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Geospatial analysis of urban expansion using the NDBI spectral index and Landsat-8 data

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ABSTRACT

This study aims to analyze urban expansion in the western part of Ramadi City using remote sensing and geographic information systems (GIS) techniques. It relies on Landsat-8 satellite data and the application of the normalized difference built-up index (NDBI) to extract the built-up area with high accuracy. The study employs a combined quantitative-spatial methodology comprising three main approaches: a quantitative analytical approach to process spectral data and derive the NDBI value; a geospatial approach to analyze the geographical distribution of the built-up area and classify neighborhoods according to urbanization levels; and a comparative-temporal approach to monitor the dynamics of land-use changes. The spatial processing involved a series of steps, including collecting Landsat-8 data; performing pre-processing operations (cropping, geometric correction, and coordinate transformations); conducting unsupervised classification; and finally, applying the NDBI equation to extract built-up areas and converting raster layers into vectors using ArcMap 10.8 software. The results demonstrated the effectiveness of the NDBI index in characterizing urban areas, revealing that the built-up area reached 2,716 hectares, representing 72.5% of the total study area (3,747.5 hectares), with clear variations in development levels among neighborhoods. This methodology contributes to providing an accurate spatial database that supports sustainable urban expansion planning and demonstrates the vital role of integrating remote sensing and GIS in assessing urban growth and guiding future planning decisions.

Keywords: built-up area, GIS, NDBI index, remote sensing analysis, urbanism

INTRODUCTION

Urban mass analysis is a fundamental aspect of contemporary urban studies, serving as a key entry point for understanding urbanization dynamics and spatial growth patterns in rapidly expanding cities. The importance of this type of analysis is particularly evident in Arab cities in general, and in Ramadi in particular, given the rapid demographic and economic transformations it has witnessed over the past decade, and the accompanying increasing pressure on urban resources and land use. Most previous studies have not employed advanced spectral indicators, especially the normalized difference built-up index (NDBI), to study urban growth at the neighborhood level in Ramadi, thus failing to identify the subtle differences between built-up and unbuilt areas. Most previous work has relied on traditional methodologies for collecting urban data or has limited itself to a general analysis that does not reflect the precise spatial variations required for sustainable urban planning.

This research offers a scientific contribution by utilizing Landsat-8 satellite imagery with enhanced spectral characteristics and employing advanced processing techniques, including geometric correction, unsupervised spectral classification, and the application of the NDBI index to extract urban mass using a quantitative-spatial methodology based on the integration of geographic information systems (GIS) and spectral analysis. This approach enables the production of accurate and standardized urban maps that can be used to compare spatial changes between neighborhoods within the study area. This study represents a pioneering applied model in the City of Ramadi, integrating spectral indices with spatial analysis to produce a high-resolution digital urban database. This database contributes to revealing urban disparities, measuring expansion rates, and identifying urban spaces that represent a strategic reserve for future expansion.

BACKGROUND OF STUDY

In recent decades, global urbanization rates have accelerated, especially in developing cities facing population growth and rapid economic change, making the study of

