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Study urban expansion in Mosul city using remote sensing data

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Abstract

Mosul city considered as the second largest city in Iraq after the capital, Baghdad, in terms of population and urban areas (residential neighborhoods) in terms of number and high population density, which requires the need to monitor the changes that occur in the city as a result of random expansion, unplanned construction in large areas. Knowing about these changes is importance to the authorities in planning and providing services for the city. The current research deals with the study of urban expansion of Mosul city using Landsat 8 satellite data for the three different years 2009, 2014, 2019, respectively. Digital processing and image classification were used to prepare and draw three urban maps to track urban growth patterns for the three different time periods, using remote sensing software. Where the results showed that significant changes occurred in the structure of the city, represented in a significant increase in residential areas at the expense of a significant decline in agricultural lands and forest lands, as the residential areas reached 96.30 km2 in 2009 and according to the study became 166.42 km2 in 2019, an increase of 70.12 km2 within ten years. This warns the authorities to take legal and planning measures to preparation to this increase and try to provide the necessary services and infrastructure for this increase rate, in addition to preventing encroachments on agricultural areas. Government departments and local authorities can benefit from this research in developing service strategies and future infrastructure projects and updating the city's base map based on the expansion rates derived from the research results.

Keywords: Image Processing; Satellites Image; Urban Planning; Decay of agricultural areas; Classification

1. Introduction

Remote sensing data provides spatial coverage of large areas with high-resolution details as a unique and integrated tool with GIS, where they have been used together in recent years to determine the size of urban expansion and monitor urban growth in a studied and more comprehensive manner than the expensive traditional survey [1]. Remote sensing data varied between satellite images and aerial images, including drone images [2], which were used to limit urban lands from agricultural lands [3]. They were also used to indicate the expansion of housing, random encroachments on the outskirts of cities [4], or even encroachments on historical and archaeological lands [5].

Where the indiscriminate expansion of cities and the increasing population growth, which exceeds the development of the infrastructure of the urban city, negatively affects climate fluctuations and increases the pollution of air, water and land, which in turn affects life in general, including human life, as a result of the indiscriminate and bad use of land [6]. Natural resources are very important for their great economic value and their multiple uses in several fields, whether industrial or agricultural, etc., and to preserve them, they must be monitored, counted, and then properly managed for the purpose of maintaining the environmental balance in Nineveh Governorate, including the city of Mosul [7]. From this point of view, the importance of using remote sensing data and its software to detect and determine the area of residential areas in the city of Mosul and the rest of the other land features, and to benefit from the information obtained from the current research in planning and managing the city in the future.

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The current research aims to study the urban expansion using remote sensing data represented by the different spectral bands of the American satellite Landsat 8 and the false color-combined satellite images, through which structural maps were prepared and drawn to track urban growth patterns for three different time periods 2009, 2014, 2019 (ten years) using the digital processing method, especially the use of the Supervised Classification process directed to these images. ERDAS program version 8.4 was used to predict changes that have a negative impact on the Mosul city, represented by an increase in the region of residential areas and a decline in green spaces and a decrease in their area.

1.1. Study Area

The current research area includes the Mosul city, which is characterized by its privileged location on the Tigris River and its distinguished position as an archaeological and heritage site, as it lies between longitudes (43°02'35"-43°18'16") east and latitudes (36°18'3"- 36°26'00") North, (Figure 1).

