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RESEARCH ARTICLE

Risks of Gully Erosion in Valley (Wadi) Mazrwan Basin in Erbil Governorate Within Kurdistan Region of Iraq

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ABSTRACT

The intensity of trenching processes in the Mazrwan Valley basin varies according to several characteristics that distinguish the study area. These include geological formations that contribute to a high level of weathering and erosion due to the region's steep slopes, represented by the highly dissected surface, the gently undulating surface, and the undulating surface according to the zinc classification. The presence of rugged rocky soil, occupying most of the Mazrwan Valley basin, activates mechanical weathering processes, leading to the collapse and sliding of rock fragments and fragmented materials after saturation with water. This, in turn, increases the speed of water and other materials, eroding the channels on these slopes, influenced by the effectiveness of climatic elements such as temperature, rainfall, evaporation, and wind.

The geomorphological effects on rock fragmentation and the overall effectiveness of organisms in the soil, through chemical and physical changes activated by weathering and erosion processes, have a significant impact. These negative effects are reflected in the dominance and activity of high trenching in the study area.

INTRODUCTION

Erosion trenching processes are among the most significant problems faced by the northern regions of Iraq due to the geological nature of the area and its steep slopes, influenced by climatic factors, especially temperature and rainfall. The temperature variation, along with the elevation differences, during the period from 1992 to 2021, results in the coldest month being January, with temperatures reaching 30.8°C, while the hottest month is July, with temperatures reaching 43.7°C. The winter rainfall accounts for 51.9%, while summer rainfall is almost negligible at 0.45%. Regarding wind, the wind speed increases evaporation, moves soil particles, and transports them toward the prevailing winds.

The average wind speed in Erbil for the same period is 2.1 m/s, contributing to removing the surface layer of soil and rock fragments, sliding them quickly when rainfall occurs, and forming watercourses that activate vertical and lateral erosion processes in the lower region of the slopes. This leads to the formation of trenches with high, medium, and light erosion. It is crucial to understand the influencing factors and develop solutions and treatments to mitigate the risks associated with these processes.

The study includes a set of questions as follows:

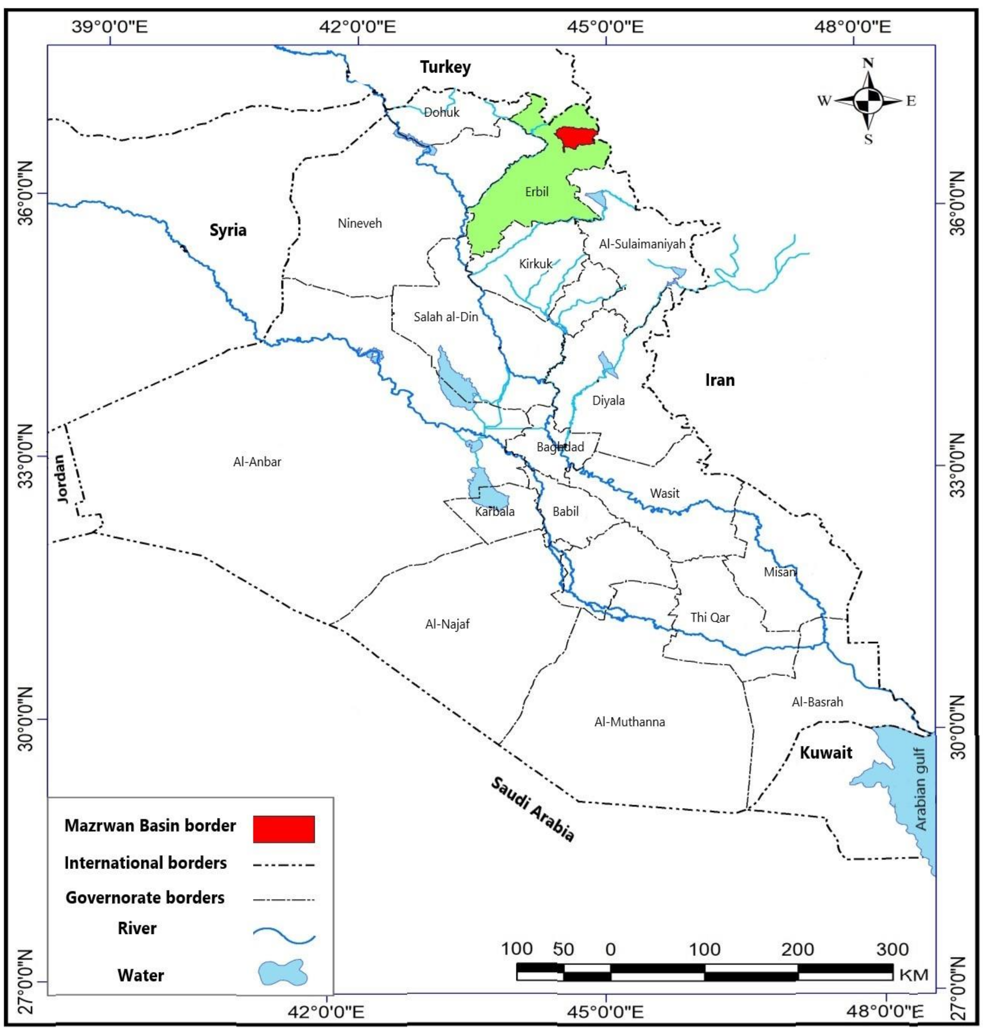
1. What are the types of geological formations that impact trenching erosion?
2. What is the relationship between surface characteristics and soil with trenching erosion?
3. What is the role of climatic elements in trenching erosion?
4. What are the categories of trenching erosion in the Mazrwan Valley basin?