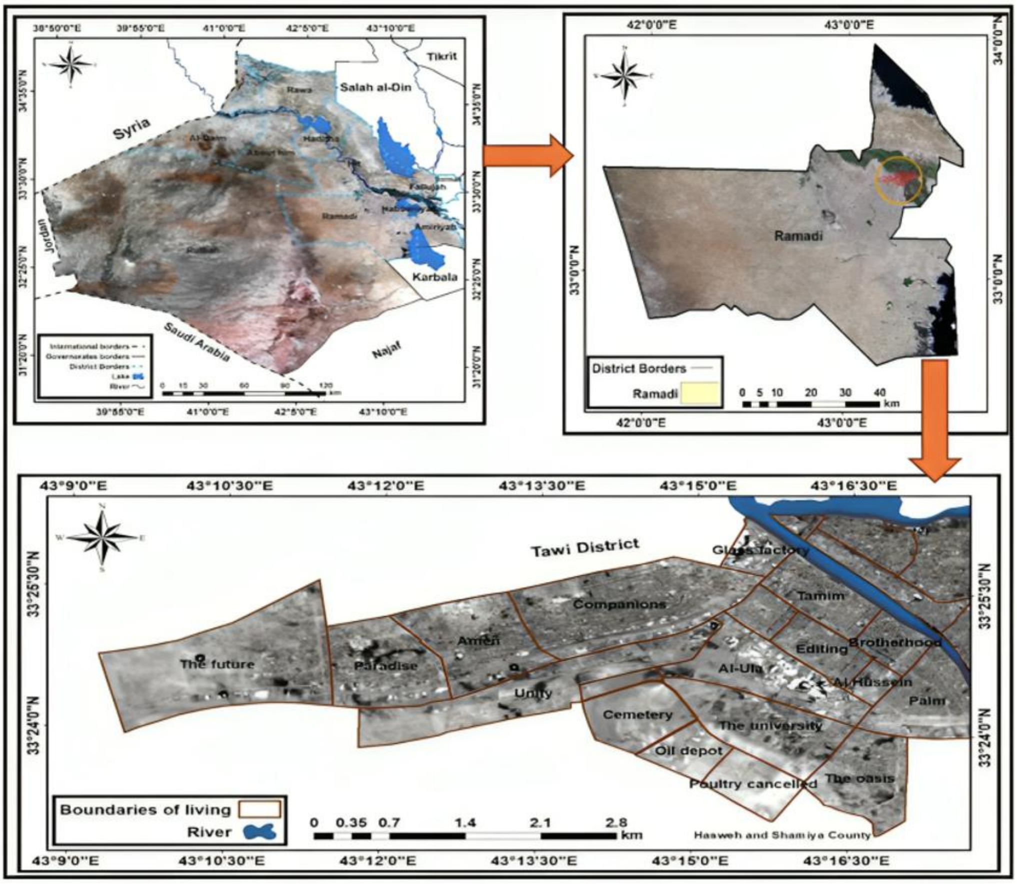

Figure 1. The geographical and astronomical location map of the study area (Source: Authors' own elaboration)

urbanization dynamics essential for sustainable urban planning (Güneralp et al., 2020; Ul Din & Mak, 2021). Accelerated urban growth often leads to significant land-use changes, such as reduced vegetation cover and the expansion of built-up areas at the expense of agricultural land and open spaces. These transformations are frequently uncontrolled, resulting in negative impacts on the urban environment and fabric, particularly in rapidly expanding cities (Ogunbode et al., 2025).

Advancements in remote sensing have enabled the use of spectral indices as effective tools for monitoring urban changes, due to their ability to distinguish built-up from non-built-up surfaces with high precision (Javed et al., 2021). The NDBI is widely used for identifying built-up areas, leveraging the spectral contrast between built-up surfaces and vegetation, and has been validated for improving urban classification using Landsat-8 data (Kebede et al., 2022). Integrating spectral indices like NDBI with GIS techniques further enhances the accuracy of urbanization analysis and supports comprehensive spatial and temporal assessments of urban expansion (Ngolo & Watanabe, 2023).

Despite global progress in spectral detection of built-up areas, detailed studies using modern spectral indices at the neighborhood level remain limited in many Arab cities, including those in Iraq, where most research has focused on city-wide analyses and overlooked local urban fabric nuances. This gap is significant, as neighborhood-level differences are crucial for developing precise and targeted urban policies 18. Additionally, many previous studies have relied on traditional classification methods or broad analyses, often lacking standardized maps that meet the needs of data-driven urban planning (Ul Din & Mak, 2021).

Recent research emphasizes the importance of spatial analysis in assessing urban expansion, demonstrating that spectral indices such as NDBI are highly effective for distinguishing urban mass from open spaces and for accurately defining internal city structures (Awasthi, 2023). However, the systematic application of these indicators in Iraqi cities, particularly in rapidly changing areas like Ramadi, remains scarce, with few quantitative spatial studies at the neighborhood scale (Ul Din & Mak, 2021).

This highlights the scientific need to study the urban mass in western Ramadi using modern spectral indices and Landsat-8 data, which would enable the creation of accurate, standardized urban databases. Such an approach would facilitate understanding of expansion patterns, reveal urban disparities, and identify areas suitable for future development, thereby supporting decision-makers in formulating urban policies based on reliable, up-to-date data (Wang et al., 2020).

Study Area

The spatial boundaries of the study area are represented by the western side, located between the latitudes (43° 9′ 0″ N) and the longitude (33° 25′ 30″ E). It is bordered to the north by Tuwei District and to the south by Haswa Al-Shamiya District. To the east, it is bordered by Al-Warar Canal and 12 neighborhoods, while to the west, it extends to the edges of the Western Plateau. Accordingly, the area of this part is 3747.5 hectares, as shown in **Figure 1**, and this information is reflected as illustrated in **Figure 1**.

Research Problem

The research problem lies in the limitations faced by traditional methodologies in monitoring and analyzing urban changes in the western part of Ramadi City, whether at the level of infrastructure changes such as buildings and roads, or in open spaces and urban expansion. Traditional methods rely on survey techniques that are time- and effort-consuming, in addition to their limited spatial and temporal accuracy in tracking the dynamics of urban growth and expansion.

