Journal Home Page: https://sjes.univsul.edu.iq/

Assessment of erosion potential and infiltration capacity in the Kasnazan pond using morphometric analysis

Israa Diyar Ahmed[1,a,*]
Zhian Abdulrahman Ahmed[2,a]
Rashad Mohammed Hassan[3,a]
Bruska Sardar Mamand[4,a]
[a] Dept. of Water Resources Engineering, College of Engineering, University of Salahaddin, Erbil, Kurdistan Region, Iraq

Article Information

Article History:
Received: October 11th , 2025
Accepted : March 31st , 2025
Available online: April, 2025

Keywords:
DEM, GIS, Kasnazan basin, slope basin, and Relief aspect.

About the Authors:
Corresponding author:
Israa Diyar Ahmed
E-mail: israa.ahmad@su.edu.krd
Researcher Involved:
Zhian Abdulrahamn Ahmed
Rashad Mohammed Hassan
Dr. Bruska Sardar Mamand

DOI https://doi.org/10.17656/sjes.10204

Abstract

Evaluating morphometric characteristics is the most efficient technique to depict the hydrologic and physiographic features of river basins. The current study focuses on investigating the morphological study of the Kasnazan basin, which is located 10 km east of Erbil city. The area of the basin is 20.39 km².To fulfill the current study goal, data from the Digital Elevation Model and geoinformation (GIS and remote sensing) methodologies were utilized to detect and assess morphometric properties (relief aspect). Various tools of the ArcGIS 10.8 software were used to prepare and produce maps, as well as to analyze and evaluate various parameter properties. Relief Aspects creates data on the river basin's erosion properties, which include the morphological aspects of the relief, entire slop, and degree of erosion. The slope of the catchment is 5% represents moderately erosion. Quantitative investigation of morphometric characteristics is extremely useful for watershed planning and management. These findings are useful for calculating watersheds for drainage management, planning for the environment, and development that is sustainable .

1. Introduction

Quantifying the available water in a watershed is required for sustainable water resource management. Morphometry is the scientific investigation and measurement of the structure of the world's topography, involving the dimension and form of its landscapes. [1]. In the end, the conceptual and methodological change of geomorphology from individualized and forward-looking study dependent on experiences to objective, deductive science dependent on observations [2]. The morphometric study really brings out the geometric uniqueness of the river landscape by looking at the level of lithology and how the structure works [3]. The morphometric study includes linear, aerial, and relief characteristics. Morphometric features are highly valuable in quantitative assessments of river basin appraisal, watershed priorities for soil and water conservation efforts, and micro-level natural resource management [4]. River basins are complex geomorphological structures shaped by various topographical factors. Relief parameters present information about the basin's elevation slope and drainage features, which influence runoff, infiltration, and processes of erosion. Relief morphometry, which involves the analysis and measurement of topographical features, has a substantial impact on erosion and infiltration processes in a watershed. The terrain of a river basin impacts how water flows, collects, and reacts with the landscape. Steep slopes and high relief ratios increase surface runoff, decreasing infiltration rates and enhancing potential of erosion. In contrast, low-relief locations allow for better retention of water and recharge of groundwater. Identifying these relationships is vital for effective management of watersheds, soil conservation, and flood control strategies. Hence, the research of the GIS and Remote sensing-based drainage basin analysis has been completed for different watersheds in order to generate exact and updated information for describing drainage basin parameters by this scientific technique.

RS/GIS technologies simplify the integration and investigation of environmental information, leading to successful and effective realization of projects. GIS is regarded as one of the best ways for detecting the environmental factors that impact the basin [5, 6]. Also, GIS is a valuable tool for spatial investigation and knowledge management due to its capacity to handle large amounts of data [7] .

Utilizing topographical maps or field investigations, drainage morphometric variables obtained from digital topographical data, which is termed Digital Elevation Model (DEM), is a quicker, moreover exact, upgraded, as well as inexpensive approach to analyzing catchment [8].

The aim of this study is to utilize Geographic Information Systems (GIS) and Remote Sensing (RS) to quantitatively evaluate the morphometric characteristics of the Kasnazan basin and their subsequent effects on hydrological processes. Specifically, the research seeks to determine key relief and drainage parameters such as stream order, drainage density, and slope to assess the basin's susceptibility to soil erosion and its capacity for water infiltration. By establishing these relationships, the study provides essential data for effective watershed management, sustainable water resource planning, and flood control strategies in the Erbil region.

