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GIS BASED URBAN LAND USE MAPPING AND PLANNING ASSESSMENT IN THE KINDA DISTRICT OF KUFA CITY

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SUMMARY

Urban land use maps give necessary information about the location and availability of different uses of lands in cities. Conventional mapping techniques take much time and money but with GIS techniques this process becomes quick and easier. This study examines the land uses of the Kinda district in Kufa city, Iraq, using GIS mapping techniques. The GIS database was prepared using the master plan of Kufa city, cadastral maps, georeferenced satellite images, and field surveys. The analysis of spatial data using ArcGIS was performed to identify the land-use types, measure their areas and percentage, and to evaluate their per capita allocation compared with Iraqi urban planning standards. The total area of Kinda District is 50.1154 hectares with 3,818 inhabitants. Residential land use took the biggest percentage (26.5728 ha; 53.023%) while streets (10.420 ha; 20.79%) and commercial land use (5.6248 ha; 11.221%) were ranked second and third, respectively. Other land-use types included: green and recreational lands (3.2906 ha; 6.566%), educational facilities (2.4381 ha; 4.864%), health care (0.9022 ha; 1.800%), and religious use (0.8704 ha; 1.736%). Per-capita allocations of residential (69.69m²/person), commercial (14.7 m²/person). The results show that the Kinda District has a relatively balanced land use pattern in terms of urban areas and adequate provision of services based on local planning standards. The study has proven that GIS technology is capable of creating accurate, cost-effective and updated maps and spatial data base for urban land use patterns.

Key words: *geographic information systems (GIS), urban land use, spatial analysis, urban planning, kufa city, land-use mapping, spatial database.*

INTRODUCTION

A map is a scientific tool that uses specific and understandable symbols to illustrate selected information, showing the characteristics of land uses and their distribution within an urban area. It can be used as an aid to planners and decision-makers to assess the extent to which planning standards are being met and to monitor their future implementation. Maps provide accurate data and information on land uses and the needs of the city's population, addressing areas of deficiency, especially when a Geographic

Information System (GIS) is used in their preparation and design [10]. A GIS is a crucial tool for spatial analysis, modeling, and presenting results in tables, reports, and flat or three-dimensional maps, therefore, cartographers give special importance to the use of the Geographic Information System in preparing and designing urban land use maps [9].

Urban land uses are defined as the spatial distribution of a city's various functions, including residential, industrial, commercial, service, recreational, and other uses, according to it, places of residence, work and services are determined and transportation and traffic depend on it [11]. Therefore, these uses should be organized and evaluated on the ground so perform their basic function without any problems [12][13]. The best urban land uses, in terms of quantity and quality, are those that meet the needs of the population and achieve balance, through the application of planning standards for residential neighborhoods, represented in the ratios of different uses and their distribution [14]. The holy city of Kufa is a historical city with a religious character for Muslims, in addition to being an important administrative and commercial center at present. Its population reached (589,415) person in 2024, This represents (30.21%) of the total population of the holy Najaf Governorate. Kinda District is a modern and planned neighborhood compared to the old city neighborhoods and informal areas. It was chosen as the subject of the study because of its different land uses and the area's urgent need for an in-depth study to show the conformity of the current land uses with the planning standards in force locally, using a cartographic study supported by a GIS. The District is located between latitudes ($32^{\circ} 1-13'N$) and ($32^{\circ} 1-45'N$) north, and longitude ($44^{\circ} 22-51'E$) and ($44^{\circ} 23-21'E$) to the east, figure 1, Its area is (0.501154) km², (area calculated using a function calculate geometry in GIS, figure 2).



Figure 1. The site of kinda district from the holy city of kufa



Figure 2. Application interface for calculating the area of the kinda district using "calculate geometry" in GIS

While Geographic Information Systems (GIS) have been widely used in urban planning and analysis, there are relatively few studies employing GIS technologies to map and evaluate urban land-use in detail at the neighborhood level in Iraqi cities such as Kufa. Existing studies mostly deal with city-wide planning, while lacking spatial databases needed for continuous assessment of the land-use appropriateness in accordance with planning criteria. Consequently, a need for more GIS studies of urban land uses at the neighborhood level arises.

