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Spatial GIS-Based Analysis in Determining the Hydrological Factors of Kirkuk Governorate

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Abstract

With the accelerating pace of urbanization and the worsening of climate change, securing adequate water resources has become critically important. Recent advancements in spatial technologies, particularly the integration of Geographic Information Systems (GIS) with Digital Elevation Models (DEMs), have emerged as vital tools for conducting hydrological and watershed analyses.

Based on the DEM, the GIS framework is used in the research to cover hydrographic explanations for all of Northern Iraq, with emphasis on Kirkuk Governorate. Hydro-environmental geospatial data: Digital Elevation Models were processed from the Shuttle Radar Topography Mission (SRTM) 30 m spatial resolution to derive drainage networks, watershed boundaries and slope distribution along with from which direction the water will flow and where it will accumulate. The results indicate that the watershed area of each of the RES (i.e., vegetated region) is dissimilar across the study site, as a reflection of geomorphology variability. The drainage pattern is dendritic and is controlled primarily by a first- and second-order stream, in moderate structural control along with an inherent surface runoff process. Elevation and slope differences primarily control the flow pathways as well as runoff concentration. The results indicate that DEM driven hydrological modeling describe a robust and resource-efficient approach for large scale hydrological evaluation. These products are valuable for flood risk assessment, watershed management and sustainable land-use planning in semi-arid environments.

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Keywords: Semi-Arid Region; GIS; Digital Elevation Model (DEM); Watershed Analysis; Drainage Network, Hydrological modeling

Introduction

Late last century, fast growth of population and accelerated expansion of urban areas in addition to climate variation over time—combined with anomalous changes in patterns (distribution and intensity) of rain—have made the management and planning for storage space of water resources extremely complex [1]. Water is a crucial enabler of livelihoods and economic stability at all local, national and global scales. It is the foundation for food security strategies and an important line of defense against drought [2]. Yet growing consumption fuelled by urban expansion and the unbridled, excessive exploitation of water resources have put increasing stress on available supplies leading to fears about sustainability for the long term [3]. In addition, high-resolution remote sensing (RS) data integrated into Geographic Information System (GIS) have been utilized in assessing and managing the land and water resource under such baselines. They are most suitable and effective for monitoring drainage systems and catchment dynamics in sensitive semi-arid environments [4, 5]. Hydrological parameters at the surface, especially regarding morphometric analysis of the drainage networks are important for identifying groundwater recharge areas, understanding watershed behavior for modeling purposes, estimating runoff in an area, demarcating boundaries of basins along with delineation of zones exhibiting different groundwater potential and geotechnical studies [6, 7]. These types of analyses can also serve to contextualize basin geomorphology, illustrating how geological structure governs terrain configuration and topography variation [8, 9]. Drainage parameters were traditionally derived from topographic maps and empirical field observations.These time-series approaches enabled important insights but had traditionally limited interpretation in a manual context and were also limited by the use of moderate resolution data [10]. Many of the traditionally utilized techniques in topographic interpretation have been replaced by elevation databases such as MODIS spectroradiometer products, ASTER Global Digital Elevation Models (ASTER GDEM), and Shuttle Radar Topography Mission (SRTM) DEMs. These datasets allow rapid, accurate and low-cost extraction of terrain information for hydrological analysis [5, 11]. Digital Elevation Models provide elemental terrain characteristics such as drainage networks, watershed boundaries, hill slope upstream contributing areas and hillslope gradient & surface aspect orientation. Consequently, the DEM based analyses are considered as major quality tools used for extending investigations of watersheds [11], studies to derive information on runoff generation and movement [5] and integrated water resources management [12]. The current study includes an integrated digital elevation model (DEM) and geographic information system (GIS) analysis applied to Kirkuk Governorate in northern Iraq. This analysis identifies watershed composition, calculates flow direction and accumulation, and characterizes the hierarchy and proportions of streams. The data encompass hydrological monitoring across multiple regions, guiding scientific principles that contribute to the development and implementation of sustainable water resource management and urban planning strategies [13-15].

Furthermore, the integration of digital elevation models with GIS-based hydrological modeling can be closely linked to broader sustainable development goals [16]. The increasing population growth in cities like Kirkuk necessitates resilient and sustainable water management systems [17]. Today, geospatial technologies enable planners to adapt to climate change while simultaneously ensuring the sustainability of economic growth through environmental conservation.

This work contributes to the robust field of urban hydrology by providing a spatially informed analytical framework that supports decision-making for policymakers, urban planners, and environmental stakeholders.

This study stresses on the strategic importance of DEM and GIS in addition to hydrological model with particular reference to sustainable urbanization in Kirkuk, Iraq by investigating crucial hydrological parameters.

Method

Study area

The current study was conducted in Kirkuk Governorate, situated in the northeastern part of Iraq covering approximately 1,475 km². Geographically, the area is situated between longitudes 44°00′E and 44°50′E, and latitude 35°13′N to 36°29′N [16]. The governorate had been chosen for its geomorphological diversity and representative terrestrial characteristics. Various forms of urban settlements, barren areas, vegetated regions, soil types mixed with water bodies as well as grass are in their infrastructures. Showing complex environmental conditions.

Due to the strategic geographic position of all areas and districts, Kirkuk City - included -was chosen as a center for investigation within the governorate. The region is a transitional zone between the irregular highlands to the north and the reasonably flat, semi-arid plains that spread southwards and south-west [17]. Aside from the value of its history, Kirkuk brings much natural resources, especially oil and minerals. Its location in the northern highland belt of Iraq adds to the diversity of topography, climate and physical environment conditions [18]. This unique combination of geomorphological, climatic, and environmental features not commonly found together in a single region suggested that Kirkuk would be an appropriate setting for investigating land use and land cover (LULC) dynamics under multiple distinct environmental pressures [13].

