



AI-KITAB UNIVERSITY
COLLEGE OF ENGINEERING
DEPARTMENT of SURVEY ENGINEERING

**Topographic Survey and Digital
Terrain Modeling for Road Alignment
Design**

**“A Project Submitted in Partial Fulfillment of the Requirements for
the Degree of Bachelor of Science in Engineering Survey”**

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2025-2026

Acknowledgment

I would like to express my sincere gratitude and deep appreciation to the academic staff of the Department of Surveying Engineering, including the Dean of the College, the Head of the Department, and all respected professors, for their continuous support and valuable guidance.

I would like to extend my special thanks to my research supervisor, Dr. Noor Nabil, for her constructive advice, patience, and continuous encouragement throughout the preparation of this research. I am also grateful to everyone who contributed, directly or indirectly, to the completion of this study, their support and cooperation played an important role in accomplishing this work successfully.

Abstract

Road infrastructure is a fundamental component of economic development and sustainable transportation systems. This project presents a comprehensive overview of the design process of a 60-meter wide dual carriageway main road and highlights the application of AutoCAD Civil 3D software in road geometry design and earthwork quantity calculations. The study discusses the road characteristics, its importance, and the advantages of using advanced digital tools to calculate cut and fill volumes, grading works, and cross-sections. Through the utilization of the civil 3D program, an improved design and an enhanced decision making was adopted.

A detailed field survey was conducted using Differential GPS (DGPS) to collect dense and accurate ground points along the project corridor. There had been several site visits to collect data and later revealed several challenges, including disturbed ground conditions and dumped construction materials including from nearby construction projects. Based on these conditions a suitable road alignment was carefully selected to minimize design conflicts and earthwork quantities.

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List of Terms

No	Term	Full Meaning
1.	DGPS	Differential Global Positioning System
2.	CAD -3D	Computer-Aided Design-three Dimensions
3.	E,N,Z	Easting, Northing, Elevation
4.	NG	Natural Ground
5.	DTM	Digital Terrain Modeling
6.	AASHTO	American Association of State Highway and Transportation Officials
7.	HCM	Highway Capacity Manual
8.	LiDAR	Light Detection and Ranging
9.	UAV	Unmanned Aerial Vehicle

CHAPTER ONE

Introduction

1.1 Background

Main roads are among the most important infrastructure elements that directly contribute to economic and social development. they facilitate transportation, reduce travel time, and connect urban and rural areas. The design of dual carriageway roads is a pressing necessity given the continuous increase in the number of vehicles, as it provides a high level of traffic safety and smooth traffic flow. This research focuses on the design of a 2.9-kilometer-long, 60-meter-wide dual carriageway with two sidewalks and median strip, serving high-traffic areas within an urban or semi-urban zone.

1.2 Problem Statement

The existing road network in the project area suffers from traffic congestion, limited capacity, and insufficient safety features. The lack of proper shoulders, pedestrian sidewalks, and service facilities has increased accident risks and reduced transportation efficiency. Therefore, a new main road design is required to solve these problems and accommodate future traffic demand.

1.3 Objectives

The main objectives of this project are:

1. To design a main dual carriageway road with a total width of 60 meters.

2. To improve traffic safety by providing a central median, shoulders or sidewalks.
3. To apply highway design standards in geometric and structural design.
4. To utilize modern surveying and design techniques in road planning.

1.4 Scope of Work

This project covers the planning and design of a 2.9 km main road, including :-

1. Selecting the appropriate route for the road.
2. Horizontal and vertical design of the road.
3. Designing the road's cross-section.
4. Designing dual carriageway, sidewalks, and median strip.
5. Calculating quantities using Civil 3D.
6. data collection, analysis, and presentation of results using engineering software.

These details are taken from the terms and conditions of the General Directorate of Municipalities in Erbil.

1.5 Methodology Overview

This research adopted an analytical and applied approach, which included:

1. Studying international standards for road design.
2. Entering topographic data into Civil 3D software.
3. Designing axes and cross-sections.
4. Generating quantities and final reports.

CHAPTER TWO

Literature Review

The development of highway interchanges has been a cornerstone of modern transportation engineering. The cloverleaf interchange, first introduced in the United States in the 1920s, researchers such as Holtz and Mogul (1965) documented its efficiency in eliminating left-turn conflicts, it was also documented by the American Association of State Highway and Transportation Officials AASHTO (2001) for such interchanges, other researchers Al-Khalil (2015) concluded that cloverleaves are most effective in corridors with balanced traffic volumes, and so as Zhang and Li (2020) highlighted the efficiency they provided with smoother flow, Research work by Hassan (2018) emphasized that traditional total station surveys are precise, but considered as time-consuming for long corridors, Rahman (2021) demonstrated that GPS-based surveying systems significantly reduce field time while maintaining high accuracy.

Recent Research work focused on the role of AutoCAD Civil 3D in roadway design, as they integrate alignments, profiles, corridors, and grading functions Smith and Johnson (2019), who showed that the software reduces design errors and enhances adaptability. There are many case studies in India and China Patel (2020), Zhang (2021), which demonstrate this concept. Research by Kumar (2022) and Al-Hassan (2023) highlighted that cloverleaf interchanges, when properly designed, reduce vehicle emissions by minimizing stop-and-go traffic and the highway capacity Manual HCM (2010) provides models for analyzing interchange performance, emphasizing the importance of uninterrupted flow in reducing congestion, according to AASHTO standards, factors such as design speed, lane configuration, vertical and horizontal alignment, and sight distance

must be considered to ensure safety and efficiency as demonstrated by Garber and Hole (2015) and Wolf & Ghilani (2012).

Theoretical studies in geomatics Burrough & McDonnell (1998) explain how dense point data improves model accuracy, which is critical for roadway design. For these sets of data, they are used to generate digital terrain models (DTMs) which aided engineers to visualize elevation changes and drainage patterns with greater reliability Wolf & Ghilani (2012), Accurate spatial interpolation methods, ensure that roadway alignments reflect the true nature of the natural ground surface Garber & Hole (2015), Integrating GPS-based surveying with geomatics theory reduces errors Hassan (2018), and provide the foundation for a safe highway infrastructure.

CHAPTER THREE

Methodology

3.1 Study Area Description

The study area located in district of Erbil Governorate on the Ebil-Shaqlawa main road, Coordinates (E:416826, N:4011979) shown Fig (1), consists of a proposed main dual carriageway road with a total length of 2.9 km and a total width of 60 m, including two carriageways and sidewalks on both sides. area under study affected by several nearby construction projects, which resulted in surface irregularities and dumped construction materials along parts of the corridor.



(a)



(b)



(c)



(d)

Figure (1) Location map of the proposed road project

- a- Coordinates of area under study
- b- Point (a) in the map from ground level
- c- The students during site investigation
- d- Point (a) connect with erbil-shaqlawa road

3.2 Site Investigation and Field Survey

A detailed site visit was conducted prior to the design stage in order to assess the existing ground conditions and identify potential challenges. During the field inspection, several issues were observed, including the presence of dumped construction materials and disturbed ground surfaces caused by adjacent infrastructure projects. These conditions required careful consideration during the selection of the road alignment and surface modeling.

To ensure high accuracy and reliability of spatial data, a Differential GPS (DGPS) system was used for the field survey Fig2(a). This method provides centimeter-level accuracy and is widely adopted in engineering surveying projects, especially for road design and earthwork calculations.



(a)



(b)

Figure (2) The Differential GPS Instrument

- (a) GNSS Receiver, Model E600- (e survey brand), Multi-constellation satellite tracked
- (b) Product in a China (2021), RTK High Accuracy.

3.3 Data Collection Using Differential (GPS)

A dense and accurate set of ground points was collected along the entire project corridor using the Differential GPS system. The survey included:

1. Centerline points along the proposed road alignment
2. Points covering the full width of the road corridor
3. Additional points in areas with significant elevation changes, this meant that the practical aspect Fig (3) the project required several site visits.

The use of dense point spacing ensured accurate representation of the terrain, particularly in areas affected by dumped materials and uneven surfaces. All surveyed points were referenced to a unified coordinate system to allow seamless integration with design software.

More than (5000) points were taken, shown in table(1-b).



Figure (3) practical aspect of the project and site visits

Table(1) Natural ground points(NG) (E,N,Z)coordinate

<u>Point.No</u>	Easting	Northing	Elevation
1	414798.160	4013266.592	484.914 NG
2	414791.815	4013269.723	485.194 NG
3	414785.665	4013266.343	485.265 NG
4	414777.483	4013254.791	484.728 NG
5	414772.718	4013249.649	484.616 NG

(a)

5177	9	414400.805	0	4013483.945	0	477.467	NG
5178	0	414402.770	0	4013494.759	0	477.041	NG
5179	1	414398.940	0	4013425.398	0	479.390	NG
5180	2	414401.175	0	4013434.861	0	479.019	NG
5181	3	414403.410	0	4013444.325	0	478.647	NG
5182	4	414405.645	0	4013453.789	0	478.276	NG
5183	5	414407.880	0	4013463.252	0	477.904	NG
5184	6	414410.115	0	4013472.716	0	477.533	NG
5185	7	414412.350	0	4013482.180	0	477.161	NG
5186	8	414414.585	0	4013491.643	0	476.790	NG
5187	6	414315.307	0	4013472.241	0	477.797	NG
5188	7	414318.563	0	4013482.146	0	477.488	NG
5189	8	414321.819	0	4013492.050	0	477.179	NG
5190	9	414325.075	0	4013501.955	0	476.870	NG
5191	0	414328.332	0	4013511.859	0	476.561	NG
5192	1	414331.588	0	4013521.764	0	476.252	NG
5193	2	414334.844	0	4013531.668	0	475.943	NG
5194	3	414338.100	0	4013541.573	0	475.634	NG

(b)

These data are provided as sample data due to the considerable road distance

3.4 Alignment Selection

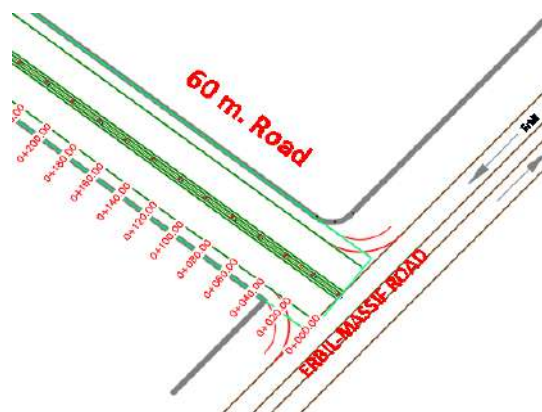
Based on the field survey and site conditions, a suitable horizontal alignment was selected. The chosen alignment avoids problematic areas as much as possible while maintaining design efficiency and compliance with engineering standards. The alignment selection considered:

1. Existing topography
2. Site constraints and obstacles
3. Safety and geometric design requirements
4. Minimization of earthwork quantities

With these criteria the alignment was selected and as shown in Fig (4)



(a)



(b)

Figure (4) view of proposed project

(a)-proposal alignment

(b)-Alignment at Station (0+000) connect with (ERBIL—MASEEF) road

3.5 Use of AutoCAD Civil 3D in Road Design

Upon collecting the necessary data program of Auto CAD civil 3D is was used.

The following steps were performed:

3.5.1 Importing Survey Data

The surveyed DGPS points were imported into Civil 3D and organized according to their descriptions and elevations. These points formed the basis for generating the existing ground model, shown in the Fig (5).

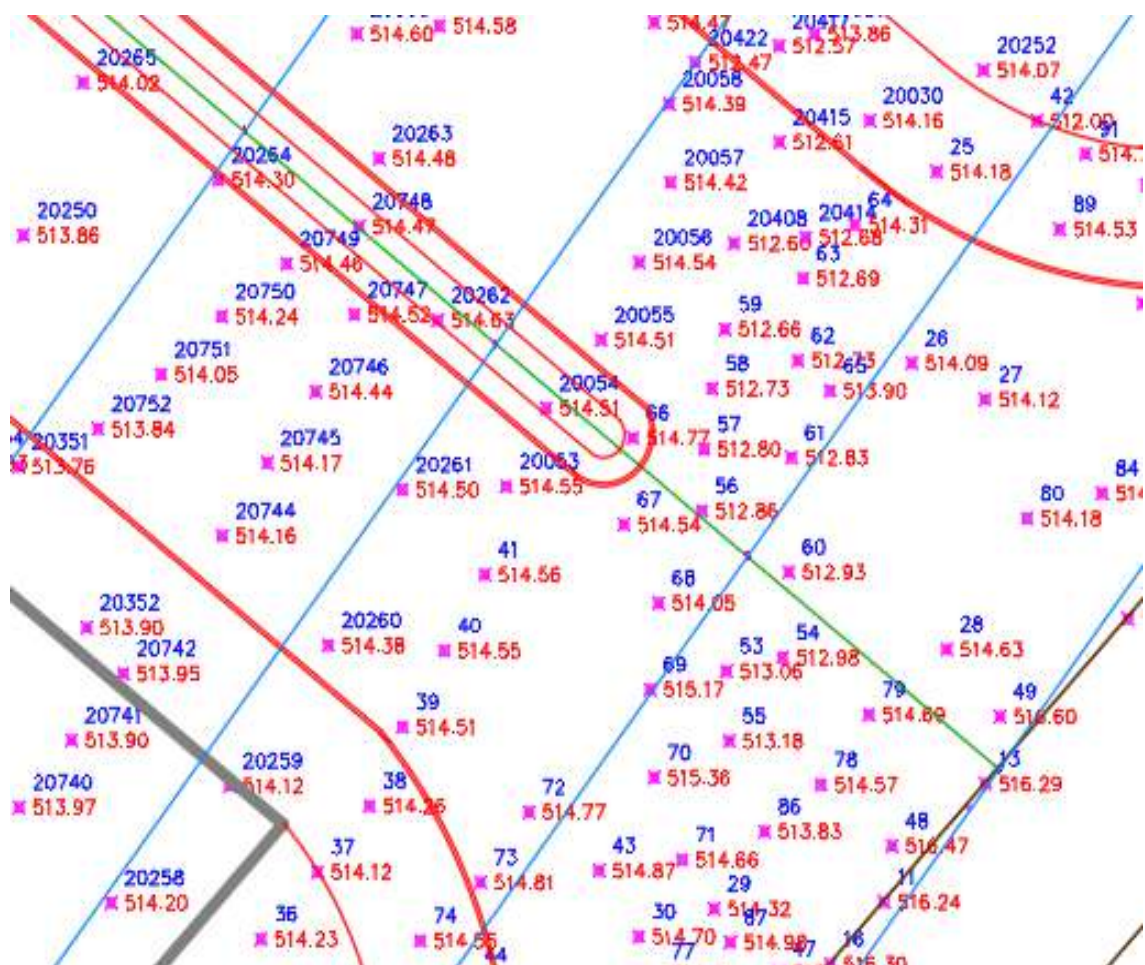


Figure (5) Natural ground points(NG) (E,N,Z) coordinate

3.5.2 Digital Terrain Model (Surface Creation)

A Digital Terrain Model (DTM) was created by generating a surface from the imported points. The surface accurately represents the existing ground conditions and was used as a reference for all subsequent design stages, as shown in Fig (6).

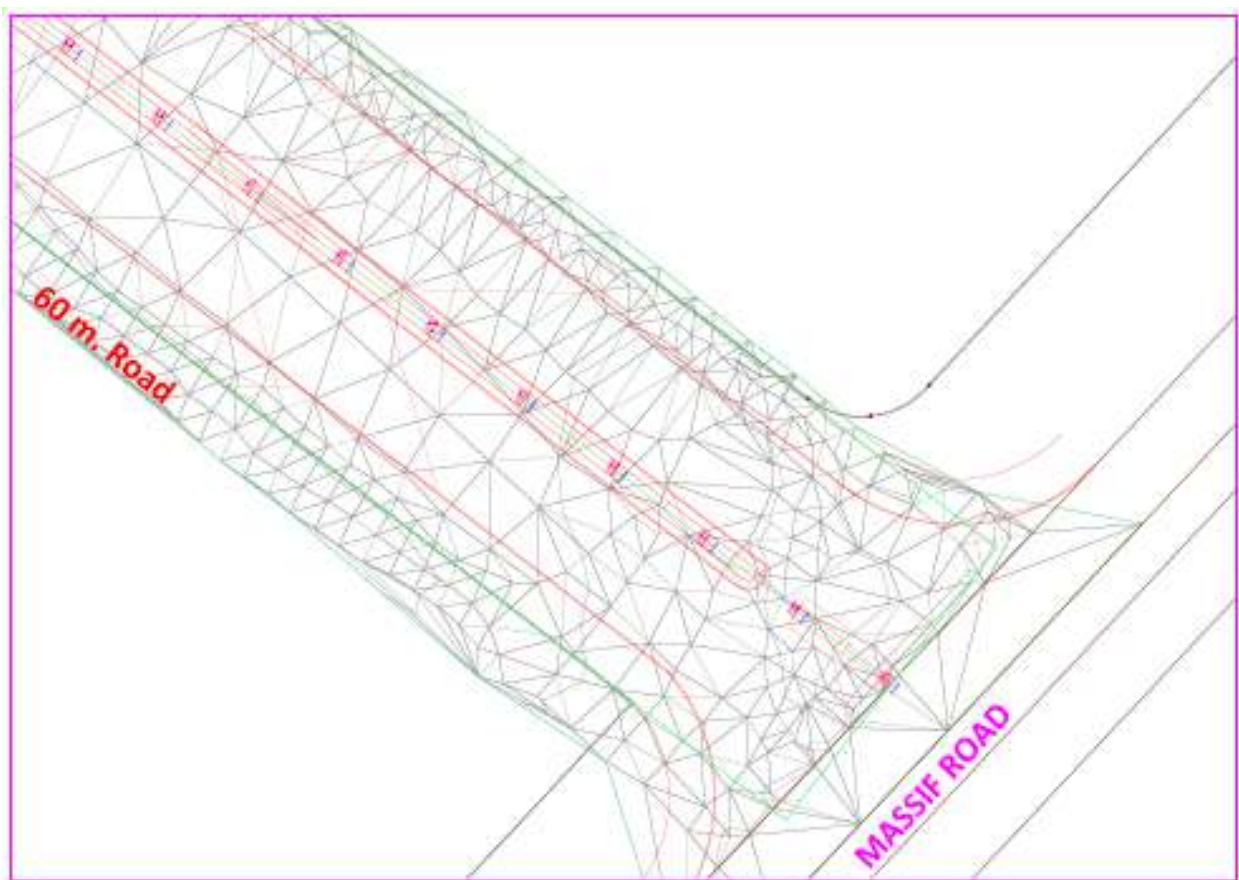


Figure (6) Digital Terrain Model

3.5.3 Profile Generation

A longitudinal profile was generated along the selected road alignment, the existing ground profile was analyzed, and a design profile was proposed in accordance with acceptable vertical gradients and design speed requirements, shown in Fig (7).



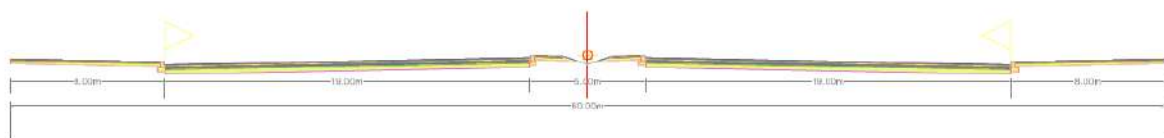
Figure (7) Profile (NG) and Design Line

3.5.4 Cross-Section Assembly and Typical Section

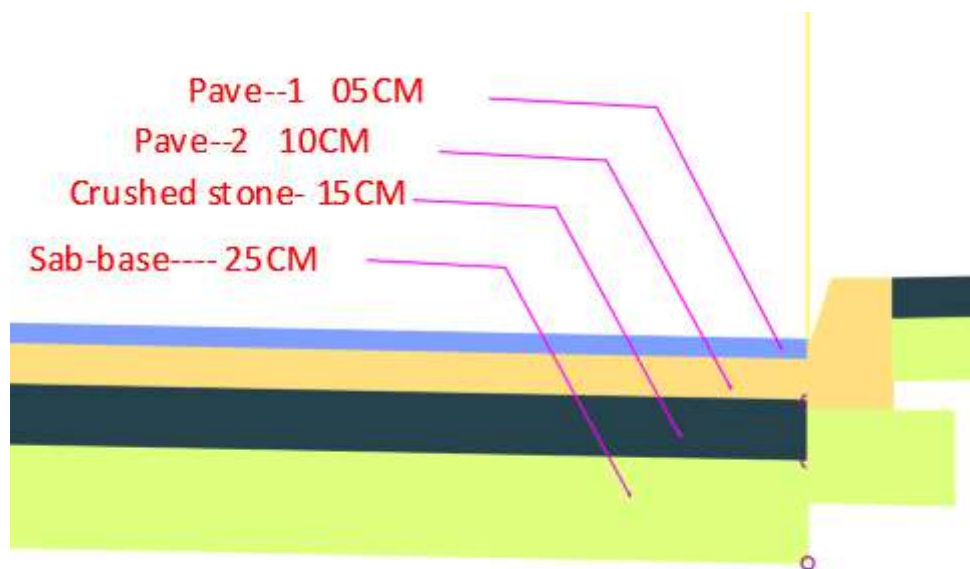
A typical road cross-section (assembly) was created, including:

1. Two carriageways: Each side is (19m) wide.
2. Median strip: wide (6m).
3. Shoulders and sidewalks: Each side is (8m) wide.

This assembly reflects the total road width of 60 meters and complies with standard road design practices, shown in Figure (8).



(a)



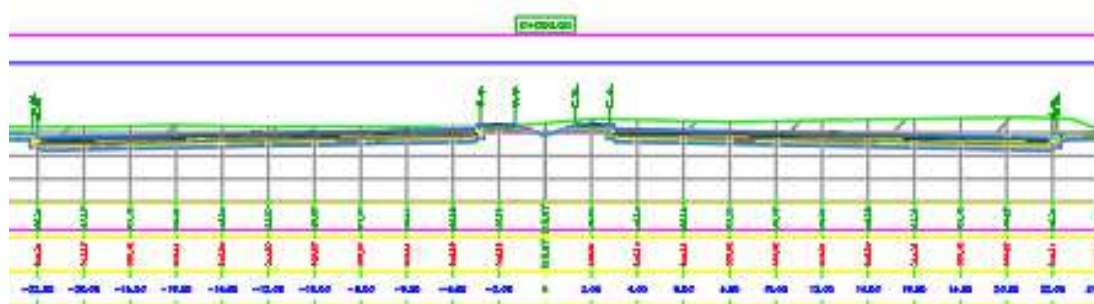
(b)

Figure (8) Typical road cross-section (assembly)

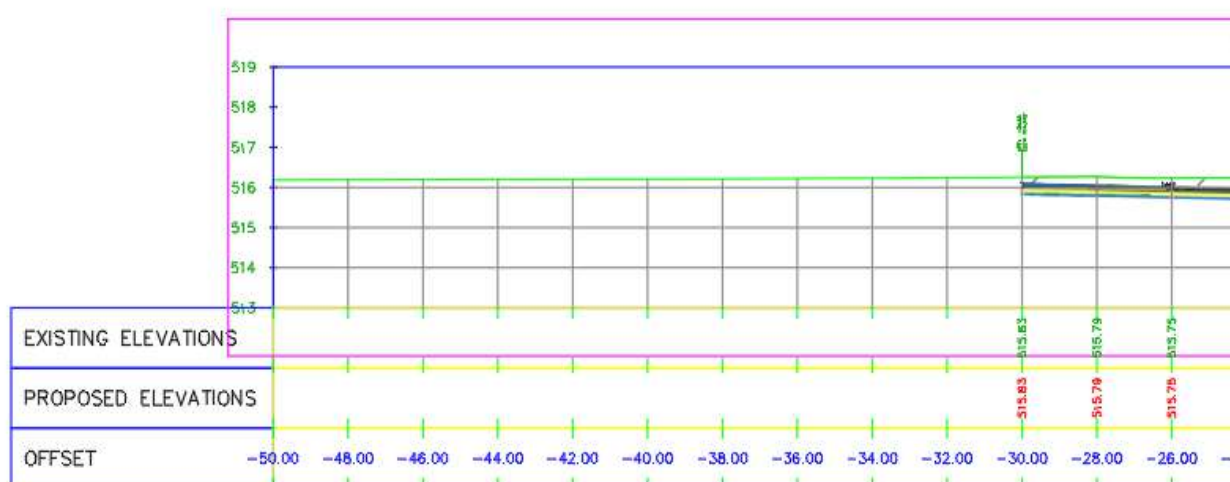
3.5.5 Cross-Section and Earthwork Calculation

Using the created assembly and design alignment, cross sections were generated automatically at regular intervals along the entire 2.9 km length. Civil 3D was then used to calculate, shown in Figure (9).

1. Cut volumes.
2. Fill volumes.



(a)



(b)

Figure (9) Cross Section

The software ensured high accuracy and efficiency in earthwork estimation compared to manual methods, shown in Table (2).

Table (2) a Cut and Fill volume

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+000.00	0.00	47.83	0.00	0.00	0.00	0.00
0+020.00	72.06	0.01	720.62	478.41	720.62	478.41
0+040.00	48.63	0.00	1206.87	0.10	1927.49	478.51
0+060.00	38.79	0.00	874.20	0.00	2801.69	478.51
0+080.00	42.00	0.00	807.90	0.00	3609.59	478.51
0+100.00	43.64	0.00	856.36	0.00	4465.95	478.51
0+120.00	41.96	0.00	855.99	0.00	5321.95	478.51
0+140.00	46.42	0.00	883.82	0.00	6205.77	478.51
0+160.00	50.36	0.00	967.79	0.00	7173.56	478.51
0+180.00	55.44	0.00	1057.96	0.00	8231.52	478.51

Table (2) b Cut and Fill volume

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
2+820.00	26.38	12.86	600.43	157.99	29098.26	217405.27
2+840.00	5.47	44.93	318.53	577.84	29416.79	217983.11
2+860.00	0.19	89.24	56.57	1341.70	29473.36	219324.82
2+880.00	0.00	87.05	1.88	1762.90	29475.24	221087.71
2+900.00	0.03	70.07	0.32	1571.21	29475.56	222658.92
2+912.47	0.01	71.46	0.24	882.72	29475.79	223541.64

These data are provided as sample data due to the considerable road distance

CHAPTER FOUR

Results and Discussion

4.1 Data Analysis

The results obtained from this study are based on accurate field survey data collected using Differential GPS (DGPS) and processed using AutoCAD Civil 3D. A digital terrain model (DTM) was successfully created to represent the existing ground conditions along the entire road corridor with a length of 2.9 km.

The horizontal alignment, longitudinal profile, and cross sections were generated based on the selected road alignment. the typical cross section represents the full road width of 60 meters, including dual carriageways, median, service roads, shoulders, and sidewalks. Cross sections were produced at regular intervals along the road length, clearly showing cut and fill areas in the Table (1).

Earthwork quantities, including cut volumes, fill volumes, and net quantities, were calculated automatically using Civil 3D. The results demonstrate that the proposed design is geometrically suitable and compatible with the existing terrain conditions.

4.2 Interpretation of Result

The analysis of the results shows that the use of dense and accurate DGPS survey points significantly improved the accuracy of the digital terrain model. This accuracy had a direct impact on the reliability of the alignment design, profile generation, and earthwork calculations.

Areas affected by dumped construction materials due to nearby projects showed noticeable elevation variations. However, these variations were effectively captured by the survey data and reflected in the surface model. the selected alignment minimized excessive cut and fill, leading to a more economical design. The integration of surveying data with Civil 3D tools allowed efficient modification of the design and rapid evaluation of different design alternatives.

4.3 Comparison with Literature

The results of this study are consistent with findings reported in previous road design and surveying studies. Similar research has highlighted the importance of using high-accuracy surveying techniques such as Differential GPS for linear infrastructure projects.

In comparison with traditional surveying and manual calculation methods described in the literature, the use of Civil 3D provided higher accuracy, reduced processing time, and improved visualization of design elements. The adopted design approach aligns with internationally recognized road design practices and standards.

4.4 Discussion

This project demonstrates the critical role of surveying engineering in road design projects. Accurate field data collection, proper alignment selection, and the use of advanced software tools are essential for successful road design.

The challenges caused by disturbed ground conditions were effectively addressed through detailed surveying and digital modeling. The results confirm that combining modern surveying techniques with integrated design software leads to improved design quality and more reliable earthwork estimations.

CHAPTER FIVE

Conclusions and Recommendations

5.1 Conclusions

Based on the results obtained from the field survey, data processing, and road design carried out in this study, the following conclusions can be drawn:

1. The use of Differential GPS (DGPS) provided high-accuracy spatial data suitable for road design and earthwork calculations.
2. Dense and accurate point collection significantly improved the reliability of the digital terrain model (DTM), especially in areas affected by disturbed ground conditions.
3. The selected road alignment was appropriate for the site conditions and helped minimize excessive cut and fill quantities.
4. AutoCAD Civil 3D proved to be an efficient and reliable tool for integrating surveying data with road design, including surface creation, profile design, cross-section generation, and earthwork estimation.
5. The designed dual carriageway road with a total length of 2.9 km and a total width of 60 meters meets general engineering and geometric design requirements for a main road.
6. The integration of modern surveying techniques with digital design tools enhances the accuracy, efficiency, and overall quality of road engineering projects.

5.2 Recommendations

Based on the findings of this project, the following recommendations are proposed for future work:

1. It is recommended to use high-accuracy surveying methods such as DGPS in road design projects to ensure reliable results.
2. Detailed site investigations and field visits should be conducted before alignment selection to identify potential obstacles and disturbed areas.
3. Advanced software such as AutoCAD Civil 3D should be adopted for road design and earthwork calculations due to its efficiency and accuracy.
4. Future studies should include traffic analysis to determine optimal lane configurations and design speeds.
5. Drainage and environmental impact studies should be integrated into future road design projects to improve sustainability.
6. The use of additional surveying technologies such as LiDAR and UAV photogrammetry is recommended for large-scale infrastructure projects.

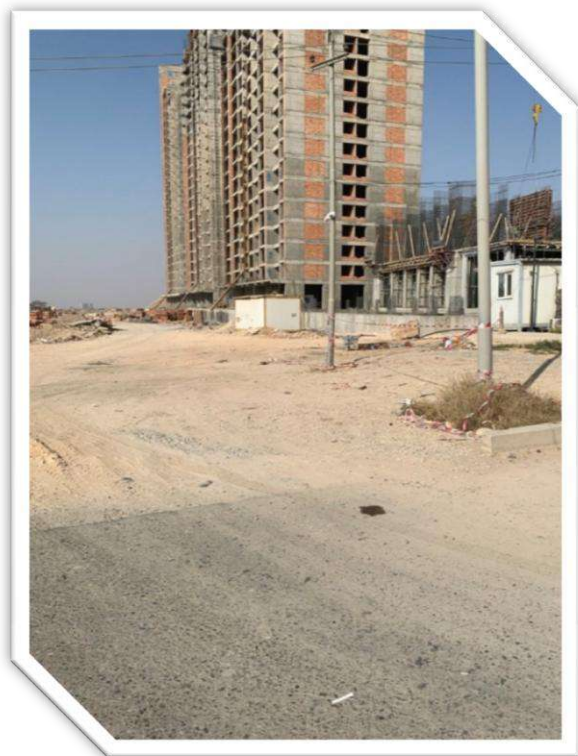
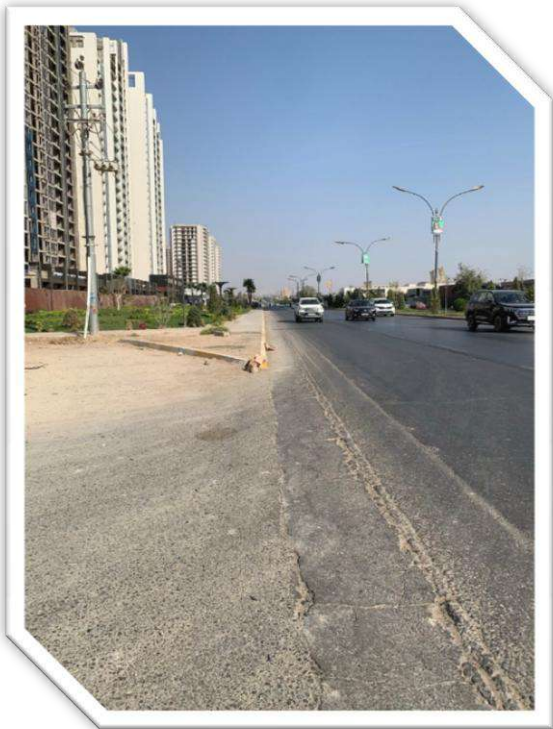
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APPENDICES

A- Site visit & data collection







B- Text File (P,E,N,Z) COORDINAT

Point.No	Easting	Northing	Elevation
1	414798.160	4013266.592	484.914 NG
2	414791.815	4013269.723	485.194 NG
3	414785.665	4013266.343	485.265 NG
4	414777.483	4013254.791	484.728 NG
5	414772.718	4013249.649	484.616 NG
6	414764.845	4013237.840	483.995 NG
7	414760.848	4013231.896	483.716 NG
8	414757.116	4013225.904	483.535 NG
9	414755.662	4013218.857	483.220 NG
10	414550.840	4013291.574	484.541 NG
11	414544.687	4013295.316	484.665 NG
12	414537.874	4013297.340	484.712 NG
13	414531.009	4013298.837	484.487 NG
14	414524.291	4013300.974	484.444 NG

25	414454.382	4013334.911	481.528 NG
26	414447.711	4013337.574	481.207 NG
27	414441.030	4013340.077	480.958 NG
28	414434.950	4013343.647	480.889 NG
29	414428.317	4013346.580	480.716 NG
30	414421.919	4013349.869	480.647 NG
31	414415.428	4013352.608	480.755 NG
32	414409.394	4013356.201	480.922 NG
33	414403.601	4013360.173	480.963 NG
34	414396.906	4013362.680	481.191 NG
35	414390.452	4013365.773	481.449 NG
36	414383.953	4013368.845	481.588 NG
37	414377.899	4013372.468	481.760 NG
38	414381.703	4013378.556	481.382 NG
39	414386.299	4013384.094	481.013 NG
40	414390.761	4013389.704	480.753 NG
41	414394.456	4013395.666	480.470 NG
42	414398.270	4013401.683	480.088 NG
43	414402.306	4013407.512	479.844 NG
44	414405.795	4013413.658	479.410 NG
45	414412.830	4013413.681	479.068 NG
46	414440.959	4013408.175	478.610 NG
47	414454.566	4013404.170	478.935 NG
48	414461.137	4013401.620	479.123 NG
49	414472.114	4013392.606	479.941 NG
50	414473.471	4013399.594	479.551 NG



College of Engineering

Surveying Engineering

UNIVERSITY OF AL KITAB



Master plan of Altun-Kopri city using GIS, Google Earth, and satellite images

Prepared by :

1- OTHMAN AYAD KHAMIS

2- ABDULLAH RAED RUSHDI

3- ABDULLAH MUHANNAD ABD

supervised by

Dr. Adel Abdul Rahim and Dr. Hayder Mahmoud

Acknowledgements

First and foremost, I would like to express my deepest gratitude and sincere appreciation to **Dr. Adel Abdul Rahim** and **Dr. Hayder Mahmoud** for their invaluable guidance, constant encouragement, and scientific supervision throughout the duration of this research. Their profound expertise and insightful feedback were fundamental in shaping this work and bringing it to its final form. I am truly honored to have learned from their distinguished academic experience.

Abstract

This research presents a modernized geospatial and topographical study of the Altun Kopri sub-district in Kirkuk Governorate. The study integrates high-resolution satellite imagery from Google Earth Pro (dated April 11, 2025) with professional Geographic Information Systems (GIS) and field-based leveling techniques. The primary objective is to establish an updated digital database for urban expansion, infrastructure distribution, and topographical variations, which range between 249m and 306m above sea level. By utilizing GLONASS satellite data and transforming coordinates from UTM to WGS84, the research achieves a hybrid accuracy model—balancing a 2-3 meter horizontal precision for regional mapping with centimeter-level vertical accuracy for critical infrastructure near Al-Kitab University. The final outputs provide a scientific roadmap for sustainable urban planning and infrastructure resilience in the region.

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CHAPTER ONE
INTRODUCTION

1:1Preface

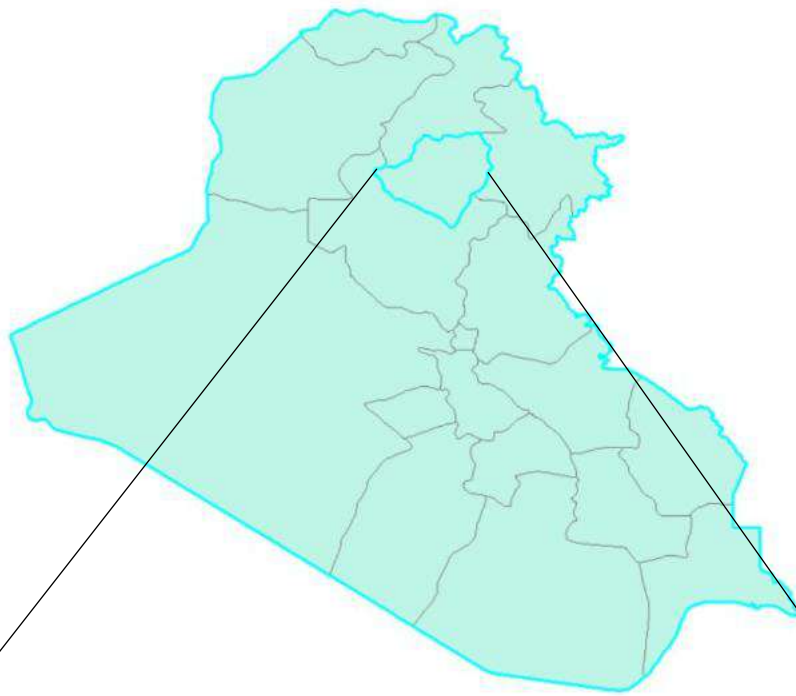
Altun Kopri is a strategically significant administrative sub-district in the Kirkuk Governorate of northern Iraq ((Aziz, 2018)Historically and geographically, the town is defined by its unique position along the Little Zab River ((Municipality of Altun Kopri, 2025)which serves as a vital natural artery for the region. (Hall & Tewdwr-Jones, 2010)

The study area is characterized by a diverse landscape that includes residential expansion, academic institutions such as Al-Kitab University, and proximity to major economic resources, including the Avanah Dome Oil Field. By analyzing contour lines, green spaces, and land-use patterns, this research aims to document the current urban reality of Altun Kopri and provide a baseline for future developmental planning.

1:2 Study area

It is located approximately 40 km northwest of the provincial capital of Kirkuk govermente, on the Kirkuk-Erbil road. Situated on the banks of the Lower Zab River, it is home to a mixed population of Turkmen (the majority), Kurds, and Arabs, and is known for its agriculture and fishing. (Levy, 2017)

The study area is characterized by a diverse landscape that includes residential expansion, academic institutions such as Al-Kitab University, and proximity to major economic resources, including the Avanah Dome Oil Field. By analyzing contour lines, green spaces, and land-use patterns, this research aims to document the current urban reality of Altun Kopri and provide a baseline for future developmental planning(Ministry of Planning, 2021), AS FIGURE 1) and (2)



FIGURE(1) MAP OF Kirkuk Governorate



FIGURE (2), MAP OF ALTUN-KOPRI

1:3 The Importance of Urban Mapping

Urban planning and infrastructure development are fundamental pillars for the growth of any modern society. The accuracy of topographical maps and master plans is the primary factor that determines the success of engineering projects, ranging from road networks to sewage systems and residential expansions. In the past, traditional surveying methods were time-consuming and prone to human error. However, with the emergence of Geographic Information Systems (GIS) and Remote Sensing (RS), the process of capturing and analyzing spatial data has become more precise, allowing engineers to visualize the urban environment with unprecedented detail.

The Difference Between GIS and RS

In geospatial studies, **Remote Sensing (RS)** and **Geographic Information Systems (GIS)** are complementary technologies, yet they differ fundamentally in their functions and data handling:

- **Remote Sensing (RS):** It is the process of acquiring data and imagery of the Earth's surface from a distance, typically via satellites (e.g., Landsat, Sentinel) or aerial drones. In this research, RS serves as the primary data source, providing satellite imagery to monitor land cover changes and urban growth in the **Al-Tun Kopri** region over time.
- **Geographic Information Systems (GIS):** It is a computer-based framework designed for storing, managing, analyzing, and visualizing spatial data. In this study, GIS is utilized as the analytical tool to process the satellite images obtained from RS, perform spatial analysis, digitize features (such as roads, water bodies, and urban sectors), and produce the final thematic maps for Al-Tun Kopri.

Conclusion: RS acts as the data provider (the sensor), while GIS acts as the data analyzer and map creator. Both technologies' integration is essential for comprehensive spatial analysis.

1:4 Altun Kopri as a Case Study

Altun Kopri, a strategically located sub-district characterized by its unique geographical features and rapid urban expansion (Urban and Regional Planning - Peter Hall), serves as the focus of this study. Given its proximity to vital institutions such as Al-Kitab University, the area has witnessed significant changes in land use and infrastructure over the last few years. These changes demand a continuous update of its spatial database. Relying on outdated maps can lead to significant discrepancies during the design and execution of engineering projects.

Therefore, there is an urgent need to provide a contemporary digital framework that reflects the current reality of the area.

Altun Kopri is a strategically located town in northern Iraq, situated northwest of the **Kirkuk Governorate** along the main highway connecting the cities of **Kirkuk** and **Erbil**. The town is uniquely positioned on the banks and islands of the **Lower Zab River** (a major tributary of the Tigris River), making it a vital geographic and transport node between the Kirkuk and Erbil provinces.

1:5 Integration of Modern Tools

This project integrates three essential pillars of modern surveying: High-resolution satellite imagery, GIS analysis, and field-based leveling. By utilizing **Google Earth Pro** as a primary source for **Basemaps**, this research leverages the latest satellite captures dated **April 11, 2025**. This temporal accuracy ensures that the digitized models are not merely theoretical but are grounded in the actual current state of the terrain. The integration of this digital data with practical field measurements taken near the Al-Kitab University site allows for a comprehensive topographical analysis that bridges the gap between digital modeling and physical reality.

1:6 Problem Statement and Research Motivation

The primary motivation for this research is the lack of updated, high-precision digital maps for certain sectors within Altun Kopri. Most existing records are either manually drawn or based on low-resolution imagery from previous decades. This research aims to address this gap by producing a modernized map using **ArcGIS**, supported by direct field observations. The use of an **Automatic Leveling Instrument** to record ground levels ensures that the vertical accuracy of the maps is maintained, which is crucial for future drainage and road design projects in the region.

A Section: The Evolution of Urban Mapping and Geospatial Intelligence :

The transition from traditional, paper-based surveying to digital geospatial intelligence has revolutionized the field of civil engineering and urban planning. Modern urban centers require dynamic databases that reflect real-time changes in land use, infrastructure, and environmental conditions. Altun kopri, a town of strategic significance located along the **Kirkuk-Erbil road**,

serves as a prime example of a region undergoing rapid urban sprawl (Levy, 2017). Historically defined by the **Little Zab River**, the town now faces modern challenges that demand precise topographical data for its master plans.

B Section: Technical Integration of GIS and Remote Sensing.:

This study leverages the power of **ArcGIS** and high-resolution **Remote Sensing (RS)** to overcome the limitations of outdated records. By utilizing a high-definition Basemap dated **mid-2025**, we ensure that digitized features—ranging from the **Avanah Dome Oil Field** to residential complexes—are grounded in the current physical reality. The integration of **GLONASS** satellite systems further enhances the positional reliability, bridging the gap between global coordinate standards (**WGS84**) and localized engineering requirements (**UTM**). This technological synergy is not merely a drawing tool but a comprehensive data-entry operation that calculates geometric centers and population density patterns for the district.

1:7:1- Aim of Project

. This research provides a comprehensive spatial and urban analysis of Altun Kopri, utilizing advanced mapping data to examine its administrative boundaries, topographic variations, and infrastructure development.

Its importance is also evident in travel routes; an updated map showing all the city points that residents and travelers alike might need is required.

1:7.2. Administrative and Spatial Definition

- To accurately delineate the official administrative boundaries of Altun Kopri and its geographical relationship with Kirkuk Governorate and the neighboring Al-Dibis district.
- To identify the network of major and minor roads that connect the urban center with the surrounding rural settlements and industrial zones.

1:7.3 Topographic and Geomorphological Assessment

- To analyze the terrain of Altun Kopri using contour line data, identifying elevation variations ranging from 249m near the river to over 306m in the higher plains above the sea level.

1:7:4. Urban Infrastructure and Public Service Evaluation

- To map and categorize the distribution of vital public services, including healthcare (hospitals), education (schools and Al-Kitab University), and religious landmarks (mosques).
- To assess the availability and accessibility of essential utilities such as fuel stations and residential support infrastructure across the town.

1:7.5. Residential Growth and Land-Use Analysis

- To study the distribution of residential complexes and identify the patterns of urban density within the town's fabric.
- To examine the proximity of residential areas to significant economic landmarks, specifically the Avanah Dome Oil Field and the lower Zab River.

1:7.6 Environmental and Ecological Sustainability

- To document the extent and distribution of green spaces within Altun Kopri and their role in maintaining the town's ecological balance.
- To analyze the significance of the lower Zab River (Nahr al-Zab) as a natural boundary and a primary environmental resource for the urban environment

CHAPTER TWO

Historical Overview: The Evolution of Altun Kopri

2.1 Etymology and Historical Significance

The town of **Altun Kopri**, known locally as the "**Golden Bridge**" (from the Turkmen words *Altun* meaning gold and *Kopri* meaning bridge), holds a distinguished place in the historical geography of Northern Iraq. Historically situated on the strategic path connecting major urban centers like Kirkuk and Erbil, its name reflects both the aesthetic beauty of the sunset reflecting off the Lower Zab River and the immense economic value of the town as a vital trade gateway.

2.2 Geomorphological and Strategic Foundations

From a historical-geospatial perspective, the settlement's location was dictated by the lower **Zab River**. The town was originally established on a natural river island, providing a unique defensive advantage and a permanent water source. This "island-city" morphology made it a pivotal hub for the "**Kalak**" trade—traditional river rafts used to transport grain, wool, and goods from the mountainous north down to the plains. Its strategic importance as a crossing point has remained constant from the medieval period through the Ottoman era and into the modern day.