The problem can be formulated through the following questions:

1. What is the accuracy and efficiency of remote sensing techniques in extracting the urban mass using satellite imagery captured by the Landsat-8 satellite?
2. Can spectral indices be employed in combination with GIS to enhance the accuracy of urban change analysis compared to traditional methods?

Research Hypothesis

The hypothesis of the study is based on answering the main research questions. Remote sensing techniques, especially spectral indices such as NDBI, have the capability to extract urban mass with high accuracy, thereby contributing to the reduction of time and effort required for traditional field studies.

1. Remote sensing data has the ability to extract the size of the urban mass with minimal effort and time after applying the necessary processing.
2. Spectral indices, including the NDBI index, play a fundamental and significant role in identifying urban mass, especially after applying digital processing to satellite imagery. GIS technologies can be used to analyze data and produce accurate urban maps, allowing for the determination of the size of the urban mass and monitoring its development over time.

Study Objectives

1. Applying spectral indices to extract urban areas using satellite data.
2. Utilizing modern technologies to monitor changes occurring in the study area, which contributes to understanding urban trends.
3. Using spatial analysis tools to identify areas that have experienced growth or decline.

Significance of the Study

The importance of the study stems from its subject, as it focuses on extracting a specific area from satellite imagery provided by satellites, which must be of high resolution due to the complexity of the urban scene and the overlap of buildings with other land uses. Therefore, clear imagery is required and we must undergo several processing stages to prepare it for analysis in order to obtain sufficient data about the study area.

1. Contributes to improving the accuracy of urban expansion analysis using remote sensing techniques, providing accurate and updated data.
2. Helps reduce time and effort compared to traditional methods, thus accelerating urban planning processes.
3. Supports decision-making related to sustainable urban planning and provides a model that can be applied to other urban areas.

METHODOLOGY OF THE STUDY

A set of modern methodologies was adopted that align with the study's subject and serve its objectives, as follows.

1. **Quantitative analytical method:** This method was adopted since the study relies on numerical data extracted from satellite imagery (Landsat-8), which was analyzed using spectral indices such as the NDBI and processed within the GIS environment. By employing this method, urban and non-urban areas were measured accurately, and the urban mass growth rate for each neighborhood within the study area was monitored. Statistical processing was also carried out, such as calculating averages and standard deviations, and neighborhoods were classified according to their urban area size.
2. **Spatial geographical approach:** Due to the nature of the topic, which addresses the geographical distribution of urban mass in Ramadi City, the spatial approach was adopted to analyze the spatial pattern of urban area expansion and its distribution among different neighborhoods. GIS techniques were used to create maps that illustrate the spatial relationship between urban and non-urban areas and to determine the geographical directions of urban expansion. This method contributes to understanding the dynamics of expansion and identifying the spatial factors influencing the formation of urban mass.
3. **Temporal comparative method:** To achieve a more comprehensive understanding of urban masses, the study employed the temporal comparative method by analyzing satellite images representing different time periods (when available). The purpose of this comparison is to identify changes in the size and distribution of the urban mass over time, which allows for measuring urban expansion rates and identifying neighborhoods that experienced rapid growth or urban stagnation. It also provides a tool to evaluate the effectiveness of previous urban planning.

The methodological integration in this study was achieved by linking the three approaches in a complementary manner. The quantitative method provides the basic numerical data, the spatial method offers a framework for analyzing geographical distribution, and the temporal method supplies tools to understand longitudinal transformations in urbanization. This methodological integration enhanced the accuracy of the analysis and provided a comprehensive view of the spatial and temporal transformations in the urban mass of western Ramadi.

The Urban Mass in the Western Part of the City of Ramadi

The urban mass emerged through the organized planning of the city, and this element reflects the interaction process that occurs between human activities and the built environment, leading to the creation of a diverse urban fabric that gives each area a distinct character. This is accompanied by an increase in land parcel sizes as well as improvements in the technologies and materials used, resulting in the enhancement of building types and the expansion of the urban mass (Mottelson, 2023). In recent years, the City of Ramadi has witnessed significant urban growth unprecedented in its geographic expansion, due to the increasing demand for services and housing units. It is observed that the western part of Ramadi has begun to expand across the Al-Warar Canal, a planned extension since the mid-1970s due to the rapid population growth and economic activities, which contributed to significant changes in the urban mass pattern of this part and how it has impacted urban planning .Through the use of remote sensing techniques and GIS, which are highly beneficial in spatial modeling and statistical analysis, the main goal of the study was achieved–extracting built-up and non-built-up areas. Therefore, these tools are the only option to derive clear information about urban areas (Adeyemi et al., 2021).

