Eco. Env. & Cons. 27 (November Suppl. Issue) : 2021; pp. (S48-S58)
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ISSN 0971–765X

Temporal change of Urban Land Use: The case of Erbil City

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(Received 20 April, 2021; Accepted 25 May, 2021)

ABSTRACT

Rapid urban change in Erbil since 2000 has increased the potential impact from human activity. One accurate way to identify and monitor the scale of urban development is through remote sensing (RS) and Geographic Information Systems (GIS). These provide a viable source of information as land cover data can be easily and effectively extracted. Erbil, like many other cities in Iraq, has experienced rapid urban spread mostly due to population growth after 2003. Previously lacking well-organized urban planning systems and principles, the city has seen uncontrollable urban growth with adverse environmental impact. This research covers three satellite datasets, Landsat 5, Landsat 8 and Sentinel-2, acquired in 2000, 2010 and 2018 respectively. The technology is used to detect changes and expansions taking place within Erbil city. Land use/land cover (LULC) maps for these years have been generated in order to determine the specific changes occuring. Use of remotely sensed data on urban growth is a simple method to support urban planners and policy-makers, and save time and money. Monitoring the spatial and temporal dynamics of Erbil's urban expansion is a challenge, and vital in establishing how best to formulate future regional urban usage, and how to maximize increasingly limited resources.

Key words : *Remote sensing (RS), Geographic Information Systems (GIS), Satellite image, Land use/land cover (LULC), Change detection Classification*

Introduction

Across the globe, but especially in emergent countries, land use / land cover has been changing as a result of rapid urban growth (Abdallah and Mohamed, 2007). One place where significant changes of this kind are seen, is the city of Erbil (Abdullah, 2012). Urbanization processes create changes to populations and behaviors. More residents mean that there is a growth in the urban area as people move in from rural places. At the same time there are also adaptations to their socioeconomic behaviors and systems of living and working (Zhou, 1999).

Erbil has experienced momentous urban development since 2000 and has been through a stage of essential conversion. The scale of development shows clearly that Erbil city has a problem with how fast urbanization is happening. It is known from previous research that the amount of cultivated land is reducing every year. This is because the rate of urban growth requires much arable and open land in Erbil to become built up land instead (Sabr, 2014).

The term 'land use and land cover change' (LULCC) refers to a wide range of ways that human beings alter or modify the surface of the planet. Land cover relates to the earth's physical and biological cover, such as vegetation, open soil, water,

and/or any artificially made structures (Ellis and Pontius, 2006).

In comparison with cover, the idea of land use is more complex. The natural sciences views land use as relating to the various ways human intervene directly on the land, for example, forestry, farming and man-made constructions. Others working in social sciences and land management see land use as having a much broader social and economic scope. (Amler *et al.*, 1999)

Human land use puts considerable pressure on natural resources (Reid *et al.*, 2005). This demand has been growing more quickly than ever before with natural ecosystems being systematically degraded to fully grasp all the potential environmental implications of shifting land cover and land use, the functions held by natural ecosystems must be understood and a sustainable land use plan to support them will need to be put in place (Elmastaº, 2009).

Sorting pixels into finite groups of separate classes or categories of data, based on their data file values, is known as classification. If a pixel meets a particular set of criteria, then it can be placed in the corresponding group or class. There are two ways pixels can be classified into different categories like Supervised and Unsupervised. These two ways are via remote sensing (RS) and geographical information systems (GIS).

RS and GIS are technologies that can provide land use /land cover mapping. They bring valuable, accurate way to measure, select and designate areas for agriculture, urban and industrial purpose(Gupta 2011). The ability to apply remotely sensed data accurately and at low cost, in connection with GIS creates an effective platform for analyzing, updating and retrieving data on changes to land cover and use (Elmasta, 2008).

Contemporary technologies like geographical information systems (GIS) and remote sensing (RS) are a precise and cost-effective way to engage with changing dynamics in the landscape. Digital change detection techniques are underpinned by multi-temporal and multi-spectral remotely sensed data and they have been shown to be very effective at highlighting landscape variations, dynamics, for example, identifying and monitoring change over time, and spotting patterns, regardless of what may be causing the change (Jensen, 1996). Evolutions in satellite quality mean that image analysis can now be carried out more often, and more successfully, than previously. GIS has enormous potential for helping to model changing dynamics of the physical land environment(Yüksek and Elmastaº 2019).

Land Use Land Cover (LULC) change analysis is crucial for environmental management purposes. It helps policy makers or those managing the land to evaluate what changes might occur in the future, as well as to work out possible implications of any change for people, ecology and the wider environment (Serra *et al.*, 2008). it is important that the LULC change maps are as high quality as possible, to support accurate planning as decision makers must understand all the relevant factors that affect each LULC change (population, agricultural growth etc.).