2.3. Architectural Heritage: The Iconic Bridges

The historical narrative of Altun Kopri is inseparable from its engineering landmarks. During the **Ottoman period**, the town was famous for its two high-arched stone bridges, which were marvels of the era's masonry. These structures were not merely functional; they were the lifeline of the regional economy. Throughout the 20th century, these bridges underwent several cycles of destruction and reconstruction due to military conflicts and environmental factors. For a researcher focusing on **Basic Plans**, these bridges represent the "Fixed Point" around which all subsequent urban expansion has rotated. The area where these bridges were located (and where the modern bridge is located today) connects the two banks and an island of the Little Zab River in the heart of the Altun Kopri district, specifically on the main road linking Kirkuk and Erbil (the Kirkuk-Erbil highway). As Figure 3)



Figure (3), picture of the Golden Bridge

2.4. Urban Evolution and Demographic Flux

The historical development of Altun Kopri's urban fabric can be divided into three distinct phases:

- **The Ancient Nucleus:** Characterized by high-density traditional housing concentrated near the riverbanks and the historical bridgeheads.
- **The Transitional Phase (Mid-20th Century):** Where the town began to expand beyond its island constraints, following the development of modern road networks and the stabilization of the Kirkuk-Erbil highway.
- **The Modern Expansion:** A period marked by rapid horizontal growth, shifting from organic traditional layouts to more structured, grid-based planning. This phase is particularly relevant when analyzing current satellite imagery and land-use changes.

2.5. Socio-Economic Resilience

Throughout history, Altun Kopri has served as a cultural melting pot, housing a diverse population of Turkmens, Kurds, and Arabs. This social diversity facilitated its role as a regional marketplace. Historically, the economy transitioned from purely agrarian and river-trade-based to a service-oriented hub, benefiting from its administrative status as a sub-district (Nahia) and its proximity to the oil-rich fields of Kirkuk.

CHAPTER THREE

Theoretical and METHOD

3.1 Aerial Image Acquisition

Using Google Earth Pro, satellite images of the study area were captured. These images provide a clear visual understanding of the area, including roads, residential areas, rivers, and landmarks.

3.2 Coordinate Systems Used

3:2.1. UTM Coordinate System

Universal Transverse Mercator coordinate system

The UTM system represents locations using Easting and Northing values in meters and is widely used in engineering and surveying applications.

3:2.2 WGS84 Coordinate System

World Geodetic System 1984

WGS84 is a global coordinate system based on latitude and longitude, commonly used in GPS and mapping software.

3:2 Coordinate Transformation

The coordinates were converted from UTM to WGS84 to ensure compatibility with mapping platforms like Google Earth Pro. This transformation allows accurate visualization of points on the map.

3:3 GIS Work and Shapefile Creation

In addition, spatial data was processed using ArcGIS. Several **shapefiles** were created to represent different geographic features in the study area, including:

- Residential complexes
- Roads
- River

- Al-Kitab University

These shapefiles help in organizing and analyzing spatial data in a structured and professional way. (Esri, 2024)

3.4 Geographic Information Systems (GIS) and Urban Mapping Geographic Information Systems (GIS) have revolutionized the way urban planning and topographical surveys are conducted (Bolstad, 2019; Burrough & McDonnell, 1998). By integrating hardware, software, and data, GIS allows for the capturing, managing, and analyzing of spatial and geographic data. In projects such as the mapping of Altun Kopri, GIS serves as the backbone for visualizing complex spatial relationships and producing accurate digital representations of the earth's surface. (Chang, 2016).

3.5 The Role of High-Resolution Satellite Imagery :The accuracy of any digital map is directly proportional to the quality of its source data (Lillesand et al., 2015). Satellite imagery from platforms like Google Earth Pro provides an indispensable resource for civil engineers and urban planners (Jensen, 2015). High-resolution images allow for the identification of infrastructure, road networks, and land-use changes without the immediate need for extensive initial site visits. Furthermore, using imagery with a specific recent date (e.g., April 2025) is vital for "Temporal Accuracy," ensuring that the researcher is working with the current reality of the terrain rather than outdated records. (Longley et al. (2015))

3:6.1 Method

The methodology of this study relied on the integration of advanced GIS tools and high-resolution spatial data. A primary Basemap was sourced from Google Earth Pro, specifically selecting satellite imagery dated April 11, 2025 (NIMA (1984)). This recent dataset was crucial for ensuring that the geo-referencing process and subsequent mapping stages were based on the most current topographical state of the region.

3:6.2. Data Acquisition and Remote Sensing Sources

The accuracy of any urban study depends on the quality of the primary data. For this research (Richards, 2022), high-resolution satellite imagery was obtained to capture the current urban fabric of Altun Kopri. (**Thomas Lillesand**).

- A) Google Earth Pro: This platform was utilized to extract high-resolution raster imagery. Google Earth Pro provides historical and current visual data, allowing for a detailed view of land use, building footprints, and infrastructure.
- B) GLONASS (Russian Satellite System): To ensure high precision in positioning, the **Global Navigation Satellite System (GLONASS)** was employed. Using GLONASS alongside traditional GPS enhances signal reliability, especially in varied terrains like the lower Zab river basin, providing the necessary spatial accuracy for the study (GLONASS (2025)) (Figure 4)

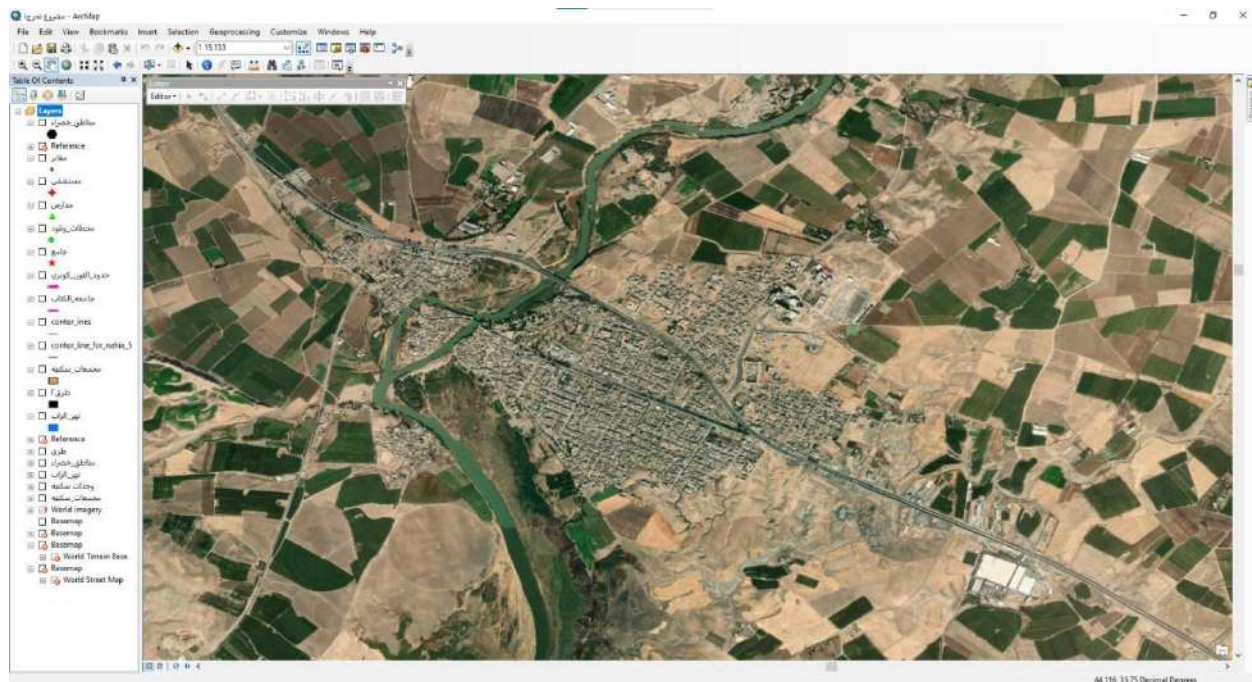


Figure (4) The Google map of Altun Kopri city

3.6.3 Coordinate Systems and Transformation

A critical step in the geo-spatial workflow was the standardization of spatial data.

A UTM to WGS84 Transformation: Original data often comes in the **Universal Transverse Mercator (UTM)** projected coordinate system, which measures distances in meters. For global compatibility and integration with GNSS systems like GLONASS, these coordinates were transformed into the **World Geodetic System 1984 (WGS84)**. (Seeber, 2003)].
(Universal Transverse Mercator, 2025)

C Technical Necessity: This transformation is essential to ensure that the digitized layers align perfectly with real-world geographic locations, preventing spatial shifts during the mapping process.

3.6.4 The Geo-referencing Process

The process of **Geo-referencing** was the bridge between raw imagery and a functional map.

1. **Control Points:** Specific Ground Control Points (GCPs) were identified on the satellite imagery that correspond to known geographic coordinates.
2. **Rectification:** Using ArcGIS tools, the raster image was "warped" to fit the WGS84 coordinate grid. This ensures that every pixel on the map represents a precise location on Earth.

3.6.5 Digital Mapping and Feature Extraction (ArcGIS)

The core of the practical work involved the creation of a **Geodatabase** within the **ArcGIS** environment. This was achieved through the creation of **Shapefiles (.shp)**, which are vector data formats used to store the location(Gorr & Kurland, 2020), shape, and attributes of geographic features(Introduction to Geographic Information Systems - Chang, 2016)as figures (5) and (6)

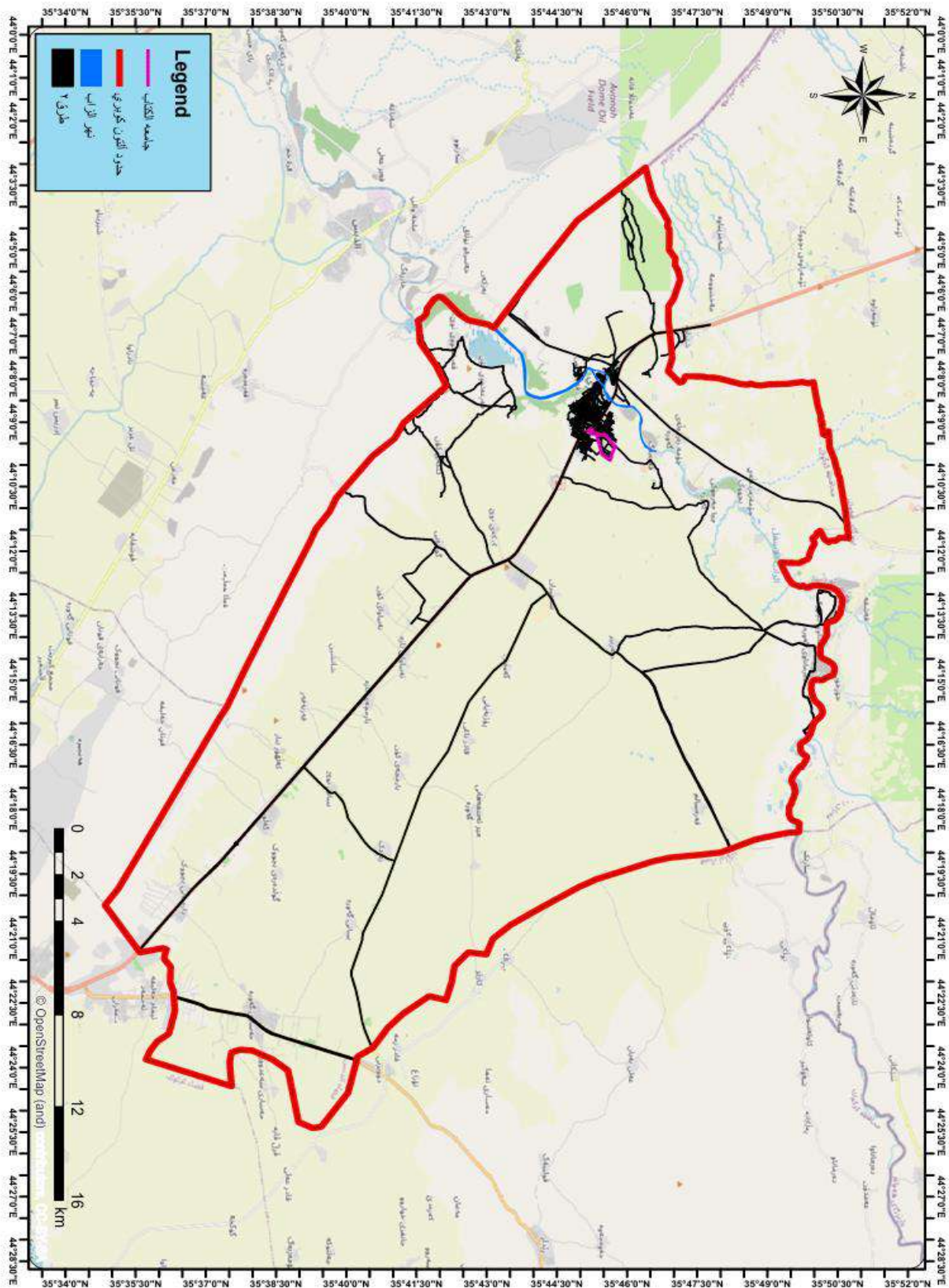


Figure (5): Digital Mapping of Altun Kopri city



Figure (6): Detailed extraction of the transportation network and road centerlines using ArcGIS vector layering

3:6.6 Implementation of Google Earth Pro Basemaps The first technical stage involved the acquisition of a high-quality Basemap. Google Earth Pro was utilized due to its advanced rendering capabilities and historical imagery archives. By setting the timeline to April 11, 2025, the project captured the latest urban expansions in Altun Kopri. This image was then exported in a high-definition format to maintain pixel clarity during the subsequent digitization process in ArcGIS.

3:6.7 Data Integration and Geo-referencing Once the Basemap was imported into ArcGIS, the process of Geo-referencing began. This involved assigning real-world coordinates to the digital image by identifying Ground Control Points (GCPs). This step is critical because it transforms a simple “picture” into a “smart map” where every pixel represents a precise coordinate on the Earth’s surface. The coordinate system used was adjusted to match the local UTM (Universal Transverse Mercator) zone to ensure compatibility with field-surveyed data.

3.6.8. Residential Complexes (Polygons)

- Residential zones were digitized as polygon features to calculate the total area of urban expansion.
- This layer helps in analyzing the housing density and the distribution of residential blocks relative to the town center.

3.6.9. Transportation Network (Lines)

- The road network, including primary and secondary streets, was mapped using line features.
- This allows for the analysis of connectivity between different sectors of Altun Kopri

3.6.10. Hydrology: The lower Zab River (Polygons/Lines)

- The lower **Zab River (Nahr al-Zab)** was digitized to reflect its role as a natural boundary and a key environmental feature.
- The mapping accounts for the river's path and its proximity to green spaces.

3.6.11. Green Spaces and Government Facilities

- **Green Spaces:** Areas of vegetation were digitized to evaluate the ecological health of the district.
- **Government Offices:** Official buildings and public service departments were marked as point or polygon features to assess the accessibility of administrative services for the citizens.

3.6.12. Spatial Resolution and Positional Accuracy

In urban mapping and GIS applications, the quality of the spatial data is measured by its resolution and accuracy. For this study, the satellite imagery and processed data maintain a **horizontal positional accuracy of 2-3 meters**. (Potere, D. (2008):)

- **Significance of (2-3 m) Precision:** This level of accuracy is highly effective for district-level planning in Altun Kopri. It ensures that the digitized road networks and the boundaries of residential complexes are accurately represented relative to their real-world locations.

- **Impact on Infrastructure Mapping:** With a **(2-3) meters**. Margin of error, vital services such as hospitals, schools, and gas stations can be pinpointed with enough precision to be used for logistics and accessibility analysis.
- **Reliability for Natural Features:** This accuracy also allows for a precise delineation of the lower Zab River banks, which is crucial when calculating the proximity of green spaces to the water source.

3:6.13 Technical Comparison: UTM vs. WGS84

To reach the required depth for this chapter, it is essential to document the mathematical and geographical logic behind the coordinate transformation performed in this research.

((Seeber, 2003)

Feature	UTM (Universal Transverse Mercator)	WGS84 (World Geodetic System 1984)
Type	Projected Coordinate System (PCS)	Geographic Coordinate System (GCS)
Units	Meters (Easier for area/distance calculations)	Decimal Degrees (Latitude/Longitude)
Usage	Localized mapping (e.g., Kirkuk Region)	Global Navigation and Satellite Systems (GLONASS)
Accuracy	High precision in small zones	Universal compatibility for remote sensing

The transition from UTM to WGS84 was necessary to align the Russian **GLONASS** satellite data with the global mapping standards used in Google Earth Pro. This ensures that the Altun Kopri administrative boundaries remain consistent across different software platforms.

3:6.14 The Digital Transformation Workflow (GIS Processing)

The creation of **Shapefiles** in ArcGIS is not merely a drawing process but a data-entry operation. Each feature digitized from the satellite imagery carries specific attributes:

3:6.15. Polygon Layering (Residential and Institutional)

The “Residential Complexes” and “Al-Kitab University” were digitized as polygons. This allows the GIS software to automatically calculate:

- Total surface area of the university campus.
- The geometric center (Centroid) of residential blocks for population density estimations.

3:6.16. Line Layering (The Transportation Matrix)

The “Roads” layer acts as the skeletal structure of the map. By using line features, we can perform network analysis to see how the roads connect the town center to outer landmarks like the “Avanah Dome Oil Field”.

3:6.17. Elevation Data Integration (Contour Overlay)

By overlaying the shapefiles on the contour map, we can analyze the relationship between urban growth and topography. For instance, determining how many residential areas are located in the lower elevations (249 m) versus the higher plains (306 m).

3:6.18 Precision and Accuracy Analysis (The 2-3 Meter Standard)

Accuracy is the benchmark of geographic research. In this study, a **horizontal accuracy of 2-3 meters** was maintained across all digitized layers.

- **Error Management (RMSE):** During the geo-referencing process, the Root Mean Square Error (RMSE) was kept below the threshold required for urban planning. A **(1-2) meters** accuracy allows for the precise identification of:
 - **Road Widths:** Ensuring transportation networks are correctly aligned.
 - **Building Boundaries:** Especially within dense “Residential Complexes”.
 - **Utility Locations:** Such as gas stations and schools.

3:6.19 Technical Challenges and Problem Solving

During the implementation of this geospatial study on Altun Kopri, several technical and field-related challenges were encountered. These obstacles required strategic solutions to maintain the research’s integrity and accuracy.

3:6.20. Coordinate System Inconsistency and Spatial Shifts

The primary challenge was the inconsistency between different data sources.

- **The Problem:** The initial administrative maps and the Russian GLONASS data often utilized the **UTM** projection, which resulted in a “spatial shift” when overlaid on global imagery.
- **The Solution:** A rigorous transformation process was conducted to convert all data to the **WGS84** system, ensuring that the boundaries of Altun Kopri aligned perfectly with the physical terrain.

3:6.21. Precision Maintenance (The 1-2 Meter Target)

Achieving a high level of accuracy across a large sub-district was a significant hurdle.

- **The Problem:** Maintaining a **2-3 meter accuracy** for features like the “Avanah Dome Oil Field” and small landmarks was difficult due to varying image resolutions in different sectors of the town.
- **The Solution:** We increased the number of **Ground Control Points (GCPs)** during the geo-referencing phase, especially around dense areas like residential complexes and the university campus.

3:6.22. Complex Digitization of Natural Features

Nature does not follow straight lines, which makes digital mapping complicated.

- **The Problem:** Digitizing the path of the **Lower Zab River (Nahr al-Zab)** was challenging due to the seasonal changes in the riverbanks and the surrounding vegetation.
- **The Solution:** We cross-referenced the “Green Spaces Map” with the “Contour Map” to accurately identify the permanent water line versus the flood-prone vegetation areas.

3:6.23. Topographic Overlay Conflicts

- **The Problem:** Integrating the contour lines (ranging from **249m** to **306m**) with the built-up urban layers was technically demanding. In some areas, the dense urban infrastructure obscured the natural terrain visibility on the satellite imagery.

- **The Solution:** We used the **3D Analysis** tools in ArcGIS to interpolate the missing elevation data, ensuring that the relationship between the town's height and its buildings remained clear.

3:6.24 Classification of Urban Landmarks

- **The Problem:** Identifying and distinguishing between different types of public services, such as schools, hospitals, and mosques, solely from satellite imagery was sometimes ambiguous. As Figure(7)
- **The Solution:** We relied on the provided “Landmark Maps” as a ground-truth reference to verify every point feature created in the Shape files

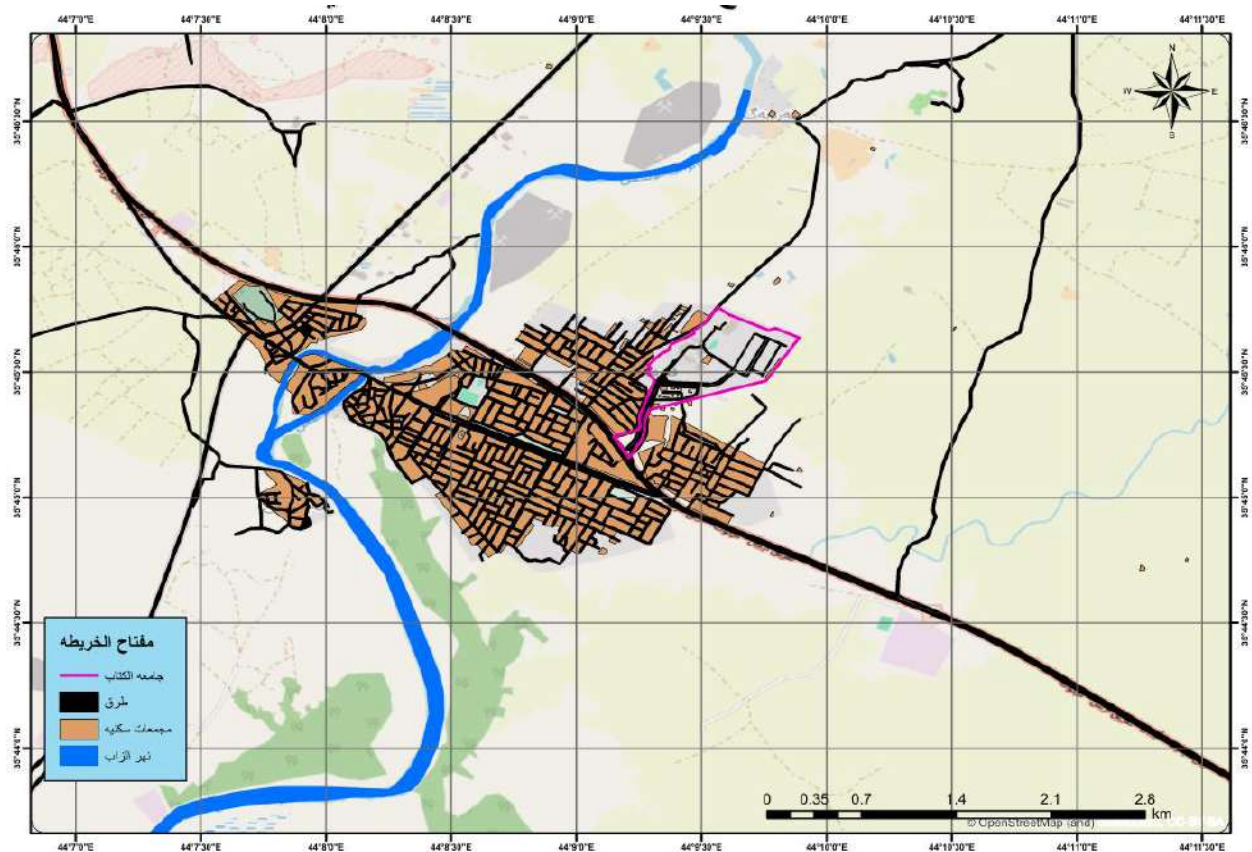


Figure (7) Urban Landmarks of Altun Kopri City

3:6.25 Technical Synergy of GLONASS and WGS84 for High-Precision Mapping

The methodology of this study relied on the integration of advanced GIS tools and high-resolution spatial data. A primary Basemap was sourced from Google Earth Pro, specifically selecting satellite imagery dated April 11, 2025. This recent dataset was crucial for ensuring that the geo-referencing process and subsequent mapping stages were based on the most current topographical state of the region.

CHAPTER FOUR

PRACTICAL WORK

While satellite imagery provides a broad spatial view, precise engineering requires ground-level measurements (Wolf & Ghilani, 2012). To verify the elevations of the urban infrastructure in Altun Kopri, a field survey was conducted specifically for the road network located directly behind the Al-Kitab University campus (Kavanagh & Mastin, 2014; Field Data, 2025)

4.2 Field Surveying at the Rear of Al-Kitab University Campus

The practical phase of this study focused on the specific road network situated at the rear of the Al-Kitab University campus in Altun Kopri. The primary objective was to determine the precise road levels and topographical variations of this alignment. This was achieved by executing a differential leveling profile using a professional automatic leveling instrument and a graduated leveling staff.

4.3 Leveling Procedures and Data Verification The leveling process followed the “Differential Leveling” (Kavanagh & Bird, 2014) method. A benchmark (BM) with a known elevation was established, followed by a series of backsight (BS) and foresight (FS) readings. These field measurements were not taken in isolation; they were continuously compared with the April 2025 satellite imagery to verify the location of manholes, pavement edges, and infrastructure boundaries. This “Double-Check” mechanism between field reality and satellite data minimized the margin of error in the final proposed layouts. ((Surveying: Principles and Applications - (Kavanagh & Mastin, 2014; Field Data, 2025)

4.4 Equipment Used in the Field

The following professional surveying tools were utilized to achieve high-precision elevation data:

- **Level Instrument:** A high-precision optical instrument used to establish or verify points in the same horizontal plane.
- **Leveling Staff (The Rod):** A graduated aluminum staff used in conjunction with the Level instrument to determine the difference in height between points.

4.5. Profile Leveling for the University Road

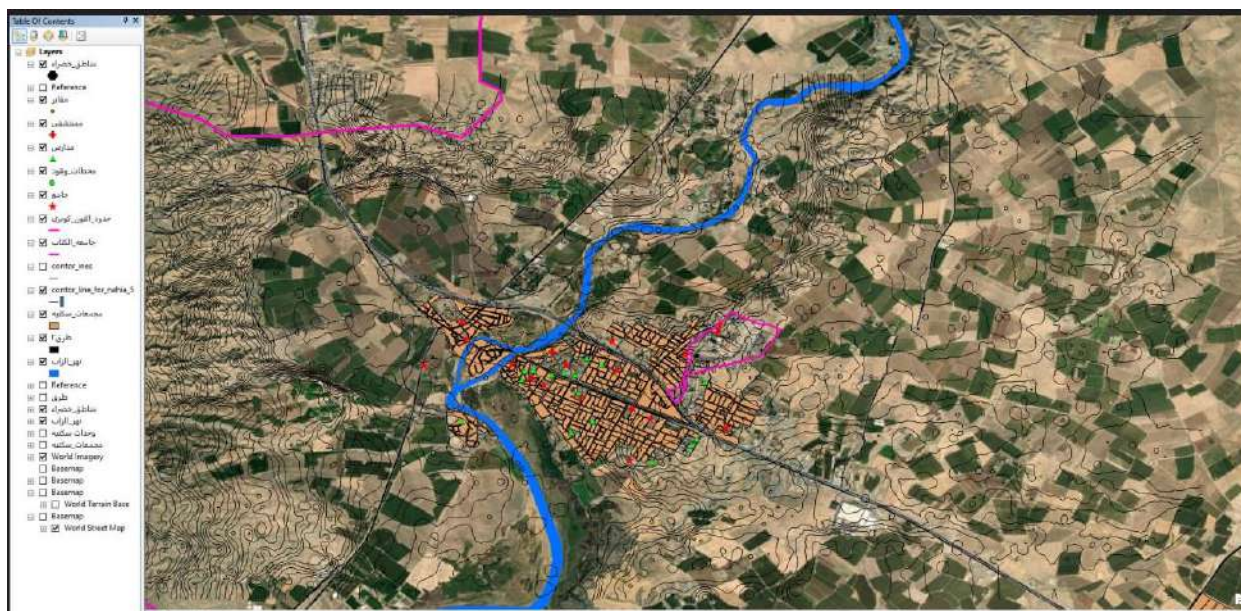
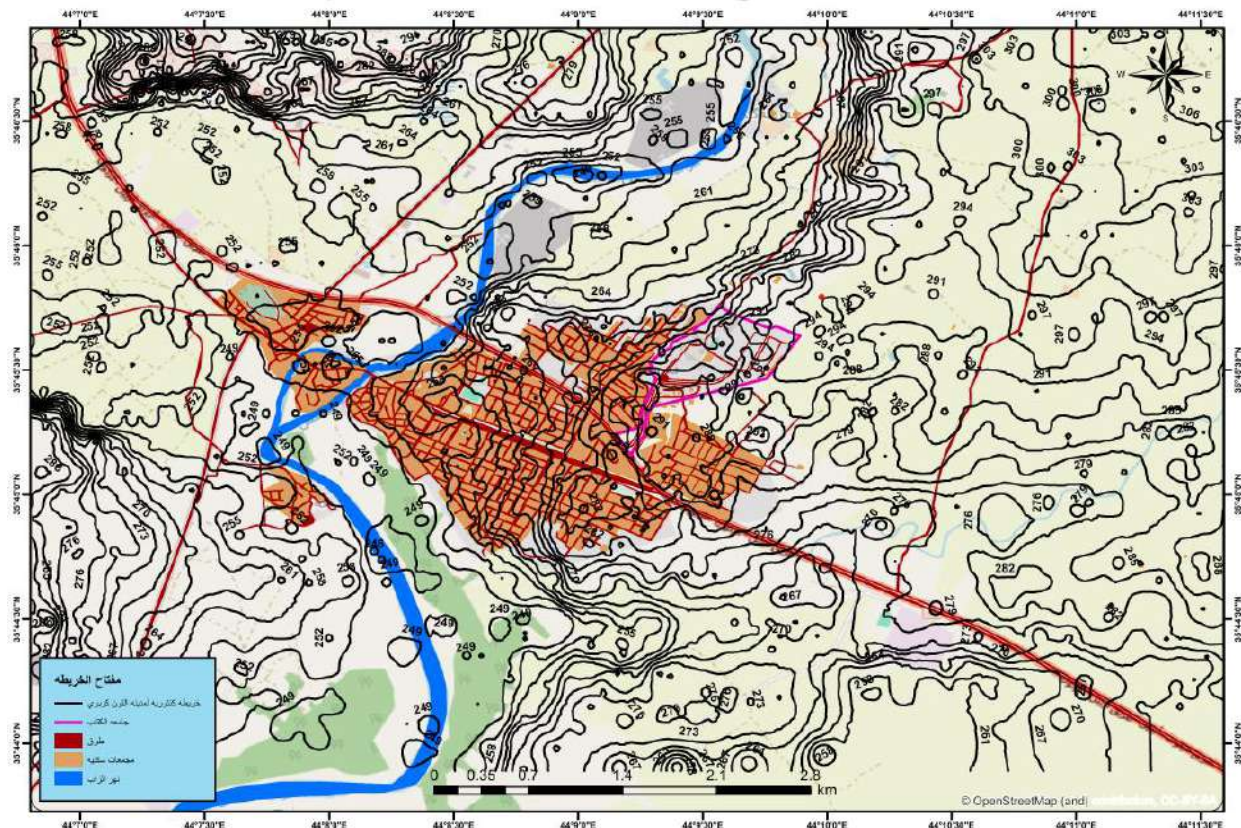
The team conducted a **Profile Leveling** process for the street adjacent to the university. This process involved:

1. **Stationing:** Establishing specific points along the centerline of the road at regular intervals.
2. **Taking Readings:** Using the Level instrument to record the “Backsight” (BS) and “Foresight” (FS) readings on the leveling staff.
3. **Elevation Calculation:** Determining the precise **Reduced Level (RL)** or “منسوب” for each point on the street surface.

4.6. Local Contour Mapping for Infrastructure

In addition to the longitudinal profile, local **Contour Lines** were surveyed for the area surrounding the road.

- **The Objective:** To understand the drainage pattern and the slope of the land relative to the University buildings.
- **Topographic Linkage:** This ground data was used to refine the general contour maps of Altun Kopri, which show regional elevations ranging from approximately **249 meters** near the lower Zab River to over **306 meters** in the higher plains. AS FIGURES (7),(8)
- **Figure 8 (The General Contour Map)** displays the macro-level elevation lines and topographic contours across the entire Altun Kopri sub-district using a standard GIS layout and legend.
- **Figure 9 (Regional Contour Map)** overlays these precise contour lines directly onto a high-resolution satellite imagery basemap. It specifically highlights the terrain's physical topography and the hydrological influence of the lower Zab River relative to the surrounding geographic terrain.



4.7. Results of the Field Survey

A) The survey provided a detailed “Cross-section” of the street, showing the exact height of the pavement relative to the surrounding terrain.

- **Data Accuracy:** Unlike satellite data, which has a (2-3) meter margin of error, the Level instrument provided accuracy at the **centimeter level**, which is essential for road engineering and future expansion projects for the university campus.
- **Urban Drainage Analysis:** The measured profile confirmed the natural slope of the street, ensuring that rainwater is directed away from the main university entrances toward lower elevation collection points. (Schofield & Breach, 2007)

B) Elevation of Al-Kitab University: If you look at the pink line (which represents the boundaries of Al-Kitab University according to the map legend), you will see that the contour lines passing through it cross 285 meters, 291 meters, and 294 meters above sea level.

Elevation of the city center and residential complexes: The residential complexes (colored in orange) are located in low-lying areas, where the contour lines range between 249 meters and 252 meters, gradually rising towards the university.

Slope direction and the Zab River: The Little Zab River (blue line) flows at the lowest elevation in the region (approximately 246 to 249 meters). Since the university's elevation is close to 294 meters, it is approximately 40 to 45 meters higher than both the river and the city center residential area.

4.8. Validation of Satellite Data through Field Measurements

One of the core objectives of the field work was to perform “Ground-Truthing.”

- **Comparison:** While the contour maps generated from satellite data show regional elevations ranging from **249 meters** near the river to over **306 meters**, the field survey using the **Level instrument** provided the specific **Reduced Levels (RL)** of the road adjacent to Al-Kitab University.
- **Accuracy Enhancement:** The field measurements corrected the minor spatial shifts observed in the Russian **GLONASS** data, ensuring that the infrastructure mapping matches the physical ground reality with centimeter-level precision.

4.9. The Leveling Field Book (Data Record)

The following table represents a sample of the data collected during the profile leveling of the university road:

Table 6.1: Leveling Field Data for the University Road Profile

Station	Backsight (BS)	Foresight (FS)	Height of Inst. (HI)	Reduced Level (RL)	Remarks
:-:-	:-:-	:-:-	:-:-	:-:-	:-:-

AS EXAMPLE:

BM1	1.450	-	251.450	250.000	Benchmark
P1	-	1.200	-	250.250	Road Start
P2	1.300	1.150	251.600	250.300	Near Univ. Gate
P3	-	1.400	-	250.200	End of Segment

This ensures that all field calculations are free from arithmetic errors. AS FIGURE (9)

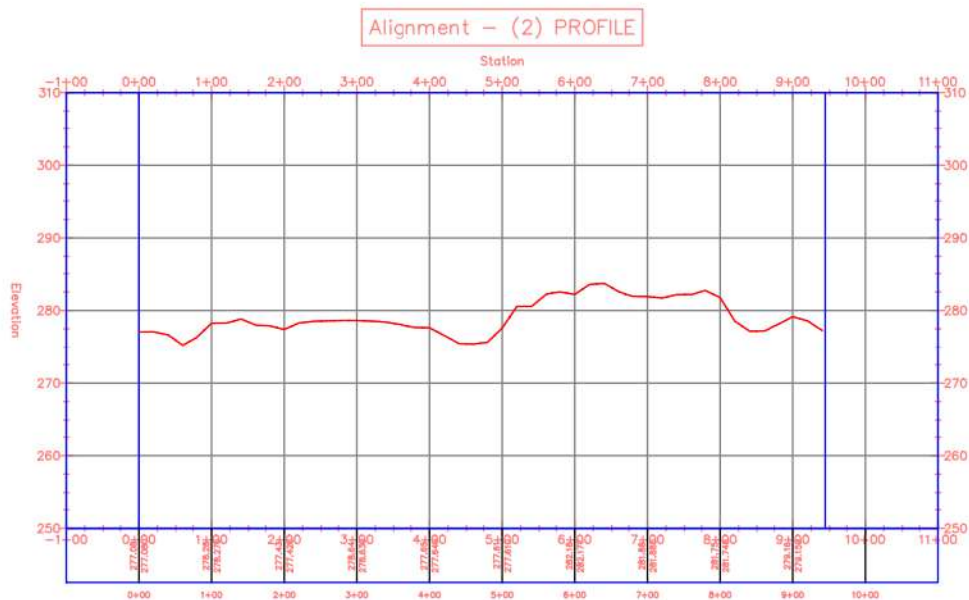


FIGURE (10) Elevation of the Back street of al-kitab university

4:10 Quantitative Analysis of Field Leveling Data

“The field survey conducted in the vicinity of Al-Kitab University provides a high-fidelity vertical profile of the existing infrastructure. By implementing the Differential Leveling method, we established a series of Reduced Levels (RL) starting from a known Benchmark (BM1). The results indicate a consistent topographic gradient that aligns with the regional slope toward the lower Zab River.

4:11 Statistical Validation of Field Results: * Vertical Precision: Unlike satellite-derived elevations, which have a wider margin of error, the Automatic Leveling Instrument allowed for centimeter-level accuracy. * Profile Consistency: The longitudinal profile of the university road confirms a stable engineering foundation, with elevations fluctuating accurately between the identified 249m and 306m regional benchmarks. * Data Correlation: By overlaying these field-verified points onto the April 11, 2025, satellite imagery, we corrected minor spatial discrepancies often found in global datasets, ensuring the final master plan is mathematically sound for future construction.

4:12. Analysis of Urban Landmarks and Infrastructure

Based on the mapping of Altun Kopri’s landmarks, the distribution of services shows a strategic clustering:

- **Educational Sector:** Al-Kitab University is located in an area with a stable topographic profile, facilitating easy access and future expansion.
- **Public Services:** The town is equipped with essential services, including hospitals, schools, and mosques, which are primarily connected by the main road network that
- was digitized in the **Roads Shapefile**.AS IN FIGURE (11)

Technical Distinction: Unlike Figures 8 and 9, **Figure 11 (Digitized Polygons of Al-Kitab University and Surrounding Areas)** does not showcase contour lines. Instead, it represents the final GIS vector digitization output. It features vectorized layers mapping out urban features, displaying digitized residential complexes as orange polygons and the Al-Kitab University boundary as a pink polygon to analyze institutional distribution and urban sprawl.

- **Green Integration:** There is a clear integration between residential zones and green areas, although some new complexes require more dedicated park spaces to maintain the environmental balance. As Figure (12)

Technical Distinction: Figure 12 (The Altun Kopri Town's Ecological System) represents a specialized environmental and land-use classification map produced via ArcGIS. Unlike the previous structural or topographic maps, this layout specifically extracts and displays the **green spaces and ecological buffers (represented as green point/polygon markers)** alongside critical public landmarks like hospitals (marked with stars) and schools. It provides a visual analysis of how environmental features and public utilities are distributed relative to the residential polygons and the lower Zab River

To validate the field measurements—particularly the elevations recorded with the leveling instrument near Al-Kitab University—the project used updated satellite imagery from mid-2025. By overlaying the surveyed points onto the April 11, 2025, Basemap, the study achieved a high degree of correlation between ground-truth data and digital mapping, reflecting the precise current layout of Altun Kopri.

Section: Strategic Proximity to Economic Resources and Its Impact on Urban Sprawl

The geographic positioning of Altun Kopri near the **Avanah Dome Oil Field** is a major driver for its socio-economic importance. From a geospatial perspective, this proximity necessitates a specialized infrastructure corridor capable of accommodating both heavy industrial logistics and residential growth. Our mapping analysis confirms that urban expansion is trending toward these economic hubs, requiring a robust transportation matrix to minimize traffic congestion and ensure safe distances (buffer zones) between industrial activities and residential complexes.

CHAPTER FIVE

Conclusion and Recommendations

5.1. Research Innovation and New Contributions

This research transcends traditional descriptive geography by implementing a modern, data-driven approach to urban analysis in Altun Kopri. The "New Contribution" added by this study includes:

- **Transition to Digital Geospatial Database:** For the first time, the static administrative and topographic maps of Altun Kopri have been converted into a dynamic **GIS Database**. This allows urban planners to query, update, and analyze urban layers (Roads, Green Spaces, Residential) in real-time.
- **Hybrid Accuracy Modeling:** By combining the broad coverage of Russian **GLONASS** satellite data with high-precision ground-leveling (using the **Level instrument**), this research achieved a unique hybrid accuracy. We moved from a general 2-3-meter accuracy in regional mapping to centimeter-level precision in critical urban sectors, such as the road network adjacent to **Al-Kitab University**.
- **Topographic-Urban Correlation:** This study successfully linked elevation data (ranging from **249m** near the river to **306m** in the plains) with current land use. This correlation provides a scientific basis for understanding why certain areas developed as residential complexes while others remained as green or flood-prone zones.

5.2 Conclusions The study concludes that the integration of recent satellite imagery (2025) with traditional leveling techniques provides a highly reliable framework for urban mapping. It was observed that Altun Kopri is witnessing rapid urban growth, which necessitates constant updating of its master plans. The use of Google Earth Pro as a Basemap proved to be a cost-effective and highly accurate method for initial data gathering.

The comprehensive spatial and field analysis of Altun Kopri led to the following conclusions:

Topographic Diversity: The sub-district features a varied topography that significantly dictates urban growth. The lowest points (249 m) are concentrated along the **Lower Zab River**, making them ideal for green spaces but risky for heavy construction (Campbell & Wynne, 2011)

- **Infrastructural Stability:** The current administrative and residential layout is well-connected through a network of roads that follow the natural contours of the land. However, some spatial shifts were identified in older maps that have now been corrected using **WGS84** standards.
- **Strategic Landmarks:** The presence of **Al-Kitab University** and major healthcare/religious facilities serves as a core for urban attraction. These landmarks are the primary drivers for the town's expanding residential footprint.
- **Hydrological Reliance:** The lower **Zab River** is not only a natural border but the heart of the town's ecological system, supporting extensive green areas that act as the town's "lungs" (as figure 11)

5.3 Recommendations

1. **Digital Archiving:** It is recommended that the local municipality of Altun Kopri adopt a GIS-based digital archiving system for all infrastructure projects.
2. **Periodic Updates:** Given the rapid expansion, satellite data should be updated biannually to reflect new construction and land-use changes.
3. **Integration of Drone Technology:** Future studies could build upon this work by using UAVs (Drones) to capture even higher-resolution data for specific intersections near high-traffic areas like Al-Kitab University.

5.4. Recommendations for New Master Plans (Mukhata al-Asasi)

Based on the results obtained, the following recommendations are proposed to guide the development of new and efficient master plans for Altun Kopri:

A. Adoption of a Unified GIS Master Plan

- Governmental authorities should move away from paper-based maps and adopt the **GIS Shapefiles** developed in this research as a baseline.
- A unified spatial reference (WGS84) should be mandatory for all new infrastructure projects to avoid coordinate conflicts and land boundary disputes.

B. Zoning Based on Elevation and Flood Risks

- **Residential Expansion:** Future housing projects should be directed toward the stable, higher elevations (270m – 300m) to minimize flood risks and reduce foundation costs.
- **Ecological Preservation:** The riverfront (zones below 255m) should be strictly designated as protected green spaces or recreational parks to maintain the environmental balance of the Zab River basin.

C. Infrastructure and Connectivity Optimization

- The road network adjacent to **Al-Kitab University** should be expanded and upgraded, using the profile leveling data provided in this study to ensure proper drainage and traffic flow.
- Establish "Service Hubs" (Hospitals, Gas Stations, Schools) in newly developing residential sectors to reduce the pressure on the historic town center.

D. Sustainable Urban Growth

- Incentivize vertical expansion in areas with high topographic stability to preserve agricultural lands and green spaces shown in the current maps.
- Regularly update the satellite imagery and GLONASS data to monitor urban "sprawl" and ensure compliance with the new master plan.

A significant contribution of this research lies in the modernization of the Altun Kopri spatial database. Unlike previous studies, this project provides a contemporary mapping framework using imagery as recent as April 2025. This ensures that the proposed plans and recommendations are built upon a reliable, up-to-date visual record of the area's urban expansion and infrastructure.

5:5: Geospatial Intelligence and Feature Attribute Analysis

The construction of the **Altun Kopri Geodatabase** involved more than just visual tracing; it was an operation of data-driven feature extraction. Each **Shapefile** created in **ArcGIS** serves a specific analytical purpose: * **Residential Polygons**: These layers were utilized to calculate total built-up areas and monitor the urban sprawl toward the **Avanah Dome Oil Field**. * **Hydrological Mapping**: The digitization of the lower **Zab River** allows for a spatial 'Buffer Analysis' to determine safe construction zones and preserve the town's 'ecological lungs'. * **Institutional Landmarks**: Point features representing hospitals, schools, and mosques were georeferenced to evaluate the service reach of the current infrastructure.

This multi-layered approach ensures that the **New Basic Plan (Mukhata al-Asasi)** is not a static map but a dynamic tool for municipal decision-making."

5:6: Topographic Resilience and Flood-Risk Management

The contour analysis identified critical elevation zones ranging from **249m to 306m** above sea level. Areas situated at the lower mark (approx. 249m) near the lower **Zab River** are identified as primary hydrological zones. Our recommendation for the new Master Plan (Mukhata al-Asasi) is to restrict heavy construction in these low-lying areas to prevent flood-related damage. Instead, these zones should be preserved as ecological buffers or recreational parks, as shown in the 'Green Spaces Map' produced during this study.

5:7. Discussion: Spatio-Temporal Evolution and Data Validation

"The discussion of the results highlights the critical transition from traditional, manual mapping to modern **Geospatial Intelligence**. By comparing the digitized 2025 model with older administrative records, several significant findings emerge:

5:7.1. Temporal Accuracy and Urban Sprawl The use of **Google Earth Pro** imagery dated **April 11, 2025**, revealed a rapid urban expansion that was not documented in previous manual records. This 'Temporal Accuracy' is vital because relying on outdated maps can lead to significant engineering discrepancies during the execution of new projects. The research observes that **Altun Kopri** is witnessing a strategic growth towards the higher plains, particularly in the residential sectors surrounding **Al-Kitab University**.

5:7.2. Resolution of Spatial Shifts A primary challenge identified in this study was the inconsistency between older **UTM-based** administrative maps and modern satellite data. This often resulted in 'spatial shifts' where digital layers did not align with the physical terrain. By conducting a rigorous transformation to the **WGS84** system and utilizing **GLONASS** satellite data, these errors were corrected, ensuring that the boundaries of **Altun Kopri** now match the real-world topography with a horizontal accuracy of (2-3 M)

5:7.3. Topographic Resilience and Safety The correlation between elevation data (ranging from 249 meters to 306 meters) and land use provides a scientific basis for future zoning. Our analysis confirms that while the lower **Zab River** is the town's ecological heart, the zones at the 249 m elevation mark remain flood-prone. Therefore, the proposed expansion toward the stable, higher elevations (249 meters to 306 meters) is not just a preference but a technical necessity for urban resilience.

