International Journal of Sustainable Development and Planning
Vol. 21, No. 3, March, 2026, pp. 1409-1420
Journal homepage: http://iieta.org/journals/ijsdp

Spatial Accuracy Assessment of Satellite Imagery and UAV-Based Aerial Imagery in Mapping Encroached Land Uses: An Applied Case Study

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https://doi.org/10.18280/ijsdp.210337

Received: 15 December 2025
Revised: 6 March 2026
Accepted: 13 March 2026
Available online: 31 March 2026

Keywords:
master plan, land use planning, land use violations, satellite image, aerial image

ABSTRACT

The phenomenon of land use violations is considered one of the urban issues with global implications, especially in cities experiencing unregulated growth. The city of Amriya Al-Somoud represents a practical example of an Iraqi city that reflects this reality, having witnessed encroachments within the master plan that affected land use patterns and infrastructure efficiency. In this context, there is a need to adopt advanced imaging tools capable of representing these violations with spatial accuracy that supports planning decision-making. The research begins by comparing the accuracy of aerial images captured by unmanned aerial vehicles (UAVs) with satellite images in representing land uses that have been encroached upon, relying on spatial analysis supported by Global Navigation Satellite System (GNSS) data to produce comprehensive maps within a geographic information system (GIS) environment. The study aims to evaluate the efficiency of each imaging tool in producing accurate maps that display land use details, property boundaries, and reveal spatial overlaps. The results show that the efficiency of representing the urban reality does not depend solely on the type of data source, but is also influenced by the nature of the urban environment and its spatial complexity; aerial images provide a high level of detail in densely populated areas within this context, while satellite images remain more suitable for wide coverage and general monitoring. The importance of the study lies in highlighting that the choice of data source should be based on the nature of the planning application and the characteristics of the location, while providing a methodology applicable to other cities facing similar challenges in land use management.

1. INTRODUCTION

Cities face the challenge of maintaining sustainable urban development, which is represented by balanced land use planning within the master plan. This is considered one of the pillars of sustainable urban development as it regulates the growth of land uses and directs activities within the city. However, the urban reality often witnesses violations of these uses, which disrupts its organizational structure and affects the efficiency of services and infrastructure, in addition to its impact on the urban landscape. In light of this reality, the necessity of preparing an accurate map of land uses according to their current state becomes evident, showing the locations, boundaries, and characteristics of the violations clearly. Hence, the importance of employing modern technologies in producing spatial data with higher clarity and accuracy, resulting in realistic maps that support institutions in making planning decisions, is confirmed.

In this context, satellite images are defined as images captured by satellites from space, characterized by their ability to cover large areas and provide long-term archival data, allowing for clear monitoring of changes at the city level, especially in open areas over time. On the other hand, aerial images captured by drones are images of the Earth's surface taken from the air using a camera mounted on an aircraft platform at low altitudes via unmanned aerial vehicles (UAVs), which grants them higher accuracy and clearer details, making them more suitable for representing densely populated urban environments.

This research addresses the city of Amriya Al-Sumoud as an applied model reflecting the reality of land use violations within the master plan, which has led to confusion in land use organization, changes from the planned uses, and their overlap with functions and services. This has resulted in distortions in the urban fabric and additional pressures on infrastructure. The research aims to analyze the efficiency of aerial images captured by drones compared to satellite images in preparing accurate maps of the violated land uses by evaluating the differences in spatial accuracy and clarity, and the ability of each to represent the congested urban features, thereby supporting spatial analysis and planning decision-making.

1.1 Research problem

The phenomenon of land use violations is considered a global urban issue, especially in developing urban environments, where cities face increasing challenges in controlling and regulating these uses due to the growth of urban encroachment patterns and their various forms. There is a need for advanced imaging tools that accurately represent these violations with high spatial precision, reflecting their actual details at the urban reality level, thereby supporting decision-making in the fields of reorganization and urban planning.

1.2 Research hypothesis

The study hypothesizes that the use of aerial imagery acquired by UAVs achieves higher effectiveness compared to satellite imagery in the re-planning of encroached land uses within the study area.

1.3 Research objective

- Determining the level of spatial accuracy and clarity of both aerial images captured by drones and satellite images in representing encroached land uses, with the aim of evaluating their efficiency in producing precise spatial data that can be relied upon in planning applications.
- Conducting a spatial comparison between aerial and satellite images to produce accurate land use maps that reflect the urban reality, along with preparing a comprehensive spatial and geographical database, contributing to supporting urban planning processes, addressing urban encroachments, and regulating land uses.
- Utilizing the results of spatial analysis to improve the accuracy of determining property boundaries and detecting overlaps between land uses and infrastructure networks, enabling municipalities and service entities to diagnose locations of spatial conflicts, address violations, and reduce disputes related to property boundaries and services.
- To evaluate the possibility of deriving a Digital Elevation Model (DEM) from both aerial and satellite imagery within the context of this study, for determining ground elevation levels and supporting land-use planning and road design, thereby improving the efficiency of infrastructure projects.
- Achieving spatial data integration by merging land use information with elements of urban infrastructure, such as energy networks, power lines, streetlights, sewage networks, and road boundaries, to produce comprehensive and clear spatial maps that accurately reflect the urban reality. This contributes to facilitating the understanding of spatial relationships between these elements and supports decision-making by planning and execution authorities with greater precision and efficiency.

1.4 Contribution of the study

The scientific contribution of this study lies in providing an applied approach that links the evaluation of the spatial accuracy of various imaging sources with urban planning requirements, particularly in addressing the phenomenon of land use violations as an urban issue with a global scope that is not limited to a specific geographical area. The study does not limit itself to comparing aerial and satellite images in terms of accuracy, but goes beyond that by utilizing the results of this comparison to produce precise maps that can be relied upon to represent the reality of urban encroachments in detail, thereby contributing to improving the accuracy of actual land use maps.

In this context, the study relies on building a comprehensive spatial representation that not only includes land uses but also encompasses elements of urban infrastructure, such as energy networks, streetlights, power lines, and manhole locations. Additionally, it involves defining the boundaries of main roads and representing the topographical characteristics of the area thru the derivation of Digital Elevation Models (DEM), which allows for a more accurate reading of the spatial relationships between the components of the urban environment.

Building on this integration, the study contributes to revealing spatial overlaps and encroachments, whether between land uses and property boundaries, or between urban activities and infrastructure networks, thereby helping to reduce spatial conflicts and improve the clarity of urban boundaries.

The Al-Amiriya area has been employed as a practical model reflecting the complexities of this phenomenon, without limiting the study's objective to its spatial aspect. The adopted methodology is characterized by its potential for generalization and application in similar urban areas suffering from unregulated growth.

Through, the study provides a practical framework that can be used by municipalities, service departments, and entities responsible for infrastructure management to support planning decision-making, improve the efficiency of service network management, and address violations more accurately and effectively.

1.5 Research methodology

This study adopted a comparative analytical approach to evaluate the spatial accuracy of aerial imagery acquired by UAVs and satellite imagery in representing encroached land uses. The methodology aimed to overcome the limitations of traditional maps by producing high-precision maps that reflect the spatial characteristics of urban encroachments, and this was implemented through four main phases.

<u>Phase One</u>

Spatial data was collected from official sources, which included satellite images, aerial photographs, as well as the city's master plan maps, to ensure the reliability of the data used in the analysis. This was followed by the identification of the (analysis area), relying on the master plan as a spatial reference, where the spatial extent of urban violations was determined.

