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Employing Geographic Information Systems in the Qualitative and Quantitative Assessment of Water Erosion in the Wadi (Dartu) Basin, West of Sulaymaniyah Governorate, North of Iraq Through the (EPM) Model

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Abstract

Using empirical model is one of the approaches of evaluating sediment yield. This research is aimed at predicting erosion and sedimentation in the (Dari to) basin in the west of Sulaymaniyah at Kurdistan Region, Iraq used EPM (erosion potential model) incorporating into GIS (geographic information system) software. This basin area is of this basin is about 336 km2. It has a range of vegetation, slope, geological, soil texture and land use types.

1. Introduction

Soil erosion is a major problem throughout the world. It is one of the most significant environmental degradation processes and has been accepted as a severe problem arising from agricultural intensification, land degradation and possibly due to global climatic change (Bhattarai, R., and Dutta, D. 2007). "Estimation of Soil Erosion and Sediment Yield Using GIS at Catchment Scale." Water Resources Management Jour. 21 (10): 1635-47.) Information on the factors leading to soil erosion can be used as a perspective for the development of an appropriate land use plan. According to Refs. [1-5], factors that influence soil erosion are rainfall intensity, soil type, slope, and land cover.

2. Materials and Methods

Indicators used in the Gavrilovic Erosion Model (EPM)

Several models have been developed to estimate soil erosion and sediment yield, with the most commonly used being qualitative assessments such as USLE, RUSLE, WEPP, SWAT, and GAVERILOVC. For qualitative assessment of erosion in the Dari basin, the GAVERILOVC model was selected. It was named EPM by Gaverilovic, standing for Erosion Potential Method, which is considered important in this field due to its association with several variables including soil lithology, vegetation cover density, slope, rainfall, and temperature. The study area is located in western Sulaymaniyah province, northeastern Iraq, bordered to the north by the Owah basin and to the south by the Dashtu basin. Its astronomical coordinates lie between

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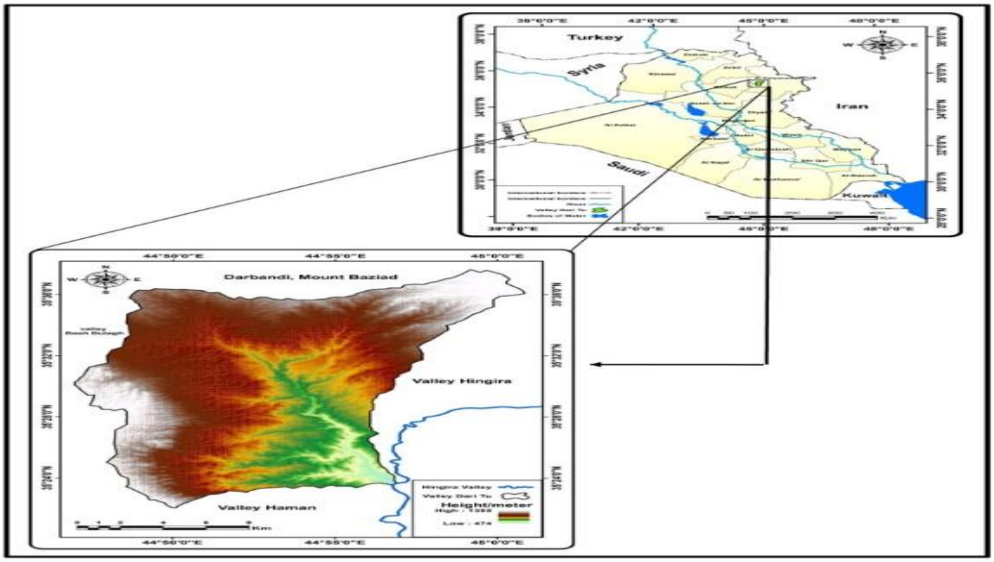
longitudes 44°46'56"E - 45°0'50"E and latitudes 35°22'4"N - 35°37'39"N, covering an area of 335 km². (Map 1).

Map (1): The Location of the Study Area.



Source: Republic of Iraq, Ministry of Water Resources, Directorate of Public Survey, Topographic Map of Iraq, 1990, Scale (100000:1), Digital Elevation Model (DEM) with Discriminative Resolution (30×30) and Outputs of the 8Arc Map 10 Program.