Remote sensing and GIS are able to demonstrate trends and rates of changes in urban areas like Erbil city. This research looks at changes in urban land between 2000 and 2018, and analyses the findings. It intends to:

- Track specific land use and changes occurring between 2000 and 2018 in Erbil city
- Create land use and land cover maps of the study area over the target periods
- Use remote sensing data to verify any spatial and temporal shifts to land use, caused by natural factors
- Assess land cover/land use change patterns, exploring main drivers of change.

Aim of The Study

The study's main goal is to identify urban growth by using ArcGIS and ERDAS techniques.The following objectives will be used:

- Use three sets of satellite imaging to generate basic data, and to identify any changes of and cover in the urban area.
- Use of data to make clear the extent of any land use changes, measuring the rate of urban growth across the chosen timeframe.
- Using geo-spatial tools to support short-term and long-term urban expansion observation, planning and monitoring, by passing on information and data to regional urban planners and policy makers.

Research Question

What rate of land use change took place in Erbil City, between the years of 2000, 2010 and 2018?

Study Area

Erbil is an ancient city, the third largest in Iraq, and has one of the oldest inhabited communities on earth. Currently the capital of the Kurdistan Region Government (KRG), according to UNESCO, its urban existence can be traced back to at least 6000 BC (Ibrahim *et al.,* 2015). with Duhok and Sulaymaniyah, it comprises the three governorates of the Kurdistan Region, located in the northern Iraq at longitude 43 ° 55′15 "N and 44 ° 05 ′31"N, latitude 36 ° 16' 45" E and 36 ° 06' 54"E. Erbil's border travel

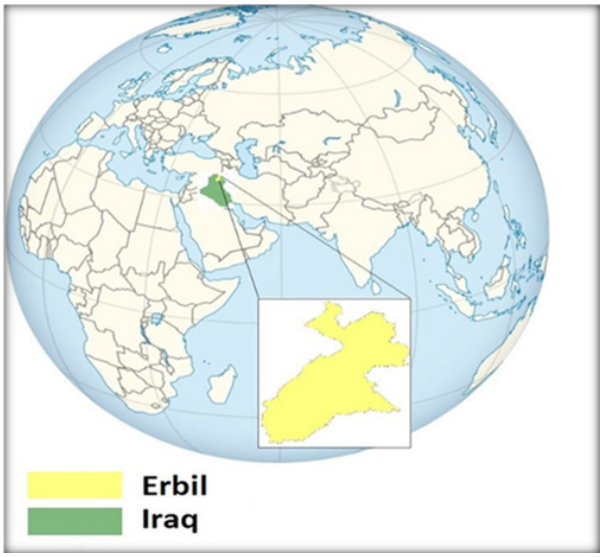

Fig. 1. World map including the Study area (Erbil city)

from Iran in the east and to Turkey in the north (Gardi and Asfahani, 2019 and Abdullah *et al.,* 2020). The total area being just over 15000 square kilometers.

The Erbil governorate is located between two rivers known as the Greater Zab in the West, and the little Zab in the East. The total area of the governorate is just over 15000 km^2 and it consists of seven districts (Erbil, Makhmur, Koyea, Shaqlawa, Choman, Soran and Merqasur)(Mohammad, 2019).

Erbil has a strong socioeconomic value to the Kurdistan region. It attracts tourists because of its location near borders of Iran and Turkey, and it has a unique climate. In the winter, middle October to early March, it is wet and cold and it is hot and dry in the summer from the end April to the end September. Rates of precipitation (rain) are decreasing due to global warming according to the Erbil Weather Station.

Population of Kurdistan Region

As Iraq achieved independence in 1932, the population of leaving British officials was estimated at roughly 3.5 million15. The first census was conducted in 1947 and showed a population of about 4.8 million. While the census of 1965 returned a total of marginally over eight million, of which 902,000 in the KRI.16 The Iraqi population was 16,335,000 at the time of the last population census conducted in 1987, of which 2,015,466 in the Kurdistan region.The Kurdistan region population was estimated at 2,861,701, with a total Iraqi population of 22,046,244 million extra now.

The eighth survey, scheduled for 2007, has been carried out since the formation of the new state of Iraq but has never been completed due to the extraordinary circumstances that accompanied the dictatorship's collapse. At the end of 2009, only a rapid population, economic institutions, and housing stocks were handled. The classification and counting of claims in the KRI also took place. (Mohammad, 2019).

Correspondingly, the KRI population's living and socio-demographic conditions have not been statistically observed for 30 years, and only esti-