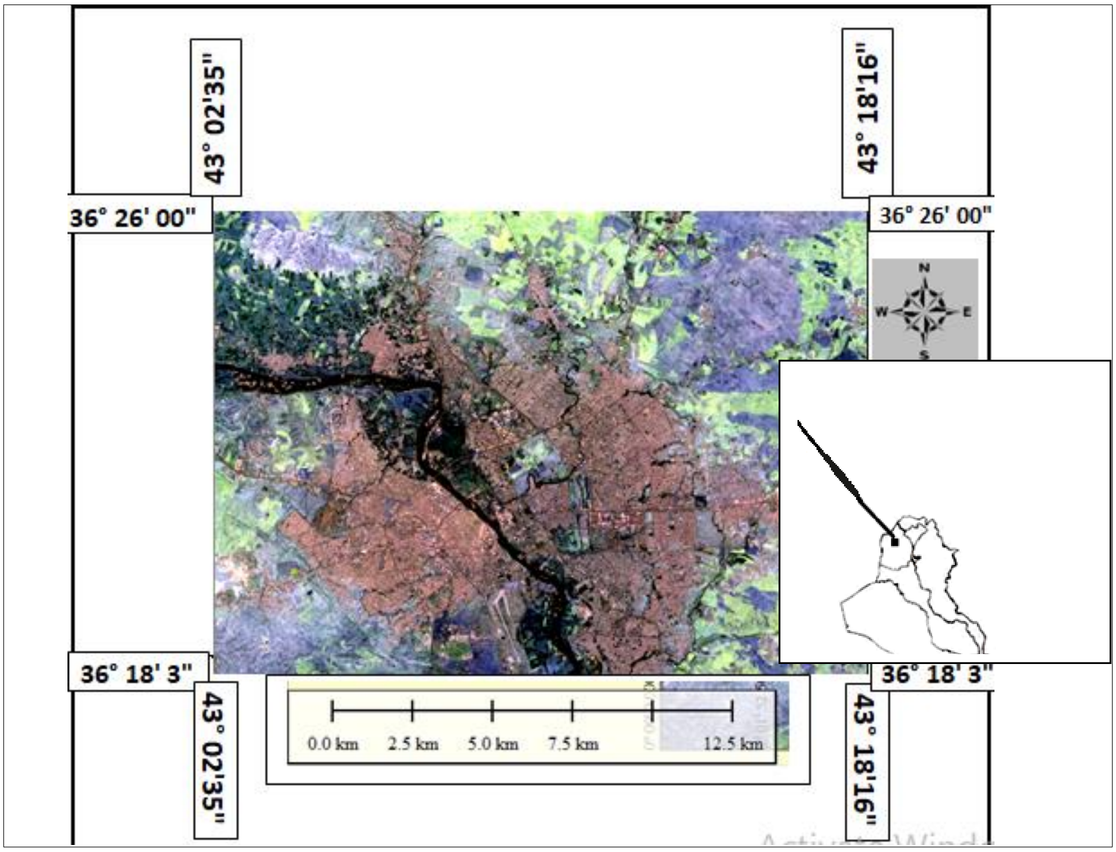

Figure 1 A satellite image displaying the research study area

2. Research Methodology

In the current research, three Landsat 8 satellite images were used, captured at successive time periods and for several different spectral bands. The action steps used was shown in Figure (2). The program (ERDAS Version 8.4) was used to conduct the action steps, and these steps will be explained in detail successively.

The first image was taken in 2009, the second was taken in 2014, and the third was taken in 2019. Three spectral bands (TM7, TM4, TM2) were selected for each satellite image from the same three satellite images mentioned above.

Parts of the satellite images have been cut off in each spectral band of the three bands used, and the cut off part represents the region of interest, which are the borders and outskirts of the Mosul city. In the second step, the three spectral bands TM7, TM4, and TM2 that were cut off were merged to form three new composite visualizations of the study area, as shown in Figure (3). The color composite images is one of the special methods in digital processing that improves the visualization to infer new information [8] and also gives better directions for classification and identification of features and land covers [9].

