Polytechnic Journal
Polytechnic Journal

Volume 13 | Issue 1 Article 5

Land Use Land Cover Changes Detection of Erbil City Using GIS and Remote Sensing

Mohammed Ghadban Mohammed
Department of Water Resource Engineering, College of Engineering, Salahaddin University,Erbil,KurdistanRegion,Iraq,
muhammed.muhammed@su.edu.krd

How to Cite This Article
Mohammed, Mohammed Ghadban (2023) "Land Use Land Cover Changes Detection of Erbil City Using GIS and Remote Sensing," *Polytechnic Journal*: Vol. 13: Iss. 1, Article 5.
DOI: https://doi.org/10.59341/2707-7799.1729

Polytechnic Journal. 2023. 13(1)
ISSN: 2313-5727
http://journals.epu.edu.iq/index.php/polytechnic

POLYTECHNIC JOURNAL

RESEARCH ARTICLE

Land Use Land Cover Changes Detection of Erbil City Using GIS and Remote Sensing

Mohammed G. Mohammed1*

[1] *Department of Water Resource Engineering, College of Engineering, Salahaddin University, Erbil, Kurdistan Region, Iraq*

***Corresponding author:** Mohammed G. Mohammed, Department of Water Resource Engineering, College of Engineering, Salahaddin University, Erbil, Kurdistan Region, Iraq.

E-mail: Muhammed.Muhammed@su.edu.krd

Received: 20 April 2023
Accepted: 3 May 2023
Published: 20 September 2023

DOI: https://doi.org/10.59341/2707-7799.1729

ABSTRACT

Erbil City, the capital of the Kurdistan region in Iraq, witnessed significant land use land cover changes over the last two decades. These Land Cover Land Use (LULC) changes were attributed to many main social, political, climactic, and economic variables, especially after 2003 in Iraq. The use of geographic information systems and remote sensing became active tools that use public satellite images to detect LULC changes in cities. Two satellite images of Erbil City for 2003 and 2020 respectively have been used to analyze and get the nature and the magnitude of the LULC changes. Six LULC classes were recognized and compared for the sake of the analysis process. The LULC included barren, croplands, grasslands, open shrublands, savannas, and urban and built-up lands. Ground truth points were randomly projected and used to compare and validate the LULC class types. A confusion matrix was calculated based on the ground truth points comparison to assess the accuracy of the classes and to get the overall accuracy for the classified LULC. The LULC changes, magnitudes, and a table of "FROM-TO" changes were obtained. The maximum decrease change rate occurred in open shrublands with an average of ~ (-47%), however, the increase change rate in croplands was ~ (+17%), and for urbanizing areas was ~ (+11%). The barren and Savanna lands were proportionally small areas compared to other classes. The outcomes resulted in total accuracy was 90% with a Kappa Coefficient value was 0.878.

Key Words: Accuracy assessment, Kappa coefficient, Change detection, GIS, Image classification.

1. INTRODUCTION

Capitals and growing cities change continuously over time in their land cover land use (LULC). The change's amount and intensity differ from place to place. This is because of many social, political, climactic, and economic variables. Kurdistan Region's LULC in IRAQ has witnessed noticeable changes during the last two decades, especially in Erbil city after 2003. The LULC change is directly or indirectly related to population growth (Kafi et al., 2014). Having recent and up-to-date LULC global data is essential for other sciences for a better understanding of the environmental effects on the population and research studies (Giri et al., 2005). The most updated and accurate data that describe the land resources and changes at different times is vital in particular in rapidly growing cities (Yuan et al., 2005). People's growth in the Kurdistan Region of Iraq (KR) has significantly surged in this area because of the sudden circumstances and demographical changes by the local and national immigrants, especially over the second decade of 2003. The dramatically increased rate of growth leads to more built-up (Sabr, 2014), croplands, and barren areas, however, there is an expected decreased rate of vegetation land cover or shrublands which may be accompanied by this growth. Nowadays, Remote sensing is one of the significant tools that would be used for fast LULC changes in the urbanizing regions. These data are powerful natural and social science materials for various patterns in inflated areas (Alberti et al., 2004). Besides, remote sensing techniques have broadly been used to analyze the LULC changes (Gilmore et al., 2008). LULC "From- To" changes monitoring and management are so important for these inflated areas' decision-making planners and developers for successful urban regions' plans (Kafi et al., 2014). Pathman and akumar (2020) stated that successful LULC management is coming from a good understanding of LULC patterns and the interactions between the human environment and natural phenomena. He defined change detection as the way of identifying the state of an object or phenomenon by observing it over various times. Zimble et al. (2003) stated that LULC change detection over time is a significant process for many other scientific applications such as climate change research, land cover planning and management, and wildlife conservation. Bansod et al. (2018), and as cited in Hussain et al. (2020), GIS and RS are significant means for analyzing and studying urbanizing areas, with urban growth mapping and population density (Pozzi and Small, 2002), urban modeling (Herold et al., 2003), analyzing the LULC changes and its impacts on the environmental ecosystem (Milesi et al., 2003; Vivekananda et al., 2021b), and current and future potential mapping of the natural resources and LULC changes (Khwarahm, 2020).

