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Hydrological Analysis of Wadi Arab Valley Dam by Integrate Soil Conservation Service and Geographic Information Systems

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ABSTRACT

This study aims to estimate the runoff volume by analyzing satellite data and Digital Elevation Model (DEM) data utilizing a set of software tools such as (ArcHydro Tool, ArcGIS) to excerpt hydrological and morphological characteristics of Wadi Al Arab Dam basin with an area of 266 km² in Jordan. Natural data "soil and land use" were analyzed and defined by the curve number (CN) method with geographic information systems (GIS). The novelty of this study lies in the application of high-resolution DEMs combined with advanced GIS techniques to achieve more precise elevation mapping and hydrological flow assessments, which were previously less accurate in similar studies. Moreover, it highlights runoff concentration time and the minimal dissection of the basin, providing a better understanding of flood potential and geomorphological traits in arid regions. This fills a gap in quantifying basin hydrodynamics compared to previous studies. Results found that the total CN for the basin was 86.5. The drainage density of the basin was found to be 4.39×10^{-5} m/m², indicating less impact from erosion factors and less dissection. The concentration time of the basin was approximately 65.69 minutes, increasing the possibility of high flood potential due to the short distance traveled by the runoff. The relief ratio was found to be low at 0.018, indicating minimal dissection and runoff in the basin. We recommended the urgent adoption of high-accuracy digital data sources due to the precision they offer when conducting quantitative measurements.

Keywords: digital elevation model, soil conservation service, geographic information systems, Wadi Al Arab Dam basin, Jordan.

INTRODUCTION

Surface water is one of the main water resources in the world due to the lack of water resources and the illegal expansion of wells, as well as groundwater is not renewable. Surface water includes river water, spring drainage, running valleys, and winter floodwater (Al-Addous et al., 2023). To manage water resources, several programs have been developed in the field of hydrology. Among them, GIS and remote sensing (RS) technologies. These tools are instrumental in analyzing satellite imagery to extract critical data and generate spatial models, which can be visualized in both two-dimensional and three-dimensional formats (Janga et al., 2023). Water table analysis and basin identification by examining the temporal and spatial variability in runoff are now considered the new trend in hydrological processes. Understanding the sources and patterns of this variability is paramount for modeling the hydrogeology of arid and semi-arid region (Gebrechorkos et al., 2022).

The identification of rain basins and flow networks is an important aspect of hydrological analysis, with applications extending to hydraulic flow studies, flood forecasting, and the assessment of pollutant deposition in surface watercourses (Zhao et al., 2024). Hydrological analysis serves real-world systems, including surface waters, wetlands, and groundwater, and thus, more understanding and management of water resource

(Kumar et al., 2023). Since the mid-1980s, there has been a growing need to predict spatially changing hydrological processes with high accuracy which has led to the era of "spatial modeling" in hydrology (Tsatsaris et al., 2021).

Digital terrain models (DTMs) and RS data have been used to describe watersheds including the identification of water populations and vegetation (Graf et al., 2018). The critical inputs for new generation of hydrological and water quality models use various forms of Digital Terrain Data such as DEMs, triangular irregular networks (TIN), and contour lines which are used in different models to provide data for spatial analysis (Franklin, 2020). DEMs are used in the background of GIS to acquire basic topographic variables such as stream networks, flow direction and watershed geometry (Jones, 2002; Shawky et al., 2019). It is widely known that GIS is an important tool to analyze data by using hydrogeological modeling, which can also be applied to obtain spatial information in digital form, (e.g., variables of soil type and land use, and land cover). This acquires a special importance for hydrological modeling (Rahmati and others, 2018; Thakur and others, 2017). Recent studies have shown that the accuracy of transactions extracted from DEMs is similar to those obtained by manual methods while the processing time is much lower (Li and Wong, 2010; Weifeng and others, 2024). These transactions include the size of the basin, slope of the basin, length of the main channel, and length of the stream. If the basin's size becomes larger, more rain will fall on it and subsequently, the surface runoff will increase (Ries et al., 2017).

RS technologies are an effective tool to assess the flood risk areas and the impact of flooding on flooded areas. RS technologies provide a source of data that can save time and manpower for the collection of topographic, and geomorphological catchment data and data analysis, also its can be used to analyze satellite images and enable more accurate classification of land uses/ land cover (Farhadi and Najafzadeh, 2021; Tehrany et al., 2017). The contemporary studies extremely advance the understanding of the Wadi Al-Arab Dam basin's hydrological and geomorphological traits through the use of advanced GIS technology and DEMs, offering complete analyses compared to previous studies. Unlike Miao et al., 2024 and Li et al., 2019, who used basic GIS techniques and traditional hydrological models, this provides accurate elevation mapping from 864 meters to -139 meters above sea level, assisting in specific comfort ratio calculations. Additionally, it identifies specified waft directions and accumulation regions for effective water resource management, which have been less exact in previous studies. Moreover, these studies classify streams into 4 orders with the usage of the Streller method, offering a complete evaluation of flow hierarchy and distribution (Fritz et al., 2020).

Despite advances in geospatial tools, water resource management in arid and semi-arid regions like Jordan remains a critical challenge due to fluctuating rainfall patterns and increasing flood risks (Al-Raggad et al., 2021; Ibrahim and others, 2020; Shatnawi and Ibrahim, 2022). Wadi Al Arab Dam basin is at high risk from ephemeral runoff and flash floods, which necessitate an in-depth knowledge of the hydrological processes that control surface runoff. The main problem targeted in this study is the absence of accurate, high-resolution hydrologic models in this area to serve as a tool for better flood risk reduction and water resource planning. The comparative advantages of these formulations are considered in the context of runoff predictions and flood risk assessment, based on a comparison with toll-like models that have not embraced both hydrological and morphological emphasis at this basin. To our knowledge, this study may be the first to use advanced hydrology analysis in combination with high resolution DEM with GIS methods to predict natural runoff volume and flood potential.

