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Kaifi Chomani
Civil Engineering Department, University of Raparin, Ranya, Sulaymaniyah, Kurdistan Region 46012, Iraq, kaifi.chomani@uor.edu.krd

Shwana Braim Hassan Manguri
Civil Engineering Department, University of Raparin, Ranya, Sulaymaniyah, Kurdistan Region 46012, Iraq

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Abstract

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Keywords

Change detection; GIS; LULC; Remote sensing; Landsat

ORIGINAL ARTICLE

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Kaifi Chomani*, Shwana Braim Hassan Manguri

Civil Engineering Department, University of Raparin, Ranya, Sulaymaniyah, Kurdistan Region 46012, Iraq

Abstract

Integration of GIS and remote sensing is a powerful source for implementing temporal analysis. The focus of this paper was to use Landsat 5 and 8 imageries to monitor the impact of urbanization and decrease of agriculture land in the Ranya city throughout five time periods (2000, 2005, 2010, 2015, and 2020). Image classification was done using ISO cluster unsupervised classification tool via ArcGIS. To calculate the kappa coefficient and assess the accuracy, random points of the outcome were compared with ground truth data using Google Earth Pro, which produced highly accurate results. According to this study, the Ranya city had the highest proportion of green space (52%) in 2000. Though, after 20 years due to rapid urbanization, Ranya's built-up regions had quickly outgrown both bare land and agricultural land, growing in size by 223.53%. However, from the year 2000−2020, green spaces and bare land both showed a clear downward trend, losing, respectively, 44.9% and 41.3% of their space and resulting in critical decline in agricultural production. Being an independent administration is one of the key causes of Ranya city's rapid urbanization and subsequent development between 2000 and 2020, in addition to other aspects like the building of numerous government and residential facilities.

Keywords: Change detection, GIS, LULC, Remote sensing, Landsat

1. Introduction

Urbanization is a global phenomenon, but it happens extremely rapidly in developing nations. This become twice for a developed country like Iraq since the year 2000. According to Bank 2023 [1] the Iraqi population for the years 2000, 2005, 2010, 2015, and 2020 rapidly increased as 24,628,858, 28,698,684, 31,264,875, 37,757,813, and 42,556,984 respectively. Due to the constant increase in population, managing water resources, protecting land, and sustainable development are currently global concerns. Urbanization causes many environmental issues such as reducing the quality of air, quality of water deteriorating, increase in land surface temperature, increasing runoff causing occasional flooding, and decrease in groundwater infiltration. Consequently, urban development monitoring is an essential step towards the development of a society with a more sustainable future [2]. Alterations of land use land cover (LULC) have a negative effect on climate patterns, dynamics of socio-economic, and natural hazards on a regional and global scale [3−5]. Besides the population growth economic development, topography, land slope, climate, and soil type [7,8]. Population growth causes an increase in human activities and has resulted in alteration in the natural landscape and environmental management [4,8]. Vegetation, water, and soil have all been negatively impacted as a consequence of rapidly changing LULC, especially in developing countries [9−11]. For urban planners and policymakers to consider the proper strategies and monitoring techniques, identifying the trends of urban land use transitions and their driving factors is critical [12].

LULC variations are important for a wide range of fields, including harvesting, hydrodynamics, forest management, earth sciences, ecology, and the environment [4,13−15]. For the environment's preservation, it is essential to determine the trends

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* Corresponding author.
E-mail address: kaifi.chomani@uor.edu.krd (K. Chomani).

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in LULC [16], although it's more simple and effective to evaluate changes in LULC due to the accessibiliy of remote sensing data [17]. Integration of GIS and satellite remote sensing (RS) is a powerful and cost-effective way to evaluate temporal and spatial changes in LULC [18,19]. Remote sensing data in the form of satellite imageries is a very useful source for LULC monitoring due to its sequential land coverage and real-time data acquisition, easy to process, and accurately georeferenced [20–22]. In addition, GIS is a decision-support tool which helps urban planning. Urban sprawl can be easily modelled in a GIS environment and reveals its spatial patterns [4]. In Iraq, several researchers have conducted research on LULC for many cities and regions for instance [23]; has conducted research on Dohuk city that shows changes in LULC and its effect on land surface temperature while [24] has used LULC for predicting land surface temperature. Sulaimaniyah city is considered as a case study by [25] for spatial modelling of LULC change. In addition [26], used a semi-automated object-based approach to detect the change in LULC in the Kurdistan region-Iraq. Furthermore, LULC change detection studies have been conducted for Baghdad city, Erbil city, Sulaimaniyah governorate, Dohuk governorate, Zakho District, Kirkuk city, Mosul district, Basrah province, and Halabja city by a number of researchers [27–35] respectively, that they used a different source of data and various methodologies.

The current study considered Ranya City as a case study for monitoring the transition of LULC, urbanization and decrease of agriculture between 2000 and 2020. For that purpose, remote sensing and GIS are integrated with the aid of ArcGIS 10.8. The outcomes of this study will be applied to future plantings, the management of resources, and the development of policies and decision-makers for the sustainable use of land in the city.

2. Methodology

2.1. Study area

Ranya, one of the most populated districts in Sulaymaniyah Governorate with a population of (102,571) people in 2018, is located in Kurdistan Region, Iraq, at 36° 15′ 15″ N and 44° 52′ 57″ E latitude and longitude (Fig. 1). It is in the northwest of Sulaymaniyah City and is approximately 93 km straight line distance from Sulaymaniyah's city