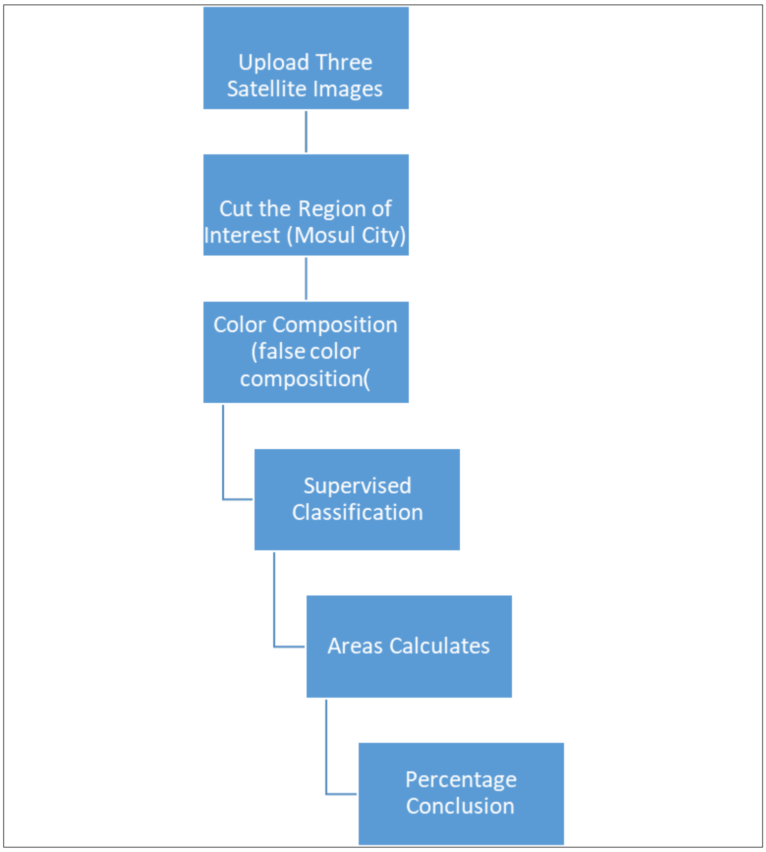

Figure 2 Scheme of the work steps adopted in the current research

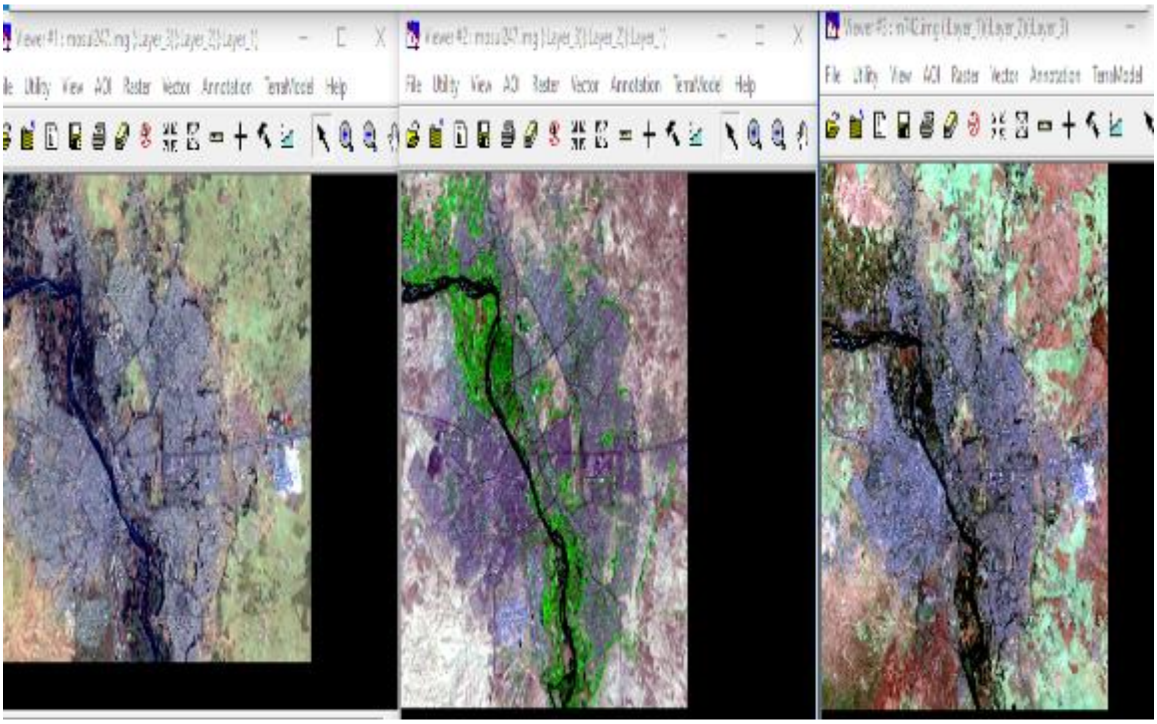

Figure 3 The satellite composite color images of the spectral bands (TM4, TM2, TM7) for the years 2009, 2014 and 2019

Through Figure 3, the urban expansion of the Mosul city was observed, represented by residential areas, as well as the rest of the other land features that were distinguished due to the difference in the spectral reflectivity of these targets.

