencing is the process of taking a virtual imagery photo, which might be a satellite image, aerial photo, or digitized map and using a geographic information system (GIS) to the imagery image to replace it with an accurate area in its exact place in the world. This process is completed by selecting pixels in the digital image and assigning them geographic coordinates. In other words, geo-referencing is the process of assigning GPS coordinates (East, North, or Lat. ϕ, Long λ) to digital image files (or raster data) so that you can line up one map directly on top of another. Geo-referencing was used in this paper to compare different temporal resolutions of satellite images and existing maps for the study area to apply classification geo-processing techniques for change detection. This shown in Fig 3

ISSN: 2957-9651
Pages: 59-71

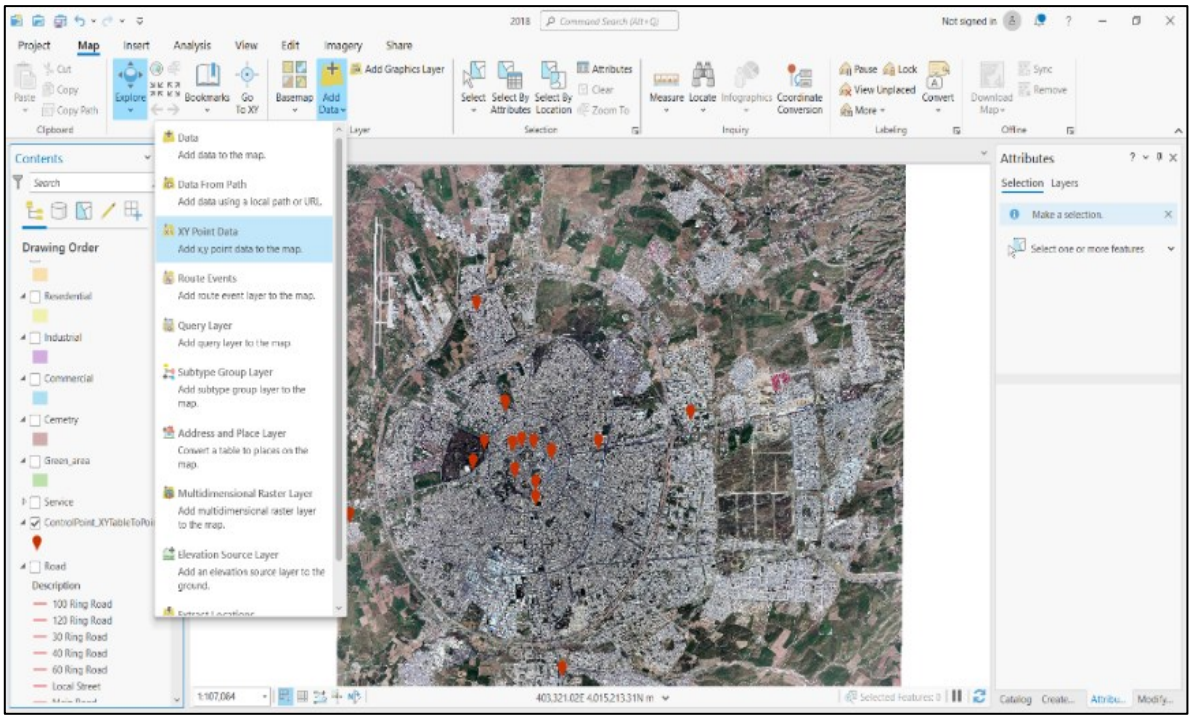

Fig. 3 Adding Ground Control Points (GCP)

As a result, all the city's land use's structure will be showed up, and Fig 4 shows the digitizing map of Erbil, 2018. **Fig 5** shows the flow chart of geo-referencing process

