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ESTIMATING THE SIZE OF WATER EROSION OF THE SLOPES OF MATEEN FOLD

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ABSTRACT
The severity of erosion was studied and its ranges were defined for the region represented by Mateen convex fold of an area (935km^2) in detail relying on (Bergsma 1983) equation which data was adopted to calculate the severity of erosion to the unit area (km^2) depending on the lengths of watercourses and the area occupied by the extension of courses and the areas were determined using the usual method of cartographic squares. The research, according to the criterion developed by (Bergsma1983) which consisted of six ranges to determine the severity of erosion, showed that a ratio of 98.96% of the study area was within the range of erosion (high, very high and severe) (34.01%, 60.92% and 4.03%), respectively in terms of order. As to the rest of the area, it fell under the influence of light erosion by (0.16%) and medium by (0.81%). The above-mentioned erosion ranges were identified and mapped to enable the scheme to take into account the risks surrounding the area to avoid them or develop solutions to meet them when planning various human activities.

KEYWORDS: erosion, Mateen convex fold, human activities.

INTRODUCTION

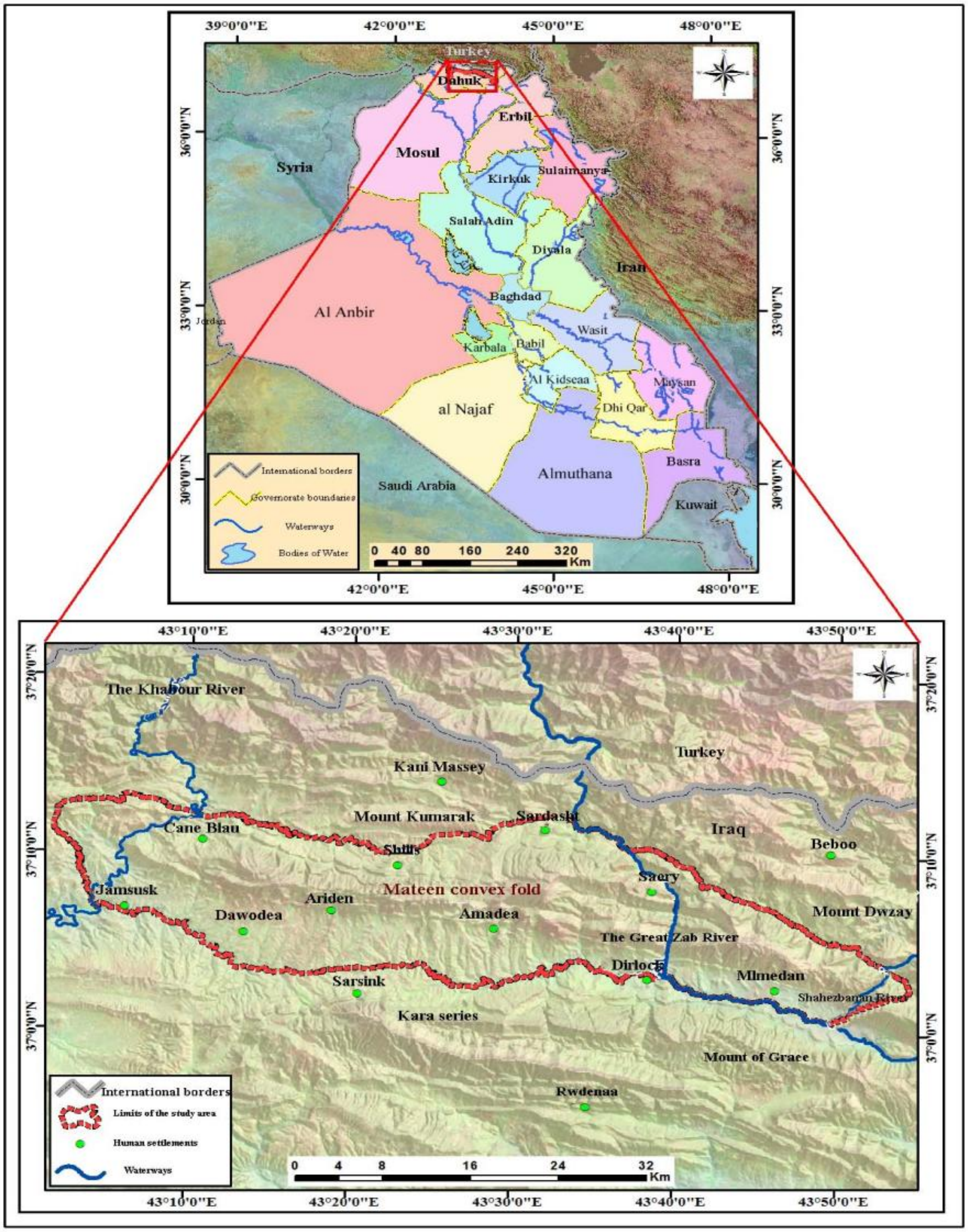
Erosion is the process of transferring surface rocks broken by the mechanical energy of the air and water chambers represented by the movement of wind, the falling and running rainwater and ice crest, which move rock crumbs to new places on which they precipitate[(1)]. Generally, it is the transfer of the resulting materials from the process of weathering and sculpture with its types from their places of disintegration to their place of deposition. The most important factors of transfer in the study area are ice and seasonal running water, each with a different effect. The study of the severity of erosion is one of the important applied geomorphologic studies in the relief areas, especially if they are exploited by human architecture? This is because there are great dangers to the human presence through the maturation and movement of rocky materials disassembled in different sizes and associated with the movement of rocky materials such as slipping and rock falls, which are overall a real threat in these areas to the urban expansion with all its types and to life and human presence, which requires determining the activity degree of this process, determining the ranges of its work and representing that by mapping, and this is what the research comes with in all its stages.The study area is located in the northern part of Iraq in the governorate of Duhouk between two latitude circles (37^{o}13' 17") and (37^{o}00'43") north, and two longitude lines (43^{o}54'31') and (43^{o}01'33") east. Naturally, it is borders from the north by the series of Kumar Mountains and from the south by the series of Kara Mountains, as from the east by Shahmazbanan River and from the west by a wavy land ending in Khabour River. The area Mateen Fold is approximately (935 km^2), (see map 1).The problem or the research is represented by the following questions: the activity degrees of the erosion process in the study area?. What are the limits of the ranges affected by each level of erosion? And what are its effects on human activities in the study area?