The importance of this study consists in contributing to better urban planning practices through development of accurate and updatable GIS-based land-use maps for Kinda District. In addition, this study quantitatively assesses distribution of urban land uses, determines the amount of per capita land uses, and checks conformity of current land uses with Iraqi planning criteria. The primary contribution of this research is the creation of a GIS supported spatial database and thematic maps of urban land uses that will be helpful for future urban development and services provision.

The report is divided into six major sections. Literature Survey (section II) gives an overview of recent research on the application of GIS in urban planning and land use. Methodology and Data (section III) provides details on the datasets used, GIS environment, process flow, spatial analysis and validation techniques. Results (section IV) show the urban land use maps and urban planning analysis. Discussion (section V) brings out the implications of the study. Conclusions and Future Research (section VI) provide the summary of the major findings and direction for further studies.

LITERATURE SURVEY

The recent developments made in GIS and spatial technologies have greatly contributed to urban planning and land use management and decision-making process. In Iraq, there have been several studies that have shown the efficiency of using GIS for studying the urban spatial dynamics and sustainable development [16][17]. The earlier study conducted on urban land use changes in Kufa City with the help of GIS and stressed upon the ability of spatial technologies for studying the urban spatial dynamics and changes [2]. Likewise, another study carried out on detecting the land use/land cover changes in Kufa City through remote sensing and GIS technologies [4].

Urban transformations and planning assessments have been another major research area of focus [18][19]. Urban transformation and prediction of future structures of Kufa City were forecasted using cellular automata and Markov Chain models, and how spatial data is important to do the same [3]. The relationship between spatial justice and the quality of life in the selected urban areas in the First Kinda neighborhood was studied at the neighborhood level, and how equitable distribution of land use can make an impact on the quality of life [1]. In another study, the relationship between regional land use and functional changes of urban areas was discussed [5].

Apart from the case study of Iraq, GIS applications in urban planning have diversified to cover the areas of suitability studies, sustainability evaluation, and environmental management. In a related effort, it has applied GIS techniques along with AHP for urban growth suitability index and proved the utility of spatial analysis in the process of urban development [6]. The evaluation of green spaces in Duhok city using remote sensing images, GIS, NDVI, and ground-truthing has validated the role of geospatial analysis in the assessment of urban environment [7][15].

Despite much research on urban expansion, land-use change, sustainability, and spatial planning, few studies have produced urban land-use maps for Kufa City using GIS tools and assessed compliance with planning requirements simultaneously. Thus, this work attempts to fill this gap by preparing GIS-based spatial database and thematic land use maps of the Kinda district and assessment of adequacy of land uses based on the Iraqi criteria for planning.

METHODOLOGY AND DATA SOURCES

Data Sources

Kinda district's Urban Land-use mapping was based on several spatial and non-spatial sources of data. The spatial data sources used included the Master plan of Kufa city at the scale of 1:60,000 provided by Architectural Design & Consulting Institute (ADCI), Cadastral maps which were acquired from Real Estate Registration Directorate and Georeferenced satellite images of Kufa and Najaf area. Moreover, field observations were undertaken to validate the current land use situation and add more attributes to the spatial features.

GIS Software Environment

The processing, analysis, and cartography of the spatial data was carried out through ArcGIS ArcMap. The GIS platform was utilized for georeferencing, digitizing, creating databases, calculating areas, analyzing, and map making. All the spatial data sets were projected into a single coordinate system for analysis purposes.