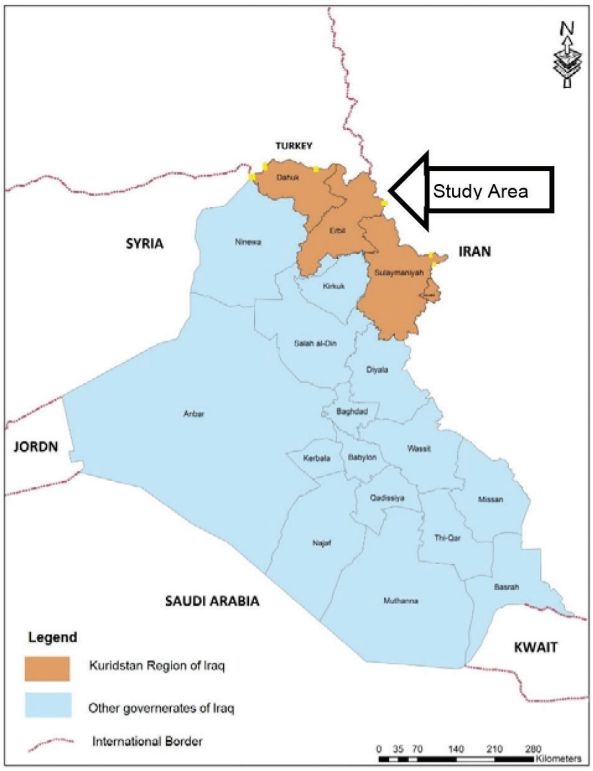

Fig. 2. Study area (Erbil city)

mates have been given. The Iraqi-and KRI-population's demographic structure was greatly influenced by urban migration and changing social patterns and war, violence, and regular internal displacement rounds during this time.

Progress on the sex-and-age-disaggregated data (SADD) estimates of the KRI population and other socio-demographic measures of households is vital as profound and rapid social change, and insecurity and population movements continue to influence the country and turn its demographic structure.The demographic study commissioned by the Federal Statistics Office of Kurdistan (KRSO), the International Organization for Migration (IOM), and the United Nations Population Fund (UNFPA) included a sample of 13,600 households, including 400 camp-based households, reflecting a reference population of 5,122,747 as of 2014.The survey represents the most up-to-date set of demographic data available and offers socio-economic metrics that are extremely necessary. It can be seen that the number of populations in Erbil, Duhok, Sulaymaniyah Provinces from 2009 to today in Table 1 is listed below (Kurdistan Regional Statistics Office -KRSO).

The Central Statistical Office (CSO) and the KRSO have regularly revised the statistics since then. The 2014 figures were used in this table, which placed the KRI population at 5,122,747 people and the total Iraqi population at 36,004,552 people.

Land Use and Land Cover Changes

Within land use research studies, land use and land cover are often defined and used interchangeably. This is due to the many information systems that can be involved in this type of research. Despite this, the two terms are distinct. Land cover refers to biophysical cover that can be observed on the earth's surface. This includes bare soil, vegetation, hard surfaces and bodies of water. By contrast, land use

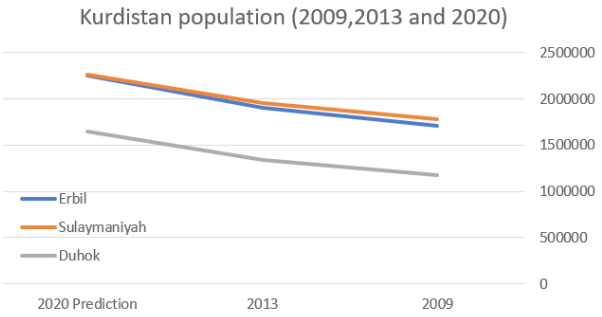

Fig. 3. Kurdistan Iraq population number in (2009, 2013, 2020)

Table 1. Iraq Kurdistan region population numbers from 2009 to 2019

Year	Erbil pop. No.	Sulaymaniyah pop. No.	Duhok pop. No.	KRG pop. No.
2009	1706182	1784853	1171231	4662266
2010	1755606	1825311	1212375	4793292
2011	1805313	1866677	1253639	4925629
2012	1855226	1908874	1294910	5059010
2013	1905970	1951818	1336944	5194732
2014	1957486	1995439	1379675	5332600
2015	2009637	2039685	1423114	5472436
2016	2062380	2084492	1467198	5614070
2017	2113391	2129794	1511658	5755043
2018	2162509	2175523	1557020	5895052
2019	2209569	2221622	1602623	6033814

Source: (Kurdistan Regional Statistics Office –KRSO http://www.krso.net/)

Table 2. Iraq Kurdistan region population growth rate from 2009 to 2019

Governorates	No.pop. 2009	No.po. 2013	%Growth rate	prediction No.pop. 2020
Erbil	1706182	1905970	2.4	2254422
Sulaymaniyah	1784853	1951818	2.1	2268050
Duhok	1171231	1336944	3.1	1648611
Total	4662266	5194732	2.6	6171083

Source: (Kurdistan Regional Statistics Office –KRSO http://www.krso.net/)

generally means the utilization of land cover, through human interactivity. Examples are agriculture, forestry, settlement and pasture, activities that alter natural land surface processes such as biogeochemistry, hydrology and biodiversity (Di Gregorio and Jansen, 1998).

Because the terms land use and land cover are not referring to the same things, it is important to remain aware of the differences and unique elements to each. Here, the specific characteristics of land use and land cover will be recognized. In general, the term land use and land cover change (LULCC) identify all types of modifying activity that humans have imposed on the surface of the earth. There are specific definitions of land cover and land use that exist, such as the Encyclopedia of Earth, "landcover refers to the physical and biological cover over the surface of land, including water, bare soil, vegetation, and/or artificial structures" (Ellis and Pontius, 2006).

