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Article

Modern Geographical Maps and Geospatial Technologies and Their Role in Supporting Planning and Development Decisions – An Analytical and Applied Study

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Abstract: Considering the digital and information revolution witnessed globally, reliance on spatial data through modern geographical maps and technologies has become a fundamental element in planning and decision-making processes. Maps have evolved from being traditional descriptive tools into dynamic analytical systems that represent and interpret spatial reality in interactive and precise ways. The emergence of Geographic Information Systems (GIS), Remote Sensing (RS), and the Global Positioning System (GPS) has brought about a qualitative shift in understanding and analyzing geographical phenomena. Today, maps are no longer static documents used solely for guidance and location determination; they have become advanced analytical tools capable of integrating massive amounts of data, processing them, and presenting results that serve urban planning, resource management, sustainable development, disaster response, and other geospatial applications. Thus, it becomes essential to study the relationship between modern geographical maps and geospatial technologies to identify their potential in improving planning performance and enhancing spatial vision for decision-makers. This research aims to systematically investigate this integration by tracing the development of maps, analyzing the role of GIS and related technologies, and presenting a practical application on a selected study area, focusing on the benefits and challenges of using these tools in developmental contexts.

Keywords: Geographical Maps, Geographic Information Systems (GIS), Remote Sensing (RS), Spatial Analysis, Development Planning, Digital Thematic Maps

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1. Introduction

1.1 Background

In the last several decades, the swiftly evolving world of digital and information technologies has profoundly changed how spatial data is recorded, processed, and used. These changes have altered the landscape of cartography, making maps less static descriptive artifacts, to elaborate analytical systems, providing dynamic visualization methods, interactivity, and layered spatial analysis abilities [1], [2], [3]. Modern geographical maps are now at the core of geospatial sciences, playing a critical role in representing and interpreting complex spatial phenomena with greater precision and efficiency[4], [5].

At the core of this evolution is the incorporation of Geographic Information Systems (GIS). GIS services yield a dynamic approach to understanding geographic meaning, providing opportunities for the management of both spatial and attribute data, and enhanced analytical functions like spatial modeling, network analytical processes, and suitability-index mapping. Likewise, Remote Sensing (RS) platforms and services, that include terrestrial and aerial photographs, as well as satellite-based imagery can provide up-to-date, high-resolution data, facilitating ongoing change detection and monitoring of environmental and land-use changes across a broad area. And finally, the Global Positioning System (GPS) has improved the pinpoint accuracy of data collection and mapping in the field, and introduced the ability to geo-locate and spatially reference data more accurately, permitting better ground-truthing of data [6].

Together, these technologies enable data-driven decision making across many sectors such as urban planning, infrastructure planning/development, environmental planning, resource management and disaster management. For example, GIS-based analyses are often implemented for service distributions in both urban and rural areas, environmental risk assessments, and sustainable development efforts. Remote sensing monitors land degradation, impacts of climate change and urban sprawl, and GPS ensures reliable location-based data for planning and operations [7].

As the world becomes more reliant on smart governance and evidence-based planning, the need for modern maps and geospatial tools has become increasingly valuable in society. They facilitate a shift away from traditional approaches to decision making that rely on old or fragmented data, and toward spatially informed decision-making frameworks that promote better efficiency, equity and sustainability [8], [9]. In various developmental contexts - like Iraq - geospatial technologies are particularly important where inequities between service provision, infrastructure and resource spending are stark, thus facilitating an improvement in regional balance in of service provision and addressing socio-economic inequity [10], [11], [12].

Despite these achievements, gaps in institution capacity, data interoperability and analytics capacity are still also a potential barrier to the use of these tools in planning frameworks. Therefore, it is worth considering how contemporary geographical maps and geospatial applications can assist planning and development decisions, primarily in the areas of practice that are currently underutilizing geospatial technologies [13], [14].