Analysis of Satellite Imagery

The analysis of satellite imagery is an important tool for understanding current and future challenges, especially in an era where the pace of urban change has accelerated. Remote sensing technology is adopted as one of the modern techniques that has facilitated the study of land cover characteristics and the classification of land uses at minimal financial and temporal costs (Wei et al., 2023).

The western part of the City of Ramadi has undergone rapid transformations in its urban mass due to increasing population pressure, availability of job opportunities, and the desire to establish projects to increase the region’s economic revenues. The study area was classified into two categories:

1. Urban and
2. Non-urban.

Through remote sensing, it was possible to detect urban changes in the study area and determine the urban mass area for each neighborhood in the western part of Ramadi. This was done through the following stages:

First. Data collection and storage stage

The data collection stage represents one of the initial processes in remote sensing, which follows the identification of the research problem. This was achieved through the initial satellite imagery: Landsat-8 imagery with a resolution of 60 cm was used, after being downloaded from the American USGS program, and then exported to ArcMap 10.8 software.

Second. Pre-processing stage

After displaying the imagery in the program, the study area is clipped using the (clip) tool in order to reduce its size and include only the required and most significant area. This stage is called pre-processing.

Third. Processing stage

This stage involves the geometric correction of the satellite imagery by transforming the image coordinates into geographical coordinates (Mushref et al., 2021). Ground control points are relied upon using the appropriate projection system according to the location of the study, and the projection zone is determined as Zoen38.

Fourth. Data analysis stage (classification)

This stage refers to the process of organizing the cells into several categories based on their spectral values. It is classified into two types: supervised classification, where the cells are arranged according to known areas and real patterns through training areas, and unsupervised classification, where the cells are arranged into categories based on their spectral values. The researcher names these categories (Hwang et al., 2024; Zhang et al., 2022).

The unsupervised classification process was carried out, and the study area was classified into a set of patterns. Following this, the building index equation was applied to illustrate the variation in urbanization occurring in the study area and to extract the urban growth rate of the city after processing in order to obtain accurate imagery. The satellite imagery was then classified into (urban mass and non-urban mass) by applying unsupervised classification algorithms for quantitative analysis of remote sensing data, which facilitates identifying land use types that appear in the study area. This enhances better city organization and service distribution across all areas. These patterns can be distinguished using spectral indices, which reduce the time needed for the researchers to extract the required data. Non-urban masses, including (vegetation cover), can be shown using the NDVI index, while areas with water bodies can be identified using MNDWI. Since the core of the study aims to extract the urban areas in a part of the City of Ramadi, the NDBI index will be used.

As a result of the development in spectral indices to extract built-up areas using satellite imagery, the built-up area index indicates the building density in the region. This depends on the spectral response principle of buildings and the different features associated with the wavelengths of the electromagnetic spectrum in terms of absorption or reflection. It achieves high reflectivity in the mid-infrared (MIR/SWIR) and lower reflectivity in near-infrared (NIR) and estimated according to the following equations (Kaur & Pandey, 2022; Kebede et al., 2022):

$$NDBI = \frac{MIRum - NIRum}{MIRum + NIRum}, \text{ Landsat-TM/ETM+} \tag{1}$$

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR}, \text{ Landsat-OLI/TIRS+} \tag{2}$$

Thus, the equation can be applied with the TM/ETM+ sensor as follows:

$$NBDI = \frac{Band5 - Band4}{Band5 + Band4}. \tag{3}$$

With the OLI sensor, the equation can be applied as follows:

$$NBDI = \frac{SWIR - NIR}{SWIR + NIR}. \tag{4}$$

The values of the results from applying the mathematical equation range between +1, which represents the highest

Table 1. Classification of the study area (based on the field survey of the study area)

	Urban mass	Non-urban mass
Classification	Residential buildings	Agricultural land
	Roads and streets	Vacant lands (non-urbanized)
	Industrial buildings	Vegetation cover
	Airports	Parks and green spaces

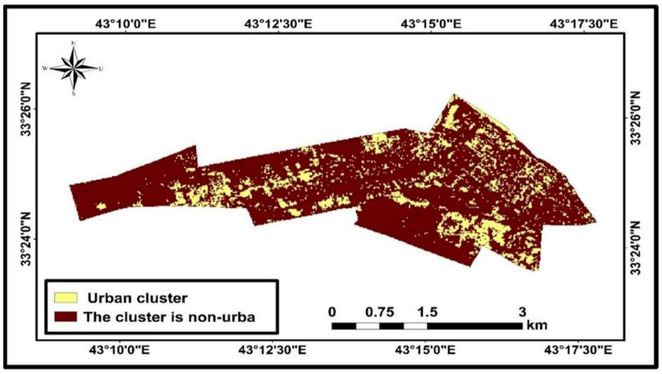

Figure 2. Urban mass map (based on satellite imagery from the Landsat-8 satellite and using the ArcMap 10)

reflection of buildings, and -1, which indicates the absence of buildings.