Several studies used the soil conservation service curve number (SCS-CN) method to confirm that urban areas with high density of buildings are more susceptible to flooding; since urban growth reduces the maximum storage amount of soil which may increase the amount of flow coefficient and the frequency of floods (Kumar et al., 2021). On the other hand, these geo-techniques are an important tool used to predict the qualitative and quantitative effects of floods and runoff (Dahri and others, 2022; Kumar et al., 2023). Hydrological models that depend on GIS have been successfully used to predict floods in urban areas.

Study aims

The Wadi Al Arab Dam is known as the main source in Jordan to secure water, regulate the flow of rainwater and floods, and generate hydroelectric power by operating power plants, which contributes an additional source of electricity for the region. This study aims to estimate the runoff volume by analyzing satellite data and DEM data utilizing a set of software tools such as (ArcHydro Tool, ArcGIS) to excerpt hydrological and morphological characteristics of Wadi Al Arab Dam basin with an area of 266 km² in Jordan. Natural data "soil and land use" were analyzed and defined by the CN method with GIS. This study provides insight to support water scarcity treatment solutions, predict future basins, and build an alternative system to extract some of the hydrological analyses. This study will define the movement network and classify streams into 4 orders, to provide an overview of the circulation hierarchy and distribution. These insights are important to design drainage structures, mitigate flood dangers, and inform city-making plans, and environmental conservation efforts.

MATERIALS AND METHODS

Study design

We employed a quantitative analytical approach, by application of mathematical equations, statistical analysis, model building, and inductive approach to estimate surface runoff using the SCS-CN, RS, and GIS analysis for the Wadi al-Arab Dam.

Study area

Wadi Al Arab dam is located in Irbid in the north of the Hashemite Kingdom of Jordan (Figure 1), located between latitudes (32 43 'and 32 54' N and latitudes 35 30 'and 35 45'), and used for irrigation and drinking water. The main structures of the Wadi Al Arab dam basin are summarized as follows: the catchment area of the basin is 262 km^2, and the total storage capacity is effective and dead (20.0, 16.9, and 3.1 million m^3, respectively). The estimated precipitation per year is 7000 m^3 and the total annual discharge is 33 million meters (Ibrahim and Al-Mashakbeh, 2016). The King Abdullah Canal is a partial source of water in the basin as well as the other part of the rainfall. The water of the reservoir is used to irrigate about 12.500 dunams from the barn to the Baqoura. It also serves as a source of drinking water in periods of water shortage by classification to the King Abdullah Canal (JVA, 1995–2002).

Data used

Landsat 8 satellite data for the year 2015, obtained from the US Geological Survey website according to the World Geodetic System (WGS 1984 UTM-Zone/37 N), DEM for 2018 with spatial resolution up to 30 m. The software used is Arc GIS v10. and ArcHydro Tools. We calculated

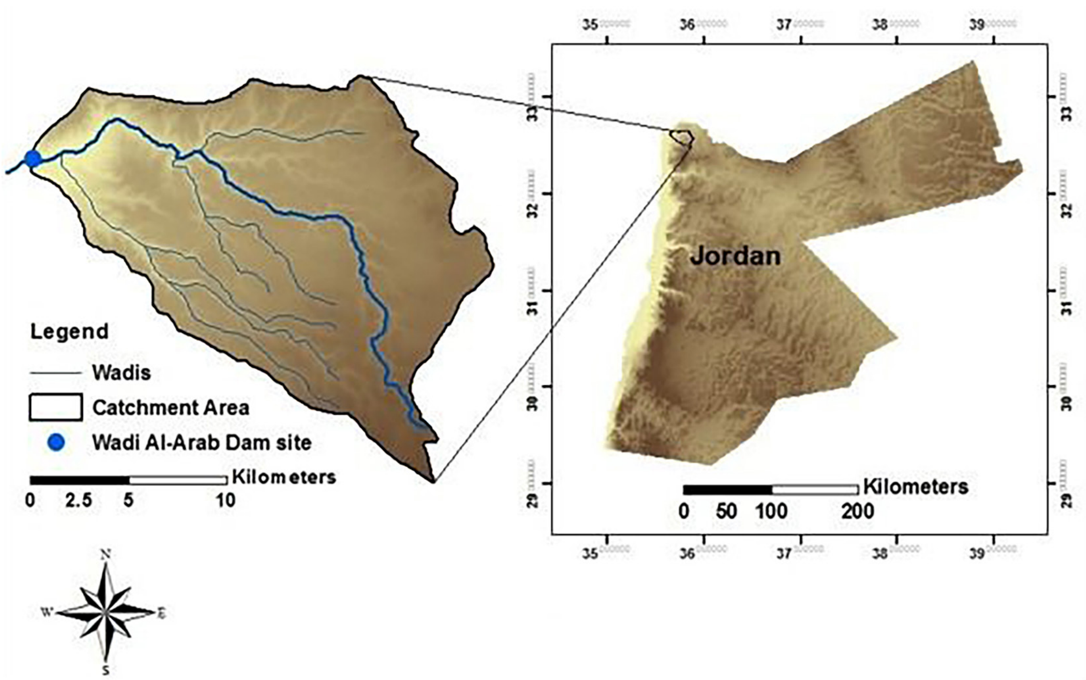


Figure 1. The site of study area

the hydrological characteristics of the runoff. The process of extracting the hydrological characteristics of the annual runoff of the Wadi Al Arab dam is shown in the following phases (Figure 2).