<u>Phase Two</u>

A field survey was conducted using a GNSS device (CHC i90), where RTK technology was employed to provide centimeter-level accuracy, making it suitable for spatial analysis purposes within the study.

Four ground control points (GCPs) were adopted due to the relatively small spatial extent of the study area, which represents a confined spatial domain. This reduced the need for a large number of points to achieve an adequate level of positional accuracy.

These points were systematically distributed to cover the boundaries, edges, and central part of the study area, ensuring balanced spatial representation and enhancing the reliability of spatial alignment between the data sources.

<u>Phase Three</u>

In the processing phase AutoCAD 2022 (Autodesk) was used to prepare and organize the base map data by reviewing and refining its boundaries, enabling its use as an accurate spatial reference in subsequent analysis stages.

Subsequently, ArcMap 10.7.1 within the ArcGIS environment (Esri) was used, where a spatial clipping operation (Clip) was applied to both aerial and satellite imagery based on the predefined study area boundaries. This was carried out to standardize the spatial framework and ensure consistency in comparison between different data sources.

Georeferencing procedures were then performed for both aerial and satellite images and aligned with the base map and the current conditions of the study area. This was followed by spatial analysis and the production of final land-use maps for both data sources, enabling a comparative evaluation of their representation of urban encroachments.

Phase Four

Spatial accuracy was assessed using ArcMap 10.7.1 by comparing coordinates derived from aerial and satellite imagery with reference coordinates obtained from GNSS measurements. Positional error for each point was calculated as the difference between extracted and reference coordinates for each axis (X, Y, Z), as expressed by the following equations:

$$Ex = Xi - Xo,\ Ey = Yi - Yo,\ Ez = Zi - Zo \quad (1)$$

where,

- Xi, Yi, Zi: coordinates derived from imagery
- Xo, Yo, Zo: GNSS-based reference coordinates
- Ex, Ey, Ez: positional errors in each axis

The total positional error for each point was then calculated using the square root of the sum of squared errors in the three axes (XYZ):

$$ErrorXYZ=\sqrt{(Ex)2 + (Ey)2 + (Ez)2} \quad (2)$$

The Root Mean Square Error (RMSE) was calculated for each axis separately using the following equations:

$$RMSE\ X=\sqrt{(\sum(Ex)^2/n} \quad (3)$$

$$RMSE\ Y=\sqrt{(\sum(Ey)^2/n} \quad (4)$$

$$RMSE\ Z=\sqrt{(\sum(Ez)^2/n} \quad (5)$$

where,

n: number of evaluated points

Σ: summation of values across all points

Horizontal positional accuracy was also calculated using the following equation:

$$\text{Horizontal RMSE} = \sqrt{(RMSE\ X)^2 + (RMSE\ y)^2} \quad (6)$$

In addition, overall spatial accuracy was calculated as:

$$Total\ RMSE = \sqrt{\frac{1}{n}\sum_{i=i}^{n} Error\ XYZ_i^2} \quad (7)$$

Based on the above, the results of these analyses were used to identify the most efficient data source in terms of accuracy and clarity in map production. In the final stage, the most accurate map generated within the ArcMap 10.7.1 environment was exported and converted into AutoCAD 2022 format, enabling its use in supporting planning and implementation applications.

2. THEORETICAL FRAMEWORK

2.1 Land use planning in light of the master plan

It is one of the most important tools that guide the course of urban development and contribute to improving the quality of life, as it includes a package of visions, plans, and strategies that ensure more efficient urban growth [1]. It is one of the most prominent planning factors directly influencing the transformation of the city, as it provides a clear vision of its future structure and determines the proposed land use ratios, their changes, and the locations of key activities [2]. Among its tools is the zoning of these uses spatially and organizing their relationships. As the governing variables change, so do the activities and functions, which is reflected in the transformation of land use patterns [3]. The process of changing land use stems from a fundamental idea to meet specific needs that emerge in a defined spatial scope, highlighting a need such as housing, roads, or services [4]. Therefore, the need for land use planning has emerged as an essential component in the urban planning process and a crucial factor in urban development. It serves as a governing and guiding framework for growth paths to control unplanned growth. The general objectives of land use planning focus on limiting uncontrolled urban growth [5].

2.1.1 Land-use encroachments, associated challenges, and approaches for their mitigation

Land use violations are unauthorized changes in the type of use, occurring as a result of individuals or certain entities seizing state-owned lands and exploiting them without legal justification, contrary to what is stipulated in the master plan. This phenomenon represents one of the most serious challenges threatening the city's urban structure due to the distortion it causes in the urban landscape and the negative impacts on the functional structure and service efficiency, resulting from weak oversight and the absence of law enforcement [6].

In light of the accelerating pace of urbanization and the increasing population growth, this phenomenon has become more complex, presenting additional challenges to land use planning. This makes addressing these challenges a planning necessity to regulate unplanned urban growth and achieve balanced urban development.

In this context, the importance of employing modern technologies, such as satellite imagery and aerial photographs, and integrating them with geographic information system (GIS) and advanced surveying tools, has emerged. These technologies play a crucial role in improving the quality of spatial data, enhancing analytical efficiency, enabling planning authorities to accurately diagnose violations, understand spatial interaction patterns, and support decision-making to address this phenomenon more effectively. Through, the role of land use planning extends beyond organizing urban resources; it becomes a proactive tool to face future challenges and achieve more sustainable urban environments [7].

2.2 Satellite image

They are visual and digital data produced by satellites to capture and measure the Earth's surface characteristics remotely. These data are captured from space by satellites orbiting at different altitudes and represent a source of remote sensing. (Figure 1) shows that the satellite sensors record this data in digital form, which is then processed to transform it into spatial products usable GIS. These images provide the capability to cover large areas while offering regular and consistent data over time, supporting monitoring, observation, and long-term change analysis. They are practically used in producing maps such as land cover and monitoring long-term temporal changes based on the archive in addition to monitoring urban growth, which makes it a supportive tool for land planning and management since satellite data is characterized by wide coverage and repetitive observation, making it very useful when evaluating large areas [8].

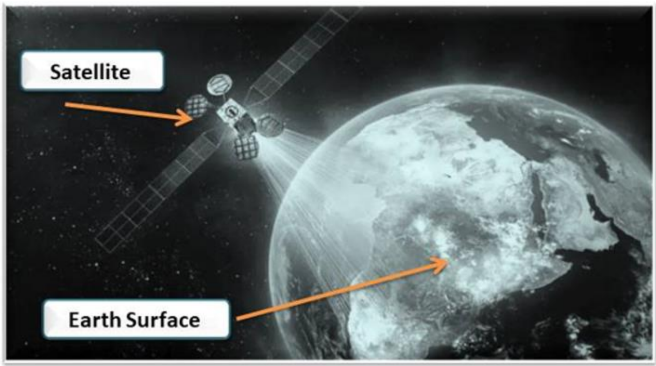

Figure 1. Illustrative representation of a satellite acquiring remote sensing imagery of the Earth
Source: Prepared for this study for illustrative purposes.