This model distinguishes itself from others by incorporating temperature as an additional indicator for assessing water erosion. It applies a series of equations as follows (Zorn, M, And B Komac, 2008):

$W= H * T * \pi * \sqrt{Z}3 * F$

Where: W = annual rate of erosion (m3/km2/year)

H = annual average rainfall (mm)

T = temperature coefficient

The temperature coefficient is extracted and extracted from the equation:

$T = (0.1 * TO + 0.1)0.5$

So, TO = annual average temperature.

Z = Potential erosion factor: It is considered one of the most important elements of the Gaverilovic model, and it can suffice alone as an indicator of erosion progress in watersheds (Blinkov, et al., 2008). It is highly beneficial in tracking erosion levels over time. Erosion levels are classified according to the value of Z, as shown in Table 6. The Z factor is derived from the equation (Zorn, M, And B Komac, 2008):

$Z= Y* Xa *(\varphi + \sqrt{Ja})$

F = Basin area (km2)

Integrating the elements of this equation into geographic information systems has allowed us to quickly and efficiently highlight the relationships between the factors controlling soil loss due to water erosion. Figure (1) illustrates a diagram outlining the application sequence of the Gavrilovic model.

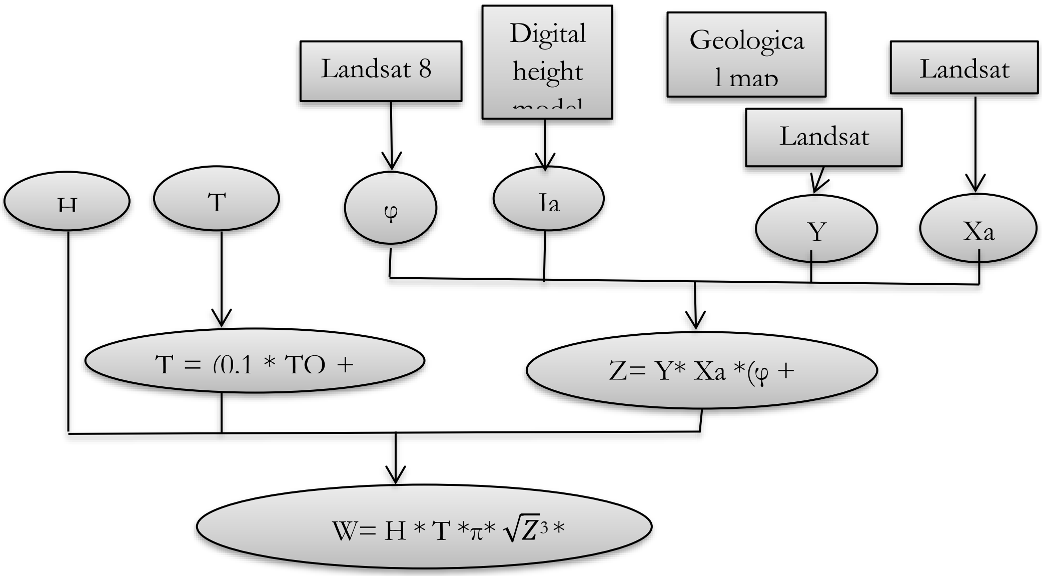


Figure (1) A Diagram of the Data Needed to Complete the Gavrilovic Model.
Source: From the Work of the Researcher

3. Indicators Used in the Gavrilovic Erosion Model (EPM)

First: Geological Formations

The stratigraphic (rock) sequence study of any area holds significant and influential importance for geomorphological and hydrological studies. It elucidates many details regarding the type, characteristics, and properties of rocks, facilitating the interpretation of their susceptibility to respond to the effectiveness of both wind and water erosion processes. Here are the most important geological formations within the study area (Map 2) Table:(1)

Injana Formation: It occupies the largest area among the other formations, covering an area of (110 km²), accounting for (32.8%). This formation is predominantly exposed in the north and northeast of the basin area.

Fatha Formation: This formation covers a small area in the form of a narrow strip extending from the northeastern part to the southeastern part of the area. It occupies an area within the basin of (9 km²), accounting for(%2.7) .