The study hypothesis was as follows:

Geological formations have an impact and effectiveness through their respective characteristics in influencing the process of trenching erosion. The study area consists of a range of formations, with the Tangraw-Shranj and Nawperdan formations covering the largest area. In this area, the surface exhibits variations in slope and ruggedness, contributing to the activity of trenching erosion through soil erosion, removal of fine materials, and their collapse after saturation with water. Particularly noteworthy is the dominant soil type, which is rugged and rocky, intensifying the effects of erosion due to its steep slopes compared to other soil types in the area. The role and impact of climatic elements (temperature, precipitation, wind) have been activated by high and moderate erosion processes, especially when compared to other erosion types in the region.

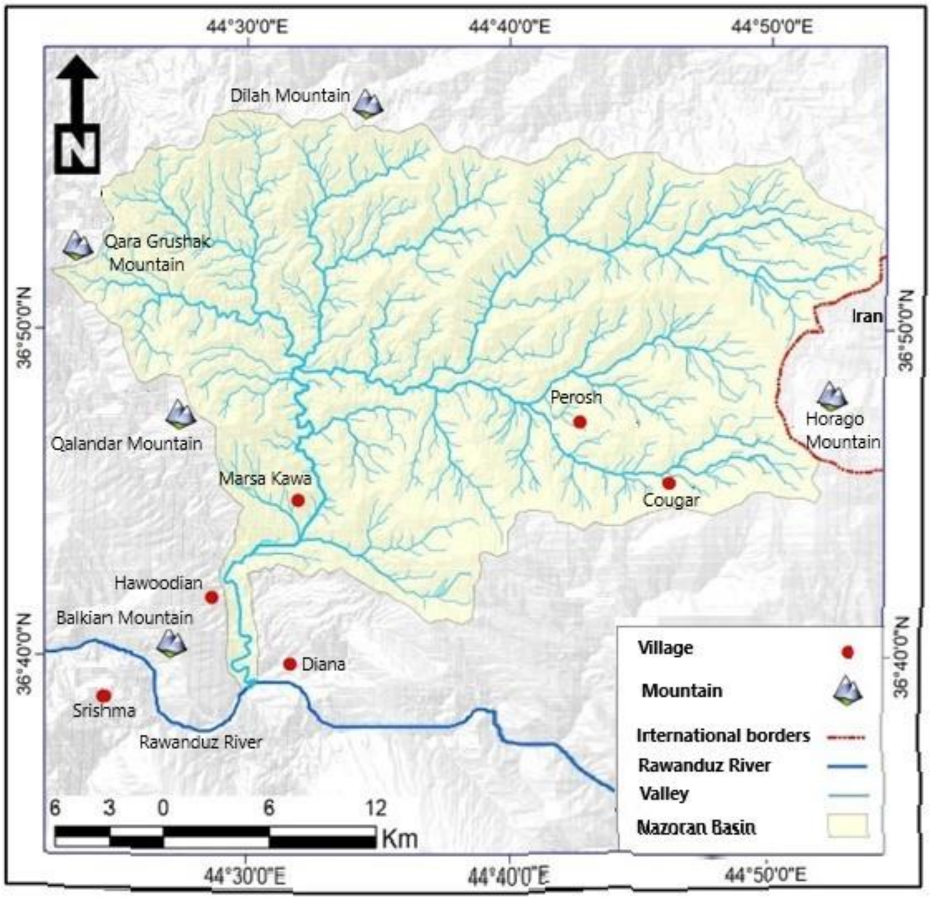
The Mazrwan Valley basin is in the northeastern part of Iraq. It is bordered to the northwest by Duhok Governorate, to the west by Nineveh Governorate, and to the south by Erbil and Kirkuk Governorates, lying between latitudes 36°40' to 36°50' north and longitudes 44°30' to 44°50' east. The basin's area is 869 square kilometres, as illustrated in map number (1).

Map (1) Geographical Location of the study area in Iraq



Source: *Ministry of Water Resources, General Authority for Survey, Administrative Map of Iraq, scale 1:1000000, 2015.*

Map (2) Of The Valley Network In The Wadi Mazrouan Basin



Source*: Arc Map 10.8 (GIS) program output.*

GEOLOGICAL FORMATIONS AND THEIR IMPACT ON TRENCHING EROSION IN THE MAZRWAN VALLEY BASIN

The geological formations play a crucial role in initiating and developing trenching erosion processes through their contributions to the erosion of channels. This is achieved through natural factors, including geological and climatic characteristics, as well as human factors, especially road construction, excavations, livestock grazing, agriculture, and more. Trenching erosion poses a serious environmental catastrophe, threatening human well-being, hindering social and economic growth, and impeding population development. The geological formations in the study area include:

Qalqalah Formation: Dating back to the Paleocene and Eocene epochs, it consists of conglomerates, sandstone, and marl. Covering approximately 63 km², it represents 7.2% of the southern and northwestern parts of the Mazrwan Valley basin.

Red Rocks Formation: Comprising layers of limestone with gypsum, anhydrite, and other detrital layers, it covers the southwestern part of Mazrwan Valley near Mersa Sawa village, spanning 24 km², making up 2.7% of the area.

Palumbo Aqra Formation: Located between the Thrust Zone and Zone Folded High, it consists of alternating limestone and marl in the northeast of Iraq, southwest of Mazrwan Valley. It occupies an area of 2 km², representing 0.2%.