2. Area under research

The area of investigation is located in the northeastern portion of Iraq. As shown in Figure (1), The Kasnazan basin is located 10 Km east of Erbil city of Kurdistan Region. The area under investigation of the basins is about 20.39 km² setting between latitude (36° 16' 11" N – 36° 12' 38" N) and longitude (44° 9' 46.01" E – 44° 14' 14.1" ″ E) with elevation ranges from 663 to 1091 m above sea level. The Kasnazan pond (Zanko Pond), located in the Kasnazan subdistrict of Erbil province, lies at a height of 17 meters. It is 180 meters long, 80 meters wide at the base, and 6 meters wide at the top. The pond was constructed to keep one million cubic meters of water, making a substantial contribution to the region's water conservation efforts. The terrain of Kasnazan Pond in Erbil is largely silty clay (CL type), with good cohesiveness and mild compressibility. These qualities contribute to water retention and the stability of the structure. Such soils are common in the region and provide efficient support for reservoirs [9]. The hydrology of the Erbil Basin, which includes Kasnazan basin, is semi-arid, with an average yearly rainfall of 394.65 mm. approximately 24.23% of this precipitation recharges groundwater, 21.77% produces surface runoff, and 54% evaporates. Groundwater flow in the basin is generally from northeast to southwest. Studies using modeling show that rivers lose approximately 33,432 m³/day into aquifers, showing linkages between surface and groundwater systems

3. Methodology and Materials

The methodology for assessing relief morphometry parameters in water resources is methodical, utilizing Geographic Information Systems (GIS) and Remote Sensing (RS) methods. The complete morphometric study was conducted in the north-eastern basin, which was produced utilizing the ArcGIS 10.8 watershed delineation technique based on SRTM (Shuttle Radar Topography Mission) DEM. For such work, SRTM DEMs with a 30-meter spatial resolution Tagged Information File Format (TIFF) were retrieved from United States Geological Survey (USGS). Then identified the Kasnazan River Basin and developed a drainage network using the obtained DEM. The sources of data were combined into a single projection utilizing the ArcGIS 10.8 GIS tool, which used the (UTM) Universal Transverse Mercator, 32N coordinate system. The technique utilized in this study work depends on the Geographical Information Systems database, with the use of hydrological tools, compound factors, and weighted overlay analysis. The steps of work are shown in Figure 2.

3.1 Relief Parameters

Relief morphometric factors play an important role in understanding erosion dynamics because they influence runoff velocity, sediment transport, and landscape stability. Several studies have demonstrated that characteristics like relief ratio, slope, and drainage density have a substantial influence on soil erosion rates [10-12].

3.1.1 Area (A)

The runoff rate in every drainage basin is calculated by its physiography and area. A represents the drainage area of basin. The basin of drainage plays an essential function of regulating the rates at which water enters the mainstream as it flows toward the outflow. The basin area of a particular order is described as the overall projected segment on a horizontal surface that provides overland flow to the order's waterway section, consisting of any lower-order branches.

3.1.2 Perimeter (P)

A basin's perimeter, represented by P, is its border length. The circulation and elongation ratio are basin parameter-dependent variables. The perimeters of several parts of watersheds were computed using GIS software that determines each polygon's perimeter automatically.

3.1.3 Stream Order

The description of stream orders belongs to the first stage of basin drainage studies. [13] introduced the method to the United States, which was significantly enhanced by [12]. It additionally states that the drainage system is made up of the hierarchical connections between the parts of the different streams.

The research area's streams were ranked using the approach proposed by [12]. The first-order stream is the smallest sensitive branch with no sub-tributaries. Two first-order river channel are linked to make a second-order stream. Two second-order streams are connected to form a third-order stream, and so on [14]

3.1.4 Number of Stream

Stream number refers to the count of separate stream branches within a drainage basin, which helps in estimating a reverse geometric relationship among the streams [14, 15] .It has been stated that the connection between the order of streams and the stream number is opposite.

3.1.5 Basin Length (Lb)

The basin length is the largest distance between the catchment's headwaters to confluence point. The basin length (Lb) was determined in ArcGIS 10.8.

3.1.6 Basin Relief (R)

Basin relief (R) is the variation between the basin's greatest elevation (Hmax) and minimum elevation (Hmin). It is a crucial factor of a drainage system as demonstrated by the elevation. Equation (1) of total relief. Higher relief encourages erosion due to higher gravitational force and steeper slopes, which enhance runoff velocity and sediment movement. [15]

$$R=H_{max}-H_{min} \quad (1)$$

3.1.7 Relief Ratio (Rh)

Relief ratio (Rh) is referring to the ratio of basin relief to the longest collateral to the main drainage line (Lb). (2) as shown in below equation: Morphometric research of the Guder sub-basin in Ethiopia found that sub-watersheds with higher relief ratios were more susceptible to soil erosion, emphasizing the necessity of taking Rh into consideration in erosion evaluations [16]

$$R_h=H/Lb \quad (2)$$

3.1.8 Relative Relief Ratio (Rr)

Relative relief (Rr) is described as (H) basin relief divided to the basin perimeter (P) [17]. As shown in equation below:

$$Rr=H/P \quad (3)$$

3.1.9 Ruggedness Number (Rn)

The ruggedness number is described as a unitless product of (H) total relief and (Dd) drainage density as the same unit [12] as shown in equation (4). It is utilized for finding the impact on the erosion potential and structural complexity of the landforms. Higher Rn values imply more difficult terrain prone to erosion and high sediment movement. [18, 19].