Analysis of soil and land use map

Spatial analysis of hydrological characteristics is one of the most important factors influencing the surface runoff process, as it reflects the climatic conditions of the drainage basins. Some of the hydrological characteristics of the Wadi al-Arab Dam study area are illustrated as follows:

Soil map

We analyzed the type of soil in the Wadi Al-Arab Dam. It is noted in Figure 3 that the soil area contains four different types: Clay soil an area of 22.9 km^2, which is equivalent to 8.6% of the area of the study. Silty Clay soil has an area of 109.6 km^2, which is equivalent to 41.2% of the area. Clay and loam have an area of 132.4 km^2, which is equivalent to 49.8% of the area, this makes its moisture content high, especially in the upper layer, which stimulates the formation of runoff in less time, unlike Stony Soil, which occupies the least area between the four soils, and an area of approximately 1 km^2, equivalent to 0.4% of the area of the study area.

Table 1 represents the soil type and its classification in km^2. It shows that the hydrological group D occupies the largest area in the study area, amounting to 264.8 km^2, equivalent to 99.6% of the study area, mostly because of the high proportion of silted areas of the Wadi Al-Arab dam, and the hydrological group C covers an area of 1.14 km^2, equivalent to 0.4% of the study area. Figure 4 shows the type of hydrological soil that composes the Wadi Al-Arab dam area, which represents Class C, D.

Land use analysis

We found seven land uses in the total area of Wadi Al-Arab dam 266 km^2, as the land category occupies the largest area, which is 134 km^2, equivalent to 50.4% of the study area. The least area is water bodies, where the area is 0.7 km^2, equivalent to 0.3% of the study area. The Aerbal land category is an area of 11.2 km^2 which is 4.7% of the area, while the Rocks has reached

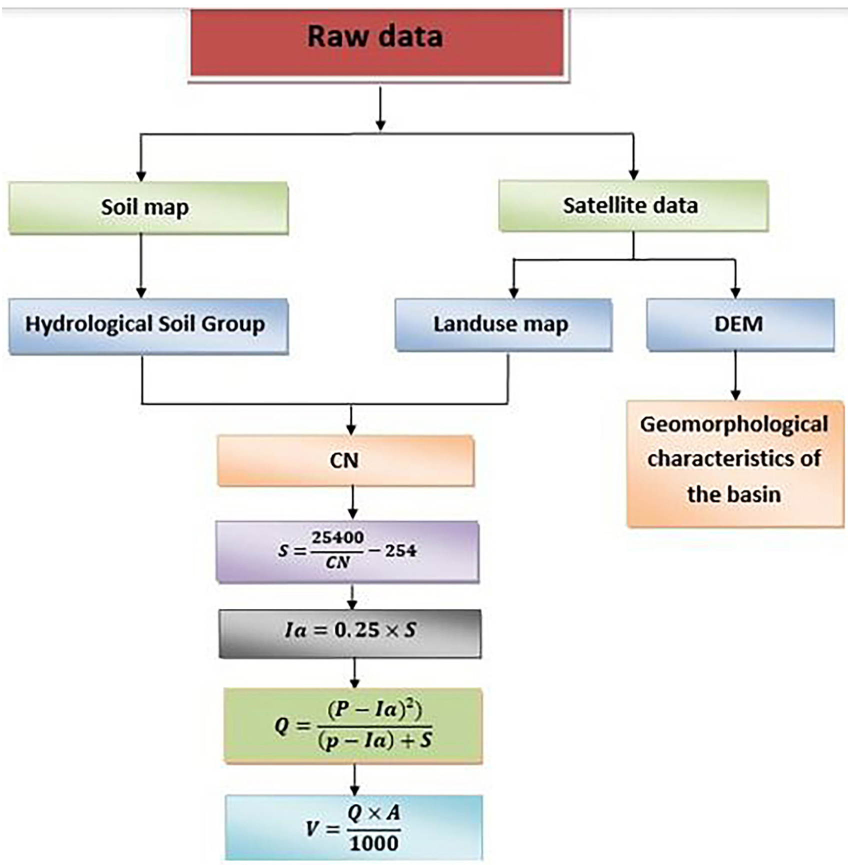


Figure 2. Schematic representation of the calculation of runoff of study area

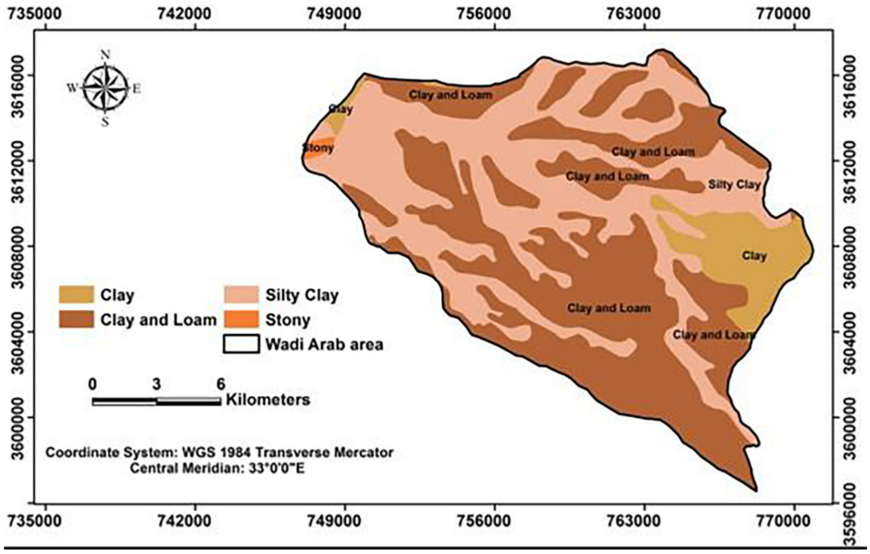


Figure 3. Map of soil types

Table 1. Represents the soil type, its classification and its areas in km^2

No.	Soil type	Hydrologic soil type	Area (Km^2)	Percentage of area (%)
1	Clay	D	22.9	8.6
2	Clay and loam	D	132.4	49.8
4	Silty Clay	D	109.6	41.2
5	Stony	C	1.1	0.4
			Sum = 266	100