Tangro-Shranj Formation: This formation is in the northeastern part of Iraq and represents a lithological unit dating back to the Cretaceous period. The rocks are predominantly immature litharenites, both physically and chemically. These sedimentary rocks are rich in carbonaceous particles and include sedimentary, igneous, and metamorphic rocks. There is diversity in the forms of heavy mineral grains in the rocks, some of which are susceptible to erosion, while others are resistant and elongated due to variations in sediment sources and transport-deposition distances. The chemical weathering in this formation is not intense, attributed to the presence of unstable minerals. Situated in the southwestern part of the Mazrwan Valley basin, near Mount Balakyan, this formation covers an area of 17 km², accounting for 1.9%. The age of the Tangro-Shranj Formation is Cenomanian-Albian, and its sediments accumulated in a deep basin with high tectonic activity.

Nawperdan Formation: Representing the Triassic era, it consists of Neomylonite limestone. Covering the outer region and extending from the Paleocene to the Oligocene, it is characterized by flysch deposits, igneous rocks, and intricate folding. It covers the largest area, approximately 475 km², representing 54.6%.

Walush Formation: A prevalent formation in Iraq, known for its resistant and weathering-resistant marl, limestone, and sandstone. Covering 289 km², it represents 33.3% of the Mazrwan Valley basin.

The total area of geological formations in the Mazrwan Valley basin is 869 km². Despite the general resistance of these formations to erosion, areas dominated by Nawperdan and Walush formations exhibit high trenching erosion due to steep slopes, increasing water speed, and the erosion of channels. The region is susceptible to high trenching erosion due to the activity and effectiveness of geomorphological processes, emphasizing the need to predict changes and mitigate future hazards.

Table (1) Area of geological formations

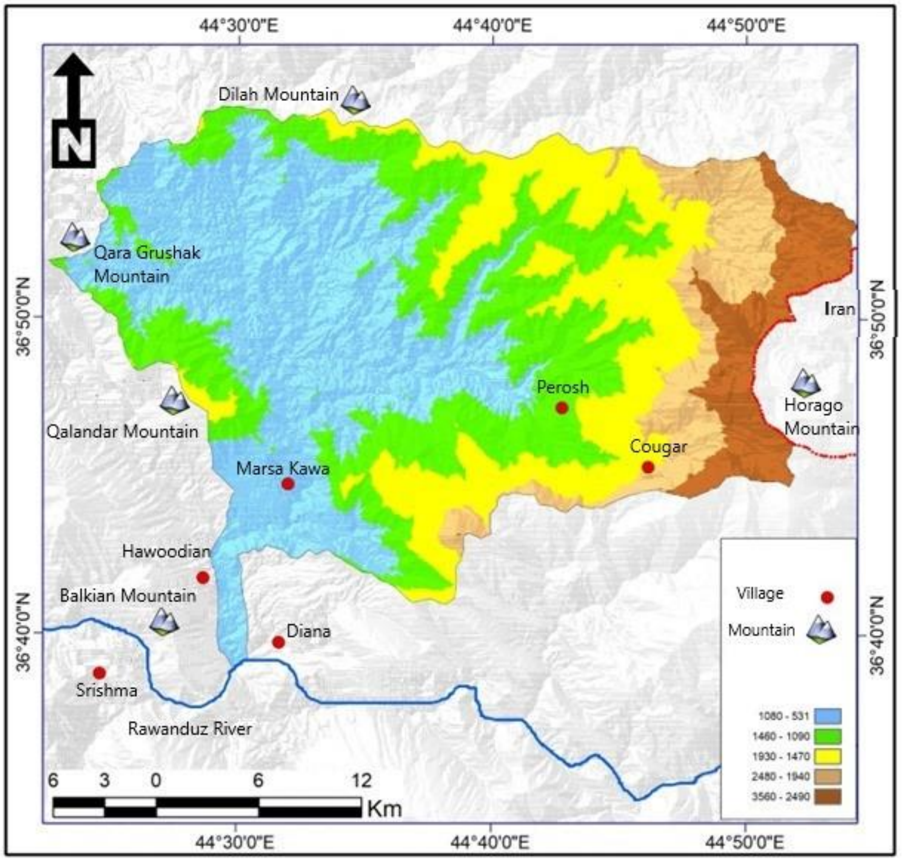
Name of Formation	**Area/km 2**	**Ratio%**
Balambo-Aqra Formation	2	**0.2**
Naobardan formation	475	**54.6**
Qalqalah Formation	63	**7.2**
Red rock Formation	24	**2.7**
Tangro-Sharansh Formation	17	**1.9**
Welsh Formation	289	**33.3**
Total	869	**100**

Source: *Areas were extracted using the Arc Map 10.8 (GIS) program*

SURFACE CHARACTERISTICS AND THEIR RELATIONSHIP TO GULLY EROSION IN THE WADI MAZROUAN BASIN

The term "contour lines" (equal elevation lines) refers to imaginary lines used to indicate the nature of terrain in geography. They pass through all points at equal elevations relative to sea level. Observing the contour map (3) of equal elevations in the study area, the highest elevation ranges between (3560-2490) meters, and the lowest ranges from (1060-531) meters, sloping northward as shown in the map (4) indicating the slope direction in the study area.