Al-Muqdadiya Formation: This formation is extensively exposed, extending from the northeastern and eastern parts of the basin area, covering an area of (36 km²), accounting for .(%10.7)

Bya Hassan Formation: This formation is widely exposed, with scattered parts in the northern, central, and western regions of the basin area. It covers an area of (73 km²), accounting for.(%21.8)

Bellaspia-Avana Formation: It covers an area of (10 km²), accounting for (2.9%) of the total area, and is exposed in the north of the basin area.

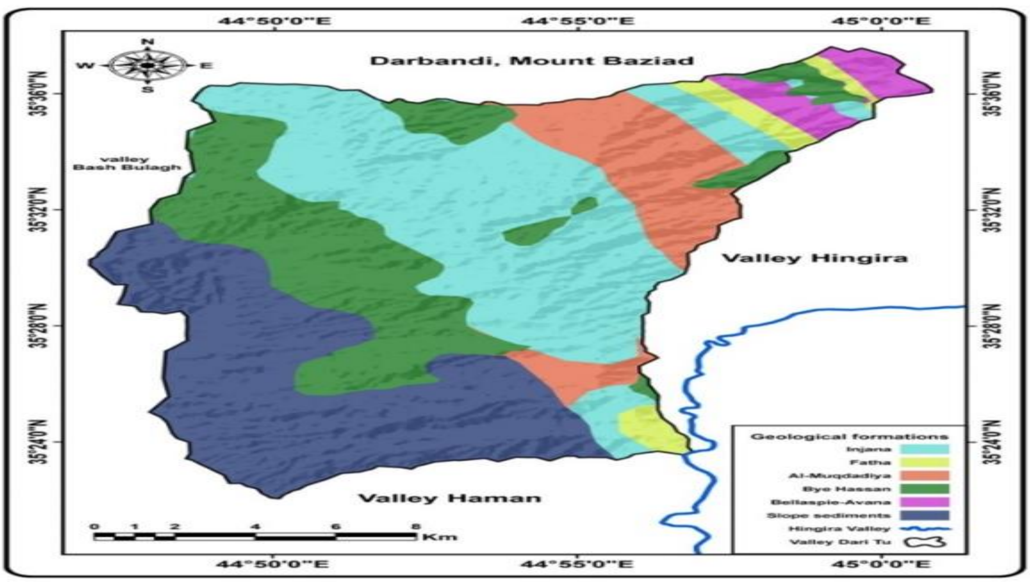
Slope Sediments Formation: This formation is exposed in the western and southwestern parts of the basin, covering an area of (79 km²), accounting for (28.9%) of the total area.

Table (1): Area and Percentages of Geological Formations of the Wadi Dartu Basin.

Geological Formations	Area Km²	Ratio%
Injana Formation	110	32.8
Fatha Formation	9	2.7
Al- Muqdadiya Formation	36	10.7
Bya Hassan Formation	73	21.8
Bellaspia- Avana Formation	10	2.9
Slop sediments Formation.	97	28.9
Total	335	100.0%

Source: Based on the Map(2)

Map (2): Geological Formations of the Wadi Dartu Basin.



Source: Republic of Iraq, Ministry of Industry and Minerals, General Establishment of Geological Survey and Mineral Exploration, Geological Map, Year 2000, Scale 1:25000.

Second: Climate

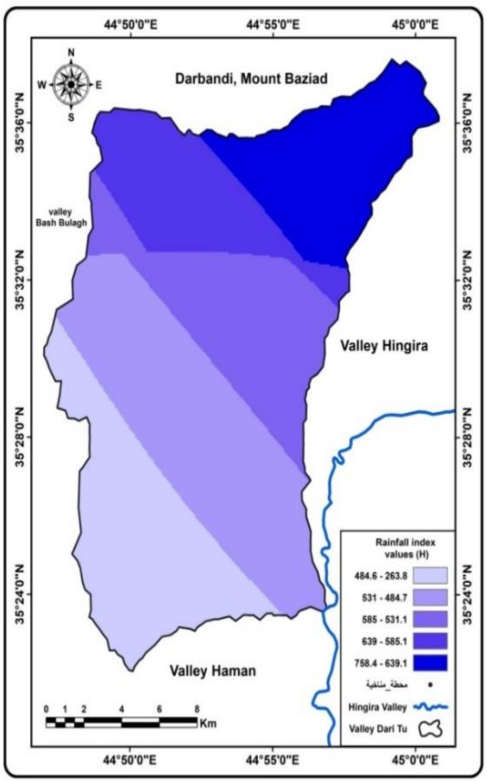
1- **Temperature Index (T):** Temperature is a crucial factor in this model, as it affects the water balance within the soil. High temperatures increase evaporation and transpiration rates, leading to the formation of a dense network of cracks that contribute to the disintegration of surface rock components in the Dari to watershed. To derive the temperature coefficient, satellite imagery (Landsat 8) was utilized to derive the annual temperature average, which was then inserted into the following equation to obtain the value of the temperature coefficient (T) (Blinkov, I., I Mincev, B. Trendafilov 2008):