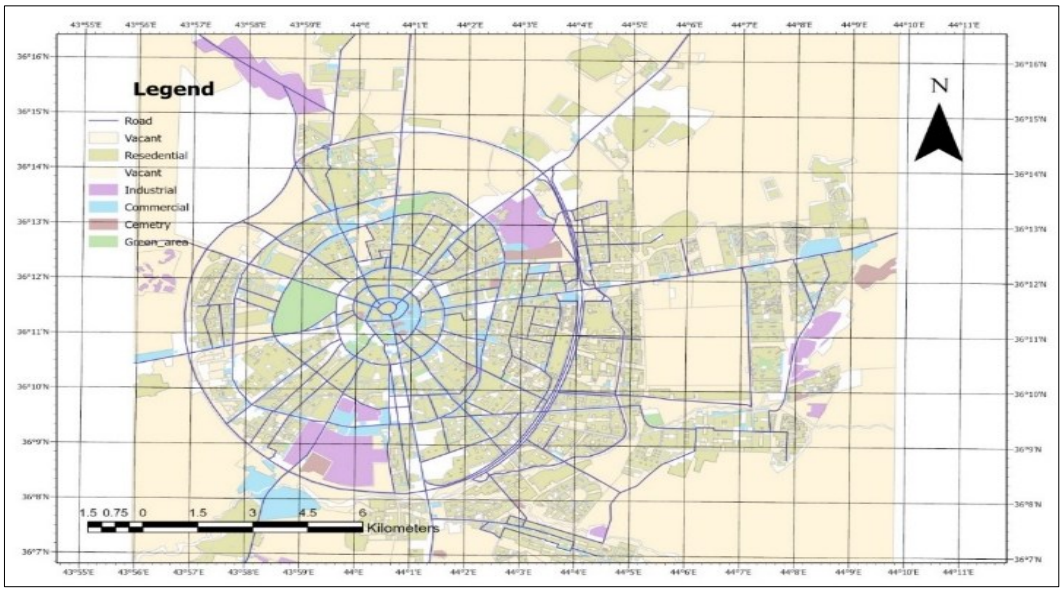

Fig. 4 Result of Digitizing Features for Erbil's Map

ISSN: 2957-9651
Pages: 59-71

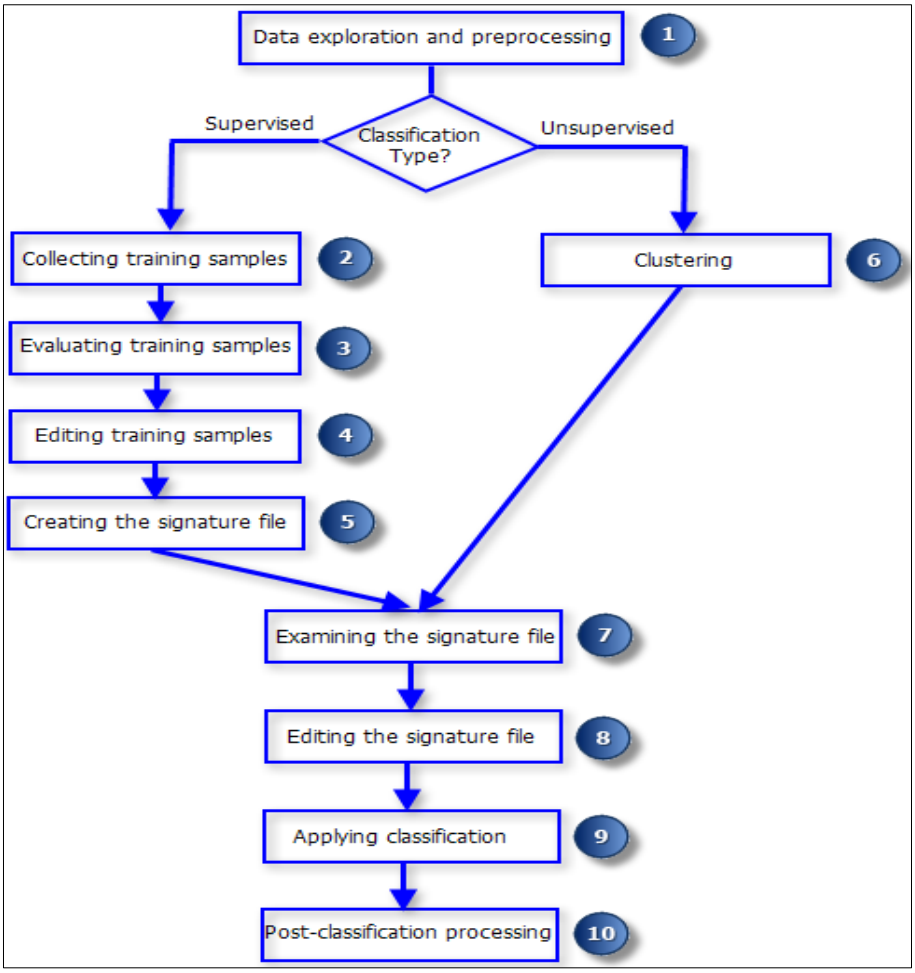

Fig.5 Classification Geo-processing

4. Results and Discussion

This section is dealing with two parts which are results and discussion. The results that have been achieved during the practical part of the research, and explaining them clearly. In addition to this, at the end of this section the distribution of urban sprawl for years 2010 and 2018 will be explained in details. Also, by adding some figures and tables due to each year's urban expansion, the changes of land cover and land use (LULC) will be better clarified.

The classified images obtained after geo-referencing and supervising classification which are showing the land use and land cover of the Erbil city are given in the following below figures. These images provide the information about the land use pattern of the study area. The different colors were used to represents the land use and land cover areas such as urban built-up area, green area, industrial areas, vacant areas, commercial areas and roads.