The research is considered as a research correlated between the natural impact and the human impact, where the research aims at determining the size of erosion exactly and determining its impact on the slopes affected by the drift and drawing a map to determine the degree of erosion activity on these slopes.

Study Area

The relief is considered as a factor affecting the river drainage temporally and spatially and affecting the difference in the arrival of the discharge waves from the upstream to the downstream and the amount of the transported sediments washed and carried from those cliffs and valleys as well as its effect on other geomorphologic processes that affect the components of the natural environment that contribute to the formation of the topography of the earth[(2)]. The study area is located between two contour lines (2200m) above the sea level at the top of Mateen convex fold at the south-east side of the study area, and the elevation line (600m) at the south-eastern ends of the wing of Mateen fold. From map (2), we see the difference in the slope of the region in each part of it with respect to the formation of the relief nature that helped in forming it and the processes that affected it, where we note that the highest elevation values are in the middle of the convex fold and then the slope gradates decreasing till reaching the wings of the fold, hence we note that the heights of Mateen convex fold have convergent contour lines from the south and north-east, they have divergent contour lines from the north, the west and the south-west of the fold, and this divergence and convergence indicate that there is a variation in relief and also a variation in height, as well as there is a convergence in contour lines in the middle of Mateen fold approximately from the north-west of the study area.

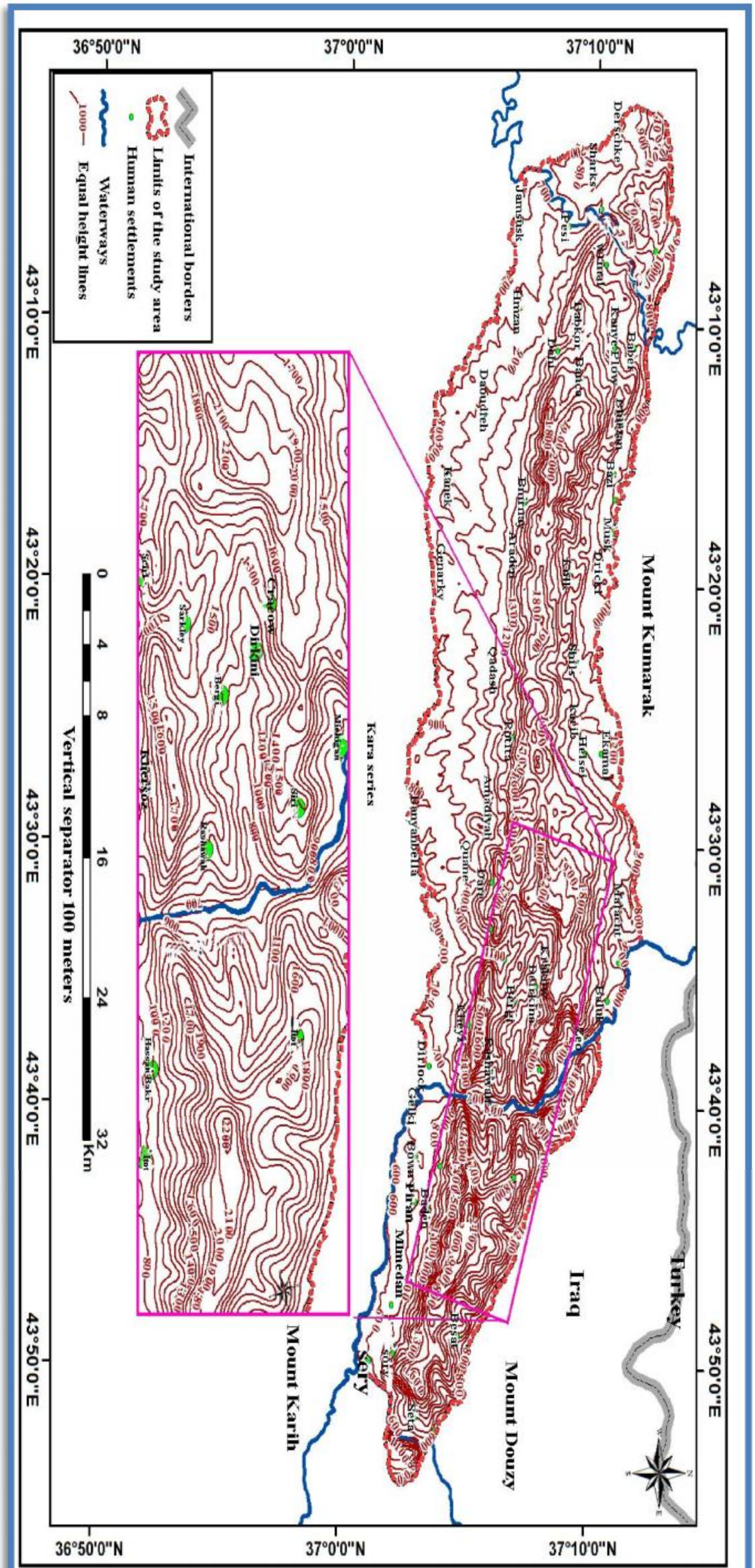
MAP 1: The location and boundaries of the study area



SOURCE: The General Authority of Survey, Iraq's Administrative Map Scale 1: 1000000.

We note from map (2) the multiplicity of the fold heights and the convergence and divergence of contour lines in it till reaching the feet of heights, where the highest contour line was (2200) in the northern part that we referred to and the lowest contour line was (600). The contour lines diverge in each of the areas of Qadash, Kani, Janarki, Kaneek, Dawoodiya, and Hamazan, as from the east, the contour lines diverge in the areas of Malamidan and Deralok and these areas were more like plane and exploited by human settlements. As to the areas of Iton, Siri, Kerko, Dirkini, Birgi, Sarkli and Hassan Bakr, the contour lines converge in them, which means an increase in the severity of slope. The study area can be divided into the following sections, as shown in map (2):

MAP 2: Lines of equal heights for the study area



Source: From the work of the researcher based on: Topographic maps of Duhouk and Nineveh governorates, scale 1: 1000000 for the year 1992 issued by the General Authority for Survey and the General Authority for Water Resources using ArcGIS 10.2 program.