After applying the equation, the areas with urban mass appear and can be distinguished from the vacant areas (Halder & Bandyopadhyay, 2021; Yasin et al., 2022). It can be concluded that the western part of the City of Ramadi has undergone rapid transformations in its urban mass due to increasing population pressure, availability of job opportunities, and the desire to establish projects to increase the region's economic revenues. The study area was classified into two categories as follows (**Table 1**):

Table 2. Area of urban and non-urban mass (based on **Figure 2** and using the ArcMap 10)

Title	Area (hectares)
Urban mass area	2,716.0
Non-urban mass area	1,031.3
Total	3,747.5

1. Urban mass and
2. Non-urban mass.

Land use in any city are the result of its historical development and its interaction with the surrounding environment. The spatial patterns of land use are formed as a result of the interaction of a set of social and economic forces that are influential and effective. These functions, as outlined in **Table 1**, occupy areas in the form of land uses that share the built-up land of the urban area (Al Saleh et al., 2022). Subsequently, the raster layer is converted into a vector for representation on maps. The ArcMap program facilitates the process of calculating the area of the urban mass and non-urbanized land (Mushref et al., 2022). The total area of the western mass was approximately (3,747.5 hectares), and a significant variation in the area sizes between neighborhoods is observed. The largest area was in the Al-Mustaqbal neighborhood (563.6 hectares), while the smallest area was in the Al-Hussein neighborhood (40.7 hectares), as shown in **Table 2**. The area is distributed between developed areas, which amounted to about (2,716 hectares), and undeveloped areas, which amounted to about (1031.3 hectares), as illustrated in **Figure 2** and **Table 2**, and **Figure 3**.

In light of the ongoing urban expansion, the need has become urgent to analyze the distribution of urban and non-urban areas in order to understand the dynamics of urban growth, which are influenced by various economic, social, and environmental factors.

