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RESEARCH ARTICLE

Evaluation of the Gully Erosion Risks in the Mamran Basin within Sulaymaniyah Governorate using GIS & RS

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ABSTRACT

The Mamran Basin is located in Sulaymaniyah Governorate - Kalar District, with a basin area of (314,746 km2), penetrated by its streams (11) agricultural villages, and thus, with its streams extending throughout all parts of these villages, it represents the arteries that feed the continuity of life in them .The erosional activity of the basin and the associated risks have been targeted, and their temporal and spatial boundaries have been identified. Regarding the temporal boundaries, they were determined by adopting rainfall data from the Sulaymaniyah station for the period (1990-2020). It was revealed that the period represented by the months of September to October signifies the stage of initial and secondary surface permeability saturation with water, which is the stage of preparation for surface water flow. Then, the stage of water flow and erosion activity begins, extending from November to the end of May, totaling (7) months. It starts gradually increasing during November, reaching its peak in January, then gradually decreasing until witnessing a state of flow interruption, stagnation, and cessation of erosion activity from June to the end of August due to the decrease in rainfall and the insufficient hydraulic support to induce water flow, especially in areas with slight slopes. Consequently, the period representing high erosion risk in the study area was defined as the period from November to the end of March. As for the spatial boundaries of the erosion activity level and the associated risks, they were determined based on the results of an equation. The results indicated that (0.6%) of the basin area is affected by moderately active erosion northwest (Bargsma, 1982) and southeast of the study area, while (15.3%) of the study area is affected by high erosion spread across scattered areas. Moreover, 80.5% of the basin area is affected by very high erosion, and (3.6%) of the basin area is affected by severe erosion .

INTRODUCTION

The basin network of the Mamran Basin is spread over an area of (314 km2), penetrated by its streams, agricultural lands on which 11 villages are based, (Ah Dalika, Tepe Krus, Kani Laktash, Darwar Khawar, Braumel Mill, Qalandar Tiko, Qabarsan, Omar Ghajan, Hama Faraj, Haji Hussein, Saqi Mustafa Thus, with its streams extending throughout all parts of the country, it represents the arteries that feed the continuity of agricultural life in all its forms.

The risks associated with the spatial boundaries of erosion have been identified within two ranges: a range of moderate risk occupying (15.9%) of the basin area, associated with boundaries represented by watershed division lines, and a range of severe risk occupying (84.1%) of the basin area. This severe risk encompasses all agricultural villages, totaling (11) villages. Therefore, it can be said that these villages must take precautions during the period between November and March due to the high risk of water erosion during this time. This risk manifests in the form of floods, slope collapses along the banks of watercourses in the Mamran Basin, in addition to the movement of various materials accompanying this level of erosion hazards.

The villages, however, in certain situations and times, these watercourses can turn into disasters in the form of rampant and sweeping floods that carry away soil and property. They can also be the cause of collapses and the movement of materials on the slopes representing the banks of the basin's network of watercourses. Therefore, Bergsma (1982) developed a model to study the erosion process and assess the accompanying risks. One of the erosion models chosen was Geographic Information Systems (GIS) to determine the prevailing erosion intensity and assess its risks. The model was applied using remote sensing technology, and the use of these technologies allows for the estimation of soil degradation due to erosion at the cell level rather than at the level of partial basins. On the other hand, traditional studies calculate erosion outcomes through field measurements or experimental solutions at the basin level, represented in a single value without considering variations at the level of secondary basins. Hence, this study aims to present an applied model for remote sensing technology and GIS in estimating erosion risks in the Mamran Basin .

Research problem

1- What is the volume and level of gully erosion activity in the Mamran Basin?
2- Is there temporal and spatial variation in erosion activity in the Mamran Basin?
3- Are there risks associated with erosion, and is there spatial variation in the magnitude of these risks?

Research hypothesis

1- The volume and level of gully erosion activity in the Mamran Basin vary from one location to another and from one climatic season to another. This variation is influenced by the amount of rainfall, the volume of surface water flow, and the density of watercourses per unit area.
2- The intensity of risks varies according to erosion activity in the study area, and there is a direct relationship between them.