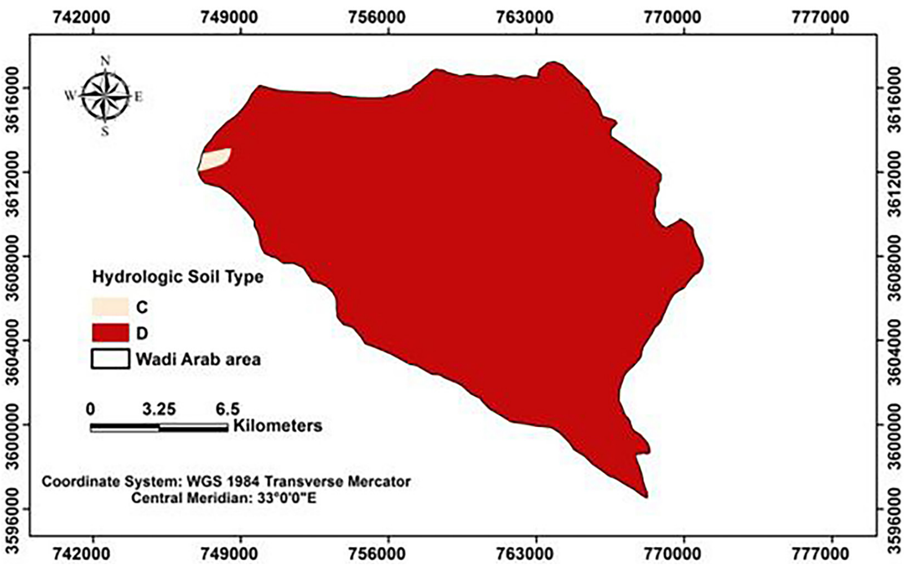


Figure 4. Hydrological soil group of study area

an area of 13.9 km^2, equivalent to 5.2% of the total area. The area of soil was 1.1 km^2 or 0.4%. Finally, Urban areas reached an area of 92.5 km^2 and 34.8% (Figure 5). The classifications of land uses and areas in km^2 and their percentage relative are performed in Table 2.

Derive curve number values

The CN of Wadi Al Arab dam area was extracted and distributed through the land use and soil type maps after the union operation within the GIS working environment. Surface runoff is

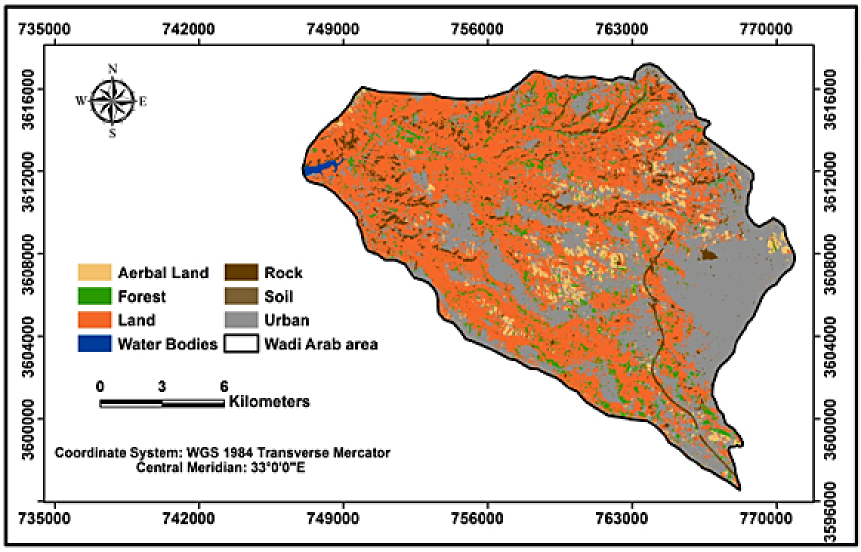


Figure 5. Landuse type of study area

Table 2. Classifications of landuse for the study area

No.	Landuse	Area (km²)	Percentage of area (%)
1	Aerbal land	11.2	4.2
2	Forst	12.5	4.7
3	Land	134.1	50.4
4	Water badies	0.7	0.3
5	Rock	13.9	5.2
6	Soil	1.1	0.4
7	Urban	92.5	34.8
		Sum = 266	100

affected by the physical characteristics of the dam such as: soil type, land use–ground cover– the inclination of the study area, as well as the temporal characteristics: intensity and durability, and the spatial characteristics of the rainstorm as the center of the storm (Zead et al., 2019). The American soil maintenance hypothesis method uses the runoff CN to express the effect of the physical properties of the basin on runoff using a single weighted value representing the runoff CN of the entire basin. The number of the runoff curve is based on two hypotheses: that the leaching of the soil follows a decreasing curve as the time of the rain wave continues, and the second: that the total initial loss constitutes 0.2 percent of the soil potential for storage after the runoff begins (Strapazan et al., 2023). The value of CN is determined based on Tables published by the US Department of Agriculture in 1984, where land uses were classified and hydrological soil categories deduced by the SCS, to derive CN values as shown in Figure 6 and its contents in Table 3. In Figure 6, it shows that the values of CN ranged from the value of (70) for the most permeable areas to (97) for the least permeable areas. This gives the impression that the basin surface tends towards producing surface runoff, because all these values are higher than the average value of (50), as the total rate of CN values for the basin was 86.5.