GIS Workflow

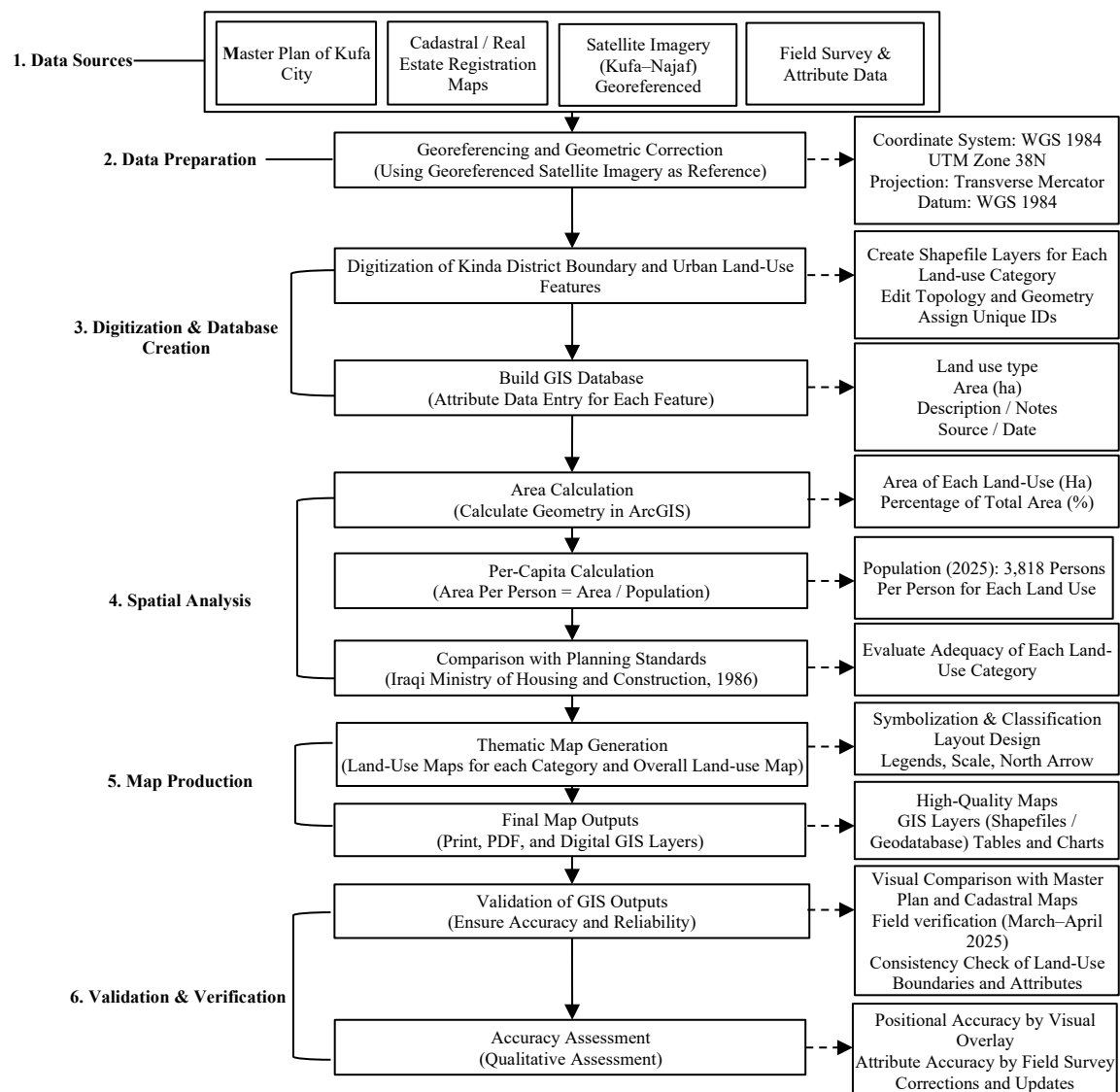


Figure 3. GIS workflow for urban land-use mapping and analysis in the kinda district, kufa city

GIS process involved the following procedures:

1. Gathering of spatial data from master plan, cadastral maps, and satellite images.
2. Geometrical correction and georeferencing of source maps through the use of already geometrical corrected satellite images as reference.
3. Generation of digitized map of Kinda District boundary and all land use features within it.
4. Generation of shapefile layers of residential, commercial, educational, health, religious, recreational, and transportation land use types.
5. Creation of attribute database which includes the descriptive information about each feature.
6. Adding of field survey information to the GIS database.
7. Calculations of area and percentage through GIS spatial analysis functions.
8. Preparation of land use thematic maps and statistics.
9. Comparing the results to Iraqi urban planning standards.

This figure 3 demonstrates the methodology that has been used in creating GIS-based maps of urban land use for the Kinda district. The process starts with the acquisition of spatial and field data, georeferencing, digitizing, database development, and spatial analysis. Areas, percentages, and per capita land use have been calculated and compared against Iraqi planning norms. Thematic mapping is the final step of this process.