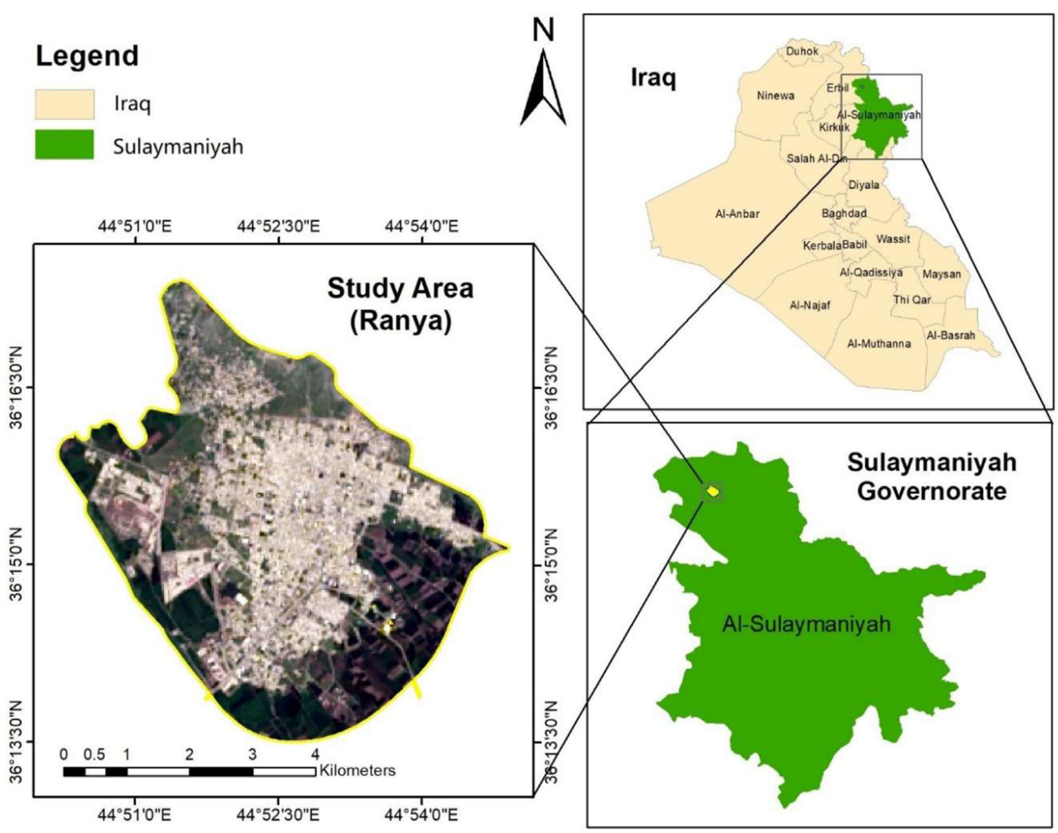

Fig. 1. Research study area (Ranya city).

centre. Its elevation with respect to the MSL is nearly between 537 and 862 m. Ranya municipality has an area of nearly 27.15 km^2. The town is encircled by three mountain regions and a lake: Asos to the east, Hajila to the west, Kewerash towards the north, and Dokan Lake to the south, which is the biggest lake in the Kurdistan region of Iraq. Considering that Ranya has a Mediterranean climate, its winters are cold and wet, while its summertime is dry and hot, with a yearly rainfall of 705 mm and an annual temperature average of (32.3 °C) [1].

2.2. Data and preprocessing

Considering quality of images, cloud cover, and dry weather, we selected available satellite images to assess LULC classification. Five remotely sensed data sets were used for Ranya city, utilizing Path/Row 169/35, the Landsat 5 satellite (thematic mapper) for the years 3 May 2000, 17 May 2005, 6 May 2010, and the Landsat 8 satellite (operational land imager) for 13 May 2015 and 10 May 2020. The data was obtained through the USGS Earth Explorer service, an open-source website for acquiring remotely sensed data. Landsat imageries that have been spatially georeferenced (GeoTIFF) were used for LULC classification. Landsat images had identical spatial resolution (30 m). We used Collection 2 Level 2 Landsat products because they were atmospherically corrected and enhanced radiometric calibration [37]. The acquired five images were then classified using LULC through ArcGIS 10.8.

3. Results and discussion

Two techniques of classification, supervised and unsupervised, are commonly used to classify images and determine identical patterns [38]. We applied an unsupervised classification technique to extract different elements of LULC, which enables a computer to categorise your image based on statistical distinctions in pixel spectral characteristics (https://www.esri.com). The Iso Cluster Unsupervised Classification algorithm was used in this study because it is based on machines and involves only a small amount of human work [39]. We used ArcGIS (version 10.8) to perform spatial analyses of the study area, including classifying of LULC, evaluating the accuracy, and monitoring changes (Fig. 3). The LULC categories were classified into the constantly appearing categories: bare land, settlement, and vegetation (Table 1).

We acquired three Landsat 5 images and two Landsat 8 images from USGS Earth Explorer. The

Table 1. LULC classification scheme.

Class	Description
Green area	Agriculture, grass and cultivated area.
Bare land	Open land, bare ground and uncultivated area.
Settlement	Built up area and roads

images had a UTM Zone of 38N and a WGS 1984 projected coordinate system. Landsat 5 and 8 have a total of 7 and 11 bands respectively. We only employed bands 1 to 7 because bands 8 to 11 were unrelated. It is noteworthy to consider that band combinations may affect the determination of different LULCs [2]. Images of poor quality make it difficult to distinguish between cultivated areas and bare land [2]. The unsupervised classification was more applicable to differentiate between the bare land and cultivated area using visual assessment and was more accurate for our study area.

After Iso Cluster Unsupervised Classification was done, raster data were changed to polygon using Raster to Polygon tool, and similar LULC parts in the attributes table were combined using geoprocessing tools (dissolve). GIS and Google Earth were used to evaluate the accuracy by making random sampling points for the various categories of land use [3]. Stratified randomised sampling points are a type of random selection that is used to test the accuracy of each LULC class by giving each class a certain number of points [4,5].

The accuracy of LULC maps for the years 2000, 2005, 2010, 2015, and 2020 was evaluated based on 263 points. We randomly assigned 54, 51, 58, 50, and 50 points, respectively, to the settlement, bare land, and green area classifications. The sample points were extracted to Google Earth Pro as kml file. Since there were no reference maps for our study area, we used Google Earth Pro to properly assess LULC classifications. Google Earth Pro satellite images were used to compare ground data with LULC map locations. Resolution, data validations, and date all affect accuracy of Landsat images [7]. However, in the absence of information related to random points, field trips should be performed [2].

For the years 2000, 2005, 2010, 2015, and 2020, we computed the producer and user accuracy within every LULC category, in addition to the Kappa coefficients and overall accuracy (Table 3). According to the Kappa coefficient agreement, the KC and OA show that the evaluation of the accuracy of LULC features for the specified years is highly accurate and acceptable (Table 2). The following formulas are the assessment criteria for calculating the kappa coefficient [5]:

Table 2. Kappa coefficient agreement [6].

No.	Kappa coefficient	Category
1	Under 0.4	Poor
2	0.4 < KC < 0.5	Fair
3	0.55 < KC < 0.7	good
4	0.7 < KC < 0.85	Very good
5	KC > 0.85	Excellent

$$UA = \frac{CR}{TR} \tag{1}$$

Where UA symbolises the accuracy of the user and CR is the proportion of rows with valid categorization. The term "TR" refers to the total of all pixels classified as "same row".

$$PA = \frac{CC}{TC} \tag{2}$$

Where CC stands for the number of pixels in each column category that were correctly classified, and PA stands for producer's accuracy. TC represents the exact classification of all pixels in the column category.

$$OA = \frac{CD}{TR} \tag{3}$$

If we define "CD" as the number of diagonally correctly classified pixels, then "OA" would refer to the overall accuracy. There are a total number of reference points, represented by TP.

$$KC = \frac{(TP * CD) - \sum(TC * TR)}{TP^2 - \sum(TC * TR)} \tag{4}$$

Where the kappa coefficient is KC.