Fig 6 and **fig 7** show the pie chart according to **Table 2** for years 2010 and 2018 respectively to give better understanding to the values of the area for the objects.

ISSN: 2957-9651
Pages: 59-71

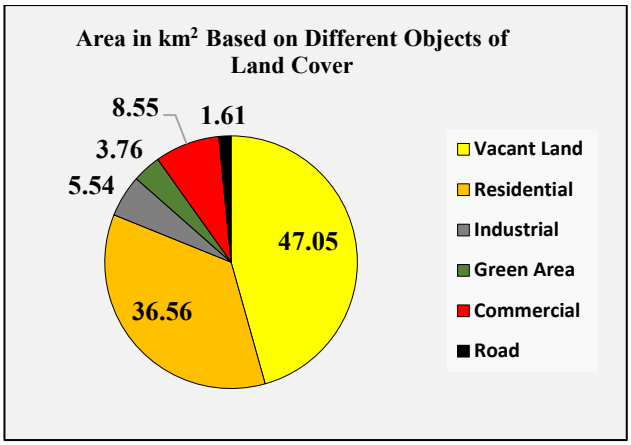

Fig. 6 Pie chart about the Land Cover Distribution in km^2 in Erbil City Derived from Classified Landsat Imagery for Year 2010.

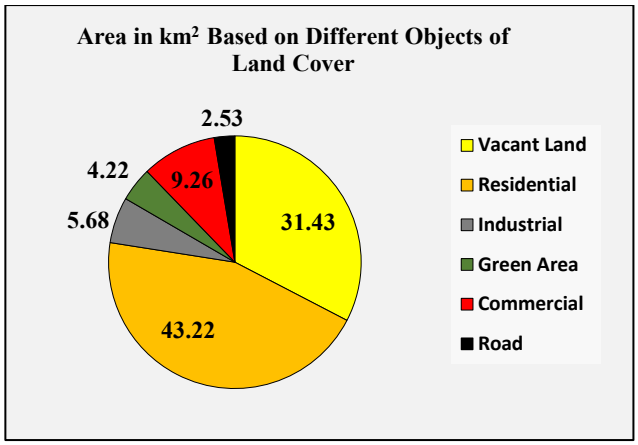

Fig. 7 Pie chart about the Land Cover Distribution in km2 in Erbil City Derived from Classified Landsat Imagery for Year 2018.

Table 2 Classification of Land Use and Land Cover (LULC) in Erbil City for 2010 and 2010

Land Cover Objects	2010		2018	
	Area (km^2)	%	Area (km^2)	%
Vacant Land	47.05	46	31.43	33
Residential	36.56	35	43.22	45
Industrial	5.54	5	5.68	6
Green Area	3.76	4	4.22	4
Commercial	8.55	8	9.26	9
Road	1.61	2	2.53	3
Total	**103.07**	**100**	**96.34**	**100**

0

a. LULC Classification of Erbil City for Year 2010 by using ArcGIS Pro:

Satellite Image of Erbil's map in 2010 is shown in **Fig 8** Landsat 7 ETM+ has been used for classifying the land cover of Erbil city in 2010 which is shown in **Fig 9**. The important objects have been marked by various colors, which represents vacant land, residential, industrial, green area, commercial, and road to be comprehensive enough to get clear idea about objectives of Erbil in 2010. All of them have been clarified in the legend on the map. For example, the areas that covered by vacant land has taken an area of 47.05 km^2 which is the largest amount comparing to the road that has taken the smallest amount of area which is 1.61 km^2. So, going back to 2010, the roads were not distributed enough through the City of Erbil, and due to the large amount of area that residential took place which is 36.56 km^2, more roads had to be built. This value shows in **Table 3.**

ISSN: 2957-9651
Pages: 59-71

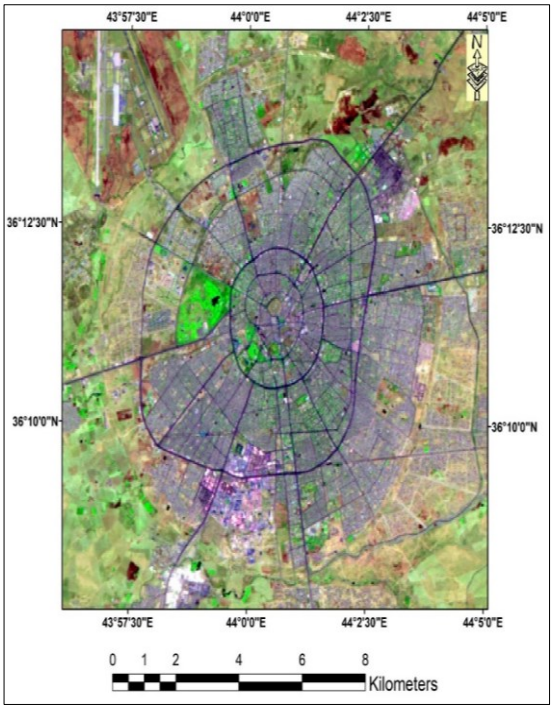

Fig. 8 Satellite Image of Erbil City in Year 2010

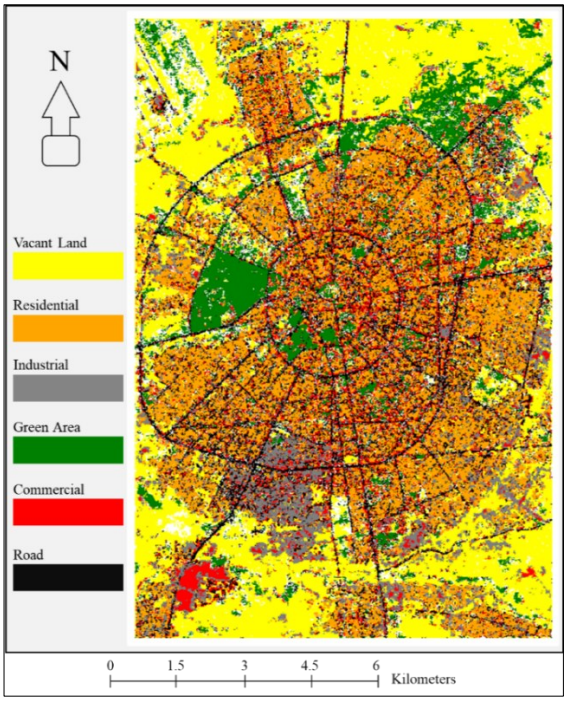

Fig. 9 Land Cover Map of Erbil City based on Landsat Image in 2010

Table 3 Classification of Land Use and Land Cover (LULC) in Erbil City for 2010

Land Cover Objects	2010	
	Area (km^2)	%
Vacant Land	47.05	46
Residential	36.56	35
Industrial	5.54	5
Green Area	3.76	4
Commercial	8.55	8
Road	1.61	2

b. LULC Classification of Erbil City for Year 2018 by using ArcGIS Pro:

Fig 10 shows the derived Satellite Image of Erbil city's map in 2018. For this year, Landsat 8 OLI is used, and it is the last year of the classification with being more developed, organized, and the city is more expanded. The classified objects that shown in **Fig 11** in the legend by different colors in which the area that road had took place in is 2.53 km^2 which is the smallest by comparison to other land cover objects while residential took the largest amount of area which is 43.22 km^2. Vacant land will come after residential as taking the largest area which is 31.43 km^2. Difference amount of area for these objects means different change in the land cover based on the urban expansion. The areas are shown in **Table 4**.