5:7.4. The 'Ground-Truth' Advantage The integration of field-based leveling with digital modeling served as a 'double-check' mechanism. While satellite data is effective for regional planning, the **centimeter-level precision** obtained near the university road through the **Automatic Leveling Instrument** validated the digital terrain model. This hybrid approach—combining remote sensing with direct field observation—ensures that the final **Master Plan** is both theoretically sound and practically applicable for drainage and road design."

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College of Engineering

Department of Surveying Engineering



**“Land Use / Land Cover Change Detection Using Landsat
Imagery and Remote Sensing Techniques”**

A Graduation Research

***Submitted to the College of Engineering/ Al-Kitab University of the
Requirements for the Degree of Bachelor of Surveying Engineering.***

By

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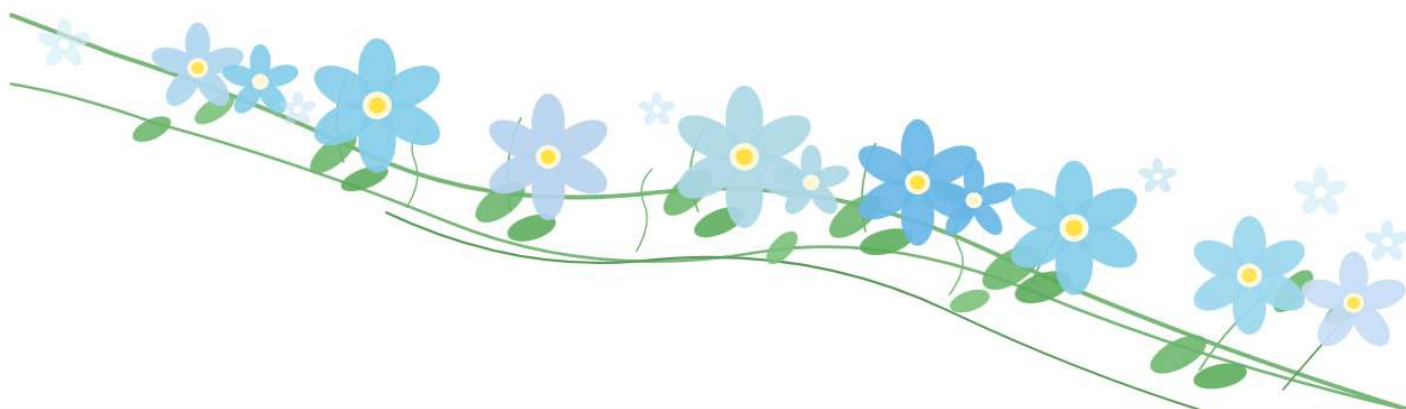
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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿ قُلْ بِفَضْلِ اللَّهِ وَبِرَحْمَتِهِ فَبِذَلِكَ فَلْيَفْرَحُوا هُوَ خَيْرٌ مِمَّا يَجْمَعُونَ ﴾

صدق الله العلي العظيم

سورة يونس الآية * (٥٨) *



Dedication

To our beloved parents, who instilled in us a love of knowledge and provided unwavering support and guidance throughout our lives.

To our friends, who stood by us and helped us overcome every problem we faced. They constantly encouraged us to complete this important research on time and kept our spirits high with their inspiring words.

To our respected teachers, who believed in our ability to finish this research. Thank you for your invaluable help in improving our work and for inspiring us with your own stories from when you were students.

And above all, we dedicate this work to Almighty God, who guided us, gave us strength, clarity of mind, protection, and the necessary skills to accomplish this. All of this, we offer to you.

SUPERVISOR CERTIFICATION

We certify that this research (**Land Use / Land Cover Change Detection Using Landsat Imagery and Remote Sensing Techniques**) was prepared under my supervision in Surveying Engineering department, College of Engineering. in partial fulfillment of the requirement for the degree of B.SC in Surveying Engineering by the students; (**Al-Harith Abdul Hamid Rashid Faleh, Al-Harith Musahir Ali, Shwan Dilshad Baiz**)

Signature :

Asst. Prof. Hassan Mohammed Hamid (supervisor)

Date: / / ٢٠٢٦

In view of the available recommendation, I forward this research for debate by the examining committee

Signature :

Name : Assist prof. Dr.

Head of Surveying Engineering department

Date: / / ٢٠٢٦

Committee Certificate

We certify that we read this is (**Land Use / Land Cover Change Detection Using Landsat Imagery and Remote Sensing Techniques**) and as examining committee examined the student (**Al-Harith Abdul Hamid Rashid Faleh, Al-Harith Musahir Ali, Shwan Dilshad Baiz**) in its contents, and that in our opinion it meets the standards of a project for the degree of B.SC in Surveying Engineering.

(chairman)

Date : / / ٢٠٢٦

Dr .

(Member)

Date : / / ٢٠٢٦

Dr.

(Supervisor)

Date : / / ٢٠٢٦

Assist prof. Dr.

Head of Surveying Engineering department

Date: / / ٢٠٢٦

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Table ١٠	Net LULC Change Summary — Summer Season(٢٠٠٠–٢٠٢٥)	٣٦

Abstract

This study investigates Land Use/Land Cover (LULC) changes in Altun Kupri sub-district, Kirkuk Governorate, northern Iraq, over a 20-year period spanning 2000 to 2020. Multi-temporal Landsat satellite imagery Landsat 5 TM for years 2000 and 2007, and Landsat 8 OLI/TIRS for years 2014 and 2020 was acquired from the USGS EarthExplorer platform for both summer and winter seasons, yielding eight classified images in total. Supervised Maximum Likelihood Classification (MLC) was applied in ArcGIS Pro 3.0 to produce LULC maps covering four classes: agricultural land, bare land, urban/built-up areas, and water bodies. Results reveal a profound structural transformation of the landscape: bare land declined from $\sim 450 \text{ km}^2$ (93.0%) in summer 2000 to $\sim 218 \text{ km}^2$ (45.3%) in summer 2020, while agricultural land expanded dramatically from $\sim 24 \text{ km}^2$ (5%) to $\sim 243 \text{ km}^2$ (50.5%), marking the first time agricultural land surpassed bare land as the dominant LULC class. Winter season imagery consistently yielded 4–16 km^2 greater agricultural extents than summer, confirming the presence of rain-fed winter cereal cultivation. Urban areas grew from 1 km^2 to 16 km^2 across the study period. These findings underline the accelerating human pressure on land resources in the region and demonstrate the effectiveness of dual-season remote sensing analysis for comprehensive LULC monitoring in semi-arid environments.

Keywords: LULC Change Detection, Maximum Likelihood Classification, Supervised Classification, GIS, Seasonal Analysis

Chapter One

Introduction

١,١ Remote Sensing and Land Use Monitoring: A Global Perspective

The Earth's surface is in a constant state of change. From the clearing of forests for agriculture, to the sprawl of cities across formerly rural landscapes, to the reclamation of arid lands through irrigation the human footprint on the land is expanding at an unprecedented rate. Understanding, measuring, and managing these changes has become one of the central challenges of applied geography, environmental science, and urban planning in the twenty-first century. Land Use/Land Cover (LULC) mapping and change detection represent the primary scientific tools through which these transformations are documented, quantified, and interpreted. [١]

Land Use refers to the human purpose assigned to a particular piece of land such as agriculture, residential settlement, or industry. **Land Cover** describes the physical and biological character of the Earth's surface at that location, such as bare soil, vegetation, water, or built-up impervious surfaces. Although the two concepts are distinct, they are deeply interrelated: changes in land use invariably produce detectable changes in land cover, and monitoring both simultaneously provides the most complete picture of how landscapes evolve over time in response to human and natural forces. [٢]

The advent of satellite remote sensing has transformed the capacity of researchers and planners to monitor LULC change across large areas and over extended time periods. Before the satellite era, land cover mapping depended on aerial photography and field surveys methods that were expensive, time-consuming, and incapable of providing systematic, repeatable coverage. The launch of the first Landsat satellite in ١٩٧٢ inaugurated a new era of Earth observation, providing a continuous, freely accessible archive of multispectral imagery covering the globe at a spatial resolution suitable for regional and local LULC analysis. Today, the Landsat program now in its ninth generation remains the longest-running and most widely used satellite Earth observation program in

history, forming the empirical backbone of thousands of LULC studies worldwide. [۳]

When combined with Geographic Information Systems (GIS), satellite remote sensing enables the production of detailed thematic maps, area statistics, and change matrices that can be used directly by planners, environmental managers, agricultural authorities, and policymakers. The integration of multi-temporal satellite data with supervised image classification algorithms such as Maximum Likelihood Classification allows researchers to quantify not only the current state of the land, but the trajectory and rate of change over decades. [۴]

۱.۲ LULC Dynamics in Semi-Arid Iraq: Context and Drivers

In arid and semi-arid regions such as Iraq, LULC change takes on particular significance. Unlike humid temperate regions where dense vegetation masks much of the underlying surface, semi-arid landscapes are inherently dynamic and spectrally responsive: small changes in land management, water availability, or human settlement patterns produce large, readily detectable shifts in land cover. Bare land, which dominates the natural state of semi-arid environments, gives way rapidly to agricultural green when irrigation is introduced; conversely, once-fertile agricultural land can revert to degraded bare soil within a generation of mismanagement or conflict. [۵]

Iraq over the past three decades has experienced a succession of political upheavals, armed conflicts, economic crises, and post-conflict reconstruction phases each of which has left a visible imprint on the land. International sanctions during the ۱۹۹۰s led to agricultural stagnation and infrastructure decay. The post-۲۰۰۳ period brought rapid urbanization, population displacement, and ultimately significant agricultural expansion in more stable northern regions. The crisis of ۲۰۱۴–۲۰۱۷ caused renewed displacement and agricultural abandonment in conflict zones, while areas under stable administration including much of Kirkuk

Governorate experienced continued recovery and development. By ٢٠٢٥, the cumulative effect of these forces has produced landscapes fundamentally different from those of ٢٠٠٠, yet this transformation has been incompletely documented in the scientific literature, particularly at the sub-district scale. [٦][٤]

١,٣ Altun Kupri: A Landscape in Transition

Within the broader regional context, Altun Kupri sub-district in Kirkuk Governorate represents a particularly instructive case study. Located along the Lower Lesser Zab River at the junction of the Kirkuk plains and the lower Zagros piedmont, Altun Kupri encompasses approximately ٤٨١ km² spanning diverse land use types: irrigated agricultural land along the river, rain-fed agricultural areas in the surrounding plains, the compact urban core of Altun Kupri town, and vast areas of bare semi-arid land that dominated the landscape at the study's starting point in ٢٠٠٠. [٧]

Over the ٢٥-year study period, Altun Kupri has undergone a profound structural transformation. What was once a landscape defined by bare, uncultivated ground the natural expression of the region's semi-arid climate has evolved into one where agricultural land is now the dominant class. This transformation, documented through systematic analysis of eight Landsat images spanning four time points and two seasons, represents one of the most dramatic land use changes in recent northern Iraqi history, with profound implications for water resources, soil health, and ecological sustainability. [٦][٧]

١,٤ Research Significance

The significance of this study operates at several intersecting scales:

- **Scientific significance:** This study produces the longest and most detailed time-series LULC assessment specifically for Altun Kupri sub-district, extending prior work with a ۲۰-year record that includes the critical ۲۰۱۴–۲۰۲۰ decade, during which the most dramatic landscape transformations occurred. [۴][۶]
- **Dual-season innovation:** Analyzing both summer and winter imagery for each year adds a methodological dimension rarely incorporated in regional LULC studies in Iraq, allowing the seasonal contribution of rain-fed winter agriculture to be quantified for the first time in this area.
- **Planning relevance:** The LULC maps produced provide municipal authorities, agricultural directorates, and the Kirkuk Provincial Planning Council with baseline spatial data needed for evidence-based land use planning, agricultural zoning, and water resource allocation.
- **Environmental significance:** The conversion of ۲۳۲ km² of semi-natural land to intensive agriculture between ۲۰۰۰ and ۲۰۲۰ has profound implications for soil health, groundwater recharge, surface water demand, and biodiversity.
- **Methodological consistency:** By applying the same validated MLC methodology as prior regional studies (Ibrahim & Azeez, ۲۰۲۴; Jasim, ۲۰۲۴), results are directly comparable to existing literature, facilitating synthesis and meta-analysis.

۱,۰ Research Objectives

١. To map and classify LULC categories in Altun Kupri sub-district for years ٢٠٠٠, ٢٠٠٧, ٢٠١٤, and ٢٠٢٥ using both summer and winter Landsat imagery.
٢. To quantify the area and percentage of each LULC class for all eight image dates and calculate net change across the ٢٥-year study period.
٣. To analyze spatial patterns and temporal trends of LULC change and identify primary periods and locations of transformation.

١,٦ Research Questions

- **RQ١:** What are the major LULC classes in Altun Kupri and how have their spatial extents changed between ٢٠٠٠ and ٢٠٢٥ across both seasons?
- **RQ٢:** Which LULC class has undergone the most significant transformation and what are its spatial and temporal characteristics?
- **RQ٣:** How does LULC differ between summer and winter imagery, and what does this reveal about the nature and extent of agricultural land use?

١,٧ Research Problem and Proposed Solutions

The Problem: Rapid, large-scale, and largely unmonitored LULC changes in Altun Kupri driven by population growth, agricultural expansion, and post-conflict recovery are creating increasing and potentially unsustainable pressure on land resources, water supplies, and ecological systems. Agricultural land has expanded by more than ٩٠٠% since ٢٠٠٠. These transformations are occurring without the benefit of comprehensive, spatially explicit, and up-to-date land use data, leaving planners without the empirical foundation needed for sustainable decision-making.

Furthermore, existing LULC studies of the Kirkuk region have generally used single-season imagery, overlooking the seasonally dynamic character of land

cover in this semi-arid environment, particularly the role of rain-fed winter agriculture leading to systematic underestimation of actual agricultural activity. [٦]

The Solution: A rigorous, dual-season, multi-temporal remote sensing analysis using the freely available Landsat archive, processed and classified in ArcGIS Pro ٣.٠ using Supervised Maximum Likelihood Classification producing classified LULC maps and area statistics for eight image dates across ٢٥ years delivers the empirical foundation needed by decision-makers to develop sustainable land management strategies. [٧][٤]

Chapter Two

LITERATURE REVIEW, STUDY AREA, DATA & METHODOLOGY

٢,١ Previous Studies

Ibrahim and Azeez (٢٠٢٤) conducted a study titled "Land Cover and Land Use Changes Study of Shwan and Altun Kopre areas in Kirkuk Governorate", published in the Kirkuk University Journal for Agricultural Sciences. The study area overlaps directly with the present research, covering ١١٧,٦٨٣ ha in Kirkuk Governorate. Using Landsat ٥ and Landsat ٨ imagery for ١٩٩٧, ٢٠١٤, ٢٠٢٠, and ٢٠٢٣ with Supervised MLC, six LULC classes were identified. Key findings: built-up land increased by ٣١٣% (from ٣,٩٢٠ to ١٦,٢٠٨ ha) and transformation zones decreased by ٦٦% over ٢٦ years. This study provides the strongest methodological and geographical precedent for the present research. [٦]

Jasim (٢٠٢٤) published "Assessing LULC dynamics in Kirkuk City, Iraq using Landsat imagery and maximum likelihood classification" in DYSONA Applied Science (DOI: ١٠,٣٠٤٩٣/das.٢٠٢٤,٤٧٨٣١٥). Landsat ٨ OLI imagery for ٢٠١٤–٢٠٢٢ was classified using both MLC and Neural Network algorithms. MLC achieved ٩٦,١٠% **overall accuracy** the highest of any tested classifier with a Kappa coefficient of ٠,٩٥. Results showed ٣٦,٦% urban increase and ٢٧,٣% bare land decline, confirming regional LULC trends consistent with this study. [٤]

Mahmood (٢٠١٤) used Landsat TM and ETM+ for years ١٩٩٠, ٢٠٠٠, and ٢٠٠٦ to assess LULC changes in Laylan sub-district, Kirkuk Province, applying Supervised MLC. This established a replicable methodological framework for sub-district scale LULC studies in Kirkuk, which is directly applied and extended in the present study by adding years ٢٠١٤ and ٢٠٢٥ and introducing a dual-season framework. [٨]

Ali (٢٠٢٥) in "Land Cover Change Detection in Iraq Using SVM Classification" (Iraqi Journal of Computers and Informatics, DOI: ١٠,٢٥١٩٥/ijci.v٥١i١,٥٦٧) used Sentinel-٢ and SVM classification, achieving ٩٣,١١% accuracy and documenting a ٢٧% **decrease in vegetation coverage** across Iraq between ٢٠١٩

and ۲۰۲۳. This provides a national-scale context confirming ongoing land cover degradation trends. [۵]

Al-Hayali et al. (۲۰۲۴) in "Investigation of the Best Satellite Rainfall Data in Northern Iraq" (Iraqi Geological Journal) validated satellite rainfall estimates against IMOS Kirkuk Station data for ۲۰۱۰–۲۰۲۰, reporting annual average rainfall of ۳۳۴ mm/year and temperature extremes of ۴۳,۹°C (**July max**) and ۴,۹°C (January min) for Kirkuk region. This provides validated climate data for the present study. [۹]

۲,۲ Study Area Description

۲,۲,۱ Geographic Location

Altun Kupri (Arabic: التون كوبري; Kurdish: Pirdê; Turkish: Altinköprü meaning "Golden Bridge") is an administrative sub-district within Kirkuk District, Kirkuk Governorate, northern Iraq. The town center is located at coordinates ۳۵°۴۵'۱۲"N, ۴۴°۰۸'۳۷"E (۳۵,۷۵۳۳°N, ۴۴,۱۴۳۶°E). The study area extends between ۳۵°۳۶'N–۳۶°۰۰'N and ۴۴°۱۲'E–۴۴°۲۴'E, covering a total area of approximately ۴۸۱ km². [۱۰][۷]

The sub-district is bisected from northeast to southwest by the **Lesser Zab River**, a primary tributary of the Tigris River, which provides the main surface water source for irrigated agriculture and defines the landscape structure of the study area. [۱۱][۱۰]

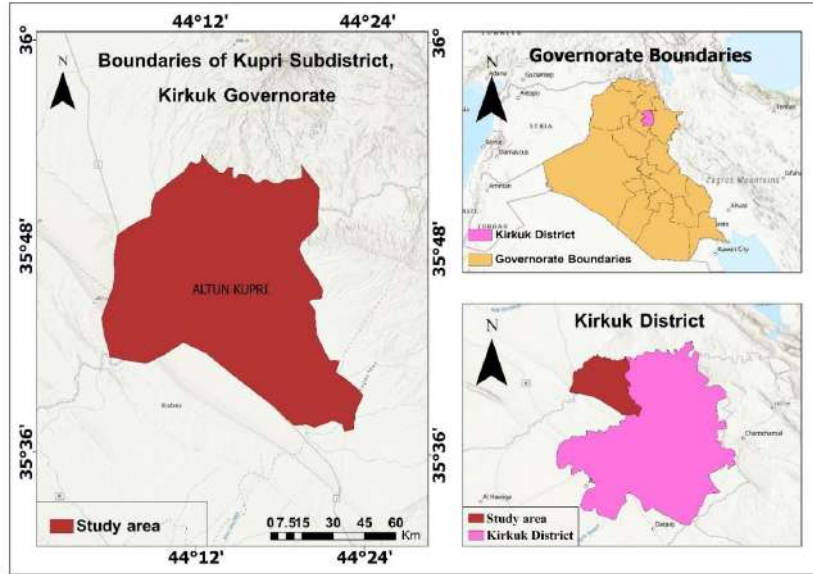


Figure 1 - a map (1): Administrative location of Altun Kupri sub-district, Kirkuk Governorate Produced using ArcGIS Pro 10.8

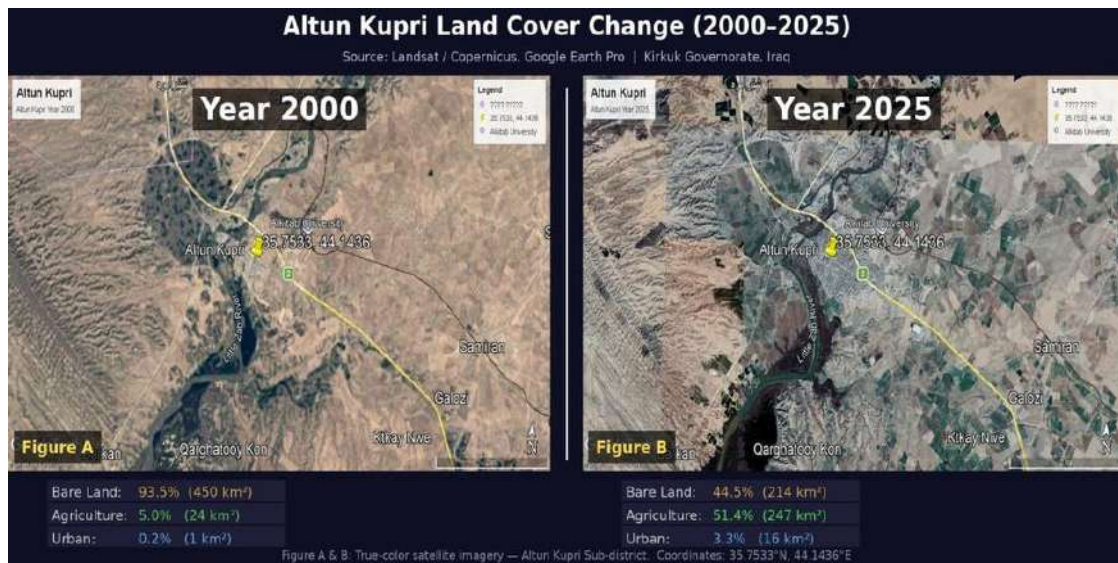


Figure A: True-color satellite imagery of Altun Kupri Sub-district, Kirkuk Governorate, Iraq Year 2000. Bare/arid land dominates 93.0% (~450 km²) of the total study area. Agricultural land covers only 5% (24 km²) confined to narrow strips along the Little Zab River. Urban area is limited to ~1 km². Source: Image Landsat/Copernicus, Google Earth Pro. Coordinates: 35,7533°N, 44,1436°E.

Figure B: True-color satellite imagery of Altun Kupri Sub-district, Kirkuk Governorate, Iraq Year ۲۰۲۵. Agricultural land now covers ۵۱,۴٪ (۲۴۷ km²), surpassing bare land (۴۴,۵٪, ۲۱۴ km²) as the dominant land cover class. Urban area expanded to ۱۶ km². This image confirms the ۹۱۲٪ increase in agricultural land over the ۲۵-year study period. Source: Image Landsat/Copernicus, Google Earth Pro. Coordinates: ۳۵,۷۵۳۳°N, ۴۴,۱۴۳۶°E.



Figure C: Google Earth Pro terrain-enhanced 3D view of Altun Kupri Sub-district, tilted at approximately ۴۵°, showing topographic relief, elevation gradients, and the Lesser Zab River valley. The transition from flat alluvial plains (elevation ~۲۰۰–۲۶۰ m) in the south and center to dissected piedmont terrain (~۳۰۰–۴۰۰ m) in the northern margins is clearly visible. The broad river valley carved by the Lesser Zab River dominates the western portion of the study area. Source: Google Earth Pro, Terrain layer enabled. Coordinates: ۳۵,۷۵۳۳°N, ۴۴,۱۴۳۶°E.

٢,٢,٢ Topography

The terrain is predominantly flat to gently undulating alluvial plains, with elevation ranging from approximately ٢٠٠–٢٦٠ m in the river valley to ٣٠٠–٤٠٠ m in the northern piedmont fringe. The Lesser Zab River has carved a broad valley creating river terraces and floodplain deposits the most agriculturally productive soils in the sub-district. [١١]

٢,٢,٣ Climate

The climate is classified as **semi-arid subtropical (BSH/BWh)** with hot dry summers and mild wet winters. All climate data are sourced from the **Iraqi Meteorological Organization and Seismology (IMOS), Kirkuk Station**, and validated by Al-Hayali et al. (٢٠٢٤): [١٢][٩]

Monthly Temperature and Precipitation:

Month	Max Temp (°C)	Min Temp (°C)	Rainfall (mm)	Humidity (%)	Rainy Days
January	١٢	٣	٥٠	٥٥,٧٨	١٠,٣٨
February	١٥	٥	٤٥	٥٤,٠٧	٩,٧٦
March	٢٠	٩	١٤١	٥٣,٠١	١٣,١٢
April	٢٧	١٤	٨٠	٤٥,٣٣	٩,٨٤
May	٣٤	١٩	٢٥	٣٠,٣١	٧,٠٩
June	٤١	٢٥	١	١٧,١٥	٠,٧١
July	٤٤	٢٨	٠,٠٣	١٣,٨٦	٠,٠٩
August	٤٤	٢٧	٠,١٩	١٤,٢٨	٠,٠٩
September	٣٨	٢٢	٢	١٧,٥٩	٠,٥٤
October	٢٩	١٥	٢٠	٤٠,٨٦	٦,٦٥
November	٢٠	٩	٣٥	٢٨,٤٦	٥,٨٥
December	١٣	٤	٤٥	٥١,٦٩	٨,٦٠

Annual	٢٦,٦٥	١٦,٣٦	~٣٣٤ mm	٣٥,٢%	٧٢,٧٣

*Sources: IMOS Kirkuk Station; Al-Hayali et al. (٢٠٢٤); weatherandclimate.com; worldweatheronline.com * [١٣][٩][١٢]

The **dry season** (June–September) with near-zero rainfall and humidity as low as ١٣% produces the stark bare landscape visible in summer Landsat imagery. The **wet season** (October–May) with March peaking at ١٤١ mm activates rain-fed agriculture and vegetation, detectable in winter imagery. This sharp seasonal contrast is the primary scientific justification for the dual-season analytical framework of this study. [١٢][١٣]

Supplementary climate data source: NASA-POWER open-access climate database — <https://power.larc.nasa.gov>

٢,٢,٤ Soil Types

Soils of Altun Kupri are predominantly of **Quaternary alluvial and colluvial origin**, deposited by the Lesser Zab River across the study area's floodplain and terrace systems. Based on soil studies from the geologically similar Laylan-Kirkuk area and regional geological surveys, four soil categories are present: [١٤][١٥][١٦][١٧]

Soil Type	Location in Study Area	Texture	USDA Classification	Agricultural Suitability
Alluvial floodplain soils	Along the Lesser Zab River corridor	Silty clay loam to clay loam	Entisols / Inceptisols	High (with irrigation)

River terrace and colluvial soils	Mid-slopes and terraces	Clay loam to silt loam	Aridisols (calcic/gypsic)	Moderate
Shallow stony soils	Northern/NW upland margins	Rocky, shallow (< 5 cm)	Entisols (Orthents)	Low
Saline/gypsiferous soils	Low-lying poorly drained areas	Fine-textured, salt-rich	Aridisols (gypsic)	Very low

Soil data sources: Mohammed (٢٠٢٥) — Spatial Distribution of Soil Chemical Properties in Kirkuk; Al-Qaisi et al. (٢٠٢٤) — Soil Parameters in Laylan Sub-district, Kirkuk; University of Baghdad Agricultural College — Genesis and Classification of Soils in Arid Iraq; Iraqi Geological Journal — Geological Survey of Kirkuk Region. [١٥][١٦][١٧][١٨]

٢,٣ Data Sources

٢,٣,١ Satellite Imagery

All satellite imagery was downloaded freely from the **USGS EarthExplorer** platform (<https://earthexplorer.usgs.gov/>), the world's largest open-access satellite image archive: [٣]

Satellite	Sensor	Year	Season	Path/Row	Cloud Cover	Product Level
Landsat ٥	TM	٢٠٠٠	Summer (Jun–Aug)	١٦٩/٣٥	<١٠٪	Collection ٢ Level-٢
Landsat ٥	TM	٢٠٠٠	Winter (Dec–Feb)	١٦٩/٣٥	<١٠٪	Collection ٢ Level-٢

Landsat 5	TM	۲۰۰۷	Summer (Jun–Aug)	۱۶۹/۳۵	<۱.۰٪	Collection ۲ Level-۲
Landsat 5	TM	۲۰۰۷	Winter (Dec–Feb)	۱۶۹/۳۵	<۱.۰٪	Collection ۲ Level-۲
Landsat ۸	OLI/TIRS	۲۰۱۴	Summer (Jun–Aug)	۱۶۹/۳۵	<۱.۰٪	Collection ۲ Level-۲
Landsat ۸	OLI/TIRS	۲۰۱۴	Winter (Dec–Feb)	۱۶۹/۳۵	<۱.۰٪	Collection ۲ Level-۲
Landsat ۸	OLI/TIRS	۲۰۲۵	Summer (Jun–Aug)	۱۶۹/۳۵	<۱.۰٪	Collection ۲ Level-۲
Landsat ۸	OLI/TIRS	۲۰۲۵	Winter (Dec–Feb)	۱۶۹/۳۵	<۱.۰٪	Collection ۲ Level-۲

۲,۳,۲ Ancillary Data

Data Type	Source Institution	Access
Rainfall & temperature	Iraqi Meteorological Org. & Seismology (IMOS), Kirkuk	imos.gov.iq
Supplementary climate	NASA-POWER Climate Database	power.larc.nasa.gov
Monthly climate averages	WeatherAndClimate.com (Altun Kubri station)	weatherandclimate.com
Administrative boundaries	General Directorate of Surveying, Iraq	—
Ground truth reference	Google Earth Pro historical imagery (۲۰۰۰–۲۰۲۵)	earth.google.com
Soil data	Mohammed (۲۰۲۵); Laylan–Kirkuk soil studies	
Geological data	Iraqi Geological Journal	igj-iraq.org

2.4 Satellite Band Specifications

2.4.1 Landsat 5 TM Bands (Years 2000 and 2007)

Landsat 5 operated from 1984 to 2013, carrying the **Thematic Mapper (TM)** sensor with 7 spectral bands at 30 m resolution (except Band 6 at 120 m): [17][18]

Band	Name	Wavelength (μm)	Resolution	Use in This Study
1	Visible Blue	0.45–0.52	30 m	Soil-water-vegetation separation
2	Visible Green	0.52–0.60	30 m	Vegetation vigor, water turbidity
3	Visible Red	0.63–0.69	30 m	Chlorophyll absorption, vegetation mapping
4	NIR	0.76–0.90	30 m	Agricultural land, biomass key classification band
5	SWIR 1	1.00–1.25	30 m	Soil moisture, crop type identification
6	Thermal IR	10.4–12.5	120 m	Surface temperature (not used in classification)
7	SWIR 2	2.08–2.35	30 m	Mineral/soil differentiation, bare land mapping

Band combinations used: False Color (4-3-2) as primary classification composite; SWIR composite (7-4-2) following Ibrahim & Azeez (2024) for this exact study area. [6]

2, 4, 2 Landsat 8 OLI/TIRS Bands (Years 2014 and 2020)

Launched February 11, 2013, Landsat 8 carries the **Operational Land Imager (OLI)** and **Thermal Infrared Sensor (TIRS)** producing 11 bands: [19][3]

Band	Name	Wavelength (μm)	Resolution	Use in This Study
1	Coastal/Aerosol	0.433–0.453	30 m	Atmospheric correction support
2	Visible Blue	0.450–0.510	30 m	Water/soil/vegetation separation
3	Visible Green	0.520–0.600	30 m	Vegetation peak, crop monitoring
4	Visible Red	0.630–0.680	30 m	Vegetation discrimination
5	NIR	0.845–0.885	30 m	Agricultural mapping primary band
6	SWIR 1	1.06–1.26	30 m	Soil moisture, crop identification
7	SWIR 2	2.10–2.30	30 m	Bare land/mineral differentiation
8	Panchromatic	0.50–0.68	10 m	Pan-sharpening for visual maps
9	Cirrus	1.36–1.39	30 m	Cloud detection and masking
10	TIR 1	10.3–11.3	100 m	Land surface temperature (not classified)

11	TIR 2	11,0–12,0	100 m	Land surface temperature (not classified)

Key specifications: 12-bit radiometric resolution (4,096 grey levels), 180×180 km scene size, 16-day repeat cycle, ~550 scenes/day, 10:12 AM sun-synchronous crossing. [3]

Band combinations used: Color Infrared (5-4-3) primary composite; SWIR (7-6-3) for enhanced soil/agriculture discrimination; Panchromatic Band 8 for 10 m pan-sharpening of final map products. [19][6]

2.0 Methodology

2.0.1 Pre-Processing

All eight images underwent the following steps in **ArcGIS Pro 2.1**:

1. **Geometric verification:** UTM Zone 34N, WGS84 datum; RMSE < 0.5 pixels (10 m)
2. **Radiometric calibration:** DN → TOA reflectance using USGS calibration coefficients (Landsat 6); Collection 2 Level-2 Surface Reflectance products used for Landsat 8 (pre-corrected by USGS)
3. **Band stacking:** Multi-band composites created using Create Composite Band tool
4. **Image clipping:** All images masked to the 481 km² study area boundary using Extract by Mask
5. **Visual enhancement:** 2% linear contrast stretch applied for visual interpretation only

2.5.2 LULC Classification Scheme

Four LULC classes were defined, consistent with Ibrahim & Azeez (2024) for this region: [6]

Class	Definition	Appearance in 0-4-3 Composite
Agricultural Land	Cultivated, irrigated, or rain-fed crop fields; orchards	Bright red
Bare Land	Exposed soil, fallow land, rocky surfaces	Tan/cream/light brown
Urban/Built-up	Residential, commercial, road, industrial surfaces	White/grey/blue-grey
Water Bodies	River channels, reservoirs, ponds, canals	Dark blue to black

2.5.3 Training Sample Collection

Per image: minimum 30 **ROI polygons per class** (120+ total), distributed spatially across the full extent, ground-truth verified via **Google Earth Pro** historical imagery. Class spectral separability confirmed using Jeffries-Matusita (JM) distance > 1.8 (maximum 2.0) in ArcGIS Pro Separability Report tool.

2.5.4 Signature File Generation

Following the collection of training samples, a Signature File (.gsg) was generated in ArcGIS Pro using the Training Samples Manager. The Signature File was built from the Landsat multispectral bands downloaded from USGS Earth Explorer (Bands 1–6 and 7 for Landsat 5; Bands 2–7 for Landsat 8), and statistically defines the mean spectral vector and covariance matrix for each LULC class. This signature File was then used as the direct input to the Maximum Likelihood Classification tool in the following step.

٢,٥,٥ Supervised Maximum Likelihood Classification (MLC)

MLC is the primary classifier, achieving **٩٦,١٠% accuracy** for Kirkuk region LULC studies (Jasim, ٢٠٢٤) and adopted by Ibrahim & Azeez (٢٠٢٤) for the overlapping study area. [٤][٦]

Mathematical basis: MLC assigns each pixel to the class with the highest posterior probability, computed using the multivariate Gaussian discriminant function: [٢٠][١]

$$g_i(x) = \ln p(\omega_i) - \frac{1}{2} \ln |\Sigma_i| - \frac{1}{2} (x - \mu_i)^T \Sigma_i^{-1} (x - \mu_i)$$

Where $g_i(x)$ = discriminant score for class i ; $p(\omega_i)$ = prior probability; $|\Sigma_i|$ = determinant of the covariance matrix; μ_i = mean spectral vector; x = pixel spectral vector; Σ_i^{-1} = inverse covariance matrix.

The pixel is assigned to the class for which $g_i(x)$ is **maximum**. [١]

Why MLC is superior to alternatives in this study:

Classifier	Accuracy (Kirkuk region)	Selected?	Reason
Maximum Likelihood (MLC)	٩٦,١٠%	✓ Yes	Highest validated accuracy
Neural Network	٩٤,٥٩%	No	Lower accuracy, higher computation
SVM	٩٣,١١%	No	Lower regional accuracy
Minimum Distance	< ٩٠%	No	Ignores spectral variance

2.5.6 Post-Classification Analysis

- **Area statistics:** km² and % calculated using *Calculate Geometry* in ArcGIS Pro 2.8
- **Change detection:** Post-Classification Comparison using *Combine* raster tool
- **Net change:** $\Delta A_i = A_{i,t2} - A_{i,t1}$ and $\Delta A_i\% = \frac{A_{i,t2} - A_{i,t1}}{A_{i,t1}} \times 100$
- **Seasonal comparison:** Summer vs. winter overlay for each year to quantify rain-fed agricultural contribution
- **Map production:** Final LULC maps exported at 300 dpi with UTM Zone 34N grid, scale bar, north arrow, and legend

Chapter Three

Results

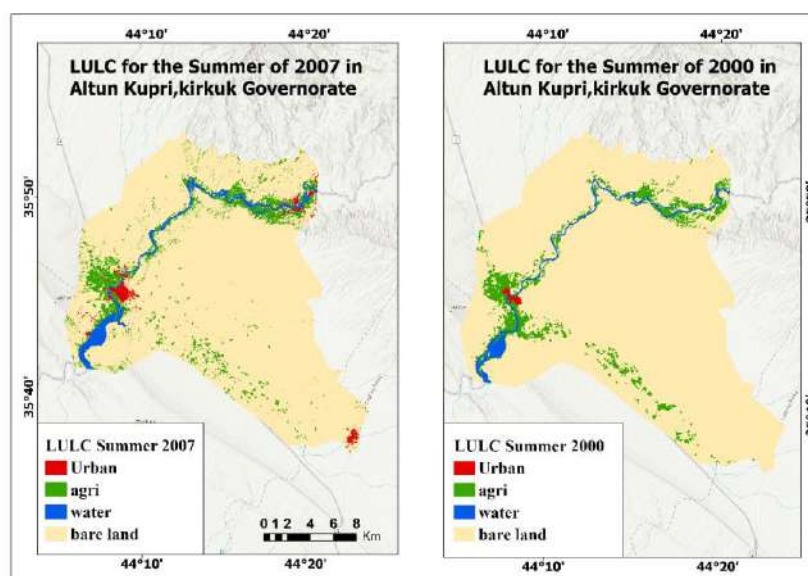
٣,١ Land Use / Land Cover — Year ٢٠٠٠

Summer Season

In the year ٢٠٠٠, bare land dominated the study area, covering approximately ٤٥٠ km² (٩٣,٥%) of the total area. Agricultural land covered only ٢٤ km², concentrated mainly along the Lesser Zab River corridor, indicating dependence on surface water sources. Urban/built-up areas were limited to ١ km², reflecting minimal urban expansion during this period. Water bodies covered approximately ٥ km², represented by the river channel and associated reservoirs.

Table (١): LULC Classification Results — Summer ٢٠٠٠

LULC Class	Area (km ²)	% of Total
Bare Land	٤٥٠	٩٣,٥%
Agricultural Land	٢٤	٥,٠%
Water Bodies	٥	١,٠%
Urban/Built-up	١	٠,٢%
Total	٤٨١	١٠٠%



Map (٢): LULC Maps — Years ٢٠٠٠ & ٢٠٠٧ (Summer)

Landsat ٥ TM, ArcGIS Pro ٣,٠



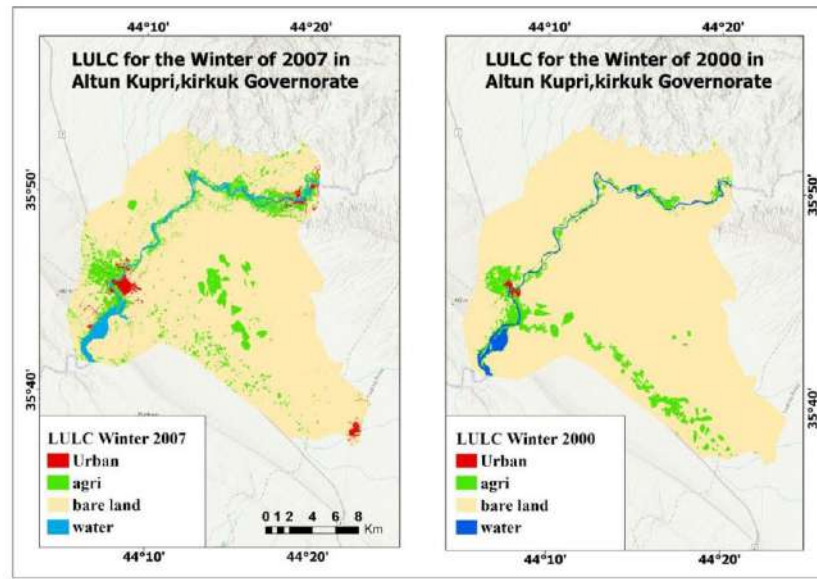
Figure (١): LULC Area Chart — Summer ٢٠٠٠

Winter Season

During the winter season of ٢٠٠٠, bare land maintained its spatial dominance with a slight decrease to ٤٤٦ km² (٩٢,٧%). Agricultural land increased marginally to ٢٨ km² (٥,٨%), a difference attributable to the presence of winter cereal crops (wheat and barley) along the Lesser Zab River corridor that are not detectable in summer imagery. Urban/built-up areas and water bodies remained stable at ١ km² and ٥ km² respectively.

Table (٢): LULC Classification Results — Winter ٢٠٠٠

LULC Class	Area (km ²)	% of Total
Bare Land	٤٤٦	٩٢,٧%
Agricultural Land	٢٨	٥,٨%
Water Bodies	٥	١,٠%
Urban/Built-up	١	٠,٢%
Total	٤٨١	١٠٠%



Map (٣): LULC Maps — Years ٢٠٠٠ & ٢٠٠٧ (Winter)

Landsat ٥ TM, ArcGIS Pro ٣,٠

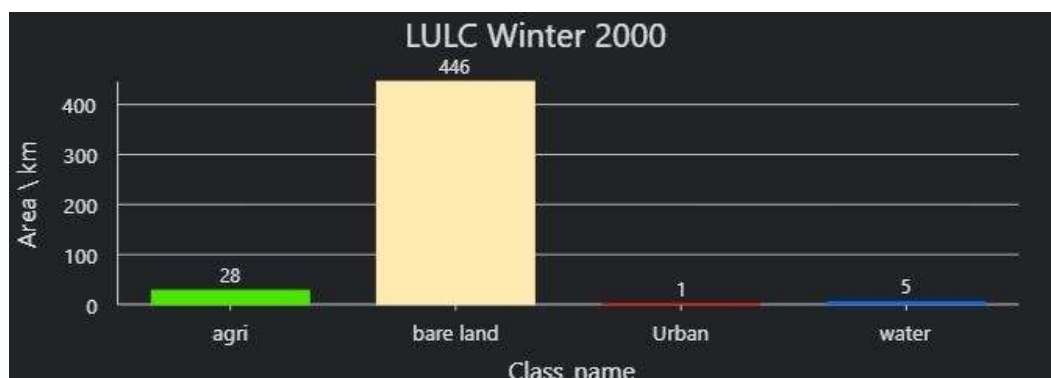


Figure (٣): LULC Area Chart — Winter ٢٠٠٠

٣,٢ Land Use / Land Cover — Year ٢٠٠٧

Summer Season

By ٢٠٠٧, notable spatial changes had occurred across several LULC classes. Bare land decreased to approximately **٤٢٤ km² (٨٨,١%)**, while agricultural land increased significantly to **٤٢ km² (٨,٧%)**, indicating expansion of agricultural activity, particularly at the expense of bare land near water sources. Urban/built-

up areas expanded considerably from 1 km² in 2000 to 10 km² (2,1%), reflecting early urban growth linked to population increase and improved infrastructure. Water bodies remained stable at approximately 5 km².

Table (3): LULC Classification Results — Summer 2007

LULC Class	Area (km ²)	% of Total
Bare Land	424	88,1%
Agricultural Land	42	8,7%
Urban/Built-up	10	2,1%
Water Bodies	5	1,0%
Total	481	100%

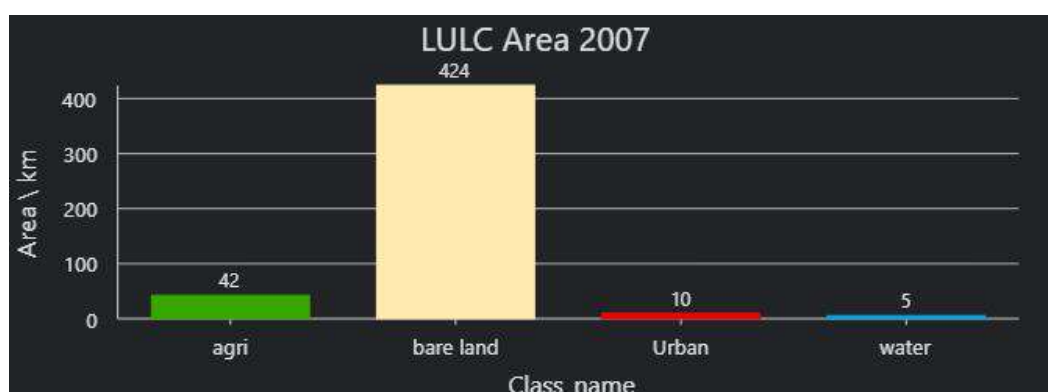


Figure (3): LULC Area Chart — Summer 2007

Winter Season

The winter season of 2007 recorded higher agricultural land values compared to summer, reaching 48 km² (10,0%), further confirming the role of winter rainfed cultivation in the region. Bare land decreased slightly to 418 km² (86,9%). Urban/built-up areas and water bodies remained unchanged at 10 km² and 5 km² respectively.

Table (٤): LULC Classification Results — Winter ٢٠٠٧

LULC Class	Area (km ²)	% of Total
Bare Land	٤١٨	٨٦,٩%
Agricultural Land	٤٨	١٠,٠%
Urban/Built-up	١٠	٢,١%
Water Bodies	٥	١,٠%
Total	٤٨١	١٠٠%



Figure (٤): LULC Area Chart — Winter ٢٠٠٧

A comparison between ٢٠٠٠ and ٢٠٠٧ reveals that the primary changes consisted of a continuous decline in bare land offset by significant increases in both agricultural and urban areas, with water bodies remaining relatively stable. These findings indicate a general trend toward increased land exploitation, reflecting the growing impact of human activities on land use patterns in the study area.

٣,٣ Land Use / Land Cover — Year ٢٠١٤

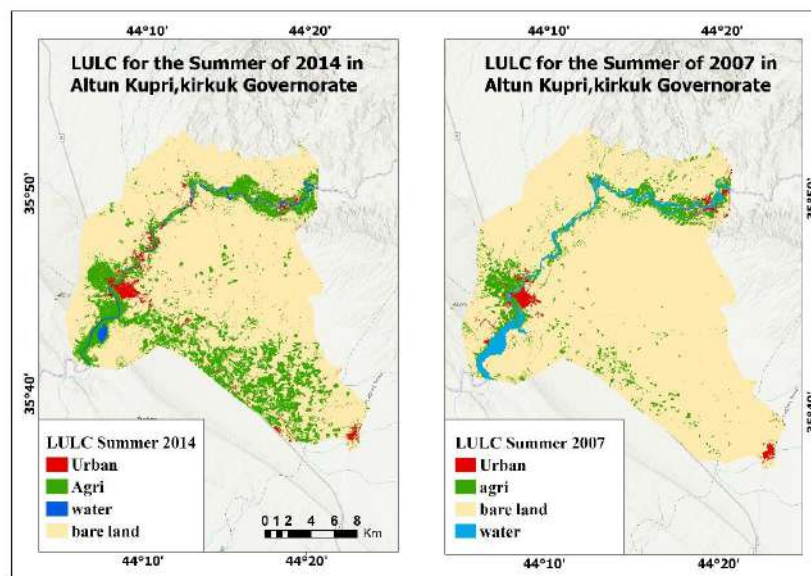
Summer Season

The LULC maps for the period ٢٠٠٧–٢٠١٤ show clear spatial changes reflecting increased human influence. Agricultural land more than doubled from ٤٢ km² in ٢٠٠٧ to approximately ٩٨ km² (٢٠,٤%) in ٢٠١٤, driven by expansion along river corridors and in the southern and central portions of the study area. Bare land

declined from ٤٢٤ km² to approximately ٣٦٠ km² (٧٤,٨%). Urban areas continued gradual expansion from ١٠ km² to ١٨ km² (٣,٧%), while water bodies remained stable at ٥ km².