2. Location

The location of the study of interest is located in the Northeast of KR (Khwarahm, 2021), in Erbil City (35° 45' N - 36° 24' N) latitude (43° 35.9' E - 44° 16' E) longitude, which is at the Capital of KR. The highest ground elevation at this city is 1092 m above sea level and the lowest ground elevation is 227 m above sea level based on the information derived from the Digital Elevation Model (dem) of 30-m resolution (USGS, 2014). The total area of KR, which includes three provinces/or governorates (Duhok, Erbil, and Sulaimani), is ~ 39,944 Km2 (Figure 1). The biggest province is Sulaimani and the smallest province is Duhok. Erbil governorate has a total area of ~ 14,547 km2. It includes 7 districts (Erbil, Choman, Kosinjaq, Makhmur, Mergasur, Shaqlawa, and Soran). The total area of Erbil district is ~ 2,554 km2. Erbil city has the Erbil Castel which is located at the center of Erbil city. Erbil city is perhaps the oldest present-day city in the world that witnessed urbanizing growth (Sabr, 2014). The climate in this providence is generally very hot in summer reaching 42,2 °C and cool, wet and in winter. The annual average maximum temperature is ~ 25.2 °C and the minimum temperature is ~ 13.9 °C. The main surrounding mountains (Choman, Mergasor, and Soran) locate in the northern and eastern parts of the Erbil Providence. The annual rainfall could range from 375 to 724 mm (Khwarahm, 2020). Guest (1966) stated and as cited in Khwarahm (2020), that Erbil is located within the most steppe zone. KR has witnessed dramatic changes after 2003, especially at the capital of KR because of mainly legislation factors and other social, economic, and political conditions. Many migrated Kurdish people who had been forced to leave outside of the KR to other countries during the 1960s to 2003 came back to the KR region (Sabr, 2014). Consequently, considerable urbanizing growth happened in this region, and Erbil in particular.

3. MATERIALS AND METHODOLOGY

3.1. Datasets

Two satellite images of Nasa LPDAAC Collections - MODIS Land Cover type MODIS MCD12Q1 V6 were required from the United States Geological Survey distribution website (EarthExplorer (usgs.gov)) and Nasa website (Earthdata | Earthdata (nasa.gov)). The MODIS land cover of 2003 and 2020 satellite images of HDF format were downloaded freely for the study area of Erbil city. Additionally, a digital elevation model of 30-m resolution from SRTM type SRTM 1 ARC-Second Global (EarthExplorer (usgs.gov)) was downloaded to show the elevations over the study area from the USGS website. The administrative areas shapefile of Iraq country was needed to extract land covers for the study area of Erbil city, the shape file was freely downloaded from the DIVA website (DIVA-GIS | free, simple & effective). All datasets are shown in **Table 1**.

3.2. LULC Classifications

The satellite images of 2003 and 2020 for the study area of Erbil City were downloaded and classified into six classes using the symbology tool available in ArcMap ver.10.6.1. The six recognized classes were barren lands which include very little vegetation and most of the land has no vegetation, croplands which most of the area are cultivated, grasslands which include short natural annual vegetations, open shrublands which include short woody perennials, savanna land covers which include high trees, and urban with built-up lands which include structural buildings with roads as shown in **Table 2**.