Spatial Analysis Procedures

The Calculate Geometry tool present within the ArcMap software was utilized in calculating the area of each of the categories. This was achieved by finding out the percentage of each land use in relation to the entire area of the district. The population figures were thereafter utilized in calculating the per capita area of each of the land use categories.

Validation and Accuracy Assessment

For the validation of the generated maps, visual comparison was made between the digitized land use boundaries and the master plan/cadastral maps. Verification was further performed through the observations on-site in order to verify the existence and classification of land uses. It is apparent from the matching results of the GIS generated output with the planning maps that the generated land uses correspond to the existing spatial structure of the Kinda District.

URBAN LAND USE MAPS IN THE KINDA DISTRICT

Urban land use maps are thematic (special) maps designed to represent the characteristics of land uses within the urban area. Accurate spatial representation of these characteristics requires a large database, so it must be reduced and modeled to be processed and analyzed by specialized software in geographic information systems by representing these elements according to specific criteria. These maps and their accompanying information (metadata) are represented in layers that enable the map user to view the geographic phenomenon in an updatable manner. This type of technology has given a prominent role in facilitating the monitoring of information and making it easier to deal with it with a kind of accuracy, speed and change. The allocation of land uses within a residential area is not a simple process. Numerous planning and environmental principles must be considered to determine the appropriate location for each use [8]. Several requirements must be met in this allocation, including: a homogeneous distribution in proportions that conform to planning standards; a road network that ensures smooth traffic flow and easy, trouble-free movement; and the distribution of public services in a way that benefits all city residents. The same applies to recreational, cultural, and green spaces. It seems that every city, regardless

of its size, must provide functions for its residents and the population of its region, and these functions occupy a spatial area in the form of land uses that share the city's built-up land, The study area included residential, educational, health, religious, green and recreational areas and roads are shown in figure 3. It was represented by the symbols of the specific area and by the colors agreed upon by geographers, where residential use is in reddish-brown, commercial buildings in grey, green areas in green and public buildings in red.

Given the importance of residential use, urban geography views the city as a form of habitation, figure 4 shows the geographical distribution map of residential use in the study area, which consisted of detached houses of average quality. The area lacked vertical housing. Residential use occupied the largest part of the district area (26.5728 hectares) out of the total neighborhood area of (50.1154) hectares, figure 5 representing (53.023%), the per capita share of residential use was (69.69) m²/person, This is higher than the limit set within the Iraqi planning standards of (50 m²/person). Accordingly, the functional efficiency of residential land uses is good, noting that the population in the Kinda neighborhood in the year (2025) reached (3818) people.

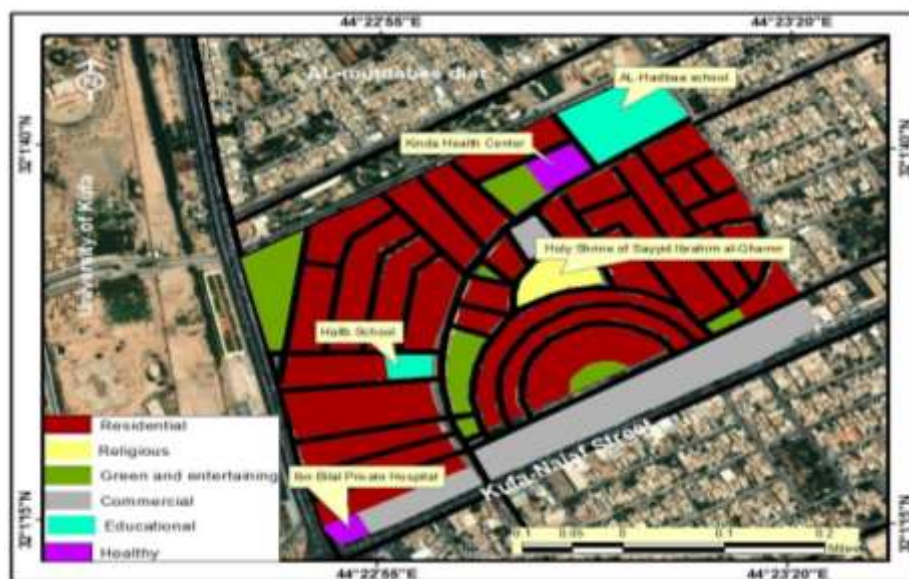


Figure 4. Urban land uses in the kinda district



Figure 5. Application interface for calculating the area of the residential land uses