Map (3) of equal elevations in the study area



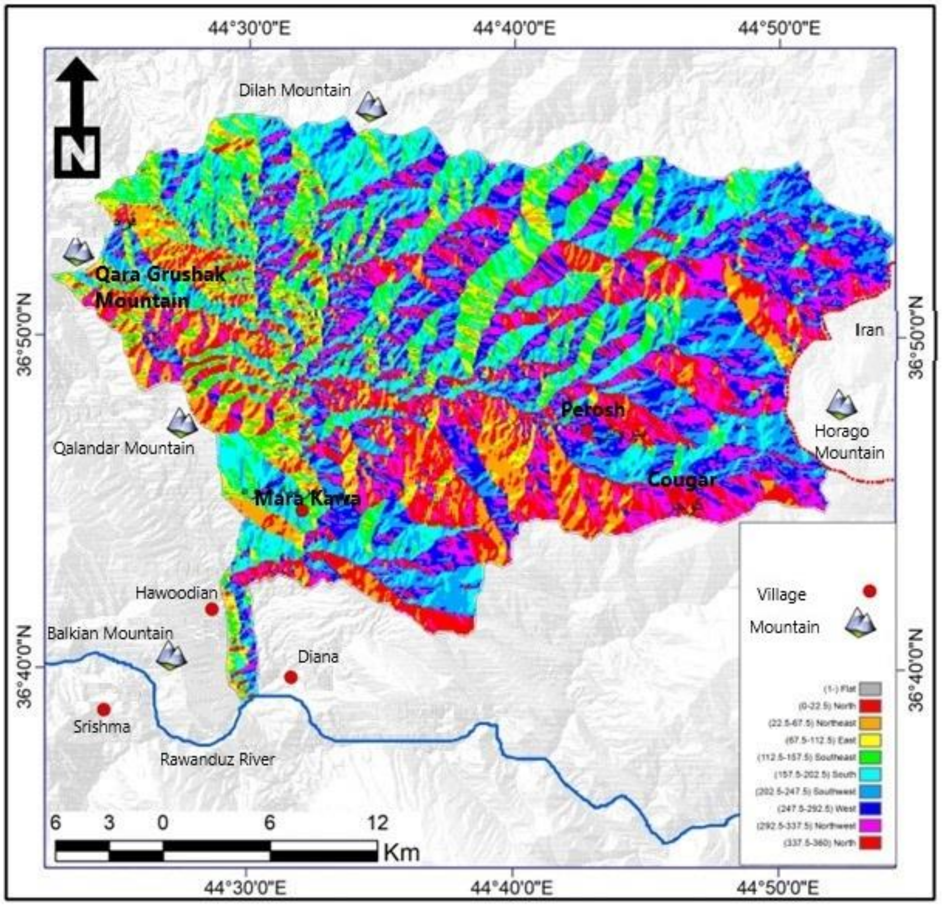
Source: Digital Eruption Model (DEM) with a resolution of 30 square meters for the year 2015 and processed using Arc Map 10.8 (GIS).

A slope is the deviation or inclination of the land from the horizontal level. The larger the slope, the greater the deviation or inclination. The slope degrees show variation in the degree and type of ruggedness, with higher slopes leading to increased water flow volume and speed, enhancing the effectiveness of gully erosion. The slope degrees vary between 2-7.9, with a surface type resembling a gently undulating surface occupying the highest area and percentage, covering (253 km 2 - 29.1%), and the steepest slope reaching (30) degrees or more, with high dissected surface type covering the least area and percentage, reaching (69 km 2 - 7.9%) in the study area.

Table (2) and Figure (5) highlight the surface slope degrees according to the zinc classification in the study area, ranging from 0-1.9 degrees, covering an area of 197 km 2 and a percentage of 22.7% for flat surfaces, 2-7.9 degrees, covering an area of 253 km 2 and a percentage of 29.1% for gently undulating surfaces, and 8-15.9 degrees, covering an area of 192 km 2 and a percentage of 22.1% for undulating surfaces.

The study and analysis of natural environmental characteristics, including geological structure, slope, and ruggedness, along with climate data, soil types, and natural cover, are essential factors in determining the hydrological behaviour of water basins. Analyzing the slopes and their nature in the study area through slope degrees helps assess the impact of gully erosion risks and the formation of watercourses, categorized based on the slope degrees. The highest slope degree and area are represented by the highly dissected surface and the gently undulating surface shows the lowest slope in the study area.

Map (4) Slope Direction in The Study Area



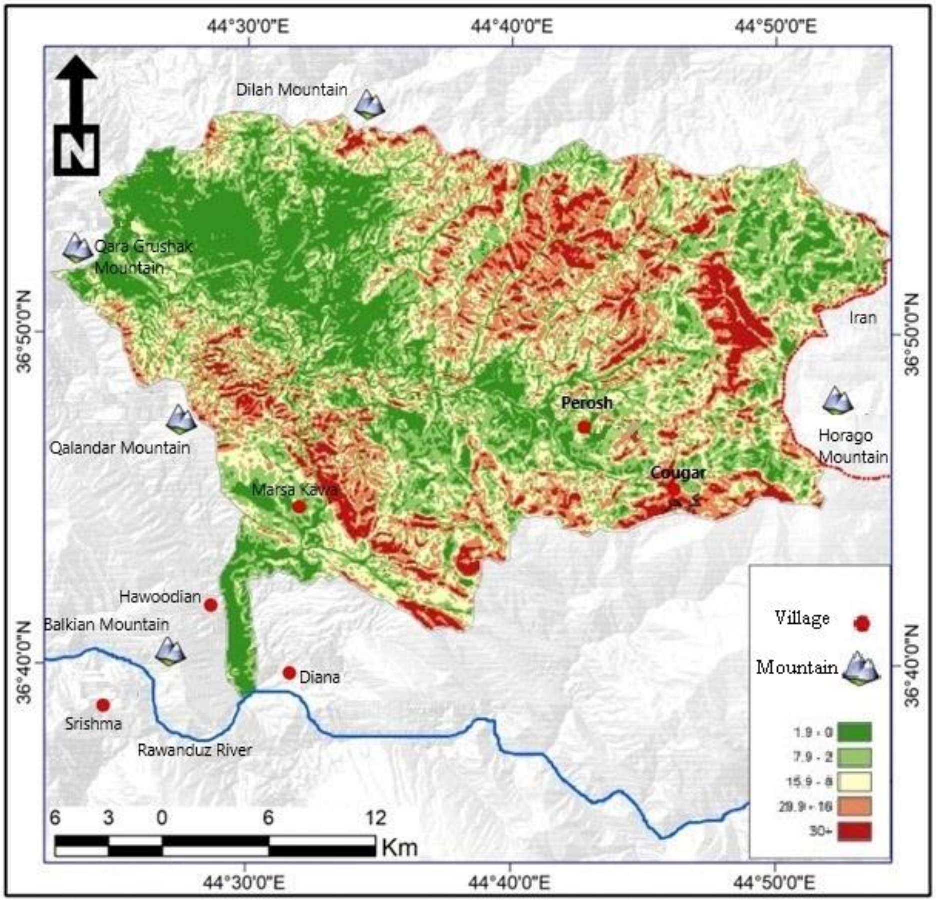
Source: *Digital Eruption Model (DEM) with a resolution of 30 square meters for the year 2015 and processed using Arc Map 10.8 (GIS).*