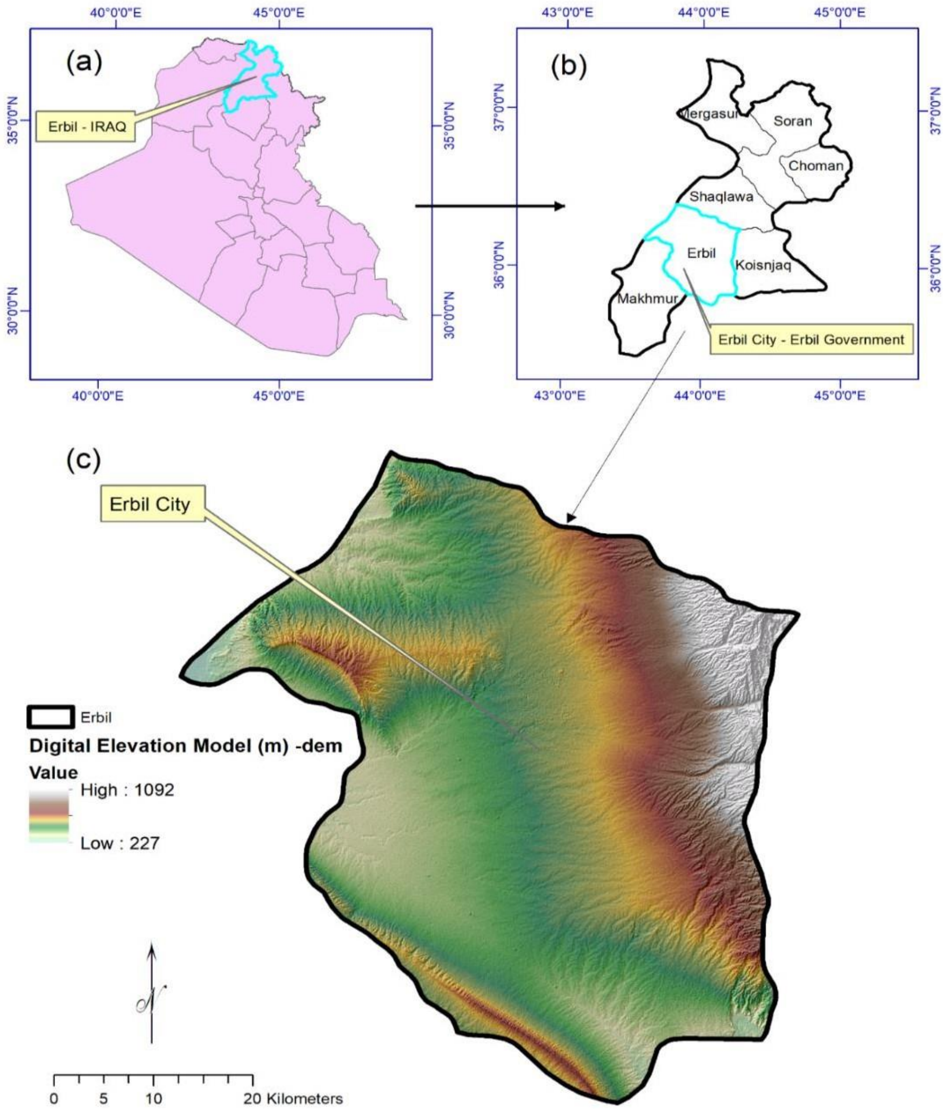

Figure 1: (a) Location of Erbil Governorate in Iraq, (b) Location of Erbil City in Erbil governorate, (c) The dem (30-m resolution) of the study area from (USGS, 2014).

Table 1: Datasets used in the study.

Year	*Name of data*	*Acquisition date*	*Format*	*Spatial resolution (m)*	*Links*
2003	Land cover land use	13/10/2022	HDF-satellite image	30	EarthExplorer (usgs.gov); https://www.earthdata.nasa.gov/
2020	Land cover land use	13/10/2022	HDF-satellite image	30	EarthExplorer (usgs.gov); https://www.earthdata.nasa.gov/
2014	Digital elevation (dem)	14/10/2022	GeoTIFF-1 Arc-second	30	EarthExplorer (usgs.gov)
2014	Administrative boundary	14/10/2022	Shapefile		DIVA-GIS | free, simple & effective

Table 2: MCD12Q1 International Geosphere-Biosphere Program (IGBP) legend and class descriptions (Sulla- Menashe and Friedl, 2018).

Name	*Legend*	*Description*
Barren	1	At least 60% of area is non-vegetated barren (sand, rock, soil) areas with less than 10% vegetation.
Croplands	2	At least 60% of area is cultivated cropland.
Grasslands	3	Dominated by herbaceous annuals (<2m).
Open shrublands	4	Dominated by woody perennials (1-2m height)10-60% cover.
Savannas	5	Tree cover 10-30% (canopy >2m).
Urban and Built-up Lands	6	At least 30% impervious surface area including building materials, asphalt, and vehicles.

3.3. Image Classification

3.4. Change Detection

To get LULC changes that occurred from 2003 to 2020, both LULC classified images for the study area of Erbil city were imported to ArcMap Ver. 10.6.1 environment, overlapped, and compared. The changes that occurred over the 17 years in this area were obtained based on the intersect Arc Toolbox available in Geoprocessing main menu. The key point in using this tool is that the LULC changes for each pixel of the study area of interest can be obtained which will be detected to see what changes occurred exactly for each pixel or area in this city over a period of time. The individual changes in the form of "**From-To**" Table as well as the total areas for each land cover class were tabulated for more statistical analysis and assessment. Finally, these changes in all areas, as well as the urbanizing area, were obtained. The change patterns and the magnitude were significant indicators for the urbanizing study area, especially for strategic decision-making and management.