After that, the Supervised Classification process was carried out for the three color-combined images consisting of spectral bands (TM7, TM4, TM2), as training areas were chosen for each of the land use categories in the search area after sorting and isolating the pixels value, for each of these categories based on the spectral reflectivity of that category.

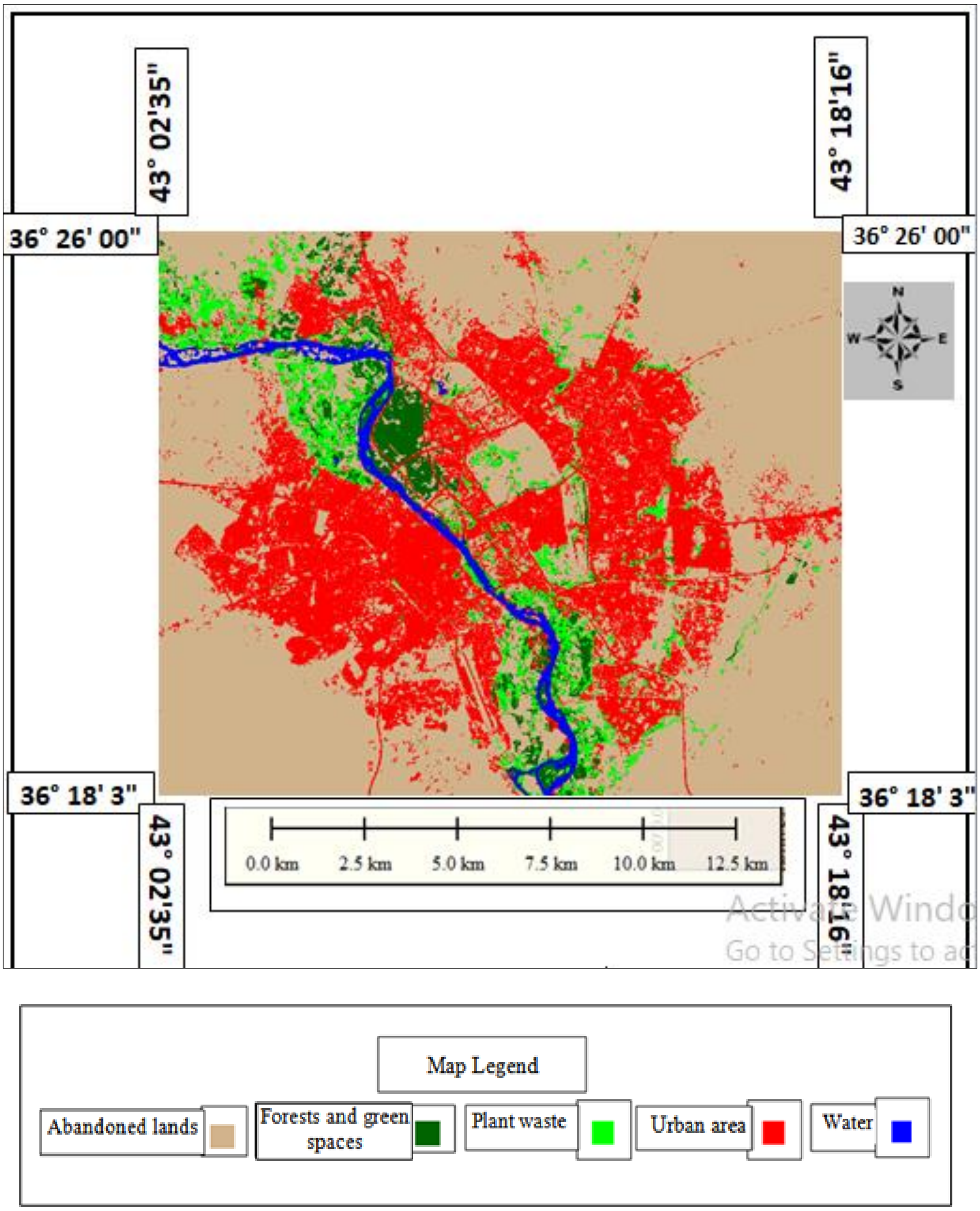

Figure 4 The urban expansion map of the Mosul city in 2009, the supervised Classification