Table 1. Urban land uses in kinda district

No.	Land use	Area (hectares)	% of the total area
1	Residential	26.5728	53.023
2	Religious	0.8704	1.736
3	Green and entertaining	3.2906	6.566
4	Educational	2.4381	4.864
5	Healthy	0.9022	1.800
6	Commercial	5.6248	11.221
7	Streets	10.420	20.79
8	total	50.1154	100%

Regarding land uses for religious services, the only such use is for the shrine of Sayyid Ibrahim ibn al-Hasan al-Muthanna ibn al-Hasan al-Sibt (peace be upon them) (Figure 4), which is one of the revered and well-known shrines among the people of Kufa and Najaf. The area of this use reached (0.8704) hectares, representing (1.736%), as shown in table 1, and figure 6. The per capita share of religious use was (2.2) m²/person, which is higher than the planning standard of (0.125) m²/person. Thus, the functional efficiency of religious land uses is considered good.



Figure 6. Application interface for calculating the area of the religious land uses

The area of green and entertaining areas in the study area amounted to (3.2906) hectares, representing (6.566) %, as shown in figure 7, while the per capita share was (8.630) m²/person.



Figure 7. Application interface for calculating the area of the green and entertaining land uses

Educational services in the Kinda neighborhood were limited to the Aleppo Primary School and the Al-Hadbaa Secondary School, and thus its area is (2.4381) and the percentage of (4.864)%, are illustrated in figure 8, while the share of each individual of it was (6.3) m²/individual, and the local planning standards stipulated that there should be one primary school for every (2000) people, and one secondary school for every (5000) people, so the functional efficiency of religious land uses is good.



Figure 8. Application interface for calculating the area of the educational land use

The study area contains the Kinda Government Health Center and Ibn Bilal Private Hospital, which represent the land uses for health services in the Kinda neighborhood only. The area of this use was (0.9022) hectares and the percentage of (1.800) % are expressed in figure 9, while the share of each individual of it was (2.3) m²/individual. The local planning standards have determined that there should be one health center for every (10000) people, so the functional adequacy of the health land uses is good.

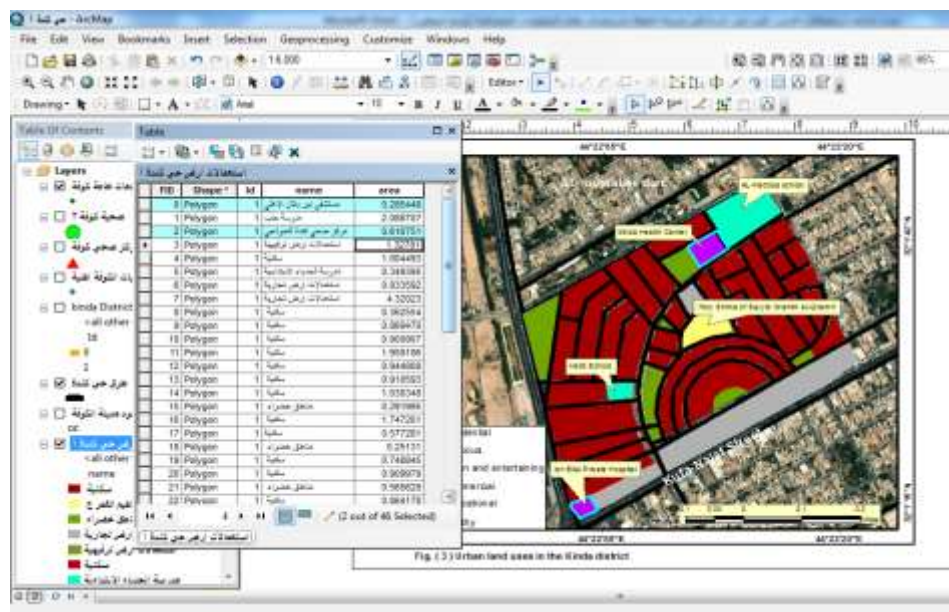


Figure 9. Application interface for calculating the area of the healthy land uses

Commercial use in the study area is distributed in the form of commercial clusters along Kufa Najaf Street, which include wholesale shops and stores and retail shops. The area of this use amounted to (5.6248) hectares and the percentage of (11.221) % are shown in figure 10, while the share of each individual of it was (14.7) m²/individual. Local planning standards have determined that there should be (2) m² per person. Therefore, the functional efficiency of commercial land uses is good.