Table (2) Area of roof slopes according to Zinc classification

Surface Type	Degrees Of Decline	Area/km 2	Percentage %
flat surface	0 - 1.9	197	**22.7**
A quivering ripple	2 - 7.9	253	**29.1**
Crispy	8 - 15.9	192	**22.1**
Segmented-fragmented	16 - 29.9	158	**18.2**
Highly chopped	30+	69	**7.9**
	Total	869	**100.0**

Source: *Areas were extracted using the Arc Map 10.8 (GIS) program*

Map (5) Degrees of slope in the study area



Source: Digital indentation model (DEM) with a resolution of 30 square meters for the year 2015 and processed using Arc Map 10.8 (GIS).

SOIL TYPES AFFECT GULLY EROSION IN THE WADI MAZROUAN BASIN.

Soil is the vertical section of the earth that displays the succession of layers from the surface to its underlying bedrock. The composition of the soil, including calcium carbonates and calcareous accumulations, is influenced by various natural factors such as water, rainfall, climatic conditions, and human activities, particularly soil management operations such as ploughing and agriculture. These processes contribute to the formation and evolution of soil through dissolution, leaching, transportation, sedimentation, and aggregation, leading to both water and wind erosion. The inclination percentage also plays a role in enhancing erosion processes, especially during rainy seasons, which promote surface water flow and the removal of soft materials. Calcium carbonates in the soil originate from bedrock and primary materials from which the soil derives, rather than through the transport or leaching of surface layer components.

The elevated level of Erbil's soil, including the Mazraun Valley, contains organic matter with active aggregates characterized by strong binding between particles. On the other hand, soil that is not susceptible to wind erosion, with diameters greater than 0.84 mm, resists due to the presence of non-erodible aggregates influenced by electrostatic forces binding soil particles through negative-charged silicate bonds. However, it lacks stability, as it breaks in weaker areas under mechanical activities.

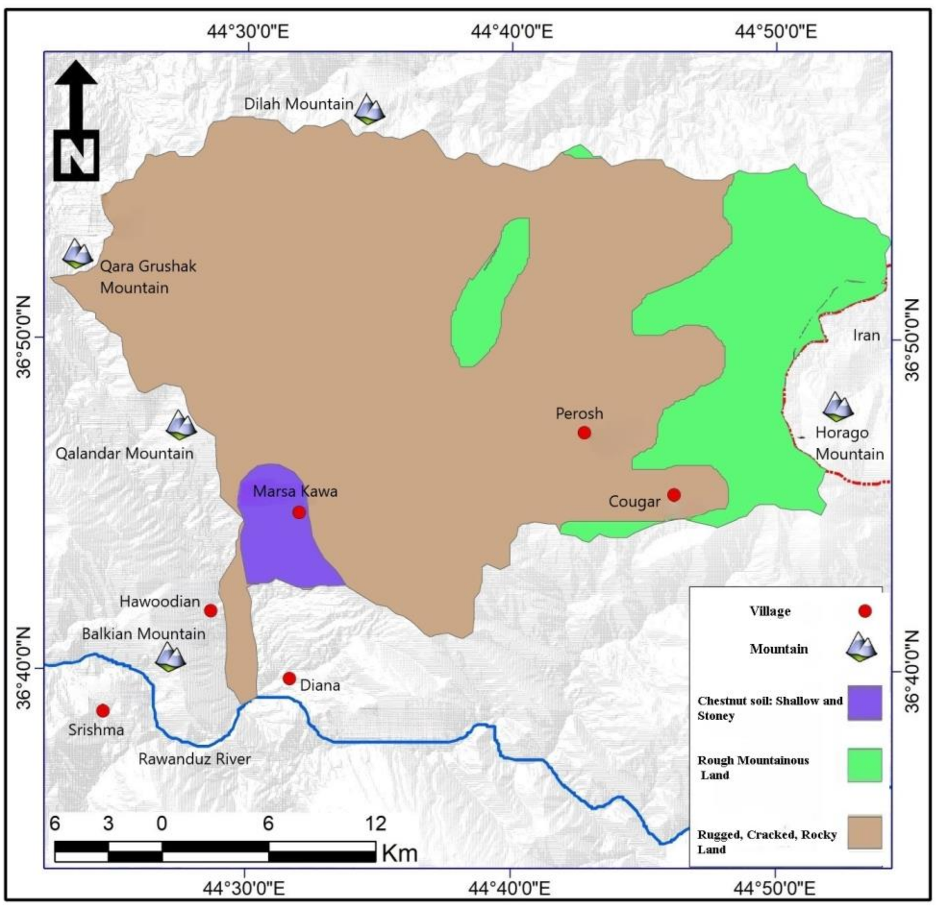
Moreover, the soil contains substantial amounts of low-solubility calcium carbonate, which binds soil particles together, contributing to the cohesion of soil particles without differentiation. The contribution of organic matter to the stability of these aggregates is minimal compared to changes in the volumetric distribution of aggregates caused by the mechanical disintegration of larger aggregates during ploughing.