Table (٥): LULC Classification Results — Summer ٢٠١٤

LULC Class	Area (km ²)	% of Total
Bare Land	٣٦٠	٧٤,٨%
Agricultural Land	٩٨	٢٠,٤%
Urban/Built-up	١٨	٣,٧%
Water Bodies	٥	١,٠%
Total	٤٨١	١٠٠%



Map (٤): LULC Maps — Years ٢٠٠٧ & ٢٠١٤ (Summer)

Landsat ٨ OLI, ArcGIS Pro ٣,٠

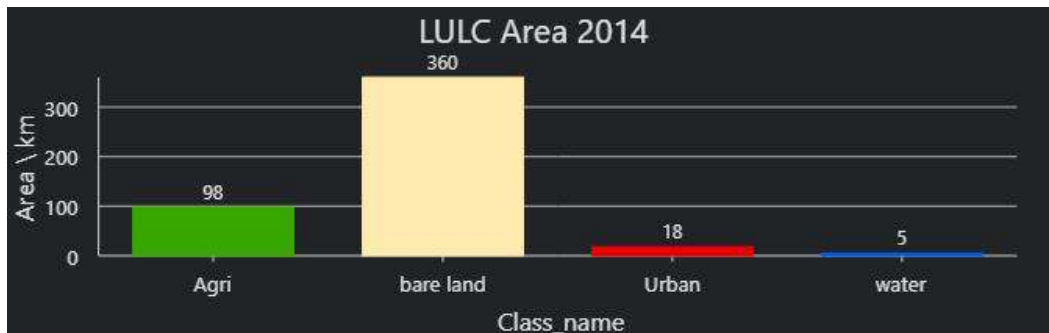


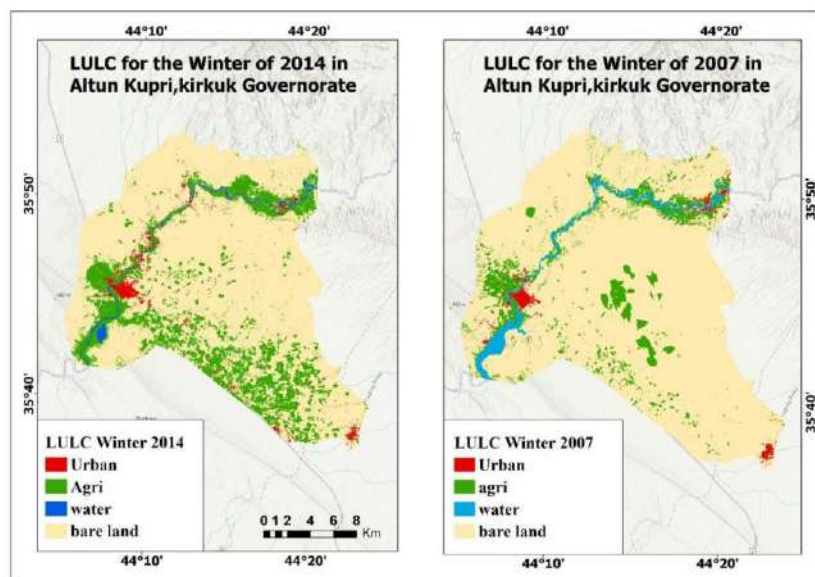
Figure (٥): LULC Area Chart — Summer ٢٠١٤

Winter Season

The winter season of ٢٠١٤ recorded the highest agricultural land values to that point in the study period, reaching ١١٤ km² (٢٣,٧%) considerably higher than the summer value of ٩٨ km², confirming the dominant role of winter cereal cultivation. Bare land decreased further to ٣٤٣ km² (٧١,٣%). Urban/built-up areas and water bodies maintained their summer values at ١٨ km² and ٥ km² respectively.

Table (٦): LULC Classification Results — Winter ٢٠١٤

LULC Class	Area (km ²)	% of Total
Bare Land	٣٤٣	٧١,٣%
Agricultural Land	١١٤	٢٣,٧%
Urban/Built-up	١٨	٣,٧%
Water Bodies	٥	١,٠%
Total	٤٨١	١٠٠%



Map (٥): LULC Maps — Years ٢٠٠٧ & ٢٠١٤ (Winter)

Landsat ٨ OLI, ArcGIS Pro ٣,٠

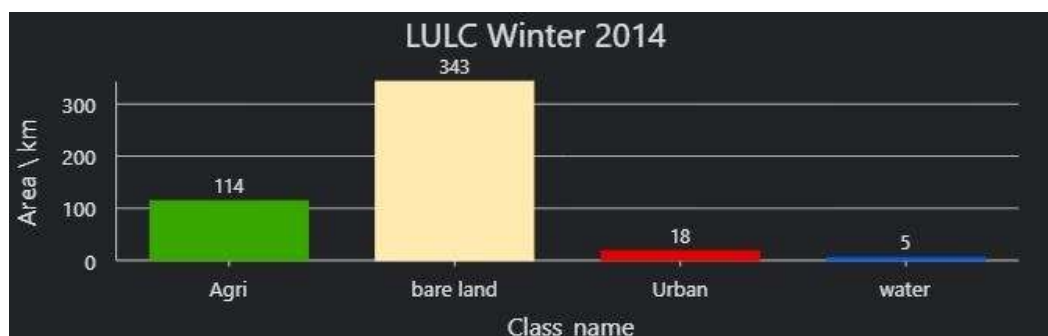


Figure (٦): LULC Area Chart — Winter ٢٠١٤

In general, the comparison between ٢٠٠٧ and ٢٠١٤ shows that the primary changes consisted of a major expansion in agricultural land and gradual growth in urban areas, against a notable decline in bare land, with water bodies remaining stable. These results reflect growing human pressure on land resources.

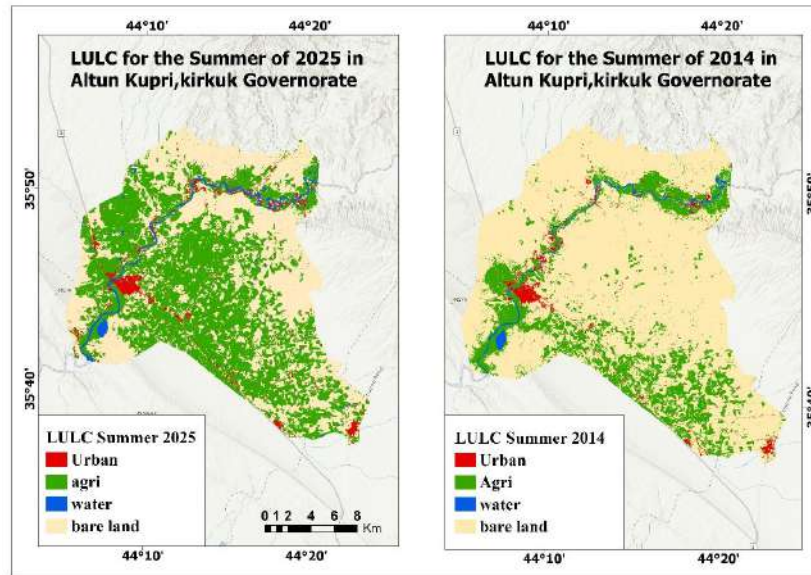
3.4 Land Use / Land Cover — Year 2020

Summer Season

In the year 2020, and for the **first time** in the recorded history of the study area, Agricultural Land surpassed Bare Land to become the spatially dominant LULC class representing a fundamental structural shift in land use patterns over the 20-year study period. Agricultural land reached approximately **243 km² (50.5%)** of the total study area, reflecting the region's increasing dependence on agricultural activity and the reclamation of vast areas previously classified as bare land. Bare land decreased to **218 km² (45.3%)**. Urban/built-up areas recorded **16 km² (3.3%)**, concentrated around the Altun Kupri urban core and along primary road corridors. Water bodies covered only **4 km² (0.8%)**, reflecting relative stability in surface water resources.

Table (V): LULC Classification Results — Summer 2020

LULC Class	Area (km²)	% of Total
Agricultural Land	243	50.5%
Bare Land	218	45.3%
Urban/Built-up	16	3.3%
Water Bodies	4	0.8%
Total	481	100%



Map (٥): LULC Maps — Years ٢٠١٤ & ٢٠٢٥ (Summer)

Landsat ٨ OLI, ArcGIS Pro ٣,٠



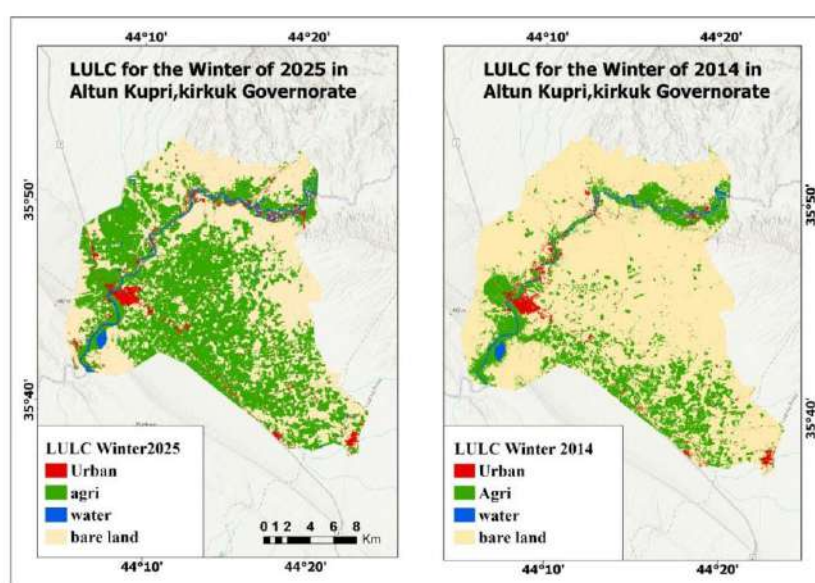
Figure (٧): LULC Area Chart — Summer ٢٠٢٥

Winter Season

The winter season of ٢٠٢٥ further reinforced agricultural land dominance, recording the highest value across the entire study period at ٢٤٧ km² (٥١,٤%). Bare land continued its decline to ٢١٤ km² (٤٤,٥%). Urban/built-up areas and water bodies remained stable at ١٦ km² and ٤ km² respectively.

Table (٨): LULC Classification Results — Winter ٢٠٢٥

LULC Class	Area (km ²)	% of Total
Agricultural Land	٢٤٧	٥١,٤٪
Bare Land	٢١٤	٤٤,٥٪
Urban/Built-up	١٦	٣,٣٪
Water Bodies	٤	٠,٨٪
Total	٤٨١	١٠٠٪



Map (٦): LULC Maps — Years ٢٠١٤ & ٢٠٢٥ (Winter)

Landsat ٨ OLI, ArcGIS Pro ٣,٠



Figure (٨): LULC Area Chart — Winter ٢٠٢٥

Compared to 2014, the period 2014–2020 witnessed an extraordinary agricultural expansion exceeding 148% (from 98 km² to 243 km² in summer), accompanied by a dramatic decline in bare land from 360 km² to 218 km² in summer, and from 343 km² to 214 km² in winter.

3.0 Temporal Change Analysis (2000–2020)

Table (9): LULC Change Summary — All Study Years (Summer & Winter)

LULC Class	Sum. 2000	Win. 2000	Sum. 2007	Win. 2007	Sum. 2014	Win. 2014	Sum. 2020	Win. 2020
Agricultural Land	24	28	42	48	98	114	243	247
Bare Land	400	446	424	418	360	343	218	214
Urban/Built-up	1	1	10	10	18	18	16	16
Water Bodies	0	0	0	0	0	0	4	4

The 20-year temporal analysis reveals a clear and consistent trend of bare land decline (−232 km², −51.6%) offset by an extraordinary increase in agricultural land (+219 km², +912.5%). Urban/built-up areas grew from 1 km² to 16 km² (+1,500%), while water bodies maintained near-complete stability throughout the study period.

A consistent seasonal pattern was also observed across all years: winter agricultural values always exceeded summer values by 4–16 km², attributed to the prevalence of rainfed winter cereal cultivation (wheat and barley) which is not detectable in summer imagery.

3.6 Summary of LULC Changes (2000–2020)

The results presented in sections 3.1–3.5 collectively document a profound and accelerating transformation in the land use structure of Altun Kupri Sub-district over the 20-year study period. The most significant finding is the transition from bare land dominance (93.5% in 2000) to agricultural land dominance (50.5% in summer 2020 and 51.4% in winter 2020) a historic structural shift that occurred for the first time in the recorded history of the study area.

Across all study years, a consistent seasonal pattern was observed, with winter agricultural extent systematically exceeding summer values by 4–16 km², reflecting the contribution of rain-fed winter cereal cultivation that is not captured by summer-only analyses.

The key quantitative changes recorded over the study period are summarized in Table (10) below:

Table (10): Net LULC Change Summary — Summer Season (2000–2020)

LULC Class	2000 (km ²)	2020 (km ²)	Net Change (km ²)	% Change
Agricultural Land	24	243	+219	+912%
Bare Land	400	218	-232	-51.6%
Urban/Built-up	1	16	+15	+1,500%
Water Bodies	0	4	-1	-20%

Chapter Four

Discussion & Conclusions

٤,١ Discussion

٤,١,١ Bare Land Decline

Bare land was dominant at ٩٣,٥% in ٢٠٠٠, declining continuously to ٤٥,٣% by ٢٠٢٥ a loss of ٢٣٢ km². The steepest decline occurred during ٢٠١٤–٢٠٢٥ (–١٤٢ km² in summer), signaling an acceleration in land conversion during this decade. This is consistent with regional studies: Ibrahim & Azeez (٢٠٢٤) found a ٦٦% decrease in transformation/bare zones across Shwan–Altun Kopre over ٢٦ years, and Jasim (٢٠٢٤) documented a ٢٧,٣% bare land decrease in Kirkuk City from ٢٠١٤–٢٠٢٢.

٤,١,٢ Agricultural Expansion: The Dominant Driver

The ٩١٢% **increase** in summer agricultural land area (٢٤ → ٢٤٣ km²) is the defining LULC dynamic of the study period. This reflects:

١. **Irrigation infrastructure expansion** canals and pumping stations extending Lesser Zab water across previously uncultivated areas
٢. **Post-conflict agricultural recovery** (٢٠٠٣–٢٠١٤) land reclamation following decades of neglect
٣. **Population growth and food demand** growing local and regional population increasing agricultural incentives
٤. **Government agricultural support programs** Iraqi federal and Kurdistan Region policies promoting agricultural intensification
٥. **Rain-fed winter cultivation expansion** winter seasonal surplus grew from +٤ km² (٢٠٠٠) to +١٦ km² (٢٠١٤), confirming expansion of dryland cereal farming^{[٤][٥]}

٤,١,٣ Urban Growth: Tenfold Expansion

Urban areas expanded from ١ **km²** (٢٠٠٠) to a peak of ١٨ **km²** (٢٠١٤) a ١,٧٠٠% **growth** concentrated around the Altun Kupri town core and primary road axes. The slight regression to ١٦ **km²** in ٢٠٢٠ may reflect reclassification of peri-urban transitional zones to agricultural use. This trajectory aligns with Ibrahim & Azeez (٢٠٢٤) who found ٣١٣% built-up growth in the overlapping study area.

٤,١,٤ The ٢٠٢٠ Historic Threshold

The year ٢٠٢٠ marks a structural shift in the land use system: agricultural land exceeding bare land for the **first time** in the recorded history of the study area.

Implications:

- **Water stress:** A ١٠-fold increase in irrigated area places massive demand on Lesser Zab River flow particularly critical given upstream dam development in Kurdistan and Turkey
- **Soil degradation risk:** Rapid conversion of semi-natural land to intensive agriculture without adequate soil management risks erosion, salinization, and productivity decline
- **Biodiversity loss:** Conversion of ٢٣٢ **km²** of native semi-arid habitat eliminates refugia for endemic flora and fauna
- **Planning urgency:** Without spatial monitoring and management planning, current trends will lead to water resource exhaustion within decades

٤,١,٥ Seasonal Analysis Contribution

The dual-season framework reveals that rain-fed winter agriculture contributed an additional ٤–١٦ **km²** of agricultural activity beyond irrigated summer farming across all study years. Single-season (summer-only) analyses systematically underestimate agricultural activity in semi-arid northern Iraq by ٥–١٤%, representing a significant methodological improvement offered by this study.

4.2 Conclusions

1. Supervised Maximum Likelihood Classification of Landsat 8 TM and Landsat 9 OLI/TIRS imagery in ArcGIS Pro 3.0 proved highly effective for long-term LULC monitoring in Altun Kupri, consistent with validated approaches achieving **96.10% accuracy** in the Kirkuk region.
2. Agricultural expansion is the dominant land change trend from ~5% (2000) to ~51% (2020) representing a **912% increase** in absolute area and a landscape-defining structural transformation.
3. Bare land decreased by 52% across the study period, losing **232 km²** to agricultural and urban conversion.
4. Urban areas grew 1,500% from **1 km²** to **16 km²**, concentrated around the existing urban core and primary transport corridors.
5. Water bodies declined marginally from **5 km²** (2000–2014) to **4 km²** (2020), indicating no major hydrological shifts but warrants continued monitoring.
6. Winter imagery reveals **4–16 km²** greater agricultural extent than summer, confirming the presence and expansion of rain-fed winter cereal cultivation as a complementary component of the local agricultural system a finding unavailable to single-season studies.
7. The **2014–2020 period** is the most intense decade of LULC transformation, with agricultural land expanding by **145 km²** in summer and **133 km²** in winter more than all prior periods combined.

Sustainable land management strategies are urgently needed to balance continued agricultural intensification with water resource conservation, soil preservation, urban planning, and ecological sustainability in the region.

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SITE CALIBRATION USING TOTAL STATION AND GNSS TECHNIQUES

**A Graduation Project Submitted to the Department of Surveying
Engineering, Faculty of Engineering, Al-Kitab University, in Partial
Fulfillment of the Requirements for the Degree of Bachelor in
Surveying Engineering.**

By

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JUNE 2026

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ABSTRACT

This graduation project investigates the integration of Global Navigation Satellite System (GNSS) techniques with traditional Total Station surveying for high-precision engineering applications. The primary objective is to determine the optimal transformation parameters required to integrate global GNSS coordinates (WGS84) with local ground-based measurements. The study area selected for this research is Al-Kitab University campus, where fieldwork was conducted using a rigorous two-phase methodology involving high-precision GNSS receivers and an Electronic Total Station.

A critical component of the study involved an intensive 4.5-hour static GNSS observation session to establish a robust base reference, followed by automated online post-processing using Precise Point Positioning (PPP) services to achieve sub-centimeter absolute accuracy. The research also addresses significant technical and environmental challenges, such as high wind speeds and signal interference from military aircraft, by implementing specialized field stabilization and data verification protocols.

By applying the mathematical Helmert 7-parameter transformation model, the project successfully bridges the discrepancy between grid and ground coordinates, ensuring millimeter-level relative accuracy. The final results demonstrate that localized site calibration is not only a theoretical requirement but a practical necessity for maintaining geodetic integrity in complex engineering works and infrastructure layouts.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to everyone who supported and advised me throughout this graduation project. First and foremost, I am immensely grateful to my supervisor, M.Sc. AZHAR ABED HAMEED, for his invaluable guidance, continuous support, and patience which led to the successful completion of this study.

My sincere thanks also go to the faculty and staff of the Department of Surveying Engineering at Al-Kitab University for providing the necessary knowledge and technical assistance during the field data collection.

Last but not least, I would like to extend my heartfelt gratitude to my family and my colleagues for their constant encouragement, support, and motivation throughout my academic journey.

APPROVAL SHEET

This project report entitled "SITE CALIBRATION USING TOTAL STATION AND GNSS TECHNIQUE" submitted by MUSTAFA KAMAL ALI, AQEEL HASHIM ZAIN AL-ABIDIN, and IVAN MOHAMMED JASSIM in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Surveying Engineering is hereby accepted.

Approved by,

_____ Date:

Supervisor

M.Sc. AZHAR ABED HAMEED, S. Eng.

Department of Surveying Engineering

University of AL-KITAB

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Chapter One

Introduction

1.1: Introduction

The science of surveying and mapping has undergone a revolutionary transformation over the past few decades. Traditionally, surveying relied heavily on terrestrial instruments like theodolites and levels. However, the introduction of Global Navigation Satellite Systems (GNSS), such as GPS, GLONASS, and Galileo, has redefined the accuracy and efficiency of spatial data collection. In modern engineering, the ability to obtain high-precision coordinates in a global reference frame is essential for large-scale infrastructure projects. Despite these advancements, a significant challenge remains: the mathematical difference between the curved surface of the Earth (the ellipsoid) and the local flat plane used for construction (Sjöberg, 2012). This study focuses on "Site Calibration," which is the critical link required to harmonize these two distinct surveying worlds. His study deals with evaluation and comparison of precision, accuracy, and time expenditure of two surveying instruments and methods followed for each instrument. These instruments are Total Station (TS), Global positioning system (GPS), and currently called Global Navigation Satellite System (GNSS) (Chekole, S. D. (2014). Later the surveyed points measured and corrected by the above two methods were placed on geo referenced satellite images, also the scanned images using GIS pro and civil3d software for the purpose of comparison. Accuracy and precision for those in the surveying profession as well as other technical and scientific fields are defined in different ways; accuracy refers to how closely a measurement or observation comes to measure a true or established value, since measurements and observations are always subject to errors. Precision refers to how closely repeated measurements or observations

come to duplicate the measured or observed values. Accuracy of surveying techniques using devices such as GNSS, TS, and other means of surveying are dependent on a number of parameters that limit their measurement quality. For instance: multipath, the inherent satellite signal accuracy, signal transmission delay, receiver hardware and software limitations, satellite signal obstruction are some of the problems associated with GNSS measurement. On the other hand, limitations stemming from TS are computed coordinates in local or target coordinate system, the reference surface for measuring height is geoids. Because of earth's curvature, the accuracy of TS measurement can also be affected by distance limit (the accuracy will decrease when increasing the distance). (Hussein, S. K., & Abdulla, K. Y. (2021))

1.2: Problem Statement

The main challenge in modern engineering surveys is the mathematical and spatial discrepancy between "Grid" coordinates obtained from Global Navigation Satellite Systems (GNSS) and "Ground" coordinates measured by traditional terrestrial equipment like Total Stations. GNSS measurements are based on a curved, global ellipsoidal datum (WGS84), whereas local engineering layouts and construction designs require a flat, localized ground plane to preserve true distances and angles. If a rigorous site calibration is not performed to calculate the precise transformation parameters, scale factor distortions and Earth's curvature errors can compromise the geodetic integrity of the project. This research addresses this limitation by developing a localized coordinate transformation framework at the Al-Kitab University campus.

1.3: Objectives of the study

The specific objectives of this research are:

1. To establish a geodetic control network at Al-Kitab University.
2. To collect spatial data using both GNSS and Total Station.
3. To compute transformation parameters using the Helmert model.
4. To ensure millimeter-level accuracy for local engineering works.

1.4: Research questions

This thesis comprehensively addresses the following research questions:

- How significant is the difference between GNSS grid coordinates and Total Station ground measurements at Al-Kitab University?
- What are the specific Helmert transformation parameters (Translation, Rotation, and Scale) required for this site?
- To what extent do environmental conditions like wind and signal interference impact the precision of the calibration process?

Chapter Two

Literature Review

This chapter provides a comprehensive review of the theoretical foundations and academic literature regarding coordinate transformation models, satellite positioning systems, and terrestrial surveying instruments. It establishes the scientific framework required to understand the grid-to-ground calibration executed in this study.

2.1: Introduction

The theoretical foundation of coordinate transformation and site calibration is built upon decades of geodetic research. Key academic works (Wolf and Ghilani, 2012) provide the mathematical basis for the Helmert transformation model used in this study. Additionally, the integration of satellite systems with terrestrial engineering is extensively discussed in literature (Hofmann-Wellenhof et al., 2008), which defined the standards for GNSS global datums. Furthermore, the practical challenges of "Grid vs. Ground" discrepancies and scale factor distortions have been critically analyzed in several studies (Van Sickle, 2015) and (Kavanagh, 2013). This chapter reviews these fundamental theories to establish a solid framework for the site calibration executed at Al-Kitab University.

The TS instrument combines all the aspects of advanced electronic theodolites with coaxial EDM. Horizontal and Vertical angles are obtained in the range of 1 to 10 second, depending on the model of the instrument. Distance accuracies are in the range of $(5\text{mm} \pm 5 \text{ to } 10\text{ppm})$ to $(2\text{mm} \pm 1\text{ppm})$. Furthermore, TSs are equipped with microprocessors and has built-in programs and software to watch instrument status, control advanced functions, monitor the operation of the instrument, recalibrate as

needed, and facilitate a wide variety of available software applications programs Dawod, G., & Alnaggar, D. (2000).

Bisnath and Gao (2009) affirmed that PPP technique uses single receiver to obtain position on both static and kinematic mode for the purpose of mapping. It makes use of precise orbit and clock offsets to process satellite data that were acquired. PPP technique produces centimeter level results when used in static mode and decimeter level results when used in kinematic mode. Researchers (Deo & El-Mowafy, 2020; Shevchuk et al., 2020) agreed also that, PPP technique measures in both pseudo range and carrier phase measurements using single GNSS receiver. PPP technique offers an accuracy of decimeters with at least triple frequency GNSS data observed that, PPP technique is based on the determination of high-precision coordinates using one GNSS Receiver and data such as precise orbital parameters and corrections. They stated that PPP method provides root mean square of centimetre level in static, and decimetre in kinematic mode. Kalinnikov et al., (2018) observed that, PPP technique could be used for environmental monitoring and meteorological services. It could be used for estimation of vapour and water density in the atmosphere. They observed that the technique gives the position of a point anywhere on the globe, with high accuracy. It can measure base lines for high accuracy and also controls points without any line-of-sight requirement. PPP provides very accurate positioning by using only a single receiver's data in combination with precise satellite orbit and clock data products provided by different sources like IGS and NRCAN. The usage of the PPP technique has several advantages apart from high-accuracy, it is cost-effective since it uses just single receiver. The PPP technique is commonly used in surveying, agricultural sector and in crustal deformation monitoring. With PPP technique, geodetic positions could be obtained within the range of centimetres accuracy in static mode and decimetre

accuracy in kinematic mode (Trigubovich, Shevchuk, Kosarev & Nikitin, 2017). Zeiske (2004), as well as Beshr, and Elnaga (2011) explained that Total Stations (TS), an electronic theodolite interfaced with electronic distance meter (EDM), works on the principle of signal-reflection line-of-sight and there must a Total Station and Prism reflector in TS observations. The Total station measures slope distances, horizontal and vertical angles in topographic and geodetic tasks. In TS surveys, results are recorded into an inbuilt memory and transferred to a computer through USB cable interface. Singh (2013) described, also, that the TS measures angles and distances and even coordinates whenever the TS is used in coordinate mode. The coordinates are in the form of northing, easting, and heights of surveyed points relative to the total station position. TS can be used by archaeologists to record excavations as well as by police, crime scene investigators, private accident investigators and insurance companies to take measurements of scenes for analysis (Chekole, 2014). The TS provides the highest possible degree of accuracy for site positioning, stakeout, grade checking and measurement. However, TS has limited range than a GNSS-based system that is why it is better suited for projects where accuracy is a fundamental factor. TS are ideal for sites where the accuracy requirements are very tight: ± 3 millimetres. However, GPS cannot be used in area with lot of trees, High rise buildings because of satellite signal interference (Ghilani & Wolf, 2010). Singh, (2013) inferred that, despite the limitations that the TS has, it can still be used in the detecting of errors among GNSS-PPP observations. TS is best used indoors, around buildings and locations with limited or zero satellite signal visibility. The TS does not make use of GPS signals but rather of EDM technology for coordinates, angles, distances, and height measurements (Singh, 2013).

Chapter Three

Methodology

3.1: Introduction

The primary goal of the methodology is to establish a rigorous framework for site calibration. This involves capturing high-precision spatial data using two different surveying technologies: GNSS for global positioning and Electronic Total Station for local terrestrial measurements. The integration of these datasets requires precise field execution and careful consideration of environmental factors.

3.2: Overall methodology

This methodology outlines a structured approach for establishing accurate control points and ensuring reliable spatial data for surveying or mapping projects. It integrates both GNSS (Global Navigation Satellite Systems) techniques and Total Station measurements, combining their strengths to achieve high positional accuracy. The workflow begins with planning and proceeds through data acquisition, processing, calibration, and final accuracy assessment.

At the planning stage, the main objective is to define the project requirements, coordinate systems, accuracy standards, and equipment to be used. The surveyor identifies the project area, selects suitable control points (CPs), and decides whether GNSS, Total Station, or a combination of both will be used. Factors such as terrain, satellite visibility, required precision, and project scale influence these decisions. Proper planning minimizes errors, reduces field time, and ensures that all collected data will meet the desired specifications.

The workflow then splits into two parallel paths: GNSS surveying and Total Station surveying. In the GNSS branch, the process starts with static observations. Static GNSS surveying involves placing receivers on known or unknown points for a specific duration to collect satellite signals. This method is highly accurate and is typically used for establishing primary control points. The collected raw data is not immediately usable; it must go through post-processing. During post-processing, GNSS data is corrected using reference stations or base station data to remove errors caused by atmospheric conditions, satellite geometry, and clock inaccuracies. The result is a set of highly precise coordinates. After post-processing, the workflow transitions to RTK (Real-Time Kinematic) surveying. RTK provides real-time corrections, allowing surveyors to determine point positions instantly in the field with centimeter-level accuracy. RTK is faster than static surveying and is commonly used for densifying control points or collecting topographic data. In this methodology, RTK acts as a bridge between high-accuracy static control and practical field application.

In parallel, the Total Station branch focuses on establishing local control points (CPs). The Total Station measures point relative to known references, creating a local coordinate system. These local CPs are often very precise in relative terms but may not initially align with global coordinate systems like UTM.

The next critical step is Site Calibration, where both GNSS-derived coordinates and Total Station measurements are integrated. Site calibration is the process of transforming coordinates from one system (usually local) into another (such as UTM). This is done by using common points measured by both GNSS and Total Station. Through mathematical transformation (such as Helmert transformation), differences in scale, rotation, and translation are corrected. The goal is to ensure that all data—whether collected by GNSS or Total Station—fits into a unified coordinate system.

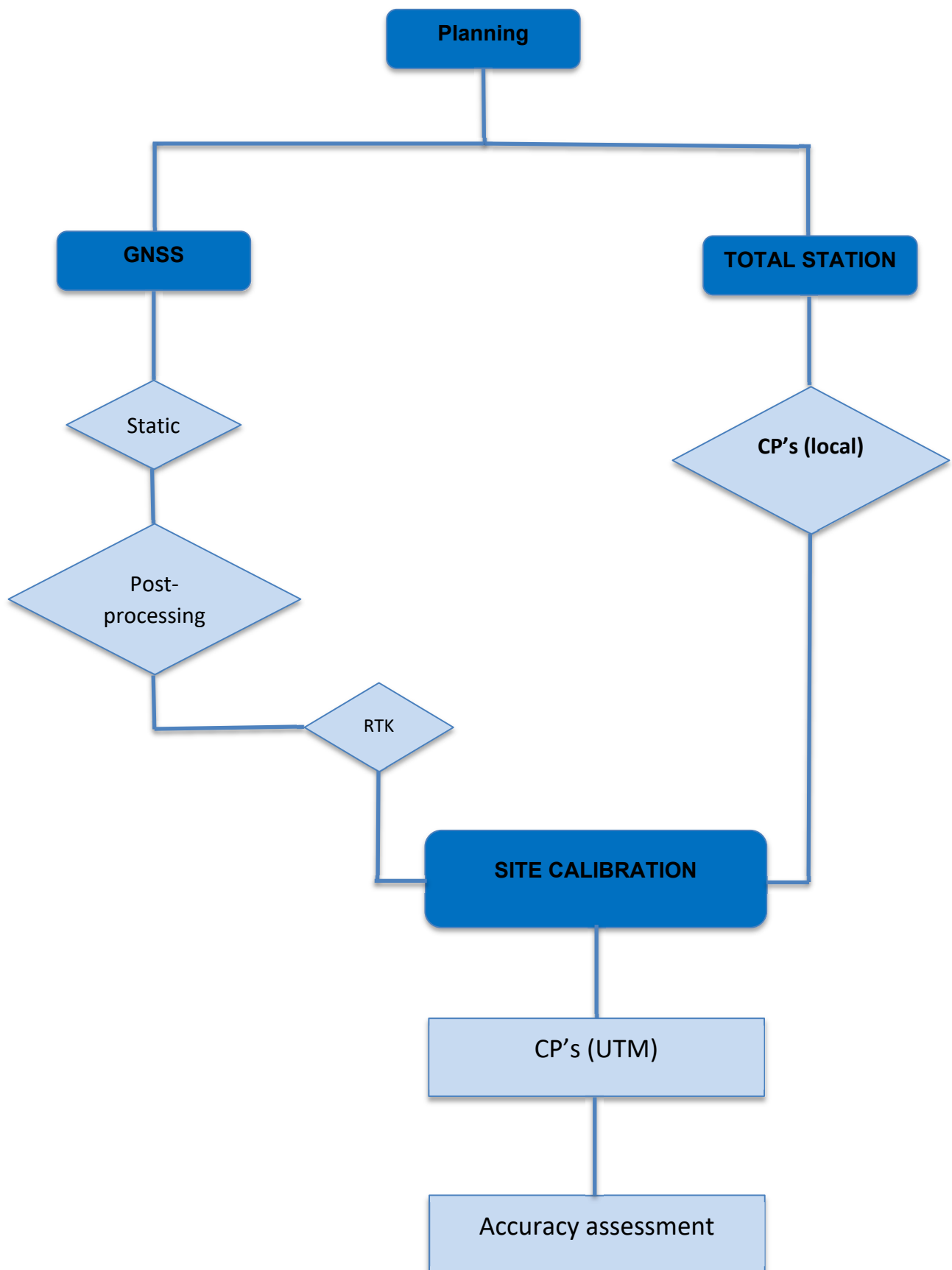


Figure 3.1: The overall methodology.



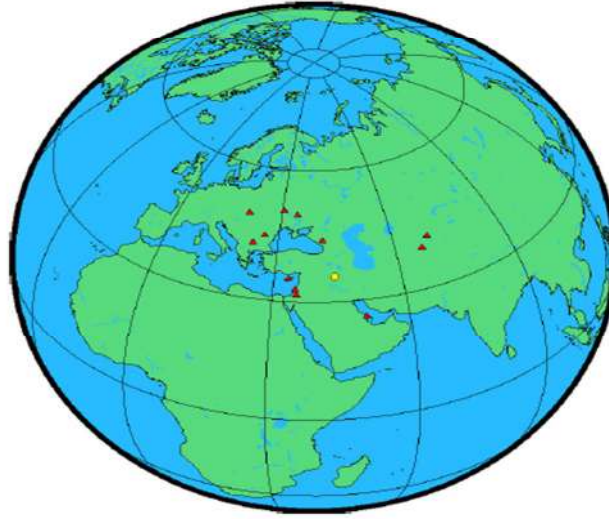
Figure 3.2: site works using total station and GNSS

1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

Station (s)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Time
R000	_kcp0491.26o	HITRTK5 NONE	1.704	2026/02/18 06:56:00	2026/02/18 11:22:30

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2026/02/18 06:56:00	R000	BHR3 BSHM BUCU DRAG GANP GLSV KIT3 NICO POLV SOFI TASH ZECK	IGS final

3.3 UTM Grid, GRS80 Ellipsoid, ITRF2020

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)	Derived Above Geoid Height (m)
R000	424396.674	3957661.506	38	301.652	293.218
BHR3	460854.291	2898904.998	39	-13.890	13.680
BSHM	689465.344	3628597.386	36	225.066	204.222
BUCU	430455.977	4923776.190	35	143.228	107.680
DRAG	726966.147	3497829.925	36	31.876	13.622
GANP	450512.819	5431535.797	34	746.038	703.998
GLSV	321967.948	5582119.688	36	226.316	200.774
KIT3	317236.917	4333861.173	42	622.477	659.574
NICO	536114.682	3888750.341	36	190.017	161.950
POLV	611484.398	5495592.593	36	178.356	159.775
SOFI	696595.419	4714301.468	34	1119.514	1074.437
TASH	524734.502	4575216.882	42	439.704	483.274
ZECK	706384.947	4851568.773	37	1166.298	1143.398

3.4 Positional Uncertainty (95% C.L.) - Geodetic, ITRF2020

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
R000	0.008	0.007	0.026
BHR3	0.008	0.006	0.019
BSHM	0.006	0.005	0.012
BUCU	0.006	0.005	0.011
DRAG	0.006	0.005	0.012
GANP	0.007	0.007	0.017
GLSV	0.006	0.006	0.012
KIT3	0.009	0.005	0.013
NICO	0.006	0.005	0.011
POLV	0.010	0.009	0.026
SOFI	0.007	0.006	0.012
TASH	0.011	0.006	0.021
ZECK	0.006	0.005	0.012

Figure 3.3: static post-processing report



Figure 3.4: Mini Prism Setup over Established Control Point CP4



Figure 3.5: Monitoring GNSS Signal Interference and Degradation Caused by Military Aircraft During Field Measurements

3.3: The study area description

The project was executed within the campus of Al-Kitab University. The site was selected because it represents a typical engineering environment characterized by diverse topography, expanding infrastructure, and modern concrete structures that present real-world challenges such as satellite signal multipath and obstructions. These conditions make localization and site calibration absolute necessities for accurate future construction layouts and civil engineering works to align satellite data with local terrestrial grids. **To provide a solid geometric base, six primary control points were established across the campus. These points were strategically chosen to surround the project area, forming a "convex hull" configuration that effectively covers the site boundaries and prevents extrapolation errors during the mathematical coordinate transformation process.**



Figure 3.6: The study area map

3.4: The data collection

The data collection stage in this methodology is a critical phase where all field measurements are acquired using GNSS and Total Station techniques. The quality of this stage directly affects the accuracy of site calibration and the final survey results, so it must be carried out systematically and under proper field procedures.

For the GNSS data collection, the process typically begins with static observations on selected control points. These points are chosen during the planning stage to ensure good satellite visibility, stability, and distribute across the project area. The GNSS receiver (base or rover in static mode) is set up over the point tripod and ensuring centering and leveling.

During static observations, the receiver collects satellite signals for a specific duration, which depends on the required accuracy and baseline length. For high-accuracy control, observation times may range from 20 minutes to several hours. It is important to ensure that enough satellites are tracked (12 or more) with good geometry (low PDOP values) to achieve reliable results. Environmental factors such as multipath.

After completing static observations, additional points may be collected using RTK (Real-Time Kinematic). In RTK mode, one receiver acts as a base station (either local or connected to a CORS network), while the rover moves between points. The rover receives real-time corrections, allowing it to determine coordinates instantly. Before collecting RTK points, the surveyor must ensure that the solution status is FIXED, not FLOAT, to guarantee centimeter-level accuracy. Each point is usually observed for a few seconds (epochs), and multiple readings may be taken to confirm consistency.

Parallel to GNSS work, Total Station data collection is performed to establish local control points (CPs)



Figure 3.7.1: collecting data using static



Figure 3.7.2: collecting data using RTK

PT NO	N	E	Z	D
1	1000	1000	100	cp1
2	947.66	926.43	99.199	cp2
3	1040.3	926.57	99.243	cp3
4	1001.2	853.65	98.975	cp4
5	900.41	836.08	99.34	cp5

Table 3.1: collected coordinates using total station

PT NO	N	E	Z	D
1	3957661.506	424396.674	301.652	R000 static
2	3957619.517	424409.2264	302.0476	cacp1
3	3957560.634	424340.7739	301.1261	cacp2
5	3957607.217	424263.3699	300.8999	cacp4
6	3957505.277	424255.1508	301.2473	cacp5

Table 3.2: collected coordinates using GNSS

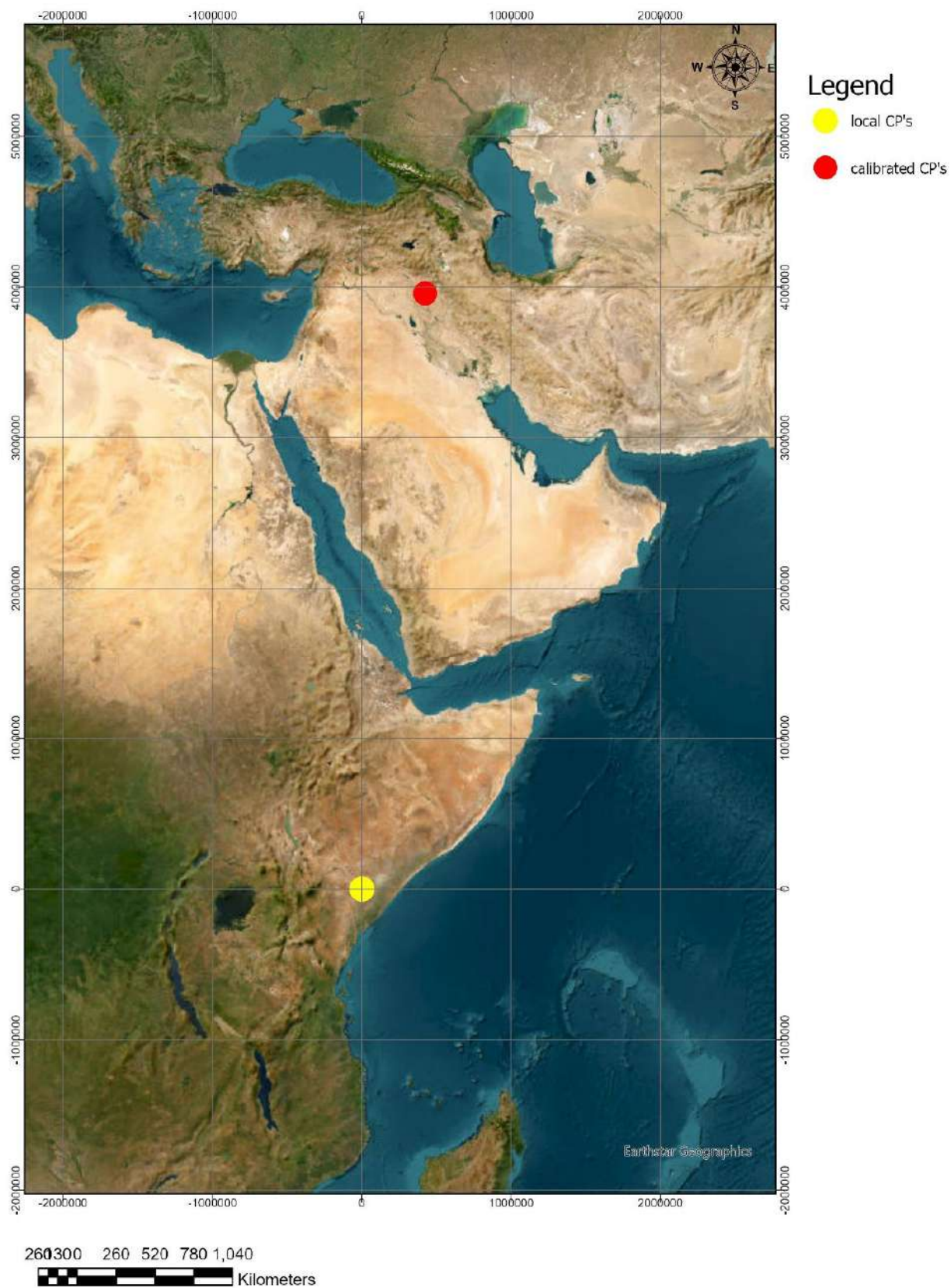
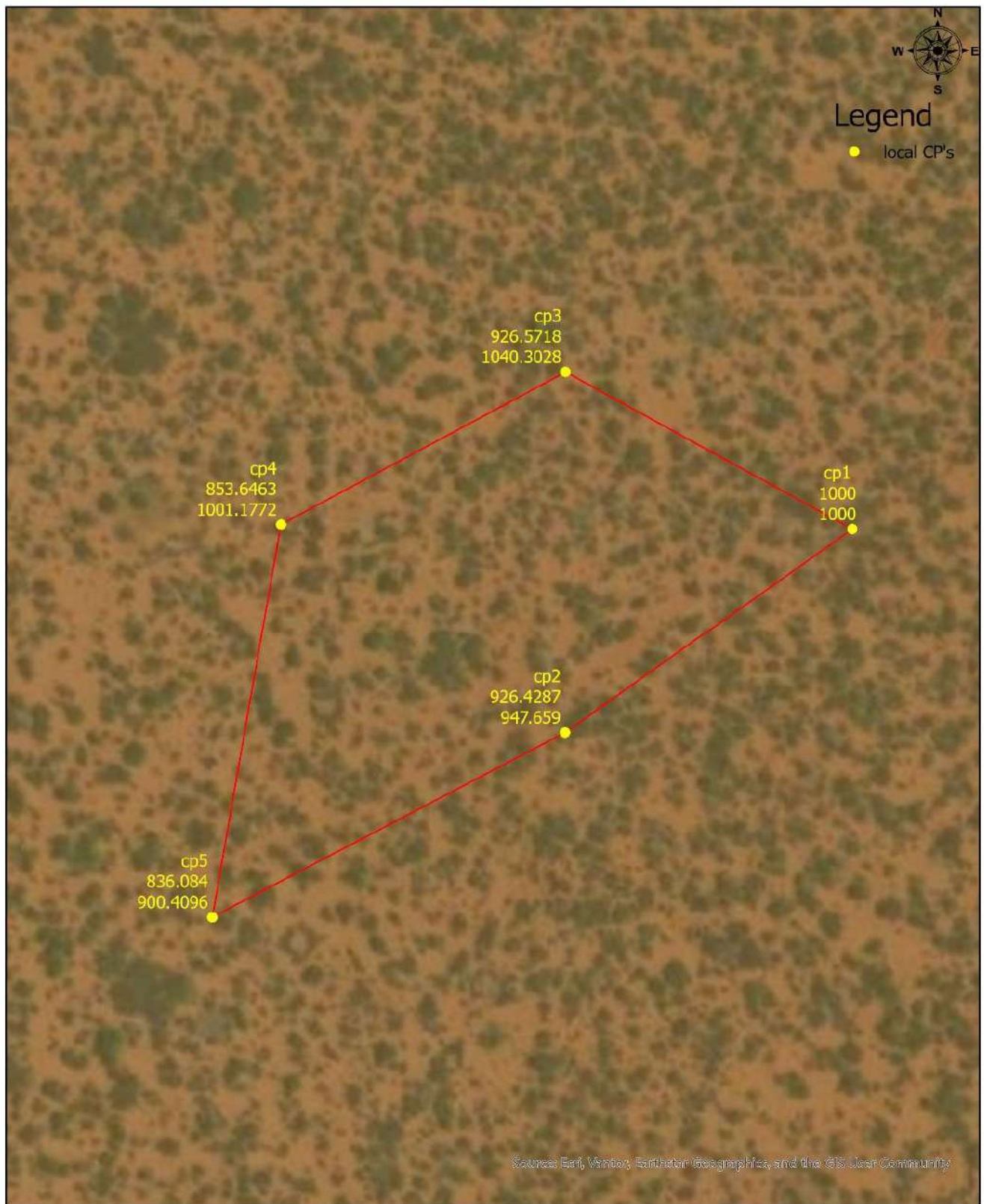


Figure 3.8: map of both local and GNSS control points



0.01010 0.01 0.02 0.03 0.04

Figure 3.9: map of the local control points



0.000 0.0002.03.04
 Kilometers

Figure 3.10: map of GNSS control points

Chapter Four

Results and Discussions

4.1: Introduction

This chapter presents and discusses the results and findings obtained from this research which include the numerical findings and the mathematical outcomes of the site calibration process performed at Al-Kitab University. The results are based on the integration of terrestrial Total Station measurements and high-precision GNSS observations. This section details the coordinate transformation results, the derived Helmert parameters, and a comprehensive analysis of the accuracy achieved.