$$Rn=H\times Dd \quad (4)$$

3.1.10 Slope gradient

Gradient ratio is an indication of the channel slope, allowing the measurement of the runoff velocity and rate of erosion. Higher slopes often lead to more erosion. The equation 5 is used for finding the basin slope according to [2].

$$Slope=R/Lb \quad (5)$$

3.1.11 Dissection index (Di)

The dissection index quantifies the degree of terrain dissection and is related directly to soil erosion. [20]. The value of the dissection index ranges from 0 (flat terrain) to 1 (highly dissected landscapes); higher values indicate increased erosional activity. The dissection index is calculated utilizing the below equation:

$$Di=Rb/aRb \quad (6)$$

In which Di which is dissection index, R is basin relief, and aRb is absolute basin relief.

3.2 Drainage density (Dd) and the stream frequency (Fs)

The drainage density (Dd) is the sum of the length of stream per unit area within the basin [13] and it is an essential factor of drainage texture evaluation. Drainage density is calculated using equation (7). [13] The drainage basin is divided into five different textures: as low (< 2), moderate (2-4), high (4-6), and very high (> 6) [21]. The stream frequency (Fs) of a basin denotes to the number of streams per unit area Equation (8)

$$Dd=Lu/A \quad (7)$$

$$Fs=Nu/A \quad (8)$$

In which: Lu is the sum of stream length. A = basin area. And Nu is the stream number.

3.3 Infiltration Number

Dd and Fs results provide information about the basins infiltration characteristics. Lower rate of infiltrations and higher surface runoff are associated with larger number of infiltrations. This analysis provides an important and remarkable perspective on the catchment area's characteristics of infiltration, revealing a definite negative link with the basin's potential to absorb and retain water through infiltration. According to [22], higher infiltration numbers lead to higher run-off and lower infiltration rates. It is defined as If. It is determined with the formula provided below.

$$I_f=Fs\times Dd \quad (9)$$

4. Results and Discussion

The relief parameter is crucial for analyzing the basin's erosive features. The relief morphometric study of the parameters, such as area and perimeter of the watershed are determined from using ArcGIS 10.8

program. The parameters used to analyze the relief aspects are derived using the standard mathematical calculation provided in Equations (1-9). The Kasnazan watersheds have a five-order stream order, as demonstrated in the Table 1 and Figure 3. The overall number of streams of Kasnazan watershed is 133 streams. There is an indirect relationship between total stream length and stream order. As stream order increases, overall stream length falls, and vice versa. Then the length of stream of watershed is depicted in the table 2. In general, the stream number and total length of the stream have a moderate opposite correlation with the stream order R2 = 0.64 and 0.56 as demonstrate in Figure 4. Table 2 demonstrates the results, which are described more in the table (2) and the description includes the following discussion.

The morphometric analysis of the basin demonstrates a hydrologically responsive basin with moderate relief, well-developed drainage characteristics, and a strong inclination toward surface runoff and erosion. The relatively small basin area (20.39 km²), The combination of a compact perimeter and a moderate basin length (7.8 km) indicates that the watershed can adapt quickly to rainfall events. These basins often produce faster runoff with shorter lag times, increasing the likelihood of localized flooding following heavy precipitation.

1. Drainage density:

The drainage network parameters strongly support this hypothesis. A total number of streams (133 stream) and considerable total stream length (37.28 km) represent a dense and well-organized drainage system. This high stream frequency implies low infiltration capacity and facilitates efficient surface runoff, especially during heavy rains. These situations are frequently associated with impermeable or poorly permeable surface materials and low vegetation cover.
Although the drainage density (1.83 km/km²) is relatively low, implying some degree of subsurface permeability and infiltration, this effect tends to be overridden by the high drainage frequency (6.5 streams/km²) and high infiltration number (8.55). Together, these parameters indicate that surface runoff dominates over infiltration, leading to enhanced soil erosion and sediment transport. This combination implies that while the subsurface may allow some infiltration, surface conditions favor rapid water movement across the terrain.