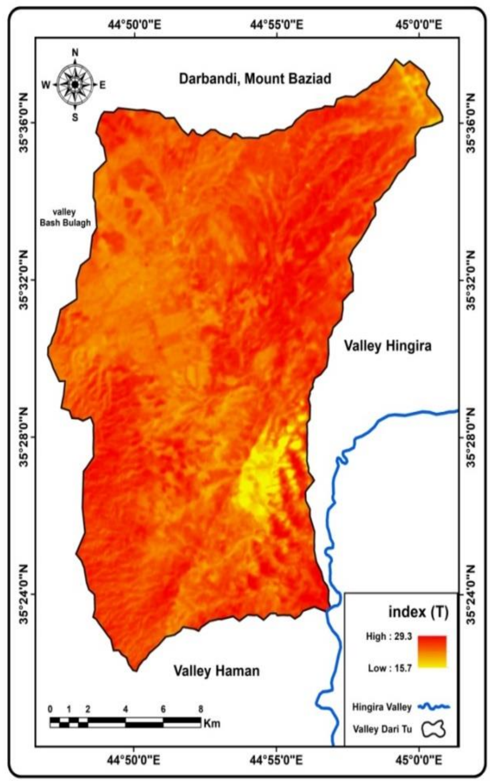
$T = (0.1 * TO + 0.1)^{0.5}$

Where TO represents the annual average temperature. Through the analysis of the temperature index (T) map, it is evident that temperatures rise in the northern and northeastern parts of the basin, then decrease towards the central and southern regions. The highest average temperature reached 29.3°C, while the lowest average reached 15.7°C (Map 3).

2- **Rainfall Index (H):** Rainfall is one of the most important primary factors driving water erosion, starting from the impact of raindrops hitting the surface, through surface runoff. Additionally, intense, and sudden rainfall events can lead to the erosion of large amounts of soil, especially in areas with no vegetation cover and characterized by steep slopes. Based on satellite imagery, the highest rainfall rate recorded was 758.4 mm, concentrated in the northern and northeastern parts. Rainfall gradually decreases towards the central and southern regions, with the lowest rate recorded at 263.8 mm in the southwestern and southern parts of the Dari to watershed (Map 4)

Map (3): Temperature Index (T). **Map (4):** Rainfall Index (H).