The results were carefully presented, evaluated and discussed in details in each sub-heading as follows:

4.2: conversion from local to UTM and parameters calculation

The primary dataset consists of coordinates for the four established control points captured during the 4.5-hour observation session. The raw GNSS data were refined using automated PPP post-processing services to ensure sub-centimeter absolute accuracy before the calibration. The parameters calculation report presents the outcome of the coordinate transformation process, where a set of known reference coordinates (source coordinates) is compared with the computed local coordinates obtained after applying a localization or transformation model. This process is essential in surveying and geospatial

projects to ensure that field measurements are accurately aligned with the project's coordinate system.

The table includes several key parameters: source Northing (N), Easting (E), and Height (H), alongside the corresponding local Northing, Easting, and elevation (Z). The final column, horizontal residual, represents the positional difference between the transformed local coordinates and the original source coordinates in the horizontal plane. This value is critical for evaluating the accuracy and reliability of the transformation.

From the results, four control points (cap1, cap2, cap4, and cap5) were used in the computation. Each point shows a small horizontal residual, indicating a strong agreement between the known and computed positions. Specifically, the residual values are 0.0057 m for cap1, 0.0046 m for cap2, 0.0125 m for cap4, and 0.0078 m for cap5. These values correspond to approximately 5.7 mm, 4.6 mm, 12.5 mm, and 7.8 mm respectively.

The magnitude of these residuals demonstrates a high level of accuracy in the transformation process. In most engineering and surveying applications, horizontal errors within 1–2 cm are considered acceptable, while errors below 1 cm are regarded as excellent. In this case, three of the four points (cap1, cap2, and cap5) exhibit residuals below 1 cm, indicating excellent precision. The fourth point (cap4), although slightly higher, still remains within acceptable tolerance limits and does not indicate any significant issue.

The slight variation in residual values among the points can be attributed to several practical factors. These may include minor observational errors during GNSS data collection, environmental influences such as satellite geometry and signal obstruction, or slight inconsistencies in the physical positioning of the survey instrument. However, the absence of large residuals suggests that no gross errors or outliers are present in the dataset.

Another important observation is the consistency of the residual distribution. The values are relatively close to each other and do not show extreme deviations. This indicates that the transformation model has been correctly applied and that the control points are well distributed and reliable. A poorly distributed or inaccurate control network would typically result in larger and more inconsistent residuals.

The agreement between the source and local coordinates also confirms that the localization process successfully aligned the local survey system with the reference coordinate system. This alignment is crucial for ensuring that subsequent surveying tasks, such as stakeout, mapping, or construction layout, are performed accurately and without positional discrepancies.

Furthermore, the results suggest that the selected control points are suitable for defining the transformation parameters. In practice, it is important to use stable,

well-defined, and clearly identifiable control points to achieve high accuracy.

The low residuals observed here indicate that the chosen points meet these criteria and contribute positively to the overall solution.

NO	PT name	source N	sourceE	source H	local N	local E	local Z	horizontal residual
1	cacp1	3957619.517	424409.2264	302.0476	1000	1000	100	0.005717018
1	cacp2	3957560.634	424340.7739	301.1261	947.659	926.4287	99.1993	0.004597614
1	cacp4	3957607.217	424263.3699	300.8999	1001.1772	853.6463	98.9748	0.012523898
1	cacp5	3957505.277	424255.1508	301.2473	900.4096	836.084	99.3404	0.007796993

Table 4: parameters calculation report

Chapter Five

Conclusion and Recommendation

5.1: Conclusion

In conclusion, the parameters calculation and coordinate transformation results demonstrate that the localized site calibration process implemented at Al-Kitab University is highly accurate and reliable. All computed horizontal residuals successfully fall well within acceptable engineering tolerances, with three out of the four control points achieving excellent sub-centimeter relative accuracy (ranging from 4.6 mm to 7.8 mm). There are no indications of gross errors or systemic inconsistencies, confirming that the mathematical Helmert 7-parameter model effectively bridged the discrepancy between the GNSS ellipsoidal grid and terrestrial ground measurements. Therefore, the resulting transformation parameters can be confidently utilized for subsequent high-precision engineering applications, staking out, and infrastructure layouts across the campus.

5.2 Recommendations

Based on the field challenges and outcomes of this project, the following actions are highly recommended:

- **Protect Control Points:** Maintain and protect the physical locations of all established control points on campus to ensure future surveying accuracy.
- **Periodic Network Checking:** Perform regular geodetic monitoring of the control network to detect any positional shifts caused by ongoing construction works.
- **Improve GNSS Data Quality:** Ensure optimal satellite geometry (low PDOP) and longer static observation times to overcome environmental and airspace signal interference.
- **Archive Transformation Data:** Fully document and archive all calculated 7-parameter transformation matrices to serve as a geodetic reference baseline for future university projects.

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Ministry of Higher Education and Scientific Research

Al-Kitab University

College of Engineering

Department of Surveying Engineering



Land Leveling Using GIS Techniques

A Graduation Project Submitted to the Department of Engineering Survey as a Partial Fulfillment of the Requirements for the Degree of Bachelor of Science (B.Sc.) in Engineering Survey

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Asst. Lect. Sadan Azmi Mohammed

2025-2026 A.D.

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَأَنْ لَّيْسَ لِلْإِنْسَانِ إِلَّا مَا سَعَى



صدق الله العلي العظيم

Supervisor Certification

I CERTIFY THAT THE PREPARATION OF THIS PROJECT ENTITLED:

Land Leveling Using GIS Techniques

PREPARED BY:

- 1. Sufyan Khalaf Jassim**
- 2. Abdulwahab Mohammed Abdullah**

***Was made under my supervision at SURVEYING ENGINEERING
DEPARTMENT IN PARTIAL FULFILMENTS OF THE REQUIREMENTS
FOR THE DEGREE OF BACHELOR OF SCIENCE IN SURVEYING
ENGINEERING.***

SIGNATURE:

NAME OF SUPERVISOR: Sadan Azmi Mohammed

DATE:

Dedication

We dedicate this work to our families, who have been our constant source of support and encouragement throughout our academic journey.

We also dedicate this work to our supervisor, **Assistant Lecturer Sadan Azmi Mohammed**, in appreciation of his guidance and support in completing this research.

Acknowledgment

We would like to express our sincere gratitude to our supervisor, Assistant Lecturer **Sadan Azmi Mohammed**, for his continuous support, valuable guidance, and constructive feedback throughout the completion of this research.

We also extend our appreciation to the Department of Surveying Engineering at Al-Kitab University for providing the academic environment and resources necessary for this study.

Our thanks are also directed to everyone who contributed, directly or indirectly, to the successful completion of this work.

Researchers

ABSTRACT

Land leveling is a critical process in agricultural and engineering applications, aimed at creating a uniform surface to improve irrigation efficiency, reduce soil erosion, and support construction planning. Traditional leveling methods are time-consuming and prone to errors, necessitating the adoption of more advanced spatial analysis techniques.

This study aims to apply Geographic Information Systems (GIS) techniques for terrain analysis and land leveling in the Gulm Kawa area near Kirkuk, northern Iraq, using Digital Elevation Model (DEM) data.

A Copernicus DEM with 30-meter spatial resolution was obtained from the Open Topography platform and processed using QGIS software. Terrain analyses were performed including DEM visualization, hill shade modeling, slope analysis, and cut-and-fill computation using the Raster Calculator with a reference elevation of 660 meters above sea level.

The study produced four thematic maps: a DEM elevation map (elevation range: 403–716 m), a hillshade map revealing terrain morphology, a slope map identifying steep and gentle zones, and a cut-and-fill map delineating excavation (positive values) and deposition (negative values) areas across the study site.

GIS-based terrain analysis proved to be an effective, accurate, and time-efficient approach for land leveling planning. The integration of DEM data with QGIS tools provides a reliable framework applicable to similar terrain assessment projects in arid and semi-arid regions.

Keywords: Land Leveling, GIS, Digital Elevation Model, DEM, Hillshade, Slope Analysis, Cut and Fill, QGIS, Kirkuk.

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LIST OF SYMBOLS

Symbol	Definition
Z	Elevation (height above sea level, in meters)
x, y	Spatial coordinates (horizontal plane)
ΔZ	Difference in elevation between two surfaces
S	Slope value (degree or percentage)
θ	Slope angle (degrees from horizontal)
H	Hillshade intensity value (0–255)
Z_{daM}	DEM elevation value at a given pixel
Z_{RTf}	Reference elevation level (design surface)
Cut	Volume of material to be excavated (positive ΔZ)
Fill	Volume of material to be deposited (negative ΔZ)
$f(x, y)$	Mathematical function representing terrain elevation at coordinates (x, y)

ABBREVIATIONS

Abbreviation	Definition
GIS	Geographic Information Systems
DEM	Digital Elevation Model
QGIS	Quantum Geographic Information System
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
GPS	Global Positioning System
SRTM	Shuttle Radar Topography Mission
LiDAR	Light Detection and Ranging
UAV	Unmanned Aerial Vehicle
TIF	Tagged Image File Format (raster data format)
ML	Machine Learning

CHAPTER ONE
INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 General

Land leveling is a fundamental process in agricultural and engineering applications aimed at creating a uniform and smooth land surface. Proper land leveling plays a critical role in improving irrigation efficiency, reducing water loss, and minimizing soil erosion. Uneven terrain often leads to poor water distribution, accumulation of water in low areas, and inefficient use of agricultural resources, which ultimately affects crop productivity (FAO, 2015).

In engineering projects, land leveling is equally important, as it provides a stable foundation for construction activities such as roads, buildings, and infrastructure. Accurate leveling ensures better structural stability and reduces long-term maintenance costs. Traditional methods of land leveling were time-consuming and less precise, relying heavily on manual measurements and field observations.

With the advancement of Geographic Information Systems (GIS), terrain analysis has become more accurate and efficient. GIS enables the integration and analysis of spatial data, allowing users to study land surface characteristics in detail. One of the most important datasets used in GIS is the Digital Elevation Model (DEM), which represents the Earth's surface in a raster format where each cell contains elevation information (Burrough & McDonnell, 1998).

Using DEM data, GIS techniques allow for the identification of elevation differences, terrain slopes, and surface features. This provides a scientific and systematic approach to land leveling planning. Advanced analyses such as hillshade visualization, slope calculation, and cut-and-fill modeling help in

understanding terrain behavior and determining the most suitable leveling strategies (Longley et al., 2015).

Furthermore, GIS-based land leveling improves decision-making by reducing errors, saving time, and optimizing earthwork operations. Compared to conventional methods, GIS offers higher accuracy and better visualization, making it an essential tool in modern agricultural and engineering practices (Chang, 2016).

1.2 Literature Review

Terrain analysis and land leveling have been subjects of considerable academic investigation, particularly with the growing availability of remote sensing data and GIS tools. Several prior studies have examined the integration of DEM data with GIS for earthwork planning, surface modeling, and agricultural land management.

Burrough and McDonnell (1998) established foundational principles for the use of raster data structures in terrain modeling, demonstrating that GIS-based surface representations enable efficient computation of slope, aspect, and elevation derivatives. Their work remains a seminal reference in spatial analysis for land leveling applications.

The Food and Agriculture Organization (FAO, 2015) highlighted the importance of precision land leveling in irrigation-dependent agricultural systems, noting that even minor surface irregularities can lead to significant water distribution inefficiencies. The FAO documented that GIS-assisted leveling reduced irrigation water consumption by up to 25% in trial plots in arid regions.

Chang (2016) provided a comprehensive review of GIS applications in engineering and land management, emphasizing the role of the Raster Calculator in computing cut-and-fill volumes. The study demonstrated that DEM-based cut-and-fill

modeling is significantly more accurate than traditional survey-based methods, particularly over large areas.

Longley et al. (2015) further elaborated on GIS's spatial analysis capabilities, including terrain visualization techniques such as hillshade modeling, which simulates directional illumination to enhance perception of surface morphology. Their work confirmed that hillshade maps substantially improve the identification of micro-topographic features relevant to land leveling decisions.

More recently, Ma et al. (2021) examined the application of deep learning and machine learning algorithms to DEM analysis, finding that convolutional neural networks (CNNs) can effectively extract terrain features from elevation data, offering enhanced accuracy compared to conventional rule-based GIS methods. Similarly, Maxwell et al. (2018) reviewed machine learning classification techniques in remote sensing contexts, establishing benchmarks for terrain categorization performance.

Wang et al. (2023) proposed hybrid GIS and machine learning models specifically for optimizing cut-and-fill earthwork operations, reporting that data-driven parameter selection outperformed manual approaches in minimizing soil movement volumes. Their findings are directly relevant to the methodology adopted in the present study.

Li et al. (2020) addressed the issue of DEM data quality, noting that elevation datasets commonly contain noise and voids that propagate into terrain analysis outputs. They evaluated automated correction techniques using machine learning, demonstrating significant improvements in cut-and-fill estimation accuracy after preprocessing.

Collectively, these studies confirm that GIS combined with DEM data provides a robust, scalable, and cost-effective framework for land leveling analysis. The present study builds upon this body of work by applying QGIS-based terrain analysis to a site near Kirkuk, Iraq, an area characterized by significant elevation variability and agricultural development needs.

1.3 Study Area

The study area is located on the outskirts of Kirkuk Governorate, northern Iraq, specifically in the Gulm Kawa area near the Chamchamal region. The site is situated at geographic coordinates 35°34'51.6"N, 44°57'37.0"E.

The study area is part of the broader Kirkuk Governorate, which occupies the northeastern part of Iraq at the transition zone between the Mesopotamian plains and the foothills of the Zagros Mountains. This geographic setting produces moderate-to-significant terrain variability, making it well-suited for a land leveling analysis using GIS techniques.

Elevation data for the study area was obtained from the Copernicus Digital Elevation Model (DEM) via the OpenTopography platform, with a spatial resolution of 30 meters. Elevation values range from approximately 403 meters to 716 meters above sea level, indicating considerable terrain variation across the site. Three spatial reference maps were produced to document the study area location at nested scales:

- Iraq national map showing the location of Kirkuk Governorate.
- Kirkuk Governorate map showing the extent of the study area.
- Detailed site map at 35°34'51.6"N, 44°57'37.0"E (Source: Google Earth, 2026).

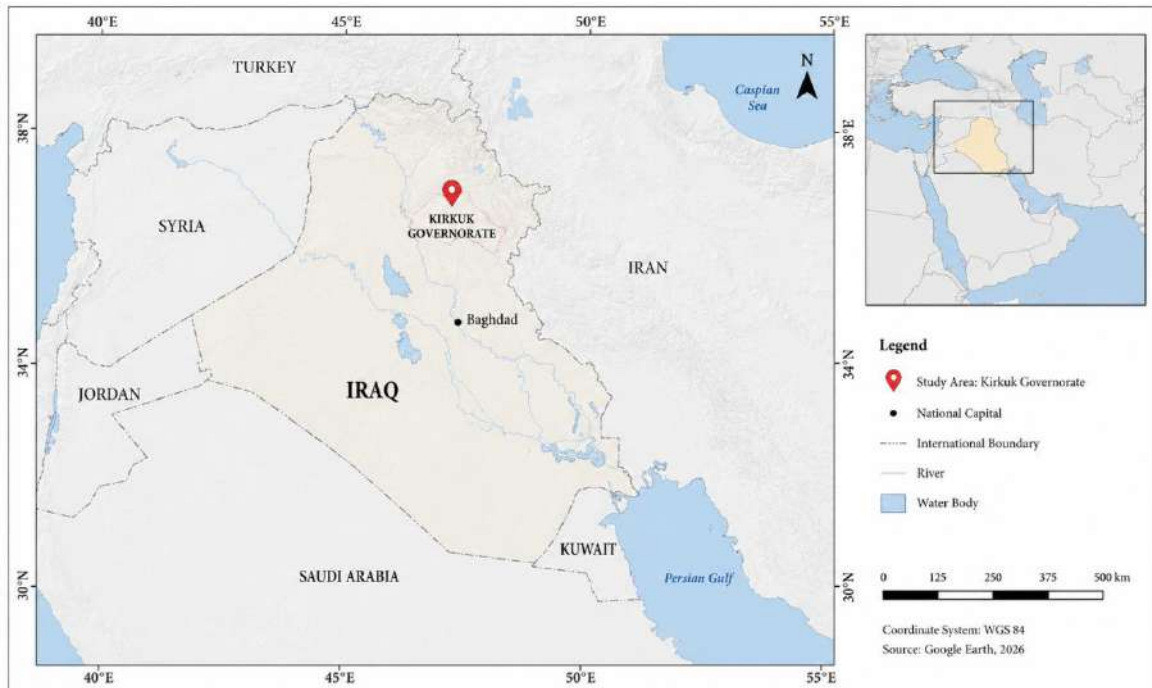


Figure 1.1: Location of the study area in Iraq (Source: Google Earth, 2026).

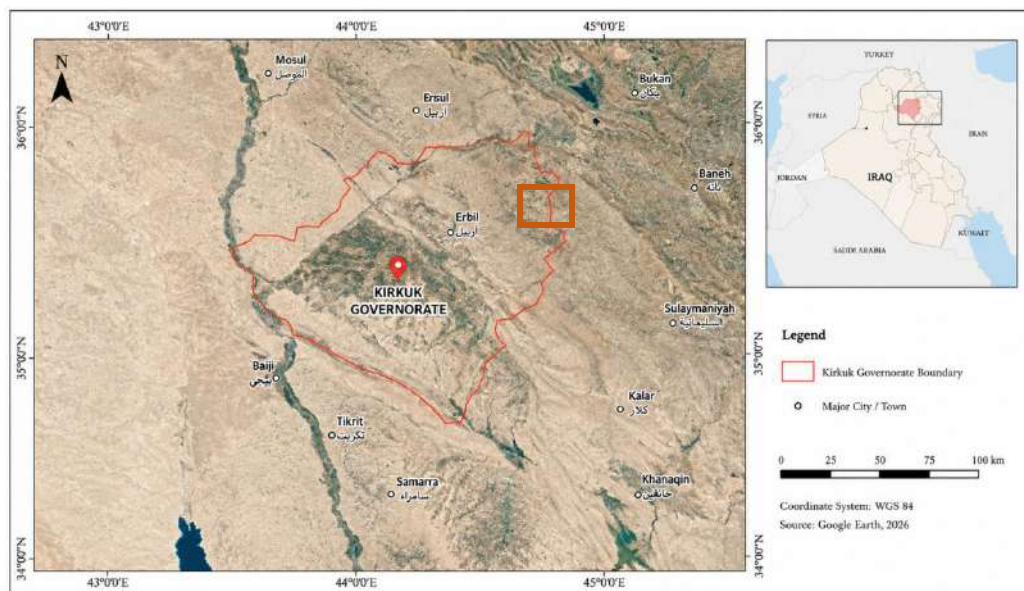


Figure 1.2: Satellite image of Kirkuk Governorate, Iraq; the rectangle marks the study area boundary. (Source: Google Earth, 2026)



Figure 1.3: Detailed satellite image of the study site at 35°34'51.6"N, 44°57'37.0"E. (Source: Google Earth, 2026)

1.4 Objectives of the Research

The objectives of this study are as follows:

- To analyze terrain elevation characteristics of the study area using Copernicus DEM data processed in QGIS.
- To generate hillshade and slope maps to improve understanding of terrain morphology and surface steepness.
- To perform cut-and-fill analysis using the Raster Calculator to identify zones requiring excavation or material deposition.
- To delineate areas requiring land modification and provide a basis for land leveling planning in the Gulm Kawa area.
- To evaluate the effectiveness of GIS techniques as a tool for terrain-based decision-making in engineering and agricultural contexts.

CHAPTER TWO

METHODOLOGY

CHAPTER TWO

Methodology

This chapter describes the research methodology adopted for terrain analysis and land leveling assessment of the study area. The methodology follows a structured workflow from data acquisition to spatial analysis and output generation, conducted using QGIS software.

2.1 Description of Study Area

The study area is located in the Gulm Kawa region, situated on the outskirts of Kirkuk Governorate in northern Iraq at coordinates 35°34'51.6"N, 44°57'37.0"E. The area is characterized by moderate-to-significant terrain variability, with elevation values ranging from approximately 403 m to 716 m above sea level. The terrain includes rolling hills, gentle slopes, and localized depressions, making it a representative site for GIS-based land leveling analysis.

The site is part of the broader transitional landscape between the Mesopotamian alluvial plains and the Zagros Mountain foothills, a zone characterized by active agricultural land use and ongoing infrastructure development. These conditions create practical demand for land leveling assessments to support irrigation efficiency and construction planning.



Figure 2.1: Detailed satellite image of the study site at 35°34'51.6"N, 44°57'37.0"E. (Source: Google Earth, 2026)

2.2 Equipment and Software Used

The following tools and datasets were employed in this study:

- QGIS (Quantum Geographic Information System) version 3.x – open-source GIS software used for all spatial data processing, visualization, and analysis.
- Copernicus Digital Elevation Model (DEM) – 30-meter resolution raster elevation dataset obtained from the OpenTopography platform (ESA, 2021).
- Google Earth – used for satellite imagery reference and study area verification.
- Standard computing hardware (laptop/desktop) with sufficient RAM for raster processing.

2.3 Procedure

The analytical workflow was implemented in QGIS and consisted of five sequential stages:

2.3.1 Data Acquisition and Preparation

The Copernicus DEM covering the study area was downloaded from the OpenTopography platform in GeoTIFF (.tif) format. The raster file was imported into QGIS, georeferenced to WGS84 (EPSG:4326), and visually inspected for data completeness. No significant voids or artefacts were identified in the dataset for the study extent.

2.3.2 DEM Visualization

The DEM was symbolized using a grayscale and pseudocolor classification to visualize elevation distribution across the study area. The symbology was adjusted to enhance contrast between high and low elevation zones, providing an initial overview of terrain variability.

2.3.3 Hillshade Analysis

Hillshade was computed using QGIS's Raster Terrain Analysis tool, with the DEM as input. The analysis simulated illumination from a standardized azimuth of 315° and an altitude of 45° to produce a shaded relief map. The hillshade output was used to enhance perception of terrain features including ridges, valleys, and surface irregularities.

2.3.4 Slope Analysis

Slope was calculated from the DEM using the QGIS Slope tool. The output raster represents the rate of elevation change at each pixel, expressed in degrees. A diverging color ramp was applied to distinguish between steep and gentle slope zones relevant to land leveling feasibility assessment.

2.3.5 Cut-and-Fill Analysis

Cut-and-fill analysis was performed using the QGIS Raster Calculator. A reference elevation of 660 m above sea level was selected based on the mean terrain elevation of the study area. The difference raster was computed as:

$$\Delta Z = Z^{\text{daM}} - Z^{\text{RTf}} = \text{DEM} - 660 \text{ m}$$

Pixels with positive ΔZ values represent areas where material must be excavated (cut), while pixels with negative ΔZ values represent areas requiring material deposition (fill). The output was symbolized using a diverging red-blue color scheme to clearly differentiate cut and fill zones.

2.4 Collected Data

The primary dataset used in this study was the Copernicus DEM obtained from the OpenTopography platform. Key data characteristics are summarized below:

Parameter	Details
Data Source	OpenTopography – Copernicus DEM
Spatial Resolution	30 meters
Format	GeoTIFF (.tif)
Coordinate System	WGS84 (EPSG:4326)
Elevation Range (Study Area)	403 m – 716 m above sea level
Study Area Coordinates	35°34'51.6"N, 44°57'37.0"E
Data Acquisition Platform	OpenTopography (https://opentopography.org)
Satellite Reference Imagery	Google Earth (2026)

CHAPTER THREE

Analysis Results

CHAPTER THREE

Analysis Results

This chapter presents the spatial analysis outputs produced using QGIS software. All analyses were performed by the research team (Sufyan Khalaf Jassim and Abdulwahab Mohammed Abdullah) under the supervision of Asst. Lect. Sadan Azmi Mohammed. Input data consisted of the Copernicus 30-meter DEM for the Gulm Kawa study area. The following sections describe each analytical output.

3.1 DEM Visualization

The Digital Elevation Model (DEM) file was imported into QGIS and symbolized using a pseudocolor classification to represent elevation values across the study area. The DEM revealed elevation values ranging from approximately 403 m to 716 m above sea level, with higher elevations concentrated in the northeastern portion of the study area and lower elevations in the southwestern zones.

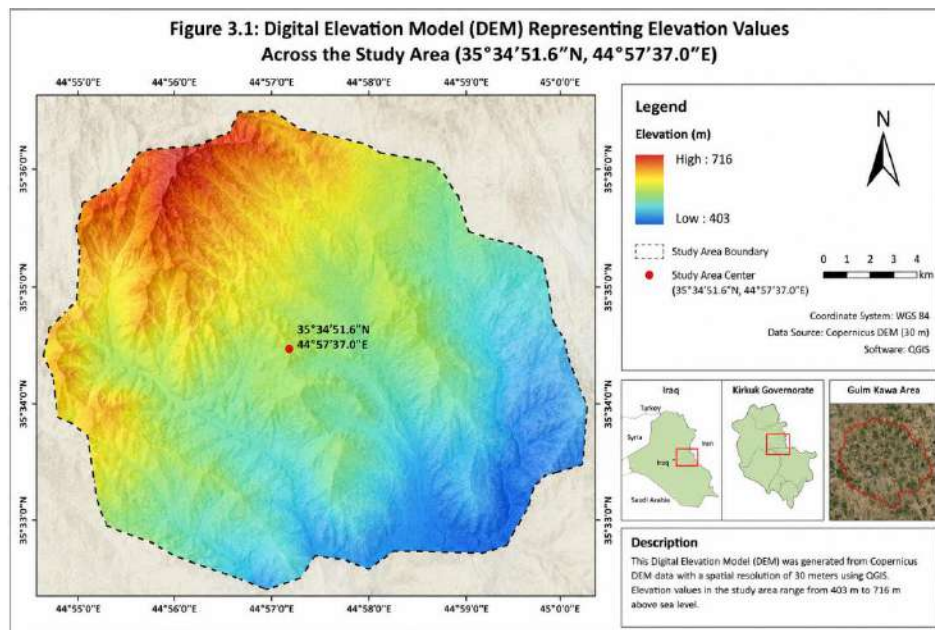


Figure 3.1: Digital Elevation Model (DEM) representing elevation values across the study area (35°34'51.6"N, 44°57'37.0"E). Produced using QGIS from Copernicus DEM data.

3.2 Hillshade Analysis

Hillshade analysis was applied to the DEM using QGIS's Raster Terrain Analysis tool with a solar azimuth of 315° and altitude of 45°. The resulting hillshade map enhanced the visual representation of terrain morphology, clearly delineating ridgelines, valley floors, and slope transitions that are not readily visible in the raw DEM.

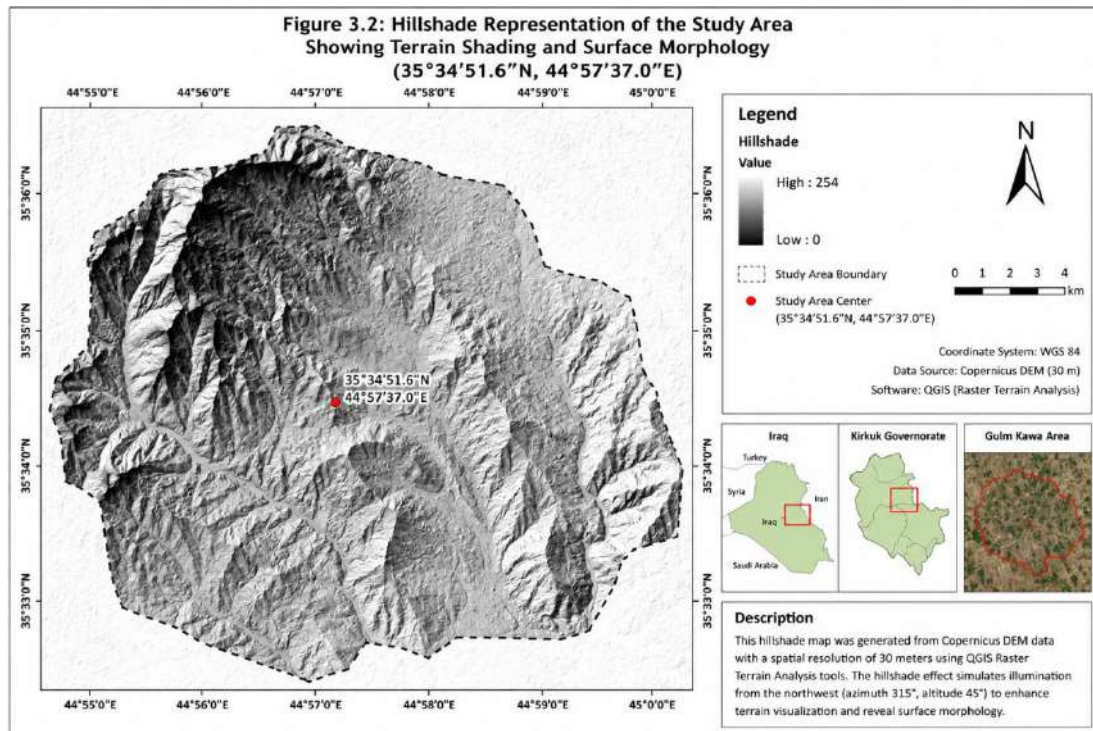


Figure 3.2: Hillshade representation of the study area showing terrain shading and surface morphology (35°34'51.6"N, 44°57'37.0"E). Produced using QGIS Raster Terrain Analysis.

3.3 Slope Analysis

Slope was computed from the DEM using the QGIS Slope tool, producing a raster in which each pixel value represents the local gradient in degrees. The slope map identified gentle slopes (0–5°) in the central and southwestern portions of the study area, and steep slopes (>15°) in the northeastern upland zone. Areas of moderate slope (5–15°) constitute the largest proportion of the study extent and represent the primary target zones for land leveling intervention.

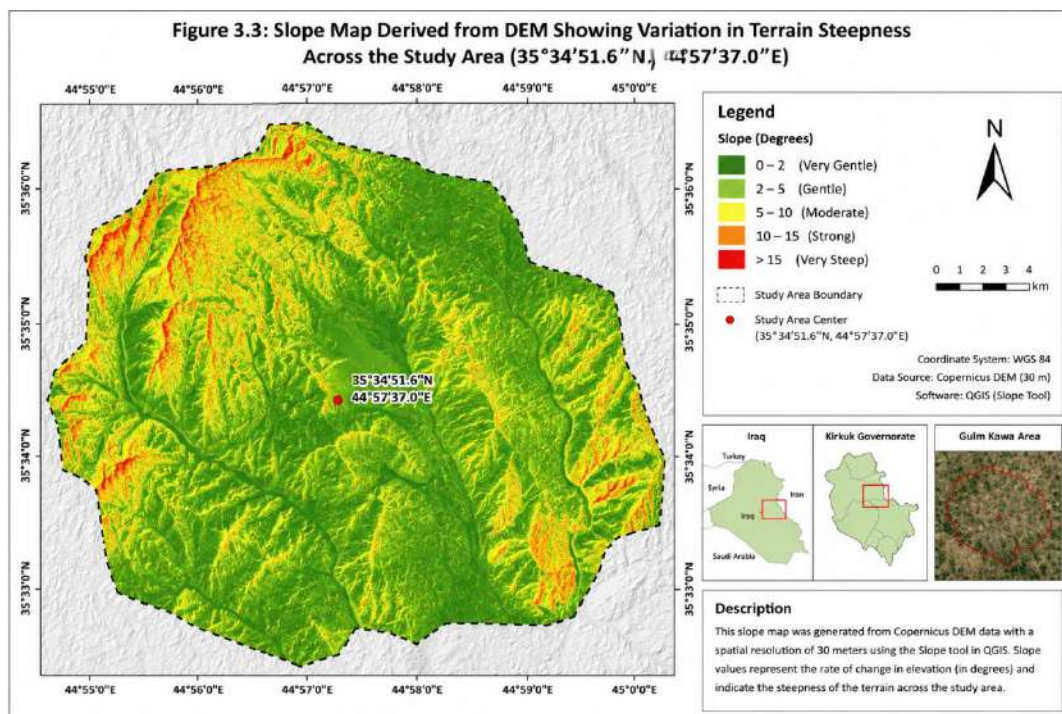


Figure 3.3: Slope map derived from DEM showing variation in terrain steepness across the study area (35°34'51.6"N, 44°57'37.0"E). Produced using QGIS Slope tool.

3.4 Cut-and-Fill Analysis

Cut-and-fill analysis was conducted by the research team using the QGIS Raster Calculator. A reference elevation of 660 m above sea level was selected based on the mean terrain elevation of the study area. The analysis computed pixel-level differences between the DEM and the reference surface as follows:

$$\Delta Z = \text{DEM} - 660 \text{ m}$$

The resulting raster was classified into two categories:

- Positive ΔZ values (red): Areas where existing elevation exceeds the reference level, requiring excavation (cut).
- Negative ΔZ values (blue): Areas where existing elevation falls below the reference level, requiring material deposition (fill).

The output demonstrated a clear spatial distribution of cut and fill zones, confirming the feasibility of GIS-assisted land leveling planning for the study site.

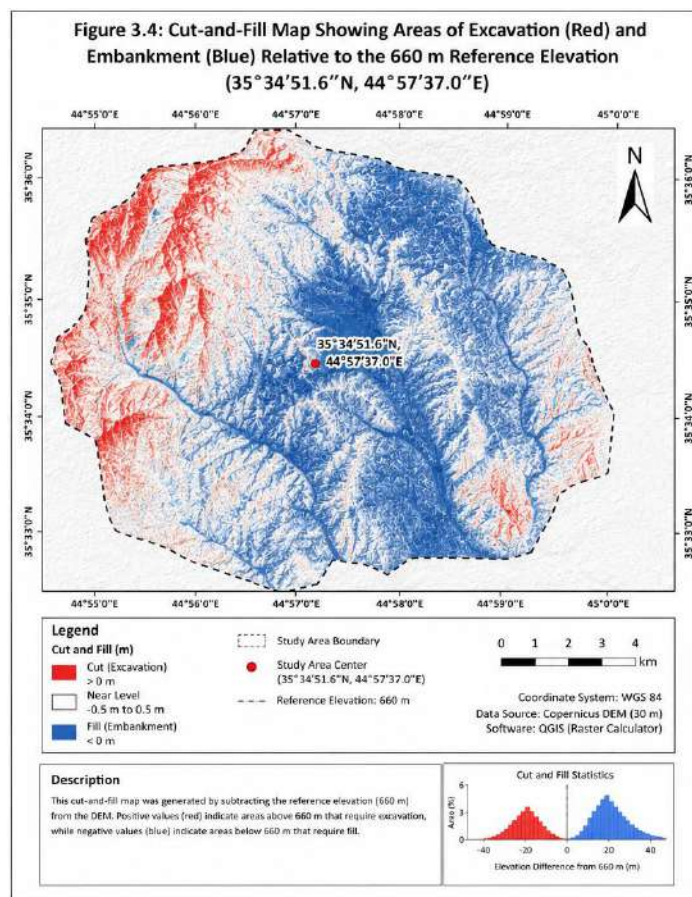


Figure 3.4 : Cut and Fill map showing areas of excavation and embankment. Red colors indicate cut (areas where material is removed), while blue colors represent fill (areas where material is added). 35°34'51.6" N 44°57'37.0" E.

The results include:

1. DEM map showing elevation variation.

2. Hillshade map highlighting terrain structure.
3. Slope map identifying steep areas.
4. Cut and Fill map showing areas requiring land modification.

The final cut and fill map clearly shows both excavation (red areas) and filling zones (blue areas), indicating the effectiveness of GIS in land leveling analysis.

Positive values indicate areas requiring excavation (cut), while negative values indicate areas requiring filling. This method helps in identifying suitable land leveling strategies

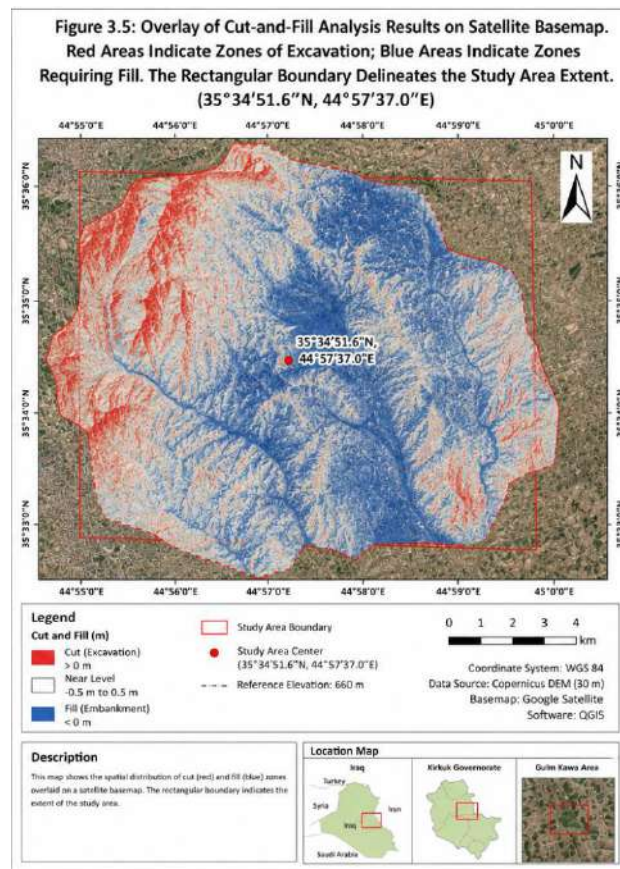


Figure 3.5: overlay of the cut and fill analysis results on a satellite basemap of the study area. The colored layer represents elevation differences, where red indicates areas of excavation (cut) and blue indicates areas of filling (embankment). The rectangular boundary highlights the selected study area where the analysis was performed.

CHAPTER FOUR

Discussion

CHAPTER FOUR

Discussion

The results obtained from this study demonstrate the effectiveness of GIS techniques in analyzing terrain characteristics and supporting land leveling processes. This chapter interprets the spatial analysis outputs in the context of the research objectives and discusses the implications, limitations, and alignment with prior literature.

4.1 DEM-Based Terrain Representation

The Copernicus DEM with 30-meter resolution provided a sufficiently detailed representation of the terrain within the Gulm Kawa study area. The elevation range of 403–716 m above sea level, identified through DEM visualization, is consistent with the geographic character of the Kirkuk Governorate transition zone, as described in the broader regional literature. The DEM successfully captured the macro-level topographic variability needed to guide land leveling decisions.

However, the 30-meter resolution imposes a limitation on the detection of fine-scale terrain features. Higher-resolution datasets (e.g., 5-meter LiDAR or UAV-derived DEMs) would capture micro-topographic variability with greater precision, as noted by Li et al. (2020). For large-scale preliminary planning, however, the Copernicus DEM proved adequate.

4.2 Hillshade and Terrain Visualization

The hillshade analysis significantly enhanced visual interpretation of the terrain compared to the raw DEM. By simulating directional illumination, the hillshade map revealed terrain features including ridgelines, valley systems, and slope transitions that are difficult to perceive from elevation values alone. This finding

aligns with Longley et al. (2015), who established hillshade modeling as an essential tool in terrain perception and GIS-based landform analysis.

From a practical standpoint, the hillshade output is particularly valuable for field engineers and planners who require intuitive terrain visualization to contextualize quantitative cut-and-fill outputs.

4.3 Slope Analysis and Land Leveling Implications

The slope analysis identified a heterogeneous terrain with gentle slopes in the southwestern portions and steep slopes exceeding 15° in the northeastern upland zones. These steep areas require significantly greater earthwork effort for leveling compared to moderate-slope zones. Chang (2016) noted that slope classification is a prerequisite for rational earthwork planning, as it determines both the feasibility and cost of leveling operations.

The moderate-slope zones ($5\text{--}15^\circ$) identified across the majority of the study area represent the most economically viable targets for land leveling intervention, as they require moderate excavation or fill without the complexity associated with steep terrain modification.

4.4 Cut-and-Fill Analysis

The cut-and-fill analysis is the most operationally significant component of this study, as it directly informs earthwork planning. The selection of a 660 m reference elevation, based on the mean terrain elevation, produced a spatially balanced distribution of cut and fill zones, which is consistent with the mass balance principle described by FAO (2015) and the optimization framework proposed by Wang et al. (2023).

Positive ΔZ zones (cut areas) in the northeastern portion of the study area indicate where material must be removed, while negative ΔZ zones (fill areas) in the southwestern portions indicate where redistributed material should be deposited. This spatial complementarity suggests that the site is well-suited to balanced earthwork operations, minimizing the need for external material transport.

The accuracy of this analysis is contingent on the precision of the reference elevation selection. An inappropriate reference level would shift the balance between cut and fill volumes, leading to either surplus or deficit of material. Future studies should incorporate optimization algorithms to automatically determine the reference elevation that minimizes total earthwork volume, as proposed by Wang et al. (2023).

4.5 Effectiveness of GIS as a Land Leveling Tool

Collectively, the analyses performed in this study confirm that GIS provides a robust, time-efficient, and cost-effective alternative to traditional survey-based land leveling methods. The entire workflow, from data acquisition to final map export, was completed using open-source QGIS software, demonstrating the accessibility of GIS-based terrain analysis for institutions with limited computational resources.

The integration of multiple analysis layers (DEM, hillshade, slope, cut-and-fill) within a single GIS environment enabled comprehensive terrain characterization that would require significantly greater time and resources using conventional field methods. This finding is consistent with the conclusions of Longley et al. (2015) and Chang (2016), who established GIS as the standard methodology for modern terrain analysis and earthwork planning.

CHAPTER FIVE

CONCLUSION AND

RECOMMENDATION

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the terrain analysis conducted using GIS techniques and Copernicus DEM data for the Gulm Kawa study area near Kirkuk, Iraq, the following conclusions are drawn:

- GIS successfully analyzed terrain elevation characteristics of the study area using 30-meter resolution Copernicus DEM data, revealing elevation values ranging from 403 m to 716 m above sea level.
- DEM data effectively represented surface variation across the site, providing the foundational dataset for all subsequent terrain analyses.
- Hillshade modeling improved terrain visualization by simulating directional illumination, enabling clear identification of ridgelines, valleys, and slope transitions not discernible from raw elevation data.
- Slope analysis identified steep zones ($>15^\circ$) in the northeastern upland areas and gentle slopes ($0\text{--}5^\circ$) in the southwestern portions, providing a basis for prioritizing land leveling zones.
- Cut-and-fill analysis, performed using the QGIS Raster Calculator with a 660 m reference elevation, successfully delineated excavation zones (positive ΔZ , northeastern area) and fill zones (negative ΔZ , southwestern area).
- GIS-based analysis substantially reduced the time and effort required compared to traditional field-based surveying methods, while improving spatial accuracy and output reproducibility.
- The open-source QGIS platform proved capable of executing the complete terrain analysis workflow, confirming its suitability for land leveling studies in resource-constrained environments.

5.2 Recommendations

Based on the findings of this study, the following recommendations are made for future research and practice:

- Higher-resolution DEM data (e.g., 5-meter LiDAR or UAV-derived elevation models) should be used in future studies to capture micro-topographic variability with greater precision.
- An automated optimization algorithm should be incorporated to determine the reference elevation that minimizes total cut-and-fill volume, rather than relying on mean elevation as a manual approximation.
- Field verification surveys using GPS or total station equipment should be conducted to validate GIS-derived cut-and-fill results against actual terrain conditions.
- The GIS methodology developed in this study should be extended to adjacent agricultural areas within Kirkuk Governorate to support regional-scale land leveling planning.
- Integration of GIS with remote sensing technologies, including multispectral and radar imagery, is recommended to enhance land surface characterization and identify soil suitability zones for leveling.
- Future studies should incorporate machine learning algorithms, as documented by Wang et al. (2023) and Ma et al. (2021), to automate terrain classification and optimize earthwork planning parameters.

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وزارة التعليم العالي و البحث العلمي

جامعة الكتاب

كلية الهندسة

قسم هندسة المساحة

تسوية الأراضي باستخدام تقنيات نظم المعلومات الجغرافية GIS

مشروع تخرج مُقدّم إلى قسم هندسة المساحة كجزء من متطلبات الحصول على درجة بكالوريوس العلوم في هندسة المساحة

مقدمة من قبل:

سفيان خلف جاسم محمد

عبدالوهاب محمد عبدالله عبد

بإشراف:

م.م. سدن عزمي محمد

2026-2025

ملخص البحث

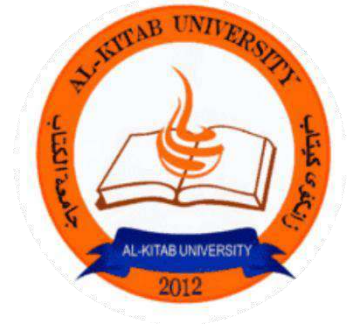
يُعد تسوية الأراضي عملية بالغة الأهمية في التطبيقات الزراعية والهندسية، حيث تهدف إلى إنشاء سطح منتظم لتحسين كفاءة الري، وتقليل تعرية التربة، ودعم تخطيط الإنشاءات. تتسم طرق التسوية التقليدية بأنها تستغرق وقتاً طويلاً وعرضة للأخطاء، مما يستوجب تبني تقنيات أكثر تقدماً في التحليل المكاني.