The heterogeneous study area with mixed land cover and urban, peri-urban (agri-urban) and semi-arid landscapes are contributing towards complications in optical remote sensing analysis linked to spectral variability. To tackle this complexity, both random and systematic sampling strategies were applied with established reference data for all LULC categories. Besides, seasonal effects were mitigated by using multitemporal imagery to enhance the classification efficacy and mapping accuracy [15].

Description of data used

The main dataset employed in this research consists of Landsat-8 data / Level-2 images dated November, 23rd, 2025. Data was obtained from the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) of the Landsat 8 satellite. The location corresponds with Worldwide Reference System (WRS-2) Path 169 and Row 35. Near-nadir viewing geometry (0.43% of the image with cloud cover) allowed the collection of high spatial resolution images with a good radiometric quality suitable for detailed analyses.

The dataset was provided in GeoTIFF format, including multispectral and thermal bands at a 30 m spatial resolution as well as a panchromatic band (spatial: 15 m). All data are mapped onto Universal Transverse Mercator (UTM) Zone 38N, WGS84. Level-2 preprocessing is radiometric calibration and atmospheric correction. Surface reflectance values were created using the Landsat Surface Reflectance Code (LaSRC), and land surface temperature (LST) data was derived from the standard Surface Temperature (ST) algorithm. To increase the accuracy of solar irradiance correction, ancillary atmospheric inputs were acquired from the Visible Infrared Imaging Radiometer Suite (VIIRS), as well as GEOS-5 atmospheric reanalysis datasets.

Apart from the satellite images, a 30 m spatial resolution Digital Elevation Model (DEM) was included in order to support terrain and hydrological analysis. The Digital Elevation Model (DEM) was obtained from the NASA Shuttle Radar Topography Mission (SRTM, 2013) through Open Topography platform. This elevation product has homogeneous coverage area, and filtering steps have been applied to mitigate radar speckle effects. 41 The DEM was used to characterize surface elevation and extract topographic parameters for hydrological analysis (like Table 1).

Table 1: Data used description

Item	description
The name of data sources	Shuttle Radar Topography Mission (SRTM GL1) Global 30 m
Taken date	16/1/2026
Provider of Data	Open Topography
Coverage rate	Global coverage

DEM Preprocessing

For the assurance in analysis, several preprocessing stages of Digital Elevation Model (DEM) had to be carried out before running hydrological modelling. A preliminary quality check is then performed: this process aims to identify phantom depressions (basins) that may result from radar interference, data distortions, or inconsistencies in the interpolation process. These depressions can obstruct simulated surface runoff paths (flow accumulation) and prevent the extraction of drainage network data.

Anomalies were then corrected using a sink-filling algorithm which increased the elevations of affected cells to the minimum required value allowing for continuous connectivity in the downhill flow direction. Hydrologically consistent DEM was generated in this conditioning process, which enhances flow routing capability, watershed delineation and extraction of drainage features.

Hydrological Factors

Sink factor

Sink hydrological factors indicate depression cells that are found in the topography of a digital elevation model (DEM), in which its surrounding cells have higher maximum altitude values, causing it to block the flow of water dispensed downward and creating hydrological discontinuities. Sinks may be real features in the landscape, like lakes, but sinks are more commonly artifacts to consider when analyzing DEM data, and they typically result from noise in the data or problems during interpolation. Mathematically, a cell is a sink when:

$$H_i \leq H_j \forall \in C(i) \quad (1)$$

where H_i is representing the central cell elevation, and H_j refers to the all-neighbor cells C(i). Prior to DEM correction and flow routing, identifying sinks is a crucial step [19].

Fill factor

To handle sinks, all depressed cells are raised to a minimal depth so that water can flow into neighboring cells. This process produces a hydrologically accurate digital model of the elevation (DEM) by ensuring continuous drainage pathways. Now, let's visualize the elevation as a filled surface:

$$H_{filled} = \max(H_{original}, H_{spill}) \quad (2)$$

Where H_{spill} represents the minimum elevation required to allow for outflow from the depression. The filling process maintains the structural integrity of the terrain while eliminating artificial flow barriers [19].

Direction of Flow factor

This factor represents the outlet surface runoff of each cell within a digital elevation model (DEM) to one of its neighboring cells with the steepest degrading slope. A popular method known as the D8 algorithm calculates the slope for each of the eight neighboring cells and routes flow to the steepest descent. The slope is determined as:

$$Slope = \frac{H_{center} - H_{neighbor}}{d} \quad (3)$$

Where d refers to the distance between two cells centers. This procedure gives a raster giving code to the direction of flow in each cell [20].

Flow Accumulation Factor

Flow accumulation factor describing the flow received by a cell or accumulated surface runoff from all upstream cells. Cells with higher accumulation values refer to valleys channel and bottoms networks, while lower cells accumulation values are ridges or will be divides. The flow accumulation is defined as:

$$Flow\ Acc_i = \sum_{j \in S(i)} 1 \quad (4)$$

Where: S(i) represents the set of cells contributing to cell i. This factor plays a key role in characterizing the drainage density and the stream network [21].

Stream Factor

Stream factors are derived from the flow accumulation grid by applying a threshold to the minimum contributing area required for channel initiation. Subsequently, a binary stream raster is generated to represent the following conditions as shown in equation 5:

$$Str_i = \begin{cases} 1, Flow\ Acc_i \geq F \\ 0, Flow\ Acc_i < F \end{cases} \quad (5)$$

Where F is an adjustable flow accumulation threshold that relates stream head to the hydrological and geomorphological processes controlling runoff concentration [22].

Watershed Factor

A watershed factor is the area of land which drains to a given outlet or pour point, or the catchment basin of those lands upstream. To delineate a watershed, a flow direction grid is used to follow the path of water as it moves from each cell and assign cells in their downstream/ outlet based on lines of drainage. A watershed factor can be expressed conceptually as:

$$WF = \{x|Flow(x) \rightarrow PO\} \quad (6)$$

Where P denotes the pour point. It considered as natural hydrological indicator for water resources and runoff evaluation [25].