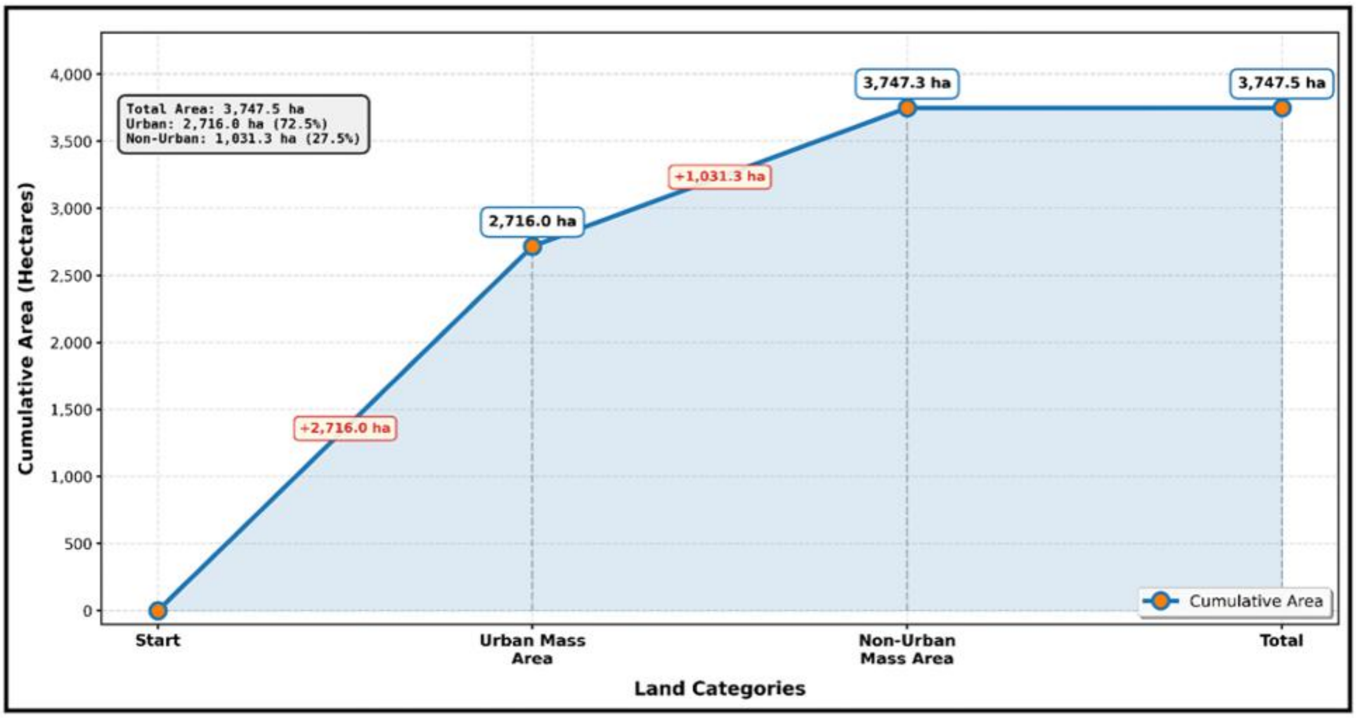

Figure 3. Distribution of urban and non-urban mass areas in the study area (Source: Authors' own elaboration)

Table 3. The area of urban and non-urban mass in the western part of Ramadi City

No	Neighborhood	Total area/hectare	Urban mass area/hectare	Percentage of urban (%)	Non-urban area/hectare	Percentage of non-urban (%)
1	Al-Mustaqbal	563.6	379	67.2	184.6	32.8
2	Al-Firdaws	258.7	144.3	55.8	114.3	44.2
3	Al-Wahda	360.7	250.6	69.5	110.1	30.5
4	Al-Ameen	271.8	212.6	78.2	59.3	21.8
5	Al-Sahabah	455.3	416.5	91.5	38.8	8.5
6	Al-Maqbara	157.9	136.9	86.7	21.1	13.3
7	Mustawda' al-Naft	87.1	65.7	75.4	21.4	24.6
8	Al-Dawajin al-Mulghaa	116.7	33.4	28.6	83.3	71.4
9	Al-Jamia	265.5	130.4	49.1	135	50.9
10	Al-Ula	260.6	188.8	72.4	71.8	27.6
11	Al-Waha	208.7	93.5	44.8	115.2	55.2
12	Al-Noor	61.8	59	95.5	2.8	4.5
13	Al-Tahrir	109.8	105	95.6	4.7	4.4
14	Al-Hussein	40.7	39.2	96.3	1.5	3.7
15	Maʿmal al-Zujaj	71.6	51.4	71.8	20.2	28.2
16	Al-Ta'mim	150.1	136.4	90.9	13.7	9.1
17	Al-Ikhaa'	85.3	80.5	94.4	4.7	5.6
18	Al-Nakheel	221.6	192.8	87.0	28.8	13.0
	Total	3,747.5	2,716.0	72.5	1,031.3	27.5

Note. Data is based on Figure 2 Landsat-8 imagery with a spatial resolution of 60 × 60 cm and ArcMap 10.8