Changes in land cover affect land use, and land use impacts land cover. Changes to one, does not necessarily come about as a result of a change to the other. Also, an alteration in land cover by land use does not automatically means that land has been degraded (Elmasta, 2009). Nevertheless, there are lots of shifts to land use that do arise because of social impacts, land cover changes and impact on biodiversity, water and radiation, trace gas emissions and other land use processes that affect global climate and biosphere (Riebsame *et al.,* 1994).

Statement of problem

Rapid increases in population due to economic and political shifts, have resulted in Erbil city growing in size over the last 20 years especially, but in a random not a planned way. Between 2000 and 2018, a significant amount of open and agricultural land has been lost to urban space (Khaleel Ismael and Ngah 2010).

This has a large impact on the environment and the land itself. In these conditions, the need to plan well and have strong awareness of all factors, is high. Remote sensing techniques in the study are able to bring good information and give a close look at how urban growth spreads and impacts. The research is valuable as its findings can support policy makers and future urbanization policies. The research adds to the existing body of literature with its unique techniques and different methodologies. The study's outcome will further assist planners with the significance to monitor and mitigate urban growth by confidently drawing on data from advance technological approaches.

Data used in this study

This research implements remotely sensed data, mainly Landsat satellite imagery, to detect urban development within the area of research. The data was collected via three Landsat images from the USGS website.(Landsat-5, Landst-8, and Sentinel-2) respectively. Geo-referenced data for UTM Zone 38, WGS 84. The photographs were taken on 22 August 2000, and on 16 August 2018, the second and third images (Sentinel-2) were taken.

Secondary sources of data, including conventional local government census data, written papers, academic textbooks, and related maps from the Municipality of Erbil City, were collected from various sources.

Methodology

Software used for data analysis

The tools used to display and interpret the findings of the study includes:

ArcGIS 10.5 and Erdas imagine 2015

Erdas 10.5 Imagine was used to classify the latest changes in land groups within the research area for image classification. For the composition of maps,

Table 3. Details from satellite images

Satellite	Landsat 5	Landsat 8	Sentinel-2
Date	2000_08_22	2010_08_10	2018_08_16
Time	07:01:12 am	07:38:53 am	07:39:17 AM
Image ID	LE07_L1TP_169035_20000822_T1	LC08_L1TP_169035_20100810T1	LC08_L1TP_169035_201800816_T1
WRS Path	169	169	169
Pixel	30m	30m	10m
Projection	UTM Zone 38N	UTM Zone 38N	UTM Zone 38N
Ellipsoid	WGS 84	WGS 84	WGS 84

three photographs from 2000, 2010, and 2018 were categorized and exported to ArcGIS 10.5, and Erdas 10.5 was used for supervised classification in order to identify improvements in land usage and land cover.Reclassification charts, such as categories built up and not built up, were used for the supervised category. During the study era, the resulting map clarifies the altered and unaltered property.

Satellite Imagery (Landsat-5 + Landsat-8 and Sentential-2) was downloaded from United States Geological Survey (USGS) (http://earthexplorer.usgs.gov).

The image Landsat-5 was taken by the satellite on 22 August 2000 and Sentenial-2 in16 August 2018 and Landsat 8 was taken by satellite on 16 August 2018. The resolution of the image is 30m. These data are able to describe the land use of the study area. Hence data from the three images reflect a time period of 18 years. The geo-reference of the satellite image is WGS_84 Datum project 38N.

Change Detection Techniques

It is vital to choose an appropriate methods or algorithm for change detection. There can be constraints due to spatial, spectral, thematic and temporal properties that affect digital change detection so it is important to generate the most precise result. Different change detection methods could produce different changes of maps depending on the algorithm they followed (Bekalo, 2009). Some techniques such as image differencing only deliver binary, change or non-change, insights. Other methods like post-classification comparison are able to deliver a complete matrix of change directions.

There are various methods of change detection within remote sensing image classification. Researchers can now classify according to image ratio, image regression, image differencing and method of change detection after classification (post classification method) (Bekalo, 2009).

This study extracted a map representing differences between initial state and final state images. This image differencing process was done via Erdas imagine software. In areas of change, there will be large positive or negative values whereas in areas of no change, differences will only be small.