1- The western side and its eastern borders Khabour River with the two heights, the first is at the far north west 1100m which descend in the direction of the Khabour up to the contour line 800m above the sea level, and the second is at the far west 1100m from which a very steep footing begins up to the contour line 900m above sea level and then to a relatively divergent horizontal distance towards the south referring to the moderation of relief and ends at the contour line 700m above sea level at which the foot ends in the Khabour also.

2- The center of the fold (the area confined between the Great Zab east and Khabour west), from observing and checking map (2) well and in view of the crowded contour lines and their intense divergence which indicates a very severe relief, we find that this part of the fold contains (5) tops that can be followed up beginning from the Great Zab river, where we find two heights, the northern at the level of 1500m above sea level near Siri village, and their eastern and northern slopes end at the level of 700m above sea level at the confluence of the Great Zab River, while their eastern borders are adjacent to the slopes of adjacent peaks and their southern borders extend to the contour line 700m above sea level and then out of the study area, while the southern peak adjacent to the Great Zab is at the level of 1700m above sea level and its slopes are characterized by their severe relief and the severest one is the slope heading east towards the Great Zab which ends at the contour line 900m above sea level with the edge of the western shoulder of the Great Zab river to the west of both peaks. We observe that the highest peak in the study area is located at the level of 2200m above sea level and its slopes extend to all directions, but it can be seen that the relief of the eastern and southern slopes is severer than the northern and western slopes, and then to the west of which appear two peaks; the fourth and fifth of this part of the region, the first at the level of 1900m above sea level and the second level at the level 2000m above sea level.

3- The east side (east of the Great Zab) from observing and checking map (2), there are also crowded contour lines, which has steep relief to the far east of the river Shahmazbanan and contains a peak near Zurya village, at a height of 1300m above sea level, and these slopes are characterized by rocky edges retreated by the freezing frost and end at the contour line 700m above sea level, and to the east of it. At Suri village, there is a peak at the height of 1600m above sea level which slopes extend to the northern side of Mateen fold though its northern slopes have more severe relief than the southern side and end at the contour line 800m above sea level, and to the far east of the fold at the level of 1100m above sea level, where this peak is characterized by severe erosion and the fall of its rocks due to freezing, forming rocky edges along the course of Shahmazabanan river and the peak ends at the contour line 800m above sea level.

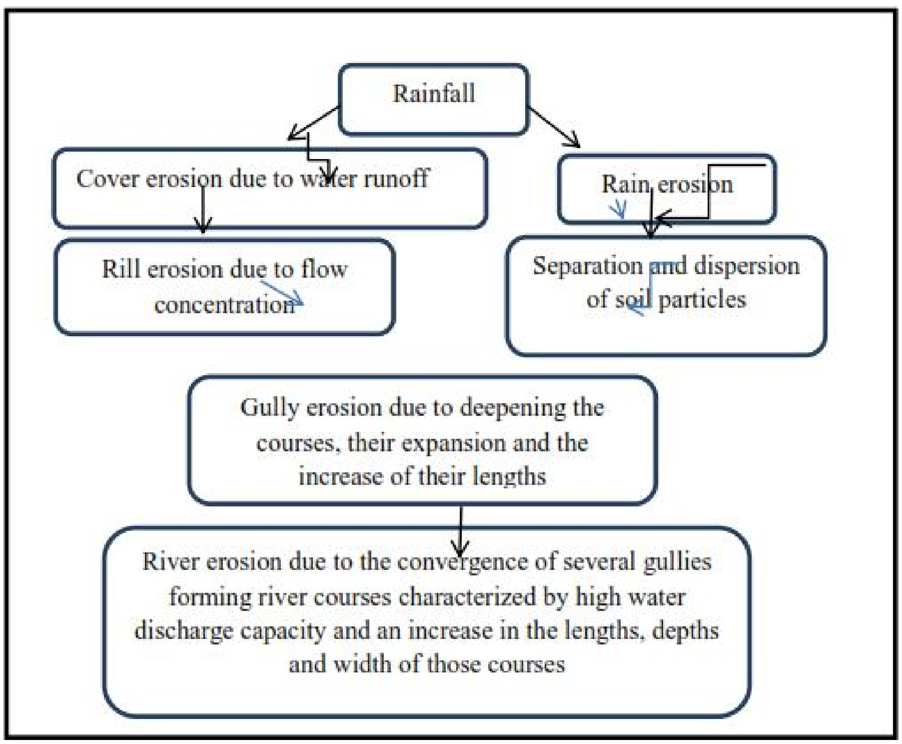


CHART 1: The stages of the development of water erosion
Source: The work of the researcher based on the Khalaf Hussein Al-Dulaimi, The Rivers- an Applied Geohydromorphometric Study, Safaa Press for Publication and Distribution, Amman, 2017, P. 228.

The erosion in the study area is closely related to the surface running waters to which the rain and the melting snow on the peaks and slopes are their main source, thus this process begins its work starting with the rainfall represented by the colliding erosion between rain drops and the fine rocky grains that can move due to collision, but with the presence of a severe degree of decline on the slopes that support the process and make it effective as the disintegrated materials have an anxious stability due to the equal effect of the power inhibiting the movement (friction) with the dynamics (body weight + earth gravity) and by adding the weight of water drops and the collision power, the materials roll and move down the slope. After collecting the rain drops on the tops, they run forming the rill flow lines and they are more effective on the disintegrated materials, as they form water sliding lines of disintegrated materials with a limited impact of hydraulic power of waters, hence this kind of erosion as its precedent is confined to soft materials. Yet, the rills very soon meet in a central point controlled by the direction of the slope to form streams with dimensions larger than the rills called tables in which water flow is the strongest and in large quantities, i.e. the hydraulic act of these waters is so great that it drives and pushes the giant rocky masses down the slope, so here appear the impacts of table gully erosion and with it appear the great dangers of this process. This process usually occupies the middle areas of the slopes and the central ranks until the formation of the main streams of rivers (see chart 1).