There is a variation in the chemical, physical, and organic properties affecting cohesion and sedimentation for different soil types in the Mazraun Valley basin. These types include rocky mountainous soil, shallow and fissured, unsuitable for agriculture, rocky and fissured rough soil covering the valley basin, and shallow, stony chestnut soil with most dark brown colour, containing organic and calcareous materials, characterized by fragile and stratified layers.

Discussing the types of soils affecting erosion in the Wadi Mazrouan Basin.

Rocky mountainous soil covers an area of 163 km 2, accounting for 18.8% of the study area, located in the northeastern part of the Mazraun Valley basin. The rocky and fissured rough soil occupies a vast area of 678 km 2, representing 78.0% and constituting most of the study area. Shallow and stony chestnut soil is situated in the southwestern part, covering an area of 28 km 2, with a percentage of 3.2%. The total combined area of these soil types amounts to 869 km 2, as depicted in Map (3) and presented in Figure and Table.(3)

Map (6) Area of soil types



Source: *Burring, P. Soils and Soil Conditions in Iraq. Ministry of Agriculture, Baghdad(1960).*

Table (2) Area of soil types

Surface type	Area/km 2	%The ratio
Chestnut soil: shallow and Stoney	163	**18.8**
Rough Mountainous Land	678	**78.0**
Rugged, Cracked, Rocky Land	28	**3.2**
Total	869	**100.0**

Source: *Areas were extracted using the Arc Map 10.8 (GIS) program*

RESULTS

Climate is one of the most significant factors influencing hydrological characteristics, especially the quantity of surface water runoff. Climatic elements, particularly temperature, play a crucial role in gully erosion, affecting geomorphology by contributing to the breakdown of rocks due to variations in temperature rates. The negative effects of climate change are reflected in agricultural, industrial, and residential areas, roads, and communication networks through soil erosion and fragmented regions.

Climate change is considered one of the major problems affecting the effectiveness and spread of gully erosion. Temperature is a key climatic element in soil formation, influencing weathering processes, including mechanical and chemical weathering. Temperature fluctuation in Erbil Governorate, which includes the Mazraun Valley basin for the period (1992-2021), varies between the coldest month of January, with a temperature of (30.8) ^{0} C, and the hottest month of July, with a temperature of (43.7) ^{0} C. This temperature variation contributes to the activity of the erosion process. Rainfall is another essential element in erosion processes, impacting various ecosystems through the dissolution of salts and chemical and physical reactions within the soil. Rainfall constituted 51.9% of winter rains during the mentioned period, while summer rainfall was almost negligible at 0.45%.

Wind speed also plays a role in erosion processes by increasing evaporation, moving soil particles, and transporting them in the direction of prevailing winds. The average wind speed in Erbil for the period (1992-2021) was 2.1 m/s. Given that the region has rocky and fissured rough soil, wind and water erosion prevail, increasing the effectiveness and impact of gully erosion. The influence of climate change is vital in shaping various topography on the Earth's surface.

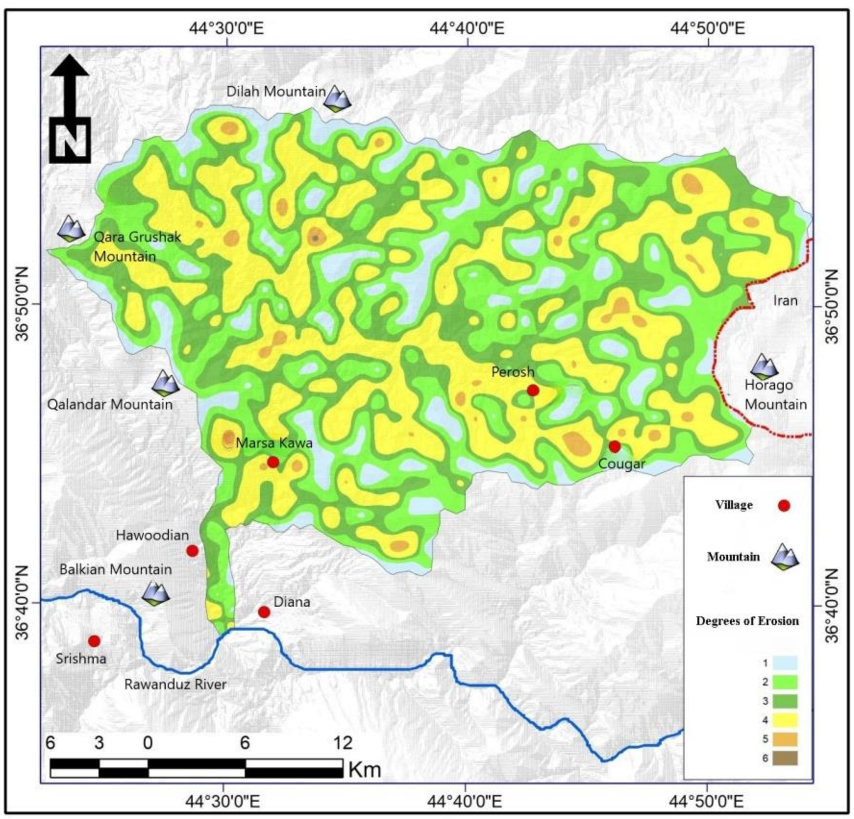
Gully erosion is a process of channel erosion that significantly contributes to changes in the Earth's surface, land degradation, and soil loss. In the study area, gully erosion encompasses six categories. The first category is very light erosion, with lengths ranging from (0 - 400) meters/km 2, covering an area of 103 km 2 and a percentage of 11.9%. The second category, light erosion, with lengths ranging from (401 - 1000) meters/km 2, covers an area of 243.4 km 2, accounting for 28.0%. The third category, moderate erosion, with lengths ranging from (1001 - 1500) meters/km 2, covers an area of 234.3 km 2, representing 27.0%. The fourth category, high erosion, with lengths ranging from (1501 - 2700) meters/km 2, covers an area of 272.6 km 2, constituting 31.4%. The fifth category, very high erosion, with lengths ranging from (2701 - 3700) meters/km 2, covers an area of 15.3 km 2, with a percentage of 1.8%. The sixth category, severe erosion, with lengths ranging from (3701 - 4700) meters/km 2, covers an area of 0.1 km 2, with a percentage of 0%. The total length of gullies is 869.0 km 2, as observed in Table (4) and Maps (7) and (8).