Post-Classification Comparisons

When comparing post-classification derived the-

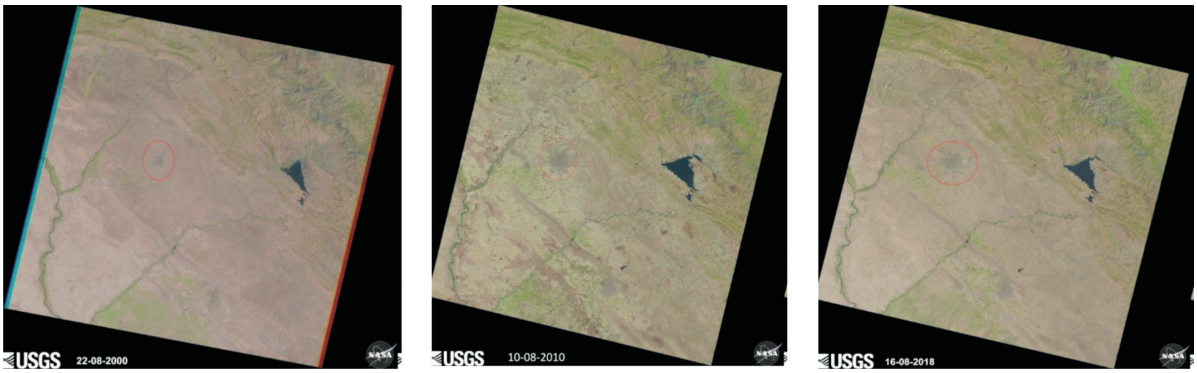

Fig. 4. Erbil governorate satellite image (study area)

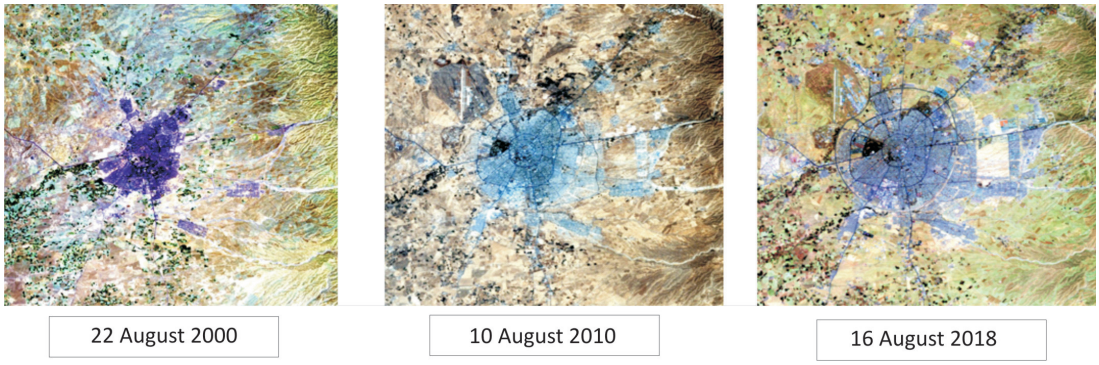

Figure 5. Erbil governorate satellite image (study area)

matic maps, the aim is to identify and classify different types of change. This is more complex than basic change detection. Supervised classification was chosen in this instance. The three LULC classes that had been defined within the classification scheme were: (1) urban/built-up areas, (2) (Vegetation) areas, (3) barren land areas (4) Agriculture (5) hilly areas (6) water. The images from the three target years 2000, 2010 and 2018 were each subjected to the

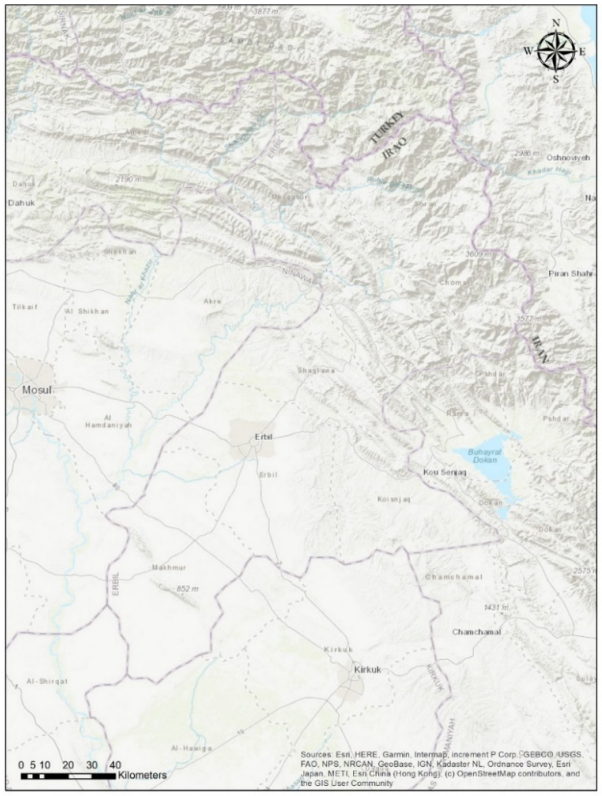

Fig. 6. Erbil governorate Topographic map (Study Area)

maximum likelihood classifier based on each date training classes.

Results and Discussion

Supervised classification was used to classify land cover classes. This was done to identify the various land cover classes, based on Landsat-5 land sat 8 and sentinal-2 images for all three decades of the study 2000, 2010 and 2018.