1.2 Problem Statement

While contemporary mapping technologies and geospatial tools are becoming more available, there is still obviously much work to be done in ensuring that data produced through these advances is integrated into planning and development processes [15]. Most organizations lack the knowledge to fully utilize the analytical and problem-structuring capabilities of GIS, and therefore only have a limited understanding of the spatial aspects of their issues and, as a result, are making uninformed and poor choices. Thus, a critical question arises:

To what extent can modern geographical maps, supported by geospatial technologies, contribute to improving planning and development decisions, and what barriers hinder their effective integration into decision-making frameworks?

1.3 Research Objectives

This study seeks to:

1. Trace the evolution of maps from traditional static forms to modern digital and interactive formats.
2. Analyze the integration between thematic mapping and Geographic Information Systems (GIS).
3. Evaluate the role of advanced geospatial technologies (GIS, RS, GPS) in supporting development and planning.
4. Apply GIS techniques through a case study of Kirkuk Governorate to demonstrate practical benefits and challenges.

1.4 Research Significance

This study is important in terms of bridging theoretical and practical dimensions of modern cartography and geospatial technologies. This study has demonstrated their analytical capabilities of modern cartography and geospatial technologies and how they can inform urban and rural planning, service delivery, environmental management, and sustainable development [16]. The study also demonstrated the importance of developing spatial intelligence for decision makers, to manage service gaps and address distributional inequalities in resources.

2. Methods and Materials

This research adopts:

1. Descriptive-Analytical Approach: To examine the evolution of maps and the role of geospatial technologies.
2. Applied GIS Analysis: Utilizing software tools such as ArcGIS and QGIS to analyze spatial data and generate thematic maps for Kirkuk Governorate.
3. Data Sources: High-resolution satellite imagery, topographic and digital maps, spatial databases, official reports, and field observations.

This study uses spatial analysis to assess service distribution, demographic density, and land use patterns to show the function of geospatial tools in informing planning and development decisions.

2. Theoretical Framework of Geographical Maps

2.1 Definition of Geographical Maps

A map can be defined as "a drawn or digital image of the surface of the earth or parts of it, which is produced at a scale for the purpose of demonstrating how natural and human phenomena are distributed or arranged, to allow for spatial analysis and geographical interpretation, and for planning and development."

The American Association of Geographers (AAG) defines it as:

“A geographical map is a symbolic and scaled-down representation of the Earth’s surface or a portion of it, drawn using a specific scale, and displaying the spatial relationships between natural and human phenomena.”

Similarly, UNESCO’s Glossary of Geographical Terms defines it as:

“A geographical map is a graphic representation of the Earth’s surface or any part of it, showing natural and human features according to a symbolic and scaled system to facilitate reading and analysis.”

3. Results and Discussion

3.1 Types of Maps

Maps are an invaluable way of presenting information about our world, but they provide very different representations of different geographical phenomena. Maps can ext complete but in various purposes, including: topographical, thematic, geological, and climatological maps that emphasize their functional and interpretive differences in geographical and planning work.

Key types include:

1. Topographic Maps: Show terrain, natural, and artificial features.
2. Thematic Maps: Focus on specific subjects such as population, climate, agriculture, or natural resources.
3. Digital Maps: Created and analyzed using computers and specialized software.

Table 1. Types of Geographical Maps.

Map Type	Simple Description	Common Uses	Presentation Method
Topographic Maps	Show Earth's shape and features such as mountains, rivers, and roads.	Urban planning, environmental studies, geology.	Contour lines and symbols
Thematic Maps	Focus on a specific topic such as population or climate.	Population analysis, resource planning, social research.	Symbols and color-coded data

Digital Maps	Created and displayed using computers and specialized software.	GIS, data analysis, smart planning.	Interactive, digital, multi-layered

Source: .