3.5. Accuracy Assessment and Validation

To validate the outcomes of the analysis of the LULC changes between 2003, and 2020 respectively for the area of interest (AOI), it was necessary to use ground-truth points, 143 randomly projected and covered points, on the study area to compare the classes' values with the trusted image for the same locations of the recognized classes using Google Earth Pro.7.3.6.9345 (64-bit). Each of these ground-truth points was projected randomly at the downloaded LULC images and compared with the associated true historical Landsat locations from Google Earth Pro. 7.3.6.9345 (64-bit). The historical Landsat imagery of 2020 was used as truth background to detect the actual class for each projected point. When the change between the predicated satellite LULC images, which is the change between the image of 2003 and the image of 2020, and the true historical stored images on Google Earth Pro.7.3.6.9345 (64-bit) of the most up-to-date image (i.e., the image of 2020) have the same LULC classification and the LULC classifications for the projected points were correctly classified and the validation satisfied and lead to increase the accuracy of the classification, otherwise the predicated LULC classifications are wrong and will reduce the accuracy of the classification. A statistical methodology was used to evaluate and assess the class accuracy and the total accuracy using Kappa Coefficient equations. Eventually, a confusion matrix table of 6 main classes of land use land cover was summarized for the AOI with individual and total areas.

3.6. Determine the Change Magnitude

The simplest way to measure the LULC changes might be the reduction or expansion in the cell size of the class. Mahmud and Achide (2012), and as cited in Kafi et al. (2014) that the change values and the percent of the change were calculated as in **Equation (1)** and **Equation (2)** respectively.

$$K = F - I \tag{1}$$

$$A = \frac{F-I}{I} \times 100 \tag{2}$$

Where: k = value of the change; F = the first event (date); I = the second event (date); A = change percentage

3.7. Error Matrix - Kappa Coefficient

The population error matrix was used to describe the remote-sensing image which has N pixels. If the downloaded image which was used to do the statistical analysis has q classes/categories, then the general population error matrix will be in the following form (Stehman and Sensing, 1996).

In order to get Kappa coefficient and the accuracy of the classification, a random sampling was necessary. Bishop et al. (1975), and as cited in Kafi et al. (2014) **Equation (3)** and **Equation (4)** were used for this purpose.

$$\text{Kappa} = \frac{\sum_{i=1} p_{ii} - \sum_{i=1} p_{i+}\, p_{+i}}{1 - \sum_{i=1} p_{i+}\, p_{+i}} \qquad (3)$$

Where $p_{ii} = N_{ii}/ N$, $p_{i+} = N_i/N$, and $p_{+i} = M_i/ N$, or **Equation 3** could be written as:

$$\text{Kappa} = \frac{\sum_{h=1} (N_{hh}/N) - \sum_{h=1} \left(\frac{N_h}{N}\right)\left(\frac{M_h}{N}\right)}{1 - \sum_{h=1} \left(\frac{N_h}{N}\right)\left(\frac{M_h}{N}\right)} \qquad (4)$$

		Reference				Row Total
		1	*2*	. . .	*q*	
Image (Stratum)	1	N_{11}	N_{12}	. . .	N_{1q}	N_1
	2	N_{21}	N_{22}	. . .	N_{2q}	N_2
	.	.	.	. . .	.	.
	.	.	.	. . .	.	.
	.	.	.	. . .	.	.
	q	Nq_1	Nq_2	. . .	N_{qq}	N_q
Column Total		M_1	M_2	. . .	M_q	N

4. RESULTS

A symbology tool was used to classify both satellite images for the AOI in 2003 LULC and 2020 LULC. Five classified classes were recognized for 2003 LULC which included barren, croplands, grasslands, shrublands, and built-up lands, whereas six classes were recognized for 2020 LULC which included barren, croplands, grasslands, shrublands, savannas, and built-up lands as shown in **Figures 2** and **3** respectively.

Change detection in each pixel of the AOI was used to assess the type and the magnitude of the LULC change over the 17 years. The geoprocessing intercept tool was used to get the changing nature of “FROM-TO” that occurred in each portion of the AOI. The portions that overlapped and showed changes between the 2003 and 2020 LULC have been written in a new map, which included 24 new portions represented in new colors associated with each area in kilometers (Figure 4). Figure 5. contains the quantitative area in km2 of the LULC changes over the 17 years.

The changing area in km^2 and the changing percent of the total area for the AOI were computed and tabulated in **Table 3.** for evaluation purposes. The results showed that the maximum LULC that occurred in Erbil City after 2003 was in croplands which increased significantly by 58.62%, which is equivalent to 1496.62 km^2, followed by open shrublands converted to croplands by 9.77% or an equivalent area of 249.42 km^2. The total area that all witnessed LULC changes was 2553.58 km^2. **Table 3.** showed that most of the “**From-To**” changes occurred over the 17 years from converting big portions of other classes such as croplands, grasslands, open shrublands, and built-up lands respectively.