The following is the detail of the types of water erosion:

1- (Colliding) Rain Erosion:

It is also known as (raindrop splash) resulting from the collision of rain drops directly with soft crumby deposits and non-cohesive materials such as weathering materials and soil particles, which disperses these sediments and particles. Also, the rain drops after colliding with the surface of the soil works at scattering large quantities of soil particles in the air and part of them scatter for more than once, resulting in the occurrence of soil erosion, also the effect of rain drops increases with the increase of hydraulic pressure they make, which reduces the filtration, resulting in increased flow on the slopes in the cover fluxes. The dispersion of rain drops leads to the separation of soil atoms and their transfer by drops or washing(3). Also, the colliding erosion makes the rain drops collide by flow which increases the capacity of the flow and its depth, and this thing affects the transfer of sediments and increases the transfer of soil components by the dynamics of turbulent flow(4). Also, the characteristics of rain drops in terms of quantity, intensity, speed, direction of rain drop and its size, all of them affect the separation of soil particles and their transfer, so the transition of soil increases with the increase of the size of particles, which means that the clay particles are more difficult in separation from the sand, but they are easier in movement(5).

The effect power of rains depends on the type of soil, as it increases in the disintegrated soil with low cohesion, it also increases in areas free of vegetation and decreases in areas where there is a vegetation cover, because it weakens the strength of rainfall, increases the strength of soil cohesion and limits the flow speed, resulting in limiting the impacts caused by rains, also the decline of slopes sometimes plays an important role in rain erosion activity(6). When the rains fall and the snow melts over the highlands in the study area, their waters descend to form non-convex sides of rills which decline coincides with the general decline of the area slopes, then they fill the joints and cracks during their fall on the surface of mountainous slopes, for information, the area receives rains from early December until June. The rains are of different types, including tornado like and thunderous, and this rainfall takes the type of water erosion in that this flow takes the waters after the fall to transfer the crumby particles from the soil to the areas of their stability in the lands of low decline.

2- Sheet (Cover) Erosion:

The cover erosion process occurs when the soil loses its land cover, especially the natural plant, as well as due to the fall of rain drops, where it hits these drops strongly, which works at the volatilization of soil atoms, their dispersion, scattering, running and flow in the process of fluxes(7). Also, the sheet flow is formed at the tops of slopes in a pervasive way or small courses that end at the bottom of the slope or it may be a sheet flow that runs over the areas of low decline, and it is in a uniform motion of soil and in light layers, where the beginning of slopes dominates the processes of cover erosion before they turn into rill and gully erosion(8). The sheet erosion also indicates the equal complete removal of soil in the form of thin layers of the surface of an area. In order to cause the erosion or the so-called peace drifting, there must be a plane surface of land and soil with a low permeability and this erosion works to remove an entire layer of soil surface, as it works to transfer soft and organic materials from the areas of high erosion to the lower areas of less height(9). The sheet erosion does not occur directly, for it occurs when rains fall heavily and strongly, and this strength leads to the collision process of drops with soil granules, especially the fine ones and their scattering in all directions forming small patches which depths reach tens of millimeters and are called the sprinkler, which occur due to the lack of vegetation cover and heavy rainfall, especially rill rains, as well as the nature of soil and the rock formation, they also result in the movement of soft materials along the slope under the influence of dynamic widespread waters. The falling rain drops collide with soil, resulting in the disintegration of its cohesive atoms, thus a cover composed of soft elements is formed on the surface, where any simple decline makes the water flow and move drifting with it the soft elements and materials, and the surface remains covered with coarse materials only(10). Therefore, the effect of this type of erosion is slight in the study area, especially as it recedes at the end of the sloping slopes when the rain waters reach it from the slopes and the flow speed decreases for its impact is almost relative.

3- Rill Erosion

It arises from random shallow gullies formed when heavy rains fall, then the sheet flow turns from diffuse flow to concentrated flow as a result of rainfalls to form a fine network of water rills that connect with each other after they drill the rocks of different hardness, disintegrate the soil and drift it, at the end a network of channels is formed in the form of ribbons with turbulent flow(11). The plane surface usually contains small cavities, where the water accumulates then and when those cavities are flooded at the lowest point, it cuts a thin channel during its movement down the slope. When this phenomenon is repeated in an endless number of points, from this process a surface cut by a group of very shallow trenches called rills arises at once and this process is known as rill drifting which is a rapid removal of the surface of the soil through the gullies of rill passages resulting from the water discharge by the energy of water running in rills which depth is less than half a meter. With the beginning of flow concentration, the rills are formed with a depth of less than (1) meter, especially in weak-formed rocks and the lack of or non vegetation, for water drops that fall do not permeate directly as they run above the surface drifting with them the soft materials of the surface layer, leading to the emergence of small tables that they develop into notches and gullies or the so-called bad lands[12]. This is observed on most limited-extension slopes of thick disintegrated soil, which is the product of surface water runoff resulting from the abundance of rainfall which leaves its effects in the shape of water lines contiguous and parallel to each other along the slope, then they unite at the feet of slopes with a waterway vertically oriented towards the rills and take their way away from the slope due to the change of the slope direction, as in pictures (1) and (2).

PICTURE 1: Water rill erosion near Soulaf summer resort

Source: The field study on 21/5/2017.

Picture 2: Water rill erosion on the slopes of the study area

Source: The field study on 1/5/2017.