3.2 Essential Elements of a Map

A geographical map is a useful and efficient method for visually communicating and interpreting spatial data [17], [18]. To be effective and interpretable, a map must incorporate the fundamental elements required to organize and present the information graphically, while also allowing readers to engage in analysis and relate to the geographical data in some way [19], [20]. Elements include:

1. Scale: Indicates the ratio between the map and reality (e.g., 1:50,000 means 1 cm on the map equals 50,000 cm in reality).
2. Legend (Key): Explains the symbols and colors used to represent different phenomena.
3. Orientation (North Arrow): Indicates the north direction, usually with an arrow or star, to help determine other directions.
4. Title: Reflects the main theme or content of the map.
5. Coordinates (Grid): Lines of latitude and longitude used to accurately locate positions on Earth.
6. Data Source and Date: Identifies the origin and preparation date of the map data to ensure credibility and accuracy.

3.3 Stages in the Development of Cartography

Cartography has evolved through several historical stages:

1. Ancient Period: Early hand-drawn maps depicted natural features and routes in primitive forms, as seen in ancient Babylonian, Egyptian, and Greek civilizations, using basic symbols and scales [21].
2. Middle Ages and Renaissance: Advances in science and tools such as the barometer and compass improved map accuracy, producing more detailed and realistic maps.
3. Modern Era: The introduction of digital technologies, GIS, and remote sensing revolutionized mapping, allowing the production and analysis of interactive, high-precision, multi-layered maps widely applied in planning, management, and development.

3.4 Modern Geospatial Technologies

The field of geography has seen significant advancements with the advent of technologies that enhance the collection, analysis, and presentation of spatial data. Tools such as GIS, RS, and GPS have become essential in understanding spatial relationships and making more effective geographical decisions, transforming how geographers and planners use maps and data, and opening new horizons in planning, development, and resource management [22], [23].

3.4.1 Geographic Information Systems (GIS)

GIS is an advanced computer-based technology used to collect, analyze, manage, and display spatially referenced data. It integrates spatial (location) data with descriptive (attribute) data to analyze relationships and support spatial decision-making [24].

Key Applications:

1. Urban planning and service distribution.
2. Natural resource management.
3. Risk and disaster analysis.
4. Transportation and infrastructure studies.
5. Supporting development-related decision-making.

Advantages:
1. Multi-layer data analysis capability.
2. Production of accurate, interactive maps.
3. Enhances spatial decision-making efficiency.

3.4.2 Remote Sensing (RS)

RS involves collecting information about the Earth's surface without direct contact, using sensors mounted on satellites or aircraft. It records and analyzes reflected or emitted radiation from objects.

Components:
1. Platform: Satellites or aircraft.
2. Sensors: Capture energy reflected or emitted from surfaces (e.g., visible light, infrared).
3. Receiving/Processing Station: Converts raw data into interpretable imagery.

Applications:
1. Monitoring vegetation and desertification.
2. Disaster tracking (earthquakes, floods, fires).
3. Land-use change analysis (agricultural, urban).
4. Producing accurate geographical maps.
5. Environmental and climate studies.

Advantages:
1. Covers vast areas quickly.
2. Provides frequent, up-to-date data.
3. Useful in inaccessible or unsafe regions.

3.4.3 Global Positioning System (GPS) and Its Role in Mapping

GPS uses satellite networks to provide high-precision location data in real time.

Mapping Applications:
1. Collecting accurate field data directly linked to GIS databases.
2. Identifying locations of geographical and human-made features (roads, buildings, crops).
3. Enhancing topographic and thematic map accuracy [25].
4. Updating and correcting outdated maps.

3.4.4 Geospatial Software (ArcGIS, QGIS, Erdas Imagine, etc.)

Geospatial software plays a key role in managing and analyzing spatial data, creating digital maps, performing spatial analysis, and generating accurate visual outputs.
1. ArcGIS: A comprehensive tool by Esri, widely used for database management, layer analysis, and creating interactive 2D and 3D maps.
2. QGIS: Open-source, user-friendly software supporting numerous plugins, often used in academic and community projects.
3. Erdas Imagine: Specialized in remote sensing and satellite image processing for environmental change detection and spatial data creation [26].

Importance:
1. Produces precise digital maps.
2. Analyzes spatial relationships.
3. Supports urban and environmental planning.
4. Enhances data-driven decision-making.