This selection process was carried out based on field work and prior knowledge of the Mosul city. This classification process resulted in three color satellite images digitally classified using a directed classification. Each of them represents urban expansion in the Mosul city for the years 2009, 2014, and 2019, respectively, as shown in Figures (4), (5), and (6).

In the penultimate step, the area of each class taken from the supervised classification process was obtained for the Mosul city in various periods and for the three digitally classified images as in Figures (7), (8),and (9).

The figures (7), (8), and (9) shows that the satellite image has been classified into five categories, which are the water category, the urban land category, the agricultural waste category, the agricultural land and forests category, and the barren land category.

For each of these categories, areas were calculated for it to be compared between them and for the different time periods of the used satellite images. As the use of these spaces will help in making decisions that benefit the directors of departments and local authorities and in building future strategies for planning and establishing infrastructure projects for the city.

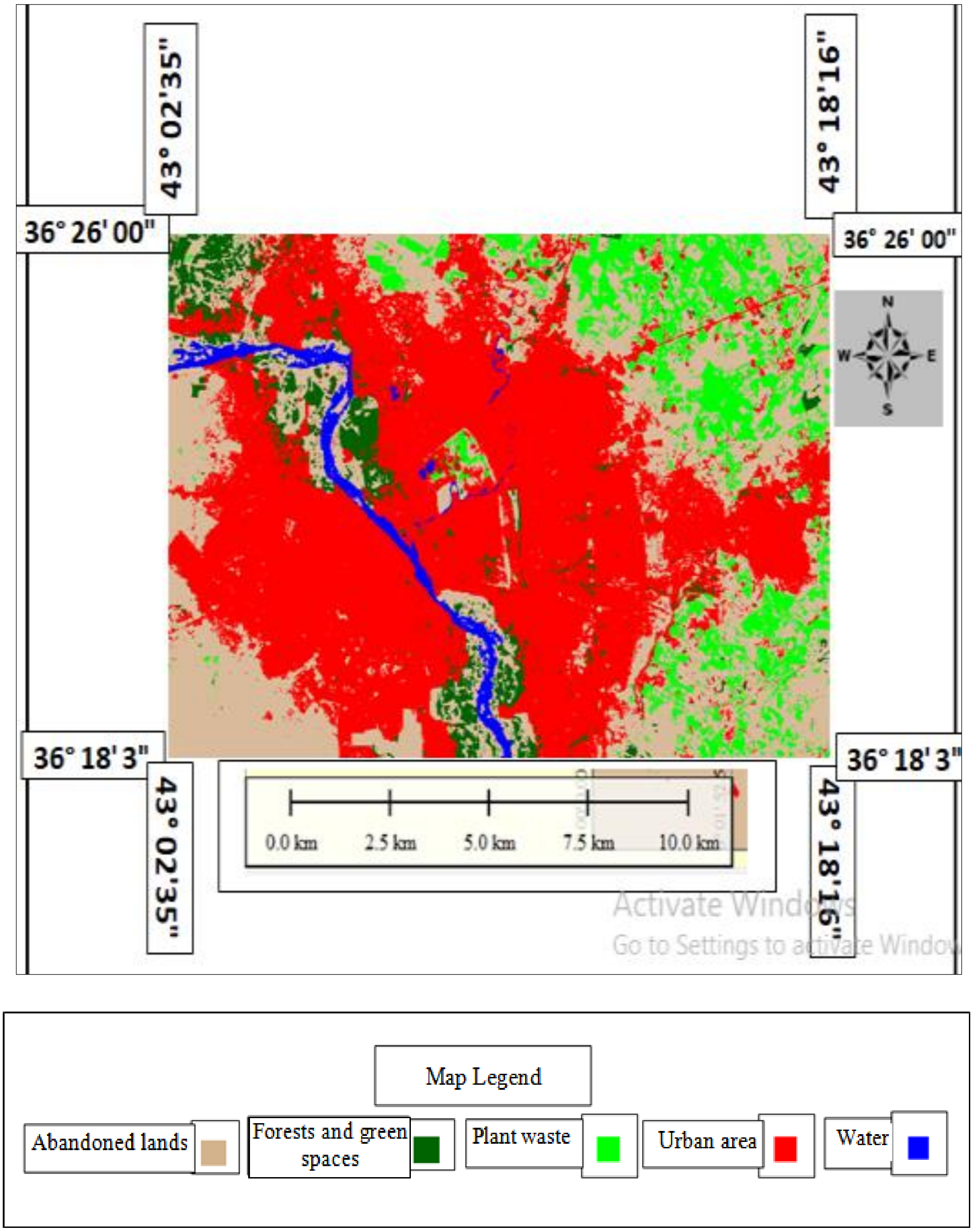

Figure 5 The urban expansion map of the Mosul city in 2014, the supervised classification