Calculation of soil water retention capacity factor (S)

Near-zero values of soil water retention capacity factor (S) indicate the low potential of the soil to retain water on the ground after the runoff, increasing the amount of water running on the surface, while soil retention represents water with the rate of water running on the surface, with a value of S close to 254 mm. This is considered the median value of S factor. The higher the potential of the soil to retain water on the surface, the higher the values of S factor than the median,

Table 3. Soil classifications and land uses with curve number and their areas in units (km^2)

Landuse + Hydrologic soil	Curve number (CN)	Area (km^2)	Percentage of area (%)
Aerbal land C	79	0.0009	0.00033
Aerbal land D	84	11.24	4.22
Forst C	70	0.006	0.0022
Forst D	77	12.55	4.71
Land C	90	0.7	0.27
Land D	95	133.3	50.1
Water Bodies C	97	0.1	0.038
Water Bodies D	97	0.54	0.2
Rock C	89	0.163	0.06
Rock D	91	13.8	5.19
Soil D	89	1.1	0.4
Urban C	94	0.05	0.019
Urban D	95	92.44	34.8
		SUM = 9395.4	99.99%

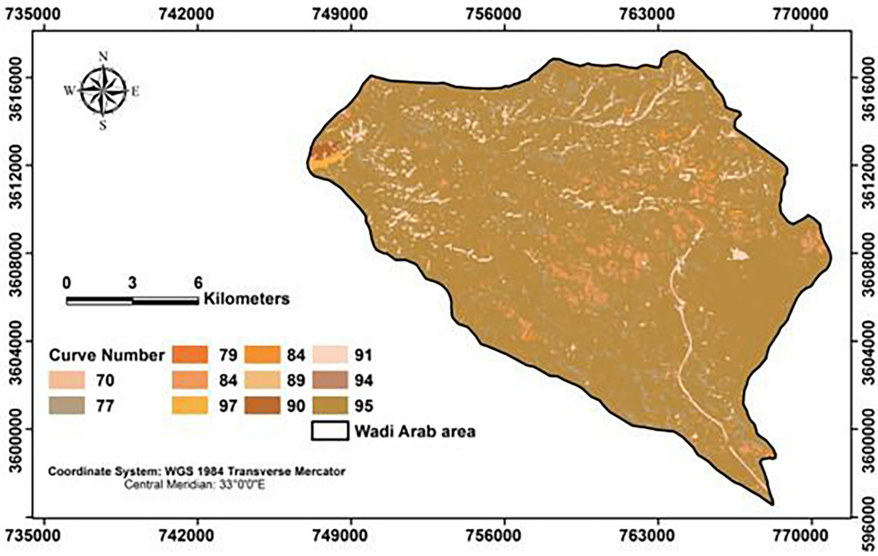


Figure 6. The distribution of CN values in Wadi Al Arab dam

leading to a decrease in the amount of runoff (Li and others, 2023). S: The potential maximum retention after runoff begins (mm), which is related to CN by the equation:

$$S = \frac{25400}{CN} - 254 \quad (1)$$

After applying the equation, S values were obtained, as shown in Table 4.

Table 4 shows the values of S factor, where the lowest value (7.9) indicates the low potential of the soil to retain water on the surface of the Earth. This means that the increase in the amount of water running on the surface and the highest value (108.9) indicate the high potential of the soil to save water. Figure 7 represents a map of the distribution of the values of S factor in the study area.

Calculation of the initial loss coefficient (Ia)

The Initial Abstraction Coefficient expresses the amount of rainwater lost before the start of runoff by evaporation, rainwater intercepted by plants, water collected in surface depressions, or by leakage, and represents one-fifth of S value. It is expressed by the following equation:

$$Ia = 0.25 \times S \quad (2)$$

where: *Ia* – initial loss before runoff, *S* – coefficient of the ability of the soil to hold water

Table 4. Represents S values and the percentage of these values relative to the study area

Landuse + hydrologic soil	Curve number (CN)	Area (km²)	S Factor	Percentage of (S) (%)
Aerbal land C	79	0.0009	67.5	13.6
Aerbal land D	84	11.24	48.4	10.1
Forst C	70	0.006	108.9	22.9
Forst D	77	12.55	75.9	15.9
Land C	90	0.7	28.2	5.9
Land D	95	133.3	13.4	2.8
Water bodies C	97	0.1	7.9	1.7
Water bodies D	97	0.54	7.9	1.7
Rock C	89	0.163	31.4	6.6
Rock D	91	13.8	25.1	5.3
Soil D	89	1.1	31.4	6.6
Urban C	94	0.05	16.2	3.4
Urban D	95	92.44	13.4	2.8
		SUM = 265.9		99.3

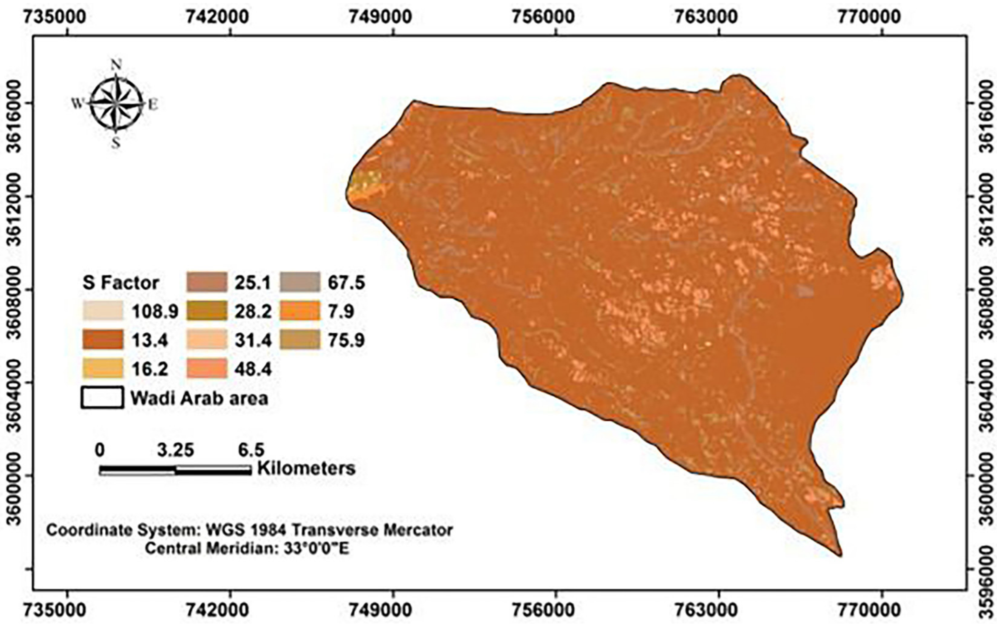


Figure 7. Soil water retention capacity map (S)

Low *Ia* values indicate a low loss of rainwater before the start of runoff, which causes rapid runoff, and high *Ia* values indicate the loss of large amounts of rainwater and thus a decrease in runoff amounts. After applying the equation to the study area, values of Ia factor were obtained. Figure 8 and Table 5 represent the *Ia* values, the area covered by the value, and the percentage of these values relative to study area.