Fig.7, Fig. 8, and Fig.9 shows the study area classified for six classes (urban, vegetation, Barren land, agriculture, hilly areas and water). Visual comparison of the Landsat images for the years 2000, 2010 and 2018 showed significant change in the six land use/ land cover classes. The red color from the image represents the build-up (urban) class and this red shading had increased from11.86% to 20.13% originally, and then a further 29.12% between 2000, 2010 to 2018. It can be seen that the built-up (urban) class indicates urban growth; most substantial urban growth was shown in 2018. In 2000 urban area is more concentrated at the center of Erbil and this expands outward to its axis linearly in different directions. The color green represents agriculture & vegetation around Erbil city. Here, the agriculture rate has decreased from 29.01% to 39.21% then 27.13% respectively, between 2000, 2010 and 2018. The color light brown, representing barren land, reduced during the period of the study, and also decreased but more gradually between the years 2000 to 2018. It is shown clearly that in 2000 it was 40.42%, decreasing by 2018 to 23.67 %. The water class does not appear clearly because there is a lack

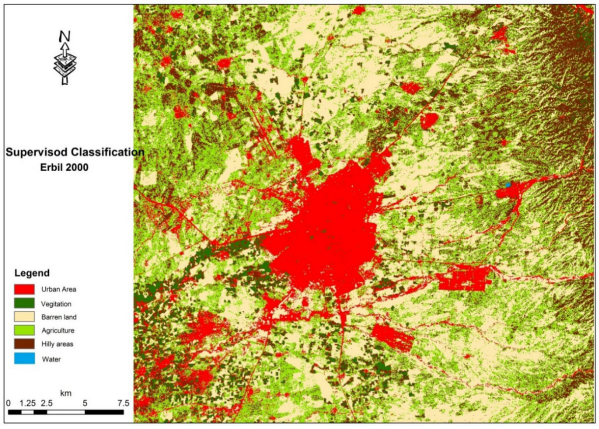

Fig. 7. Supervised classification for LU classes for the year 2000, (Source: Author)

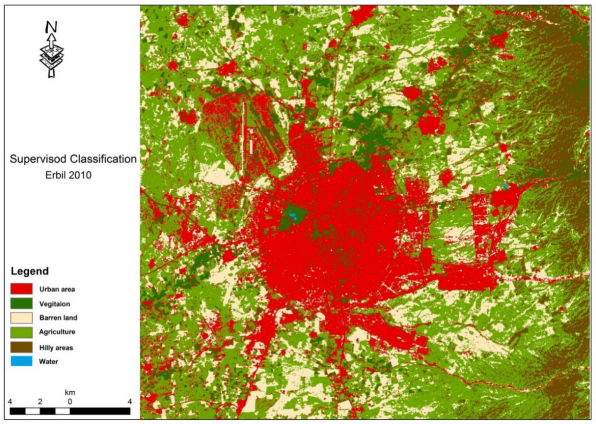

Fig. 8. Supervised classification for LU classes for the year 2010, (Source: Author)

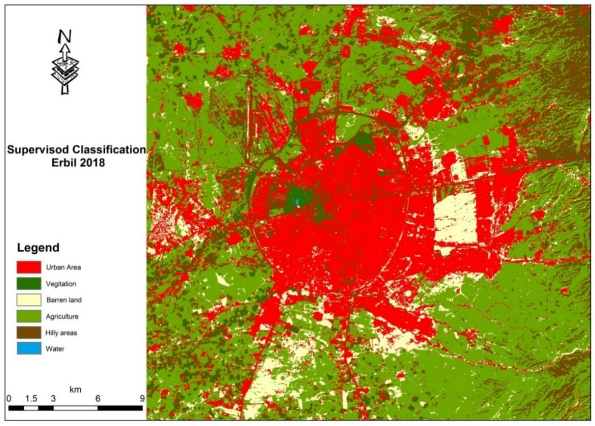

Fig. 9. Supervised classification for LU classes for the year 2018, (Source: Author)

of water in the city of Erbil. It can be seen that the water in 2000 was 3.04%, and by 2018 it had become 0.31%.

It can be seen from Table 4 that Urban Area was much smaller than 2018 because the number of populations was lower than 2018. Moreover, agriculture in 2000 was greater than 2018 and the area of the barren land has been reduced up to 2018. The reason for these significant changes is likely to be significantly due to the fact that, from 2000 to 2003, people were experiencing a financial crisis and after the fall of the former regime in Iraq, those living in the North of Iraq were in a better situation and began to try to develop their city.

In developing countries, cities facing many problems due to rapid urbanization, and the process of urban growth tend to be characterized by lack of planning and limited information to predict the direction of growth. In Erbil city, over the last 18 years, large areas of open land and (agriculture) have been transformed into more urban, deprived areas with considerable impact on social, economic,