2. Relief

Relief-related parameters further clarify the basin's geomorphic behavior. The watershed relief of 428 m implies significant elevation change, which enhances stream flow velocity and erosion force. Furthermore, the moderate relief ratio (0.055) and low relative relief (0.02) show that slopes are not excessively steep, indicating a fairly dissected landscape. This suggests that the basin has undergone significant geomorphic change and is approaching maturity, with erosion processes that are active but not excessive.

3. Ruggedness number

The ruggedness number (0.56) indicates moderate terrain roughness and verifies that the basin is moderately susceptible to erosion and runoff. This value indicates that, while the area is not highly unstable, it is still vulnerable to land degradation if subjected to improper land use methods like deforestation or unregulated development.

4. slope

As shown in Figure 5, The average basin slope of 5% further supports this interpretation. Such slopes allow continuous runoff generation without causing catastrophic mass wasting. Therefore, during high-intensity rainfall events, persistent runoff can gradually remove topsoil, especially in areas lacking adequate vegetation cover.
In general, the integrated morphometric characteristics indicate that the basin is moderately prone to erosion, with surface runoff playing a significant role in its hydrological function. The high stream frequency, increased infiltration number, moderate relief, and gentle-to-moderate slopes indicate that soil conservation and watershed management techniques are required to reduce erosion risk and enhance water retention. Afforestation, contour farming, and check dam construction would all help to improve infiltration, reduce runoff, and maintain basin stability over the long term.

5. Conclusion

This study successfully utilized GIS and remote sensing techniques to investigate the morphometry of the Kasnazan watershed, identifying a 5th-order dendritic to sub-dendritic drainage system. The analysis categorized the basin into five distinct orders and revealed a drainage density of 1.83 km/km², which signifies a terrain with moderate to high erosion potential and low infiltration capacity, leading to increased surface runoff and decreased water absorption. Furthermore, the basin's low relief ratio (0.055) and low relative relief indicate a landscape with fewer resistant rocks and limited groundwater recharge potential. With an average basin slope of 5%, the area is characterized by moderate erosion, emphasizing the importance of these findings for future runoff studies, effective land and water resource management, and the implementation of strategic erosion control measures within the watershed.

References

[1] Prakash, K., et al., *Morphometric analysis using SRTM and GIS in synergy with depiction: a case study of the Karmanasa River basin, North central India.* Applied Water Science, 2019. **9**: p. 1-10.

[2] Ibrahim, J.R., *Morphometric Relief Aspects Identification of Khabour River Basin.* QALAAI ZANIST JOURNAL, 2021. **6**(2): p. 1003-1027.

[3] Pophare, A.M. and U.S. Balpande, *Morphometric analysis of Suketi river basin, Himachal Himalaya, India.* Journal of earth system science, 2014. **123**: p. 1501-1515.

[4] Aravinda, P. and H. Balakrishna, *Morphometric analysis of Vrishabhavathi watershed using remote sensing and GIS.* International Journal of Research in engineering and Technology, 2013. **2**(8): p. 514-522.

[5] Al-Gburi, M.R., *GIS-Based Spatial Distribution of Flood Hazards in the Chamchamal Basin, Sulaymaniyah, NE Iraq.* The Iraqi Geological Journal, 2025: p. 155-168.

[6] Khalil, A., O.A.I. Abdullah, and A.T. Kareem, *GIS Application for Creating Potential Flood Map Using AHP: A Case Study in Chaq-Chaq Valley, Sulaymaniyah City, Kurdistan Region, Iraq.* The Iraqi Geological Journal, 2024: p. 254-263.

[7] Mikail, A.Q. and R. Hamad, *Mapping Flood Vulnerability by Applying EBF And AHP Methods, in the Iraqi Mountain Region.* Science Journal of University of Zakho, 2023. **11**(1): p. 1-10.

[8] Singh, P., A. Gupta, and M. Singh, *Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques.* The Egyptian Journal of Remote Sensing and Space Science, 2014. **17**(2): p. 111-121.

[9] Qader, Z.B., Z. Karabash, and A.F. Cabalar, *Analyzing geotechnical characteristics of soils in Erbil via GIS and ANNs.* Sustainability, 2023. **15**(5): p. 4030.

[10] Bashir, B. and A. Alsalman, Morphometric *and Soil Erosion Characterization Based on Geospatial Analysis and Drainage Basin Prioritization of the Rabigh Area Along the Eastern Red Sea Coastal Plain, Saudi Arabia.* Sustainability, 2024. **16**(20): p. 9008.

[11] Schumm, S.A., *Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey.* Geological society of America bulletin, 1956. **67**(5): p. 597-646.

[12] Strahler, A.N., *Quantitative geomorphology of drainage basin and channel* networks. Handbook of applied hydrology, 1964.