ISSN: 2957-9651
Pages: 59-71

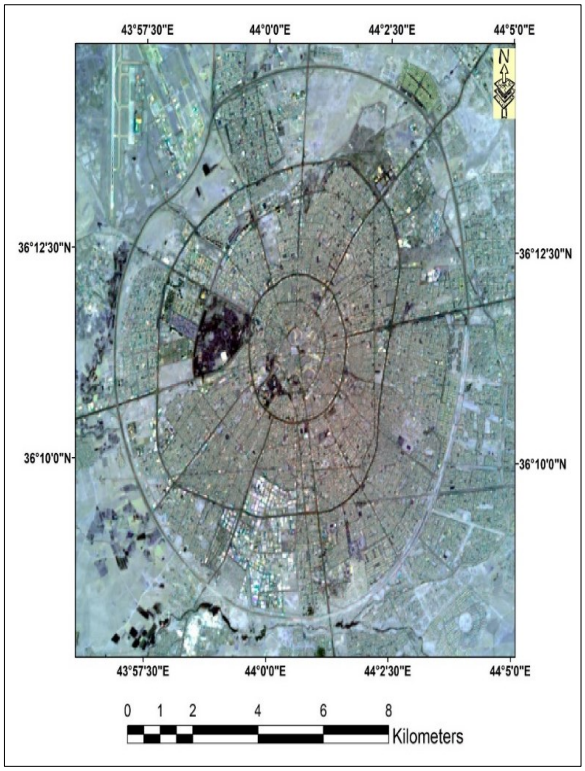

Fig. 10 Satellite Image of Erbil City in Year 2018

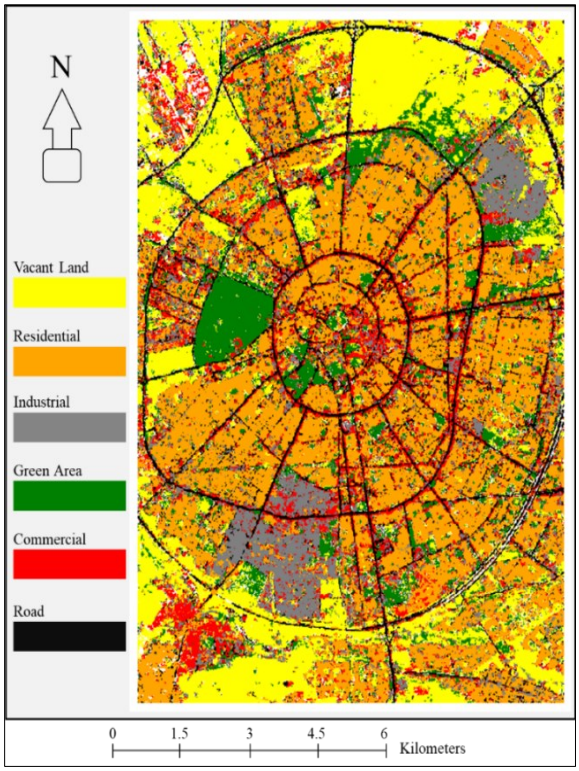

Fig. 11 Land Cover Map of Erbil City based on Landsat Image in 2018

Table 4 Classification of Land Use and Land Cover (LULC) in Erbil City for 2018

Land Cover Objects	**2018**	
	Area (km^2)	**%**
Vacant Land	31.43	33
Residential	43.22	45
Industrial	5.68	6
Green Area	4.22	4
Commercial	9.26	9
Road	2.53	3
Total	**96.34**	**100**

ISSN: 2957-9651
Pages: 59-71

Classification Accuracy Assessment

Land use and land cover map was compared to the reference data to evaluate the level of accuracy of the classification. The reference data has been arranged based on choosing sample points randomly, the field knowledge and Google earth. A hand-held GPS (Global Positioning System) is used to identify the exact position of the place under consideration during visiting the field with latitude and longitude geographic coordinate system, and Easting and Northing UTM, 38N WGS84 projected coordinate system and its type by visual observation. The ground truth data obtained was used to verify the classification accuracy. Furthermore, according to the classifications that have been done. The values of kappa coefficient for years 2010 and 2018 Tare shown in **Table 5**. In addition to this, as it shows in the table, the overall classification accuracy for 2010 and 2018 are between 68-78%.