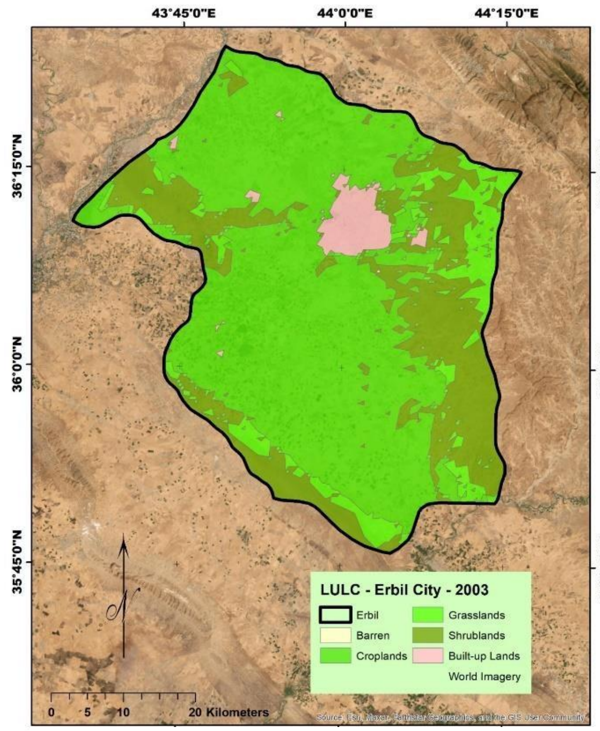

Figure 2: The LULC map for Erbil City - 2003 from (Earthdata | Earthdata (nasa.gov)).

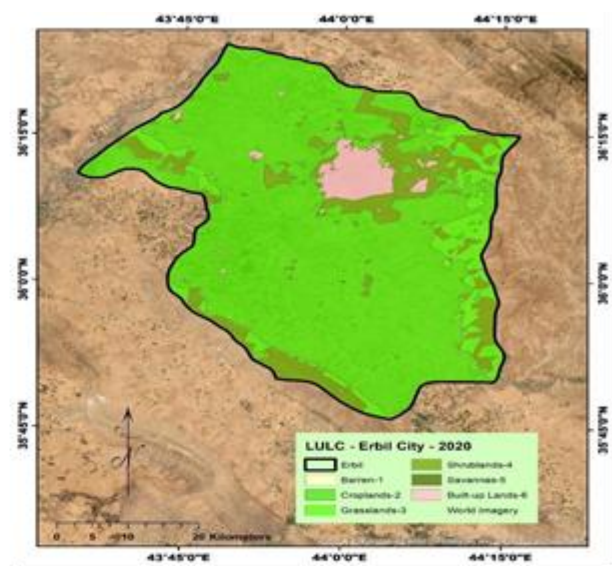

Figure 3: The LULC map for Erbil City - 2020 from (Earthdata | Earthdata (nasa.gov)).

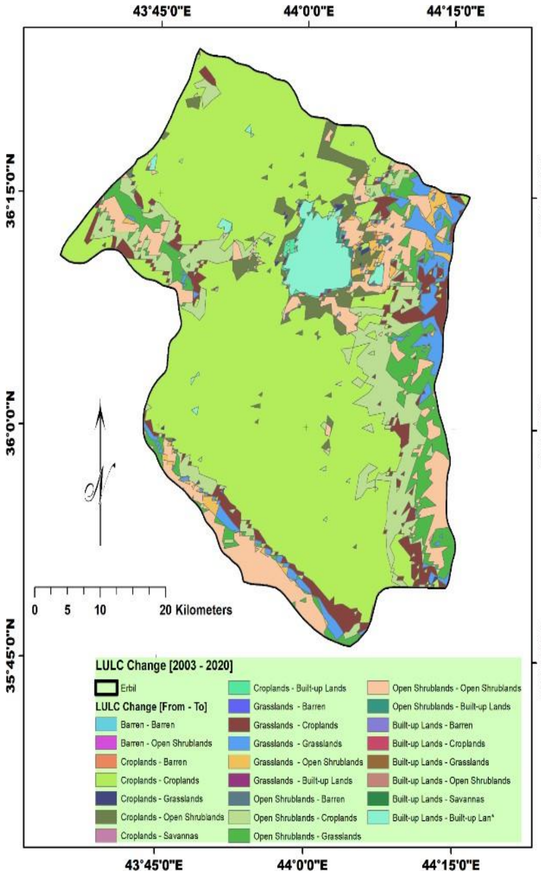

Figure4: The LULC |(From-To)changes map for Erbil City(2003-2020)