Table (4) Area of gully erosion types

Degree of erosion	Classification of erosion	The length of the furrows is meters/km 2	Area km 2	%
1	Very light erosion	0 – 400	103.3	**11.9**
2	Light erosion	401 – 1000	243.4	**28.0**
3	Moderate erosion	1001 – 1500	234.3	**27.0**
4	High erosion	1501 – 2700	272.6	**31.4**
5	Very high erosion	2701 – 3700	15.3	**1.8**
6	Severe erosion	3701 – 4700	0.1	**0.0**
Total			869.0	**100.0**

Source: *Areas were extracted using the Arc Map 10.8 (GIS) program.*

Map (7) Types of Gully Erosion



Source: *Arc Map 10.8 (GIS) output*.

The dominant category and degree of erosion in the study area are the fourth category, high erosion, followed by light and moderate erosion. Very light, very high, and severe erosion occupy small areas and percentages due to the geological formations and the prevailing surface type with gentle undulations and undulating relief. The moderate and severe slopes in the study area contribute to increased erosion effectiveness and processes, leading to soil erosion and the clearing of vegetation on steep slopes. This results in the collapse and sliding of rock fragments and fragmented materials after saturation with water, particularly on those slopes. Consequently, the high erosion category prevails over the other categories. Areas with light and very light erosion concentrate in locations with lower slopes. Additionally, the prevalent soil type, rocky and fissured rough soil, enhances the effectiveness and impact of erosion due to its steep slopes compared to other soil types.

CONCLUSIONS:

Here are some of the conclusions the study has reached:

1. The geological formations' area was extracted using Arc Map 10.8 (GIS), revealing the highest area and percentage for the Nawbordan and Lwosh formations with an area and percentage of (475 km 2, 54.6%) and (289 km 2, 33.3%), respectively. The lowest area and percentage belong to the Blambo-Aqra, Tangro-Sharansh, Red Rocks, and Qulqula formations, with areas of (2 km 2, 0.2%), (17 km 2, 1.9%), (24 km 2, 2.7%), and (63 km 2, 7.2%), respectively, forming a total area of (869 km 2).

2. The geological formations study in the Wadi Mzurwan basin indicates that the Nawbordan formation, consisting of solid igneous rocks, occupies the largest area and percentage in the basin, reaching 475 km 2 and 54.6%. The Lwosh formation covers an area of 289 km 2, accounting for 33.3% of the study area. While it is generally resistant to erosion, it is considered a high-risk area due to its steep slopes, enhancing the effectiveness of weathering and high erosion, especially gully erosion.

3. There is variation in elevation, slope, and ruggedness in the study area. The highest elevation ranges from (3560-2490) meters, and the lowest ranges from (1060-531) meters with a northern slope. The slopes vary between 2-7.9 degrees, with undulating surface type covering the highest area and percentage (253 km 2, 29.1%), and a high degree of slope covering the lowest area and percentage (69 km 2, 7.9%) in the study area. The high gully erosion activities are more pronounced with increased slope percentage, leading to the removal of soft materials.

4. Climate elements play a significant role in gully erosion, especially temperature and its geomorphological impact on rock fragmentation due to variations in temperature rates. The study shows that high gully erosion is activated with increased slope percentage, leading to soil erosion and the clearing of vegetation, especially in areas with high degrees of slope.

5. The high gully erosion processes are activated in the study area, particularly in gullies with lengths ranging from 1501 to 2700 meters/km 2, forming the highest area and percentage (272.6 km 2, 31.4%) compared to other erosion categories in the study area.

6. Utilizing modern geographic techniques to monitor the types and extent of gully erosion in the study area for developing treatments and solutions with the highest precision and in the least time and effort. Employing satellite imagery with high spatial resolution to identify the causes of gully erosion and its future impacts. Using visualizations that represent different periods helps avoid issues associated with it.

7. Encouraging the adoption of agricultural methods such as tree and grass planting, along with the use of sand and stone check dams. These methods work to control gully erosion, support soil, and protect it from gully drift. Establishing laws and regulations that discourage the cutting and overgrazing of vegetation to mitigate the problems associated with gully erosion.

REFERENCES

Ahmed Saif Al-Ahmedi. (2005). Unerodible soil aggregates in the soil of dry and semi-dry regions / Northern Iraq. Journal of Rafidain Agriculture, issue 3, p.33.