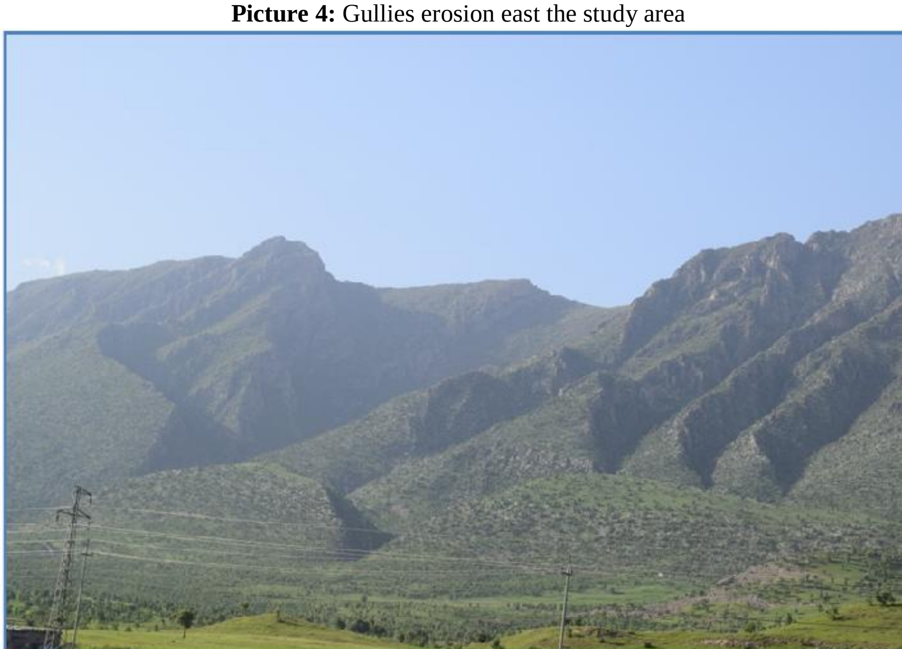
4- Gullies Erosion

There are many different viewpoints in the definition of gullies erosion, hence there is an agricultural viewpoint and a geomorphologic viewpoint. So, from a geomorphologic point of view, they are river channels that can easily move and transport materials by runoff or traction and drag on the feet of slopes, and erode the sharp sides of the courses of those waters which are affected by transitory flash floods during rain storms, and the gullies expand when there are large amounts of waters above the surface, as the bottom erosion and the edges increase due to water ability to erode, especially after the increase of soil saturation with water[17]. We can define it according to field observation as an erosion and degradation activity concurrent with each other and it occurs when water flow are in large amounts and with a pushy and rushing speed in that it can slit trenches, and this type of erosion requires concentrated efforts to expand the gullies made by the runoff, where its work heads vertically to lead to the creation of deep watercourses regardless of any other dimension in these courses (length or width), and this is only shown in the steep slopes with heavy waters because the deepening requires these two factors. Through the field survey, it is noted that nearly 70% of the slopes of the study area is affected by severe cutting of the table erosion as a result of their severe decline and the abundance of water flow at them in addition to the weakness of rock resistance to water processes, for the rocks in the study area are of limestone, lime and dolomite, all without exception applied with the clay stone which is very weak resistant to water processes, which led to the collapse of the rocky structure at the lines of rapid and abundant water flow in the slopes of steep decline, forming a wide network of table watercourses which is what we call water basins in the study area. Note picture (3) and (4).

Picture 3: Gullies erosion in the study area

Source: The field study on 28/4/2017.

Picture 4: Gullies erosion east the study area



Source: The field study on 28/4/2017

Evaluating the Size of Water Erosion:

To evaluate the size of water erosion in the study area (Mateen fold), Bergsma (1983) equation is adopted which is based on the study of surface water drainage network extracted from the space visuals using (ArcGIS 10.2) program through which we can know the characteristics of water erosion and their work intensity according to the following equation[(14)]:

$$AE = \frac{\sum L}{A}$$

where:
AE = average of erosion m/km^2.
ΣL = Total lengths of gullies/ m.
A = Unit area (location) km^2.

On its base, the study area is divided including the drainage network by a network of squares of equal area based on (ArcGIS) program, and the area of each square unit of the network equals (4km^2). Also, the area of some squares is incomplete in some natural border areas of the study area, and topographically irregular, therefore, the Area Coverage Law by the squares method (area = complete squares + incomplete squares/2) is adopted.

Each unit is given a number representing its X and Y position as in map (3). The unit area and the lengths of the gullies that lie within it are measured inside the network. The average of erosion in each unit area is calculated by dividing the lengths of gullies to the area of each unit after classifying the values of erosion averages calculated to its degree according to the criterion developed by (Bergsma 1983)[(15)], as shown in table (1).

TABLE 1: Degrees of erosion according to Bergsma system

Degree of erosion	Average of erosion m/km^2	Intensity of erosion
1	1 - 400	Very light erosion range
2	401 - 1000	Light erosion range
3	1001 - 1500	Medium erosion range
4	1501 - 2700	High erosion range
5	2701 - 3700	Very high erosion range
6	3701 - 4700	Intensive erosion range

Bergsma, Rainfall Erosion Surveys for Conservation Planning, ITC Journal, Vol. 2, 1983, P.175.

Through map (5) and table (2), the results showed that the area of study was divided into six ranges of erosion based on the distribution of the percentages of areas shown in the previous table, where each range is distinguished from the other by the amount of erosion efficiency and the amount of erosion differs from region to region according to the difference of geological structure, the decline of land surface, the permeability of rocks, and the vegetation cover. The ranges were as the following:

1- **Very light erosion range:** This range is represented by very light erosion is in one location northwest the study area with an area of (0.423km^2) and a percentage of (0.04%) of the area of the total study area, as in Table (2), where the erosion efficiency in this range is very low because it falls within ranges represented by the beginnings of rill water runoff or it is free of the effects of water runoff and it is affected by rain colliding erosion.

2- **Light erosion range:** As to the second range, it includes the light erosion range in one location also northwest the study area with an area of (1.585km^2) and a percentage of (0.16%) of the area of the total study area, and it is the same as the previous one affected by the beginnings of rill runoff with light erosive impact, note map (5).

3- **Medium erosion range**: This range is represented by the medium erosion range in (5) sites that are located in the far north-east and north-west of the study area with an area of (7.60km^2) and a percentage of (0.81%) of the area of the total study area. The erosion located within this range is medium due to its situation within the beginnings of table ranges of watercourses. Here, the hydraulic momentum of waters has a great role that is reflected on the average activity of erosion, but not high or severe as it represents the beginning of the starting point of the erosive work.