Research importance

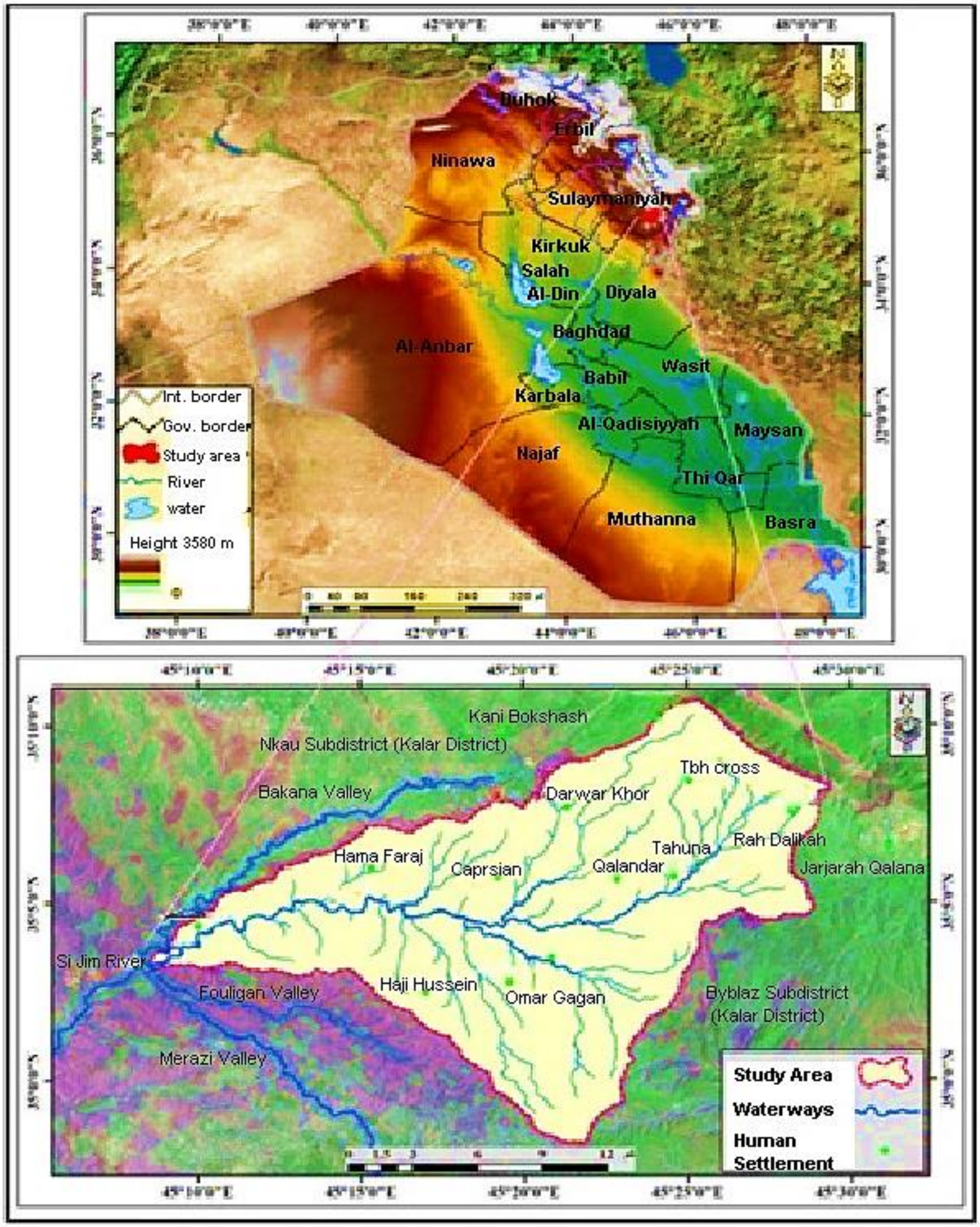
The importance of the study is embodied in calculating the value of erosion in detail and determining the level of risks associated with erosion by adopting a quantitative analysis method and reliable data sources, namely satellite sources, and using programs for deduction and accurate processing of satellite data that end with high-accuracy result outputs that contribute to building a database that will be used in the long term to develop the region and address its problems.

Boundaries of the study area

The study area is located in Sulaymaniyah Governorate, Kalar District. It is bordered by Darbandikhan District to the north, Khanaqin District in Diyala to the east, Jalloulah Subdistrict in Diyala to the south, and Kifri District in Salah al-Din to the west. The area of the Mamran Basin is 314.746463 square kilometers.

Astronomically, the basin is bounded by latitude lines (34°15' to 34°35' N) and longitude lines (33°45' to 23°45' E). Refer to Map (1) for visual reference.

Map (1) Location of the study area in Iraq



Source: *Administrative Map of Iraq, drawing scale (1:1000000), General Directorate of Survey, 2015*.

Analysis of gully erosion rates in the Mamran Basin

The activity of water erosion processes is influenced by several factors that actively contribute to continuously and variably altering the surface features of the land. Among these factors are lithological characteristics, surface slope, vegetation cover density, and most importantly, the key factor that significantly increases the activity of water erosion processes: rainfall. Rainfall in dry and semi-arid environments is characterized by heavy precipitation over a short period, leading to the formation of flash floods. This is the case in the study area, where the increase in the activity of water erosion processes reaches extremely dangerous levels due to the large annual rainfall accumulation, reaching 675.3 mm. Refer to Table (1) and Figure (1) for details. Water erosion processes are directly affected by climatic elements, particularly the rainfall element.