Table 5 Accuracy Metrics for Land Cover Classification

Years	Overall Accuracy (%)	Kappa (%)
2010	68.13	65.43
2018	78.02	77.35

Fig. 12 shows the results of digitizing of the changes that happened during 2010 for poor zone. Each map is including legend and scale. Generally, each legend on the map is showing the classes that classified on the land cover which are residential, vacant land, green-area, commercial, cemetery, industrial, public services, and road. Each of these classes have been showed in different colors in order the changes be clear on the map that happened to the city. On the other hand, the results of digitizing of rich zone for year 2018 shows in Fig. 13 for the changes that happened in the city of Erbil. Like poor zone, the legend on the maps of rich zone represents the most important classes that includes in the land cover, such as residential, commercial, industry, green area, vacant land, cemetery, road, and control points, each in different color to give more clearance to the urban sprawl.

Furthermore, poor zone and rich zone in Erbil City exist like in any other country with the difference of lifestyle due to incomes. Also, the developments that are done for the rich zone are based on the income of people that they have, so because of economic situation the poor zones might be more sprawled than the rich zones.

ISSN: 2957-9651
Pages: 59-71

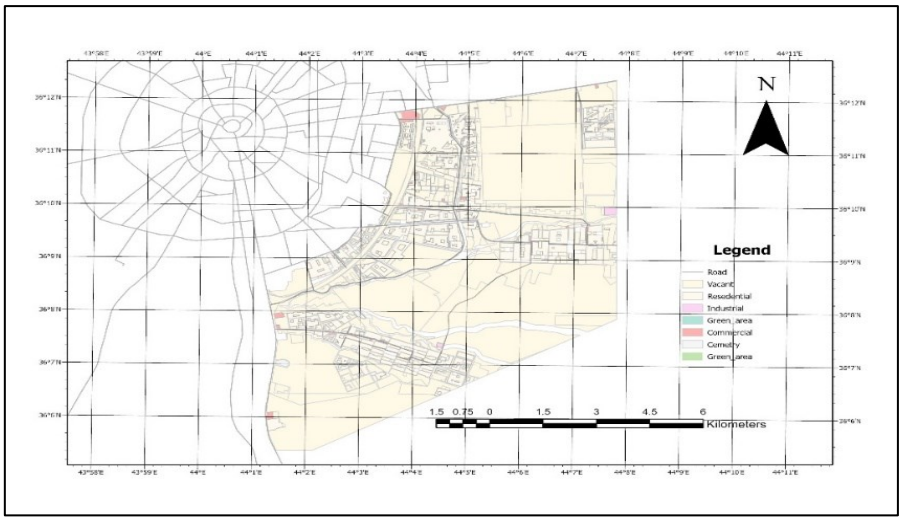

Fig. 12 Development of Urban Sprawl in Poor Area in Erbil City in 2010

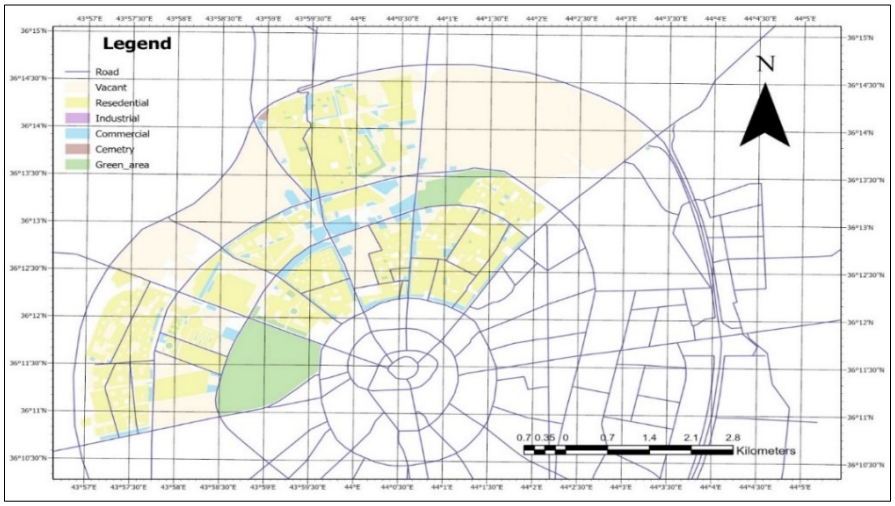

Fig. 13 Development of Urban Sprawl in Rich Area in Erbil City 2018

Based on the results of the land cover objects for both years 2010 and 2018 the area of each object has been changed based on the number of population and urban expansion. So, a comparison between the changed areas of the land cover can be done according to each year. For instance, the area of vacant land has been decreased by 33.20% from 2010 to 2018. Whereas, the urban area which includes each of residential, industrial, green area, commercial, and road is increased in its amount of area by 15.87%. This results from that, in 2010 the amount of area where urban area took place was 56.02 km^2 while in 2018 become 64.91 km^2 in Erbil city. All these values are shown in **Table 6**.