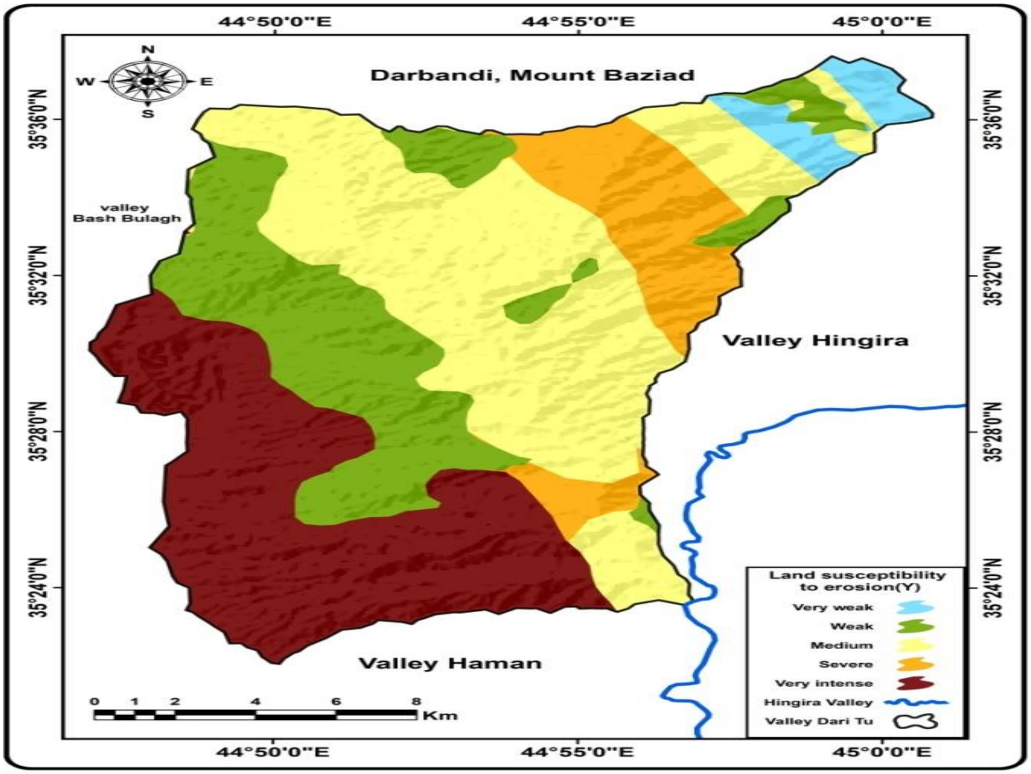




Source: Based on Landsat 8 Satellite Visuals.

Secondly, Soil Erodibility Index (Y): To determine the soil erodibility index, we relied on the soil map and geological map of the Dari to watershed, classified into five categories based on erodibility. From the map (Map 5) Table (2), it is evident that there is variation in the categories of soil and rock resistance to erosion. Moderate erodibility appears over a large area of the basin, covering approximately (119 km²) or (35.5%) of the total basin area. On the other hand, the least area among the five categories is highly severe erodibility, covering about (20 km²) or (2.6%) of the total basin area.

Map (5): Erosion Susceptibility Index (Y) for the Dartu Valley Basin



Source: Relying on the Geological Map, Bjornck's Soil Classification, and the Outputs of the Arc Map 10.8 Program.

Table (2): Areas and Percentages of the Erodibility Index (Y) for the Wadi Dartu Basin.

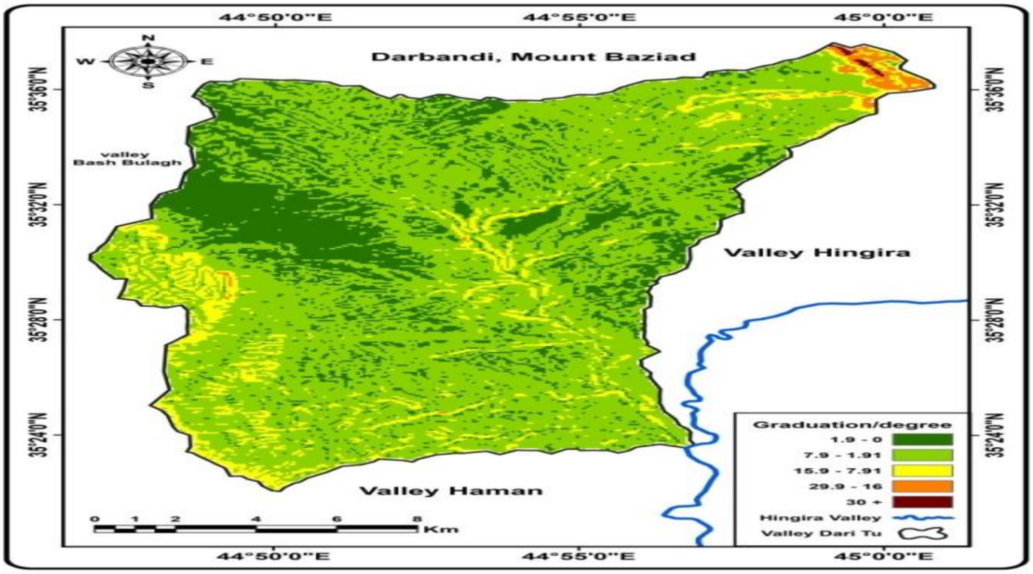
Susceptibility of land to erosion (Y)	km2	Ratio
Very weak	97	28.9
Weak	36	10.7
Medium	119	35.5
Severe	73	21.8
Very intense	9	2.6
Total	335	100

Source: Based on the Map(5)

Third: Regression Index (Ja)

Topographic characteristics are among the primary factors that determine the activity of watercourses, as well as their capacity for erosion, transport, and sedimentation. Flow velocity increases with the steepness of the slope. The Dari to watershed was divided into slope classes according to the Zorn classification, as shown on the map (Map 6) Table (3). The slope degree for the first-class ranges from (0-1.9), representing areas of low relief scattered in the northern and northwestern parts of the basin, covering an area of (69 km²) or (5.7%). The second class of slope degree (2-7.9) occupies the largest area, covering (230 km²) or (68.6%). Mountainous areas with slopes greater than (30) degrees are represented in the northeastern part, covering an area of (3 km²) or (0.8%) of the total basin area.