Determination runoff depth (Q)

The runoff depth (Q) depends on the characteristics of the rainstorm in terms of intensity and duration, also it is considered the interaction of the rainstorm with the characteristics of the ground cover and soil permeability, so runoff depth formed on the surface is different. Accordingly, runoff depth of the study area was estimated based on the computational average of the annual rainstorms from the period (2008–2018) as shown in (Table 6), based on the components of the land cover and soil hydrology represented by the CN in addition to the amounts of rain falling on the study area. Runoff depth is calculated by the following equation:

$$Q = \frac{(P - Ia)^2)}{(p - Ia) + S} \quad (3)$$

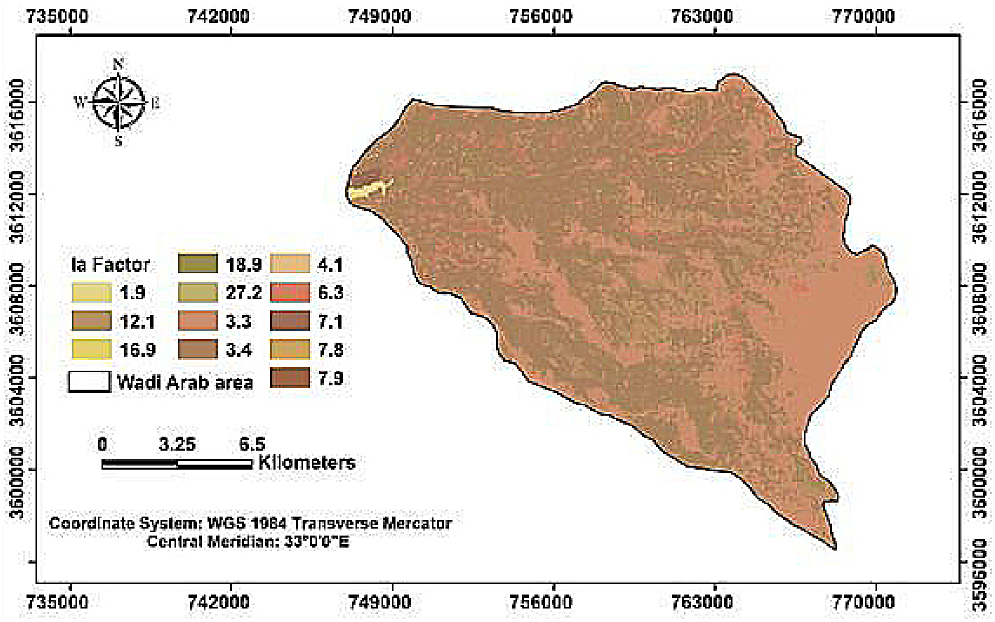


Figure 8. Map of Ia factor of study area

Table 5. Represents IA values and the percentage of these values relative to study area

Landuse + Hydrologic Soil	Curve number (CN)	Area (km^2)	S Factor	Initial abstraction (Ia)	Percentage of (Ia) (%)
Aerbal land C	79	0.0009	67.5	16.9	14.2
Aerbal land D	84	11.24	48.4	12.1	10.2
Forst C	70	0.006	108.9	27.2	22.9
Forst D	77	12.55	75.9	18.9	15.9
Land C	90	0.7	28.2	7.1	5.9
Land D	95	133.3	13.4	3.4	2.9
Water bodies C	97	0.1	7.9	1.9	1.6
Water bodies D	97	0.54	7.9	1.9	1.6
Rock C	89	0.163	31.4	7.9	6.7
Rock D	91	13.8	25.1	6.3	5.3
Soil D	89	1.1	31.4	7.8	6.6
Urban C	94	0.05	16.2	4.1	3.4
Urban D	95	92.44	13.4	3.3	2.7
		SUM = 265.9			99.9

Table 6. Represents the total and the computational average amount of precipitation (mm) in the last ten years

Year	The total amount of precipitation (mm)	Avg of the amount of precipitation (mm)
2008	238.23	20
2009	428.66	36
2010	283.79	24
2011	404.08	34
2012	464.19	39
2013	366.35	30.5
2014	234.61	19.5
2015	243.55	20.3
2016	293.61	24.5
2017	114.8	9.6
2018	373.71	31.1

where: Q is the runoff depth (mm), P is the precipitation (mm), S is the potential maximum retention.

After reviewing the values of rainstorms for the study area, Table 7 was created, which shows each year and the average rainstorms within it and runoff depth in that year.

Estimate the runoff volume (V)

The volume of the runoff reflects the total runoff to the area of the study, it is considered an important hydrological calculation, where the runoff volume is estimated based on calculations of runoff depth. Runoff volume is expressed by the following equation:

$$V = \frac{Q \times A}{1000} \quad (4)$$

where: V – runoff volume (m^3), Q – runoff depth (mm), A – study area (m^2), 1000: conversion coefficient from (mm) to (m).

RESULTS AND DISCUSSION

Hydrology analysis

The hydrological analysis of the Wadi Al-Arab Dam basin using DEM processing capabilities. These capabilities facilitate the creation of a waterway community, the explanation of sub-basins, and the identity of downstream points for every circulation. The process consists of addressing anomalous elevation values (sinks fill), with elevation values starting from 864 meters above sea level on the basin's resources to -139 meters at its mouth Figure 9a. This elevation is vital for calculating the relief ratio.