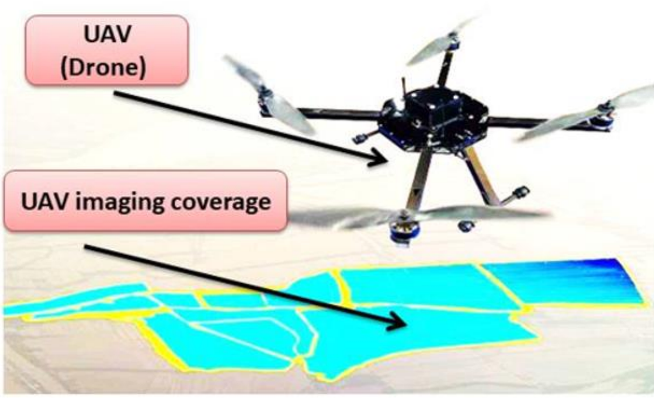

Figure 2. Illustrative representation of a UAV capturing high-resolution aerial imagery.
Source: Prepared for this study for illustrative purposes.

2.3 Aerial image taken by an unmanned aerial vehicle

Recent technological developments in geographical and engineering sciences have enhanced the use of aerial photography acquired by UAVs, which provide accurate spatial data that support detailed representation of land and spatial features. Aerial imagery is considered an effective tool for producing and updating maps, as it enables precise measurement of distances and areas, supporting efficient mapping processes compared to traditional field survey methods. In addition, it facilitates the generation of three-dimensional representations that contribute to a better understanding of topographic characteristics. Aerial imagery is applied in various fields, including agriculture, soil monitoring, environmental studies, geology, civil engineering, urban planning, project monitoring, and the development of land-use and transportation maps [9]. Among the different types of aerial imagery, images captured by UAVs (Figure 2) represents a technique capable of acquiring spatial data from low altitudes, enabling detailed representation of urban environments, including buildings and natural features [10].

2.4 The importance of aerial imagery (UAV) and satellite images in preparing high-precision land use maps

The drone technology is a scientific and effective option for managing urban spaces, and its importance is particularly highlighted by the precise data it provides, which contributes to supporting planning and decision-making within urban environments. These drones are equipped with high-resolution cameras to capture images and videos from multiple angles [11]. When integrated with GIS and Global Navigation Satellite Systems (GNSS), they achieve clear gains in data collection, analysis, and decision support, producing accurate urban data that can be used to prepare detailed land use maps within a GIS environment. This environment can be used to create and display information, manage spatial databases by organizing, processing, and analyzing them, and produce outputs in the form of tables and maps [12], Through these outputs, urban planners can read the spatial relationships between various infrastructure elements more accurately and make more informed decisions regarding land use, transportation networks, and service development priorities [13]. Additionally, they can link their data to GIS to produce three-dimensional models and representations (DEM), enhancing the understanding of urban reality, increasing the efficiency of analysis and planning, and making the use of these aircraft highly valuable in planning practices [14]. Through, accurate maps enhance the functions of public records such as land and property registers and reduce disputes over property boundaries, thereby supporting transparency in ownership and increasing community trust [15]. This is difficult to achieve with traditional satellite remote sensing methods, which are usually linked to fixed revisit cycles and have lower spatial resolution capabilities in many products [16]. However, satellite imagery cannot be dispensed with in planning decisions, as satellite remote sensing provides a wide range of captured data, in addition to archives extending over decades, which enhances the ability to monitor long-term changes, making it very useful when evaluating large areas [17].

Contemporary urban trends indicate an increasing rate of unplanned urban growth, which has resulted in encroachments on urban land uses and deviations from the allocations defined in master plans. This situation highlights the need for land-use planning approaches based on accurate data that reflect current conditions.

Within the context of this study, although satellite imagery provides wide spatial coverage and valuable temporal archives, its ability to capture fine-scale changes in complex urban environments—particularly in accurately delineating property boundaries within high-density areas—is considered limited. This necessitates the use of higher-accuracy data sources to effectively achieve the objectives of the study.

In contrast, aerial imagery acquired using UAVs offers higher spatial resolution, enabling a more detailed representation of boundaries, areas, locations, and land-use patterns. This level of precision is particularly important for applications related to calculating property and public space areas, as well as for supporting regulatory and development decisions through the production of high-accuracy digital maps that clearly define property boundaries and public domains.

Accordingly, such data provide a practical basis for supporting urban planning decisions, especially in densely populated urban environments, which has led to the identification of a set of indicators to measure this accuracy, as presented in Table 1.

Table 1. Indicators of the theoretical framework to be measured in the practical component for comparing the accuracy of satellite and aerial imagery

No.	Indicator	Method of Measuring the Indicator
1	Spatial accuracy	Measuring metric accuracy by comparing the derived coordinates in both images with Ground Control Points (GCPs) obtained using a Differential GPS (GNSS) surveying device.
2	Resolution	Comparing the amount of detail that appears in each image, such as the ability to distinguish small features and how clearly small details are defined in each image, like buildings, roads, or natural landmarks, by analyzing the detail accuracy in both images.
3	Precision of areas and dimensions	Calculating the areas accurately for each image and comparing the results between the two images.
4	Type of use	Distinguishing the type of use, whether residential or other uses, through analyzing certain characteristics in the images, such as building patterns, color usage, and urban structure.
5	Extraction of the Digital Elevation Model (DEM) that represents the elevations of the Earth's surface	By proving either of the two methods capable of extracting the DEM through GIS systems for inputting spatial data and converting it into an elevation map, it helps in understanding the natural terrain of the land, which in turn aids in better and more accurate land use planning and road design.
6	Cost and time	Comparison of the cost of data collection using drones with the cost of data collection using satellites, and which one is faster in the duration it takes for each technology to collect and process the data.

3. PRACTICAL FRAMEWORK: A CASE STUDY IN THE AL-AMARIYAH DISTRICT

3.1 Geographical and astronomical location of the study area

The city of Amriya Al-Somoud is a vital part of the Al-Anbar Governorate in the central region of Iraq, specifically in its southeastern part. It is distinguished by its strategic intermediate location to the west of the capital, Baghdad, and to the south of the city of Fallujah. Amriya overlooks the Euphrates River opposite the city of Fallujah and extends deep into the desert towards Lake Razzaza from the southwestern side [18]. Its spatial dimensions are approximately 22 km from the center of Fallujah District to the north and about 48 km from the center of Baghdad to the east, while it is about 63 km away from the city of Ramadi to the west. Astronomically, the study area is located between the latitudes (32.45–33.20)° North and the longitudes (43.30–44.20)° East (Figure 3).

3.2 Unplanned land uses for the study area

The way residents utilize urban land reflects their level of awareness and the degree of civilizational development. The more organized and well-planned land use is, the more harmonious and efficient the city appears. Conversely, any encroachment or random use of urban land has a direct impact on the city's form and function and may disrupt its present and future urban and developmental trajectories. Therefore, achieving a certain level of balance within the city requires the presence of clear regulatory frameworks and planning procedures that consider human needs while preserving the cohesion of the urban fabric and the overall structure of the city [19]. Amriya Al-Somoud like many other cities, exhibits various forms of land-use encroachments within its urban area, particularly in locations close to basic services. These encroachments vary in type, size, form, and spatial extent, which affects the regularity of the urban fabric and reduces the efficiency of infrastructure systems, as illustrated in Figure 4. This phenomenon represents one of the urban challenges associated with increasing pressure on land within cities, necessitating the reorganization of these land uses and their integration into a more coherent planning framework with formally developed neighborhoods.