[13] Horton, R.E., *Erosional development of streams and their drainage basins; hydrophysical approach to quantitative* morphology. Geological society of America bulletin, 1945. **56**(3): p. 275-370.

[14] Ali, S.A. and N. Khan, *Evaluation of morphometric parameters—a remote sensing and GIS based approach.* 2013.

[15] Horton, R.E., *Drainage-basin characteristics.* Transactions, American geophysical union, 1932. **13**(1): p. 350-361.

[16] Gezahegn, R. and F. Mengistu, *Morphometric and land use land cover analysis for the management of water resources in Guder sub-basin, Ethiopia.* Applied Water Science, 2025. **15**(2): p. 18.

[17] Melton, M.A., *An analysis of the* relations *among elements of climate, surface properties, and geomorphology*. Vol. 11. 1957: Department of Geology, Columbia University New York.

[18] Dofee, A.A., P. Chand, and R. Kumar, *Prioritization of soil erosion-prone sub-watersheds using geomorphometric and statistical-based weighted sum priority approach in the middle Omo-Gibe River basin, Southern Ethiopia.* International Journal of Digital Earth, 2024. **17**(1): p. 2350198.

[19] Patton, P.C. and V.R. Baker, Morphometry *and floods in small drainage basins subject to diverse hydrogeomorphic controls.* Water resources research, 1976. **12**(5): p. 941-952.

[20] Farhan, Y., et al., *Quantitative analysis of geomorphometric parameters of Wadi Kerak,* Jordan*, using remote sensing and GIS.* Journal of Water Resource and Protection, 2015. **7**(6): p. 456-475.

[21] Choudhari, P., et al., *Morphometric based prioritization of watershed for groundwater potential of Mula river basin, Maharashtra, India.* Geology, Ecology, and Landscapes, 2018. **2**(4): p. 256-267.
[22] Rai, P.K., et al., *A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India.* Applied Water Science, 2017. **7**: p. 217-232.

تقييم احتمالية التآكل وقدرة التسرب في بركة كاسنزان باستخدام التحليل المورفومتري

المستخلص

يُعد تقييم الخصائص المورفومترية الأسلوب الأكثر فعالية لتصوير الخصائص الهيدرولوجية والفسيوغرافية لأحواض الأنهار. تركز الدراسة الحالية على دراسة مورفولوجية حوض كسنزان، الواقع على بُعد ١٠ كيلومترات شرق مدينة أربيل. تبلغ مساحة الحوض ٢٠.٣٩ كيلومتراً مربعاً. ولتحقيق هدف الدراسة الحالي، استُخدمت بيانات من نموذج الارتفاع الرقمي ومنهجيات المعلومات الجغرافية (نظم المعلومات الجغرافية والاستشعار عن بُعد) لاكتشاف وتقييم الخصائص المورفومترية (الجانب الإغاثي). واستُخدمت أدوات متنوعة من برنامج ArcGIS 10.8 لإعداد الخرائط وإنتاجها، بالإضافة إلى تحليل وتقييم خصائص معلمات مختلفة. يُنشئ برنامج Relief Aspects بيانات حول خصائص تآكل حوض النهر، والتي تشمل الجوانب المورفولوجية للتضاريس، والانحدار الكامل، ودرجة التآكل. يُمثل انحدار حوض التجميع، الذي يبلغ ٥٪، تآكلاً معتدلاً. يُعدّ البحث الكمي للخصائص المورفومترية مفيداً للغاية في تخطيط وإدارة مستجمعات المياه. وتُستخدم هذه النتائج لحساب مستجمعات المياه لإدارة الصرف، والتخطيط البيئي، والتنمية المستدامة.

الكلمات المفتاحية:

DEM , GIS وحوض كاسنازان ، حوض المنحدر ، جوانب التضاريس

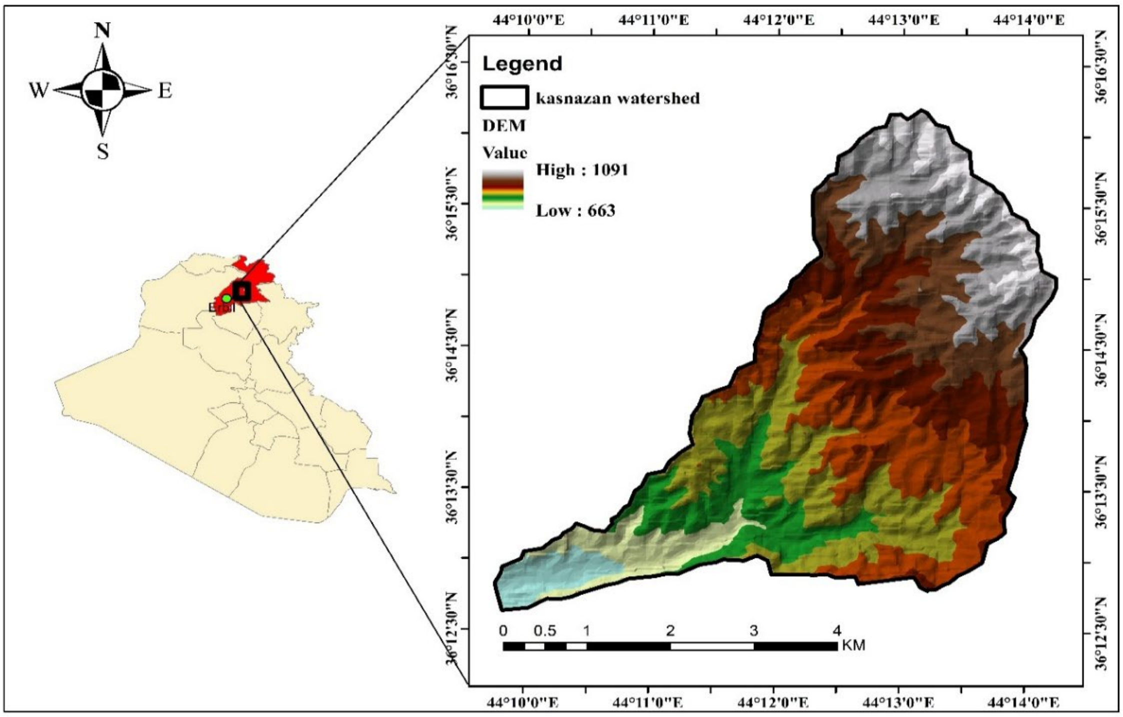

Figure 1. Kasnazan Watersheds Location Map

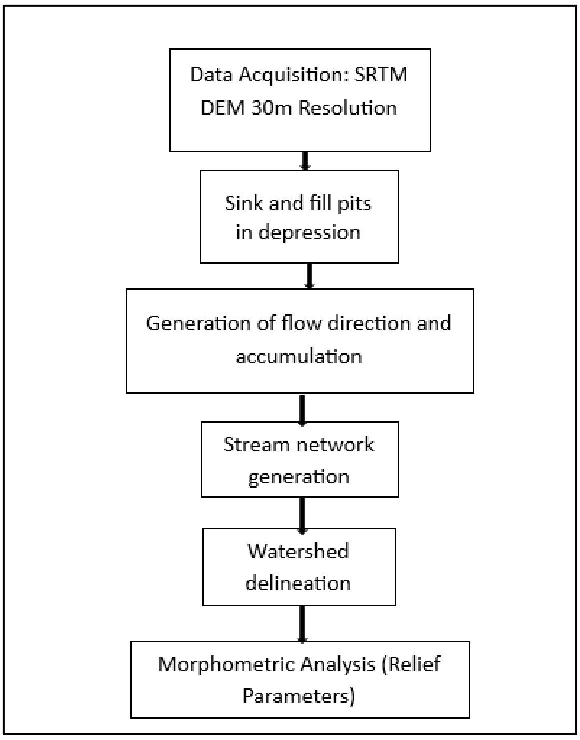

Figure 2. A flowchart of research methods

Table 1. The kasnazan watershed drainage study

Stram Order	No. of Stream	Total Length of Streams (Km)
1	106	32.96
2	20	2.72
3	4	0.86
4	2	0.73
5	1	0.01
total	133	37.28

Table 2. Assessment of morphometric characteristics and their importance

SI NO	Morphometric Parameters	Unit	Results	Significance
1	Area, A	Sq Km	20.39	Smaller the area, Larger is the runoff and vice versa.
2	Basin Perimeter, P	Km	23	Relative relief ratio based upon perimeter of basin.
3	Basin Length, Lb	Km	7.8	As the length of basin increases, the max discharge decreases.
4	Total no of Streams, Nu	Nos	133	More streams suggest a high stream frequency.
5	Total stream length, Lu	Km	37.28	length of stream shows improved drainage, which promotes runoff and increases erosion risk in responsive land.[22]
6	Drainage Density, Dd	Km/ SqKm	1.83	Small amounts represent generally flat areas with permeable subsurface layers.
7	Watershed Relief, R	M	428	Increases as the elevation difference between the stream's source and outlet increases.
8	Relief Ratio, Rh		0.055	This value suggests a moderate watershed slope, implying balanced topography with modest runoff and erosion risk [11].
9	Relative Relief, Rr		0.02	The watershed relief increase relative relief increase.
10	Ruggedness Number, Rn		0.56	This value represents moderate sensitivity to erosion and runoff, acceptable for varied land use, with caution in the steeper zone.
11	Drainage Frequency, Df		6.5	This suggests impermeable surface materials, significant runoff, and extensive terrain segmentation. These conditions may raise erosion risk and necessitate soil conservation.[13]
12	infiltration number		8.55	Suggests low infiltration capacity and excess surface runoff which extremely increases erosion risk and .often caused by high drainage density and frequency [22].
13	Basin slope	%	5	This value causes moderately erosion. While not as forceful as steeper slopes, it allows for persistent surface runoff, which can slowly remove soil, particularly during heavy rains.