Map (6): Slope Index (Ja).



Source: Relying on the Digital Elevation Model (DEM) with a Discriminant Resolution (30×30), and the Outputs of the Arc Map 10.8 Program.

Table (3): Areas and Percentages of Regression Degree.

Degree of regression	Area km2	Percentage
0 – 1.9	69	20.5
2 – 7.9	230	68.6
8 – 15.9	27	8.0
16 - .29.9	6	1.7
+ 30	3	0.8
Total	335	100%

Source: Based on Map(6)

Fourth: Soil Protection Index (Xa)

The Soil Protection Index in the EPM model refers to the level of vegetation cover density in the watershed, which helps in soil stabilization, reducing flow velocity, increasing water permeability within it, and reducing its erosion. Vegetation cover plays a role in reducing the severity of erosion by protecting the soil from direct rainfall. To evaluate the role of this index in its relationship with soil loss, reference was made to the criteria defined by Gaverilovic in the following table.

Table (4): Soil Protection Index criteria for Gavrilović.

Soil Protection Index	**value Xa**
dense mixed forests	0.2- 0.05
Coniferous forests and vegetation scattered on the side of the canals	0.4- 0.2
Pastures and dense forests	0.6-0.4
Degraded pastures	0.8-0.6
Barren lands	1.0-0.8

Source: Stefanovic, M., Z. Gavrilovic and M. Miliojevic 2004, Erosion Potential Method and Erosion Risk Zoning in Mountainous Regions in Internationals Symposion Iterprevent - RIVA/TRIENT.

The values of the vegetation cover index (NDVI) were extracted after classifying the watershed into five categories based on the criteria defined by the model. Xa was calculated according to the following equation (Stefanovic, M., Z. Gavrilovic, and M. Miliojevic, 2004):

$$Xa = (Xa\ NDVI - 0.61) * (-1.2)$$

So, Xa = soil protection index.

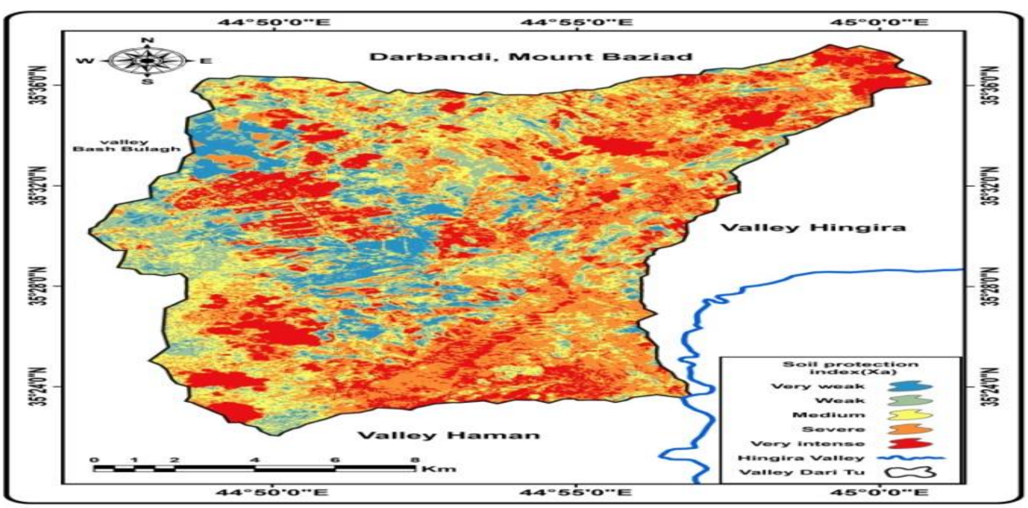
Xa NDVI = Vegetation cover coefficient adjusted to soil protection criteria.