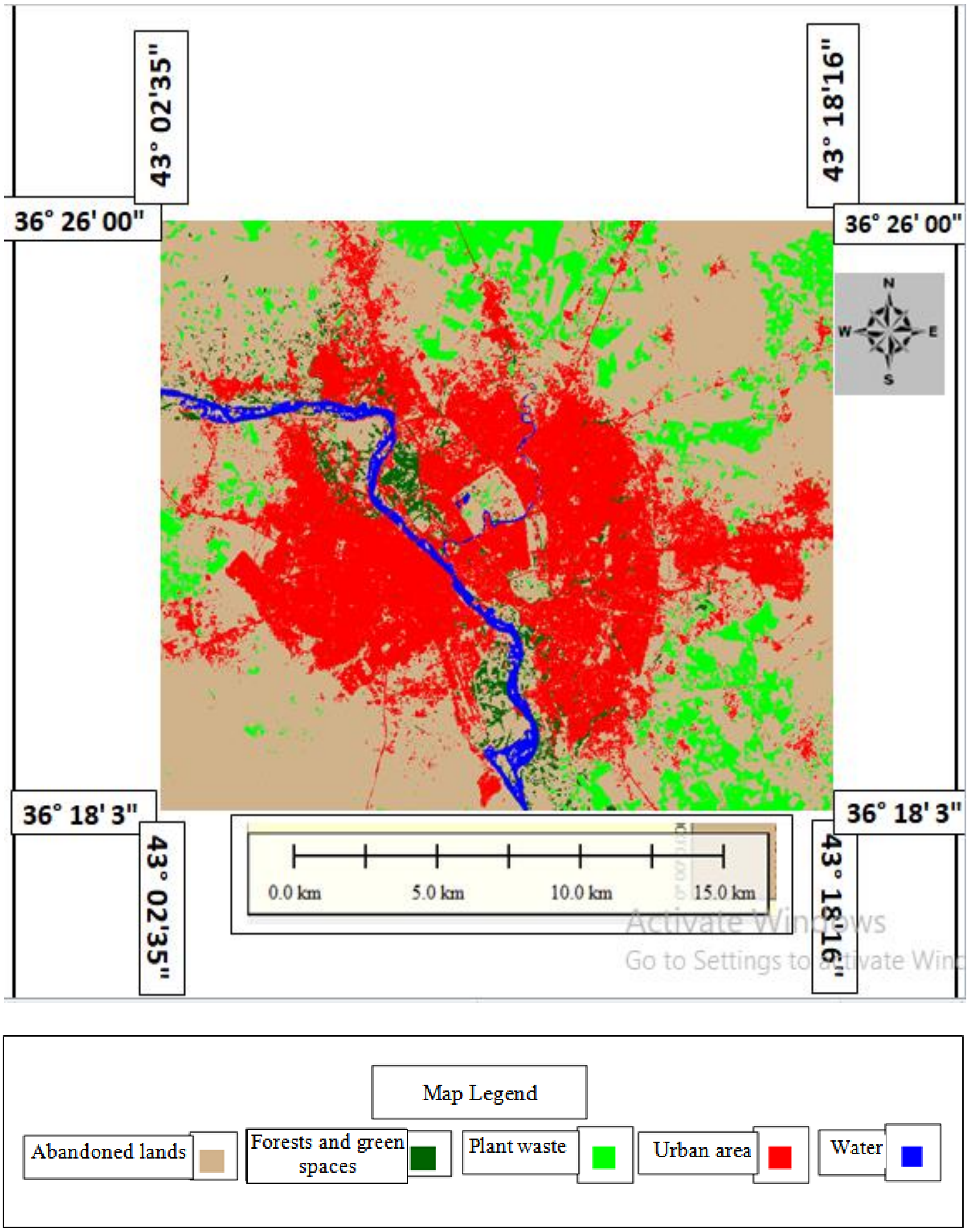

Figure 6 The urban expansion map of the Mosul city in 2019, the supervised classification

Row	Class Names	Histogram	Color	Area	Red	Green	Blue	Opacity
0	Unclassified	0		0	0	0	0	0
1	Class 1 مياه	12692		1142.28	0	0	1	1
2	Class 2 مناطق سكنية	184907		16641.6	1	0	0	1
3	Class 3 مخلفات الحصاد	61553		5539.77	0	1	0	1
4	Class 4 غابات ومساحات خضراء	16608		1494.72	0	0.392157	0	1
5	Class 5 أراضي متروكة(بور)	343440		30909.6	0.823529	0.701961	0.54902	1

Figure 7 The area of each category for a supervised classified satellite images, of 2009 year

Row	Class Names	Histogram	Color	Area	Red	Green	Blue	Opacity
0	Unclassified	0		0	0	0	0	0
1	Class 1 مياه	12592		1042.28	0	0	1	1
2	Class 2 مناطق سكنية	123710		11135.5	1	0	0	1
3	Class 3 مخلفات الحصاد	47842		4305.78	0	1	0	1
4	Class 4 غابات ومساحات خضراء	23670		2130.3	0	0.392157	0	1
5	Class 5 أراضي بور	170611		15355.02	0.823529	0.701961	0.54902	1

Figure 8 The area of each category for a supervised classified satellite images, of 2014 year

Row	Class Names	Histogram	Color	Area	Red	Green	Blue	Opacity
0	Unclassified	0		0	0	0	0	0
1	Class 1 مياه	7585		682.65	0	0	1	1
2	Class 2 مناطق سكنية	106996		9629.64	1	0	0	1
3	Class3 مخلفات الحصاد	9802		832.18	0	1	0	1
4	Class 4 غابات ومساحات خضراء	25829		2474.61	0	0.392157	0	1
5	Class 5 أراضي متروكة (بور)	231923		20873.1	0.823529	0.701961	0.54902	1

Figure 9 The area of each category for a supervised classified satellite images, of 2019 year

Finally, the area of each item was tabulated and the area was converted into square kilometers, as well as the percentages of items in the current search area were calculated as in Tables (1), (2), (3).