The heavier the rainfall, the greater the amount of surface runoff and consequently the increase in erosional activity causing soil and rock material to be washed away from highland areas towards the lowland plains in the Mamran Basin, which represent the floodplain of the basin. Surface runoff affects the upper layers of the earth's surface, leading to soil erosion and its displacement from one place to another. Thus, surface runoff is the main factor contributing to soil degradation. The risks of water erosion lie in the loss and deterioration of many ecosystems by depleting agricultural lands, degrading soil fertility, and threatening human structures and activities with collapse, such as dams, water reservoirs, and human settlements due to sedimentation of erosion materials, leading to reduced capacity, shortened lifespan, and collapse. Additionally, finding treatment and solutions for these issues in the near term is difficult, as it requires a series of complex and lengthy procedures.

Mountainous areas in Iraq are among the regions continuously exposed to water erosion hazards, including erosion and soil loss, due to the intensity of rainfall causing floods and flash floods. This is one of the major environmental problems facing the study area.

1. Time limits for water erosion activity:

The temporal boundaries of the temporal pathway of water erosion activity in the study area are clarified through the data provided in Table (1) and Figure (1). It can be stated that the process of water erosion due to runoff is associated with the time required for saturation first. This period is linked to the amount of rainfall on the land surface, the type of soil texture (cracks and surface pores), and the extent to which these voids are filled. Subsequently, the stage of water flow begins from the dividing line to the outlet, and during this flow, watercourses are formed, taking on different names depending on their dimensions. Some are simple streams, while others are water channels with depths significantly exceeding their capacities, usually found in areas with steep to moderate slopes and land with low resistance to water erosion.
According to this concept, we can observe three temporal stages of erosion in the study area as follows:

1. Saturation Stage: Represented by the months of September and October, with a total rainfall of 40.4 mm. Refer to Table.(1)
2. Flow and Erosion Activity Stage: Spanning over (7) months from February to the end of May, with varying intensity depending on the amount of rainfall. It starts with increasing severity from February, where the rainfall reaches 99.7 mm and peaks in March with 125.4 mm, followed by a gradual decrease starting from February, with rainfall levels dropping below the peak in May to 94.5 mm. The intensity also decreases during the spring season, specifically in March and April. In May, water flow slows down significantly, stagnating and forming scattered water pools as water flow halts with signs of water pooling and saturation. Refer to Table (1) and Figure.(2)

3. Flow Interruption and Dryness Stage: Extending from June to the end of August due to the absence of rainfall during this period.

Table 1: Total monthly and annual rainfall (mm) at Sulaymaniyah station for the period(2020-1990)

Station/ Month	**Sulaymaniyah**	**Seasons**
September	2.3	Autumn
T1	38.1	
T2	99.7	
Quarterly total	140.1	
K1	112.1	Winter Season
K2	125.4	
February	94.5	
Quarterly total	322.1	
March	99.7	Spring Season
April	74.0	
Mays	29.5	
Quarterly total	203.2	
June	0.0	Summer Season
July	0.0	
Dad	0.0	
Quarterly total	0.0	
Annual total	**675.3**	

Source:
1. Republic of Iraq, Ministry of Transport, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Department, unpublished data, 2022.
2. Kurdistan Region of Iraq - Sulaymaniyah, Meteorology Department, unpublished data,

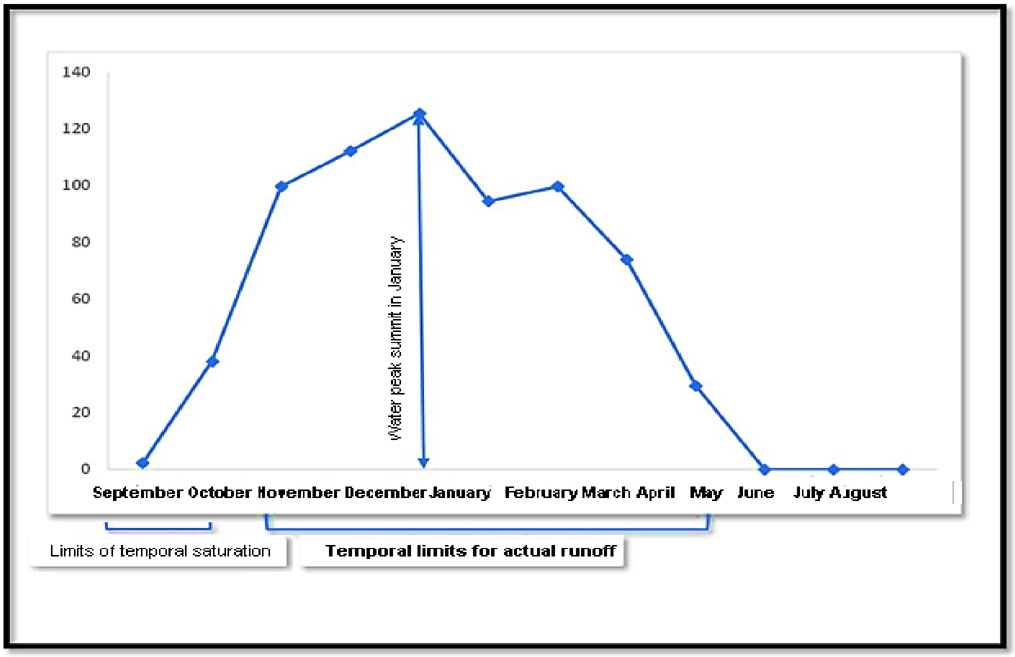


Figure 1: Total monthly and annual rainfall (mm) at Sulaymaniyah station
For the period(2020-1990)
Source: *Worked by the researcher based on data from Table (1).*