3.5 Integration Between Maps and Geospatial Technologies

3.5.1 Linking Thematic Maps with GIS

Thematic maps represent specific geographical phenomena, such as population distribution or natural resources. Integrating them into GIS transforms them from simple visual displays into powerful analytical tools for decision-making.

GIS stores thematic map data in analyzable spatial layers (e.g., roads, population density, soil, land use). Advanced operations like overlay analysis, proximity analysis, and spatial pattern recognition can then be performed. For instance, combining a population density map with healthcare facilities can identify underserved areas needing medical centers.

This integration has applications beyond planning, including agriculture, environmental management, disaster response, transportation, and education—making maps interactive and analytical rather than static representations.

3.5.2 Analytical Value of Geospatial Technologies

Modern geospatial technologies, especially GIS, add significant analytical value by processing large and complex spatial datasets. Through tools like layer overlays, route modeling, and spatial regression, they help identify risk zones, prioritize investments, and locate service gaps. Dynamic, updatable maps enhance decision-making efficiency in planning and administrative contexts.

3.5.3 Practical Applications of Integration

1. Urban Planning: Using GIS and population density maps to identify infrastructure deficits.
2. Resource Management: Combining vegetation maps with RS data to monitor desertification.
3. Transportation: Analyzing road networks and population maps to optimize transit routes.
4. Disaster Response: Integrating data and maps to locate affected areas and direct rescue teams effectively.

3.6 Practical Application – Case Study (Kirkuk Governorate)

3.6.1 Study Area Selection

Kirkuk Governorate in Iraq was selected due to its strategic location, natural resources, and demographic diversity. The region exhibits significant variations in land use, service distribution, and infrastructure, making it an ideal model to demonstrate the role of integrating maps and geospatial technologies in planning and development, see Figure 1.

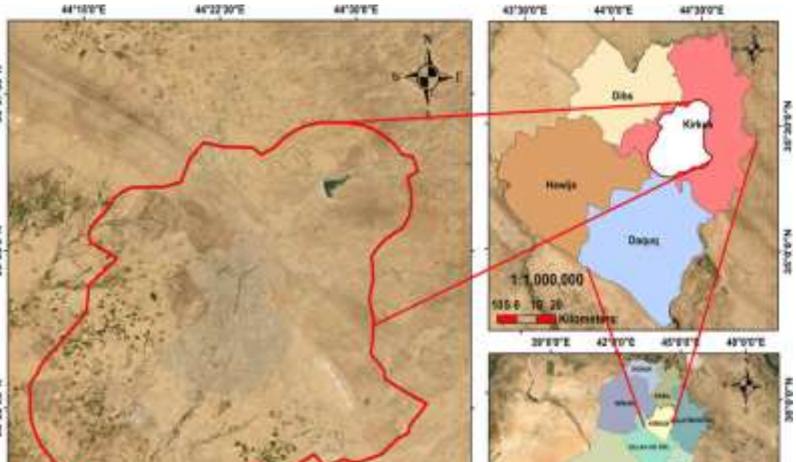

Figure 1. Map Location of Kirkuk Governorate in Iraq
Source: (Project).

3.6.2 Data Collection

Data was gathered from multiple sources:

1. High-resolution satellite imagery (e.g., Sentinel, Landsat).
2. Topographic and digital maps to identify natural and human-made features.
3. Population and service data from official reports and local agencies.

4. Field observations and Google Earth data.

3.6.3 GIS Database Development

Using ArcGIS and QGIS, a spatial database was built including layers for:

1. Road and transportation networks.
2. Distribution of healthcare centers, schools, and public services.
3. Land use (agricultural, residential, industrial).
4. Administrative boundaries within the governorate.
5. Population distribution by administrative units.

3.6.4 Data Analysis

Key spatial analyses conducted included:

1. Service Distribution Analysis: Revealed concentration of schools and health centers in urban cores, with rural service deficits.
2. Population Density Analysis: Produced density maps showing overcrowded areas lacking adequate services.
3. Overlay Analysis: Identified priority zones for service provision through multi-layer integration.