Stream ordering determines the best threshold value for extracting the drainage community. After experimentation, a threshold price of one changed into diagnosed as ultimate for the take a look at the vicinity (Ozulu and Gökgöz, 2018). Streller method to circulate order category, the basin's streams have been categorized into 4 orders, totaling 1968 streams shown in Figure 9d. The first order includes 1083 streams (55%), characterized by using more numbers and lengths of streams. The second order comprises 540 streams (27.4%), the third order includes 214 streams (10.9 %), and the fourth-order has 131 streams (6.6 %), noted for shorter lengths and fewer streams. These classifications give important information about the basin's hydrological shape and flow hierarchy (Figure 9e, Table 8).

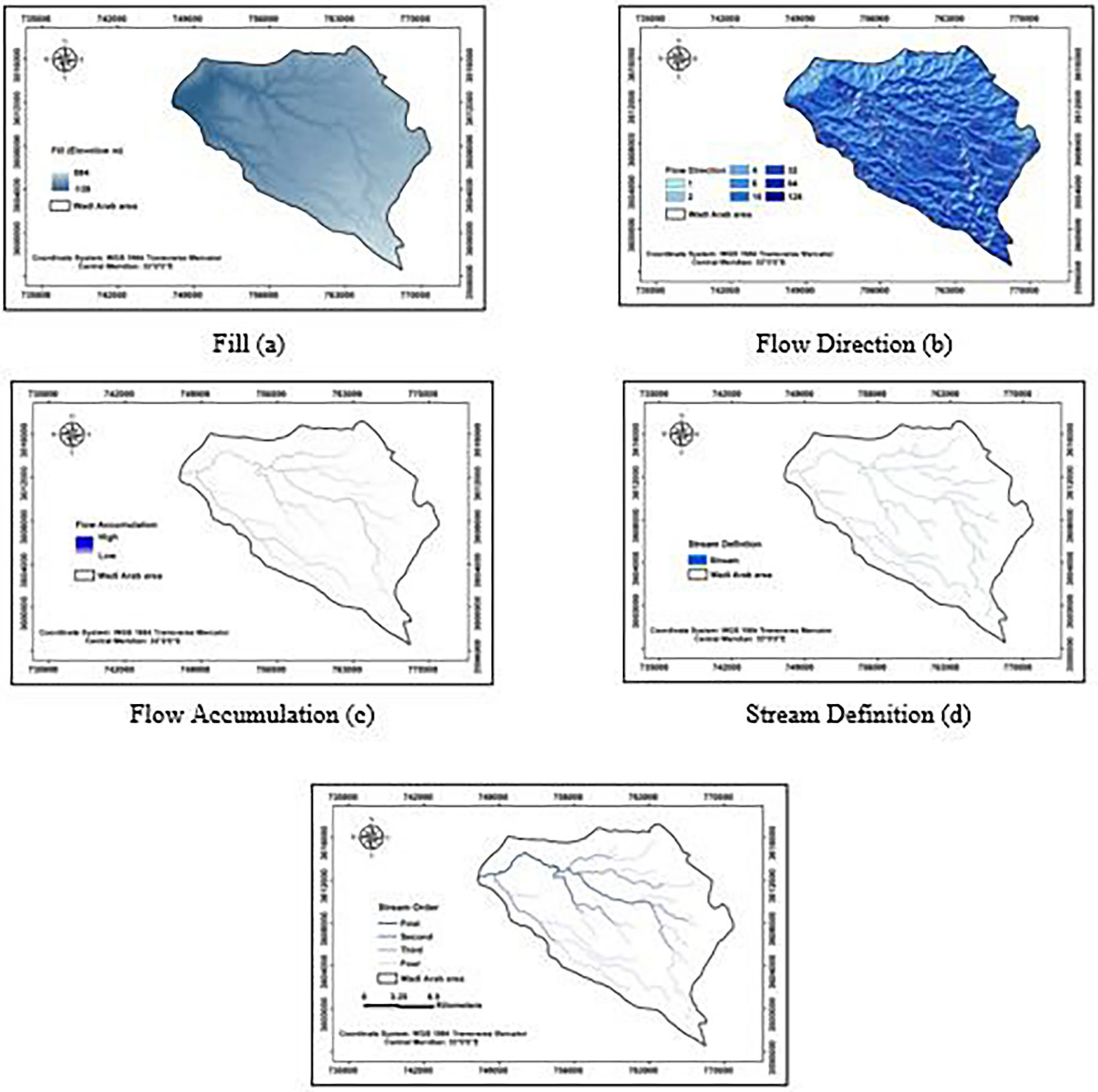
The next step is determining the drift route, by how water transfers from one cellular to adjacent cells. Results indicated that the direction of the northwest (cost 32), with versions in waft guidelines represented via extraordinary shades: eastward float (fee 1, mild blue), westward float (fee sixteen, medium blue), and northeastward go with the flow (value 128, darkish blue) Figure 9b. The flow accumulation device calculates the quantity of contributing cells for every mobile based on streams, which glide in the direction of the northwest of the Wadi Al-Arab Dam basin Figure 9c.