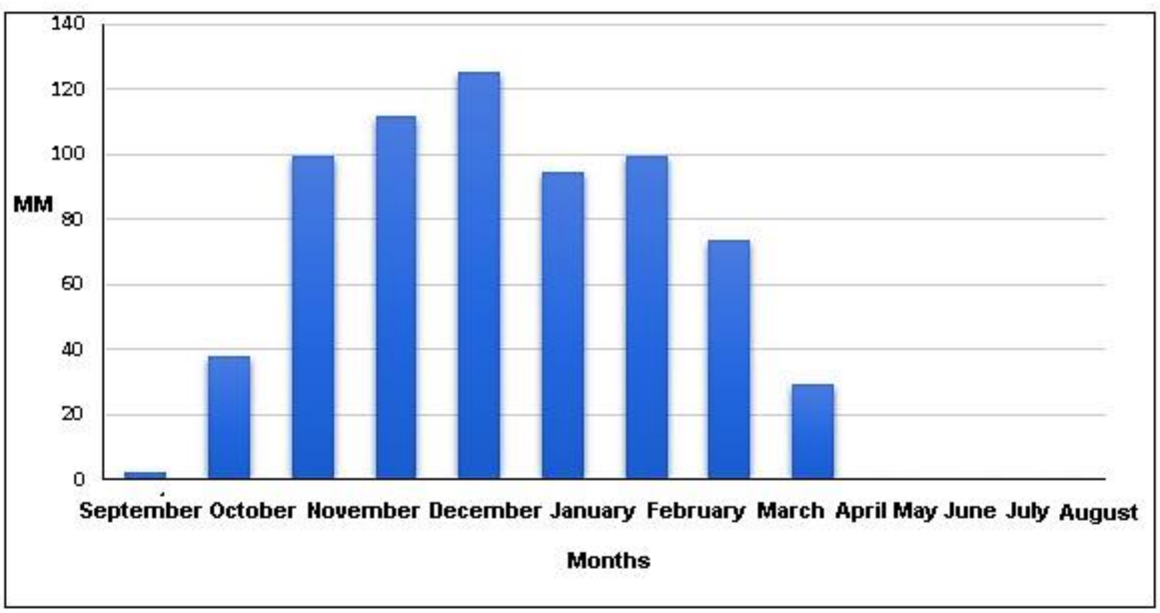


Figure 2: Time limits of gully erosion activity in the Mamran Basin
Source: *The researcher's work based on data from Table(1)*

2. Spatial limits of water erosion activity:

The level of intensity of gully erosion of the Mamran Basin was measured based on the Bergsma equation, which relied on seven levels (1) (Bergsma 1982) and as shown in Table(2)
The sum of the lengths of the grooves in the basin / m, the equation for groove erosion= Basin area/km2

Table 2: Classification of degrees of groove erosion according to Bergsma (1982) classification.

Degree of complexity	Description	Erosion rate m/km2
1	Very light pressing range	0-400
2	Light intrusion range	401-1000
3	Medium frequency range	1001-1500
4	High frequency range	1501-2700
5	Very high frequency range	2701-3700
6	Extreme urgency range	3701-4700
7	Very intense range	More than 4700

Source: Bergsma, E.I. (1983): "Rainfall Erosion Surveys for conservation planning", ITC Journal, vol. 2 (p 166-174).

Through applying the equation and according to the classification by the contour mapping, it is evident that the Mamran Basin has been affected by the process of erosional incision for all sites, totaling (96) sites classified according to the contour mapping into (4) zones ranging from moderate to severe degrees of erosion ranging between (3-6) and varying areas for each range totaling (314.757676 km^2) and varying lengths of streams from one range to another, with very high erosion rates totaling (10711.4283 m/km^2). Please refer to Table (3) and Map.(2)