3.6.5 Production of Thematic Maps

The GIS analysis resulted in thematic maps including:

1. Health center distribution.
2. Population density by district.
3. Land-use classification.
4. Service gap areas.

These maps visually highlighted strengths and weaknesses in Kirkuk's development context, providing actionable insights for planners, see Figure 2 & 3.

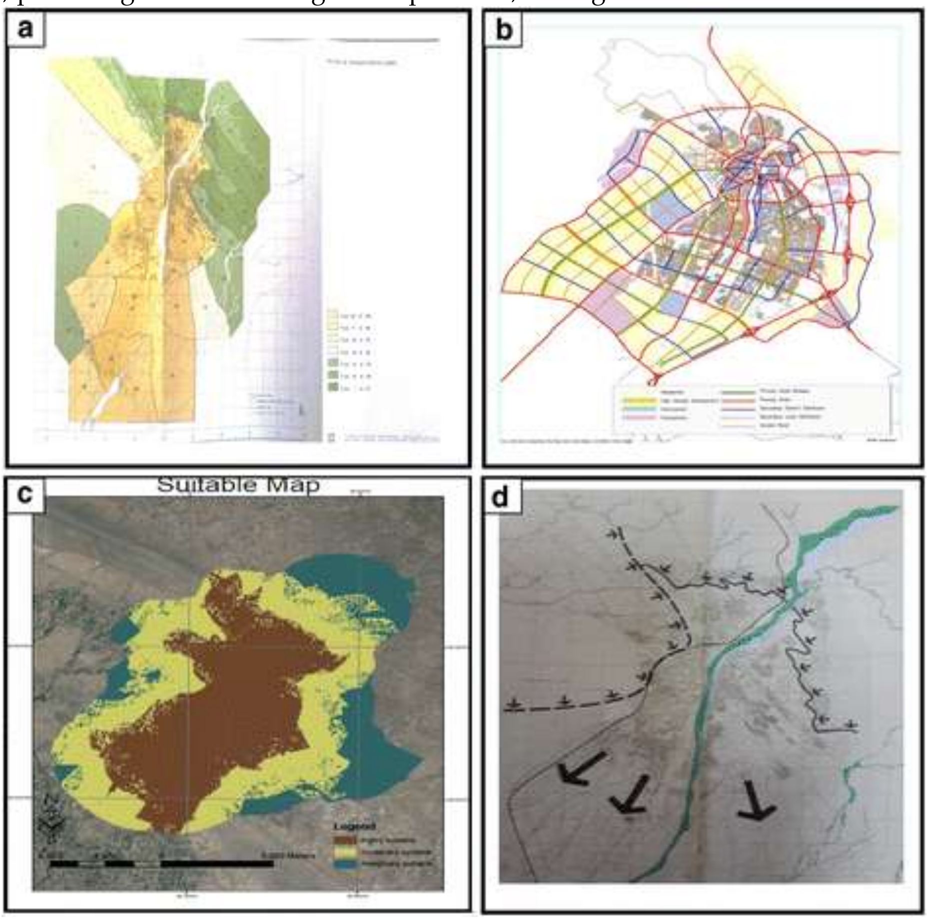

Figure 2. Map Various Types of Maps Used in Urban Planning and Land Use Analysis in Kirkuk Governorate

Source: (Omar & Raheem, 2016).