Morphometric analysis

Morphometric analysis is considered one of the most important scientific methods used in geomorphological studies, because this method

Table 7. The calculation of runoff depth (mm) and runoff volume (m^3) for study area

Year	Avg of the amount of precipitation (mm)	Runoff depth (Q) (mm)	Volume of runoff depth (V) (m^3)
2008	20	6.95	1848700
2009	36	19.7	5240200
2010	24	9.88	2628080
2011	34	17.99	4785340
2012	39	22.31	5934460
2013	30.5	15.1	4016600
2014	19.5	6.6	1755600
2015	20.3	7.17	1907220
2016	24.5	10.27	2731820
2017	9.6	1.04	276640
2018	31.1	15.55	4136300



Fill (a)

Flow Direction (b)

Flow Accumulation (c)

Stream Definition (d)

Stream Order (e)

Figure 9. Hydrology analysis maps

provides quantitative measurements that give a clear picture of the subject through the conditions affecting the shape, and to which possible to link them within a quantitative framework that is not subject to differences in descriptive viewpoints.The results of the geomorphological analysis are presented as follows:

River bifurcation ratio

The percentage of bifurcation ratio is important because it controls the rate of classification and examines the relationship between the number in each order of two consecutive (Shekar and Mathew, 2024). Variation in the ratio of the displacement leads to the difference in the number of each order, depending on geological and climatic conditions for Wadi Al-Arab Dam basin (Gariano and Guzzetti, 2016).

Table 9 shows river levels and number of streams for each of the four orders and the bifurcation ratio of the study area, where the bifurcation ratio is obtained by the following mathematical equation:

$$RBR = \frac{No. of\ watersheds\ in\ one\ order}{No. of\ watersheds\ in\ the\ next} \quad (5)$$

where: RBR – river bifurcation ratio

Drainage density

Drainage density is a morphometric measure in geomorphological study since it indicates the exposure of the Earth's surface in the processes of carving and cutting by watershed (Figure 10).

Table 8. Represents the number of stream order

Stream order	Numbers of watershed in each order	Percentage (%)	Total lengths of watershed (km)
First	1083	55.0%	205.31
Second	540	27.4%	98.50
Third	214	10.9%	40.64
Four	131	6.6%	24.63
	SUM = 1968		SUM = 369.1

Table 9. Preparation of watershed for different order in the study area by their bifurcation ratio and general bifurcation rate

Stream order	Numbers of watershed in each order	River bifurcation ratio	The number of watersheds in two consecutive orders	River bifurcation ratio × the number of watersheds in two consecutive orders	Bifurcation rate
First	1083	2	1623	3246	$\frac{5693.35}{2722} = 0.47$
Second	540	2.5	754	1885	
Third	214	1.63	345	562.35	
Four	131	–	–	–	
SUM	1968	6.13	2722	5693.35	

The high value of drainage density reveals that it is affected by erosion factors and the intensity of the basin cut, (topographic texture is soft, if it is more than 10 based on Smith’s). Its topographic texture is rough, as well as the small numbers and lengths of the watershed in the basin (Gao and others, 2022). It can be calculated by the following equation:

$$DD = \frac{Swl}{Dba} \tag{6}$$

where: *DD* – drainage density, *Swl* – sum of watercourse lengths of all drainage basin ranks (m), *Dba* – drainage basin area (m^2)

The lengths of the watershed for each four orders, the study area, and the calculation of the drainage density of the Wadi Al-Arab Dam basin are presented in Table 10.

Relief ratio

The relief ratio indicates the interrelationship between the basin relief and its length. It affects the degree of general regression, understanding the topographic situation and its impact on the formation of land features as well as predicting the size of the transported sediments quantitatively and qualitatively. Its impact may extend to great distances from them and contribute to the formation of different geomorphological forms, increasing the speed of arrival of water output:

$$RR = \frac{Dhl}{L} \tag{7}$$

Figure 10. Relationship between stream order and watershed

Table 10. Represents the drainage density of the study area

Stream order	Lengths of watershed (km)	Study area (km²)	Drainage density
First	205.3	266	$\frac{369.1}{266} = 1.38$
Second	98.47		
Third	40.63		
Four	24.62		
SUM	369.1		

Table 11. Represents the calculation of relief ratio and the concentration time (in min) of the study basin

Highest height (m)	Lowest height (m)	Length of basin (m)	Relief ratio	Concentration time
445	139 -	32785.2	$\frac{(445-(-139))}{32785.2}$ = 0.018	275.36

where: *RR* – relief ratio, *Dhl* – the difference between the highest and lowest level in the drainage basin (m), *L* – length of the drainage basin (m)

Calculation of concentration time

We calculated the concentration time by the following equation:

$$tc = 0.01947 \times (\frac{L^3}{\Delta H})\wedge 0.385 \quad (8)$$

where: *tc* is the time of concentration (hours), *L* is the length of the mainstream (m), *S* is the average slope of the basin.

The highest and lowest height, length of the stream, relief ratio and concentration time of Wadi Al-Arab Dam basin are summarized in Table 11.

CONCLUSIONS AND RECOMMENDATIONS

This study performs a hydrological analysis of the Wadi Al Arab Dam basin using the SCS-CN method integrated with GIS. The study successfully estimated the runoff potential by analyzing satellite data, DEM data, and soil and land use characteristics. Results demonstrated that the CN for the basin was 86.5, indicating a high potential for runoff. The drainage density, concentration time, and relief ratio further confirmed the basin's susceptibility to flooding under certain rainfall conditions. The analysis also highlights the importance of utilizing high-resolution digital data for hydrological modeling, as these methods provide more accurate assessments of the watershed's geomorphological and hydrological characteristics than previous studies. Thus, the goal of integrating GIS and hydrological models to estimate runoff and assess flood risks is successfully achieved.

Our results fill a gap in understanding the hydrological dynamics of the Wadi Al Arab basin and provide a valuable tool for water resource management and flood risk assessment. These insights can inform future efforts to mitigate flood risks in the region by guiding infrastructure development and water management policies. We recommend further studies to improve the precision of runoff prediction models by integrating real-time data from advanced remote sensing technologies in other countries. Future studies are also recommended to explore the impact of climate variability on the hydrological behavior in other basins. We also recommend employing GIS technology and digital elevation models in natural studies related to the morphometric characteristics of drainage basins in our Arab region in general and Jordan in particular is necessary for the effort and time. Also, a need to rely on digital data sources with high accuracy for the accuracy they provide when conducting quantitative measurements, which in turn reflects on the results and representation of maps with all liquidity through modern technologies represented by GIS.

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