After an assessment of accuracy, the area and percentages for LULC classes were derived for analysis (Fig. 3) (Table 4).

This study monitored changes in LULC in Ranya city from 2000 to 2020 using a unique blend of USGS remote sensing data and GIS tools. The result showed that, in 2000, over 50% of Ranya's territory was covered by green area which was the highest LULC, followed by nearly 36% of bare land (Table 4), however, settlement area was the lowest with only about 12% (Fig. 4). Surprisingly, in only 20 years Ranya lost about 16% of its green area and 11% of its bare land (Table 5) just to be replaced by a dramatic increase of settlements with a change from only 12% to almost 40% which made it to be the highest LULC in 2020 (Table 4). The reason for this prompt urbanization was due to the immediate development of Ranya city in 20 years such as becoming an independent administration in 2012, building several Institutional facilities like opening the University of Raparin in 2010, increasing business enterprises, new residential areas, and government service areas. Although the Kurdistan government's unplanned employment after 2003 increased people's personal income, a significant number of individuals left their rural villages and farming lifestyles and immigrated to Ranya's central area, our findings align with previous researches who also observed urbanization and its impact of the environment [45–49].

The result of our research shows that from 2000 to 2020 green areas and bare land lost 4.4 and 2.8 km^2 respectively, while urban areas increased by 7.2 km^2 (Table 4). Although, the most rapid urbanization was from 2000 to 2005 when the settlement area

Table 3. Evaluating accuracy of the classified LULC. (PA) Producer accuracy, (UA) user accuracy.

Year	2000		2005		2010		2015		2020	
LULC	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA
Green area	96	92.31	95.46	87.5	100	97.56	100	76.2	90	94.74
Bare land	94.12	88.89	81.25	92.86	50	100	77	90.91	90	75
Settlement area	83.33	100	100	100	100	100	85.71	100	95	100
Overall	92.59		92.16		98.28		92		92	
Kappa Coefficient	0.88		0.88		0.96		0.82		0.88	

Table 4. LULC map areas and percentages for 2000, 2005, 2010, 2015 and 2020 (Ranya city).

Year	2000		2005		2010		2015		2020	
LULC (Area)	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Green area	14.19	52.28	12.85	47.40	12.81	47.23	11.65	42.93	9.79	36.09
Bare land	9.72	35.81	7.42	27.36	6.95	25.60	5.88	21.69	6.88	25.38
Settlement area	3.23	11.91	6.85	25.24	7.37	27.17	9.60	35.38	10.45	38.53
Total	27.13	100	27.13	100	27.13	100	27.13	100	21.12	100

Table 5. Change in LULC between 2000 and 2005, 2005—2010, 2010—2015, 2015—2020 and 2000—2020 (Ranya city).

Year	2000—2005		2005—2010		2010—2015		2015—2020		2000—2020	
LULC (Area)	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Green area	−1.34	−4.9	−0.04	−0.1	−1.16	−4.3	−1.86	−6.86	−4.4	−16
Bare land	−2.3	−8.5	−0.47	−1.7	−1.07	−3.9	+1	+3.69	−2.84	−10
Settlement area	+3.62	+13.3	+0.52	+1.9	+7.37	+27	+0.85	+3.1	+7.22	+26

doubled from 3.23 km^2 to 6.68 km^2 (Fig. 5) which the fall of the Sadam Hussein regime and recognizing the autonomy of the Kurdistan region by the Iraqi government had significant impact on this matter. Our result showed that from 2000 to 2020, the total area of urban/built-up increased dramatically (223.53%), while green area and bare land significantly decreased (44.9%) and (41.3%), respectively. Urban/built-up is the land cover feature that is changing at the fastest rate, followed by vegetation and bare land, in that order.

The LULC change was extracted from (2000—2005, 2005—2010, 2010—2015, 2015—2020, and 2000—2000) (Fig. 2; (a), (b), (c), (d), and (e)). Our result (Fig. 6; a) shows that from 2000 to 2005, areas of 2.14 km^2 and 3.32 km^2 of bare land transitioned into urban/built-up and green areas, respectively. 3.01 km^2 transitioned from the green area to bare land, and also 1.57 km^2 was replaced by the settlement area. However, as expected, settlement areas were barely replaced with vegetation and bare land by only 0.01 km^2 and 0.09 km^2, respectively (Table 6).