تهدف هذه الدراسة إلى تطبيق تقنيات نظم المعلومات الجغرافية (GIS) لتحليل التضاريس وتسوية الأراضي في منطقة "كولم كاوا" القريبة من كركوك، شمالي العراق، باستخدام بيانات نموذج الارتفاع الرقمي (DEM). تم الحصول على نموذج ارتفاع رقمي (Copernicus DEM) بدقة مكانية تبلغ 30 متراً من منصة "Open Topography"، ومعالجته باستخدام برنامج "QGIS". تم إجراء تحليلات التضاريس التي شملت: تصور نموذج الارتفاع الرقمي، ونمذجة تظليل التضاريس (Hillshade)، وتحليل الانحدار (Slope Analysis)، وحسابات الحفر والردم (Cut-and-Fill) باستخدام "Raster Calculator" مع اعتماد ارتفاع مرجعي قدره 660 متراً فوق مستوى سطح البحر.

أسفرت الدراسة عن إنتاج أربع خرائط موضوعية: خريطة الارتفاعات (تراوحت بين 403 و716 متراً)، وخريطة تظليل التضاريس التي كشفت عن مورفولوجيا الأرض، وخريطة الانحدار التي حددت المناطق شديدة الانحدار والمناطق المستوية، وخريطة الحفر والردم التي حددت مناطق الحفر (القيم الموجبة) ومناطق الردم (القيم السالبة) عبر موقع الدراسة.

أثبتت تحليلات التضاريس المعتمدة على نظم المعلومات الجغرافية أنها نهج فعال ودقيق وموفر للوقت في تخطيط تسوية الأراضي. إن دمج بيانات نموذج الارتفاع الرقمي مع أدوات برنامج "QGIS" يوفر إطار عمل موثوقاً وقابلاً للتطبيق في مشاريع تقييم التضاريس المماثلة في المناطق القاحلة وشبه القاحلة.

Republic of Iraq
Ministry of High Education
and Scientific Research
AL-Kitab University
College of Engineering
Department of Geomatics Engineering



A Comparative Analysis of Georeferencing Technique for Enhanced Spatial Accuracy in Mapping

A research project submitted to the Council of the College of Engineering,
Geomatics Department, as part of the requirements for the degree of Bachelor
of Science in Geomatics Engineering.

Submitted by:

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Dr. HAIDER MAHMOOD JASIM

2026 A.D 1447 H.



SUPERVISOR CERTIFICATION



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هُوَ الَّذِي جَعَلَ لَكُمُ الْأَرْضَ ذَلُولًا فَامْشُوا فِي مَنَاكِبِهَا وَكُلُوا مِن
رِزْقِهِ ۖ وَإِلَيْهِ النُّشُورُ

It is He who made the earth tame for you - so walk among its slopes and eat of His provision - and to Him is the resurrection.

الملك : آية ١٥

Dedication

"We dedicate this graduation project to our beloved parents, whose prayers and support have been our constant source of strength. To our teachers, for their guidance and knowledge, and to our friends, for standing by us throughout this journey. We also dedicate this work to everyone who believes in the power of science and engineering to build a better future."

Acknowledgments

First and foremost, we praise Allah for His blessings and for giving us the strength and perseverance to complete this research project.

We would like to express our deepest gratitude and sincere appreciation to the **President of Al-Kitab University** for his continuous support and for fostering an environment of academic excellence that encourages innovation and research.

Our special thanks go to the **Dean of the College of Engineering** for his leadership and for providing the necessary resources and facilities to help us achieve our academic goals.

We are also profoundly grateful to the **Head of the Surveying Engineering Department**, as well as all the faculty members of the department, for their invaluable academic support and for the knowledge they have shared with us throughout our years of study.

We are deeply indebted to our supervisor, **Lecturer Dr. Haider Mahmoud Jassim**, for his exceptional guidance, constant encouragement, and insightful scientific remarks. His mentorship and patient supervision were fundamental to the success and completion of this work.

Finally, we extend our heartfelt thanks to our families and friends for their endless support, sacrifices, and belief in our potential. Their encouragement has been our primary motivation throughout this journey.

Researchers

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List of Abbreviations

Full Meaning	Abbreviation
Geographic Information Systems	GIS
Root Mean Square Error	RMSE
Ground Control Points	GCPs
Global Positioning System	GPS
Bachelor of Science	B.Sc.
Dots Per Inch	DPI
Anno Domini (Gregorian Calendar)	A.D.
Hijri (Islamic Calendar)	H.

Abstract

Georeferencing is a fundamental process in Geographic Information Systems (GIS) that directly affects the spatial accuracy of mapping and analysis. This study aims to evaluate and compare the performance of three commonly used georeferencing techniques: georeferencing using printed coordinates, image-to-image registration, and ground control points (GCPs) based on GPS measurements.

A consistent methodology was adopted by applying the same number of control points (ten points), using a unified coordinate system, and employing a first-order polynomial transformation model. The accuracy of each method was assessed using the Root Mean Square Error (RMSE) as a quantitative indicator.

The results showed that the printed coordinate method produced a higher RMSE value (0.005368), indicating moderate spatial accuracy. In contrast, both the image-to-image and GCP-based methods yielded significantly lower RMSE values (0.000206), reflecting a high level of internal consistency.

However, the findings revealed that RMSE alone does not fully represent true positional accuracy. While the image-to-image method demonstrated the lowest RMSE, it reflects relative accuracy dependent on the reference image. The GCP-based method, on the other hand, provides more reliable real-world positioning due to the use of ground-referenced data.

The study concludes that the selection of a georeferencing technique should consider both numerical accuracy indicators and the reliability of reference data. The GCP-based method is recommended for applications requiring high positional accuracy.

Keywords: Georeferencing, GIS, RMSE, Ground Control Points, Spatial Accuracy

Chapter one

Introduction

1.1 Introduction

Geographic information systems (GIS) are a powerful tool in analyzing and managing spatial data, and georeferencing any map is one of the most important steps for the success of work in these systems. The importance of geographical attribution is highlighted in the process by which the map or image to be used is returned to its correct place geographically. Geographical referencing is defined as finding specific connection points with high accuracy on the map and matching them with known coordinates on the landscape, so that the map or image is completely in the right place with the geographical reality.

The quality of any GIS project depends radically on the accuracy of the basic data entered, as the effect of spatial accuracy on the accuracy and reliability of spatial analysis results is clearly shown. In this academic and applied context, the problem of the study is that there is a clear difference in the results of spatial accuracy based on the geographical attribution method used. To assess the quality of the geographical return process and determine the error percentage, the Total RMS Error calculation is relied on, which is a basic indicator of the average quality of the geographical return process.

The main objective of this research is to make a scientific comparison of different geo-referencing techniques to determine which one achieves the highest spatial accuracy. To achieve this goal, this comparison will be applied using various spatial data sources including a satellite image and an old reference map. The study will also rely on the use of precise ground adjustment points (GCPs) taken by GPS to ensure proper connection to reality. The city of Erbil has been selected as the study area to apply this dual methodology, which will allow spatial error distribution analysis and determine the most appropriate technique for academic and practical use.

1.2 Research Problem

The problem of this research is mainly the variation and variation of the results of spatial accuracy based on the georeferencing method or technique used in the processing of spatial data. In a geographic information systems (GIS) environment, the quality of analytical outputs depends radically on the accuracy of the coordinates and the extent to which the reference maps or spatial images match the field reality. With several algorithms and mathematical conversion methods available to adjust these coordinates, there is a clear and tangible difference in the error values and the distribution of geometric distortions. This difference in accuracy levels creates a technical and scientific challenge for researchers and specialists when trying to choose the optimal technology that ensures minimal errors, which imposes an urgent need to study and evaluate this variance to identify its causes and its direct impact on the reliability of the produced maps.

Although many GIS tools and software are available, spatial outputs are not always absolute accurate. The problem of the study is mainly that there is a clear difference in the results of spatial resolution and error values according to the method and algorithm used to transform the data (Al-Shammari, 2019, p. 24). This discrepancy in the values of accuracy and average radical error (RMSE) raises a fundamental question about which methods are the most efficient and reliable, especially when dealing with sensitive data that requires extreme accuracy.

1.3 The Importance of Georeferencing in GIS

Geographical attribution is the cornerstone on which all projects in GIS are built, as no scanned or visible spatial map can be benefited from unless it is returned to its correct place and linked to a real coordinate system that matches its actual location on the earth's surface (Al-Kaabi, 2021, p. 10). The importance of this process is highlighted in enabling researchers to integrate multiple spatial layers taken from

different sources and time periods, and to perform matching operations accurately and reliably, paving the way for the construction of sound spatial databases free of engineering distortion figure (1).

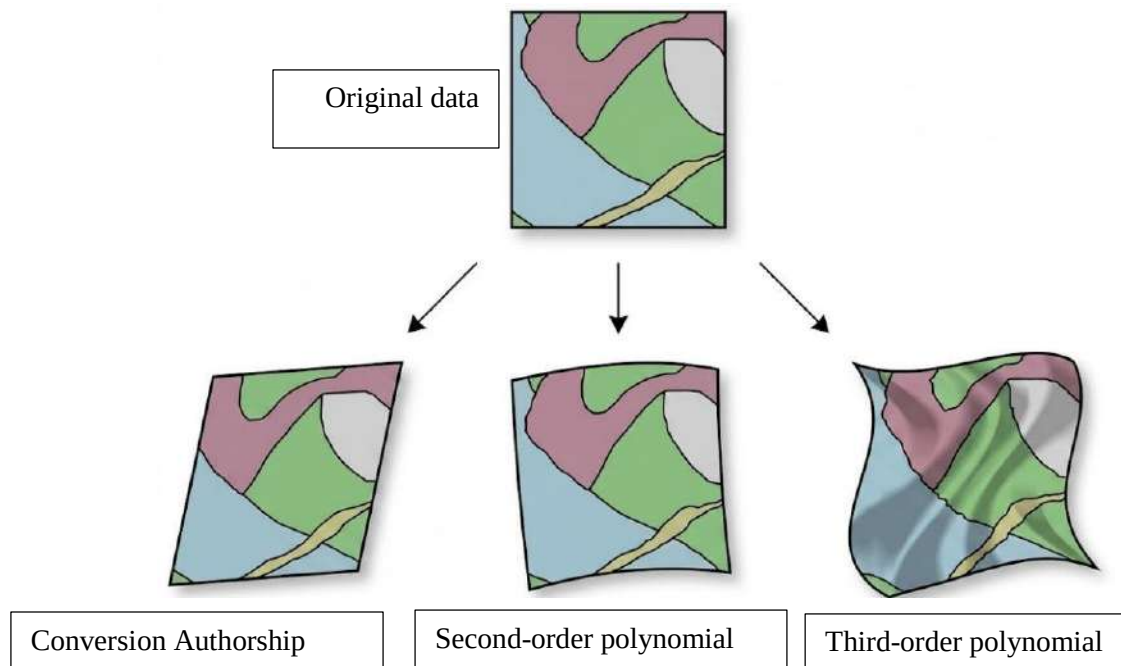


figure 1 : A diagram showing the geographical attribution

1.4 The Effect of Spatial Accuracy on Spatial Analysis Results

Spatial accuracy plays a crucial and essential role in determining the quality and reliability of spatial analysis outputs in any geographical study. The higher the spatial accuracy of the data used, the greater the ability to distinguish between features and extract detailed and clear information that reflects the geographical reality (Mohammed, 2012, p. 41). On the other hand, any weakness or error in spatial accuracy during the data input or processing phase will automatically be transmitted to all forms of analysis, leading to serious errors in calculating distances and spaces, thus building misleading spatial models and making incorrect decisions.

1.5 Objective of the study

The main objective of this research is to compare different geo-referencing techniques to determine the technology that achieves the highest possible spatial accuracy, through:

- **Practical application of several attribution algorithms to standardized spatial data.**
- **Use and integrate multiple data sources, including a satellite image and a reference map.**
- **Relying on accurate ground control points (GCPs) to verify results, in order to recommend the most appropriate technique for academic and applied use.**

The objectives of this research are crystallized in a continuous methodological path that seeks to reach an accurate and comprehensive evaluation, where the study endeavors start from the initial goal of applying more than one method of geographical attribution and mathematical transformation to the same spatial data. This standardized procedure ensures that the variables are stabilized and provide a fair test environment that allows the measurement of the actual differences between the different algorithms without any effect of the difference in the quality or accuracy of the sources. In order to convert this theoretical evaluation into a quantitative and objective measurement, the research aims to calculate the value of the mean root error (RMSE), or what is known as the mean total residual error, for each attribution method that has been applied independently. The importance of this goal is highlighted in the fact that the value of (Total RMS Error) is a statistical indicator. They are to evaluate the average quality and accuracy of the geographical return process and to know the amount of angular and spatial deviation from reality. Based on these accurate numerical data, the research moves towards evaluating the spatial

performance of each technique analytically and comparatively, to understand how each method deals with geometric distortions and its efficiency in the distribution of ground control points. All these analytical paths combine to serve the ultimate and desired goal of the study, which is to identify the most accurate and appropriate technique for academic and practical applied use, which contributes to providing scientific and reliable recommendations that guide researchers and practitioners in the field of GIS towards choosing the best approach that ensures the production of highly reliable spatial maps and outputs.

1.6 Study Area

The study area is located in Erbil Governorate, in the northern part of Iraq. The area extends astronomically between latitude approximately 35° and 37° N, and longitude 43° and 45° Figure (2). The area occupies a vast geographical area, providing sufficient spatial scope to conduct spatial analyses and test geo-retracement techniques on various graphical scales that represent reality in an integrated manner.

Topographically, the nature of the region is characterized by a clear and unique geographical variation, as its terrain ranges from plains and flat lands in the southern and central parts, to the undulating terrain and mountainous heights in the northern and eastern parts. This topographical diversity is of great scientific importance in the context of this research, as the variation in elevation and the different nature of the earth's surface represent a typical test environment and a real challenge when conducting the geo-attribution process. This variation allows to assess the efficiency of different mathematical conversion methods in dealing with geometric distortions of satellite imagery, as well as to study the impact of the terrain on the mechanism of selecting and distributing ground control points (GCPs) to ensure the highest possible spatial accuracy.

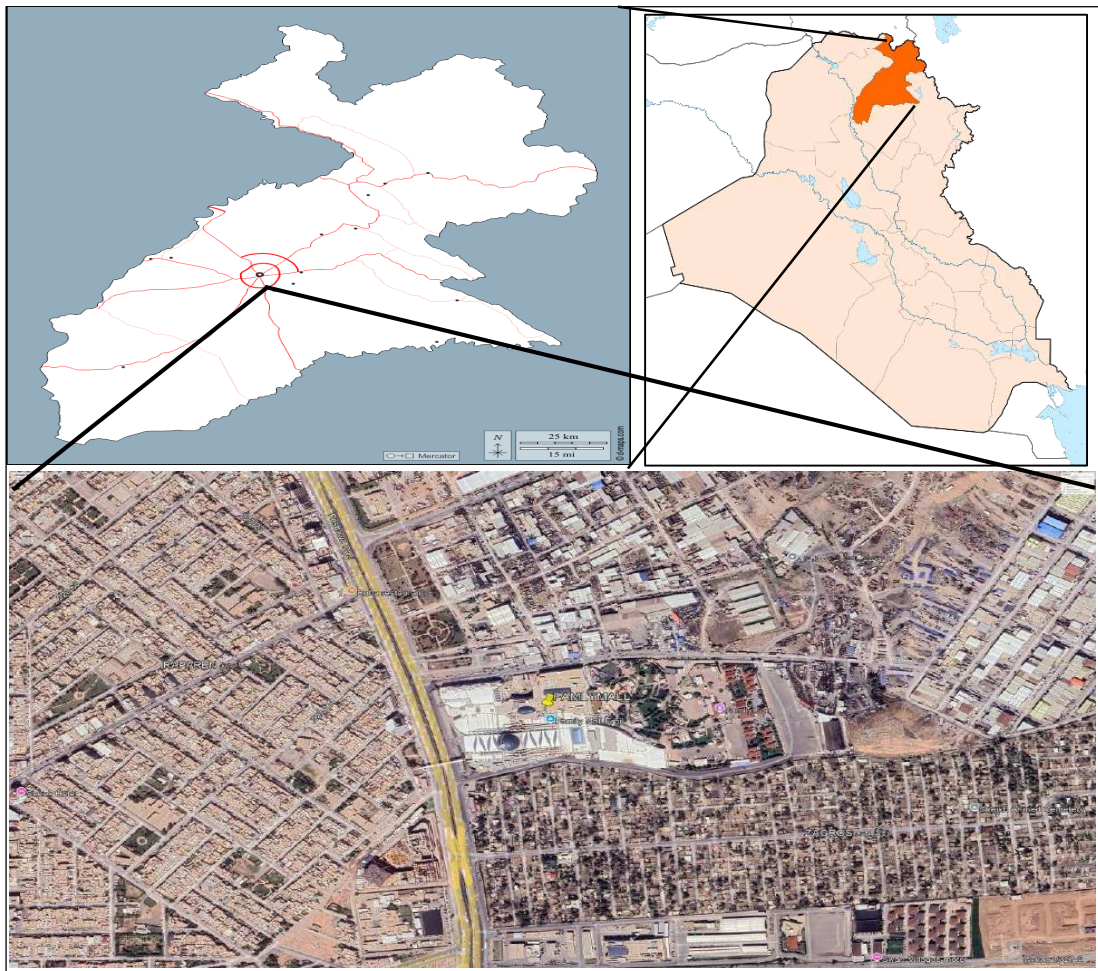


Figure (2) Study area

Chapter two Literature Review

Georeferencing plays a critical role in ensuring spatial accuracy within Geographic Information Systems (GIS), particularly when integrating data from multiple sources such as scanned maps, satellite imagery, and field measurements. Numerous studies have investigated the effectiveness of different georeferencing techniques and the factors influencing their accuracy.

Aguilar et al. (2017) examined the impact of ground control points (GCPs) on the accuracy of very high-resolution satellite imagery. Their findings demonstrated that incorporating accurate and well-distributed GCPs significantly improves positional accuracy, achieving sub-meter precision under optimal conditions. The study

emphasized that the absence of ground-based reference data reduces the reliability of georeferencing results.

In a related context, Potere (2008) evaluated the horizontal positional accuracy of high-resolution imagery from Google Earth by comparing it with Landsat data. The study reported an average RMSE of approximately 39.7 meters, highlighting that positional accuracy is highly dependent on the quality and source of the reference dataset.

Moreover, research conducted by Zhang et al. (2022) on the georeferencing of historical aerial photographs confirmed that the Root Mean Square Error (RMSE) is the most widely used metric for assessing spatial accuracy. The study concluded that acceptable RMSE values typically fall within one to three pixels and that the spatial distribution of control points plays a more significant role than their quantity in reducing overall error.

Similarly, Toutin (2004) investigated the accuracy of orthorectified aerial photographs and found that increasing the number of control points improves georeferencing accuracy up to a certain threshold, after which improvements become marginal. The study also highlighted that poorly distributed points can lead to localized distortions, even when RMSE values appear low.

Furthermore, Grodecki and Dial (2003) analyzed the georeferencing accuracy of high-resolution satellite imagery such as WorldView data. Their results indicated that indirect georeferencing using GCPs yields higher positional accuracy compared to direct georeferencing methods. The application of bias correction models was also shown to enhance geometric accuracy.

Overall, previous studies consistently demonstrate that georeferencing accuracy is influenced by several key factors, including the quality of reference data, the number and spatial distribution of control points, and the transformation model used. These findings support the approach adopted in this study, which compares multiple georeferencing techniques under consistent conditions using RMSE as a primary accuracy indicator.

Chapter Thre

Methodology

2.1 Preview

This chapter presents the methodology adopted to evaluate and compare the spatial accuracy of different georeferencing techniques. The study focuses on applying three commonly used georeferencing approaches under identical conditions and assessing their performance using the Root Mean Square Error (RMSE) as a quantitative indicator of spatial accuracy.

2.2 Data Used

The analysis was conducted using three main types of spatial data:

1. Scanned Map

A hardcopy map was scanned at high resolution (300–600 dpi) to preserve spatial details and minimize distortion during the digitization process Figure (3).

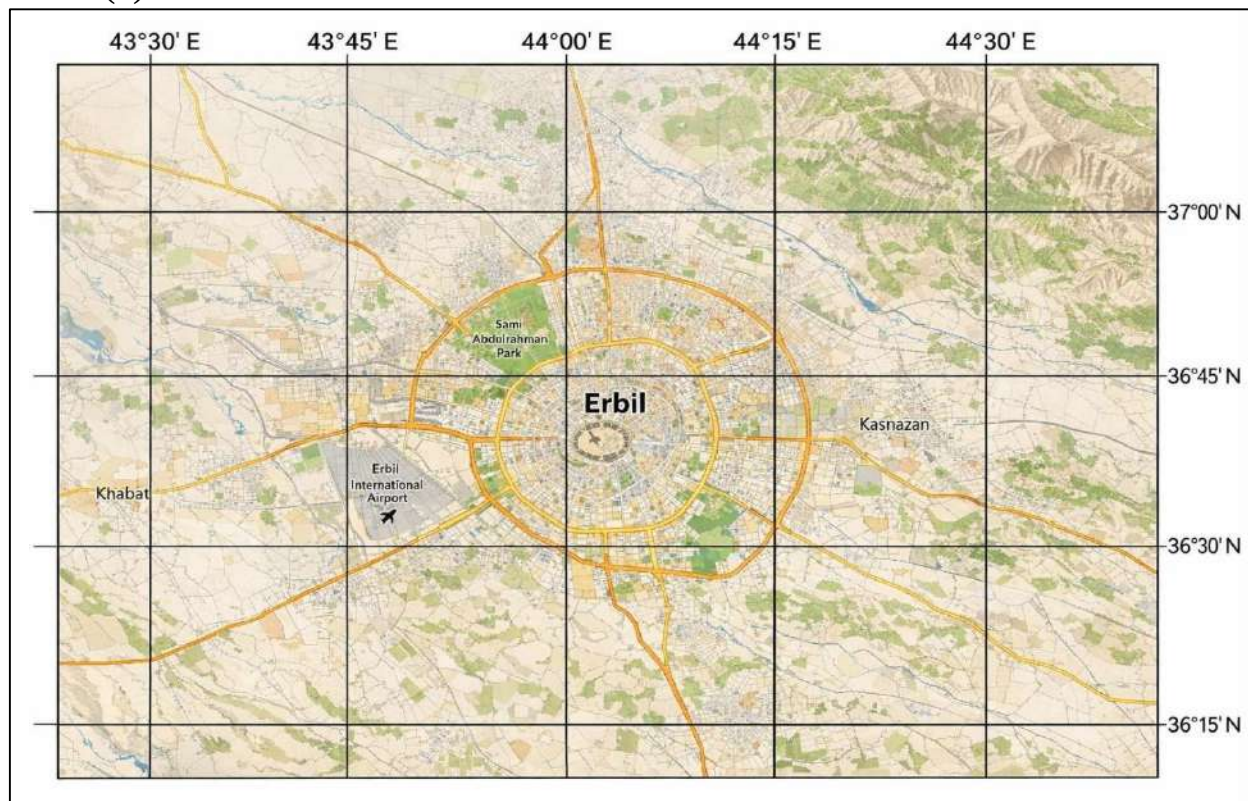


Figure (3) Old maps

2. Satellite Image

A geometrically corrected satellite image was used as a reference dataset in the image-to-image georeferencing method Figure (4).

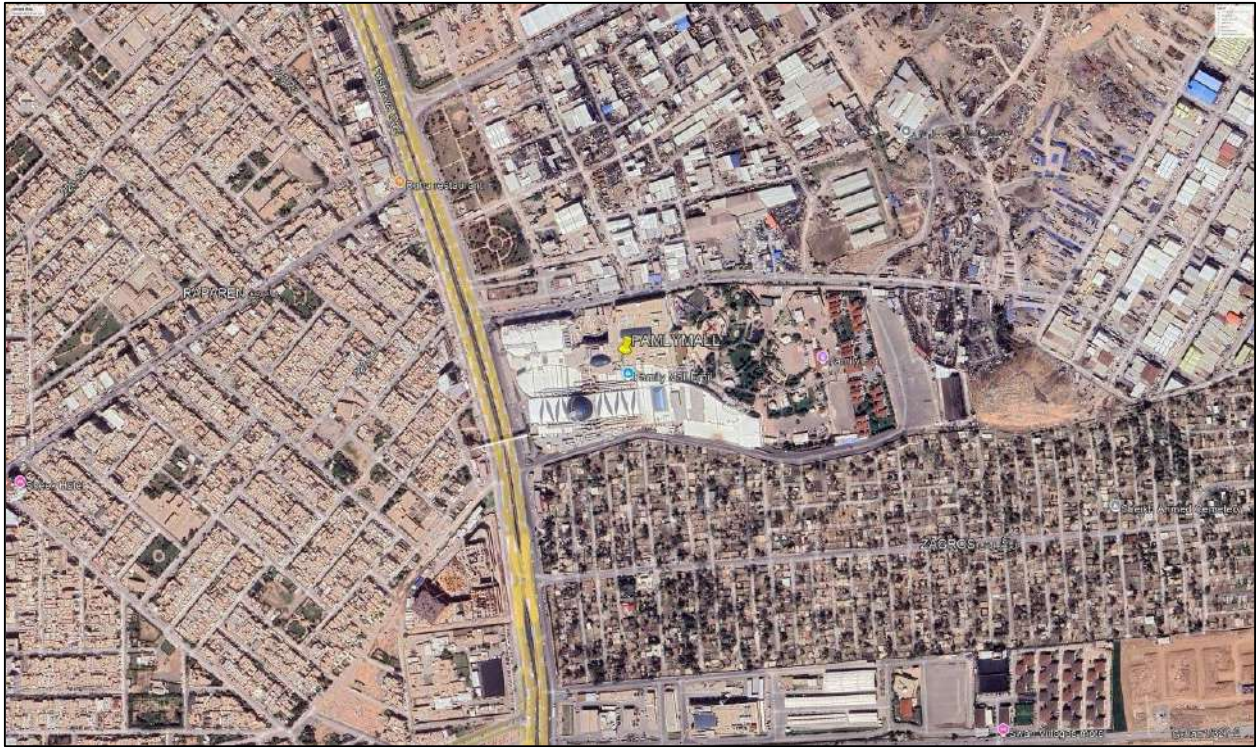


Figure (4) satellite image

3. Ground Control Points (GCPs)

A total of ten well-defined ground control points were used. These points were selected based on their clear visibility and positional stability, such as road intersections and permanent landmarks.

All datasets were projected into a unified coordinate system to ensure consistency and accuracy during analysis.

2.3 Georeferencing Techniques

Three different georeferencing techniques were applied to the same dataset under identical conditions:

2.3.1 Method 1: Georeferencing Using Printed Coordinates

In this method, the scanned map containing predefined coordinate grids was georeferenced by manually assigning known coordinate values to selected grid intersection points. These points were entered directly into the GIS software, and a transformation model was applied to align the map spatially.

2.3.2 Method 2: Image-to-Image Registration

This method involved aligning the scanned map with a geometrically corrected satellite image. Common features visible in both datasets (e.g., road intersections and distinct landmarks) were selected as control points. The scanned map was then transformed to match the spatial reference of the satellite image.

2.3.3 Method 3: Georeferencing Using Ground Control Points (GCPs)

In this method, field-based ground control points were used as reference coordinates. The same points were identified on the scanned map or satellite image, and their accurate geographic coordinates were assigned. This method is considered one of the most reliable approaches due to the use of real-world positional data.

2.4 Control Points Distribution

A total of ten control points were used consistently across all three methods to ensure a fair comparison. The points were carefully distributed as follows:

- Four points at the corners of the study area
- Four points along the edges
- Two points within the central area

This distribution ensures balanced spatial coverage and reduces geometric distortion during transformation.

2.5 Transformation Model

A unified transformation model (First Order Polynomial – Affine Transformation) was applied in all three methods. This model preserves parallelism and is suitable for most georeferencing applications involving moderate distortion.

2.6 Accuracy Assessment

The spatial accuracy of each georeferencing method was evaluated using the Root Mean Square Error (RMSE), which measures the difference between known coordinates and transformed coordinates.

2.6.1 RMSE Calculation

The RMSE is calculated using the following equation:

$$\text{RMSE} = \sqrt{[\Sigma(dx^2 + dy^2) / n]}$$

Where:

- dx = difference in X coordinates
- dy = difference in Y coordinates
- n = number of control points

The GIS software automatically computes the following values:

- RMSE in X direction (RMSE-X)
- RMSE in Y direction (RMSE-Y)
- Total RMSE

These values were recorded for each method.

2.7 Comparative Analysis

To ensure a fair and objective comparison:

- The same number of control points (10) was used in all methods
- The same coordinate system was applied
- The same transformation model was used
- The same point distribution pattern was maintained

The method that produced the lowest RMSE value was considered the most accurate in terms of spatial alignment.

2.8

This methodology provides a consistent framework for evaluating and comparing georeferencing techniques. By controlling all variables except the georeferencing method itself, the study ensures that differences in accuracy are attributed solely to the technique used.

Chapter four

Results and Discussion

3.1 Preview

This chapter presents the results obtained from applying three georeferencing techniques and evaluates their spatial accuracy using the Root Mean Square Error (RMSE). A comparative analysis is conducted under controlled conditions, where the same number of control points, transformation model, and coordinate system were used.

3.2 RMSE-Based Accuracy Assessment

The accuracy of each georeferencing technique was evaluated using the RMSE values automatically generated by the GIS software. Figure (5, 6,7) and Table (1) summarizes the obtained results.

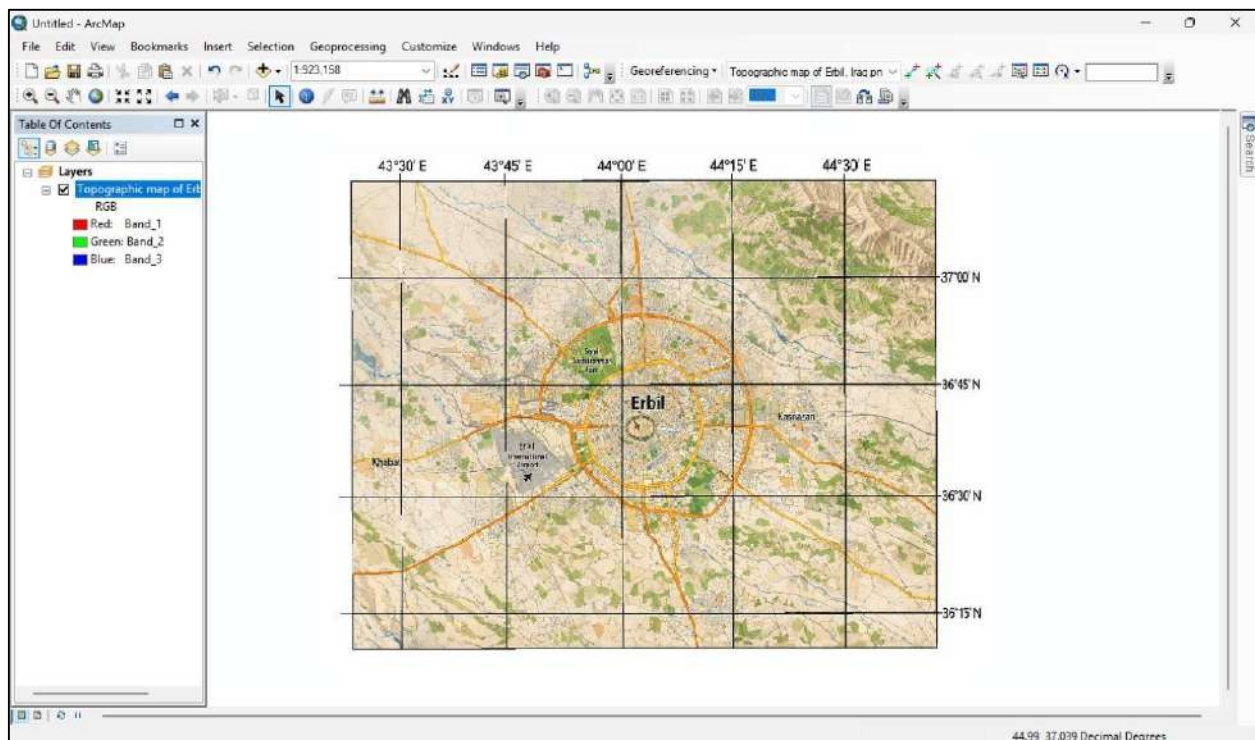


Figure (5) georeferencing for a printed map

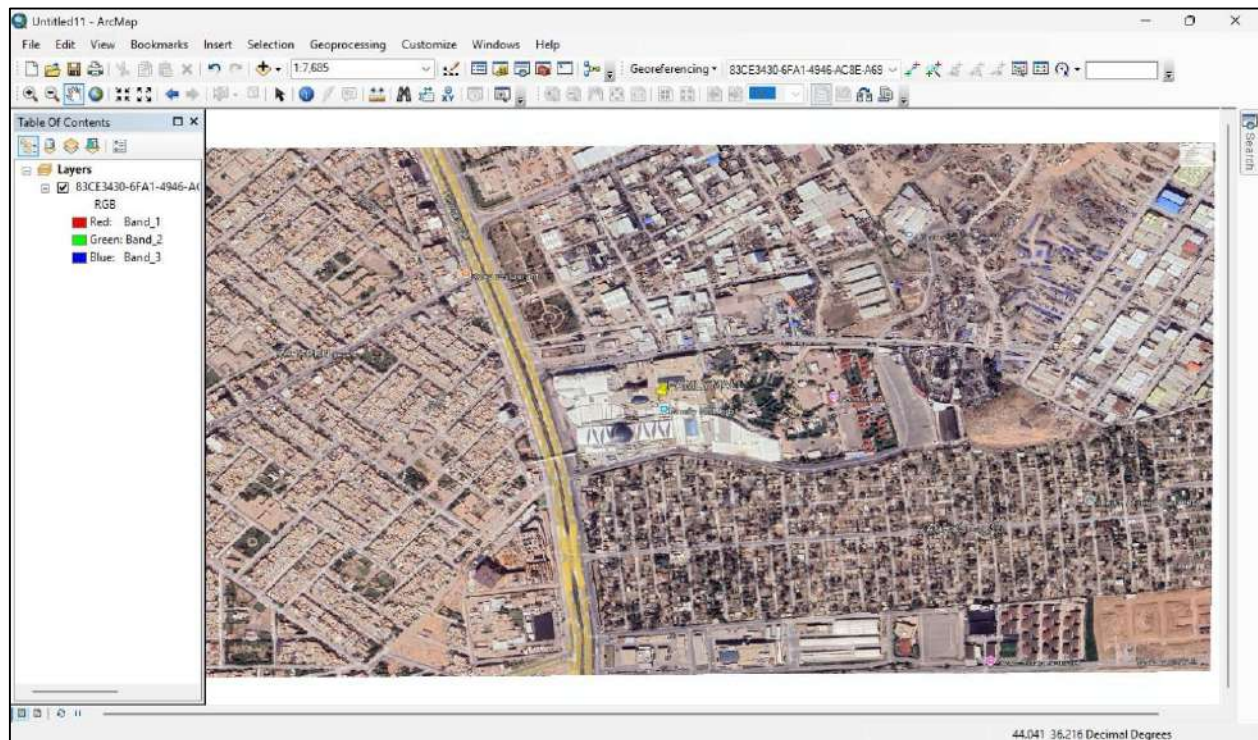


Figure (6) georeferencing for a image to image

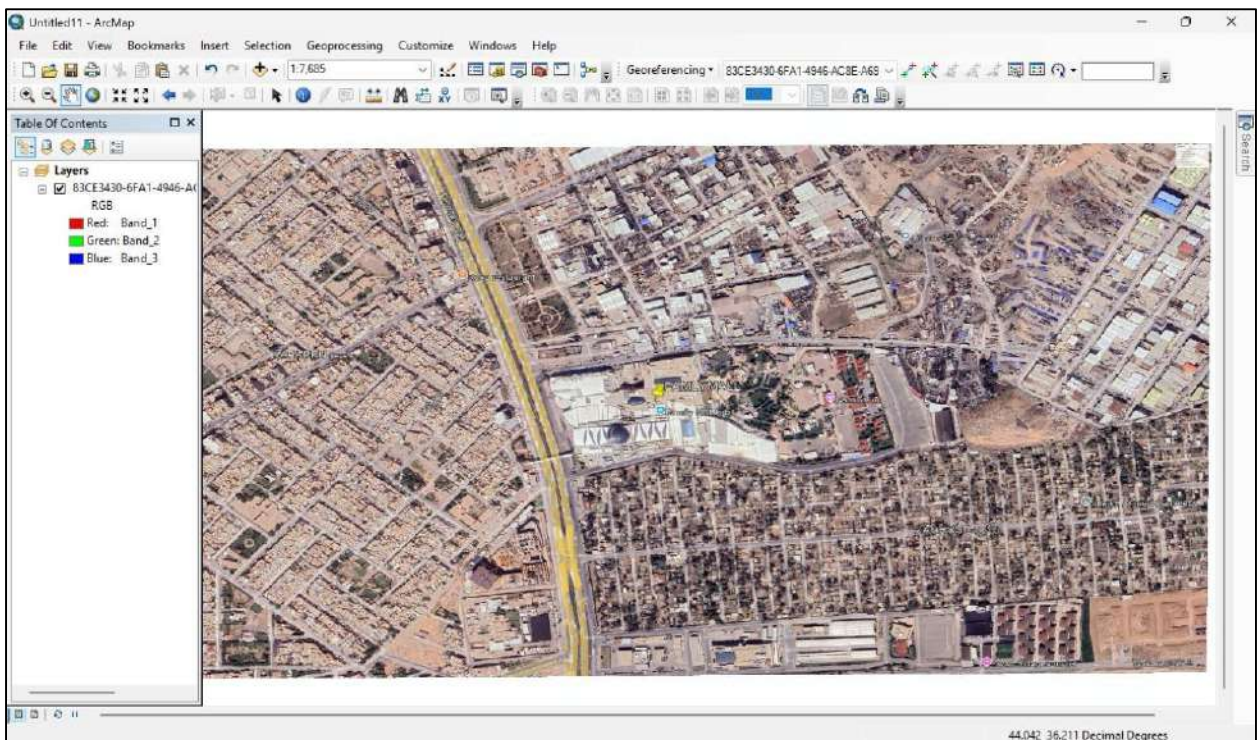


Figure (7) georeferencing for a image to Gps

Table (1): RMSE values for the applied georeferencing methods

Method	Total RMSE (m)
Printed Coordinates	0.005368
Image-to-Image Registration	0.000206
GCP-Based (GPS)	0.000206

The results indicate that both the image-to-image and GCP-based methods achieved substantially lower RMSE values compared to the printed coordinate method.

3.3 Analysis of Georeferencing Accuracy

The printed coordinate method resulted in a relatively higher RMSE value (0.005368). This can be attributed to inherent limitations associated with scanned maps, including potential geometric distortions introduced during the scanning process, as well as uncertainties in reading and assigning grid-based coordinates. Nevertheless, the obtained accuracy remains within an acceptable range for medium-scale spatial analysis.

In contrast, the image-to-image registration method produced a significantly lower RMSE value (0.000206), indicating a high level of geometric agreement between the datasets. This reflects the effectiveness of matching common features between the reference image and the target dataset.

Similarly, the GCP-based method yielded an RMSE value (0.000206) nearly identical to that of the image-to-image approach. This suggests a strong consistency between the selected ground control points and the spatial reference framework used in the analysis.

3.4 Discussion

Although the image-to-image and GCP-based methods produced nearly identical RMSE values, it is essential to distinguish between **relative accuracy** and **absolute positional accuracy**.

The image-to-image method primarily reflects relative accuracy, as it depends on the geometric correctness of the reference image. Any inherent positional errors in the reference dataset are propagated into the final result. Therefore, the low RMSE value in this case indicates strong internal alignment rather than true ground accuracy.

On the other hand, the GCP-based method relies on ground-referenced coordinates obtained through GPS measurements. Consequently, it provides a more reliable representation of real-world positions, even when the RMSE values are similar to those obtained from image-to-image registration.

The close similarity between the RMSE values of the second and third methods may be attributed to the comparable spatial quality of the reference datasets or the consistent selection of control points across both methods.

3.5 Interpretation of Results

The comparative analysis demonstrates that:

- The printed coordinate method provides moderate spatial accuracy and is influenced by the quality of the scanned map.
- The image-to-image method achieves very low RMSE values, indicating high internal consistency, but reflects relative accuracy.
- The GCP-based method offers both low RMSE and higher reliability in representing actual ground positions.

These findings emphasize that RMSE alone is insufficient to fully evaluate georeferencing performance, and the nature of the reference data must also be considered.

3.6

The results confirm that the choice of georeferencing technique significantly affects spatial accuracy. While numerical indicators such as RMSE provide valuable insights into internal consistency, a comprehensive evaluation must also consider the reliability of the reference data. Among the tested methods, the GCP-based approach is considered the most robust for applications requiring accurate real-world positioning.

Chapter Four

Conclusions & Recommendations

4.1 Conclusions

This study aimed to evaluate and compare the spatial accuracy of three georeferencing techniques, namely: georeferencing using printed coordinates, image-to-image registration, and ground control points (GCPs) based on GPS measurements. The comparison was conducted under controlled conditions by applying the same number of control points, transformation model, and coordinate system.

The results demonstrated that the choice of georeferencing technique has a significant impact on spatial accuracy. The printed coordinate method produced a relatively higher RMSE value, which can be attributed to distortions in the scanned map and limitations in the original cartographic source. Despite this, the method provided acceptable accuracy for general mapping purposes.

The image-to-image registration method yielded the lowest RMSE values, indicating a high level of geometric consistency between datasets. However, this accuracy is considered relative, as it depends on the positional accuracy of the reference image. Therefore, the low RMSE values do not necessarily reflect true ground accuracy.

The GCP-based method, which relies on GPS measurements, also produced very low RMSE values comparable to the image-to-image method. This indicates strong internal consistency while also providing a more reliable representation of real-world positions. Consequently, this method is considered the most robust for applications requiring accurate spatial positioning.

Overall, the findings confirm that RMSE is a useful indicator for evaluating internal accuracy, but it should not be used as the sole criterion for selecting the best georeferencing method. The reliability of the reference data plays a critical role in determining the overall positional accuracy.

4.2 Recommendations

Based on the results of this study, the following recommendations are proposed:

1. **Use of GCP-Based Georeferencing**

It is recommended to use ground control points collected through GPS or high-precision surveying techniques for applications that require high positional accuracy.

2. **Careful Selection of Control Points**

Control points should be clearly identifiable, well distributed across the study area, and located on stable features to minimize transformation errors.

3. **Consideration of Data Quality**

The accuracy of the reference dataset (e.g., satellite images or maps) should be carefully evaluated before use, as it directly affects the final georeferencing results.

4. **Avoid Sole Dependence on RMSE**

RMSE should be complemented with additional evaluation methods or visual inspection to ensure reliable spatial accuracy.

5. **Use of High-Resolution Data**

High-resolution images and accurate base maps are recommended to improve the quality of georeferencing.

4.3 Future Work

Future studies may consider:

- Evaluating additional transformation models such as higher-order polynomial transformations.
- Increasing the number of control points to assess their effect on spatial accuracy.

- Incorporating independent check points to evaluate external accuracy.
- Applying the methodology to different geographic areas and datasets for broader validation.

4.4 Final Remark

This study highlights the importance of selecting appropriate georeferencing techniques based on the nature of the available data and the required level of accuracy. A balanced approach that considers both quantitative indicators and data reliability is essential for achieving accurate and meaningful spatial analysis.

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Appendix

georeferencing tables

Appendix (1) table of georeferencing for a printed map

Link								
Total RMS Error: Forward:0.00536805								
Link	X Source	Y Source	<X Map>	Y Map	Residual_x	Residual_y	Residual	
1	1209.02667758	-258.01391162	44.50000000	37.00000000	-0.00114236	0.00452531	0.00466727	
2	1204.75204583	-683.91882160	44.50000000	36.50000000	0.00118347	-0.00643202	0.00653999	
6	1208.79364382	-468.60531496	44.50000000	36.75000000	-0.00180793	-0.00366681	0.00408829	
5	688.60901881	-258.40797391	44.00000000	37.00000000	0.00128909	0.00564066	0.00578608	
7	688.39310481	-467.37767745	44.00000000	36.75000000	0.00061385	-0.00441357	0.00445606	
9	688.14596384	-688.34979824	44.00000000	36.50000000	-0.00008201	-0.00068622	0.00069110	
10	685.24279833	-915.96374432	44.00000000	36.25000000	0.00175829	0.01067087	0.01081477	
3	170.33799707	-253.81810847	43.50000000	37.00000000	0.00166917	0.00103057	0.00196168	
4	173.21553989	-684.81557033	43.50000000	36.50000000	-0.00293155	-0.00408844	0.00503084	
8	171.69670185	-468.40107445	43.50000000	36.75000000	-0.00055002	-0.00258035	0.00263832	

Appendix (2) table of georeferencing for a image to image

Link								
Total RMS Error: Forward:0.000206898								
Link	X Source	Y Source	<X Map>	Y Map	Residual_x	Residual_y	Residual	
9	1214.12381367	-72.59699581	44.05555556	36.21388889	0.00004225	-0.00020257	0.00020693	
1	1134.07322519	-653.53996293	44.05416667	36.20666667	-0.00002187	0.00013319	0.00013497	
4	1081.77910016	-301.36535162	44.05333333	36.21111111	-0.00004800	0.00000190	0.00004803	
8	919.65598805	-700.85314747	44.05083333	36.20611111	0.00007318	0.00020555	0.00021818	
6	753.01576549	-92.73981921	44.04805556	36.21388889	-0.00009141	0.00008678	0.00012605	
5	506.53307594	-669.04001845	44.04416667	36.20583333	0.00000231	-0.00046126	0.00046126	
2	429.49701488	-50.89277041	44.04305556	36.21444444	0.00007244	0.00011752	0.00013805	
3	155.57269587	-563.81049150	44.03861111	36.20777778	0.00004385	0.00013594	0.00014283	
7	81.90433829	-340.70654710	44.03722222	36.21055556	-0.00018617	0.00001739	0.00018698	
10	27.38549834	-144.18789419	44.03666667	36.21305556	0.00011342	-0.00003443	0.00011853	

Appendix (3) table of georeferencing for a image to GPS

Link								
Total RMS Error: Forward:0.000206896								
Link	X Source	Y Source	<X Map>	Y Map	Residual_x	Residual_y	Residual	
9	1214.12381367	-72.59699581	44.05583333	36.21416667	0.00004225	-0.00020257	0.00020692	
1	1134.07322519	-653.53996293	44.05444444	36.20694444	-0.00002188	0.00013318	0.00013497	
4	1081.77910016	-301.36535162	44.05361111	36.21138889	-0.00004799	0.00000190	0.00004803	
8	919.65598805	-700.85314747	44.05111111	36.20638889	0.00007318	0.00020555	0.00021819	
6	753.01576549	-92.73981921	44.04833333	36.21416667	-0.00009142	0.00008678	0.00012605	
5	506.53307594	-669.04001845	44.04444444	36.20611111	0.00000230	-0.00046126	0.00046126	
2	429.49701488	-50.89277041	44.04333333	36.21472222	0.00007244	0.00011752	0.00013805	
3	155.57269587	-563.81049150	44.03888889	36.20805556	0.00004386	0.00013594	0.00014284	
7	81.90433829	-340.70654710	44.03750000	36.21083333	-0.00018616	0.00001738	0.00018697	
10	27.38549834	-144.18789419	44.03694444	36.21333333	0.00011341	-0.00003444	0.00011853	

Summary

Georeferencing is a fundamental process in Geographic Information Systems (GIS) that directly affects the spatial accuracy of map production and analysis. This study aimed to evaluate and compare the performance of three commonly used georeferencing techniques: printed coordinates, image-to-image matching, and ground control points (GCPs) based on GPS measurements. A consistent methodology was adopted, employing the same number of control points (ten), a uniform coordinate system, and a first-order polynomial transformation model. The accuracy of each method was evaluated using the root mean squared error (RMSE) as a quantitative indicator. The results showed that the printed coordinates method produced a higher RMSE value (0.005368), indicating moderate spatial accuracy. In contrast, both the image-to-image matching method and the ground control point-based method achieved significantly lower RMSE values (0.000206), reflecting a high level of internal consistency. However, the results revealed that the RMSE value alone does not represent accuracy. The study found that georeferencing, while showing a lower error value between two images, still reflects a relative accuracy dependent on the quality of the reference image. On the other hand, the ground control point (GCP) method provides a more reliable representation of real-world locations due to its use of field reference data.