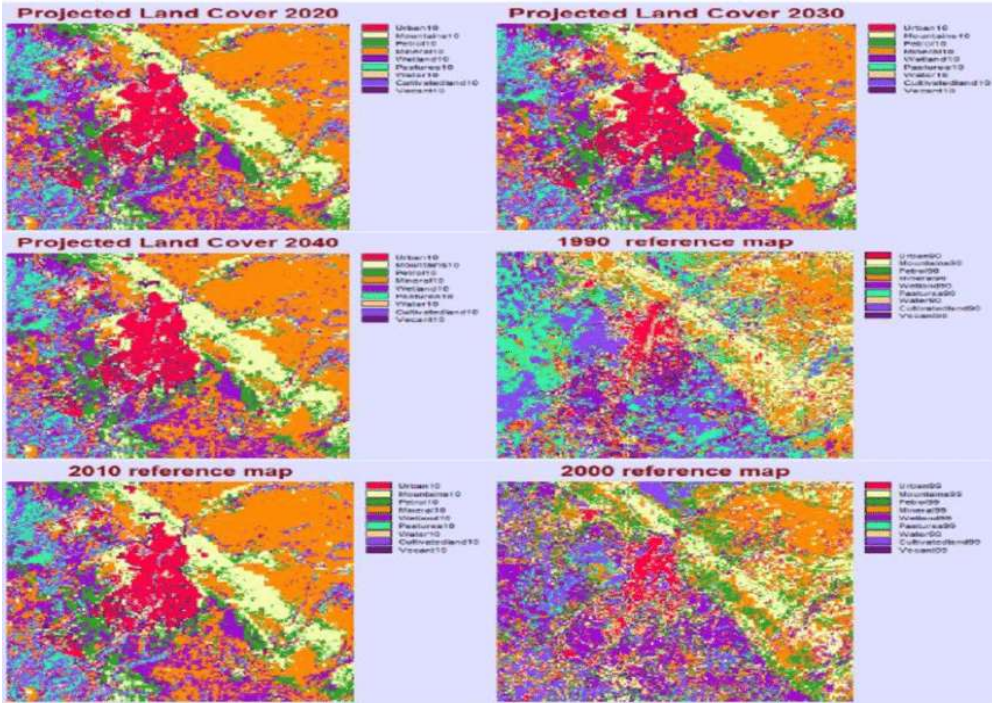

Figure 3. Map Land Use Changes in Kirkuk Governorate for the Period 1990–2040. Source:.

Based on the above steps and the models utilized, which were built on the geographic database of the governorate, along with the study and analysis, the following findings were revealed:

1. The maps and analyses indicated a clear disparity in the distribution of services compared to population density, particularly in rural areas.
2. The study uncovered the absence of integrated spatial planning in certain areas and an imbalance in resource distribution.
3. The results confirmed the importance of using GIS techniques as a supportive tool in urban and rural planning.

4. Conclusion

Geographical maps of all types, particularly thematic maps, serve as precise scientific tools for representing spatial phenomena and analyzing geographical relationships. Their effectiveness, however, is significantly enhanced when integrated with modern geospatial technologies such as GIS, RS, and GPS. The findings of this research demonstrate that such integration is a vital instrument for supporting decision-makers, especially in planning and development fields, by providing accurate, analyzable, and updatable spatial data.

The applied study on Kirkuk Governorate illustrated how GIS-supported thematic maps can identify service gaps and population disparities, thereby guiding developmental planning more equitably and efficiently. The analyses also emphasized the necessity of incorporating spatial analysis into decision-making mechanisms to ensure a more balanced allocation of resources and services.

Accordingly, this research recommends the widespread adoption of modern geospatial technologies in planning and governmental institutions, along with the development of national expertise in this domain, due to their strategic role in enhancing spatial management and fostering urban and community development.

Recommendations

Based on the results and analyses of this study, several recommendations are proposed to promote the use of geographical maps and modern geospatial technologies in supporting development and planning:

1. Strengthen the use of GIS in governmental and local institutions and link it to an updated national spatial database.
2. Regularly update geographical maps using remote sensing techniques to ensure the availability of real-time, accurate data that supports planning processes.
3. Focus on training and capacity building for professionals in cartography and spatial analysis through specialized training programs and academic courses.
4. Encourage the use of digital thematic maps in analyzing developmental phenomena such as population, services, transportation, and resources, aligning them with sustainable development goals (SDGs).
5. Promote inter-agency integration (planning, municipalities, environment, education, health, etc.) to ensure unified data sharing and achieve a comprehensive development vision.
6. Integrate geospatial technologies into education to instill spatial awareness and enhance analytical thinking among students and researchers.

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