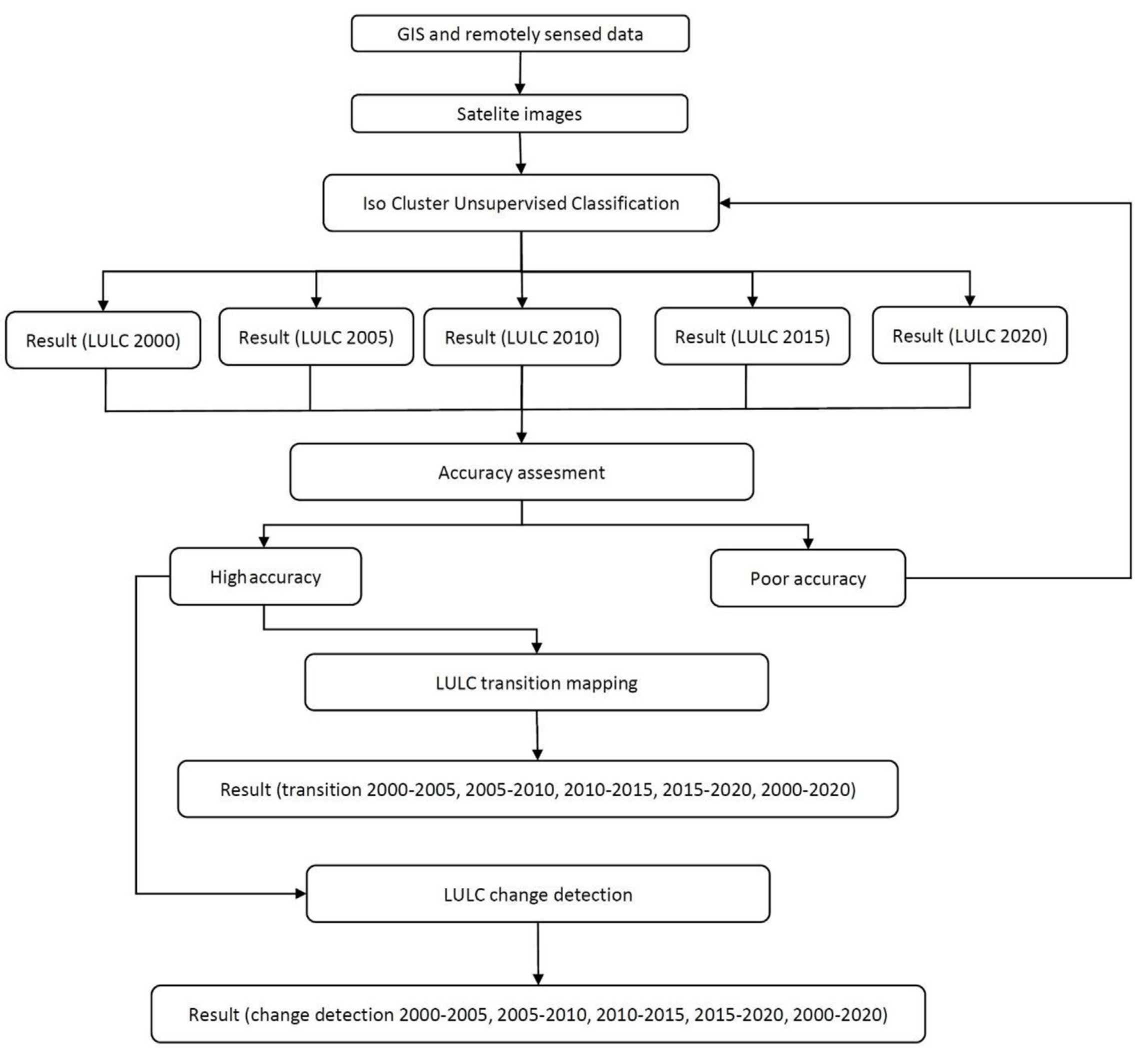

Fig. 2. Flowchart of LULC change detection.

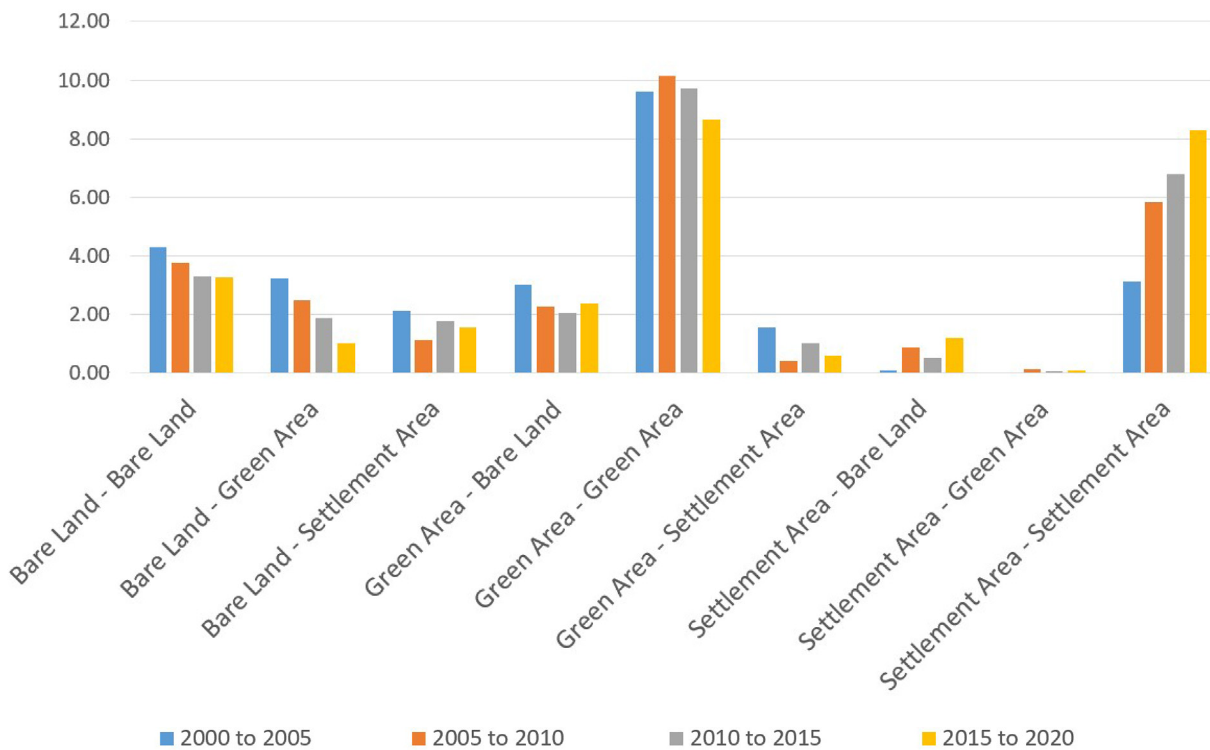

Fig. 3. LULC Transition of Ranya (2000–2005, 2005–2010, 2010–2015, and 2015–2020), area in km^2.

The result indicates that for 2005–2010 (Fig. 6; b) urban/built-up and green areas replaced 1.18 km^2 and 2.5 km^2 of bare land area, respectively. Although merely 0.41 km^2 of green features were replaced by settlement area, 2.28 km^2 transitioned from green area to bare land. However, vegetation and bare land transitioned from settlement area by 0.14 km^2 and 0.88 km^2, respectively (Table 6). Between 2010 and 2015 (Fig. 6; c), 1.77 km^2 of bare land and 1.03 of green features were transformed into settlement areas. While 1.87 km^2 of bare land and 0.6 km^2 of urban features migrated into the green