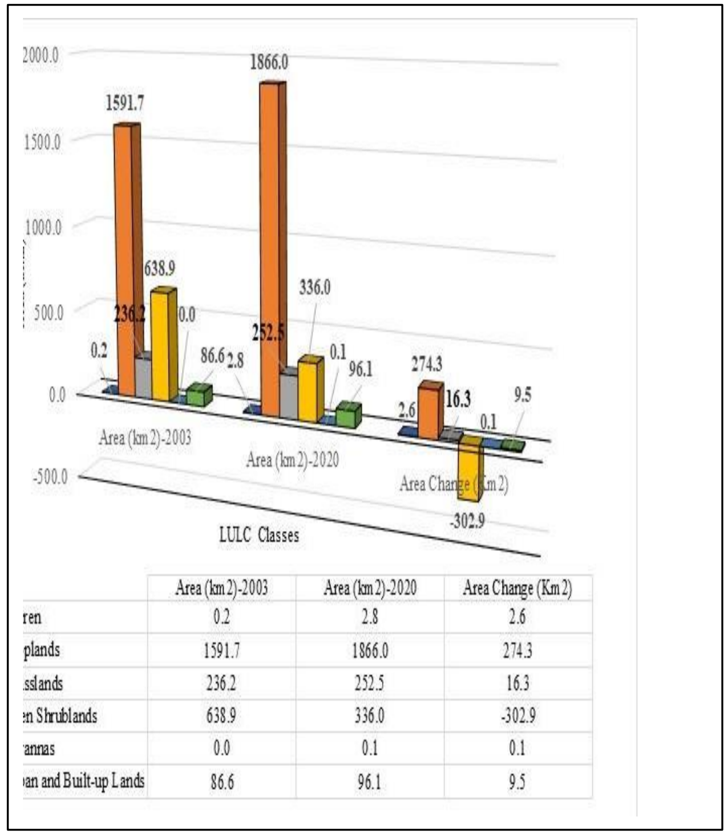

Figure 5: The LULC quantitative changing area graph in km² for Erbil City (2002-2020)

Table 3: LULC “From-To” changes with associated changing areas (km^2) during 2003-2020.

LULC Change (From-To)	*Changing Area (Km^2)*	*Change Percent (%)*
Barren - Barren	0.11	0.004
Barren - Open Shrublands	0.04	0.002
Built-up Lands - Barren	0.07	0.003
Built-up Lands - Built-up Lands	85.27	3.339
Built-up Lands - Croplands	0.35	0.014
Built-up Lands - Grasslands	0.29	0.011
Built-up Lands - Open Shrublands	0.60	0.023
Built-up Lands - Savannas	0.06	0.002
Croplands - Barren	0.43	0.017
Croplands - Built-up Lands	5.55	0.217
Croplands - Croplands	1496.92	58.620
Croplands - Grasslands	5.22	0.204
Croplands - Open Shrublands	83.50	3.270
Croplands - Savannas	0.09	0.004
Grasslands - Barren	0.17	0.007
Grasslands - Built-up Lands	1.01	0.040
Grasslands - Croplands	119.34	4.673
Grasslands - Grasslands	84.82	3.322
Grasslands - Open Shrublands	30.85	1.208
Open Shrublands - Barren	2.02	0.079
Open Shrublands - Built-up Lands	4.27	0.167
Open Shrublands - Croplands	249.42	9.767

A total of 143 pixels, each pixel representing 30 m x 30 m, were projected randomly to check change types using true historical images from Google Earth Pro. 7.3.6.9345. The accuracy per class was obtained for each land cover in the study area of interest. The accuracy per grasslands class was found to be the highest value at 97%, followed by grasslands at 95% class accuracy, on the other hand, the barren class was found to have the lowest class accuracy at just 82%.

Table 4: Confusion matrix table of LULC change derived from satellite data (2020).

User	*LULC*	*Barren*	*Croplands*	*Grasslands*	*Shrublands*	*Savannas*	*Built-up*	*Total*	*Accuracy per class (%)*
1	**Barren**	14	0	0	0	0	3	17	**82**
2	**Croplands**	1	39	0	0	0	1	41	**95**
3	**Grasslands**	0	1	29	0	0	0	30	**97**
4	**Shrublands**	0	1	1	14	0	0	16	**88**
5	**Savannas**	0	0	0	2	9	0	11	**82**
6	**Built-up**	2	0	0	0	2	24	28	**86**
	Total	17	41	30	16	11	28	**143**	

Table 5: The observed Kappa value for LULC change (2003-2020).