To address this, the study relies on the use of satellite imagery and high-resolution aerial images captured by unmanned aerial vehicles (UAVs) (drones) for the study area (Figure 5), in addition to Differential Global Positioning System (GNSS) measurements, in order to produce an accurate map of encroached land uses. The final outputs were generated using ArcGIS and AutoCAD.

The two aforementioned images were used to produce two land-use maps using ArcMap 10.7.1, with the aim of comparing the level of spatial data accuracy for each map. Based on the map that demonstrated higher accuracy, a dedicated spatial and attribute database was developed to represent its characteristics more precisely.

The results presented in Figure 6 indicate that land-use mapping using both satellite and aerial images within the study area revealed differences in accuracy levels. In this case, the satellite image did not support a mapping scale finer than 1:1000 due to relatively limited clarity, resulting in a more generalized representation of certain land uses, primarily residential.

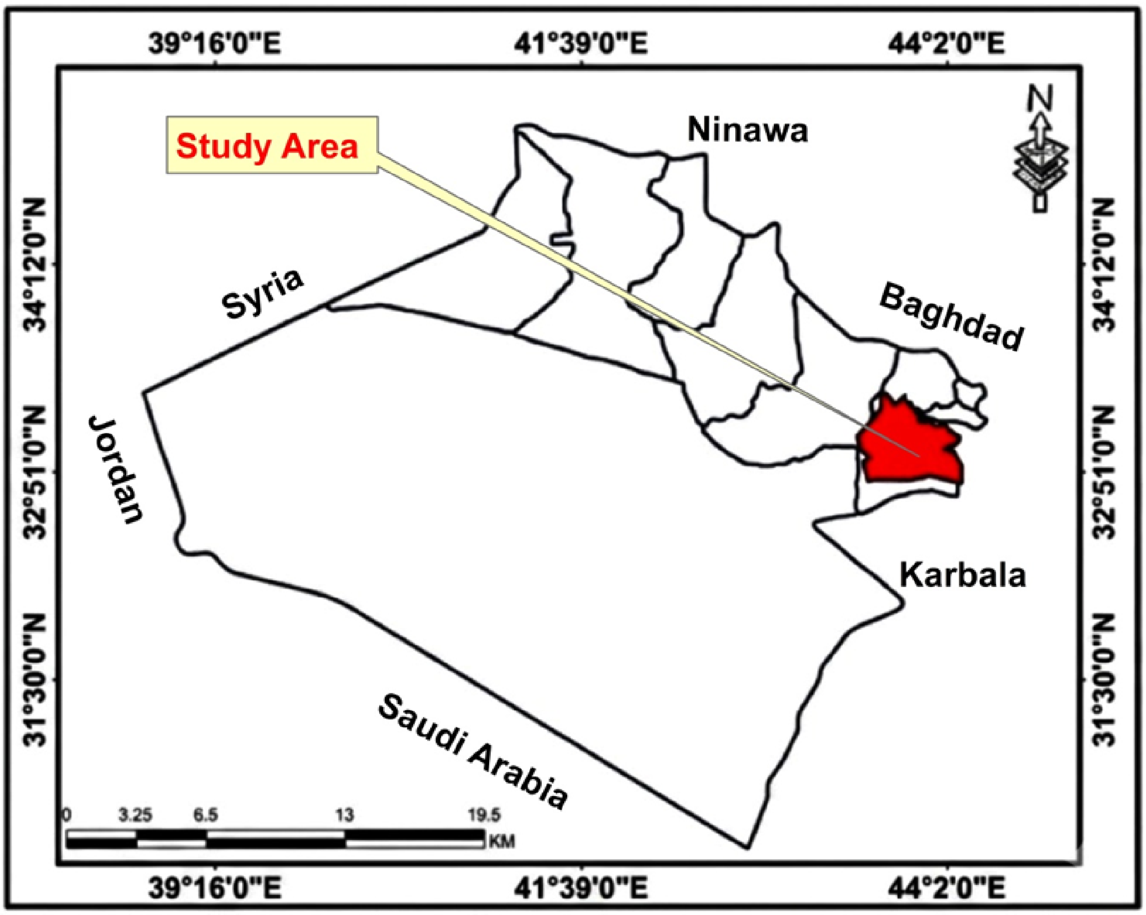

Figure 3. Location map of the study area (Amriya) within Anbar Governorate, Iraq
Source: Prepared within this study based on the [18].

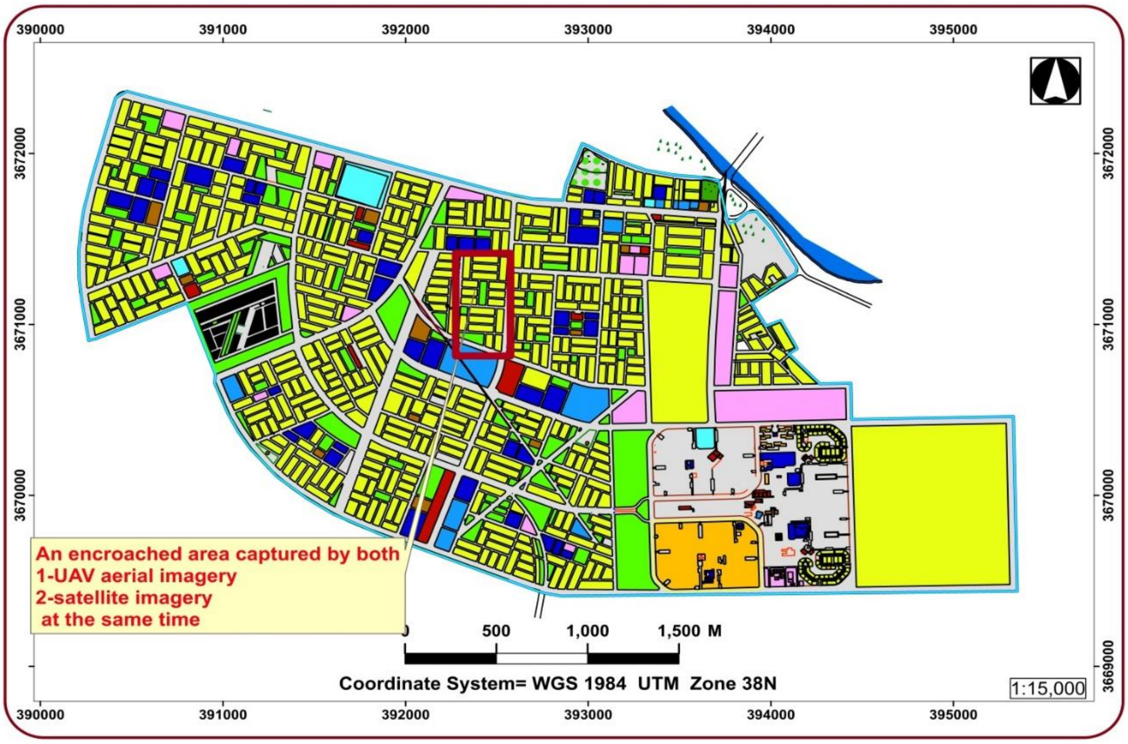

Figure 4. Distribution of land-use encroachments within study area
Source: Prepared within this study using ArcMap analysis, field survey, and available spatial data.