Basin factor

This factor is a generally big scale topographically hydrological indicators which are delineating all areas draining through natural pouring. These will be identified automatically from the digital elevation model without use of prior defined pour points. Basins are created by identifying the common terminal drainage outlet of cells in an area. In larger hydraulic studies and geomorphological analyses, aqueduct basin boundaries are defined by the terrain morphology [26].

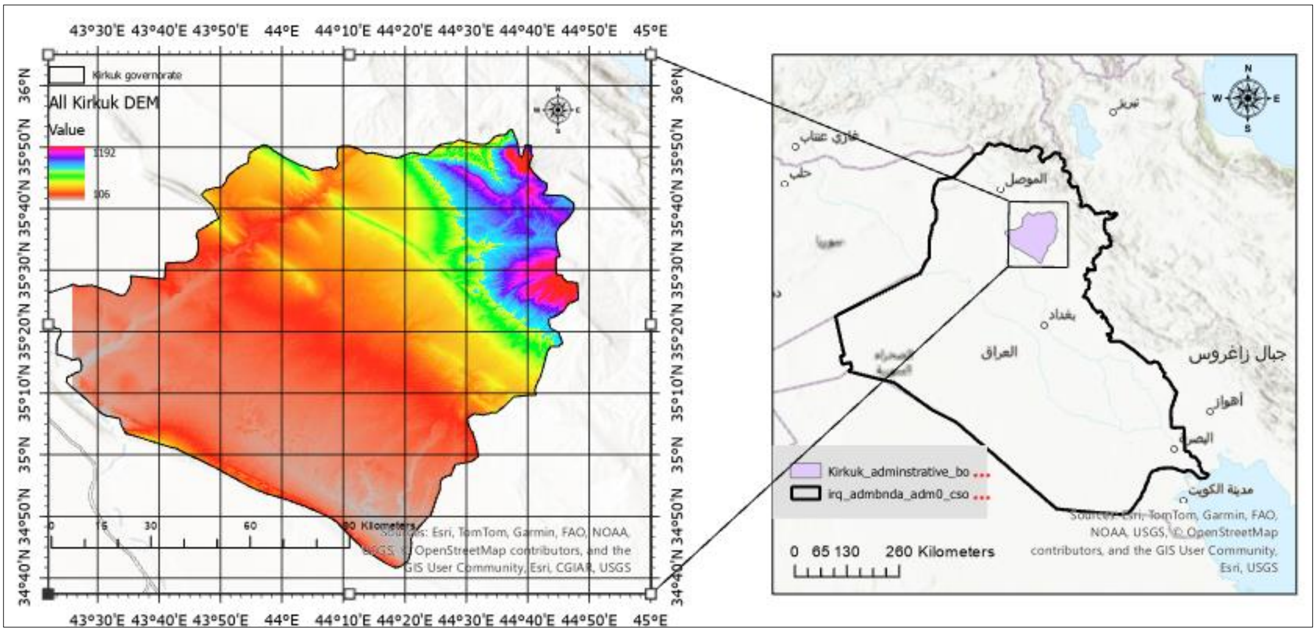
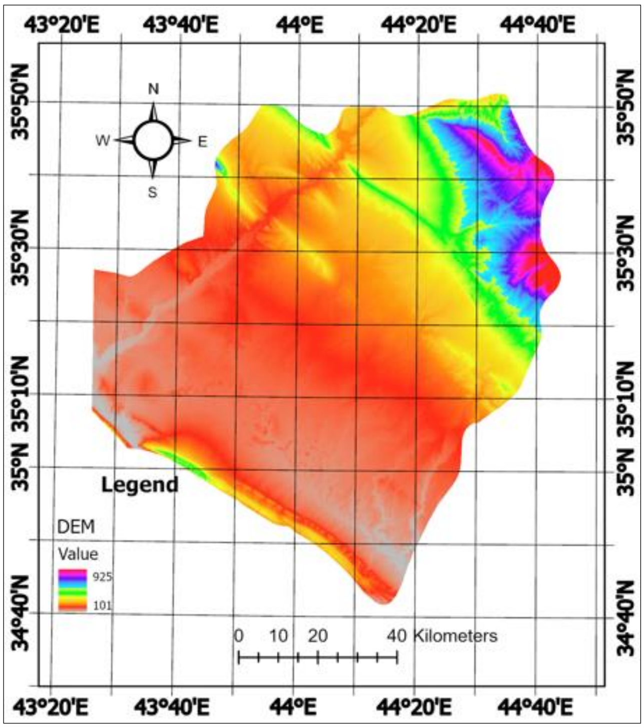
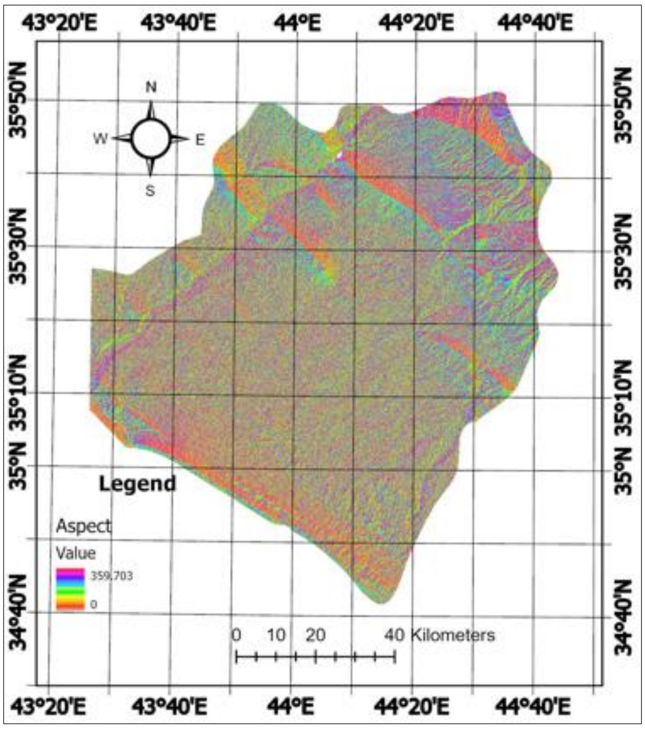
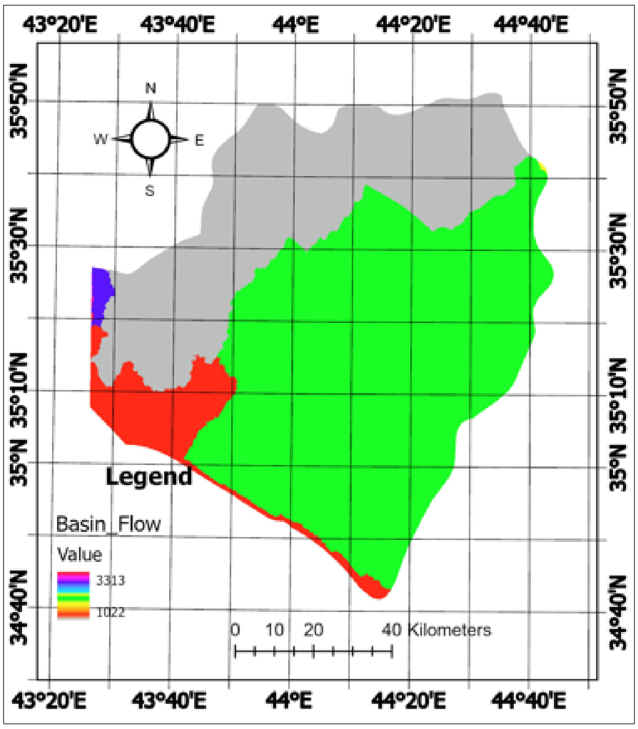