Observed Kappa	**Standard Error**	**0.95 Confidence Interval**	
		Lower Limit	Lower Limit
0.878	0.031	0.817	0.938

DISCUSSION

The barren area has raised from 0.20 km² in 2003 to 2.8 km² in 2020. Some of these areas came after converting other classes to barren, these classes' changes were caused by urbanization and other related factors. Open shrublands, croplands, grasslands , and built-up have been changed respectively to barren classes. Most LULC changes occurred in the croplands class which increased significantly over the 17 years. These LULC changes might be because of the significant increase in population and new immigrants coming to the country due to the big political changes in the region and its neighbors in general, and in the Kurdistan region in particular. The noticeable raise in the number of human and immigrant people from inside and outside of the region needed more secure food resources such as croplands. The total changing LULC area was 274.3 km², which represents (+17%), as shown in **Figure 5**. Additionally, the next biggest area change increase was in the grasslands class which surged from 236.2 km² in 2003 to 252.5 Km² in 2020 (i.e., an increased rate in LULC was +7%). Most of the grasslands came from the open shrublands, croplands, and built-up land changes. The drastic decrease in LULC changes that occurred in the AOI was in the open shrublands which dropped from 638.9 km² to 336.0 km² in 2020. The decrease rate in the LULC was ~ (-47%). The majority of the open shrublands have been converted to croplands, grasslands, urban and built-up, and barren successively as shown in **Table 3**. The other changes were in the urban and associated areas which increased within this time due to urbanizing, the area change was ~9.5 km². This increased rate in the LULC class, which is ~ (+11%) because of the need for more habitats and more new roads for the increased growth of people. Large portions of

CONCLUSION

Using satellite images was effective in assessing individual and overall changes in LULC for the selected location in Erbil City. This evaluation was so important for decision-making and city planning purposes, especially for an emerging city like Erbil City throughout the period 2003 to 2020. The LULC changes were expected to continue for the upcoming years. Looking at the previous LULC changes was essential to understand the changing pattern for the study area. The LULC change detection information in the form of "**From - To**" gave valuable detailed results for each individual and overall pixels, with their LULC change percentage. The maximum change occurred in the Open shrublands which declined significantly from (638.9 km^2) in 2003 to (336.0 km^2) in 2020, a LULC change of (-302.9 km^2). The decline rate in the open shrublands was ~ (-47%). On the other hand, the maximum increased LULC that occurred during the study period was in croplands from (1591.7 km^2) to (1866.0 km^2), a LULC change of (+274.3 km^2). The increased change rate in croplands was ~ (+17%). The other increased LULC changes were in grassland, urban and built-up, barren, and Savannas areas with different change rates. The(+11%) which was considered a good indication of developed areas in the capital. The barren and Savanna lands were proportionally small and not noticeable areas to other bigger LULC classes. The results of using supervised classification showed that the change detection algorithm was successful and powerful in analyzing the LULC changes just from two satellite images of the AOI. The total accuracy was 90% and the Coefficient of Kappa was 0.878 which is more than the minimum required total accuracy of 85% as stated by Anderson's (1976) classification scheme.

REFRENCES

ALBERTI, M., WEEKS, R., COE, S. J. P. E. & SENSING, R. 2004. URBAN LAND-COVER CHANGE ANALYSIS IN CENTRAL PUGET SOUND. 70, 1043- 1052.

ANDERSON, J. R. 1976. A LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA, US GOVERNMENT PRINTING OFFICE.

BANSOD, R., DANDEKAR, U. J. J. O. P. & PHYTOCHEMISTRY 2018. EVALUATION OF MORNA RIVER CATCHMENT WITH RS AND GIS TECHNIQUES. 7, 1945-1948.

BISHOP, Y. M. M., HOLLAND, P. & FIENBERG, S. E. 1975. DISCRETE MULTIVARIATE ANALYSIS: THEORY AND PRACTICE.

GILMORE, M. S., WILSON, E. H., BARRETT, N., CIVCO, D. L., PRISLOE, S., HURD, J. D. & CHADWICK, C. J. R. S. O. E. 2008. INTEGRATING MULTI-TEMPORAL SPECTRAL AND STRUCTURAL INFORMATION TO MAP WETLAND VEGETATION IN A LOWER CONNECTICUT RIVER TIDAL MARSH. 112, 4048-4060.

GIRI, C., ZHU, Z. & REED, B. J. R. S. O. E. 2005. A COMPARATIVE ANALYSIS OF THE GLOBAL LAND COVER 2000 AND MODIS LAND COVER DATA SETS. 94, 123-132.

GUEST, E. R. 1966. INTRODUCTION TO THE FLORA, AN ACCOUNT OF THE GEOLOGY, SOILS, CLIMATE, AND ECOLOGY OF IRAQ WITH GAZETTEER, GLOSSARY, AND BIBLIOGRAPHY. FLORA OF IRAQ, 1, 313 PP.

HEROLD, M., GOLDSTEIN, N. C. & CLARKE, K. C. J. R. S. O. E. 2003. THE SPATIOTEMPORAL FORM OF URBAN GROWTH: MEASUREMENT, ANALYSIS AND MODELING. 86, 286-302.