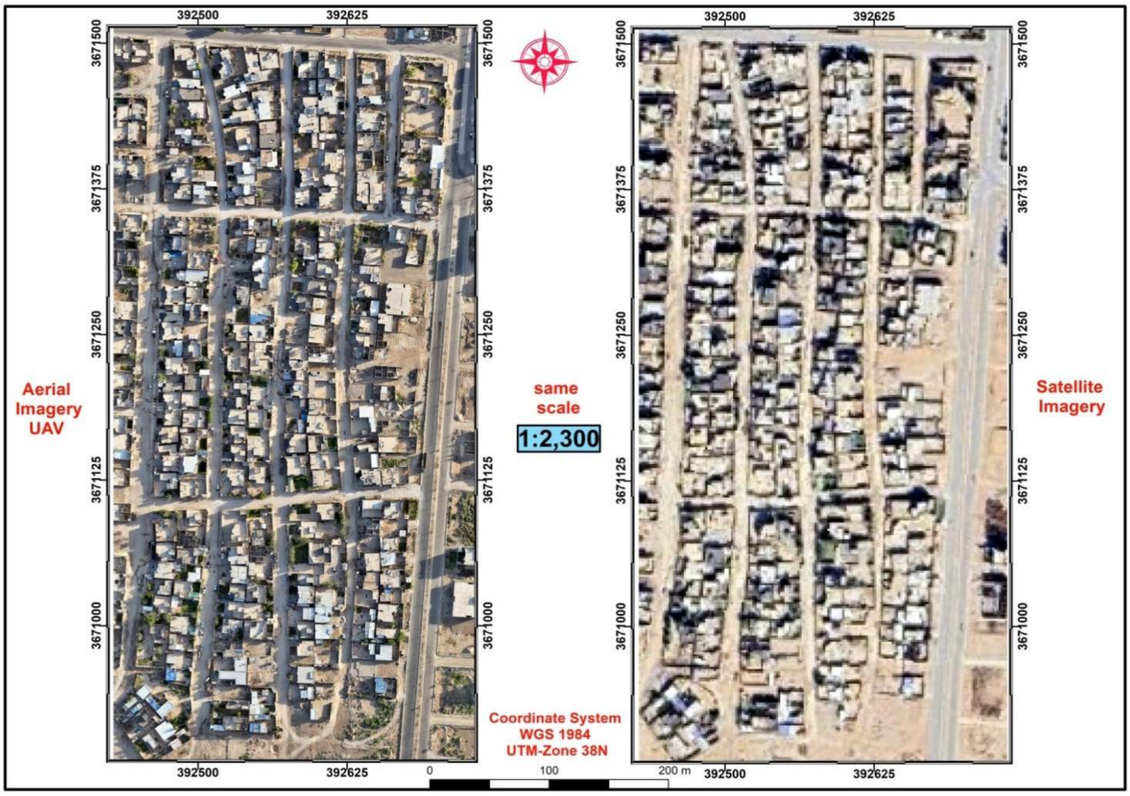

Figure 5. Aerial image captured by drone and satellite image of the encroachment area [20]

Notes: Georeferencing of both images was performed simultaneously using ground control points (GCPs) collected with a GNSS device. The data were then processed using AutoCAD, and the final map was produced using ArcMap 10.7.1.

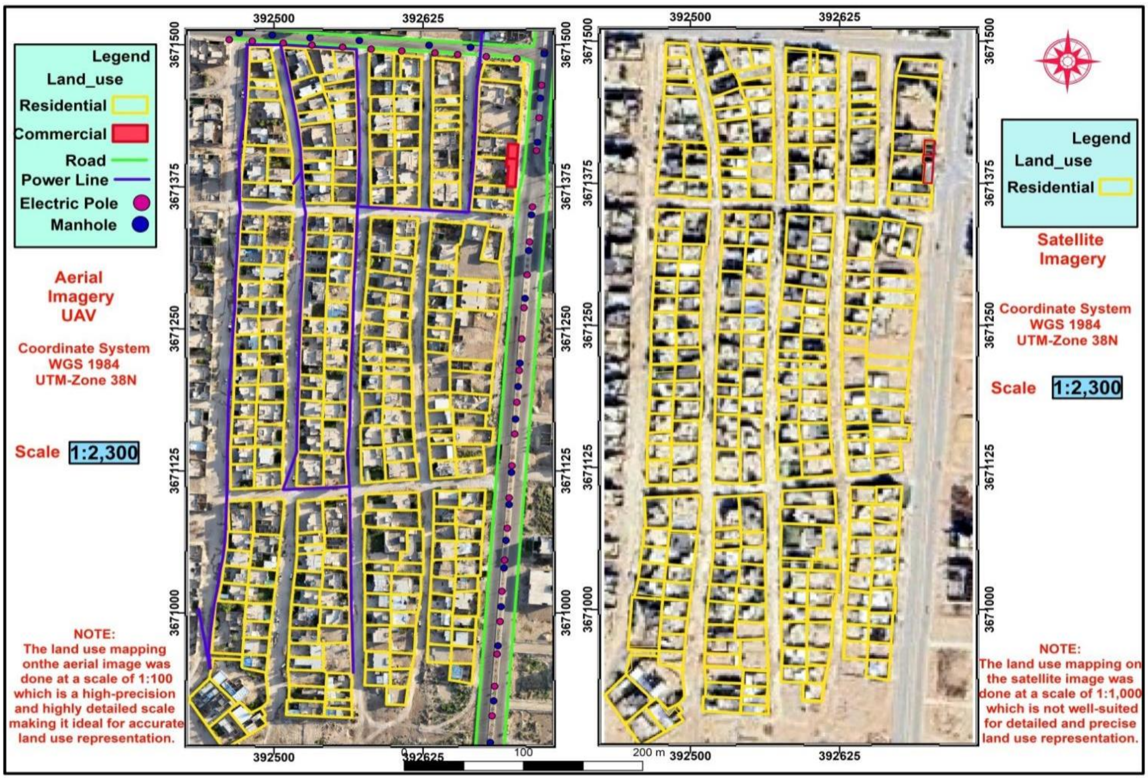

Figure 6. Land-use map derived from both aerial and satellite images

Source: Prepared within this study based on the analysis of aerial and satellite imagery.

In contrast, the aerial image within the study area allowed the use of a 1:100 scale, contributing to relatively higher spatial accuracy and enabling clearer differentiation among various land-use types, including residential, commercial, power lines, roads, manholes, and light poles.

The comparison results within the study area indicate that the differences in clarity are not only related to the characteristics of each data source, but are also influenced by the specific urban conditions of the study area, which is characterized by high urban density, overlapping land uses, and spatial complexity. Aerial imagery demonstrated relatively higher effectiveness in representing fine spatial details within encroachment areas in the study area, where the small size and overlap of elements require higher spatial accuracy for proper identification.

In contrast, satellite imagery within the study area showed relative limitations in representing fine details in spatially complex environments, particularly in areas characterized by high urban density.

Based on the above, spatial alignment between the data sources was achieved within this study by projecting ground control points (GCPs) collected using a GNSS device onto both the aerial and satellite images. Analytical outputs were generated to quantify spatial deviations in coordinates and areas using ArcMap 10.7.1 (Figure 7), based on the equations presented in the study methodology. In addition, the capability of each data source within this study to derive a Digital Elevation Model (DEM) was evaluated (Tables 2-5).