Fig 1: The study area



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43°40'E
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44°20'E
44°40'E
35°50'N
35°30'N
35°10'N
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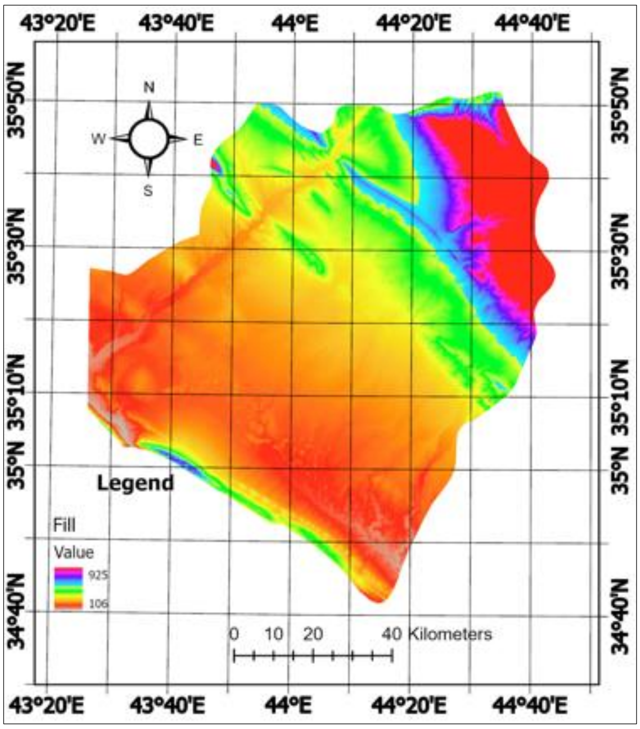
1022
0 10 20 40 Kilometers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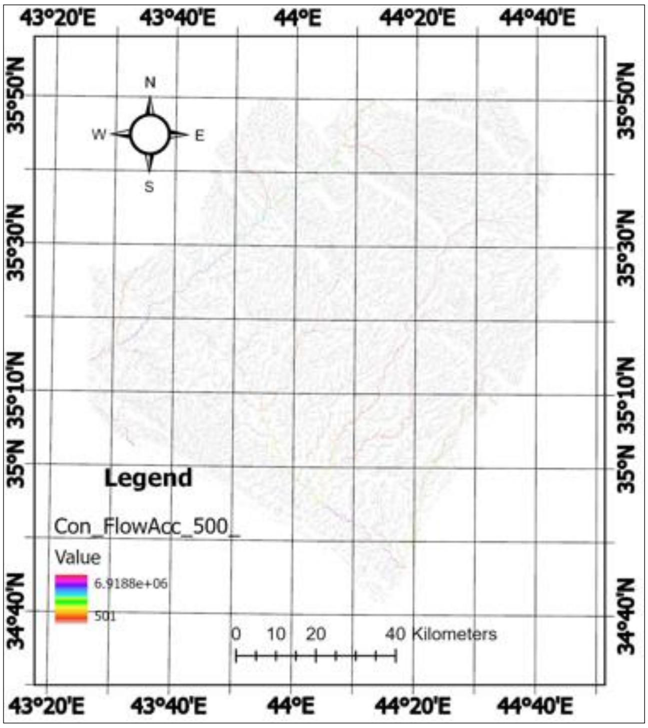
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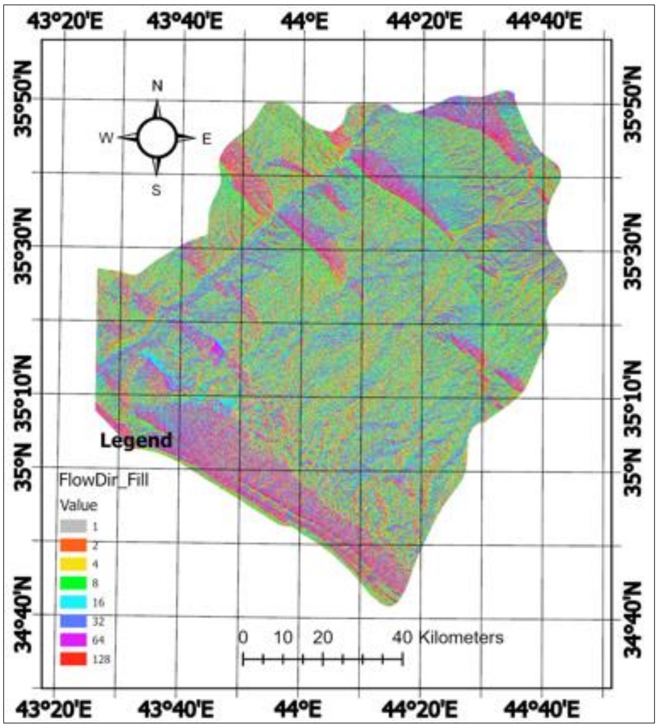
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128