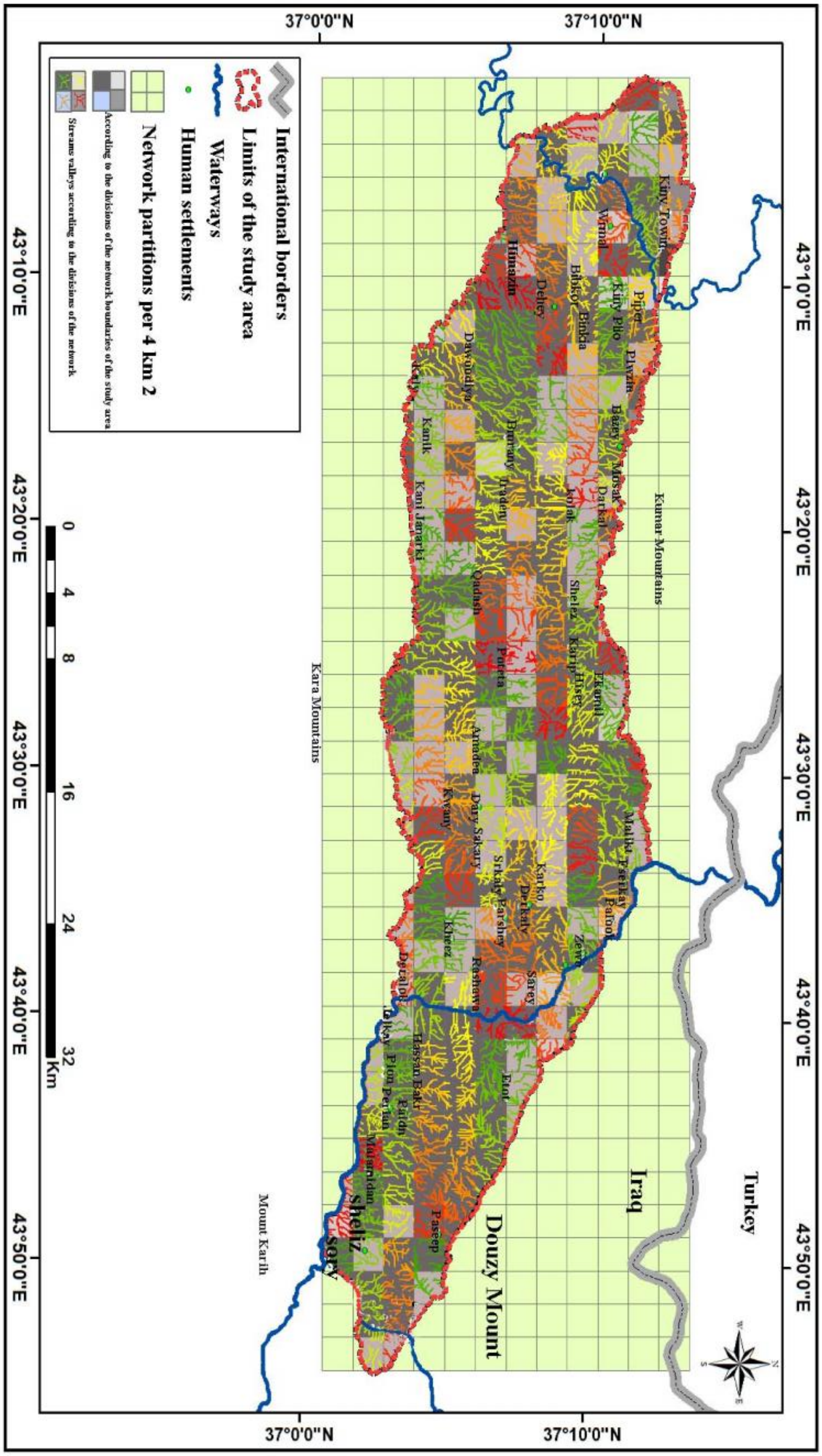
TABLE 2: The degrees and areas of erosion in the study area

Degree of erosion	Number of sites	Total area of erosion range km^2	Percentage	Severity of erosion
1	1	0.42	0.04%	Very light
2	1	1.58	0.16%	Light
3	5	7.60	0.81%	Medium
4	91	318.08	34.01%	High
5	155	569.84	60.92%	Very high
6	13	37.71	4.03%	Severe
Total	266	935.24	100%	

Source: From the work of the researcher based on table (1) and map (2).

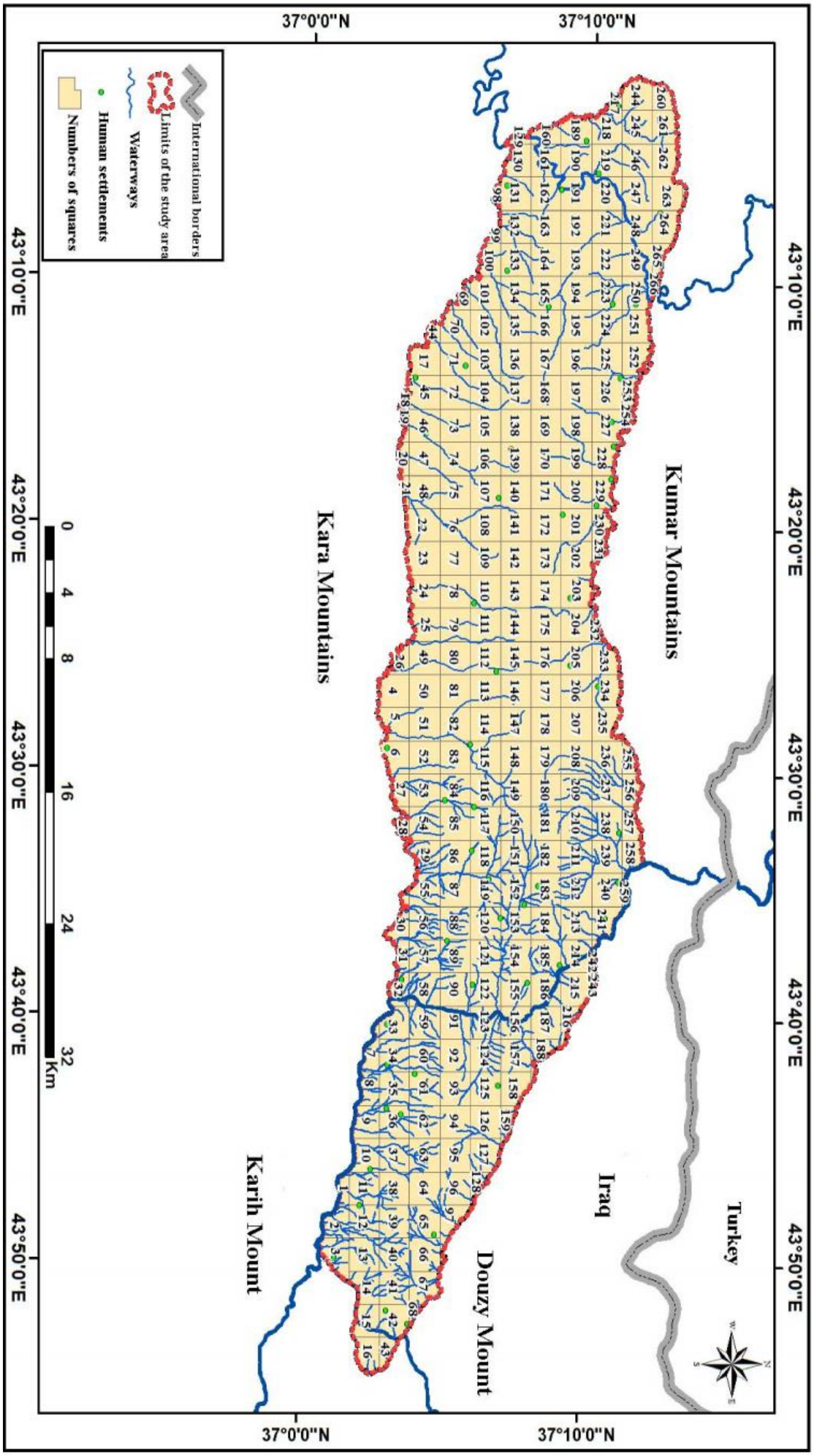
4- High erosion range: This is range of high erosion, where the waterways are characterized by their rapid work in rock erosion and the transfer of the crumbs resulting from the erosion process. The sites within this range were (91) with and area of (381.08km^2) and a percentage of (34.01%) of the total area of Mateen fold.