Ishaq Saleh Al-Akam, & Nawal Kamel Alwan. (2017). Comparison between (SCS-CN) and (GIUH) methods for estimating surface runoff volume for Dwayrij Basin using GIS. Journal of the College of Education for Girls, University of Baghdad, issue 1, p.28.

Ishaq Saleh Al-Akam, & Najah Saleh Hadi. (2016). Some geomorphological aspects of the Tigris River between the villages of Dujmah and Al-Sindiya in Al-Khalis District/Diyala Governorate. Journal of the College of Education for Girls, University of Baghdad, 27(2).

Ishaq Saleh Al-Akam. (2014). The relationship between surface runoff and geomorphological variables of eastern Iraqi wadis. Journal of the College of Arts, University of Baghdad, 108.

Ishaq Saleh Al-Akam, & Marwa Abdul Salam Mohammed. (2015). Hydrological system of the Tigris River in Baghdad City. Journal of the College of Education for Girls, University of Baghdad, issue 4, p.26.

Aya Al-Tayf Jassim. (2020). Delineation of tectonic range and source of deposits for Tangjero Sandstone Formation in selected sections of Erbil Governorate - Northern Iraq. Journal of Educational and Scientific Studies - College of Education - University of Baghdad, 5(16).

Iman Mohammed Hassan, & Saheb Hassan Khudair. (2022). Hydrological analysis of the natural environment characteristics of the Erbil Basin. Research Journal of Basic Education, Special Issue of the Fourth International Scientific Conference / Historical and Geographical Studies.

Iman Mohammed Hassan, & Saheb Hassan Khudair. (2022). Hydrological analysis of the natural environment characteristics of the Erbil Basin. Special Issue for the Fourth International Educational Conference / Historical and Geographical Studies, University of Mosul College of Education for Human Sciences.

Buhry Salem Fatah Al-Saffar. (2020). Spatial variation of tourist climate patterns in Erbil Governorate. Lare Journal of Philosophy, Linguistics, and Social Sciences, 36.

Badr Jadooa Al-Maamouri, & Oras Ghani Abdul Hussein. (2012). Aspects of fluctuation and climate change and influencing factors. Special Issue for Research Taken from University Theses and Dissertations, p.1.

Janan Abdul Amir Abbas. (2007). Determination of the sedimentary environment of the Kut-Batir Formation in the southern fold of the Iraqi sedimentary plain. Journal of the College of Education for Girls, University of Baghdad, 18(1).

Khaldoun Abbas Mala. (2006). Evaluation of hadrochemical properties of the springs flowing on the western side of Tigris River in Tikrit - Northeast Iraq. Iraqi Journal of Geology and Mining, vol. issue 1.

Khalaf Hussein Al-Dulaimi. (2001). Applied geomorphology: Applied landform science. The Hashemite Kingdom of Jordan for Publishing and Distribution, Amman.

Sahab Khalifa Al-Samarrai, Ann Rajab Ahmed, & Quds Osama Qawam. (2014). The impact of climatic and morphodynamic processes on soil erosion in the Kallat Basin. Sar Men Raa Journal, issue 10, p. 39.

Saif Saleh Mohammed Al-Khalify, & Majid Magdi Abdel Majeed Al-Matouli. (2020). Iraqi National Journal of Earth Sciences. College of Petroleum and Mining Engineering, University of Mosul, 20, p2.

Abdul Salam Mahdi Saleh Al-Taraf, Yassin Saleh Karim Al-Jwaini, & Luay Musa Rawi. (2012). Sedimentology and mineralogy of the functional layers of the Fatha Formation and determining its environmental location in the Mukhaoul Fold - North of Baiji City. Tikrit Journal of Pure Sciences, College of Science, Tikrit University.

Leila Mohammed Qahraman. (2017). Geographic distribution of calcium carbonates in the soil of Erbil Governorate. Qalat Lai Zanest Scientific Journal, issue 2.

Mujbil Mohammed Obeid Al-Jumaili, & Hudhaifa Maan Najm Al-Hamdani. (2016). Application of some thermodynamic standards for zinc sorption in four soil models from Northern Iraq. Journal of Tikrit University for Agricultural Sciences, 16(1).

Hala Mohammed Abdul Rahman, & Intidhar Mahdi Imran. (2015). Land classification of Wadi Al-Salam Basin. Journal of the College of Education for Girls, University of Baghdad, 2.

Kamal H. Karim, & Mushir M. Baziany. (2007). Relationship between Qulqula Conglomerate Formation and Red Bed Series, at Qulqula Area, NE-Iraq. Iraqi Journal of Earth Sciences, issue 7, p.15.

Visva-Bharati. (n.d.). Rill, gully erosion risk of lateritic terrain in South-Western Birbhum District, West Bengal, India. University, Santiniketan – 731235, Sociedade & Natureza, Uberlândia, 21(2).

Youssef Sami Haj Bazal. (2022). Geomorphological risks of slopes in Erbil. Al-Meed Journal, vol 11, p. 42.

Jibo, A. A., Laka, S. I., & Ezra, A. (2020). The effects of gully erosion on physical and socio-economic activities in Akko Local Government Area of Gombe State, Nigeria. FUTY Journal of the Environment, issue 14 vol. (2).

Ahmed J. Al-Bawi, Alaa M. Al-Abadi, Biswajeet Pradhan, & Abdullah M. Alamri. (2021). Assessing gully erosion susceptibility using topographic derived attributes, multi-criteria decision-making, and machine learning classifiers. Vol. 12, issue 1.

Okwu-Delunzu, V. U., Iwueke, N. T., & Aniagolu, C. O. (2018). Gully erosion and its environmental impact in Eke, Udi Local Government Area of Enugu State. Environment and Ecology Research, 6, p.5.