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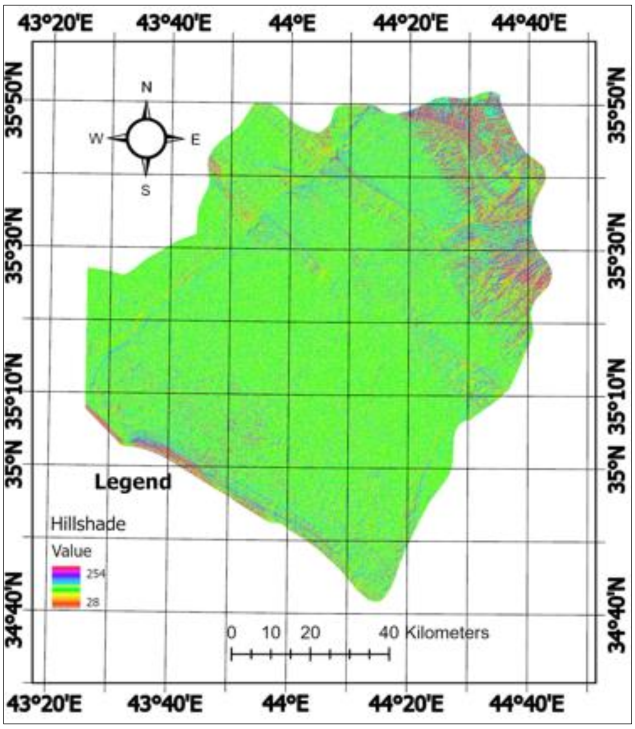
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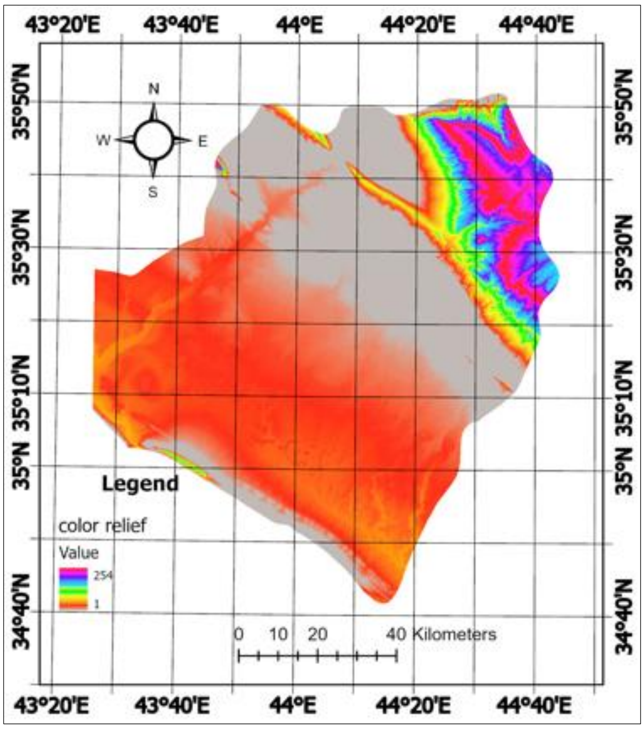
254
28
0 10 20 40 Kilometers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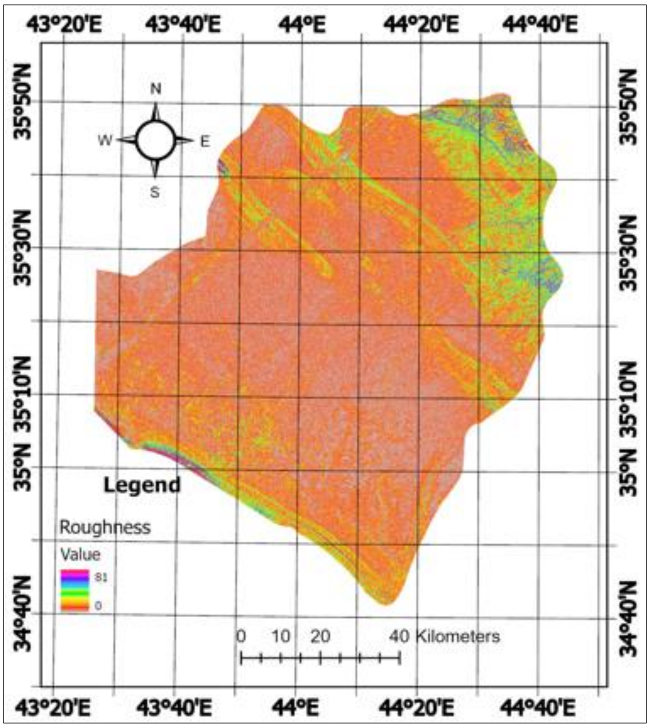
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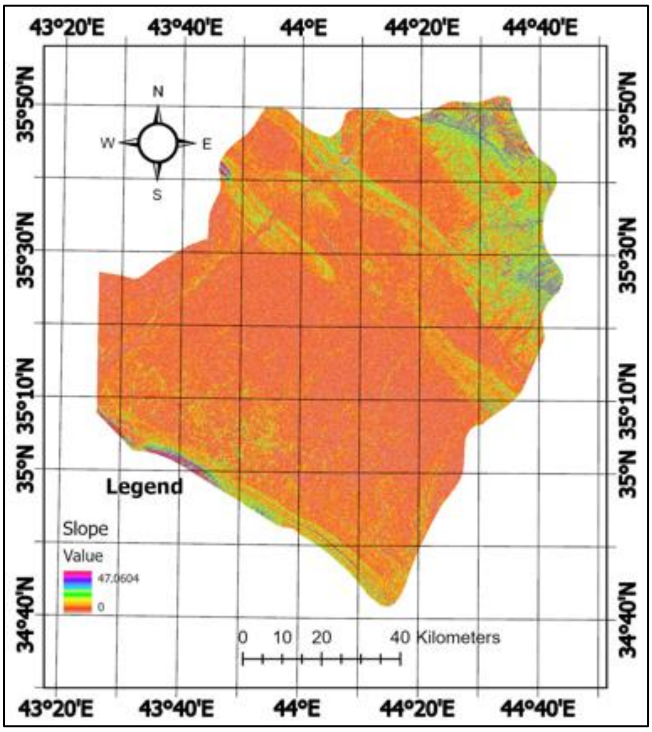
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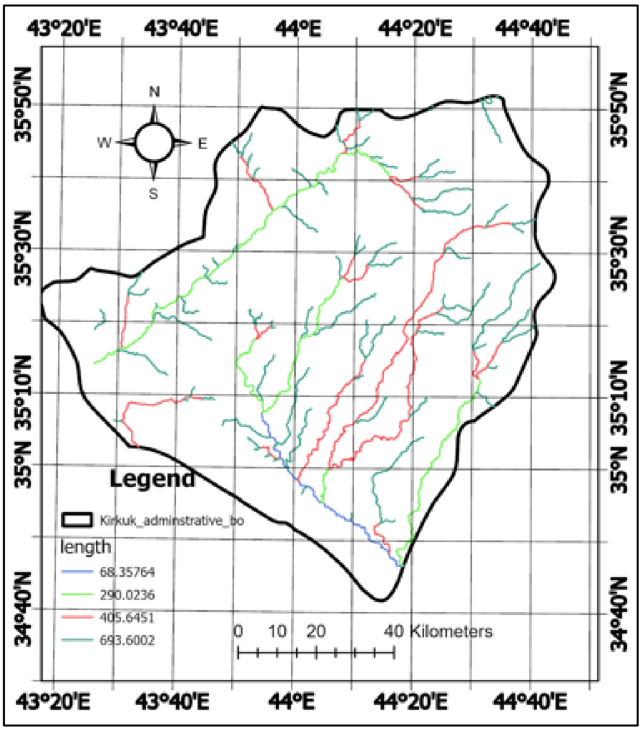