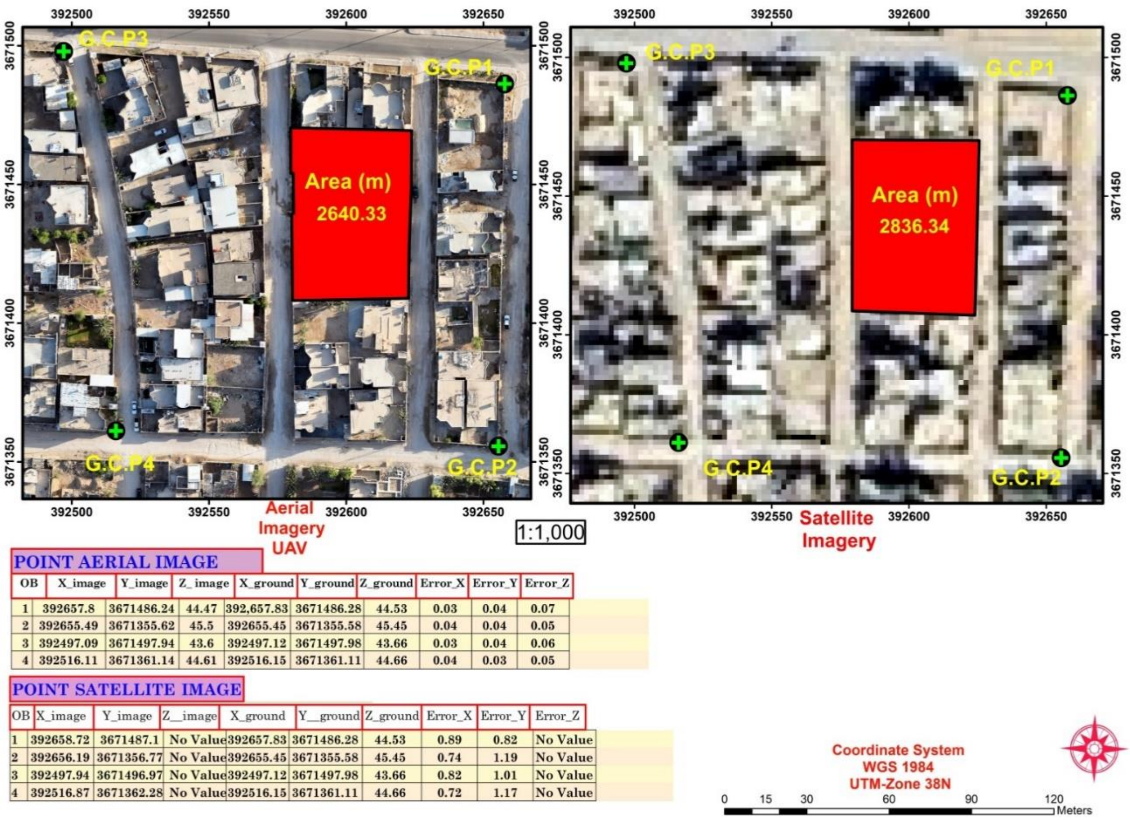

Figure 7. Comparison of spatial accuracy between Global Navigation Satellite System Real-Time Kinematic (GNSS RTK) data and aerial and satellite images (1:1000)

Source: Prepared within this study based on ground control points collected using a GNSS device and processed in ArcMap. The figure was generated, and a report was produced to quantify the spatial error rate for both image sources.

Table 2. Positional errors (X, Y, Z) and error in (XYZ) derived from UAV aerial imagery

OB	ERROR X (m)	ERROR Y (m)	ERROR Z (m)	ERROR(XYZ) (m)
1	0.03	0.04	0.07	0.086
2	0.04	0.04	0.05	0.075
3	0.03	0.04	0.06	0.078
4	0.04	0.03	0.05	0.070

Table 3. Root Mean Square Error (RMSE) values for UAV aerial imagery (X, Y, Z, Horizontal XY, and Total XYZ)

RMSE X (m)	RMSE Y (m)	RMSE Z (m)	Horizontal RMSE (XY) (m)	Total RMSE (XYZ) (m)
0.0353	0.0377	0.058	0.0516	0.0774

Based on the equations presented in the methodology section, positional errors were calculated for each point by comparing coordinates derived from aerial and satellite imagery with GNSS reference coordinates along the [X, Y, and Z] axes (Figure 7), followed by the derivation of [Horizontal RMSE XY] and [Total RMSE] values.

Table 4. Positional errors (X and Y) derived from satellite imagery

OB	ERROR X (m)	ERROR Y (m)
1	0.89	0.82
2	0.74	1.19
3	0.82	1.01
4	0.72	1.17

Table 5. Root Mean Square Error (RMSE) values for satellite imagery (X, Y, and Horizontal XY)

RMSE X (m)	RMSE Y (m)	Horizontal RMSE (XY) (m)
0.795	1.058	1.32

The results of these calculations were presented in Tables 2-5, illustrating the positional error for each point along with the derived values, enabling the assessment of spatial accuracy for each data source and supporting a quantitative comparison of their effectiveness in representing land use within this study.

The comparison results between maps derived from aerial and satellite imagery, supported by the results presented in (Figure 7 and the associated Tables 2-5, revealed clear differences in their ability to support precise planning.

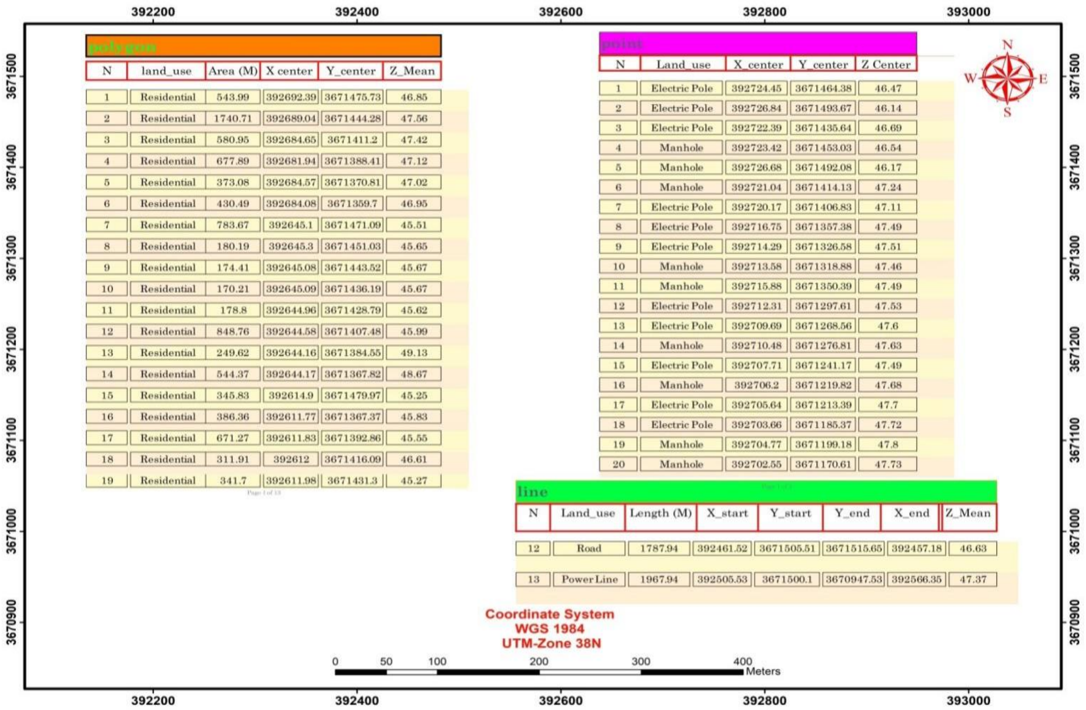

Figure 8. The report presents the geographic and spatial database derived from the most accurate aerial image used in land-use mapping within the study area

Source: Prepared within this study based on the analysis of aerial imagery using ArcMap 10.7.1.