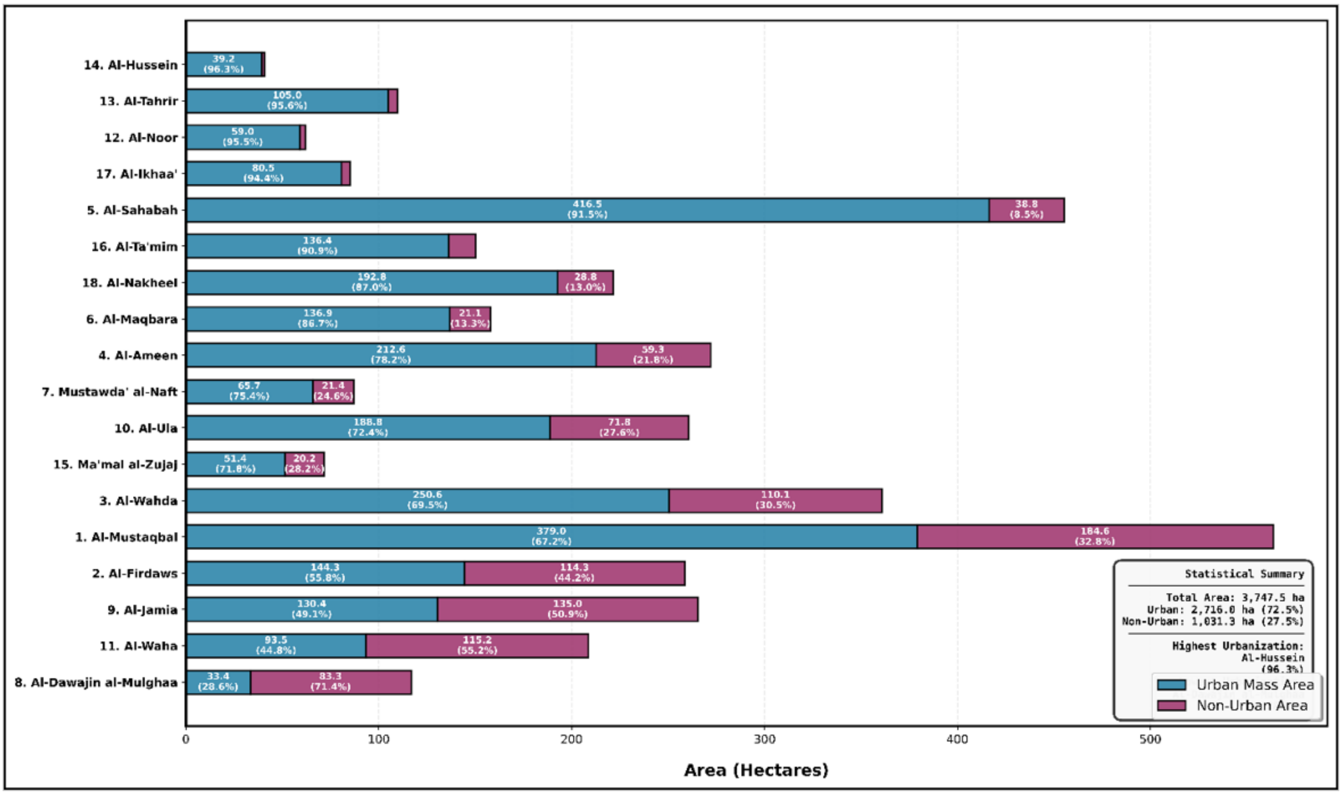

Figure 4. Urban and non-urban mass distribution by beighborhood (Source: Authors' own elaboration, based on Table 3)

As population growth increases, the urban built-up area expands due to a growing desire for construction, which results in a significant gap between developed and undeveloped urban areas. This indicates that there are large unused spaces that could serve as reserves for future expansion. This can be observed through a comparison between the areas occupied by the urban mass and the areas lacking residential neighborhoods, as shown in Table 3.

Through Table 3, the urban mass was classified by area in a scientific and systematic manner, by applying quantitative classification using classes based on area values, through the use of GIS tools and statistical analysis. Figure 4 depicts the urban and non-urban mass distribution by neighborhoods based on Table 3. Manual classification was used, as follows:

1. **High urban mass (more than 9%):** This found in the neighborhoods of Al-Hussein, Al-Tahrir, Al-Noor, Al-Ikhaa, Al-Sahaba, and Al-Ta'meem with respective percentages of 96.3, 95.6, 95.5, 94.4, 91.5, and 90.9. This is due to the low land prices in these areas, which encouraged low-capital investors to develop them.

2. **Medium urban mass (between 6-9%):** This includes Al-Nakheel, Al-Maqbara, Al-Ameen, Oil Depot, Al-Ula, Glass Factory, Al-Wahda, and Al-Mustaqbal with percentages of 87.0, 86.7, 78.2, 75.4, 72.4, 71.8, 69.5, and 67.2. The reason behind this is the population growth at a rate proportionate to the available resources in the area, which encouraged job opportunities and prompted people to move from densely urbanized areas to less developed ones.
3. **Low urban mass (less than 6%):** This includes the neighborhoods of Al-Firdaws, Al-Jami'a, Al-Waha, and Canceled Poultry Farms with percentages of 55.8, 49.1, 44.8, and 28.6. The reason lies in the small size of these neighborhoods, which limits the possibility of expansion and construction, leading to fewer residential units. Also, the presence of industrial activities reduces the attraction for residents due to noise and pollution, in addition to the presence of poultry farms which are unsuitable for housing and infrastructure development This classification is illustrated.
4. Accordingly, we find a significant variation in the areas between the neighborhoods. This is due to the unbalanced urban planning in this part. According to the data in the table, the urban area in the region is large, with non-urban areas also being extensive. The highest percentage appears in the following neighborhoods of Al-Dawajin Al-Mulghah, Al-Waha, Al-Jami'a, and Al-Firdaws with percentages of 55.2, 71.6, 50.9, and 44.2 hectares. The reason for the creation of this open space is the presence of large areas of unused land in these neighborhoods. Several factors contribute to this, such as the lack of services that encourage the utilization of these lands. Urban development appears randomly, or these areas may be used for industrial purposes, which reduces people's tendency to settle in these areas, or they may contain facilities like poultry farms, which are unsuitable for housing and infrastructure. However, these areas can be utilized in the future.

As for the neighborhoods where the open space percentage is moderate, they include Al-Mustaqbal, Al-Wahda, Glass Factory, Al-Ula, Oil Depot, and Al-Amin with percentages of 32.8, 30.5, 28.2, 27.6, 24.6, and 21.8 hectares. This is due to the presence of well-organized urban planning that divides spaces for public facilities and services, which helps in rational land use between construction and green areas, improving the open space without overbuilding.