Map 3: The cadastral units to extract the erosion of Mateen fold



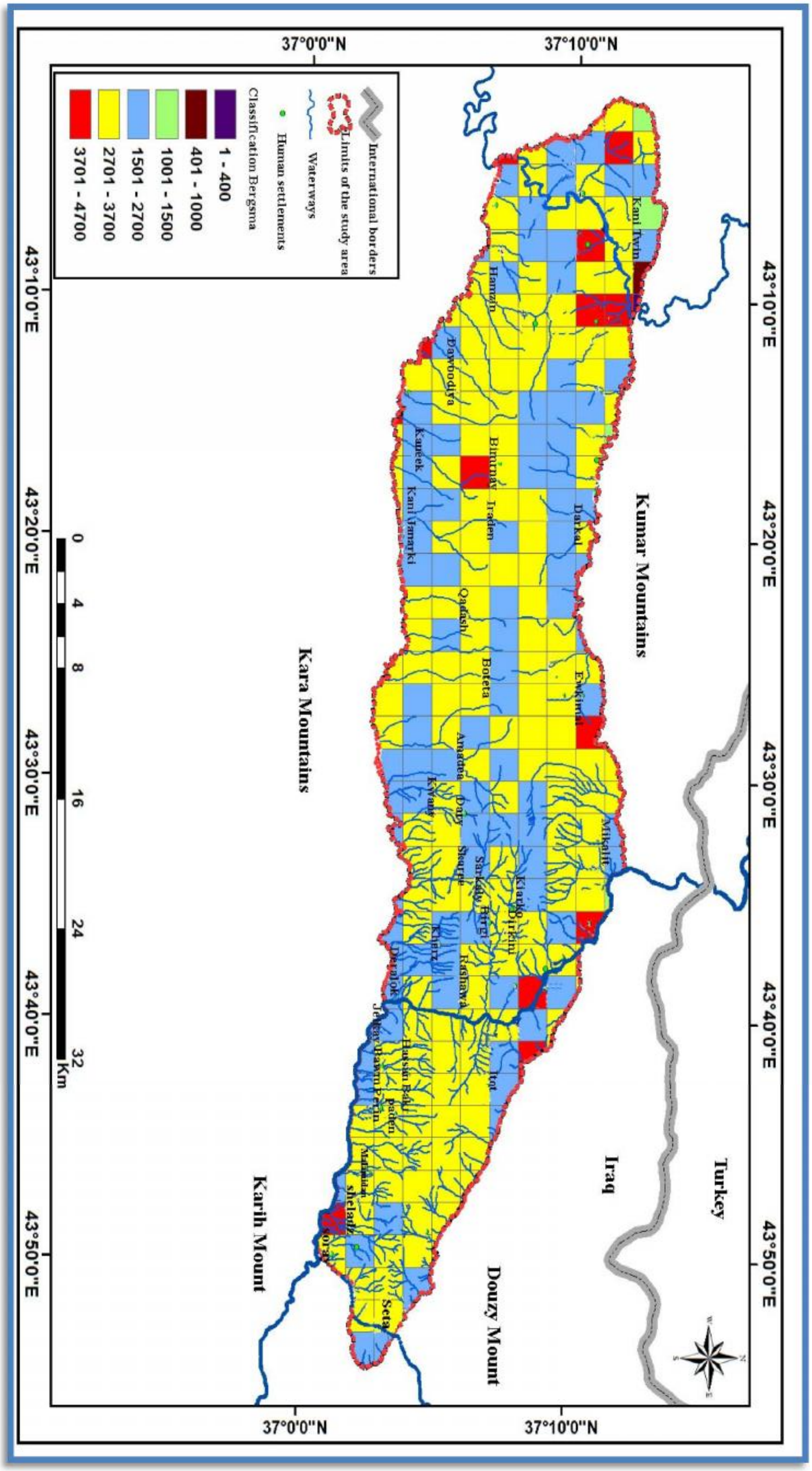
Source: The work of the researcher using ArcGIS 10.2 program.