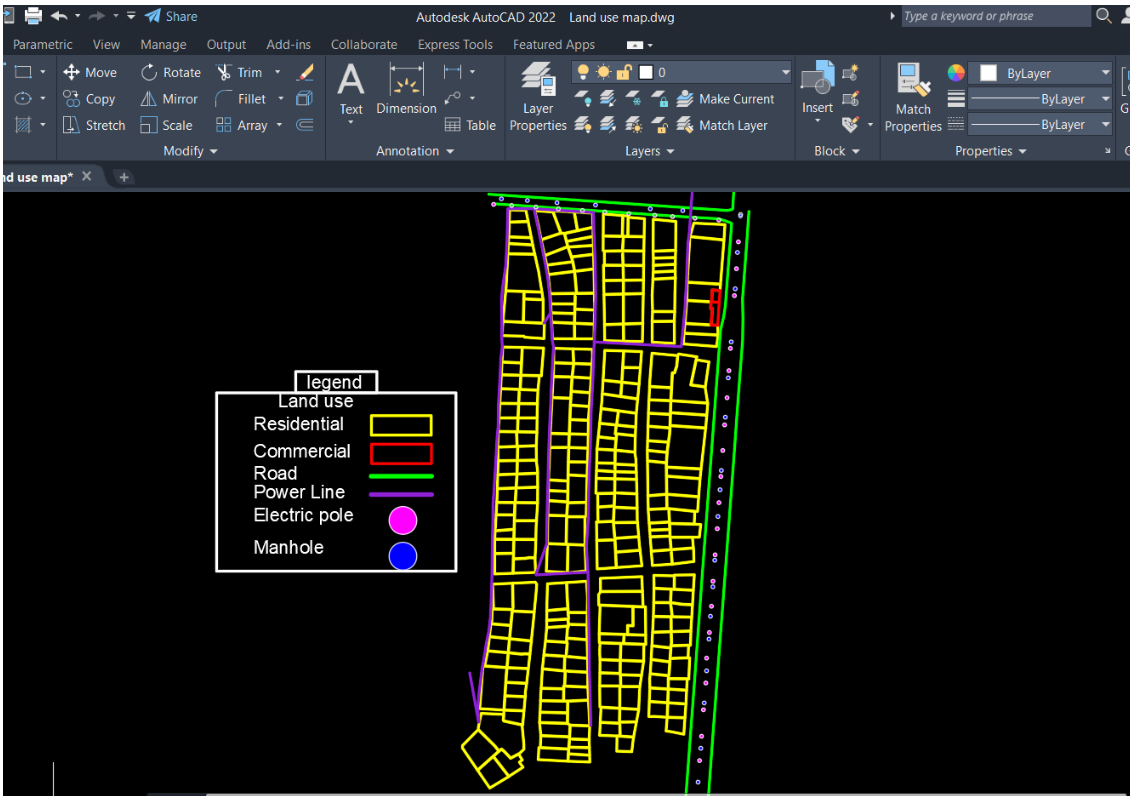

Figure 9. Land-use map derived using ArcMap 10.7.1 and converted into AutoCAD format to support implementation processes and planning decision-making within the study area

Source: This study, using ArcMap 10.7.1 and AutoCAD 2022.

The tabulated results indicate that aerial imagery achieved a higher level of spatial accuracy compared to satellite imagery at the same mapping scale (1:1000). The horizontal RMSE (RMSE XY) reached approximately [0.0516 m], while the total RMSE (RMSE_XYZ) reached approximately [0.0774 m], reflecting a high level of spatial accuracy. In contrast, the horizontal RMSE for satellite imagery reached approximately [1.32 m], indicating a lower level of spatial accuracy compared to aerial imagery. Furthermore, Tables 2-5 and Figures 6 and 7 show that aerial imagery provided a higher level of spatial detail, enabling clearer identification of fine-scale features such as property boundaries, narrow paths, and service-related elements. In contrast, satellite imagery showed limitations in representing these details within the context of the application.

The results also indicate differences in area extraction accuracy between the two data sources, where aerial imagery demonstrated a higher level of conformity with on-ground conditions in delineating land-use areas, as reflected in the comparative analysis.

With regard to the Digital Elevation Model (DEM), the results indicate that aerial imagery enabled the generation of a more accurate elevation model, where the vertical error did not exceed approximately [0.06 m] according to the tabulated results. This is attributed to the quality of spatial data and its integration with GNSS data. In contrast, satellite imagery within the context of this study did not demonstrate the capability to generate a Digital Elevation Model (DEM), due to the lack of integration with GNSS data, which limited its ability to accurately represent topographic characteristics.

Accordingly, the results of this study confirm that data derived from aerial imagery provide a more accurate and detailed spatial database (Figure 8) within the context of the study, thereby enhancing the efficiency of spatial analysis and supporting more precise planning decision-making.

In this context, the most accurate map produced within the ArcMap 10.7.1 environment (Figure 6) was converted into AutoCAD 2022 format. This was carried out to provide planning and implementation authorities, as well as service departments within the study area, with precise digital maps that can be directly utilized in design and execution processes (Figure 9).

This procedure was conducted to enhance the applicability of spatial analysis outputs within the study area in practical applications, contributing to linking geographic analysis results with implementation requirements.

4. STUDY LIMITATIONS

Although the findings of this study demonstrated that aerial imagery acquired by UAVs achieved higher spatial accuracy within the study area compared to satellite imagery, several constraints should be considered within this context.

- With regard to UAV-based data acquisition, data collection within the study area may be subject to certain limitations, particularly in densely populated urban environments. These include regulatory restrictions on UAV operations, as they are governed by legal frameworks, which require compliance with relevant regulations prior to data collection. In addition, accessibility to certain locations may be limited, and data quality can be affected by weather and atmospheric conditions. Furthermore, covering large areas requires additional time and effort due to flight time limitations associated with battery capacity.
- With regard to satellite imagery, although it provides rapid coverage of large areas and offers valuable archival data, its relatively limited spatial resolution within this study may affect the representation of fine details, particularly in high-density or spatially complex urban environments, especially in environments similar to the study area that involve overlapping land-use patterns and require precise planning decisions.

5. CONCLUSION

The results of this study indicate that the variation in spatial accuracy between satellite imagery and aerial imagery acquired by UAVs is not merely a technical difference, but reflects differences in the ability to represent urban reality, which directly influences the effectiveness of planning decisions. The representation of encroached land uses is influenced not only by the type of data source, but also by the characteristics of the urban environment and the level of spatial complexity in this context.

Aerial imagery demonstrated relatively higher capability in capturing fine spatial details in densely built-up areas within the study area, whereas satellite imagery was associated with representing more generalized patterns within the same spatial context.

From this perspective, the findings of this study emphasize that the selection of imaging data type is an integral component of planning decision-making. This selection should be based on the nature of the application and the required level of accuracy, particularly in environments characterized by mixed land uses and complex spatial relationships.