In contrast, the areas with a low percentage of open space include Al-Maqbara, Al-Nakhil, Al-Tameem, Al-Sahaba, Al-Ikha, Al-Noor, Al-Tahrir, and Al-Hussein with percentages of 13.3, 13.0, 9.0, 8.5, 5.6, 4.4, 4.5, and 3.7 hectares. The reason for the scarcity or lack of open space in these areas is the high population density in limited parts of the city, which leads to the full utilization of the area. The weak planning prevents leaving land for expansion within the neighborhood, pushing the development into areas allocated for recreation, and there is a lack of horizontal growth, with buildings being constructed vertically.

RESULTS

Analysis of Landsat-8 satellite imagery using the NDBI revealed significant urban expansion in the western part of Ramadi. The built-up area reached 2,716 hectares, representing 72.5% of the total study area of 3,747.5 hectares, while undeveloped land comprised 1,031.3 hectares, or 27.5%. This distribution indicates a substantial reserve of vacant land that could be allocated to future planned expansion.

The results also showed a clear spatial variation in urbanization levels among neighborhoods. Some neighborhoods–such as Al-Hussein, Al-Tahrir, Al-Nour, and Al-Ikhaa–recorded high urbanization rates exceeding 90%, reflecting a dense urban pattern with limited open spaces. Conversely, other neighborhoods–such as Al-Dawajin Al-Mulghaa, Al-Waha, and Al-Jami'a–exhibited low urbanization rates and large areas of undeveloped land, in some cases exceeding 70% of the total neighborhood area. These disparities point to an imbalance in urban growth, partly due to variations in land prices, the distribution of services and economic activities, and previous planning choices.

Medium-density neighborhoods, such as Al Nakheel, Al Ameen, Al Oula, and Al Mustaqbal, have exhibited a transitional urban pattern trending toward further expansion due to the availability of infrastructure and services, making them prime candidates for further development in the near future.

Remote sensing and GIS techniques have proven highly effective in accurately extracting these patterns. The combination of unsupervised classification, spectral index analysis, and raster to vector transformation has enabled the production of high-resolution standard maps that facilitate comparisons between neighborhoods and accurately depict the boundaries between built-up and undeveloped areas. The NDBI index has also demonstrated its ability to clearly distinguish between built-up areas, vegetation, and vacant land, confirming its suitability for studying urban expansion in rapidly changing environments.

It can be said that the western part of Al Ramadi is experiencing rapid urban transformations, manifested in the expansion of built-up areas, increasing disparities between neighborhoods, and the continued presence of large undeveloped areas. These results represent an accurate spatial database that can contribute to supporting sustainable urban planning, guiding development decisions, and identifying spatial priorities for expansion in line with actual urban trends in the city.

DISCUSSION

The urban transformations witnessed in the western part of Ramadi city during 2024 reflect a clear dynamic resulting from the interaction between rapid population growth and increasing community needs. Advanced geospatial technologies, particularly remote sensing and GIS, have contributed to improving the ability to analyze and understand complex urban phenomena in depth. The results of this study demonstrate the importance of adopting innovative urban planning models. The NDBI has proven effective in accurately identifying urban areas, strategically directing investments, and monitoring the distribution of inhabited and uninhabited areas.

This type of geospatial analysis contributes to providing accurate spatial insights that support decision-making processes in the field of urban expansion management. This underscores the growing role of spatial data in providing reliable data on land use, enhancing planners' ability to develop resilient and sustainable urban policies.

CONCLUSIONS

The study results show that the western part of Ramadi has witnessed noticeable urban expansion, with urban areas now covering approximately 2,716 hectares, representing 72% of the city's total area. This contrasts with 1,031.3 hectares of undeveloped land, which remains a significant reserve for future expansion. The analysis also revealed a marked spatial variation in urbanization levels among neighborhoods. Some areas exhibit high urban density and limited open spaces, while others contain large proportions of undeveloped land.

The study demonstrated the effectiveness of remote sensing and GIS techniques in tracking urban transformation and accurately identifying expansion patterns in both time and space. This strengthens their potential as key tools for supporting decision-making and producing accurate high-accuracy standardized maps of urban land use.

Based on these findings, it is clear that enhancing the city's planning framework requires the urban fabric through the development of spatially analyzed development plans, along with a review of existing urban plans to align with actual growth trends. The results also confirm the importance of expanding the use of modern geospatial technologies to create accurate urban databases that support sustainable planning efforts and improve the distribution of services and green spaces within the urban fabric.

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