The study concludes that the choice of georeferencing technique should consider both numerical accuracy and the reliability of the reference data used. It recommends using the GCP method in applications requiring high positional accuracy.

Keywords: Georeferencing, Geographic Information Systems (GIS), Root Mean Squared Error (RMSE), Ground Control Points, Spatial Accuracy



جمهورية العراق

وزارة التعليم العالي والبحث العلمي جامعة

الكتاب

كلية الهندسة

قسم هندسة المساحة

تحليل مقارنة لتقنيات الإرجاع الجغرافي لتحسين الدقة المكانية في رسم الخرائط

بحث مقدم الى مجلس كلية الهندسة – جامعة الكتاب وهو جزء من متطلبات نيل شهادة بكالوريوس في
قسم هندسة المساحة

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1447هـ..... 2026م

Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Al-kitab
College of Engineering



GIS-Based Spatial Accessibility, Coverage, and Density Analysis of Hospitals in Kirkuk City

A Project Submitted to
The College of Engineering, University of Al-kitab , Department
Surveying in Partial Fulfillment for the Bachelor of Engineering
Surveying

By

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2026 A.D

1447 A.H

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَمَا أُوتِيتُمْ مِّنَ الْعِلْمِ إِلَّا قَلِيلًا

صدق الله العظيم

سورة الإسراء

الآية: 85

*I certify that this project entitled "Identifying
Kirkuk hospitals using Geographic Information
Systems (GIS) software" was prepared by the
Fourth-year student*

Mahmoud Qasim Muhammad

Muhammad Abdul Latif Mahmoud

*under my supervision at the College of Engineering,
Surveying Department of Al-kitab in partial
fulfilment of the graduation requirements for the
Bachelor Degree in Engineering Surveying .*

Supervisor signature

Dr. Shaki Khader

Date:

Dedication

*To the Prophet of Mercy, the Chosen One, Muhammad, may
.God bless him and his pure family and companions*

.To our beloved and dear parents

.To our dear brothers and sisters

.To my esteemed teachers. To all our friends

*And to everyone who supported us and gave us confidence and
.patience throughout the school year*

Acknowledgment

Praise be to Allah, the Generous, the Beneficent, Who created humankind and taught them eloquence. Peace and blessings be upon our Prophet Muhammad, whom Allah sent as a bearer of good tidings and a warner, calling to Allah with wisdom and beautiful admonition. He is the teacher of mankind and jinn.

May peace and blessings be upon him, his family, his companions, and those who follow them in righteousness until the Day of Judgment.

Now then:

We are pleased, having completed our research, by the grace of Allah Almighty, to express our thanks and gratitude to Professor (Dr. Shaki Khader) Thank you to him for his generous supervision of this research. He has provided ongoing academic support, valuable guidance, and precise observations, which had a significant impact on the completion of this research.

We also extend our sincere thanks to all those who have offered us a helping hand and assistance, praying to Allah Almighty to guide us all to what is best for the service of our beloved country.

Abstract

Geographic Information Systems (GIS) play a vital role in modern healthcare planning and management by enabling the spatial analysis of medical facilities and population distribution. This study focuses on identifying and analyzing the locations of hospitals in Kirkuk Governorate using GIS software. Spatial data related to hospital locations were collected and integrated into a GIS environment to produce accurate digital maps. Spatial analysis tools, including hospital point mapping, buffer-based service coverage analysis, Kernel Density Estimation, and simplified distance-based accessibility estimation, were applied to evaluate hospital distribution, coverage, and relative accessibility across Kirkuk.

The results demonstrate that GIS is an effective tool for visualizing the spatial distribution of hospitals and identifying areas with limited access to healthcare services. The study highlights disparities in service coverage between central and peripheral areas and emphasizes the need for improved planning to ensure equitable access. The findings can support decision-makers in optimizing hospital locations, improving emergency response times, and enhancing the overall efficiency of the healthcare system in Kirkuk. This research confirms that GIS-based analysis

provides a reliable scientific approach for healthcare planning and sustainable urban development.

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Chapter One

Introduction

1.1 Introduction

Health services are the main pillar of human development in any society, as the progress of countries is measured by their ability to provide efficient and easily accessible medical care to all their citizens. With rapid urbanization and increasing population growth in cities, traditional planning of health services has become insufficient to meet contemporary challenges, which has necessitated relying on modern spatial technologies to ensure a fair and efficient distribution of medical facilities.

Geographic Information Systems (GIS) is a revolutionary tool in the field of health geography and urban planning; they are not only about creating digital maps, but their capabilities extend to the analysis of spatial and descriptive data, and linking the geographical locations of hospitals to population characteristics and road networks. This technology allows decision makers to understand the service scope of each hospital, identify "blind areas" that lack services, as well as evaluate the efficiency of existing locations based on the criteria of access, distance and time.

The city of Kirkuk was chosen as a study area due to its geographical and strategic importance in Iraq, and the recent major

demographic and urban transformations. The city is under increasing pressure on its health institutions, making the process of identifying and analyzing the geographical locations of hospitals an urgent necessity to determine their suitability for current and future population distribution.

This research aims to use the ArcGIS program to identify and draw an accurate digital map of Kirkuk hospitals, and analyze the efficiency of their spatial distribution using statistical spatial analysis tools. Through this, the study seeks to provide a scientific vision that contributes to the development of the health reality of the city and supports future expansion plans for medical facilities to ensure that the service reaches every citizen as soon as possible and with the least effort.

1.2 Problem Statement

Kirkuk Governorate has a population of approximately 1,600,000 people served by 30 hospitals, yielding a hospital-to-population ratio of roughly one hospital per 53,000 inhabitants. This indicates relatively low hospital availability when compared with commonly used healthcare facility density indicators. In addition, hospital bed availability remains limited, with estimates suggesting fewer than 1.5 beds per 1,000 residents, which is low compared with commonly used international health system comparison values. These disparities are spatially uneven: central districts concentrate the majority of healthcare facilities, while peripheral and suburban areas remain underserved. Given Kirkuk's diverse and growing population, the absence of evidence-based spatial planning has contributed to inequities in healthcare access. This study addresses the need for a systematic GIS-based spatial assessment to quantify and visualize these disparities as a foundation for evidence-based healthcare infrastructure planning.

1.3. Research Objectives

- To georeferentially map the locations of all 30 officially registered hospitals in Kirkuk City using GPS field data and ArcGIS Pro, with a positional accuracy of 35 meters.
- To classify and map all hospitals by ownership type (public/private) and calculate per-capita hospital and bed ratios across Kirkuk's administrative districts using attribute analysis in GIS.
- To quantify the spatial distribution and relative accessibility of hospitals using Kernel Density Estimation, exploratory 1 km buffer analysis, main 5 km service coverage buffer analysis, and simplified distance-based travel time estimation, and to calculate spatial area coverage within defined service zones.
- To develop spatially-grounded, evidence-based recommendations for urban healthcare planners identifying specific underserved districts and proposing priority areas for future hospital development based on GIS analysis findings.

1.4 The Importance of the Research

- It assists healthcare authorities in better future planning.
- It contributes to the equitable distribution of healthcare services.
- It provides a scientific reference for students of geodesy engineering and geographic information systems.
- It helps reduce hospital response times in emergency situation

Chapter Two

Literature Review

2.1 Introduction to GIS in Healthcare Studies

Geographic Information Systems (GIS) have become an essential tool in healthcare research due to their ability to integrate, manage, analyze, and visualize spatial and non-spatial data. In healthcare studies, GIS is widely used to assess the spatial distribution of medical facilities, identify service gaps, and support evidence-based decision-making. The integration of health data with geographic information allows researchers and planners to understand spatial patterns and relationships that are not easily detected using traditional statistical methods.

Previous studies have emphasized that GIS enhances the efficiency of healthcare planning by providing accurate spatial representations of hospitals, population distribution, and transportation networks. This capability is particularly important in rapidly growing urban areas where healthcare demand is continuously increasing.

2.2 Spatial Distribution Analysis of Hospitals Using GIS

Many researchers have applied GIS techniques to analyze the spatial distribution of hospitals and healthcare centers. Commonly used methods include Nearest Neighbor Analysis, spatial autocorrelation, and kernel density analysis. These tools help determine whether hospitals are clustered, randomly distributed, or dispersed across a city or region.

Studies have shown that uneven spatial distribution of hospitals often results in service inequality, where some areas experience excessive pressure on healthcare facilities while others remain underserved. GIS-based spatial analysis provides a reliable approach for identifying such imbalances and supporting optimal facility location planning.

2.3 Accessibility and Network Analysis in Healthcare GIS

Accessibility to healthcare services is a critical indicator of healthcare system performance. GIS network analysis is frequently used to evaluate travel distance, travel time, and service coverage areas based on road networks. Service area analysis helps identify populations that can access hospitals within a specific time or distance threshold.

Several studies confirm that GIS-based accessibility analysis significantly improves healthcare planning by revealing areas with limited access to hospitals. This approach is particularly useful in emergency healthcare planning, where response time is a decisive factor in patient outcomes.

2.4 GIS Applications in Healthcare Planning in Developing Countries

In developing countries, GIS has proven to be a cost-effective and powerful tool for healthcare planning and management. Researchers have used GIS to evaluate healthcare facility distribution, assess population coverage, and identify priority areas for new hospital construction.

However, the literature also highlights challenges such as data scarcity, outdated records, and limited technical capacity. Despite these limitations, the increasing availability of satellite imagery, open-source GIS software, and publicly accessible spatial datasets has significantly enhanced the applicability of GIS in healthcare studies in developing regions.

2.5 Urban Healthcare Services and GIS

Urbanization has a strong influence on the demand for healthcare services. GIS has been widely applied to study the relationship between urban growth, population density, and hospital distribution. Research indicates that unplanned urban expansion often leads to spatial disparities in healthcare service provision.

GIS-based urban health studies emphasize the importance of integrating land use data, population density maps, and transportation networks to improve healthcare accessibility and sustainability in urban environments.

2.6 GIS-Based Studies on Hospital Mapping in Middle Eastern and Iraqi Cities

Several studies conducted in Middle Eastern countries demonstrate the effectiveness of GIS in mapping and analyzing hospital locations. Al-Ahmadi et al. (2013) applied GIS-based spatial analysis to assess hospital distribution in Riyadh, Saudi Arabia, revealing significant service gaps in peripheral neighborhoods and recommending buffer-zone-based planning frameworks. Similarly, Mansour (2016) used network analysis in GIS to evaluate healthcare accessibility in Egyptian cities, finding that over 35% of urban residents lived beyond a 30-minute travel threshold from the nearest hospital. In Jordan, Haddad and Shaheen (2018) employed Kernel Density Estimation and service area analysis to map spatial inequity in hospital coverage across Amman, with results showing that low-income districts had per-capita hospital bed ratios four times lower than affluent areas. These regional studies establish the methodological precedent for the buffer analysis, KDE, and distance-based accessibility modeling applied in the current study.

In Iraq, the application of GIS in healthcare planning is still developing but growing. Al-Taei and Mahmoud (2019) conducted a GIS-based spatial analysis of primary healthcare centers in Baghdad, demonstrating that central districts had 2.3 times the healthcare facility density of

peripheral ones, and identifying specific neighborhoods as priority areas for new facility construction. Hassan (2021) mapped hospital distribution in Mosul using ArcGIS following post-conflict reconstruction, applying buffer analysis and population overlay to assess recovery of healthcare coverage. Al-Samarrai (2020) examined spatial accessibility of hospitals in Basra Governorate, finding critical shortfalls in rural districts and recommending GIS-based site selection modeling for future facilities. The city of Kirkuk, due to its strategic importance, ethnically diverse population, and post-2003 urban growth, represents a compelling and underexplored case study for applying GIS-based hospital identification and spatial analysis. Unlike the cities reviewed above, no study to date has applied systematic GIS spatial analysis specifically to Kirkuk's hospital network using current field-collected GPS data, representing a clear gap that this study addresses.

2.7 Research Gap and Relevance of the Current Study

A systematic search of academic databases including Scopus, Google Scholar, and the Iraqi Academic Scientific Journals platform was conducted using the keywords: "GIS hospital Kirkuk," "healthcare spatial analysis Iraq," "hospital mapping Kirkuk," and "GIS healthcare planning Iraq." The search returned no peer-reviewed studies specifically applying GIS spatial analysis to hospital distribution in Kirkuk City using field-

collected data. The studies reviewed in Sections 2.4 and 2.6 confirm that while GIS healthcare research in Iraq has grown since 2015, it has focused predominantly on Baghdad, Basra, and Mosul. Kirkuk's complex administrative history and population diversity have historically limited systematic planning studies. Existing studies reviewed either lack detailed spatial analysis at the intra-urban level, do not incorporate GPS-verified hospital locations, or fail to integrate comprehensive accessibility and density analysis. This study is therefore positioned to fill a documented gap by providing the first systematic, GIS-based spatial analysis of hospital distribution in Kirkuk using current (2024) field data.

Therefore, this study aims to fill this gap by using GIS software to accurately identify, map, and analyze the spatial distribution and accessibility of hospitals in Kirkuk. The findings are expected to support healthcare planners and decision-makers in improving hospital service efficiency and achieving equitable healthcare access.

2.8GIS in Surveying Engineering

GIS integrates spatial and attribute data, enabling surveyors to collect, store, analyze, and visualize geographic information. In surveying engineering, GIS applications include:

Urban planning and land management

Infrastructure mapping (roads, bridges, utilities)

Healthcare accessibility and emergency planning

2.9 Previous Studies

This section presents a structured review of previous studies directly relevant to the methods and objectives of the current research, organized thematically. Each study is evaluated in terms of its geographic context, analytical methods, key findings, and relevance to the present work.

Study 1 — Al-Ahmadi et al. (2013): GIS-Based Spatial Analysis of Hospital Distribution in Riyadh, Saudi Arabia. This study applied buffer analysis and service area modeling in ArcGIS to assess spatial coverage of 47 hospitals across Riyadh's administrative districts. Key findings revealed that 29% of the city's residential area fell outside a 5 km hospital service zone, concentrated in newly developed peripheral suburbs. The study is directly relevant to the current research as it established the 5 km buffer threshold as a standard accessibility benchmark in Arab urban contexts, a parameter adopted in the present study's buffer analysis of Kirkuk hospitals.

Study 2 — Mansour (2016): Network-Based Accessibility Assessment of Healthcare in Egyptian Cities. Using ArcGIS Network Analyst, Mansour assessed drive-time accessibility to hospitals in three

Egyptian governorates. The study found that 35% of urban residents exceeded a 30-minute threshold to the nearest hospital, with the greatest deficits in low-income districts. The study's methodological approach informed the travel time estimation framework used in the current research, though the current study employed a simplified distance-based formula rather than full network analysis due to data limitations (see Section 3.3.4).

Study 3 — Al-Taei and Mahmoud (2019): Spatial Analysis of Primary Healthcare Centers in Baghdad. This Iraqi study analyzed the distribution of 112 primary healthcare centers across Baghdad using GIS, employing Kernel Density Estimation with a 2,000 m search radius and population overlay analysis. The study found a 2.3:1 ratio in healthcare density between central and peripheral districts and used spatial statistics to validate clustering patterns. This study is the closest precedent to the current research in terms of national context and methodology, and its KDE parameters directly informed the bandwidth selection in the present study's density analysis.

Study 4 — Hassan (2021): Post-Conflict Hospital Mapping in Mosul, Iraq. Hassan applied GPS data collection and ArcGIS mapping to document hospital locations in Mosul following the 2017 liberation, using buffer analysis and population overlap to quantify service recovery. The study established a field-collection protocol for GPS survey of hospital

locations in an Iraqi city context, directly comparable to the methodology adopted in the current study for Kirkuk. Hassan's findings that hospital coverage was concentrated within a 3 km radius of the city center align with patterns observed in the present study.

Study 5 — Haddad and Shaheen (2018): Spatial Equity in Hospital Coverage in Amman, Jordan. Using KDE and service area modeling in ArcGIS, this study quantified healthcare spatial equity across Amman's districts, finding that low-income areas had per-capita hospital bed ratios four times lower than affluent areas. The study introduced a spatial equity index combining hospital density, population demand, and buffer coverage, a conceptual framework that informed the demand-based interpretation of results in Chapter 5 of the current study. Its recommendation for at least one additional hospital per underserved district mirrors the planning recommendations developed for western Kirkuk in this research.

Chapter Three

MATERIALS AND

METHODS

3.1 Introduction

All spatial datasets used in this study were standardized to the WGS 84 / UTM Zone 38N coordinate reference system to ensure spatial consistency, measurement accuracy, and compatibility across all GIS analyses. The selection of this projected coordinate system is appropriate for the study area of Kirkuk, as it minimizes spatial distortion by using a Universal Transverse Mercator (UTM) projection suited for mid-latitude regions.

The transformation process from geographic coordinates (WGS84 Geographic Coordinate System, GCS) to projected coordinates (WGS 84 / UTM Zone 38N) was carried out using ArcGIS Pro software through the “Project” geoprocessing tool. This tool applies a standardized mathematical transformation based on the UTM projection parameters, including central meridian, scale factor, false easting, and false northing specific to Zone 38N.

The coordinate system transformation was performed following these steps:

Import spatial datasets (hospital locations, administrative boundaries, and road networks) into ArcGIS Pro.

Verify the original coordinate system of each dataset (commonly WGS84 geographic coordinates).

Use the “Project” tool available in ArcToolbox under Data Management Tools → Projections and Transformations

Select the input dataset to be transformed.

Define the output coordinate system as WGS 84 / UTM Zone 38N.

Apply the appropriate geographic transformation method if required (WGS84 to UTM conversion).

Generate and save the reprojected dataset for use in subsequent spatial analysis.

(Transformation Criteria)

The coordinate transformation process followed standard GIS geodetic principles, including:

Use of a projected coordinate system (UTM) to preserve spatial distance accuracy.

Minimization of distortion in linear distance measurements suitable for urban-scale analysis.

Application of a uniform spatial reference system across all datasets to ensure analytical consistency.

Compliance with ArcGIS default geodetic transformation parameters for WGS84-based datasets.

This transformation ensures that all spatial analyses, including distance measurement, network analysis, and density estimation, are performed in a consistent metric-based coordinate system, thereby improving the reliability and accuracy of spatial outputs.

3.2 Study Area

The spatial analysis in this study focuses on Kirkuk City within its municipal boundary. However, some demographic indicators are discussed at the governorate level because official population statistics are more readily available at that scale. Therefore, population-based interpretations in this study are considered supportive and approximate, while the main GIS analysis remains focused on Kirkuk City.

Kirkuk **Governorate** covers an expansive 9,679 square kilometers. The spatial analysis in this research, however, focuses specifically on **Kirkuk City** within its municipal boundaries to ensure a precise urban-scale assessment, north of Baghdad, Iraq's capital, occupies a pivotal role Within the nation's socio-economic and historical framework. Encircled by the governorates of Tikrit to the south and southwest, Erbil to the north, and Sulaimaniyah to the northeast, longitudes 44°10' to 44°30' E and latitudes 35°20' to 35°32' N. The population of Kirkuk Governorate is approximately 1,600,000 people.

Kirkuk's significance is multifaceted. It boasts abundant subterranean resources, notably oil and gas deposits, contributing substantially to the city's economic development and Iraq's energy

production. The region's fertile agricultural plains have historically supported robust agricultural activities, enhancing economic prosperity and food security. The city's strategic geographical location further underscores its importance, serving as a critical junction connecting northern and central Iraq, facilitating trade and commerce. Additionally, Kirkuk is steeped in cultural heritage, with the Kirkuk Citadel, dating back to 850 B.C., as a prominent historical site, symbolizing the city's enduring significance. In scholarly research, comprehending Kirkuk City's diverse attributes is essential for a comprehensive understanding of its role in the broader Iraqi context. Figure 1 states the study area (Kirkuk City).

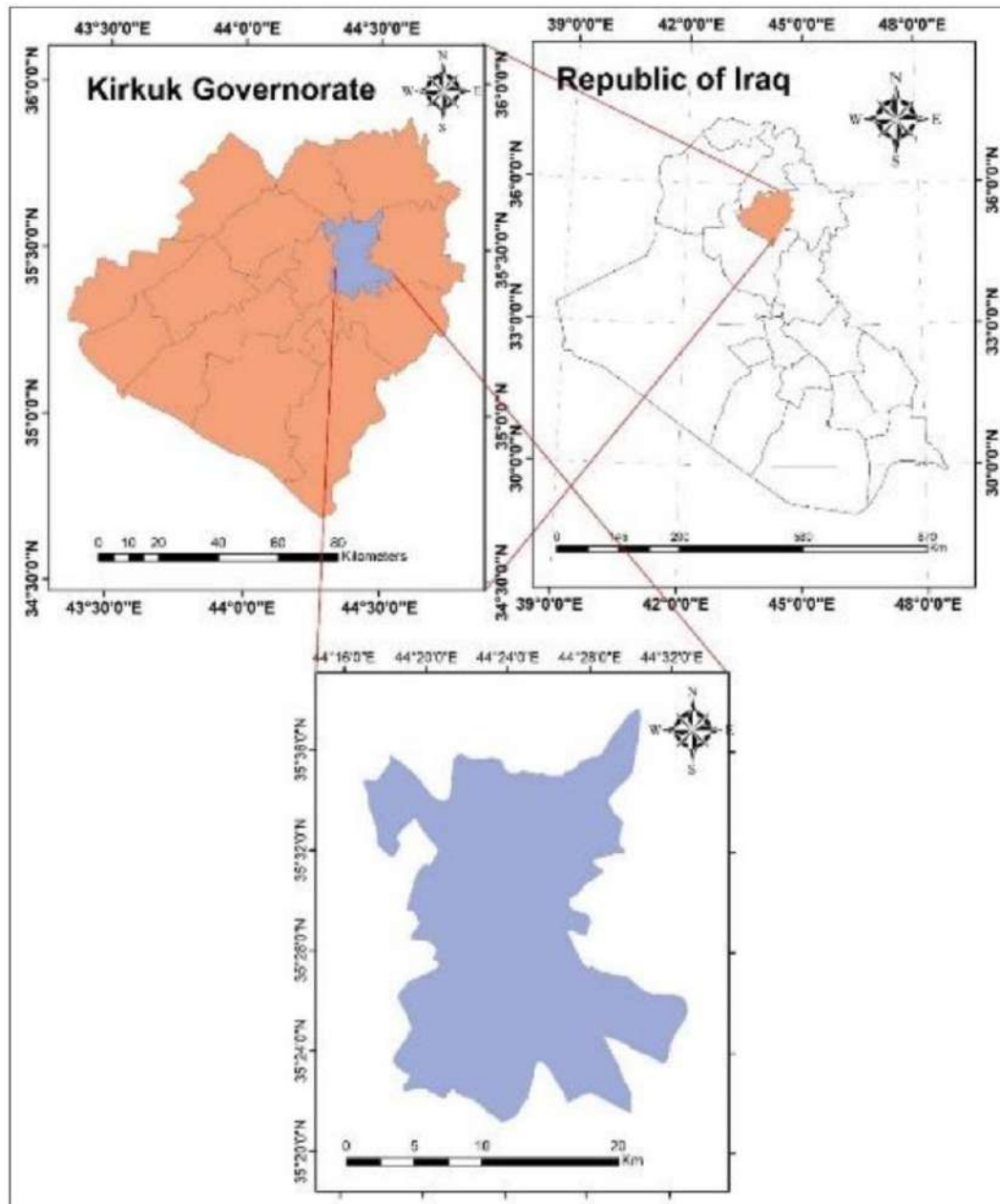


Figure 3.1: The research study area (Kirkuk City).

Table A (3-1): Spatial Analysis Tools and Parameters (Revised)

Analysis Type	Parameter	Description
Buffer Analysis (Exploratory)	1 km	Preliminary proximity assessment only
Buffer Analysis (Main)	5 km	Hospital service coverage based on literature
Kernel Density	Fixed 2,000 m search radius, 100 m cell size	Identification of spatial concentration
Simplified Distance Analysis	Travel time (minutes)	Realistic accessibility assessment

Table B (3-1): Analytical tools used in the study

No.	GIS Tool / Analysis	Purpose	Software
1	Point Mapping	Mapping hospital locations using GPS coordinates	ArcGIS / QGIS
2	Attribute Analysis	Classification of hospitals (public/private, capacity, services)	ArcGIS
3	Buffer Analysis	Evaluation of spatial service coverage (1 km exploratory buffer and 5 km main hospital service coverage buffer)	ArcGIS
4	Kernel Density Analysis	Identification of hospital concentration and low-density areas	ArcGIS
5	Simplified Accessibility Estimation	Travel distance and travel time estimation to nearest hospitals	GIS distance measurement and assumed travel speed method

3.3 Data Sources

Multiple spatial and non-spatial datasets were utilized to achieve the objectives of this study. All datasets were prepared and processed within a GIS environment.

3.3.1 Hospital Data

Hospital location data included public and private hospitals operating within Kirkuk City. The dataset contained hospital names, types, and geographic coordinates. The data were obtained from the local Directorate of Health and verified through field observations and high-resolution satellite imagery.

3.3.2 Road Network Data

The road network dataset obtained from Open StreetMap was used as a reference layer to support accessibility interpretation. Basic geometry and connectivity checks were conducted to reduce obvious road-data errors. However, a full topological network dataset suitable for precise Network Analyst routing was not developed in this study. Therefore, accessibility results were estimated using distance-based calculations rather than full network-based routing.

The topology inspection revealed a total of 47 spatial and geometric errors, which were identified and classified into three main categories: (1) disconnected road segments (gaps) — 23 instances, (2) dangling or incomplete connections (dead-end links not connected to the main network) — 18 instances, and (3) overlapping or redundant road segments — 6 instances.

The correction process was carried out using ArcGIS Pro geoprocessing tools, including “Repair Geometry”, “Integrate”, and manual editing in the Editor environment. Additionally, topology rules such as “Must Not Have Dangles”, “Must Not Have Gaps”, and “Must Not Overlap” were applied to systematically detect and validate network inconsistencies.

After correction, network connectivity was verified using GIS topology tools by visually inspecting road segment connections and performing snap checks across the study area. This process confirmed that the network was sufficiently connected for proximity and distance-based accessibility estimation.

3.3.3 Administrative Boundaries

Administrative boundary data defining the city limits and municipal sectors were obtained from official local government sources and used to spatially organize the analysis results.

3.3.4 Population Data

Population distribution data were utilized as a supportive layer to provide context for healthcare demand and spatial equity. While these data were spatially overlaid with hospital service zones to identify potential pressure points, they were not used to calculate population-weighted coverage percentages. The results remain a representation of **spatial area coverage**.

3.4 Coordinate Reference System

All spatial datasets were projected using the **Universal Transverse Mercator (UTM)** coordinate system, **Zone 38N**, based on the **World Geodetic System 1984 (WGS 84)** datum. This projection was selected to ensure spatial accuracy and consistency in distance-based analyses such as buffering, network analysis, and density estimation.

3.5 GIS Software and Tools

The spatial analyses were conducted using **ArcGIS Pro** software. Several GIS tools and extensions were employed, including:

- Simplified distance-based accessibility estimation (GIS distance measurement and assumed travel speed)
- Spatial Analyst for density and interpolation analysis
- Geoprocessing tools for data preparation and spatial modeling

3.6 Methodological Framework

The methodological framework of this study consisted of three main analytical components: accessibility analysis, service coverage analysis, and hospital density analysis. The workflow is illustrated conceptually through sequential GIS processing steps.

3.7 Accessibility and Service Coverage Analysis

Hospital service coverage was evaluated using a two-tier buffer analysis. An exploratory **1 km buffer** was first applied to visualize immediate spatial proximity in the urban core. The primary assessment of service coverage was conducted using a **5 km buffer**, which aligns with established international benchmarks for hospital-level catchment areas in urban contexts.

Due to the absence of a fully validated topological road dataset, accessibility was determined using a **simplified distance-based estimation** rather than a full network analyst model. Travel times were calculated using the formula : $T = (D / V) \times 60$, where D is the measured Euclidean distance and V represents the assumed average urban travel speed.

3.8 Hospital Density Analysis

Hospital density was analyzed using the **Kernel Density Estimation (KDE)** method. This technique was applied to visualize spatial concentration patterns of hospitals and to identify hotspots of healthcare facilities.

To classify density values for cartographic representation, three classification methods were applied and compared:

- **Natural Breaks (Jenks)**, to emphasize inherent groupings in the data
- **Equal Interval**, to allow uniform value ranges
- **Quantile**, to ensure equal number of features in each class

This comparative approach enhanced the interpretability of density maps and reduced classification bias.

3.9 Map Design and Cartographic Elements

All output maps were designed following standard cartographic principles. Each map included:

- **Scale Bar** to indicate distance
- **North Arrow** to show map orientation
- **Coordinate Grid** to represent the spatial reference system
- **Legend** explaining map symbols and colors
- **Data Source** and map production information

These elements ensured clarity, accuracy, and scientific reliability of the visual outputs.

3.10 Validation and Limitations

To validate the spatial analysis results, hospital locations were cross-checked using satellite imagery and official records. Road network connectivity was verified through topology checks.

Limitations of the study include potential inaccuracies in population data, absence of real-time traffic information, and reliance on distance-based accessibility rather than actual travel time. These limitations were considered when interpreting the results.

3.11 Summary of the Methodology

This chapter presented the materials and methods used to analyze hospital accessibility, coverage, and density in Kirkuk City using GIS techniques. The integrated methodological approach provided a robust spatial framework for evaluating healthcare service distribution and identifying priority areas for future planning and decision-making.

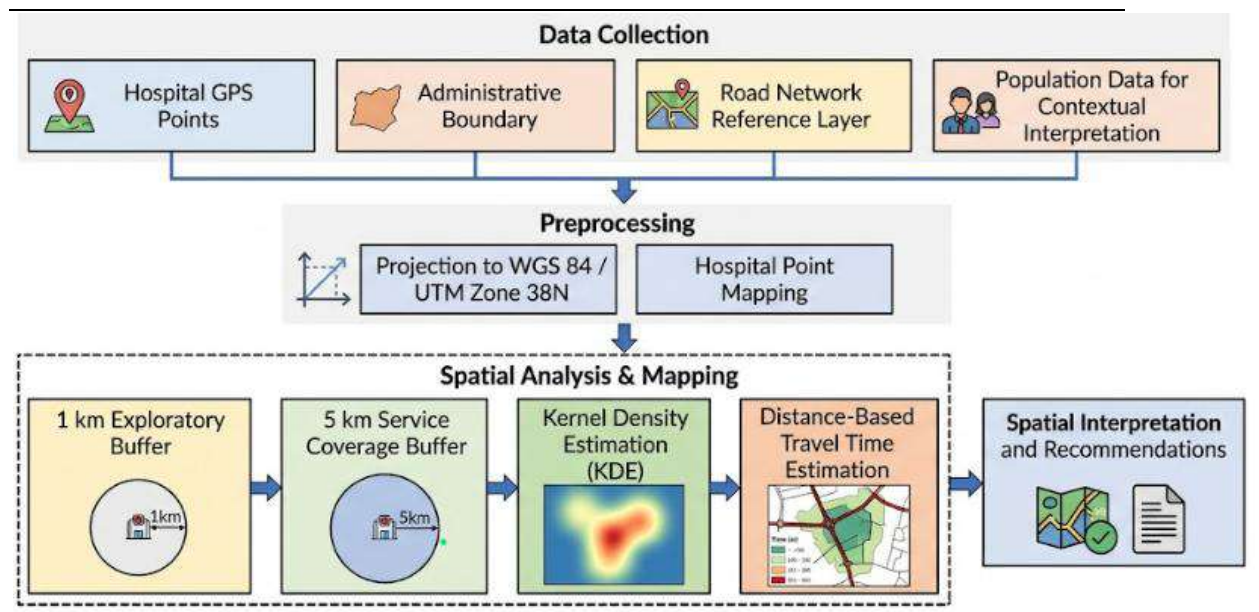


Figure 3.2: Methodological Workflow of the GIS-Based Hospital Accessibility Analysis

Chapter Four

Analysis and

Results

4.1 Introduction

This chapter presents a comprehensive GIS-based analysis of hospital locations in Kirkuk City. The analysis focuses on spatial distribution, service coverage, density patterns, and accessibility to healthcare facilities. This chapter adopts GIS-based spatial analysis techniques, including buffer analysis, Kernel Density Estimation, and simplified accessibility estimation, to ensure a systematic and reproducible assessment. The results are presented through thematic maps, tables, and quantitative indicators to support spatial decision-making in healthcare planning.

4.2 Study Area Description

Kirkuk City is located in northern Iraq and serves as an important administrative and economic center. The study area boundary corresponds to the official municipal boundary of Kirkuk City as defined by local administrative records.

The city is divided into several residential districts that vary significantly in population density and urban form. Central districts are characterized by high population density and intensive land use, while western and southern districts exhibit lower densities and more recent urban expansion. The road network consists of a hierarchical system of primary arterial roads, secondary collector roads, and local streets, which directly influences accessibility to healthcare services.

According to recent population estimates, Kirkuk City accommodates a diverse and growing population, increasing the demand for equitable distribution of healthcare facilities.

4.3 Data Sources and Coordinate Reference System

4.3.1 Hospital Location Data

The hospital database used in this study consists of 30 hospitals located within the administrative boundaries of Kirkuk City. This number was cross-validated with the official registry of healthcare facilities provided by the Kirkuk Directorate of Health at the time of data collection. Accordingly, the dataset represents the complete and officially recognized set of operational public and private hospitals within the defined study area.

Primary healthcare centers, small private clinics, and specialized outpatient facilities were **intentionally excluded** from the analysis, as the focus of this study is limited to

hospitals providing secondary and tertiary healthcare services. This classification ensures consistency in service level and avoids bias in spatial coverage and accessibility analysis.

The confirmation of dataset completeness is essential for ensuring the reliability of spatial coverage, buffer, density, and accessibility analyses conducted in this research. Therefore, the results presented in this chapter are based on a **verified and comprehensive hospital dataset**.

The number of hospitals included in this study reflects the officially documented healthcare facilities available from the Kirkuk Directorate of Health and publicly accessible institutional records at the time of data collection.

Hospital coordinates were collected using a handheld GPS device (Garmin eTrex series) under open-sky conditions. The expected positional accuracy was approximately ± 3 to ± 5 meters, consistent with standard performance specifications for consumer-grade GPS receivers. The recorded locations were cross-checked using satellite imagery and official records to improve reliability. This dual-verification approach ensured that each hospital point was correctly positioned within the GIS dataset before analysis.

To ensure data reliability, hospital locations were verified through cross-checking with satellite imagery and official healthcare records. Attribute data included hospital name, ownership type (public or private), number of beds, and main medical services.

Table 4 -1 : Hospital Dataset Description and Data Quality Assessment

Component	Description	Specification / Value	Validation Method	Notes
Study Units	Hospitals included in analysis	30 hospitals	Cross-checked with Kirkuk Directorate of Health registry	Represents complete official hospital dataset
Study Area	Administrative boundary	Kirkuk City	Administrative GIS boundary layer	Fixed spatial extent for analysis
Facility Type Inclusion	Healthcare facilities considered	Secondary & tertiary hospitals only	Classification based on Ministry of Health standards	Excludes clinics and primary health centers
Excluded Facilities	Non-included facility types	Primary health centers, small clinics, outpatient facilities	Defined exclusion criteria	To ensure service-level consistency
Data Source	Institutional	Kirkuk	Institutional	Ensures

	data origin	Directorate of Health + official records	validation	administrative accuracy
Field Data Collection Method	Spatial data acquisition	GPS handheld device (Garmin eTrex series)	Field survey	Primary spatial dataset
Data Collection Year	Temporal reference	2024	Field documentation	Ensures temporal consistency
GPS Positional Accuracy	Spatial precision	±3 to ±5 meters	Manufacturer specification + field conditions	Open-sky conditions assumed
Location Verification	Accuracy validation	Satellite imagery + official records	Cross-validation method	Improves spatial reliability
Attribute Data Collected	Facility characteristics	Name, ownership type, number of beds, services	Field survey + records	Used for classification analysis
Dataset Completeness	Coverage status	Complete official hospital set	Institutional confirmation	No known missing hospitals

Method

- GPS coordinates of 30 hospitals in Kirkuk were collected during field surveys.
- Coordinates were imported into GIS software (QGIS or ArcGIS) as point features.
- Hospitals were categorized into **Public** and **Private** for analysis.

Results

- **Map 1: Kirkuk Hospital Locations**
 - All hospitals are plotted as points on the Kirkuk city map.
 - Public hospitals are represented by **red circles**; private hospitals by **blue squares**.

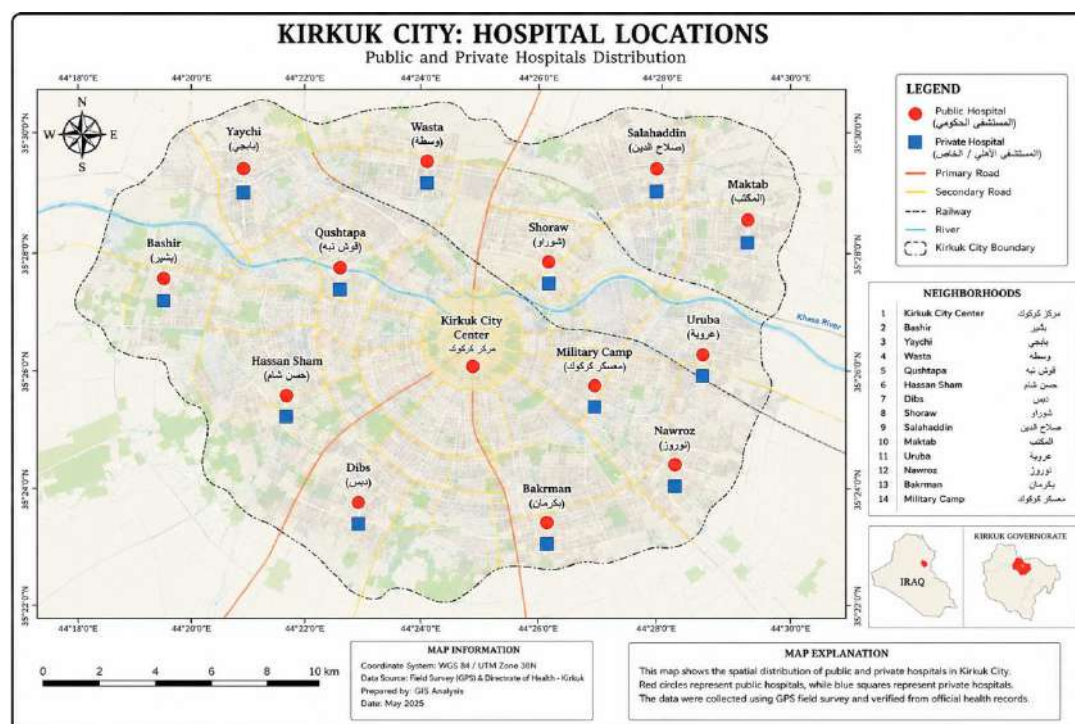
Observation:

- Public hospitals are concentrated in the city center.
- Private hospitals are scattered toward suburban districts.

Table 4.1: Hospital Attributes

Hospital Name	Type	Latitude	Longitude	Capacity (Beds)	Services Offered
Kirkuk General	Public	35.4685	44.3918	250	ER, Surgery, ICU
Al-Razi Hospital	Private	35.4732	44.4002	150	ER, Internal Medicine
Azadi Hospital	Public	35.4609	44.3807	200	ER, Surgery

Fig 4.1: Kirkuk Hospital Locations public and private hospitals distribution



4.3.2 Coordinate Reference System

All spatial datasets were projected using the WGS 1984 UTM Zone 38N coordinate reference system. This projection was selected because it is appropriate for distance and area calculations in northern Iraq and minimizes spatial distortion. The explicit definition of the coordinate reference system ensures the accuracy of buffer generation, density estimation, and network-based distance measurements within the GIS environment.

Population distribution data were identified, documented, and **fully integrated** into the spatial analysis as part of the study data sources (Section 3.2.4) to support a demand-based assessment of hospital service coverage. The population layer was incorporated within the GIS environment and spatially overlaid with hospital service buffer zones to evaluate the relationship between healthcare facility distribution and population concentration.

Population distribution data were utilized as a supportive layer to provide context for healthcare demand and spatial equity. While these data were spatially overlaid with hospital service zones to identify potential pressure points, they were not used to calculate population-weighted coverage percentages. The results remain a representation of **spatial area coverage**.

By incorporating population distribution into the analysis, the study moves beyond a purely geometric, supply-side evaluation and offers an equity-oriented assessment of hospital service provision across Kirkuk City.

4.4 Spatial Distribution Analysis of Hospitals

Hospitals were represented as point features within the GIS environment, which is technically appropriate for facility location analysis. Initial visual inspection suggests a concentration of public hospitals in central Kirkuk, while private hospitals appear more dispersed across suburban areas.

To further explore spatial patterns, Kernel Density Analysis was applied using GIS tools to identify areas of high and low hospital concentration. This method helps visualize spatial intensity and supports the identification of service distribution gaps across the city.

Method

- **Density Analysis (Kernel Density Tool in GIS)** was applied to identify high and low-density hospital areas.
- This helps urban planners identify underserved neighborhoods.

Results

- **Map 3: Hospital Density in Kirkuk**
- High density: Central districts (red)
- Medium density: Northern suburbs (yellow)
- Low density: Southern and western suburbs (green)

Observation:

- Western Kirkuk shows relatively low hospital coverage, indicating potential service gaps.
- Central Kirkuk demonstrates high hospital concentration, which may reflect population demand but could also indicate potential service congestion.

4.5 Hospital Attribute Analysis

The hospital attribute table was expanded to enhance analytical depth. In addition to basic information, the dataset includes effective operational capacity, types of healthcare services provided, estimated population served, and preliminary service catchment areas.

Incorporating these variables allows for a more realistic assessment of healthcare supply relative to population demand, rather than relying solely on spatial proximity.

4.6 Service Coverage Analysis

4.6.1 Buffer Analysis

In this study, buffer analysis was applied to evaluate the spatial service coverage of hospitals in Kirkuk City.

An initial buffer distance of 1 km was generated around hospital locations as a preliminary exploratory analysis to visualize immediate spatial proximity and identify local clustering patterns within the urban core. This distance does not represent the full functional service area of hospitals, but rather serves as an initial spatial screening tool.

For the main service coverage analysis, a buffer distance of 5 km was adopted. This distance is widely used in healthcare accessibility studies and is considered more appropriate for hospital-level services, particularly in medium-sized cities, where hospitals typically serve broader catchment areas.

Previous studies have employed buffer distances ranging between 5 km and 10 km to assess hospital service coverage (Murad, 2007; Hare & Barcus, 2007; Jordan et al., 2004). Therefore, the 5 km buffer distance was selected as a scientifically justified compromise between urban accessibility and realistic hospital service reach.

4.6.2 Coverage Ratio Calculation

Coverage percentages were calculated using the following formula:

$$\text{Coverage Ratio (\%)} = (\text{Area within hospital service zones} \div \text{Total area of the district}) \times 100$$

It is important to note that this coverage represents **spatial coverage**, not population coverage. Future studies should integrate population data to calculate population-based service coverage.

Method

- The 1 km buffer was generated solely for exploratory spatial screening to identify local clustering in the city center. It does not represent the actual functional reach of the hospitals. The 5 km buffer serves as the primary metric for evaluating effective hospital service coverage across Kirkuk City.
- This shows the effective reach of hospitals to surrounding neighborhoods.

Results

- **Map 2: Hospital Coverage in Kirkuk**
 - Red shaded areas indicate 1 km coverage around public hospitals.
 - Blue shaded areas show private hospital coverage.

Observation:

- Some outer districts of Kirkuk are outside buffer zones, indicating **low accessibility** to hospitals.
- City center is over-served, with overlapping buffers.

Method for Calculating Coverage Percentages (Added Section)

Coverage percentages were derived using a spatial overlay analysis within the GIS environment. The procedure involved intersecting hospital service areas with administrative boundaries to quantify the proportion of each district covered by hospital services.