Map 4: The numbers of cadastral units to extract the erosion of the study area

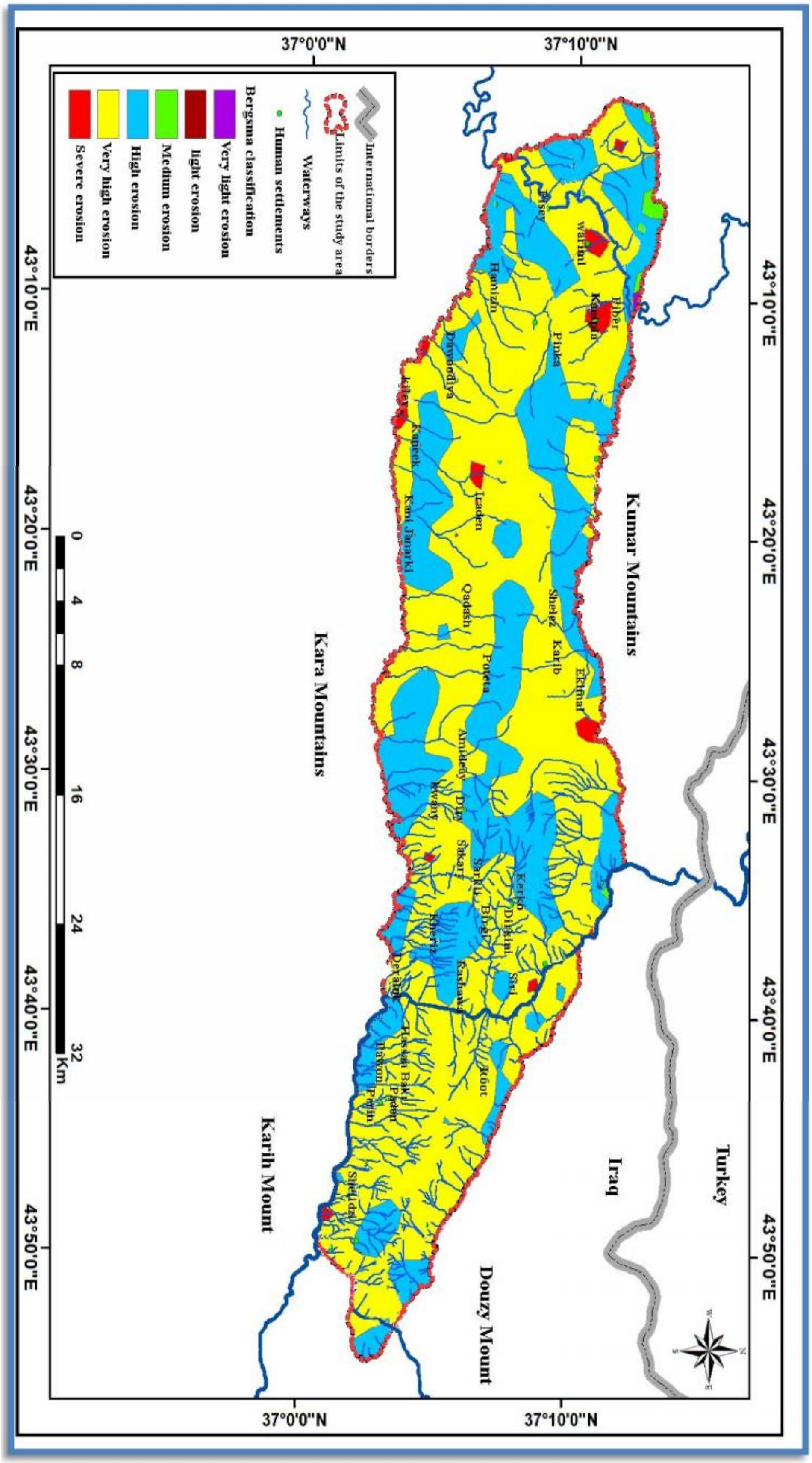


Source: The work of the researcher using ArcGIS 10.2 program.

MAP 5: Classification of rill erosion of Bergsma



Source: The work of the researcher based on ArcGIS 10.2 program.



Source: The work of the researcher based on ArcGIS 10.2 program.

5- **Very high erosion range**: This range is characterized by very high erosion and has the greatest effect and the largest area, where the number of sites were (155) with an area of ($569.84km^2$), i.e. with a percentage of (60.92%) of the total area of Mateen fold, where this range occupied the areas of light, medium and severe declines affected by the very high water erosion in that the erosion helped the geological structure, especially the sediments of the fourfold time which worked at activating the gullies erosion, also the runoff in this range is at its utmost as a result of the formation of the upper river ranks resulting from the convergence of water tables by the effect and direction of the decline. Thus, this range and the severe range mentioned later combine the steepness with water increase, which is reflected on a significant increase in the speed of the water flow, the disorder degree and the increase of the hydraulic momentum of waters, resulting in a significant increase in the activity of the process of erosion.

6- **Severe erosion range**: It is the last range represented by thesevere erosion, which occupied areas far less than high erosion range and the number of its sites were (13) and their area ($37.71km^2$), i.e. with a percentage of (4.03%) of the total area of the study area.

Conclusion

• The area of the study is of a severe relief and its height ranges between (600-2200m) above sea level, resulting in the contribution and operation of geomorphologic processes with quick response to those processes that make these relief areas of dangerous range difficult to exploit and called the range of geomorphologic risks.

• By the application of Bergsma equation to the study area and the division of the area into (266) sites. The very light erosion range was one location with a percentage of (0.04%). As to the light erosion range, it was also within one location with a percentage of (0.16%), while the medium erosion range included five sites with a percentage of (0.81%). Whereas the lands that were under high erosion range were (91) sites with a percentage of (34.01%) followed by very high erosion range of (155) sites with a percentage of (60.92%), and then the severe erosion range of (13) sites with a percentage of (4.03%) of the total area of the study area, indicating the response of the rocks to the intensity of rain erosion factors to which the region is exposed.

• The slopes of the study area with a percentage of (98.96%) are within the hazardous limits of water erosion and therefore they are not suitable for human use within these limits and measures and treatments should be taken in case of necessity.

Recommendations

• Attention should be given to the vegetation cover, the cultivation of the feet of slopes and their protection of rain erosion.

• Attention should be given to making fences and concrete barriers to reduce the fall of rock blocks.

• Put a limit to the construction of projects and buildings close to the slopes of geomorphologic hazards or warning by laying marks referring to those risks.

Footnotes

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