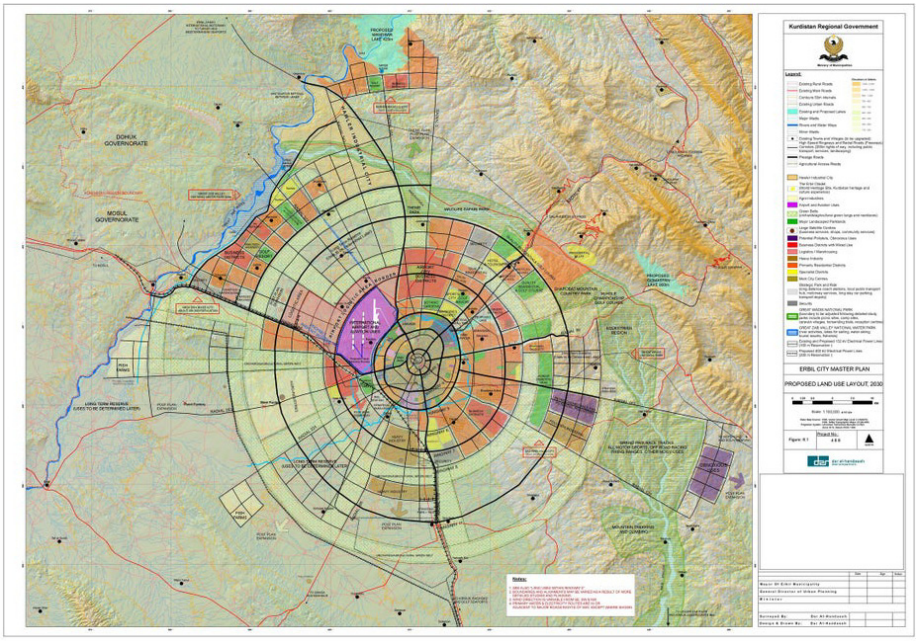

Fig. 10. Erbil governorate master plan which was approved in 2009 (source: Ministry of Municipality)

Table 4. LULC by (km^2) for the year 2000, 2010 and 2018

	LULC-2000		LULC-2010		LULC-2018	
Land Use	Area km^2	%	Area km^2	%	Area km^2	%
Urban	118.9	11.86	201.81	20.13	291.80	29.12
Vegetation	25.38	2.53	45.79	4.56	49.96	4.98
Barren land	405.03	40.42	205.27	20.47	237.27	23.67
Agriculture	290.73	29.01	392.95	39.21	271.9	27.13
Hilly areas	159.01	15.88	152.16	15.17	148.03	14.77
Water	3.04	0.30	4.21	0.42	3.14	0.31
Total	1002	100	1002	100	1002	100

physical and environment. Limitations to this research field should be addressed by carrying out more of such studies, which apply remote sensing and GIS techniques in order to support development in this important area.

The Period 2003- 2013

Erbil city as a capital, witnessed considerable growth and development after 2003. The first draft master plan for the city was prepared between 2006-

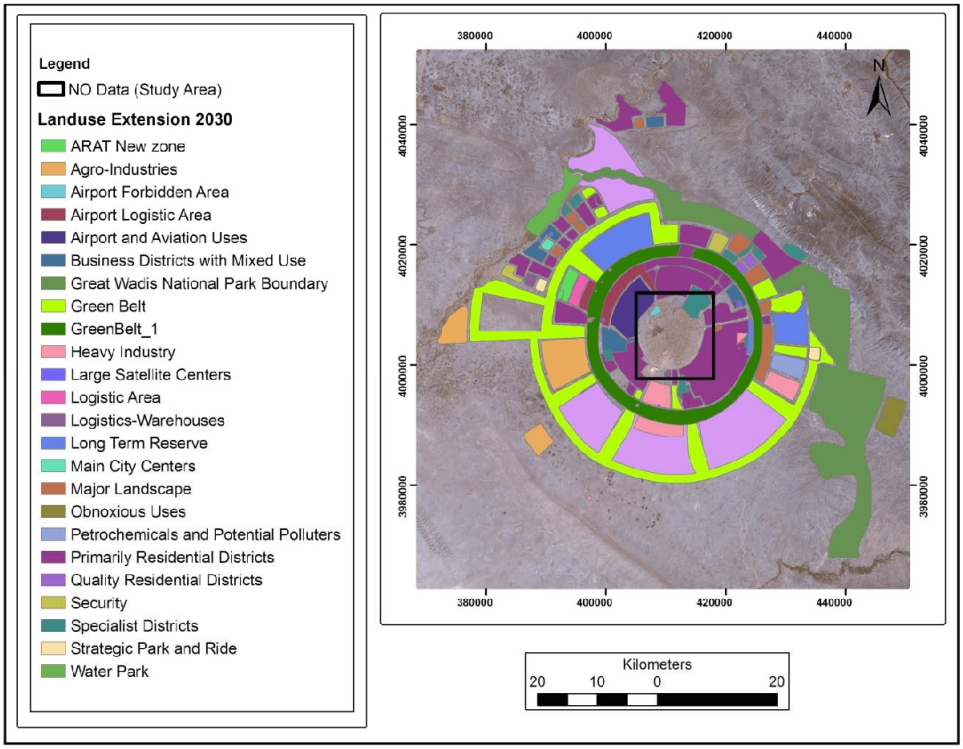

Fig. 11. Map of Proposed Land use according to Master plan of Erbil city up to 2030. (source: Erbil municipality, 2012)