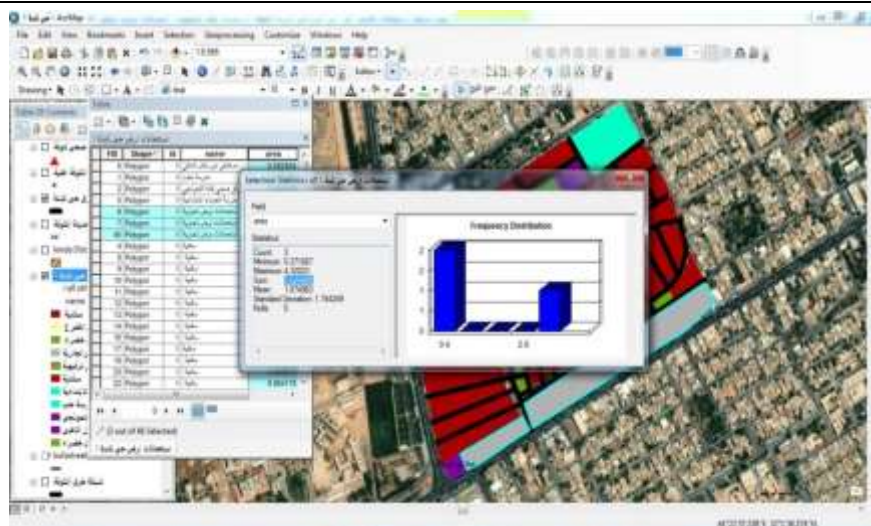


Figure 10. Application interface for calculating the area of the commercial land uses

Road use occupies an area of 10.42 hectares of the residential area, representing 20.79% are illustrated in table 1 and figure 11. The per capita share of this land is 27.3 m²/person, while local planning standards stipulate 12 m² per person. Therefore, the functional efficiency of land use for transportation is good. The neighborhood's streets are well-connected, providing access to public transportation routes and adequate access for public services such as waste collection, delivery services, and emergency services.

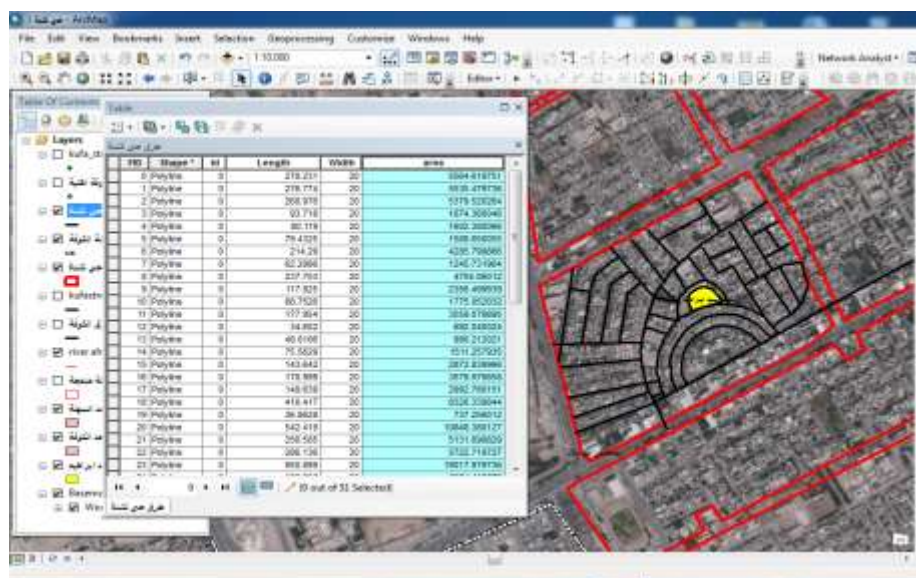


Figure 11. Application interface for calculating the area of the street land uses