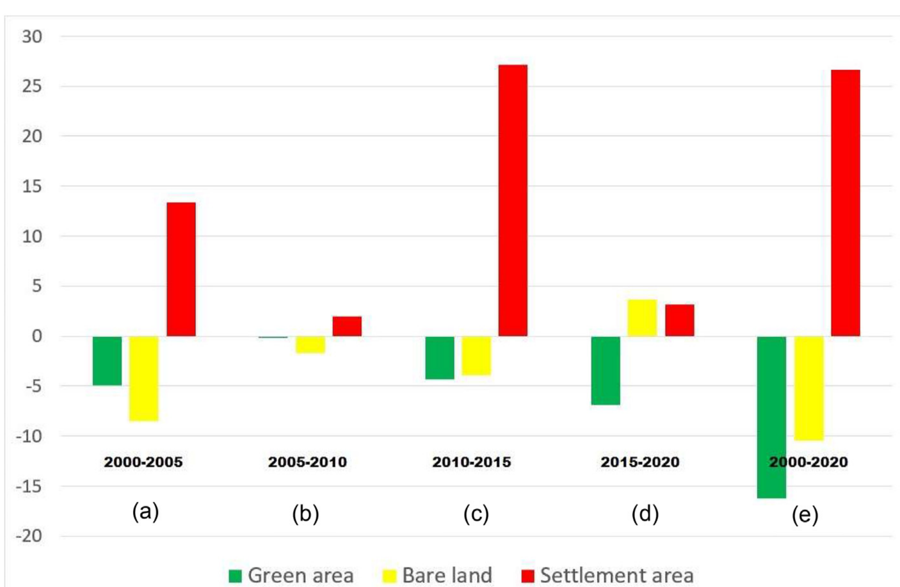

Fig. 4. Changes of different land uses from 2000 to 2020: (a) 2000–2005, (b) 2005–2010, (c) 2010–2015, (d) 2015–2020, and (e) 2000–2020.

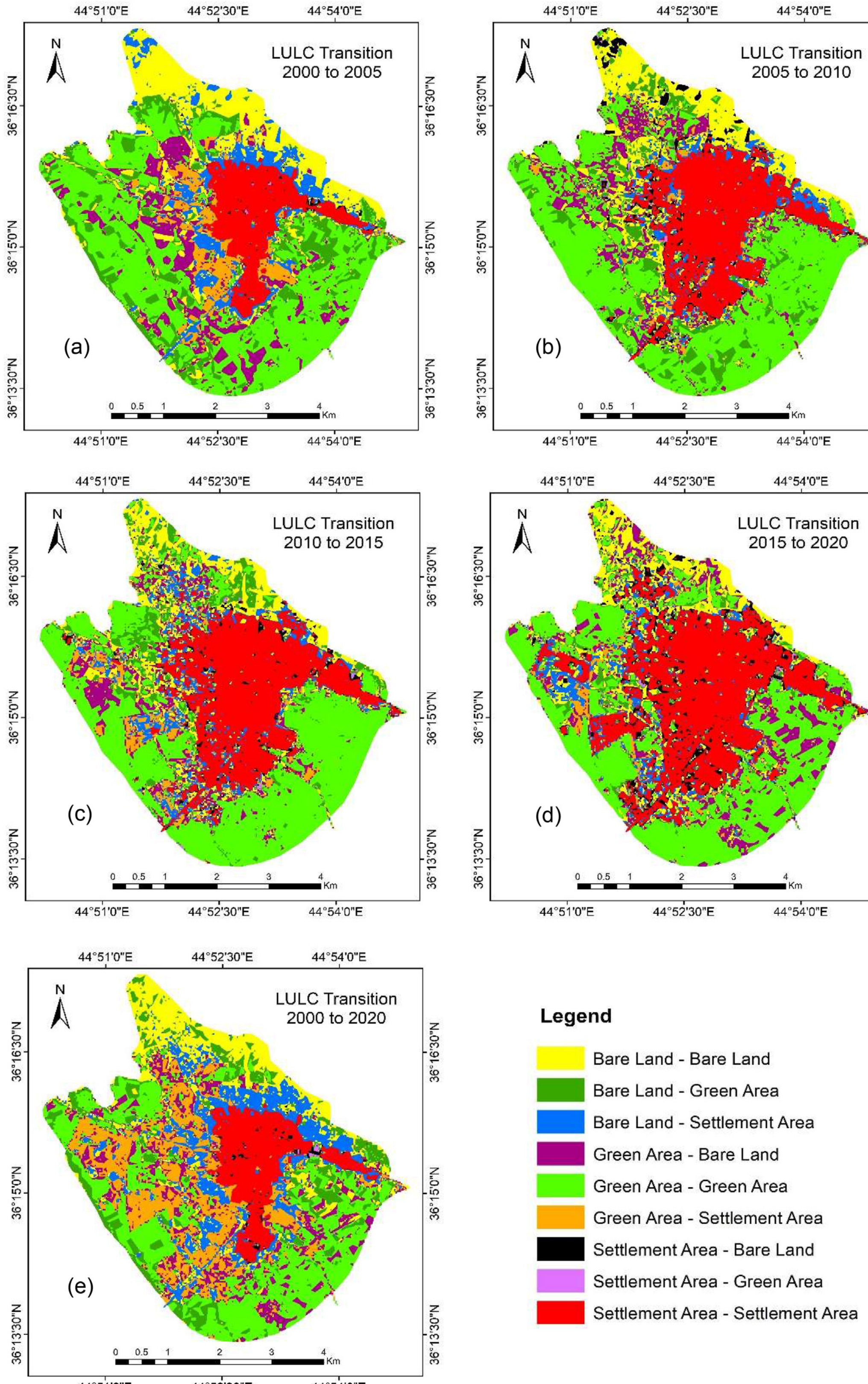

Fig. 5. LULC transition of Ranya for the years; (a) 2000−2005, (b) 2005−2010, (c) 2010−2015, (d) 2015−2020, and (e) 2005−2020.