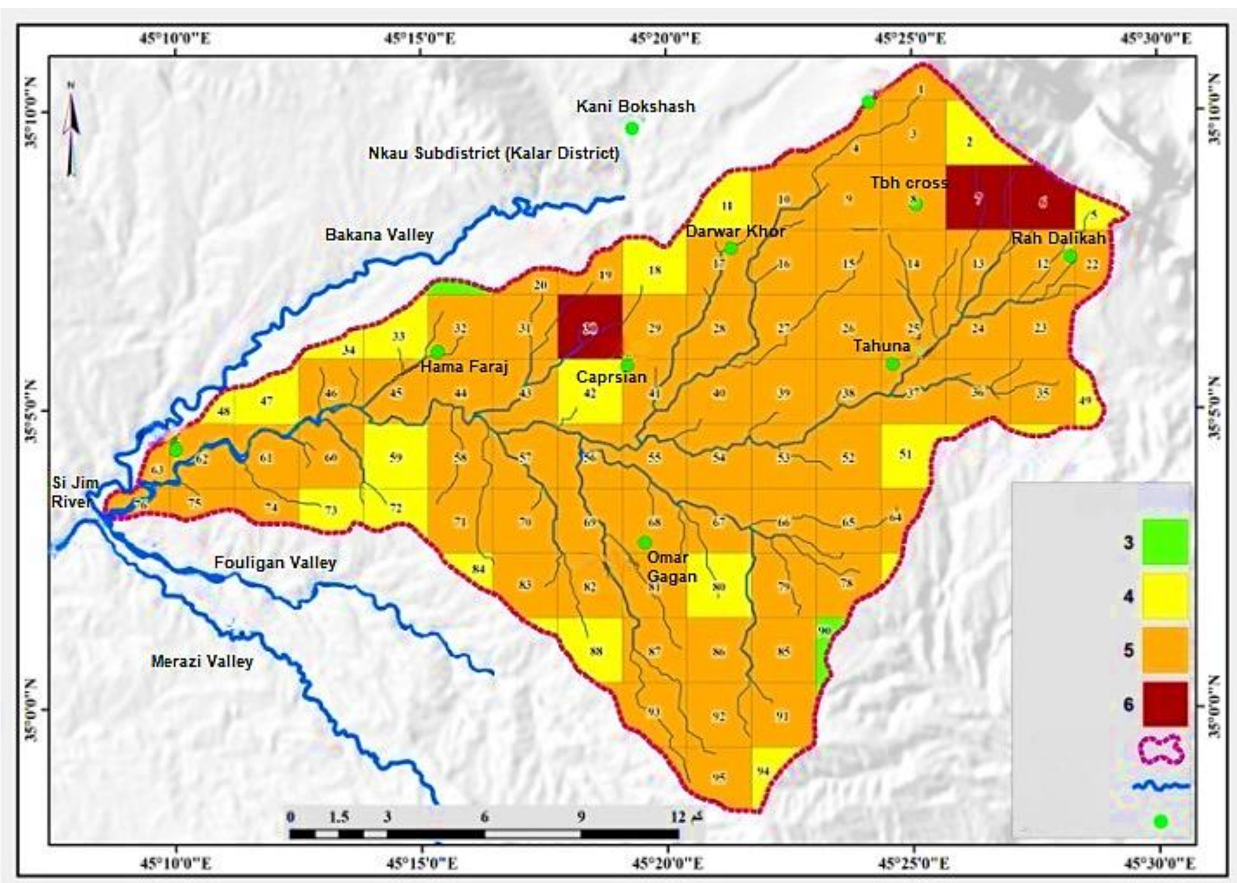
Based on the data provided in Table (3) and Maps (2-3), it is possible to identify (4) zones of varying degrees of erosion. This variation can be attributed to several factors, most notably the geological structure and the rate of surface slope. For the Mamran Basin, the activity of erosion processes depends on the rock characteristics of the basin, the permeability of the rocks, and their susceptibility to erosion due to their low strength as they are rocks deposited in a weakly cohesive freshwater river environment, consisting of conglomerates, sandstones, gravels, and sands. Additionally, the sparse vegetation cover, the abundance of water, the speed of surface water flow, and the density of watercourses and their varying sizes also contribute to erosion. These zones are as follows:
Zone of moderate erosion: This zone covers an area of (1.818441 km^2), representing (0.5777279%) of the total area, with an erosion rate of (1,327.51076 m/km^2), accounting for (12.3934109%) of the total erosion rates of the basin. It is the smallest and least active zone of erosion, classified as level (3) according to the Bergsma classification. This zone consists of very limited small areas within the basin, mainly in the northwestern and southeastern parts. These areas have moderate to gentle slopes and are composed of rock formations that are weakly resistant to water erosion and have high permeability. Please refer to Map (2-3) and Table.(3)

Table 3: Classification of gully erosion rates for the Mamran Basin according to Bergsma (1982) classification

Degree of erosion	Number of sites	Total sewer lengths/m	Area/km2	percentage%	Erosion rate m/km2	percentage%	Erosion level
3	2	2414	1.818441	0.57772729%	1327.51076	12.3934109%	Medium
4	21	119457	48.161657	15.3011859%	2480.80287	23.1559702%	High
5	70	785460	253.226924	80.4513895%	3101.80287	28.9578951%	very high
6	3	43913	11.550654	3.66969732%	3801.77607	35.4927239%	Severe
Total	96	-	314.757676	100%	10711.4238	100%	-