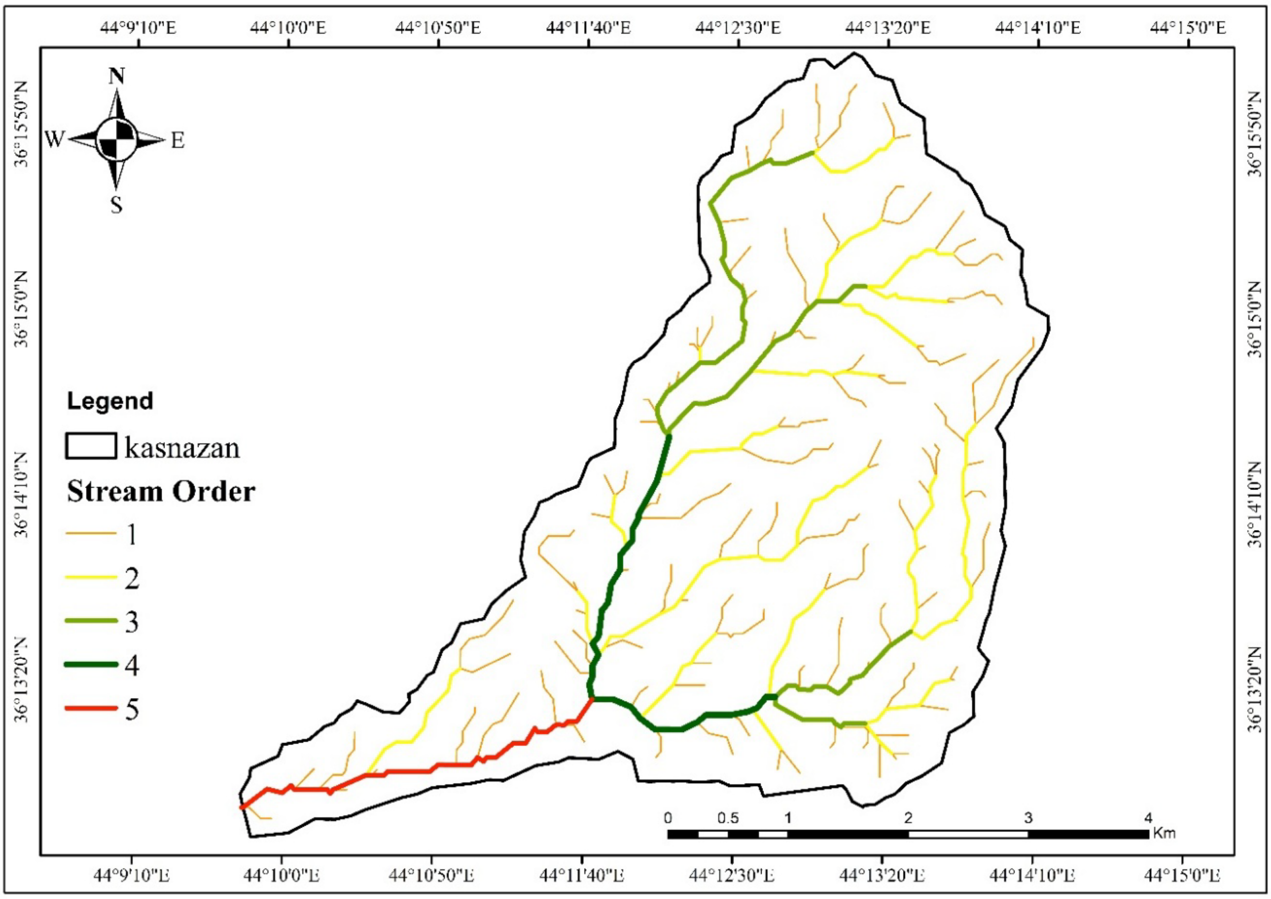

Figure 3. Stream order distribution map of the kasnazan watersheds

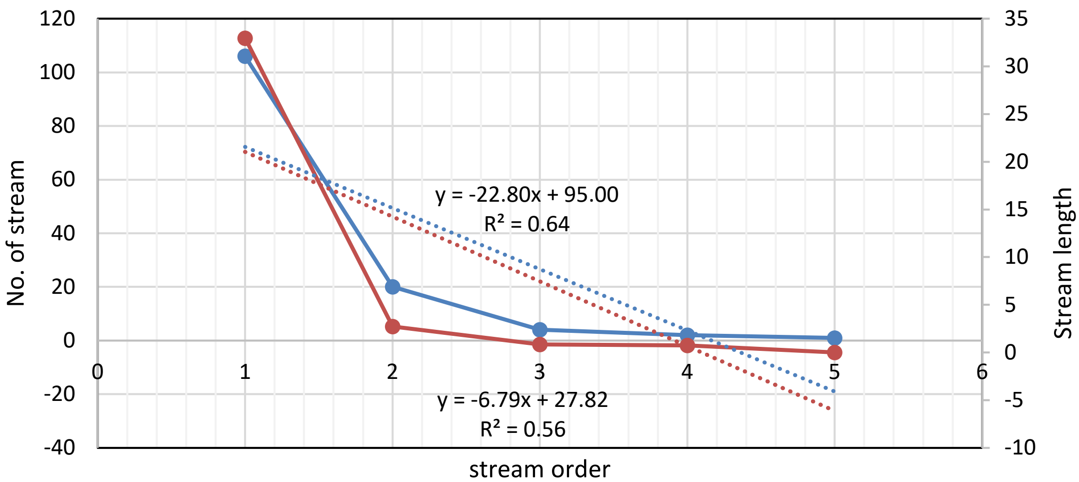