Table 1 Area of each category for a satellite image (2009) using the supervised classification

	Category Name	Area KM²	Percentage %
Class 1	Water	6.83	1.98
Class 2	Urban	96.30	27.92
Class 3	Plant waste	8.32	2.41
Class 4	Forests and green spaces	24.75	7.18
Class 5	Abandoned lands	208.73	60.51
Total		344.93	100

Table 2 Area of each category for a satellite image (2014) using the supervised classification

	Category Name	Area KM²	Percentage %
Class 1	Water	10.42	3.07
Class 2	Urban	111.35	32.78
Class 3	Plant waste	43.06	12.68
Class 4	Forests and green spaces	21.30	6.27
Class 5	Abandoned lands	153.55	45.20
Total		339.68	100

Table 3 Area of each category for a satellite image (2019) using the supervised classification

	Category Name	Area KM²	Percentage %
Class 1	Water	11.42	2.05
Class 2	Urban	166.42	29.86
Class 3	Plant waste	55.40	9.94
Class 4	Forests and green spaces	14.95	2.68
Class 5	Abandoned lands	309.1	55.47
Total		557.29	100

3. Results and Discussion

Figure (3) shows that the reflectivity is high in soils, sandy and muddy lands when using Band TM7, while the reflectivity of residential areas is high in Band TM2, as well as the reflectivity of rocks, stones and gypsum rocks, while the reflectivity of plants is high in forth Band TM4. The principles and foundations of interpretation of aerial and space images such as (shape, mottling, size, shadow, pattern, degree of darkening, texture, topographical location, geographical location) were adopted in distinguishing the varieties that have high reflectivity in the same beam, and this is consistent with the principles of remote sensing [10].