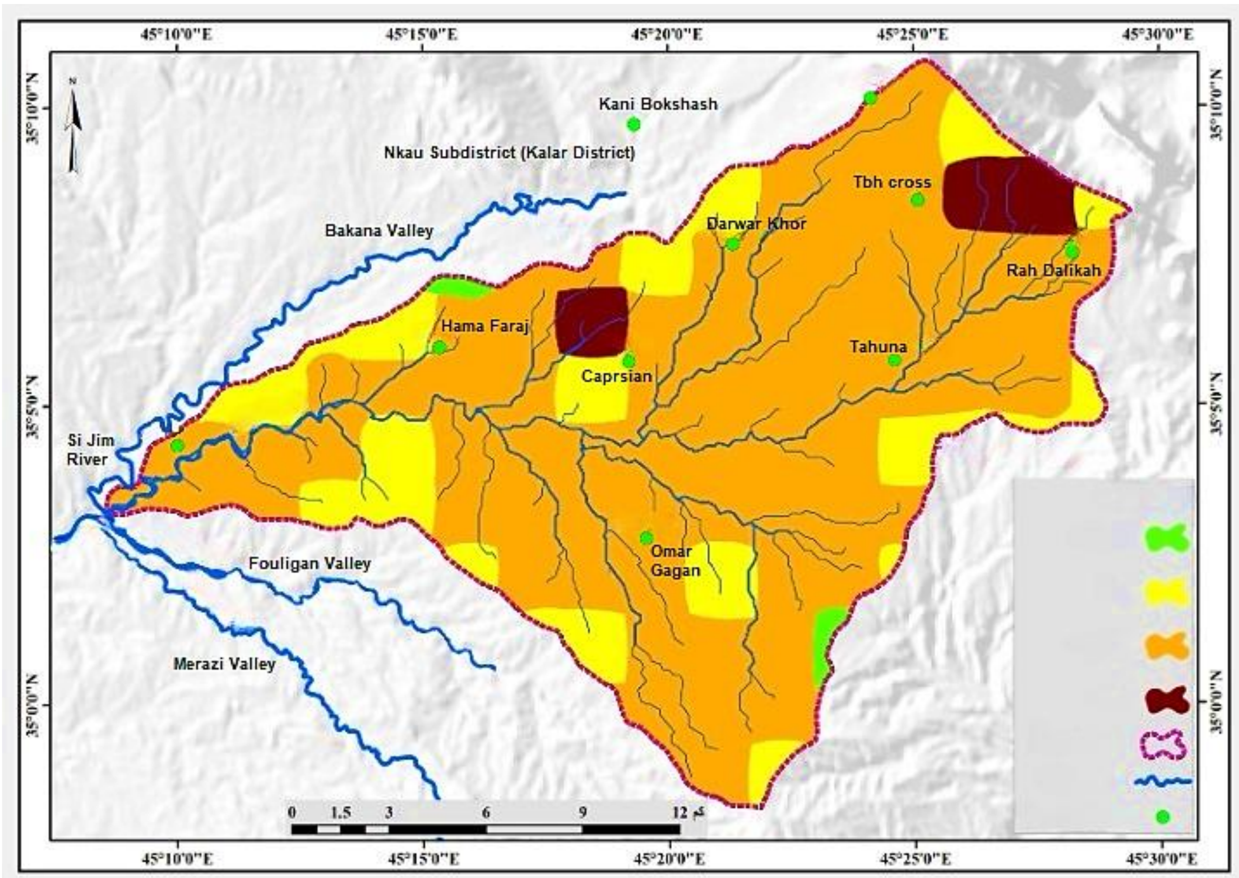
Source: *Based on DEM data and using ARC GIS v 10 software.*

Map (2) Degrees of erosion of the Mamran Basin



Source: Researcher based on digital elevation model (DEM) data using ARC GIS V10.4 program

Map (3) of the gully erosion zone in the Mamran Basin



Source: Researcher based on digital elevation model data and v 10. 4 ARC GIS and using the DEM program.

2. Zone of high erosion: This zone has an area of (48.161657 km^2), accounting for (15.3011859%) of the total basin area, with an erosion rate of (2,480.3341 m/km^2), representing (23.1559702%) of the total erosion rates of the basin. It is classified as level (4) according to the Bergsma classification and is distributed throughout the basin in scattered areas with weakly resistant riverine rock formations to water erosion due to their low strength. Refer to Map (2-3) and Table (2).

3. Zone of very high erosion: This zone covers an area of (253.2269624 km^2), constituting (80.4513895%) of the total area of the Mamran Basin. It is the largest and most widespread zone of water erosion in the Mamran Basin, with a very high erosion rate of (3,101.80287 m/km^2) and classified as level (5) according to the Bergsma classification. This zone is present in all parts of the basin with weakly resistant rock formations to water erosion. It is characterized by high water abundance, fast surface water flow, sparse vegetation cover, and high density of watercourses. Please refer to Map (2-3) and Table.(2)

4. Zone of severe erosion: This zone occupies an area of (11.550654 km^2), accounting for (3.66969732%) of the total area, with a very high erosion rate of (3,801.77607 m/km^2), representing (35.4927239%) of the total erosion rates. It is classified as level (6) according to the Bergsma classification and is located in small parts of the northern and northeastern parts of the

basin within limited areas, particularly in the spring areas. This zone is characterized by high density of watercourses and fast surface water flow, weak and non-resistant rock formations to water erosion, low vegetation cover density, and increased levels of water erosion activity, including incision erosion in the Mamran Basin. Refer to Map (2-3) and Table (2).