Fig 3: Hydrological parameters extracted in the study

4. Results and Discussion

This study mapped the surface hydrological behaviour of Kirkuk Governorate through the combination of SRTM-derived Digital Elevation Model (DEM) with Geographic Information Systems (GIS) techniques. After DEM conditioning via the detection and filling of sinks, hydrological continuity was established to allow an accurate calculation of both flow direction and flow accumulation. These outputs enabled the extraction of drainage networks, watershed boundaries and the delineation of basins (see Figure 3). Morover, five major drainage basins were identified within the study area by the hydrological delineation process (Table 2). Basin 2, the largest one according to area (5,670.97 km²), and Basin 1 (3,315.95 km²). The rest of the basins are much smaller: Basins 4, 5, and 3 have an area of 607.12 km², 89.03 km² and 60.76 km² respectively.

The spatial heterogeneity in watershed configuration is significant, with the largest basin exceeding its smallest counterpart more than ninety times. From a hydrological perspective, such differences have significant impacts on the generation of runoff, drainage density patterns, flow convergence and flood risk. Large basins usually have delayed peak discharge and significant storage potential, while smaller ones are likely to respond more quickly to precipitation events, which increases the likelihood of localized flooding.

Table 2: Basin area

Object-number	Grid item	Area km²
1	1	3315.95
2	2	5670.96
3	3	60.75
4	4	607.11
5	5	89.03

In general, bigger river basins have a higher retention capacity and convey surface runoff over much larger distances than smaller basin areas whereas water bodies in smaller basins respond more rapidly hydrologically to rainfall given they have less flow paths and extends at shorter lengths. Thus, the comparison of upstream and downstream sub-basins is essential for overall water resource management, flood reduction planning, as well as conservation programs in the Kirkuk watershed. Using flow direction and flow accumulation outputs in ArcGIS Pro the drainage network was delineated. This was followed by a number of iterative calculations where stream extraction was conducted on the pyramidal [38], with an appropriate accumulation threshold applied to determine streambeds, which were classified into four hierarchical orders according to structured connectivity and grid code values.

Summarizing the total stream length by order shows that first-order streams dominate, representing headwater and minor tributary channels. The total length of these streams is approximately 693.60 m, which corresponds to nearly 46% of the total channel length. Second-order streams contribute some 405.65 m in total (27%) and third-order streams account for 290.02 m in total (19%). Table 3 shows that fourth-order streams, which are the lowest class of stream hierarchy identified at this study site, have the smallest cumulative total length (68.36 m or 8% of total length). A high ratio of low-order streams indicates a highly entrenched drainage network, characteristic of semi-arid lands, in which surface runoff is fragmented among many small tributaries prior to entering larger uninterrupted channels. It is a hierarchical distribution, which has significant impacts on the runoff concentration, sediment transport dynamics and flood potential in any part of the basin.