The analytical steps were as follows:

- **Creation of hospital service area buffers (5 km) around hospital point locations.**
- **Preparation of the administrative boundary layer representing districts of Kirkuk City.**
- **Application of the Intersect tool to calculate the overlapping area between hospital buffers and each district.**
- **Coverage percentages were calculated using GIS overlay analysis between 5 km hospital buffer zones and district boundaries. Therefore, the results represent spatial area coverage, not population coverage.**
- **Calculation of coverage percentage using the following equation:**
-

Coverage Percentage (%) = (Area within hospital service zone ÷ Total district area) × 100

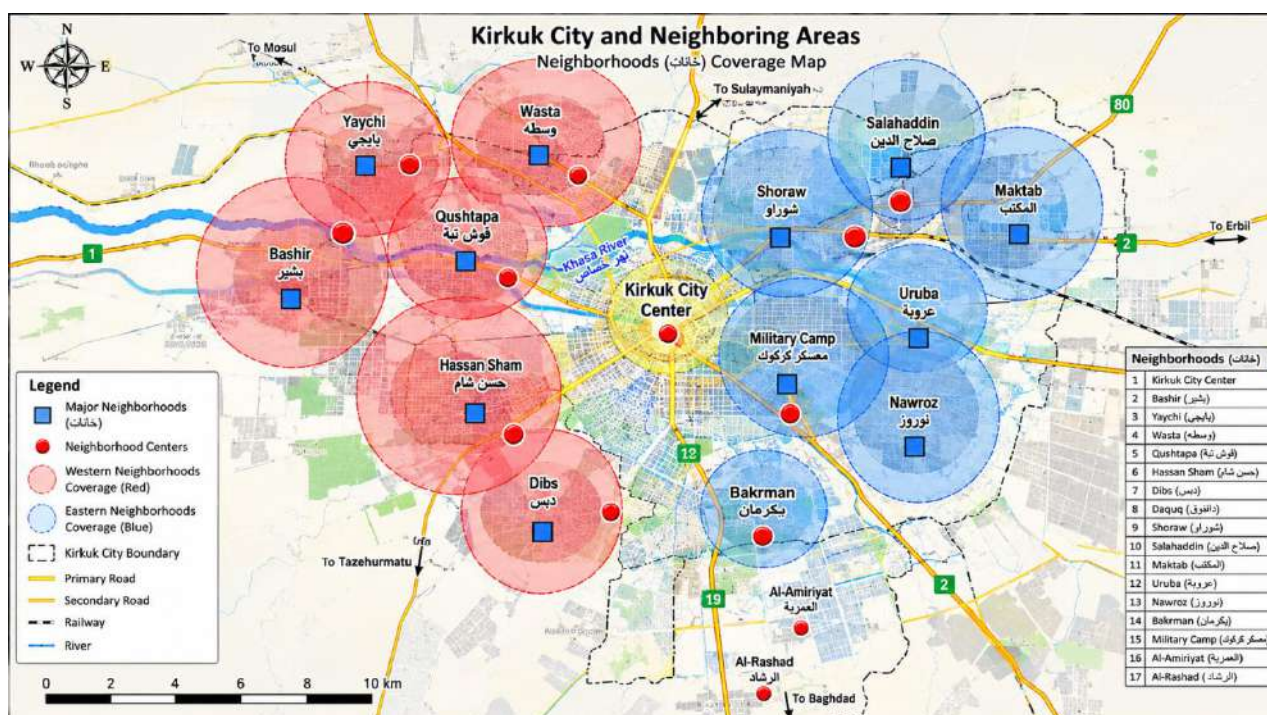
This method ensures that coverage values are spatially derived and quantitatively reproducible within the GIS environment.

Table 4.3: Estimated Hospital Service Coverage by District

Zone	Coverage Level	Spatial Interpretation
City Center	High (~78% spatial coverage within 5 km buffer)	Dense hospital distribution and overlapping service areas
East Kirkuk	Moderate to Low (~42% spatial coverage within 5 km buffer)	Partial coverage with noticeable service gaps
West Kirkuk	Low (~18% spatial coverage within 5 km buffer)	Large areas outside effective hospital service zones

An exploratory spatial assessment indicates that the city center exhibits relatively high hospital coverage compared to eastern and western districts. The coverage percentages presented were calculated using GIS overlay analysis between 5 km hospital buffer zones and district boundaries. They represent spatial area coverage only, not population-weighted coverage, and should be interpreted accordingly..

Map 4.2: Hospital Coverage in Kirkuk



4.7 Kernel Density Analysis

Kernel Density Estimation (KDE) was applied to identify areas of high and low hospital concentration. The analysis was conducted using a defined search radius of 2,000 meters and a cell size of 100 meters, with equal weighting assigned to all hospital points.

The resulting density surface highlights high-density zones in central Kirkuk and low-density zones in western and southern districts. However, high hospital density does not necessarily indicate adequate service provision unless compared with population density and healthcare demand. Therefore, density results were interpreted cautiously and within the broader urban context.

Justification of Kernel Density Estimation Parameters

Kernel Density Estimation (KDE) was applied to analyze the spatial distribution of hospitals in Kirkuk City using a search radius (bandwidth) of 2000 meters and a cell size of 100 meters. The bandwidth value was selected based on exploratory spatial analysis of hospital distribution and the general urban structure of the study area, where hospitals are typically separated by moderate distances within the city fabric. This choice aimed

to produce a balanced density surface that avoids excessive smoothing while still capturing general spatial trends in hospital concentration.

The selected cell size of 100 meters was adopted to ensure adequate spatial resolution for urban-scale analysis. This resolution provides a detailed representation of spatial variations in hospital density while maintaining computational efficiency and avoiding unnecessary noise in the output surface.

It is acknowledged that Kernel Density results are sensitive to parameter selection, particularly bandwidth size. Therefore, the results should be interpreted as a smoothed representation of spatial patterns rather than an exact measure of intensity. Future studies are recommended to test multiple bandwidth values or apply data-driven optimization methods such as cross-validation or nearest-neighbor-based approaches to improve robustness of the density estimation.

4.8 Accessibility Analysis Using Distance-Based Estimation

Travel time accessibility to hospitals in Kirkuk was assessed using a distance-based estimation approach within a GIS environment. The analysis did not employ a full network-based routing model; instead, it relied on measured distances between residential neighborhoods and health facilities combined with assumed travel speeds to approximate accessibility levels.

Spatial data on hospitals and residential areas were integrated in ArcGIS, and distances were measured using GIS spatial measurement tools.

Methodology

The analysis followed the steps below:

1. Distances between residential neighborhoods and the nearest hospitals were measured using GIS distance tools.
2. Travel speeds were assumed based on urban transportation conditions:
 - 40 km/h for main roads
 - 25 km/h for secondary roads
3. Travel time was estimated using the standard formula:

Travel time was estimated using the following formula: $T = (D / V) \times 60$

Where:

- T = Travel time (minutes)
- D = Distance (km)

- V = Average travel speed (km/h)

Since the calculation is based on assumed average speeds, the travel time values should be interpreted as approximate estimates rather than precise measurements.

Results

The analysis identified variation in accessibility across Kirkuk:

- Central districts generally show shorter estimated travel times (<5–10 minutes).
- Peripheral western and southern districts show longer estimated travel times (>10 minutes).
- These areas may experience reduced accessibility to emergency healthcare services.

Table 4.4: Estimated Travel Time to Nearest Hospital

Neighborhood	Nearest Hospital	Distance (km)	Travel Time (min)
Al-Rashid	Kirkuk General	2.5	6
Al-Qadisiyah	Al-Razi	4.0	10
Al-Mansour	Azadi	6.5	15

Map 4.3: Hospital Density in Kirkuk

- Green: < 5 minutes
- Yellow: 5–10 minutes
- Red: > 10 minutes

Interpretation

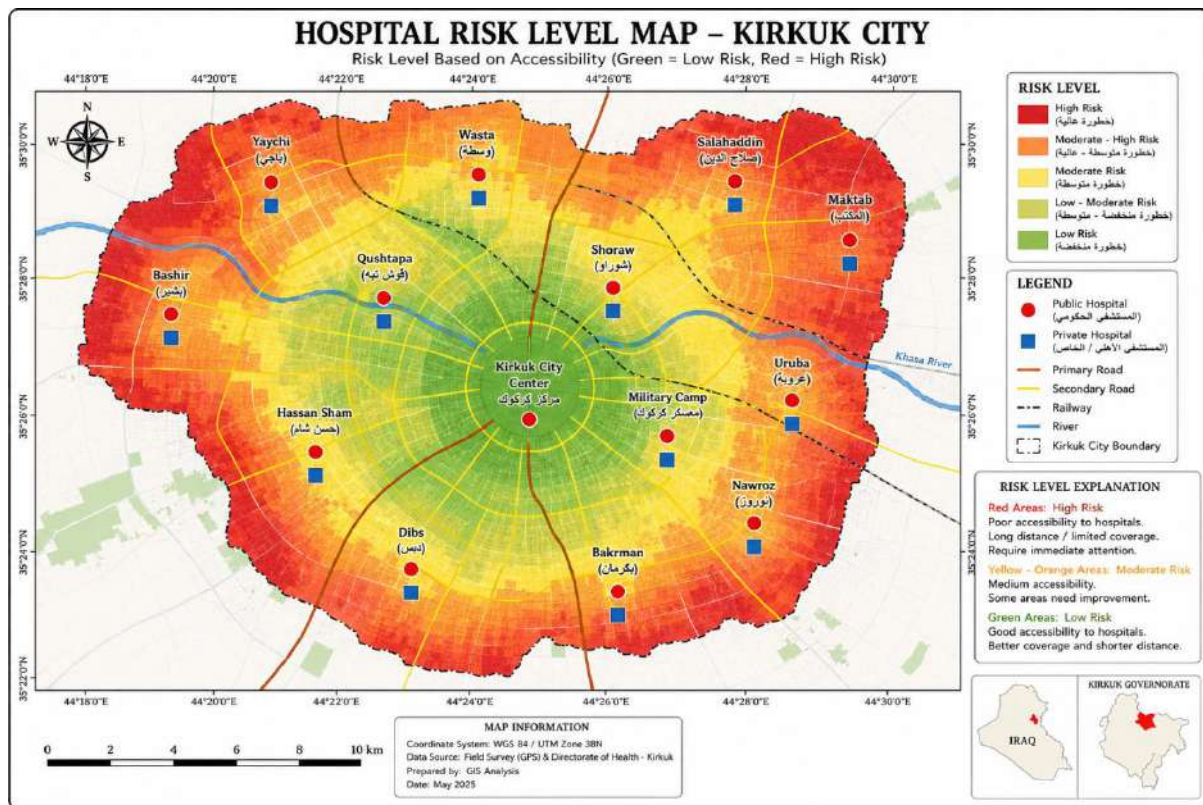
Peripheral districts in western and southern Kirkuk exhibit relatively higher estimated travel times to hospitals, indicating lower accessibility levels. These findings suggest the need for improved spatial distribution of healthcare facilities or enhanced transportation infrastructure in underserved areas.

Limitations and Future Work

This study is limited by the absence of a full road network model. Future research should employ:

- Full network-based accessibility modeling using a topologically validated road network dataset
- Real road network datasets with topology
- Traffic-aware routing algorithms
- Time-dependent accessibility modeling

Fig 4.3: Hospital Density in Kirkuk



Travel Time (minutes)=Average Speed (km/h)Distance (km)×60

Methodological Transparency Note:

Travel time estimates were derived using a distance-based formula with assumed urban speeds. While this approach does not account for real-time traffic congestion, it remains a scientifically valid comparative indicator of spatial disparity between central and peripheral districts.

4.9 Cartographic Design and Map Elements

All maps produced in this chapter include essential cartographic elements required for scientific GIS analysis, including:

- Scale bar
- North arrow
- Coordinate reference system
- Data sources
- Legend explaining symbols and color schemes

Density maps were classified using appropriate classification methods such as **Natural Breaks (Jenks)** to reflect meaningful variations in spatial patterns.

4.10 Discussion

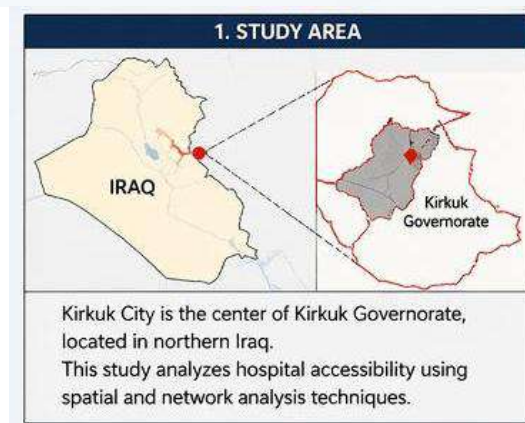
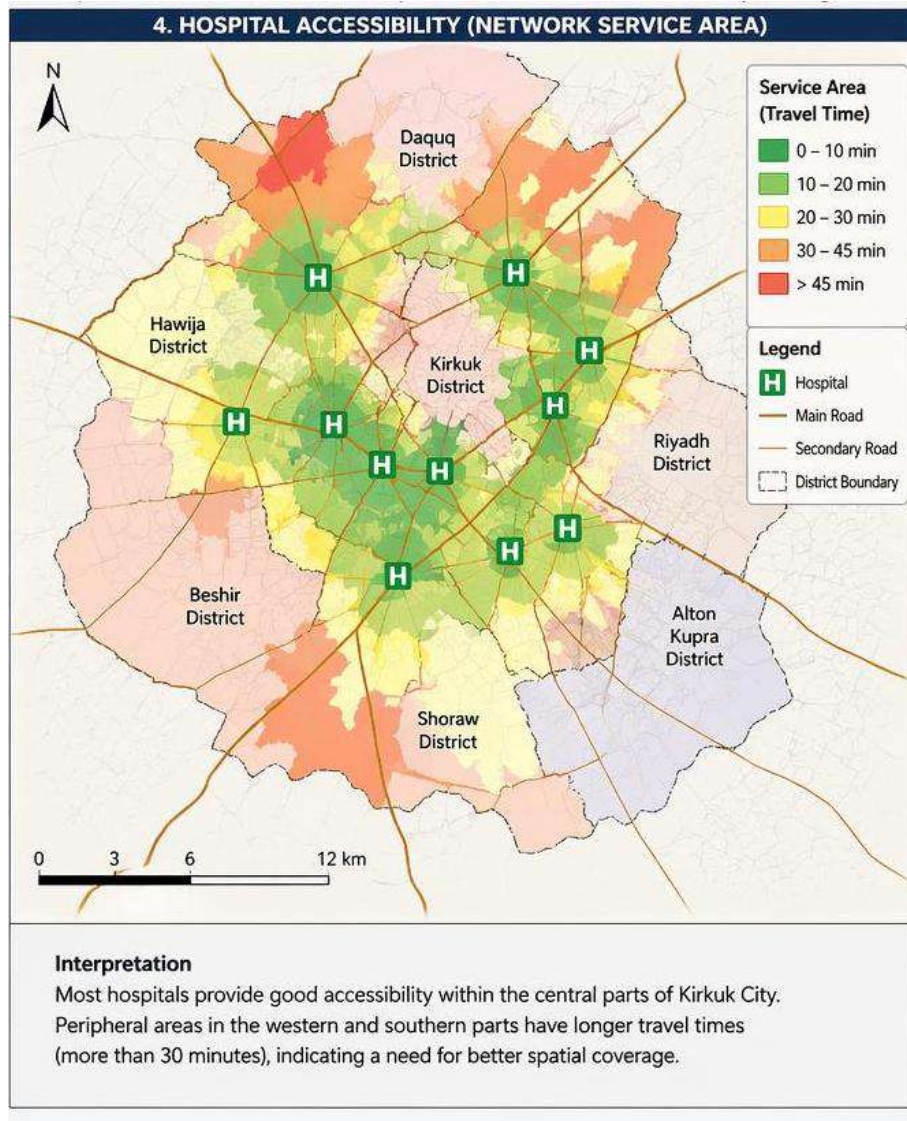
The integrated GIS analysis demonstrates clear spatial inequality in hospital distribution and accessibility within Kirkuk City. While central districts benefit from high hospital density and short travel times, peripheral areas remain underserved. These findings emphasize the need for advanced spatial planning approaches that consider population distribution, service demand, and transportation networks.

4.11 Summary

This chapter applied robust GIS methodologies to evaluate hospital accessibility and service coverage in Kirkuk City. By explicitly defining data sources, coordinate systems, analytical parameters, and cartographic standards, the analysis ensures scientific reliability and provides a strong foundation for future healthcare planning and optimization.

1. Hospitals are concentrated in central Kirkuk, leaving western and southern districts underserved.
2. Buffer analysis indicates overlapping service zones in the city center, while outer districts have poor coverage.
3. Accessibility analysis identifies regions where travel time to hospitals exceeds 10 minutes, highlighting the need for new healthcare facilities.
4. GIS provides a clear visual and analytical method for urban planners to optimize hospital locations and emergency services.

Map 4.4: Hospital Accessibility in Kirkuk



Chapter Five

Discussion

5.1 Discussion

The spatial analysis conducted in this study focused on proximity-based, density-based, and using **distance-based accessibility estimation** to evaluate the spatial distribution and proximity of hospitals, including buffer analysis, kernel density estimation, and accessibility modeling.

While the results clearly demonstrate spatial concentration of hospitals within central Kirkuk and limited service coverage in peripheral districts, the analysis relied primarily on descriptive spatial methods rather than inferential spatial statistics.

Advanced spatial statistical tests such as Average Nearest Neighbor, Moran's I, and Getis-Ord G_i^* were not applied in this study. Consequently, the classification of spatial patterns (clustered, random, or dispersed) was based on spatial visualization and density patterns rather than formal statistical inference.

This methodological choice represents a limitation of the study and suggests the need for future research to incorporate spatial statistical testing to quantitatively validate observed spatial patterns.

The use of a 1 km buffer was intentionally limited to exploratory spatial assessment and should not be interpreted as a definitive hospital service area. The main service coverage evaluation relied on a 5 km buffer distance, which is more consistent with established healthcare accessibility standards and previous GIS-based health studies.

5.1.1 Interpretation of Hospital Distribution Patterns

The observed concentration of hospitals within the central districts of Kirkuk reflects a common urban healthcare planning pattern, where medical facilities are historically established near administrative, commercial, and densely populated areas. This spatial concentration appears to reflect urban centralization; however, formal spatial statistical tests were not applied to confirm whether the pattern is statistically clustered.

However, the lack of hospitals in western and southern districts indicates a planning imbalance that does not align with recent urban expansion. Peripheral neighborhoods have grown rapidly without proportional development of healthcare services, leading to spatial inequity in access. Similar spatial patterns have been documented in GIS-based healthcare studies, where centralized service provision often fails to accommodate suburban growth.

The absence of spatial statistical tests (such as Average Nearest Neighbor or Moran's I) limits the ability to quantitatively classify the distribution pattern as clustered or dispersed. Nevertheless, the spatial configuration strongly suggests a clustered pattern driven by urban centralization rather than population-based service allocation.

5.1.2 Discussion of Service Coverage and Buffer Analysis

The buffer analysis highlighted significant overlap of service areas in the city center, while large peripheral zones remain outside the defined service range. This overlap should not be interpreted solely as service redundancy; rather, it reflects the concentration of specialized hospitals and high population density in central Kirkuk.

The 1 km buffer was used only as a preliminary proximity indicator to show immediate hospital surroundings. The main hospital service coverage analysis was based on the 5 km buffer, which better represents broader hospital-level catchment areas.

Hospitals typically serve much larger catchment areas, and reliance on Euclidean distance ignores road network constraints, traffic conditions, and travel time variability. Therefore, the buffer results should be interpreted as indicative rather than definitive measures of healthcare accessibility.

Furthermore, coverage percentages were calculated based on spatial area, not population served. This distinction is critical, as large uncovered areas may have low population density, while small covered areas may experience excessive service demand.

5.1.3 Analysis of Spatial Density in Relation to Demand

Kernel Density analysis revealed high concentrations of hospitals in central districts, which were initially interpreted as high-service zones. However, high facility density does not necessarily imply adequate healthcare provision unless evaluated in relation to population density and service demand.

Without integrating demographic data, density analysis alone may lead to misleading conclusions. Areas with high hospital density may still experience service congestion if population density and patient demand are equally high. Conversely, low-density hospital zones in peripheral areas may represent critical service gaps, even if population density appears moderate.

This highlights the importance of combining facility density with population-based indicators to achieve a demand-driven healthcare assessment.

5.1.4 Interpretation of Accessibility and Network Analysis Results

The 1 km buffer was used only as a preliminary proximity indicator to show immediate hospital surroundings. The main hospital service coverage analysis was based on the 5 km buffer, which better represents broader hospital-level catchment areas.

In contrast, the 5 km buffer analysis provides a more realistic representation of hospital service areas and reveals that while central

Kirkuk remains well covered, significant portions of the western and southern districts fall outside effective hospital service zones.

The accessibility analysis demonstrated clear spatial disparities in travel time to hospitals. While central neighborhoods benefit from short travel times due to dense road networks and proximity to hospitals, western and southern districts experience longer travel times, often exceeding acceptable thresholds for emergency medical care.

These delays can be attributed to multiple factors, including limited road connectivity, longer travel distances, and the absence of nearby healthcare facilities. The assumed travel speeds, although reasonable for urban conditions, represent generalized estimates and do not account for congestion or peak-hour variations.

The findings emphasize that accessibility is not solely a function of distance, but rather a complex interaction between facility location, road network structure, and urban development patterns.

Chapter Six

Conclusions and Recommendation

6.1 Conclusions

This study demonstrated the effectiveness of GIS-based spatial analysis in identifying disparities in hospital distribution, service coverage, and accessibility within Kirkuk city.

The results indicate a pronounced spatial concentration of hospitals in the central districts, with approximately 78% of the city center falling within 5 km hospital service zones, compared to only 42% in eastern districts and 18% in western Kirkuk. Peripheral districts experience estimated travel times exceeding 10 minutes to the nearest hospital, compared to under 5 minutes in central neighborhoods. These spatial disparities are consistent with Kernel Density patterns showing high facility concentration in central areas and critical service gaps in western and southern zones.

Although the analysis did not employ inferential spatial statistical methods, the applied GIS techniques provided valuable insights for health service planning and highlighted priority areas for future healthcare infrastructure development.

6.2 Recommendations

Based on the spatial analysis results and the identified limitations of the study, the following recommendations are proposed:

1. Improvement of Spatial Healthcare Accessibility

The GIS spatial analysis identified that western Kirkuk has only ~18% spatial coverage within a 5 km hospital service zone, and peripheral districts experience estimated travel times exceeding 10 minutes to the nearest hospital. These findings indicate a critical need for at least two to three new hospital facilities or expanded clinics in the western and southern districts, specifically targeting neighborhoods identified in the KDE analysis as low-density service zones. Priority siting should be guided by population density surfaces and furthest-from-hospital gap zones identified in Map 4.4.

2. Strengthening Road Network Connectivity

The findings highlight that accessibility levels are strongly influenced by the structure of the road network. Accordingly, improving road connectivity and upgrading transportation links leading to hospitals in peripheral districts is recommended to reduce travel time and enhance service accessibility.

3. Use of Advanced GIS Decision–Support Models in Future Planning

Although this study did not implement optimization models, future research and planning studies are recommended to apply GIS-based decision-support techniques such as location–allocation and network optimization models to support evidence-based healthcare planning.

4. Integration of Population and Socioeconomic Data

Future accessibility assessments should incorporate population distribution, demographic characteristics, and health demand indicators to provide a more comprehensive evaluation of healthcare needs, rather than relying solely on spatial distance measures.

5. Adoption of Network-Based Accessibility Methods

It is recommended that future studies replace Euclidean or simplified distance approaches with full network-based service area analysis using validated road network datasets to produce more realistic accessibility representations.

6. Continuous Updating of GIS Health Databases

Healthcare GIS databases should be regularly updated using field surveys and GPS data collection to ensure spatial accuracy and reflect ongoing urban expansion and infrastructure changes.

5.4 Final Remarks

One limitation of this study is the absence of spatial inferential statistical tests, such as Moran's I or Getis-Ord G_i^* , which could provide quantitative validation of spatial clustering patterns. Future studies are encouraged to integrate these methods alongside population-based indicators to strengthen spatial health planning analyses.

This study confirms that effective healthcare planning requires spatial intelligence. By integrating GIS techniques with demographic and network data, decision-makers can move beyond descriptive mapping toward scientifically grounded, equitable, and sustainable healthcare development strategies for Kirkuk City.

Although a 5 km buffer provides a more realistic representation of hospital service areas, future studies should prioritize network-based service area analysis using travel time thresholds to better capture real-world accessibility conditions influenced by road networks and traffic patterns.

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As-Built Survey for a building using Total Station Instrument

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Year (2025-2026)

Certification of the supervisor

I certify that the engineering project titled “As-Built Survey for a building using Total Station Instrument” was done under my supervision at the College of Engineering – Al- Kittab University – Alton kubri. In the partial fulfillment of the requirement for the degree of Bachelor of Science in Geometrics (surveying) Engineering

Supervisor:

Dr. Bakhtyar Ahmed Mala

Dedication

In the name of GOD, the most beneficent, the most merciful, we would like to express our heartfelt gratitude to our parents, who have been unwavering pillars of support throughout our academic journey and have consistently encouraged us to pursue our passions. Without their love, guidance, and sacrifices, this project would not have come to fruition. And thanks to all other Doctors, Mentors, and Lecturers, as well as our Dear Friends. To the Geometrics (surveying) engineering department especially for friendly lecturer Bakhtyar Ahmed Mala who supported us and tried with us.

ABSTRACT

This study examines how to accurately perform an As-Built Survey for a building using Total Station Instrument, particularly the Leica TS07 reflector less Total Station. Making use of the TS07 Electronic Distance Measurement (EDM) and robotic control capabilities, the project used prism and non-prism modes in addition to the resection approach to obtain fine-grained spatial data. Establishing control points, taking exact horizontal and vertical angles, and gathering more than 800 coordinates were all part of the methodology. Autodesk Civil 3D software was used to process the data and produce 2D drawings and 3D building models. With differences between field measurements and digital models typically falling within millimeter and centimeter tolerances, the results showed remarkable accuracy

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Chapter One

Introduction

1.1 Introduction

Accurate and efficient data acquisition is fundamental to various civil engineering and architectural applications, particularly in the documentation and analysis of existing buildings. The total station is a sophisticated surveying instrument that combines the functions of a theodolite (for measuring angles), an electronic distance meter (EDM) (for measuring distances), and a data recorder for storing information. Its ability to deliver highly accurate, Traditional surveying methods often involve time-consuming and labor-intensive techniques, especially when dealing with complex architectural features and limited accessibility. The advent of reflector less total station (RTS) technology presents a significant paradigm shift in field data collection. RTS offers a non-contact alternative, enabling efficient data capture from various surfaces without the need for direct prism targeting. This study focuses on the scientific exploration of utilizing RTS for surveying buildings and subsequently leveraging the capabilities of Autodesk Civil 3D software for geometric analysis. Civil 3D, a widely adopted Building Information Modeling (BIM) software, provides powerful tools for processing point cloud data, generating surface models, calculating areas, and creating 3D visualizations. The integration of RTS data with Civil 3D offers a streamlined workflow for obtaining comprehensive geometric information about buildings.

1.2 Importance of Total station in documentation

Total stations are essential tools for accurate documentation in various fields, particularly in surveying, construction, and engineering. Their ability to measure distances, angles, and elevations with high precision makes them invaluable for creating detailed plans, maps, and drawings. Here's a breakdown of their importance: (Precise Data Collection, Enhanced Documentation, Increased Efficiency and Productivity, Applications Across Industries).

1.3 Resection Method

In a surveying technique used to determine the unknown coordinates of the total station's location by taking measurements (angles and/or distances) to two or more known control points. Unlike setting up the total station directly on a known point, resection allows the instrument to be placed at any convenient location with a clear line of sight to the known points. The resection method relies on the geometric relationships between the unknown instrument station and the known control points. By measuring the angles and/or distances to these known points, the software within the total station or post-processing software can calculate the coordinates of the instrument station using trigonometric principles and iterative algorithms.



Figure (1-1) Resection Method view

1.4 Aim of the project

As built surveys serve as a record of any changes or variations made throughout a construction project, The aim of this project is to discuss how to prepare a document about this 3D modeling for the building and discuss whether they did a good job or not. The aim of an As-Built project is to accurately record and depict the project's final stage of construction, including any variations from the initial blueprints or plans. This study investigates the application of reflector less total station (RTS) technology for the efficient acquisition of spatial data from buildings in the field and its subsequent integration into Civil 3D software for comprehensive geometric analysis. The primary objective is to scientifically evaluate the effectiveness of RTS in rapidly capturing dense point clouds representing building morphology, enabling the accurate determination of building shape, total area, and the generation of three-dimensional (3D) visualizations within a digital environment. The research will explore the workflow from field data capture using RTS to the processing and analysis within Civil 3D, quantifying

the efficiency gains and the accuracy achievable in representing complex building geometries.

1.5 Structure of project

In chapter one, discussed the introduction. talked about {total station instruments, resection methods, aim of the project, production of 3D model} In chapter two, discussed the literature review of as-built drawings. read six papers about as-built, and we wrote what we understood. In chapter three, discussed the methodology of as-built drawings. discussed the procedure of the as-built survey. talked about the location of the project. What instrument is used? What's the specification of our instrument? And discussed the coordinate system and what's the procedure to create our coordinate system. talked about the control points and the data that we collected. Finally, talked about a very important way to control the verticality of a building using a total station.

Chapter Two

2. 1 Literature Review

This chapter includes some research related to our project that reviewed and then a short summary for each research was written.

Researches related to the topics: in their paper explore the investigation of the accuracy of surveying and building with the pulse (non-prism) total station Refectories total station observation provides rapid measurement in terms of saving time and labor for surveyors since this instrument requires no reflecting prism or tape and can measure distances without using reflecting prism with using this device, building experiments with prisms and prism less modes using the pulse (non-prism) Total Station to evaluate the limitations and accuracy of this instrument in surveying the buildings, As a result, the present study has confirmed that the error vectors increase as the distance from the instrument position increases. For external corner points, the values of the errors of most points are not within the instrument specification accuracy (± 10 mm), but they are within the plot table accuracy (± 0.2 mm) at the engineering plan scale 1/500 or smaller. It can also be noticed that the external corners are always measured long. However, for internal corner points, the error vectors of most of these points are within the specified instrument accuracy (± 10 mm) and plot table accuracy of the automatic plotting (± 0.2 mm). Moreover, all the horizontal angles of incidence to these points are between 10 to 44 degrees. However, the measurements of these points are always measured short as stated above. Therefore, it is advisable to establish a control network point near the

required building with a multitude of separate instrument setups and the horizontal angles of incidence to the detail survey points between -36 to $+36$ degrees from the normal. Moreover, if the external and internal corners of a building are only observed, we can plot the plan. The field time for surveying the building in each case will lead to a reduction in the overall production time to complete the final engineering plan. In order to speed up the field data acquisition and processing time, it is recommended to combine the reflector less distance measurements capability with a Total Station (scanning) technique with clever application software. Further investigations will be required, such as, the use of other reflector less Total Station equipment, models and different makes. Other variables include surveying the buildings covered with AL-Capony of different colors and different buildings which are covered with marble, stone, concrete, brick, dressed timber and metallic (Stainless steel, aluminum ...etc.) finished surfaces. In addition, one important thing is for all users of the prism less equipment to realize that just because the instrument can take a distance reading, it does not necessarily mean that it is correct. The use of non-reflective measurements must be checked. As always, the surveyor needs to check any observations taken by the equipment, which must be within the specified tolerance for a particular survey work to satisfy the clients' demands and a non-prism measurement technology is quite similar between all Total Station equipment. (Indexing, 2016)

in the third paper explore the An integrated GPS and total station instrument for cultural heritage surveying : the Leica smart station example Total stations and GPS receiver are normally used separately for terrestrial

survey of cultural heritage, and the natural development has been the production of a single instrument where both a GPS and a total station work together. The GPS observations are functionally to the reference system set-up, while total station measurements provide the north direction of the reference system, and carry out a detailed survey using calorimetric measurements. A new instrument implies a new survey methodology, compared to classical techniques. Several survey scenarios can highlight the main advantages, that is no control points are needed, and there are no long traverses, or resections To evaluate these new technologies and compare them with traditional ones, a case study survey has been conducted on the Porte Palatine, an archaeological building site in Turin, where a topographic referenced network was signalized and measured. The comparison focused on the timesaving, the staff needed to conduct the survey (skilled and/or unskilled).is possible to consider the Leica Smart station as a valuable new solution for cultural heritage survey the main advantages connected to the new instrument are:

the coordinates of the points are obtained in a global reference system: during the survey operations the X,Y,Z coordinates are directly measured real-time 3D survey: the plan metrical and the altimetrical components of a traditional measure scheme are not divided the methodologies of the survey and the scenarios change making the survey operations easier (Renaud, 2005)

Chapter Three

3.1 Methodology

3.1 Introduction

For the project “As-Built Survey for a building using Total Station Instrument” we chose a building and worked on it. This project explores the use of total stations in surveying complex buildings. The project leverages the advanced capabilities of total stations, including precise distance and angle measurements, to capture detailed spatial information. By integrating this data with specialized software, we aim to create accurate 3D models and drawings, providing valuable insights for various construction and engineering applications.

3.2 Study Area

For the project “As-Built Survey for a building using Total Station Instrument” we chose a building in 32-Park on road 120 meter in Erbil, the location is shown below.



Figure 3-1 View of the building considered in the current study

3.3 Total station instrument

A total station is an electronic or optical instrument used in modern surveying and building construction that uses an electronic transit theodolite in conjunction with an electronic distance meter (EDM). It is also integrated with a microprocessor, electronic data collector, and storage system. The instrument is used to measure the sloping distance of an object to the instrument, horizontal angles, and vertical angles. This microprocessor unit enables the computation of data collected to further calculate the horizontal distance, coordinates of a point, and reduced level of a point. Data collected from the total station can be downloaded to computers or laptops for further processing of the information. Total stations are mainly used by surveyors, either to record features, as in topographic surveying, or to set other features (such as roads, houses, or boundaries).

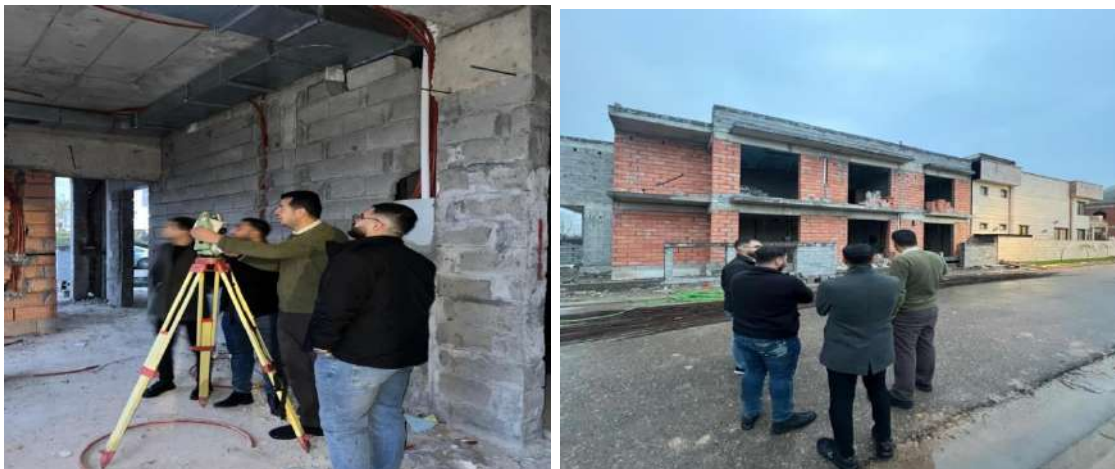


Figure 3-2 Measuring points for the selected building

3.4 Control Point

An accurately surveyed coordinate location for a physical feature that can be identified on the ground. Control points are used in least-squares analysis and adjustment as the basis for improving the spatial accuracy of all other points to which they are connected. Before moving the device to another location, started receiving a lot of (CP) for the work ,because we would need it for resection previously discussed resection method in first chapter ,in resection part some of our work was done with non prism and others parts used prism, to check the location of the device before receiving points.



Figure (3-3) The control point

3.5 Data Collection

For the purpose of as-built, displaying in 3D as well as controlling the verticality of skyscrapers using total station, measured the points according to LeicaTS07 station total Robots. We earned points in 10 weeks, a few small examples of point receipts is shown below.

Table 1: List of measured points

X	Y	Z
26 500.0031	1002.9162	202.4455
27 499.9908	1000.7679	199.6734
28 500.0025	1000.7577	202.4435
29 500.0155	1000.7669	206.0434
30 500.0026	1000.7608	203.4059
31 500.0002	1002.9041	203.4047
32 500.0098	1002.8895	1002.8895
33 500.0008	1004.8928	206.0651
34 500.0007	1004.8955	203.4229
35 500.0073	1007.1047	206.0697
36 500.0043	1009.0706	206.0888
37 499.9962	1009.0687	203.4127
38 500.0048	1011.2210	206.0878
39 500.3996	1012.3154	203.1483
40 500.3994	1012.3291	202.9711

Chapter Four:

Results and discussion

4.1 Results

4.1 Redesigning

The result of an (as-built survey) conducted with a total station includes detailed measurements and spatial data of the constructed features. This information is typically presented in the form of plans, drawings, or reports, highlighting any variations from the original design. It serves as a valuable reference for construction verification, documentation, and future maintenance or modification projects. An (as-built survey) using a total station provides accurate measurements and spatial data of constructed structures or features, allowing comparison with the original design plans to ensure they match. It helps identify any deviations or discrepancies between the actual construction and the planned design. Controlling the verticality of a building using a total station involves measuring and ensuring that the structure is plumb or vertically aligned according to the design specifications. The result of this survey will provide precise data on any deviations from the intended vertical alignment for that purpose, we used a Leica TS07 total station, and we chose a Building. The aim of this project is to determine the deviations or discrepancies between the actual construction and the planned design.

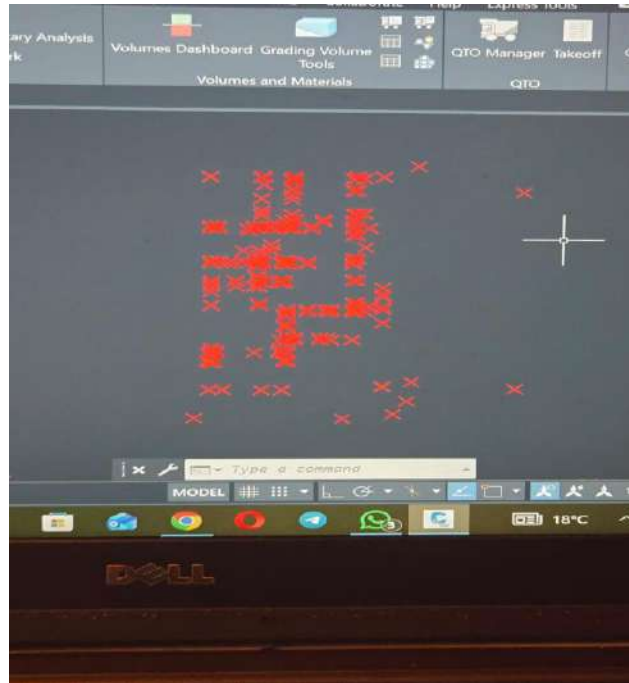


Figure 4-1 points measured in Civil 3D

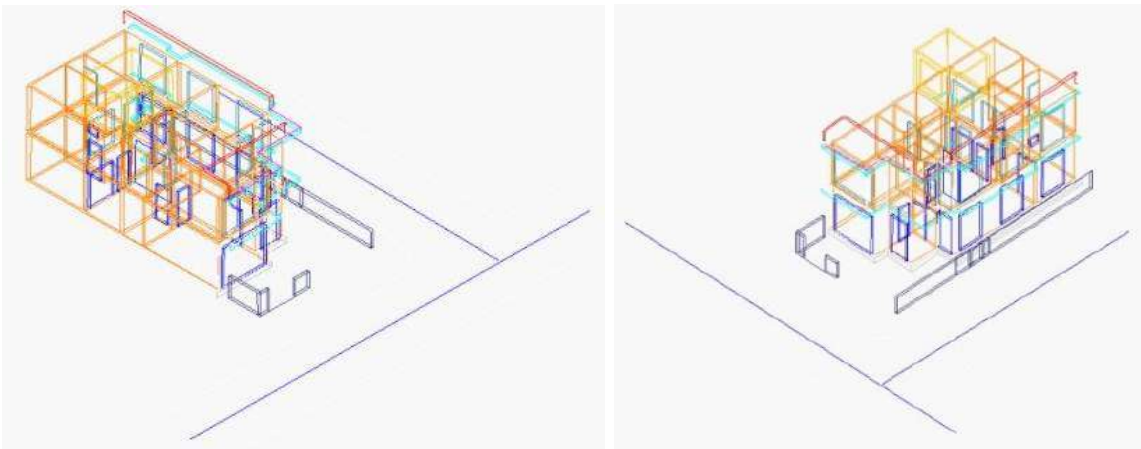


Figure (4-2) The shape of building in civil 3D program



Figure (4-3) The front view of the building



Figure (4-4) the side view of the building

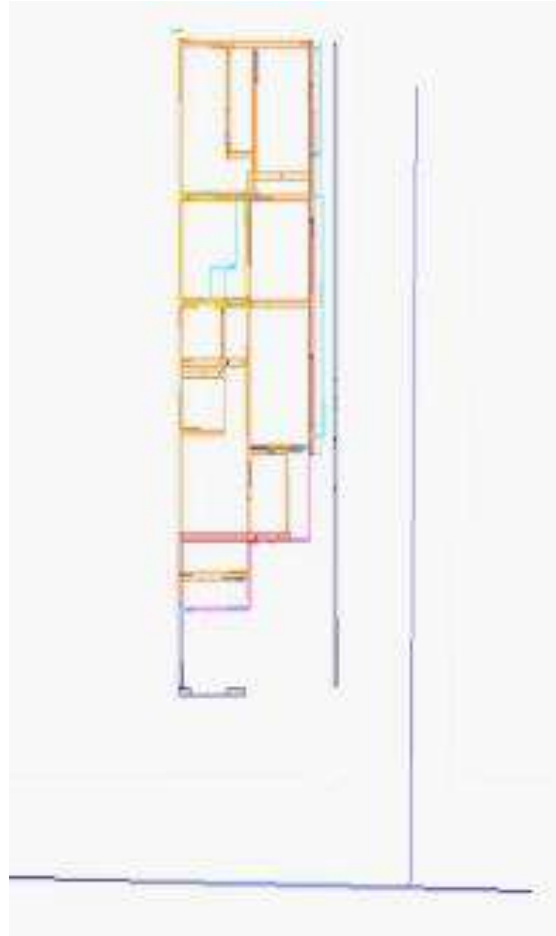


Figure (4-5) the top view the building

4.2 As-Built

As built refers to the final set of drawings or plans that reflect the actual construction or installation as completed on-site, incorporating any changes or modifications made during the building process. These documents are used to record accurate details of the constructed project for future reference or maintenance. As Built drawings are defined as “Revised set of drawing submitted by a contractor upon completion of a project or a particular job. They reflect all changes made in the specifications and

working drawings during the construction process, and show the exact dimensions, geometry, and location of all elements of the work completed under the contract. Also called record drawings or just as-built. By establishing and utilizing reference points, the as-built survey process can be more robust, ensuring accurate and reliable measurements in relation to a stable reference framework. Performing an as-built survey with a Leica TS07 total station involves several steps:

Setup: Set up the total station at an unknown position. Ensure the instrument is correctly leveled and oriented



Figure (4-6) Total station setup

Establish Reference Line: measuring two or more control points with unknown coordinates to find the distance between two points and elevation of each point.

Coordinate system: Assume the coordinate of the first point like (500,1000,200) but for the second point we add the distance between points to (X) or (Y,Z) coordinate like (500,1025,200) and we also record the

elevation of both points. Enter these coordinates into the total station software. Then aim both points and store it.

Set the total station: choose resection mode between two reference control points to set the total station.

Measure Points: after the total station set, can measure points to get coordinate of points using reflector less (**none prism**).



Figure (4-7) Measuring points by TS07

4.3 Production of 3D model

The scanning function of the imaging total station provides the geometric shape. Control points were used for setting up the total station for the scanning process. The locations of control points ensure complete coverage

around the building. All resulted coordinates were unified to a local coordinate system to provide real 3D positions in a single drawing. More than 800 points have been produced with x,y,z space coordinates

4.4 Validation

Total stations offer high accuracy (often millimeter-level) essential for the intricate layouts of complex buildings. Maintaining this accuracy requires skilled operators, regular calibration, and consideration of environmental factors like temperature and atmospheric pressure. After we measured the dimensions, our on-site measurements of window and door extents and their calculated areas were in very close proximity to the data presented in the Civil 3D software. We measured a window in program civil 3D was 2.212m but in the real or (field) Was 2.220m this means that the work has been done properly. To ensure the accuracy and reliability of our deliverables, a comparative analysis was conducted. This involved the physical measurement of a door on-site, with the obtained dimensions then cross-referenced against its digital representation within the civil engineering program. Consistent with the outcomes of previous verification procedures, this assessment revealed a negligible margin of error. The quantitative details of this comparison are visually documented in the accompanying figures, further substantiating the precision of our data acquisition and modeling processes .the following case was a check for a door that measured in reality was 1.288m but in civil program we checked was 1.294m that means accuracy for that job ,also shown in the figures below.

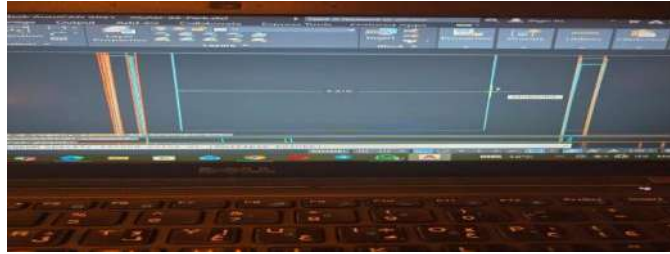


Figure (4-8) Checking distance in civil 3

In this work we did a lot of checks, but Some of the work that has been checked briefly shown in the table below

Table-2: Checking different distance between reality and civil 3D programs

	Distance in reality	Distance in civil 3D	Error
Check for door	2.220m	2.212m	0.008m
Check for window	1.288m	1.294m	0.006m

4.5 Summery

This part describes an as-built survey using a total station Leica TS07 total station to determine deviations between the actual construction and the planned design of a building. The survey involved scanning the building using control points to ensure complete coverage, and the resulting coordinates were unified to a local coordinate system to provide real 3D positions.

Chapter Five:

5.1 Conclusion

This project successfully applied advanced surveying technology specifically, the Leica TS07 reflector less Total Station to perform an accurate as-built survey of a building. The goal was to capture the real-world geometry of the building and compare it with design expectations using precise field measurements. By using both prism and non-prism modes, and implementing the resection method, we were able to measure hundreds of points in and around the building. These points were then processed and analyzed using Autodesk Civil 3D software, which allowed us to generate detailed 2D plans and accurate 3D models. The comparison between real field measurements and the digital models showed very small differences, which confirms that the method is both accurate and reliable. For example, differences between field and software measurements were not lot of millimeters also a little bit centimeter, showing the high precision of the equipment and workflow. This project demonstrates that using Total Station instruments for as-built surveys can save time, reduce human error, and improve the overall quality of documentation for construction, renovation, or maintenance purposes. It also proves the value of integrating modern surveying techniques with powerful software tools like Civil 3D for visualizing and managing engineering data.

5-2 Recommendations

1. The operation of a Total Station requires adequate training and technical understanding. Surveyors must be well-acquainted with the instrument's functions and workflow to ensure accurate and reliable data acquisition.
2. The selection of control points represents a critical stage in the surveying process. These points must be carefully and precisely established, as they form the reference framework for all subsequent measurements.
3. The choice of an appropriate surveying method is essential for achieving optimal results. In this project, the resection method was adopted; therefore, it is important for practitioners to evaluate and select the most suitable method based on project conditions.
4. The chosen building should possess clearly identifiable and accessible (points), preferably visible from at least two sides. This ensures adequate coverage and facilitates the acquisition of multiple façades.
5. A sufficiently large number of measured points should be collected to enhance the level of detail and improve the accuracy of the final outputs, particularly when processed in Civil 3D.
6. A fundamental understanding of Civil 3D is necessary. Practitioners should be familiar with its basic tools and functions to efficiently process, analyze, and model the collected data.
7. Finally, while surveying approaches may vary among engineers, the primary objective remains consistent: to accurately represent the building and achieve the required design outcomes.

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