HUSSAIN, S., MUBEEN, M., AHMAD, A., AKRAM, W., HAMMAD, H. M., ALI, M., MASOOD, N., AMIN, A., FARID, H. U., SULTANA, S. R. J. E. S. & RESEARCH, P. 2020. USING GIS TOOLS TO DETECT THE LAND USE/LAND COVER CHANGES DURING FORTY YEARS IN LODHRAN DISTRICT OF PAKISTAN. 27, 39676-39692.

KAFI, K., SHAFRI, H. & SHARIFF, A. AN ANALYSIS OF LULC CHANGE DETECTION USING REMOTELY SENSED DATA; A CASE STUDY OF BAUCHI CITY. IOP CONFERENCE SERIES: EARTH AND ENVIRONMENTAL SCIENCE, 2014. IOP PUBLISHING, 012056.

KHWARAHM, N. R., QADER, S., ARARAT, K. & FADHIL AL-QURAISHI, A. M. 2021. PREDICTING AND MAPPING LAND COVER/LAND USE CHANGES IN ERBIL /IRAQ USING CA-MARKOV SYNERGY MODEL. EARTH SCIENCE INFORMATICS, 14, 393-406. KHWARAHM, N. R. J. E. P. 2020. MAPPING CURRENT AND POTENTIAL FUTURE DISTRIBUTIONS OF THE OAK TREE (QUERCUS AEGILOPS) IN THE KURDISTAN REGION, IRAQ. 9, 1-16.

MAHMUD, A. & ACHIDE, A. J. E. R. J. 2012. ANALYSIS OF LAND USE/LAND COVER CHANGES TO MONITOR URBAN SPRAWL IN KEFFI-NIGERIA. 6, 130-135.

MILESI, C., ELVIDGE, C. D., NEMANI, R. R. & RUNNING, S. W. J. R. S. O. E. 2003. ASSESSING THE IMPACT OF URBAN LAND DEVELOPMENT ON NET PRIMARY PRODUCTIVITY IN THE SOUTHEASTERN UNITED STATES. 86, 401-410.

PATHMAN & AKUMAR, V. J. W. N. O. N. S. 2020. A STUDY OF LAND COVER CHANGE DETECTION IN ODDUSUDDAN DS DIVISION OF MULLAITIVU DISTRICT IN SRI LANKA BASED ON GIS AND RS TECHNOLOGY. 29, 198-211.

POZZI, F. & SMALL, C. 2002. VEGETATION AND POPULATION DENSITY IN URBAN AND SUBURBAN AREAS IN THE USA. THIRD INTERNATIONAL SYMPOSIUM OF REMOTE SENSING OF URBAN AREAS, 1-6.

SABR, C. J. H. S. S. R. C.-R. 2014. A STUDY ON THE URBAN FORM OF ERBIL CITY (THE CAPITAL OF KURDISTAN REGION) AS AN EXAMPLE OF HISTORICAL AND FAST GROWING CITY. 3, 325- 340.

STEHMAN, S. J. P. E. & SENSING, R. 1996. ESTIMATING THE KAPPA COEFFICIENT AND ITS VARIANCE UNDER STRATIFIED RANDOM SAMPLING. 62, 401-407.

SULLA-MENASHE, D. & FRIEDL, M. A. J. U. R., VA, USA 2018. USER GUIDE TO COLLECTION 6 MODIS LAND COVER (MCD12Q1 AND MCD12C1) PRODUCT. 1, 18.

USGS, DIGITAL ELEVATION IN: AGENCIES, E. A. C. (ED.) 2014 ED. EARTHEXPLORAL USGS, U.S. DEPARTMENT OF GEOLOGY AND COOPERATING AGENCIES.

VIVEKANANDA, G. N., SWATHI, R. & SUJITH, A. 2021B. MULTI-TEMPORAL IMAGE ANALYSIS FOR LULC CLASSIFICATION AND CHANGE DETECTION. EUROPEAN JOURNAL OF REMOTE SENSING, 54, 189-199.

YUAN, F., SAWAYA, K. E., LOEFFELHOLZ, B. C. & BAUER, M. E. J. R. S. O. E. 2005. LAND COVER CLASSIFICATION AND CHANGE ANALYSIS OF THE TWIN CITIES (MINNESOTA) METROPOLITAN AREA BY MULTITEMPORAL LANDSAT REMOTE SENSING. 98, 317-328.

ZIMBLE, D. A., EVANS, D. L., CARLSON, G. C., PARKER, R. C., GRADO, S. C. & GERARD, P. D. J. R. S. O. E. 2003. CHARACTERIZING VERTICAL FOREST STRUCTURE USING SMALL-FOOTPRINT AIRBORNE LIDAR. 87, 171-182.