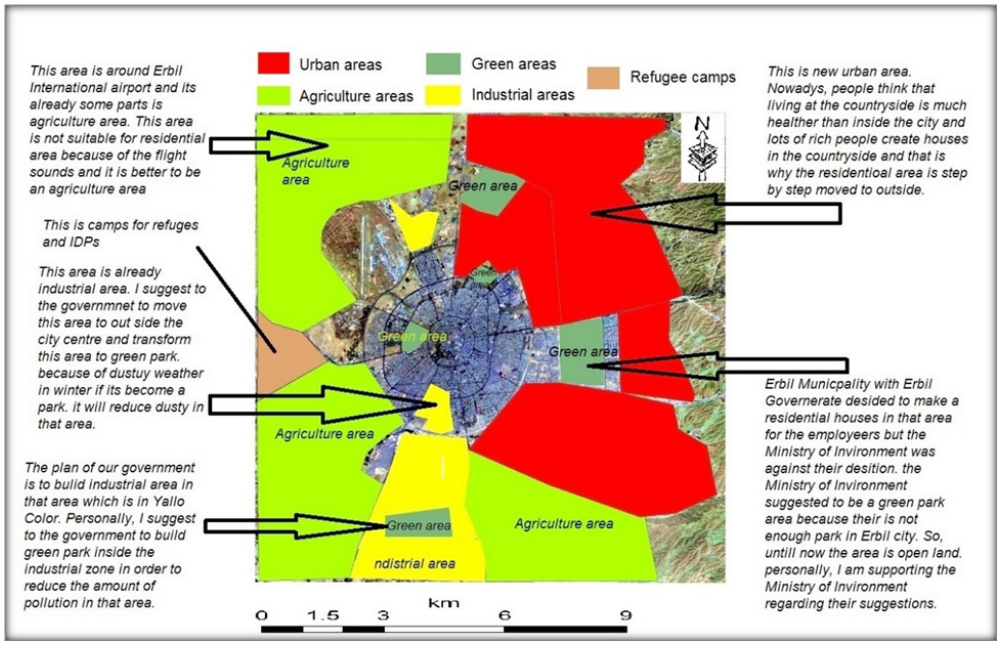

Fig. 12. Map of overgrown plan areas according author's idea. (source author)

2009. This was followed by preparation of the city center master plan (see the Fig. 10), with guidelines for the buffer zone of the citadel. This master plan for the first green belt area, issued an investment law from the Kurdistan parliament for Kurdistan number 4 in 2006. This resulted in the building of many residential complexes within Erbil city. Some amendments to the building regulations like this, led to considerable changes in the urban form and shape of the city (Hussein *et al.,* 2018).

The LULC maps of the target areas can be used for reference, and as a guide for strategy planning and management. Moreover this study is able to support decision makers in Erbil City in their efforts to make effective and environmentally beneficial policy and choices.

At present, the KRI plans to create new infrastructure in the Erbil region, and have recently built 120 mile road. It is interesting that the Government decided to build new residential areas far away from the centre of the city.

This is an overgrown city plan map is created by the author of this paper as a suggestion map in order to help the decision maker for the future changes that will occur in the city of Erbil.

Conclusion

Methods used in this research have been shown as suitable and effective in achieving the study objectives and addressing the research question. Remote sensing approach is essential for identifying patterns of urban land use/ land cover in order to support effective urban management and decision making processes relevant to the study. RS is a strong tool for monitoring urban growth as it is able to support the visualization of various land use/land cover classes in diverse spatio-temporal resolution. Using remote sensing method, the study has successfully analysed spatial patterns of urban growth and measure levels of changes in the urban land use/land cover classes

Rapid rates of urban expansion were seen between 2000 and 2018. In 2000, the rate was 118.9 km^2. By 2018, significant changes across the urban land use/land cover classes increased the rate of the change in the (urban) built-up area to 291.80 km^2.

Population growth is associated with an increase in the need for residential land and urban space for extra facilities. These pressures leads to significant change in urban land use/land cover classification. Rising population in the study area demonstrates higher pressure on social services, demand for housing, and even greater demand for residential land that can lead to even more transformed land use /cover. Changes in land use/land cover in the study area might be due to extreme demand for land consumption and poor agricultural practices like continuous farming and over browsing.

In addition, both political and socio-economic factors have played significant roles in determining those alterations in the land use/cover within the area of study. Findings from the study show that there has been rapid change in the built-up classes, after the UN removed economic sanctions on Iraq in 2003. The country then experienced a fast pace of economic development with the construction of infrastructure like roads, as well as growth in social facilities. Rural-urban migration is a key factor likely to have contributed to the urban sprawl in the study area.

Acknowledment

I would like to thank GOD for his help and support. Without His help it would have been impossible to succeed in this project. I would like to express my deep gratitude to my supervisor, Prof Dr. Necmettin Elmastas for their patient guidance, encouragement and useful criticism of this research work. Many thanks to Mr. Twana Hamad at Harran University, Soil Department, for technical support and guidance throughout paper preparation.

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