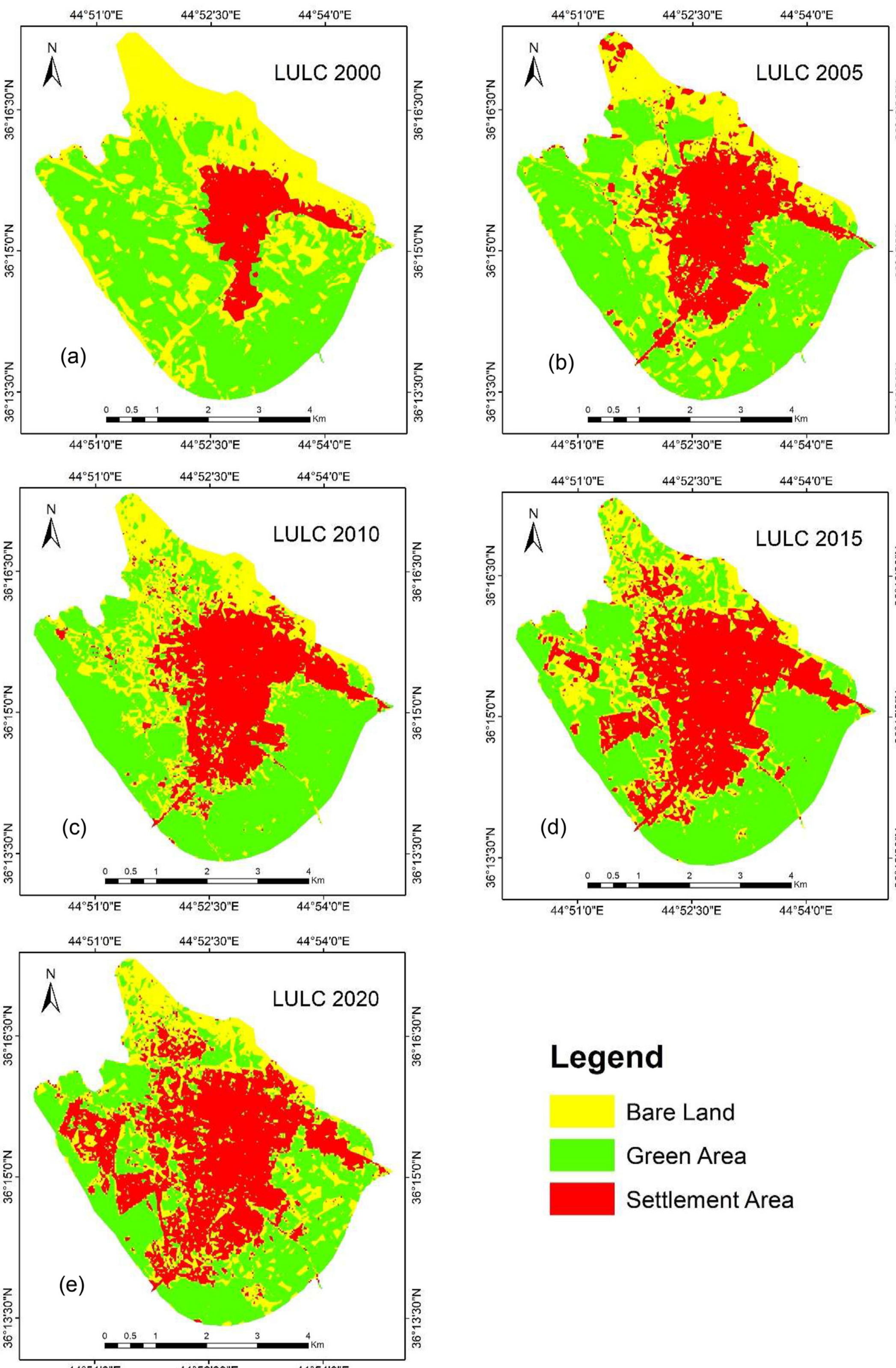

Fig. 6. Ranya LULC maps; (a) 2000, (b) 2005, (c) 2010, (d) 2015, and (e) 2020.

Table 6. Transition of Ranya (2000–2005, 2005–2010, 2010–2015, 2015–2020, and 2000–2020).

Transition	2000 to 2005 (km^2)	2005 to 2010 (km^2)	2010 to 2015 (km^2)	2015 to 2020 (km^2)	2000 to 2020 (km^2)
Bare Land - Bare Land	4.31	3.76	3.29	3.28	3.65
Bare Land - Green Area	3.23	2.50	1.87	1.02	2.85
Bare Land - Settlement Area	2.14	1.14	1.77	1.56	3.17
Green Area - Bare Land	3.01	2.28	2.07	2.38	3.07
Green Area - Green Area	9.59	10.15	9.71	8.65	6.87
Green Area - Settlement Area	1.57	0.41	1.03	0.59	4.22
Settlement Area - Bare Land	0.09	0.88	0.51	1.20	0.15
Settlement Area - Green Area	0.01	0.14	0.06	0.10	0.04
Settlement Area - Settlement Area	3.13	5.82	6.80	8.29	3.05

area, 2.07 km^2 of bare land and 1.03 km^2 of the settlement area, respectively, replaced the green area. However, approximately 0.51 km^2 of settlement area was replaced by bare land (Table 6). As for the 2015–2020 transition (Fig. 6; d), the results showed that 1.56 km^2 and 1.02 km^2 of bare land changed to urban/built-up and green areas, respectively.

Moreover, 2.38 km^2 of green area replaced bare land, and merely 0.59 km^2 of green features changed to the settlement area. However, settlement areas were replaced with vegetation and bare land by only 0.11 km^2 and 1.2 km^2, respectively (Table 6). According to the results (Table 6), for the overall transition between 2000 and 2020 (Fig. 6; e), 4.22 km^2 of green space and 3.17 km^2 of bare land, respectively, were transitioned to urban/built-up areas. Only 0.15 km^2 of settlement features were converted to bare land, while 3.07 km^2 of green area replaced by bare land. The amount which transitioned from settlement to green space was only 0.04 km^2, however, 2.85 km^2 of green area replaced bare land in overall between 2000 and 2020.

The largest LULC shift to settlement areas for the time periods 2000–2005, 2005–2010, 2010–2015, and 2015–2020, respectively, was the bare land area, followed by the green area. However, from 2000 to 2020, the green area, after which bare land, represented the largest land cover transition into urban areas (Fig. 2). Before urban growth, the agricultural areas in Ranya municipality thrived, supported by the natural Qula water that flowed in the city center. This water source significantly contributed to the success of local agriculture, especially during the months of summer. However, the rapid urbanization shifted the dynamics. The Qula water, once predominantly used for agriculture resources, began to be a critical source for drinking purposes, leading to its diminished flow. Consequently, the agricultural areas that once flourished were replaced by urban areas. This critical transformation caused a radical decline in agricultural productivity, affecting the amount of locally produced food, which made Ranya city rely on external sources of vegetation to meet the needs of its inhabitants. The shift from a self-sustaining agricultural model to dependence on external sources raises critical questions about the long-term implications for food production and security in the wake of urbanization.

According to what we have studied, Ranya's total LULC immediately changed in just 20 years. In particular, built-up areas significantly expanded. Whereas, agriculture and barren lands have decreased dramatically. The majority of the recent settlement places were built on the previously used agricultural and bare lands (Fig. 6). The demand for new residential areas, as well as education, business and service opportunities, were the main driving forces behind the growth of settlement features [8].

Several future research directions are suggested from this research based on the outcome of spatio-temporal analysis for Ranya city. Investigating the impact of specific socio-economic of the observed land use and land cover changes is one critical area for further research, especially in relation to urban development and agriculture. Moreover, developing predictive models to analyse the potential consequences of ecology related to land use changes could be a focus for future studies. Furthermore, the policy implications of planned urbanization and expansion of infrastructure is essential for Ranya city. Understanding the environmental changes in detail are significant for future land management and local urban planning strategies.