Furthermore, **Fig. 7** which is a bar chart clearly shows the changed area of the land cover in km^2 for years 2010 and 2018 clearly Also, the results showed that in 2010 the area of the vacant land was larger than residential area, but they have been exchanged in 2018. This means that urban sprawl happened because of unlimited increase in the residential area in a way that vacant area which includes agriculture decreased in its amount of area. Finally, based on the results of the kappa coefficient for years 2010 and 2018 in this study, the classifications' power of acceptance is substantial agreement for both years respectively because the ranges are between 0.61-0.80 [16].

ISSN: 2957-9651
Pages: 59-71

Table 6 Comparison in Land Cover Objects Due to Area in km^2 in 2010 and 2018

Land Cover Objects	2010		2018	
	Area (km^2)	%	Area (km^2)	%
Vacant Land	47.05	46	31.43	33
Urban Area	56.02	54	64.91	67
Total	**103.07**	**100**	**96.34**	**100**

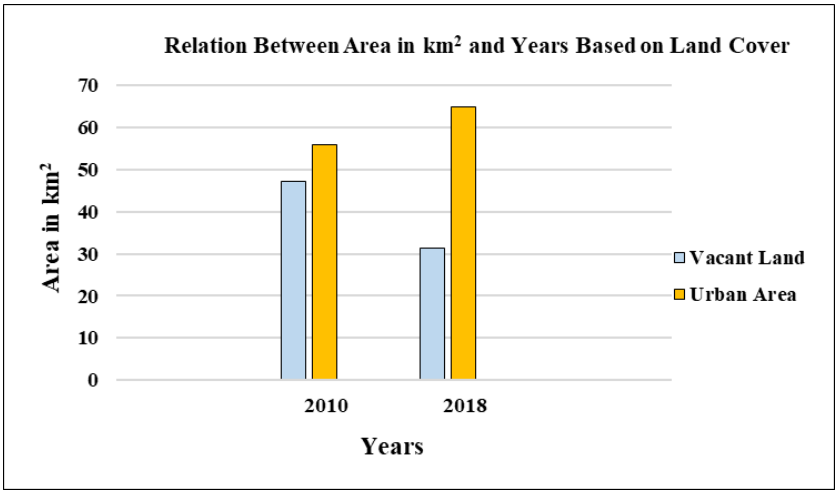

Fig.14 Bar Chart about Changed in Area of Land Cover in Years 2010 and 2018

5. Conclusion and Recommendations

Conclusion

The results from the classification of Erbil City showed that because of the rapid expansion of urbanization, land use and land cover have been changed quickly. According to the changes in the land cover objects of 2010 and 2018, all of them increased, except vacant land. The number of populations in Erbil Governorate in 2010 was 1,755,606, while it increased to 2,162,509 in 2018. In other words, the population number increased by 23.18% from 2010 until 2018. So, with the increase in the number of populations, there must be more areas for urban objects, especially green areas.

Some reasons caused urban sprawl are the following:

1. Most of the open spaces are replaced with residential areas because of the rapid growth of the population. This results in increasing urban areas and decreasing agricultural lands.
2. People are requesting bigger and better houses in the town, so they meet all their demands, which will be a reason for the expansion of the urban areas. This results in a lack of infrastructure, including transportation.
3. People have been migrating from their cities, and they used to reside in Erbil to find jobs for a better lifestyle.
4. The lack of primary and secondary roads in Erbil City is another reason that caused traffic congestion with the increase in the number of populations.
5. Many high-quality residential projects have been constructed, which forcing people to buy and live there from inside or outside Erbil City.