Table 3. The network of Stream area

Object-color	Grid item	Length (km)
Dark-Green	1	693.600
Red color	2	405.645
Green color	3	290.023
Blue color	4	68.357

The apparent decrease in total stream length with increasing stream order is a common pattern given the hierarchical structure of dendritic drainage systems. First-order tributaries within such networks combine to produce higher order channels that grow in complexity but decrease in number (many-ones). As a general rule, the greater the number of lower-order streams, the more dense and connected drainage network that has capacity to quickly capture and redirect surface flow away from the land following precipitation events. In contrast, monsoon rivers are classified into medium and high orders streams which are the principal conduits for the transfer of water and sediment through a basin.

Following this classification schema, a map of the stream network was created and color-coded in GIS software from dark green (first-order streams) to blue (fourth-order channels). Such a measurement greatly improves spatial definition of channel distribution and functional delineation relative to meso-scale convergence zones, primary flow pathways, and deposition areas.

This hydraulic block, as part of sub-watershed is a crucial track for detailed analysis of the stream order and its association with hindrances to the surface runoff pathways & also sedimentary and hadrochemical transfers. This data is crucial for water resource management, flood hazard evaluation, and renewable allocation of basin resources.

Table 4: The flow direction description of raster area

Grid class	Shape length	Area in km^2
Class 1	780.106	983.267
Class 2	764.910	731.270
Class 4	1349.632	1946.174
Class 8	1159.062	1135.25
Class 16	1512.134	2135.801
Class 32	862.088	826.107
Class 64	1082.616	1386.691
Class 128	615.915	599.245

The raster of flow direction was converted to polygon so that the spatial extent for each directional class could be quantified. The flow directions were tabulated, and the neighbouring polygons having same grid code value were dissolved to generate contiguous areas with prevailing aspects of flows across individual watershed (extracted in Table 4).

A highly variable finding across the eight categories in this analysis was area or shape length (perimeter) [39.4%]. In Class 16, the highest spatial spread was observed with an area of approximately 2135.80 km² and the range was represented as 1512.13 units. Class 4 (1,946.17 km²) and Class 64 (1,386.69 km²) are the second winners, where success determinants of these classes take control over flow direction in areas that can be associated with main drainage patterns or dominant flow routes shaped by topography [18–23]. In contrast, the small area of Class 128 (599.25 km²) was the smallest among other classes of impervious surface whereas Class 1 had an appreciable medium area value of 983.27 km². The pronounced variability of area and perimeter of polygons per flow direction classes suggests this heterogeneity in topography within the Watershed. Natural variability in terrain and differential contributing areas yield these spatial features. At a hydrological modelling context, these differences eventually also influence overland flow routing as well as hydrological connectivity and hence accumulation or erosion-prone areas. This aspect is crucial, as polygon representations provide spatial information about prevailing runoff patterns and form a solid foundation for advanced watershed management and planning efforts.

In Kirkuk, the impact of various topographic characteristics imported from a digital elevation model was analyzed using flow direction analysis to determine how these characteristics influence hydrological processes. Elevation ranges from 106 m (353 ft) to 925 m (3037 ft), indicating a wide range of topography that affects flow gradient control, watershed boundaries, and runoff paths. Furthermore, long-term surface roughness (0–81 m) varies spatially between smooth plains and rugged surrounding terrain, determining infiltration capacity and runoff generation characteristics. Hillshade values (28–254) were similarly analysed to yield insight into relative solar exposition across the landscape. The shaded areas hold water; the sunlit slopes dry out quickly. To facilitate interpretation of the effects of terrain orientation, we also computed aspect values between 0° and 359.7°, because southern slopes often receive less solar energy (and may have higher soil moisture content) than those that face north: as a rule, northern slopes have generally a higher temperature and lower humidity than southern-exposed slopes. Gradients of terrain slope over 0° and 47°. This will result in an increase of runoff from steep slopes which are generally less pervious and thus more prone to flooding in the absence of retentive structures.

In hydro-environmental perspective, the elevation, roughness, hill-shade, aspect and slope parameters represent local hydrological dynamics effectively in Kirkuk. This complicates land use planning and sustainable water resource management solutions by making it challenging to locate sites prone to urban or soil erosion, though flood-prone areas guide the identification of such potential locations for conservation in favour of maintaining productivity.

Conclusion

Digital elevation models (DEMs) were used in conjunction with Geographic Information Systems (GIS) to conduct spatial analysis and develop a robust framework for visualizing, identifying, and interpreting hydrological features in Kirkuk Governorate, northern Iraq. Key surface hydrological features, such as catchment areas, drainage networks, flow patterns, runoff accumulation, and topographical variables, were systematically assessed using SRTM digital elevation model data within a GIS environment, employing standard hydrological techniques.

The identification of five hydrologically independent basins, exhibiting markedly different spatial extents, encompasses the overall geomorphological control of both surface runoff dynamics and catchment response behavior. Based on stream rank, tree-like drainage patterns were also observed in lower-ranked streams. This structural configuration exhibits a relatively better response capacity to hydrological phenomena and exhibits greater vulnerability to erosion and/or flash floods (particularly in the upper reaches of the basins or sub-basins); the remaining area identity provides compelling evidence of this. The study also highlighted the flow direction and accumulation methodology, demonstrating how elevation gradients and local slope variations control surface runoff paths and concentration zones.

Topographic parameters derived from the digital elevation model (DEM), such as elevation, slope, direction, surface roughness, and hill shading, were key factors in determining the hydrological characteristics of the study area. These parameters are directly related to surface runoff velocity, infiltration capacity, erosion potential, and the location of resulting floodplains in the region. Spatial datasets enabled the simulation of temporal surface hydrological responses under the influences of open, semi-arid, urban, and peri-urban areas.