4. Conclusion

This research used a mixture of USGS remote sensing data and GIS tools to monitor the LULC transition between 2000 and 2020 in Ranya city. GIS is great tool for analyzing and displaying spatial data, and remote sensing is time efficient and cost effective for acquiring data for researcher, although google earth pro is accurate tool for assessing accuracy of LULC classification especially for under-development countries. Ranya city had the largest percentage of green space (52%) in 2000, however, due to growing populations and development activities, the settlement areas in Ranya rapidly increased in size by (223.53%) after 20 years, exceeding both agricultural land and bare land.

Bare land and green areas, on the other hand, lost 41.3% and 44.9% of their land from 2000 to 2020, respectively, which showed a significant overall downward trend. Most of the newly constructed settlement areas have replaced the formerly used agricultural lands and bare fields. In addition to other factors such as the building of multiple institutional facilities, new residential areas, rising business enterprises, and government service areas, becoming an independent administration is one of the main reasons for this rapid urbanization and immediate development of Ranya city between 2000 and 2020. In the next years, Ranya's excessive population will lead to a high demand for land and a shortage of space for urban growth. Also a radical decline in agricultural productivity will occure due to the decrease in agriculture area raising significant questions related to food production in the future. To prepare for upcoming issues and manage LULC effectively, the government should implement efficient policies and procedures. Since most settlements in Ranya only have one or two floors, we recommend the government to consider developing new high standard apartments rather than two-story structures in the future, particularly for government building sectors. The research emphasizes the urban development implications in Ranya city, caused by a significant expansion in built-up areas and a simultaneous decrease in agriculture and barren lands. The study identifies the independent administration of the city and development of infrastructure as key points resulting this fast urbanization, offering valuable and effective insights for urban planning and policy decision makers to consider these environmental impacts.

Author contributions

All authors contributed to the study conception and design. Material preparation and data collection were performed by [K. C.], and analysis were performed by [K. C.] and [S. B. H. M.]. The first draft of the manuscript was written by [K. C.] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors have no conflicts of interest to declare.

References

[1] Bank TW. Iraq world bank data. Washington, DC USA: World Bank Group; 2023. Available from: https://data.worldbank.org/indicator/SP.POP.TOTL?end=2020&start=2000&view=chart.

[2] Sharma R, Joshi P. Monitoring urban landscape dynamics over Delhi (India) using remote sensing (1998e2011) inputs. J Indian Soc Remote Sens 2013;41:641–50. https://doi.org/10.1007/s12524-012-0248-x.

[3] Chakilu G. MogesM.Assessing the land use/cover dynamics and its impact on the low flow of Gumara Watershed, Upper Blue Nile Basin, Ethiopia. Hydrol Curr Res 2017;7(2). https://doi.org/10.4172/2157-7587.1000268.

[4] Hegazy IR, Kaloop MR. Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. Int J Sustain Built Environ 2015;4(1):117–24. https://doi.org/10.1016/j.ijsbe.2015.02.005.

[5] Sewnet A. Land use/cover change at infraz watershed, North western Ethiopia. J Landsc Ecol 2015;8(1):69–83. https://doi.org/10.1515/jlecol-2015-0005.

[6] Shimelis G, Ragahavan S, Bijan D, Assefa M. Spatial delineation of soil erosion vulnerability in the Lake Tana Basin, Ethiopia. Hydrol Process 2009;10:3738–50. https://doi.org/10.1002/hyp.7476.

[7] Yalew SG, Mul ML, Van Griensven A, Teferi E, Priess J, Schweitzer C, et al. Land-use change modelling in the Upper Blue Nile Basin. Environments 2016;3(3):21. https://doi.org/10.3390/environments3030021.

[8] Sankhala S, Singh B. Evaluation of urban sprawl and land use land cover change using remote sensing and GIS techniques: a case study of Jaipur City, India. Int J Emerg Technol Adv Eng 2014;4(1):66–72.

[9] Chomitz KM, Kumari K. The domestic benefits of tropical forests: a critical review. World Bank Res Obs 1998;13(1):13–35.

[10] Bruijnzeel LA. Hydrological functions of tropical forests: not seeing the soil for the trees? Agric Ecosyst Environ 2004;104(1):185–228. https://doi.org/10.1016/j.agee.2004.01.015.

[11] Cheruto MC, Kauti MK, Kisangau DP, Kariuki PC. Assessment of land use and land cover change using GIS and remote sensing techniques: a case study of Makueni County, Kenya. Romania: OMICS International; 2016. https://doi.org/10.4172/2469-4134.1000175.

[12] GebreMedhin A, Biruh W, Govindu V, Demissie B, Mehari A. Detection of urban land use land cover dynamics using GIS and remote sensing: a case study of Axum town, Northern Ethiopia. J Indian Soc Remote Sens 2019;47:1209–22. https://doi.org/10.1007/s12524-019-00974-y.

[13] Weng QA. remote sensing? GIS evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, China. Int J Rem Sens 2001;22(10):1999–2014. https://doi.org/10.1080/713860788.

[14] Hassan Z, Shabbir R, Ahmad SS, Malik AH, Aziz N, Butt A, et al. Dynamics of land use and land cover change (LULCC) using geospatial techniques: a case study of Islamabad Pakistan. SpringerPlus 2016;5:1–11. https://doi.org/10.1186/s40064-016-2414-z.

[15] Solaimani K, Arekhi M, Tamartash R, Miryaghobzadeh M. Land use/cover change detection based on remote sensing data (A case study; Neka Basin). Agric Biol J N Am 2010;1(6):1148–57. https://doi.org/10.5251/abjna.2010.1.6.1148.1157.

[16] Pasha SV, Reddy CS, Jha C, Rao PP, Dadhwal V. Assessment of land cover change hotspots in Gulf of Kachchh, India using multi-temporal remote sensing data and GIS. J Indian Soc Remote Sens 2016;44:905–13. https://doi.org/10.1007/s12524-016-0562-9.

[17] Shooshtari SJ, Silva T, Namin BR, Shayesteh K. Land use and cover change assessment and dynamic spatial modeling in the Ghara-Su Basin, northeastern Iran. J Indian Soc Remote Sens 2019;48(1):81–95. https://doi.org/10.1007/s12524-019-01054-x.

[18] Herold M, Goldstein NC, Clarke KC. The spatiotemporal form of urban growth: measurement, analysis and modeling. Rem Sens Environ 2003;86(3):286−302. https://doi.org/10.1016/S0034-4257(03)00075-0.