The results also showed the changes that occurred for the years 2009, 2014, 2019 by observing the urban expansion maps in the city of Mosul (Figures (4), (5), (6)), respectively, which relied on directed classification, in addition to observing figures (7), (8), (9), and tables (1), (2), (3). Where the results of the tables showed the great changes that took place in the city of Mosul, which was represented by a gradual increase in the area of the residential areas category, significantly, as its area was 96.30 km2 in 2009 and became 166.42 km2 in 2019, i.e. an increase of 70.12 km2 during the last ten years, and this was of course at the expense of a large decrease In the area of forests and green spaces, its area was 24.75 km2 and became 14.95 km2, i.e. a decrease of 9.8 km2, for the same period of studied time.

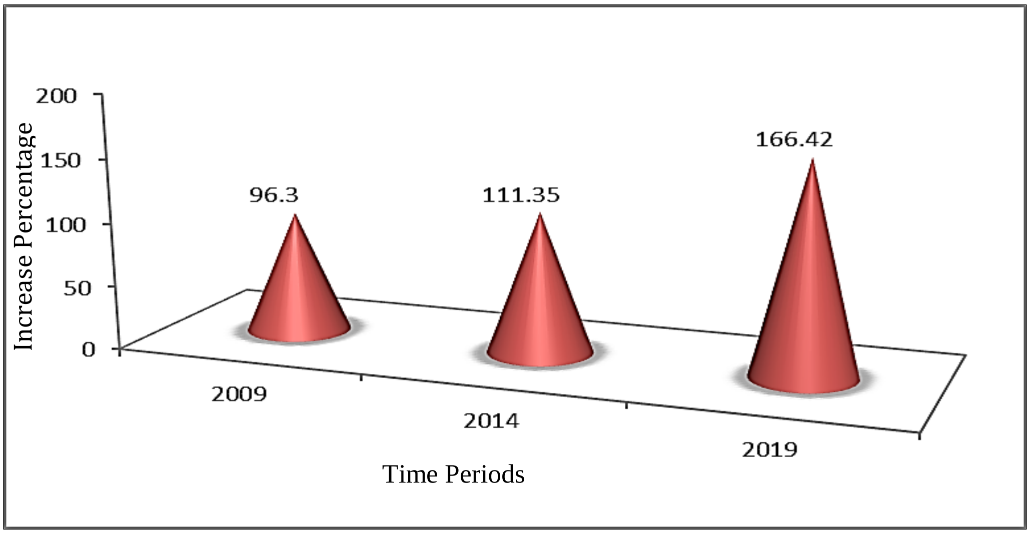

Figure 10 The increase of residential and urban areas in the study area during three different time periods.

4. Conclusion

Satellite images, remote sensing techniques and software were used to study the urban expansion of the city of Mosul, and the following were concluded:

- The importance of using remote sensing data in studying the changes taking place in the city of Mosul, where American satellite Landsat-8 (TM) and the color composite techniques used in the current research have proven their effectiveness in distinguishing the various land features and determining them spatially in the Mosul city.
- The digitally classified satellite images showed the classification of the expansion taking place in the Mosul city, which overwhelmed the forests and green spaces within the city and reduced them to a large extent, while their area should be increased and developed.
- The high potential of the ERDAS program in producing three modern digital maps of urban growth patterns for different periods of time, classified in color, and thus calculating the area of the five categories with extreme accuracy, with the least time and effort and at a low cost.
- Government departments and local authorities can benefit from this research in developing service strategies and future infrastructure projects and updating the city's base map based on the expansion rates derived from the research results.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to disclosed.

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