In conclusion, the digital elevation model and GIS approach used in this study is an effective and cost-efficient method with implications for regional hydrological analyses and may also be beneficial in data-poor areas. The produced hydrogeological distribution maps, with their spatial indicators, are a fundamental reference for supporting decision-making in sustainable water resource management, flood mitigation planning, and urban development strategy and planning at the Kirkuk Governorate level. Future research should rely on high-resolution elevation data, multi-time observational rainfall records, and even modeling of predicted hydrodynamics under climate change scenarios to develop accurate forecasts and plan long-term environmental sustainability initiatives.

References

1. Sivakumar B. Global climate change and its impacts on water resources planning and management: assessment and challenges. Stoch Environ Res Risk Assess. 2011;25(4):583–600.
2. Hanjra MA, Qureshi ME. Global water crisis and future food security in an era of climate change. Food Policy. 2010;35(5):365–377.
3. Castillo DJ. Population dynamics and water resource consumption in Spokane, WA. 2018.
4. Hasan SF, Shareef MA, Jaber HS. Influence of noise equivalent beta naught estimation on backscattering image classification of TerraSAR-X. Geod Cartogr. 2024;50(2):104–112.
5. Salahalden VF, Shareef MA, Al Nuaimy QA. Characterization of the chemical properties of deposited red clay soil using GIS-based inverse distance weighted method in Kirkuk City, Iraq. Ecol Eng Environ Technol. 2023;24.
6. Maarez HG, Jaber HS, Shareef MA. Utilization of geographic information system for hydrological analyses: a case study of Karbala province, Iraq. Iraqi J Sci. 2022:4118–4130.
7. Memon A, Patel Y, Parangi T. Exploring watershed dynamics: a comprehensive review on morphometric analysis and geospatial techniques. ISH J Hydraul Eng. 2024;30(5):744–757.
8. Shareef MA, Toumi A, Khenchaf A. Estimating water quality parameters using SAR and thermal microwave remote sensing data. In: Proceedings of the 2nd International Conference on Advanced Technologies for Signal and Image Processing (ATSIP). IEEE; 2016. p. 1–6.
9. Alam M, Alam MM, Curray JR, Chowdhury ML, Gani MR. An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history. Sediment Geol. 2003;155(3-4):179–208.
10. Ajaj QM. Remote sensing-based land surface temperature retrieval in Kirkuk City, Iraq using GIS and TES algorithm: a climatic concern. 2025.
11. Huang C, Chen Y, Zhang S, Wu J. Detecting, extracting, and monitoring surface water from space using optical sensors: a review. Rev Geophys. 2018;56(2):333–360.
12. Sharma A, Tiwari KN. A comparative appraisal of hydrological behavior of SRTM DEM at catchment level. J Hydrol. 2014;519:1394–1404.
13. Noori AM. GIS-based morphometric quantitative and hydrologic analysis of Khasa Basin in Kirkuk City, Iraq. Sci Res J Eng Comput Sci. 2023;3(1):8–15.
14. López-Ramos A, Martínez-Santos P, Martínez-Alfaro PE. Assessment of morphometric parameters as the basis for hydrological inferences in water resource management: a case study from the Sinú River Basin in Colombia. ISPRS Int J Geo-Inf. 2022;11(9):459.
15. Shakir B, Shareef MA, Al Nuaimy QA. GIS-based spatial interpolation approaches for soil parameter assessment: a case study from the Taza Khurmatu District, Kirkuk Governorate, Northern Iraq. Iraqi Geol J. 2025:117–129.
16. Azeez SM, Shareef MA, Omer FM. Assessing the environmental quality of Kirkuk City and Taza District based on pressure-state-response framework for winter 2023 using remote sensing and GIS. Al-Kitab J Pure Sci. 2025;9(2):154–168.
17. Salahalden VF, Shareef MA, Al Nuaimy QA. Mapping clay and clay mineral deposits in Kirkuk City using Landsat satellite data.
18. Dara JQ, Omer FM, Shareef MA. Assessment of the air

pollution risk in Kirkuk Government with the analytic hierarchy process (AHP) model.
19. Ali CA, Shareef MAS, Al Nuaimy QA. Estimating soil parameters using C-band synthetic aperture radar in Laylan, Iraq. Ecol Eng Environ Technol. 2024;25.
20. Shekho HK, Shareef MA. Landfill site suitability assessment based on GIS and multicriteria analysis: a case study of Kirkuk City. Al-Kitab J Pure Sci. 2025;9(2):140–153.
21. Jenson SK, Domingue JO. Extracting topographic structure from digital elevation data for geographic information system analysis. Photogramm Eng Remote Sens. 1988;54(11):1593–1600.
22. O'Callaghan JF, Mark DM. The extraction of drainage networks from digital elevation data. Comput Vis Graph Image Process. 1984;28(3):323–344.
23. Tarboton DG. A new method for the determination of flow directions and upslope areas in grid digital elevation models. Water Resour Res. 1997;33(2):309–319.
24. Montgomery DR, Dietrich WE. Where do channels begin? Nature. 1988;336(6196):232–234.
25. Tiwari A, Hsuan E, Goswami S. Spatiotemporal water quality assessment in spatially heterogeneous Horseshoe Lake, Madison County, Illinois using satellite remote sensing and statistical analysis (2020–2024). Water. 2025;17(20):2997.
26. Amer A, Alhadithi M, Shareef MA. Creating landslide susceptibility map using frequency ratio (FR) model in Soran City, Irbil Province, Iraq. In: AIP Conference Proceedings. AIP Publishing LLC; 2024.
27. Singh P, Gupta A, Singh M. Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques. Egypt J Remote Sens Space Sci. 2014;17(2):111–121.
28. Aziz NA, Abdulrazzaq Z, Mansur MN. GIS-based watershed morphometric analysis using DEM data in Diyala River, Iraq. Iraqi Geol J. 2020:36–49.

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