From this study, the aims have been achieved, such as finding the reasons for the change of urbanization in land use and land cover for the years 2010 and 2018. Also, examining the points made changes to the land use within the study area and finding the reason for urban sprawl on infrastructure for years 2010 and 2018 in Erbil

ISSN: 2957-9651
Pages: 59-71

City. More ever, using the GIS technique to discover the changes that have happened to the map of Erbil due to the land use and land cover.

Recommendations

1. Expanding the city is better vertically rather than horizontally and preserving the agricultural lands by avoiding replacing them with accommodation.

2. Keeping the city away from constructing personal houses by people, instead constructing a limited number of projects where residents can meet their requirements at a suitable cost.

3. Limiting the growth of the number of migrations by the government.

4. Building up more of the secondary roads and connecting them to the primary roads. On the other hand, reducing the use of personal vehicles, instead using busses and other public ways of transportation to reduce traffic congestion caused by urban sprawl.

5. Reducing the construction of residential projects by the government**.**

6. References

[1]. Deng, J. S. Wang, K. Hong, Y. and Qi, J. G. (2009). Patio-temporal dynamics and evolution of land use change and landscape to rapid urbanization. Landscape and Urban Planning, 92(3-4), 187-198.

[2]. Donnay, J. P. Barnsley, M. J. and Longley, P. A. (2001). Remote Sensing and Urban Analysis. Taylor & Francis London, 1-18.

[3]. Esri. (n.d.). Introduction to ArcGIS Pro—ArcGIS Pro-Documentation. https://pro.arcgis.com/en/pro-app/latest/get-started/get-started.htm

[4]. Hamad, R. (2019). A remote sensing and GIS-based analysis of urban sprawl in Soran District, Iraqi Kurdistan | Sprin gerLink, 2(24)

[5]. Jensen, J. R., and Cowen, D. C. (1999). Remote Sensing of Urban/Suburban Infrastructure and Socio-Economic Attributes. Photogrammetric Engineering & Remote Sensing, 65(5), 611-622.

[6]. Klug, Stefan, & Hayashi, Yoshitsugu. (2012). Urban sprawl and local infrastructure in Japan and Germany. Journal of infrastructure systems, 18(4), 232-241.

[7]. Long, R. (1998). Organization Sociology. Encyclopedia Britannica Article. http://www.csbs.utsa.edu/users/rlong/intrurb.htm

[8]. Meaille, R., and Wald, L. (2007). Using geographical information system and satellite imagery within a numerical simulation of regional urban growth. Taylor & Francis Online, 4(4), 445-456.

[9]. Rafferty, J. P. (2023). Urban sprawl | Definition, Examples, Problems, Causes, & Alternatives| Britannica.

[10]. Sui, D. Z., & Zeng, H. (2001). Modeling the dynamics of landscape structure in Asia's emerging desakota regions: a case study in Shenzhen. Landscape and urban planning, 53(1-4), 37-52.

[11]. Sukkar, Ahmad, Zainedin, Sawsan Abou, & Fakhani, Hani. (2021). Informal settlements in Syria: What approach after the conflict? – Arab Reform Initiative.

[12]. Treitz, P. M. Howarth, P.J. Gong, Peng. (1992, January). Application of Satellite and GIS Technologies for Land-Cover and Land-Use Mapping at the Rural-Urban Fringe: A Case Study. Photogrammetric Engineering & Remote Sensing, 58(4), 439-448.

[13]. Weng, Q. (2002). Land Use Change Analysis in the Zhujiang Delta of China Using Satellite Remote Sensing, GIS and Stochastic Modeling. ResearchGate, 64(3), 273-284.

[14]. Weng Q. (2001). A remote sensing-GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. International Journal of Remote Sensing, 22(10), 1999-2014.

[15]. Yeh, A. G. O., & Li, X. (1998). Sustainable land development model for rapid growth areas using GIS. INT. J. Geographical Information Science, 12(2), 169-189.

[16]. Zach. (2021, February 22th). Cohen's Kappa Statistic: Definition & Example - Statology.