From a methodological perspective, the results of this study showed that the integration of high-resolution aerial imaging techniques with GNSS data, geographic information systems (ArcGIS), and engineering design software (AutoCAD) contributed to the production of comprehensive spatial maps. These maps extend beyond land-use classification to include infrastructure elements and topographic characteristics, enhancing data reliability and improving the representation of urban reality within the context of this study.

At the practical level, the study demonstrates that utilizing these outputs supports planning authorities by providing accurate spatial databases that can be directly applied in design and implementation contexts. This contributes to improving land-use management, organizing urban growth, and reducing spatial overlaps between properties, activities, and infrastructure.

6. RECOMMENDATIONS

In light of the findings of this study, an integrative approach is recommended for planning authorities, municipal departments, and relevant entities. This approach is based on integrating aerial imagery acquired by UAVs with GNSS data, GIS, and AutoCAD in land-use mapping activities, with the possibility of applying this approach in similar cases that share comparable spatial and urban characteristics with the context of this study.

The results of this study indicate that such integration enhances coordinate reliability and spatial representation accuracy, supporting the production of detailed digital maps and models that can be used for property boundary delineation and encroachment monitoring.

The results further indicate that applying this approach may contribute to reducing disputes related to inaccuracies in property boundaries, improving the efficiency of plan implementation, and enhancing public confidence in land records and associated administrative procedures.

In contrast, within the context of this study, the results indicate that satellite imagery remains valuable in providing wide spatial coverage and temporal archives. However, its use is more appropriate as a complementary tool, particularly in applications that do not require high levels of spatial detail in complex urban environments, especially when compared to aerial imagery within this study, which demonstrated higher spatial accuracy and a greater ability to represent fine details.

The study also highlights the importance of adopting continuous mechanisms for updating spatial data and improving its management efficiency, contributing to more effective land management practices.

Accordingly, this study highlights that the systematic integration of spatial data sources represents a practical approach to improving map accuracy and strengthening its role as a supportive tool for planning decision-making and addressing land-use issues within this context. The findings also suggest that this methodology may be applicable in similar urban environments that share comparable spatial and morphological characteristics with the study context.

ACKNOWLEDGMENT

This work was supported by the Urban and Regional Planning Center for Postgraduate Studies, University of Baghdad.

REFERENCES

[1] Hamd, A.H., Motlak, J.B. (2025). Stages development and updating of the master plan for the city of Baghdad by adopting spatial techniques. Journal of Planner and Development – University of Baghdad, 30(1). https://jpd.uobaghdad.edu.iq/index.php/jpd/article/view/532.

[2] Al-Shadidi, H.A.S., Al Kaabi, M.M.F. (2024). Impact of investment projects in changing master plan of Najef Holy City. Pakistan Journal of Life & Social Sciences, 22(2): 491-505. https://doi.org/10.57239/PJLSS-2024-22.2.0036

[3] Hasson, S.I.K., Dhumad, K.F. (2018). The effect of urban land use changing on green area neighborhoods No. 336 & 338 in Baghdad - case study. Journal of Engineering – University of Baghdad, 24(12): 1-20. https://doi.org/10.31026/j.eng.2018.12.09

[4] Yassir, F.A.A., Ibrahim, M.A.J. (2023). The dynamics of the oil industry in shaping land uses: a case study of the Zubair oil field. Journal of Planner and Development – University of Baghdad, 28(3). https://jpd.uobaghdad.edu.iq/index.php/jpd/article/view/423

[5] Alwan, K.H., Omran, S.H. (2023). Asmarat inventory interpretation for tourism land use planning and growth management. IOP Conference Series: Earth and Environmental Science, 1129: 012037. https://doi.org/10.1088/1755-1315/1129/1/012037

[6] Kareem, N.A. (2025). Transgressions and their effects on the form the basic design of AI Mansour. Midad Al-Adab Journal, 15(40): 2161-2186. https://doi.org/10.58564/ma.v15i40.1811

[7] Sheikhazami, A., Ghaemmaghamifard, A. (2024). An introduction to the role of land use planning in urban development plan. Proceedings of the 5th International Conference, Mashhad, Iran. https://www.researchgate.net/publication/387792981

[8] Kumar, B. (2025). Utilizing drones and satellite imagery in crop monitoring and precision farming: An application of the WASPAS method. REST Journal on Data Analytics and Artificial Intelligence, 4(2): 13-25. https://doi.org/10.46632/jdaai/4/2/2

[9] Dawod, G. (2013). An Introduction to Aerial Photographs and Satellite Images (A Book in Arabic). https://doi.org/10.13140/RG.2.1.4614.5764

[10] Djimantoro, M.I., Suhardjanto, G. (2017). The advantage by using low-altitude UAV for sustainable urban development control. IOP Conference Series: Earth and Environmental Science, 109: 012014. https://doi.org/10.1088/1755-1315/109/1/012014

[11] Mahmood, M.A., Ghazal, N.K., Mahmood, F.H. (2024). Optimizing spatial accuracy for photogrammetric processing of drone-based 3D mapping. Iraqi Journal of Science – University of Baghdad 65(7): 4124-4138. https://doi.org/10.24996/ijs.2024.65.7.45

[12] Al-Rawe, M.K. (2021). Use the application of geographic information systems in the distribution of the electrical network. IOP Conference Series: Earth and Environmental Science, 754: 012030. https://doi.org/10.1088/1755-1315/754/1/012030

[13] Kamarulzaman, A.M.M., Jaafar, W.S.W.M, Said, M.N.M., Saad, S.N.M., Mohan, M. (2023). UAV implementations in urban planning and related sectors of rapidly developing nations: A review and future perspectives for Malaysia. 15(11): 2845. https://doi.org/10.3390/rs15112845

[14] Abdulhassan, A. (2025). Integration of UAV and GNSS data for accurate land use mapping at Wasit university. Wasit Journal of Engineering Sciences, 13(3): 74-85. https://doi.org/10.31185/wjes.Vol13.Iss3.742

[15] Prabowo, G.S., Bisri, M., Asmara, R., Sugeng, A., Suprapedi, Aziz, A. (2025). Development of a precision map of the village based using drone imagery to improve the quality of planning. Jurnal Pembangunan dan Alam Lestari, 16(1): 39-47. https://doi.org/10.21776/ub.jpal.2025.016.01.05

[16] Xu, H., Wang, L., Han, W., Yang, Y., Li, J., Lu, Y., Li, J. (2023). A survey on UAV applications in smart city management: Challenges, advances, and opportunities. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 16: 8982-9010. https://doi.org/10.1109/JSTARS.2023.3317500

[17] Varga, K., Szabo, S., Szabo, G., Dévai, G., Tothmeresz, B. (2015). Improved land cover mapping using aerial photographs and satellite images. Open Geosciences, 7(1): 15-26. https://doi.org/10.1515/geo-2015-0002

[18] Sabea, A.M., Mashhadani, A.H.N. (2018). Monitoring the changes between the land cover and land uses in the area of Amiriya Fallujah. Journal of Tikrit University for Humanities, 25(10): 185-203. https://doi.org/10.25130/jtuh.25.10.2018.09

[19] Al-Hadithy, I.T.O.S. (2025). Spatial analysis of urban land use violations in the city of Hit. Wasit Journal for Human Sciences – Wasit university 21(2): 266-249. https://doi.org/10.31185/wjfh.Vol21.Iss2.967

[20] U.S. Geological Survey. https://www.usgs.gov