Figure 4. The association between stream number and length values and stream order values in the Kasnazan watershed.

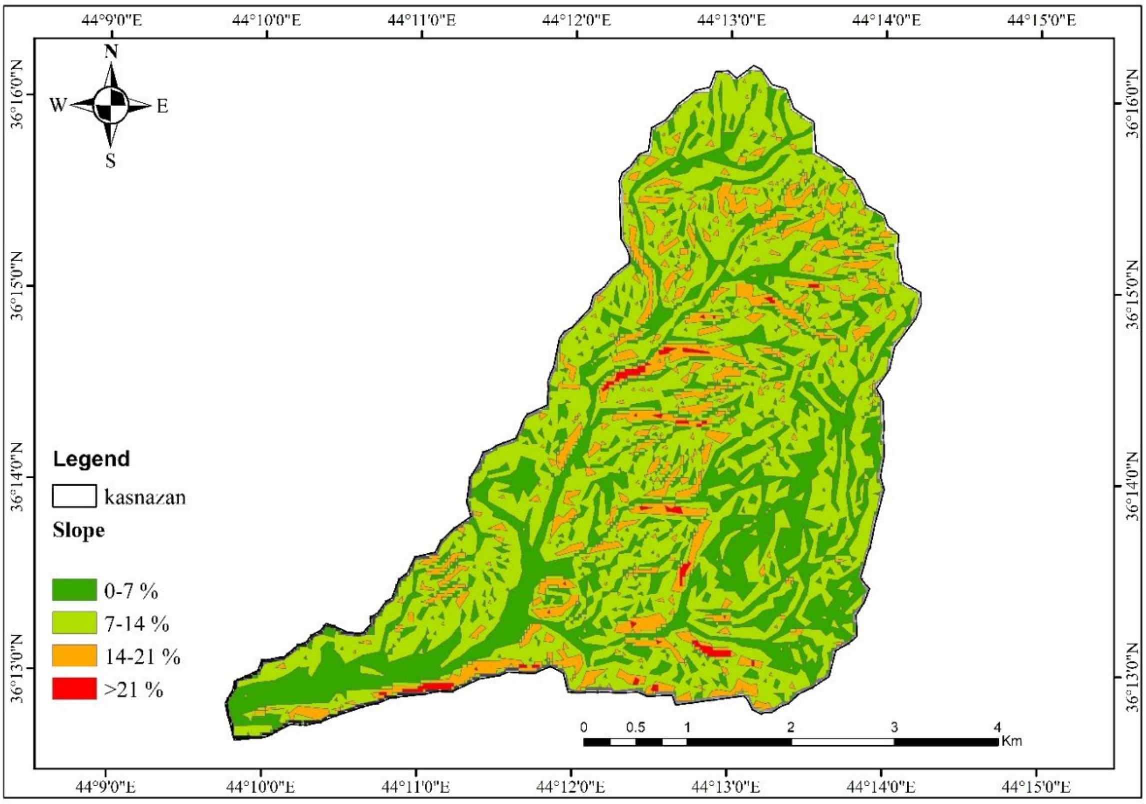

Figure 5. Slope of Kasnazan Basin