Evaluation of the risks of gully erosion in the Mamran Basin:

The risks of water erosion processes in the Mamran Basin are closely related to the basin area. An increase in the area indicates a significant water input, as well as an increase in the number and density of watercourses. Consequently, there will be extensive activity in erosion and hydraulic sculpting processes. Thus, the Mamran Basin represents a significant risk of erosion ranging from moderate to severe. Based on the data in Table (3), we can identify the risks associated with water erosion processes in the Mamran Basin by comparing level three with level four, considering it as a moderate risk with a substantial area of (49.980098 km^2), accounting for (15.8789129%) of the total basin area, and an erosion rate of (3808.31363 m/km^2), representing (35.5522014%) of the total erosion rates. Furthermore, comparing level five with level six, considered as severe risk, with a considerable area of (264.777583 km^2), accounting for (84.1210871%) of the total basin area, and an erosion rate of (6903.57894 m/km^2), representing (64.4477983%) of the total erosion rates. Consequently, the Mamran Basin experiences an increasing level of erosion activity with a severe risk level, which is larger and more widespread than the moderate risk range. Please look at Table (4) and Map.(4)

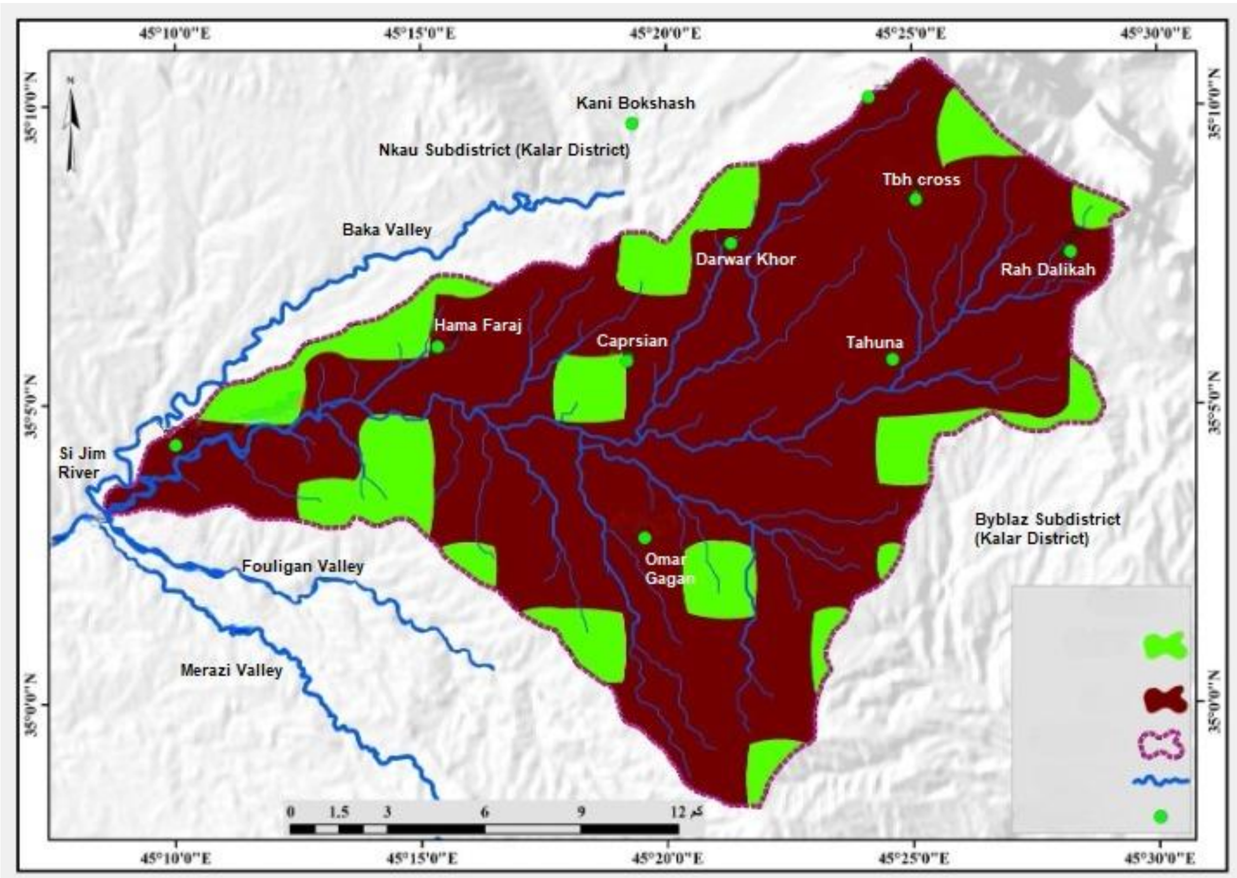
Table 4: Risks of gully erosion for the Mamran Basin