Comparison with Planning Standards

Overall results show that in Kinda District most of the types of urban land use conform to or exceed planning standards prescribed by law. The amount of residential land provided (69.69 m²) significantly exceeds the minimum planning standard of 50 m² per resident. The available commercial land exceeds the minimum planning standard (14.7m² vs. 2m²) and is followed in this respect by transportation land (27.3 m² per person, vs. 12 m²). The available educational, health, and religious facilities comply with minimum requirements based on population size. These findings imply a reasonably well-balanced overall urban structure in Kinda District, with an adequate level of service. Due to the absence of comparable GIS-based land-use datasets for the other districts of Kufa City, a direct comparison with those districts has not been possible. Future research may be conducted to extend the analysis to adjacent

districts to compare the distribution of urban land use and the efficiency of planning between districts.

DISCUSSION

From these results, the study can clearly see that GIS is an efficient tool for mapping, analysis, and evaluation of urban land uses on a neighborhood basis. This study found out that the residential land use constitutes the biggest percentage of the total land use in Kinda District, which is 53.023%. Moreover, the allocation per capita of residential, commercial, transportation, educational, health care, and religious land uses conforms to and even exceeds the standards set by the Iraqi Ministry of Housing and Construction. This shows that the district has an urban structure that is fairly balanced and adequate in terms of service delivery than the required minimum standards. On the other hand, the lack of facilities such as kindergarten, youth centers, civil defense services, and handicrafts industry areas reveals scope for urban development.

From a pragmatic point of view, the spatial database created using GIS technology in this research would assist municipal administrations and decision-makers in assessing changes in land use, determining service deficiencies, and making future investment decisions. The thematic maps produced by this research serve as a useful decision-making tool for urban management and resource allocation. Moreover, the database could be regularly updated in light of any future demographic and spatial changes taking place in the district.

Nevertheless, there are a number of limitations of the current research which should be considered. First of all, this research is confined to one specific district of Kufa city and thus cannot be easily generalized to other urban areas. Secondly, in the course of this research, no remote sensing tools were applied and the analysis was based on planning maps, cadastral information and field observations.

Future studies need to extend their investigations into more than one district in Kufa city and beyond other Iraqi cities to facilitate urban comparison studies. The incorporation of satellite imagery at higher resolution, UAV data, and GIS spatial modeling can help in making the map even more accurate. The longitudinal study of land use changes will be beneficial for urban planning and development.

CONCLUSIONS

The study showed the efficiency of GIS in preparing, analyzing, and mapping urban land use for the Kinda District in Kufa City, Iraq. The integration of spatial information from the master plan of the city, the cadastral map, satellite images, and fieldwork resulted in a GIS database for assessing the spatial pattern and adequacy of major land uses in the city. The findings showed that the total area of the district is 50.1154 ha, with a population of 3,818 people. The land use which occupied the biggest part of the area is residential, with an area of 26.5728 ha (53.023%), followed by streets which covered an area of 10.420 ha (20.79%), commercial use which covered 5.6248 ha (11.221%), green and recreational uses which covered 3.2906 ha (6.566%), education which covered 2.4381 ha (4.864%), health which covered 0.9022 ha (1.800%), and religion which covered 0.8704 ha (1.736%). The per capita analysis shows that the majority of land use types meet or exceed the established planning standards set forth by the Iraqi Ministry of Housing and Construction. With regard to the allocation of residential land area, it reached a total of 69.69 square meters (m²) per person, and was above the recommended minimum area of 50 m² per person. Commercial land use came in at 14.7 m² per person compared to prescribed standards, and transportation land use was at 27.3 m² per person versus the recommended minimum area. These results indicate that the Kinda District, as a whole, has a relatively balanced urban structure and adequate levels of service. However, there were still deficiencies found in a few of the facility types evaluated, such as: kindergarten facilities; youth centers; civil defense services; and handicrafts facilities. The current investigation has established the importance of GIS as a dependable and economical means of urban planning and spatial studies. Further work needs to be done in order to carry out land use study in other districts of the city and using the latest technologies of GIS and remote sensing data in order to look into the time aspect of land use changes.

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