[19] Serra P, Pons X, Saurí D. Land-cover and land-use change in a Mediterranean landscape: a spatial analysis of driving forces integrating biophysical and human factors. Appl Geogr 2008;28(3):189−209. https://doi.org/10.1016/j.apgeog.2008.02.001.

[20] Chen X, Vierling L, Deering D. A simple and effective radiometric correction method to improve landscape change detection across sensors and across time. Rem Sens Environ 2005;98(1):63−79. https://doi.org/10.1016/j.rse.2005.05.021.

[21] Yuan F, Sawaya KE, Loeffelholz BC, Bauer ME. Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing. Rem Sens Environ 2005;98(2):317−28. https://doi.org/10.1016/j.rse.2005.08.006.

[22] Tewabe D, Fentahun T. Assessing land use and land cover change detection using remote sensing in the Lake Tana Basin, Northwest Ethiopia. Cogent Environ Sci 2020;6(1):1778998. https://doi.org/10.1080/23311843.2020.1778998.

[23] Faqe Ibrahim GR. Urban Land use land cover changes and their effect on land surface temperature: case study using Dohuk city in the Kurdistan region of Iraq. Climate 2017;5(1):13. https://doi.org/10.3390/cli5010013.

[24] Edan MH, Maarouf RM, Hasson J. Predicting the impacts of land use/land cover change on land surface temperature using remote sensing approach in Al Kut, Iraq. Phys Chem Earth, Parts A/B/C 2021;123:103012.

[25] Khwarahm NR. Spatial modeling of land use and land cover change in Sulaimani, Iraq, using multitemporal satellite data. Environ Monit Assess 2021;193(3):148. https://doi.org/10.1016/j.pce.2021.103012.

[26] Nasir SM, Kamran KV, Blaschke T, Karimzadeh S. Changeof land use/land cover in kurdistan region of Iraq: a semi-automated object-based approach. Remote Sens Appl 2022;26:100713. https://doi.org/10.1016/j.rsase.2022.100713.

[27] Dibs H, Hasab HA, Al-Rifaie JK, Al-Ansari N. An optimal approach for land-use/land-cover mapping by integration and fusion of multispectral landsat OLI images: case study in Baghdad, Iraq. Water Air Soil Poll 2020;231(9):488. https://doi.org/10.1007/s11270-020-04846-x.

[28] Khwarahm NR, Najmaddin PM, Ararat K, Qader S. Past and future prediction of land cover land use change based on earth observation data by the CAeMarkov model: a case study from Duhok governorate. Iraq. Arabian J Geosci 2021;14(15):1−14. https://doi.org/10.1007/s12517-021-07984-6.

[29] Alkaradaghi K, Ali SS, Al-Ansari N, Laue J. Evaluation of land use & land cover change using multi-temporal landsat imagery: a case study Sulaimaniyah Governorate. Iraq J Geogr Inf Syst 2018;10(6):247−60. https://doi.org/10.4236/jgis.2018.103013.

[30] Khwarahm NR, Qader S, Ararat K, Fadhil Al-Quraishi AM. Predicting and mapping land cover/land use changes in Erbil/Iraq using CA-Markov synergy model. Earth Sci Inform 2021;14(1):393−406. https://doi.org/10.1007/s12145-020-00541-x.

[31] Mustafa YT, Ismail DR, editors. Land use land cover change in Zakho District, Kurdistan Region, Iraq: past, current and future. In: 2019 International Conference on Advanced Science and Engineering (ICOASE). USA: IEEE; 2019. https://doi.org/10.1109/ICOASE.2019.8723758.

[32] Hasan SF, Shareef MA, Hassan ND. Speckle filtering impact on land use/land cover classification area using the combination of Sentinel-1A and Sentinel-2B (a case study of Kirkuk city, Iraq). Arabian J Geosci 2021;14(4):276. https://doi.org/10.1007/s12517-021-06494-9.

[33] Saleh AM, Ahmed FW. Analyzing land use/land cover change using remote sensing and GIS in Mosul District, Iraq. Ann Rom Soc Cell Biol 2021:4342−59.

[34] Hadeel A, Jabbar M, Chen X. Application of remote sensing and GIS to the study of land use/cover change and urbanization expansion in Basrah province, southern Iraq. Geo-Spatial Inf Sci 2009;12(2):135−41. https://doi.org/10.1007/s11806-009-0244-7.

[35] Al-Doski J, Mansor SB, Shafri HZM. Monitoring land cover changes in Halabja City, Iraq. Int J Sens Related Netw (IJSRN) 2013;1:20−30.

[37] USGS USGS. USGS EarthExplorer. USA: USGS; 2023. Available from: https://earthexplorer.usgs.gov/.

[38] Thapa RB, Murayama Y. Urban mapping, accuracy, & image classification: a comparison of multiple approaches in Tsukuba City, Japan. Appl Geogr 2009;29(1):135−44. https://doi.org/10.1016/j.apgeog.2008.08.001.

[39] Yeo L, Mohamad WW, Hasan R, Othmani N, Hamid NA, Ramlee N, editors. An integrated framework for assessing land-use/land-cover of Kelantan, Malaysia: supervised and unsupervised classifications. IOP Conf Ser Earth Environ Sci 2022;1053(1):012026. https://doi.org/10.1088/1755-1315/1053/1/012026. IOP Publishing.

[45] Hussein BA. Geographical analysis of ruralization phenomenon in Rania city and impact on their urban environment. J Univ Raparin 2021 Sep 29;8(3):79−109.

[46] Bharath HA, Tanbir S, Anita G. Understanding the changing LULC and its effect on air quality through field-based measurement and model-based approach. In: IGARSS 20232023 IEEE international geoscience and remote sensing symposium. USA: Institute of Electrical and Electronics Engineers (IEEE); 2023. p. 3640−3. https://doi.org/10.1109/IGARSS52108.2023.10282640.

[47] Regassa B, Kassaw M, Bagyaraj M. Analysis of urban expansion and modeling of LULC changes using geospatial techniques: the case of Adama City. Remote Sens Land 2020;4(1−2):40−58. https://doi.org/10.21523/gcj1.20040104.

[48] Gaur S, Singh R. A comprehensive review on land use/land cover (LULC) change modeling for urban development: current status and future prospects. Sustainability 2023;15(2):903. https://doi.org/10.3390/su15020903.

[49] Zaheer Abbas, Guang Yang, Yuanjun Zhong, Yaolong Zhao. Spatiotemporal change analysis and future scenario of LULC using the CA-ANN approach: a case study of the greater bay area, China. Land 2021;10(6):584. https://doi.org/10.3390/land10060584.