Risk level	Total sewer lengths/m	Area/km2	Percentage%	Erosion rate m/km2	Percentage%
Medium	121871	49.980098	15.8789129%	3808.31363	35.5522014%
Severe	829373	264.777583	84.1210871%	6903.57894	64.4477983%
Total	-	314.757681	100%	10711.8926	100%

Source: Based on DEM data, and using ARC GIS v 10.4

From observing the map, it's evident that the zone with severe risk encompasses all the agricultural villages in the study area, totaling (11) villages. The real danger lies in flash floods, which studies have shown result in economic losses equivalent to one-third of the total losses from all natural disasters. They are a major cause of more than half of the total fatalities caused by all natural disasters. This impact escalates when urban expansion reaches flood-prone areas, leading to losses in lives and properties and increasing the level of risk. This was evident in the study area on (16/2/2024), causing material losses to bridges, roads, and buildings. Please refer to images (1.2.3.).

Map (4) Dangers of gully erosion in the Mamran Basin



Source: *Based on digital elevation model (DEM) data using ARC GIS V10.4 program*.

Figure 1: Torrential floods that swept through residential areas in the study area (Kalar District)

Figure 2: Torrential floods sweep through Kalar district.

Source :https://www.alalam.ir/news/

Figure 3: Road collapse due to floods in Kalar district

Source :https://www.facebook.com/share/YQiNZajH8DXZdeXU/?mibextid=WC7FNe

The water flow in the study area is characterized by its tendency to quickly and unexpectedly transform into torrents and floods. This type of flow often leads to the flooding of water in large quantities beyond its channels. The reason for this lies in the fact that the sources of the basin are much higher in elevation and steeper in gradient compared to most parts of the basin. Additionally, there is a significant volume of water input in a short period of time. The Mamran Basin is characterized by sources with gradients ranging between (20°-35°), which constitute (4%) of the basin area, while the remaining parts of the basin consist of gently sloping lands. (Sari Mohammad Baqer: 2021, p.117)

This means that the water flow comes with very rapid discharge rates, followed by a slowing of the flow due to the gentle gradient. This slowing leads to a rapid rise and peak in water levels, culminating in devastating floods that cause bank collapses and the movement of rock materials in all forms within the channel. This condition is likely one of the major reasons for flow obstruction, thus contributing significantly to flooding. The presence of rocky masses in the watercourse exacerbates the slowing of the flow and the diversion of water from its path.

(xiao.lin:1999) Many studies have indicated that the usual duration of flash floods does not exceed 6 hours.

There is no doubt that weather bulletins have become highly reliable and accurate in determining weather conditions, and therefore the warning accompanying these bulletins about floods and torrents has a major role in reducing the loss of property and lives. Note the pictures(6-5-4) .

Figure 4: Rockfall in Kalar District

Figure 5: Erosion of cliffs due to torrential floods in Kalar district

Source: The researcher based on the field study

CONCLUSIONS

1. Based on the climatic data, the annual precipitation in the study area is substantial, reaching (675.3 mm), leading to the formation of rapid torrents, which in turn increases the rates of water erosion activity to very dangerous levels in the study area.
2. The study identified and analyzed the rates of water erosion in the study area by defining temporal and spatial boundaries. The temporal boundaries consisted of three erosion stages: saturation stage during the months of (September - October) with a total rainfall of (40.4 mm), the flow and erosion activity stage during (7 months) from November to May with varying intensity depending on the rainfall amounts during this period, and the stagnation and cessation of flow stage extending from June to the end of August due to lack of rainfall.
3. The study identified the time period representing the peak of erosion hazard in the study area, which extends from February to the end of March.
4. The study defined the spatial boundaries for the level of water erosion activity in the study area based on the results of the Bergsma equation, dividing the area into (4) erosion zones: moderate, high, very high, and severe. The results indicated that the highest levels of water erosion hazards in the study area within the Bergsma boundaries are the very high erosion zone, covering (80.5%) of the basin area, and (15.3%) of the basin area affected by high erosion, scattered in various parts of the basin.
5. The study identified hazards associated with spatial boundaries of erosion in two ranges: a moderate risk zone occupying (15.9%) of the basin area, represented by areas along water division lines, and a severe

risk zone occupying (84.1%) of the basin area, represented within the boundaries of agricultural villages totaling (11 villages).

RECOMMENDATIONS

1. Water dispersion in groundwater recharge areas and the construction of dams in various parts of the recharge area.
2. Improving the channels of flash floods to make them capable of accommodating the flowing floodwaters by widening, deepening, and increasing their slope gradient.
3. Establishing barriers on the sides of main watercourses in the basin and eliminating bends or breaks in the channels that serve as outlets for water beyond the channel boundaries.
4. Opening emergency drainage channels in areas where floodwaters dominate and utilizing pumps as a quick relief solution to alleviate the impact of water inundation.

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