The soil protection index Xa increases in areas with high vegetation density, ranging from (0.2-0.05) to (0.8-1) for barren lands. It is evident from the map (Map 7) Table (5) that very weak erosion is widespread in scattered parts of the basin, covering an area of (26 km²) or (7.7%), where vegetation cover reduces erosion and runoff intensity. Severe erosion, on the other hand, occupies the largest area of the basin, reaching (114 km²) or (34.0%).

Table (5), Map (7): Area and percentage of Soil Protection Index Xa for the Dari Tou Valley Basin Soil Protection Index (Xa).

Soil Protection Index (Xa)	Area km2	Ratio%
very weak	26	7.7
Weak	55	16.4
Medium	76	22.7
Severe	114	34.0
very intense	64	19.1
Total	335	100

Source: Based on the Map(7)



Source: Relying on the Output of Arc Map 10.8.

Fifth: Current Erosion Index Φ:

The values of the index (φ) vary depending on the size of the watersheds. The researcher relied on the equation formulated by Milevski (2008), based on Landsat 8 satellite imagery (Zorn, M, And B Komac, 2008):

$$\varphi = \sqrt{TM3/Qmax}$$

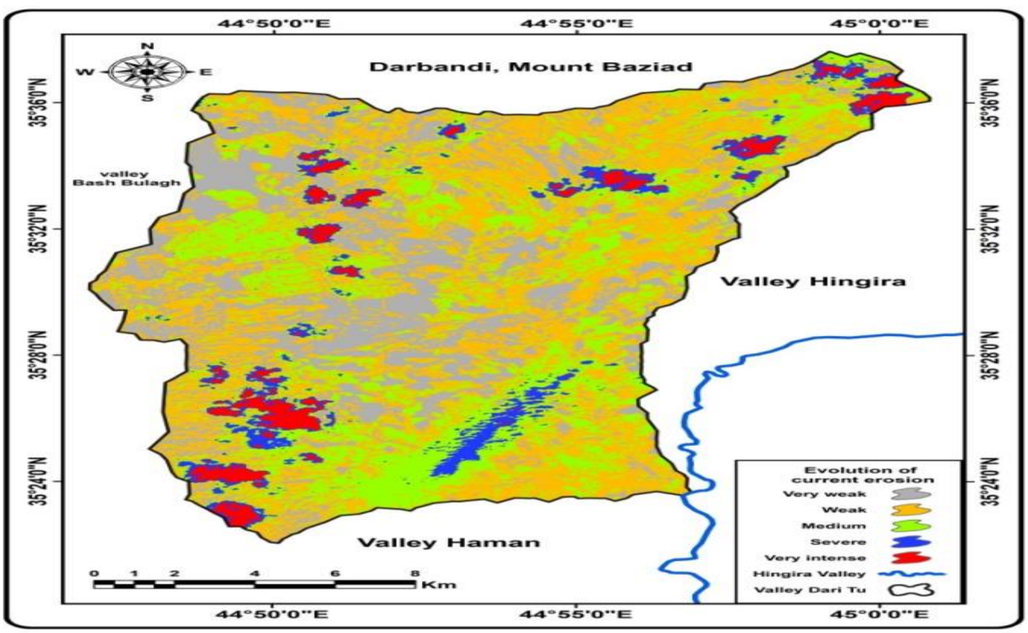
According to the results of this equation, the highest values were recorded for lands with weak erosion, covering an area of (145 km²) or (43.2%). As for very severe erosion, it occupies a smaller area, reaching approximately (11 km²) or (3.0%). It is scattered in various parts of the basin (Map 8) Table.(6)

Table (6): Area and Percentage of Current Erosion Index φ

Evolution of current erosion	Area km2	Percentage %
very weak	81	24.1
Weak	145	43.2
Medium	81	24.7
Severe	17	5.0
very intense	11	3.0
	335	100

Source: Based on Map(8)

Map (8): Current Erosion Index φ.



Source: Relying on the Output of Arc Map 10.8.

Thirdly: Application of the EPM Model for Quantitative Assessment of Erosion and Model-Specific Indicators: Discussion and Conclusions.

After relying on the aforementioned indicators and their respective equations, and processing them, a map of erosion was derived using two indices (Z and W). The potential erosion coefficient Z was extracted, defined as a synthesis model, as observed in the equation (Milevski,

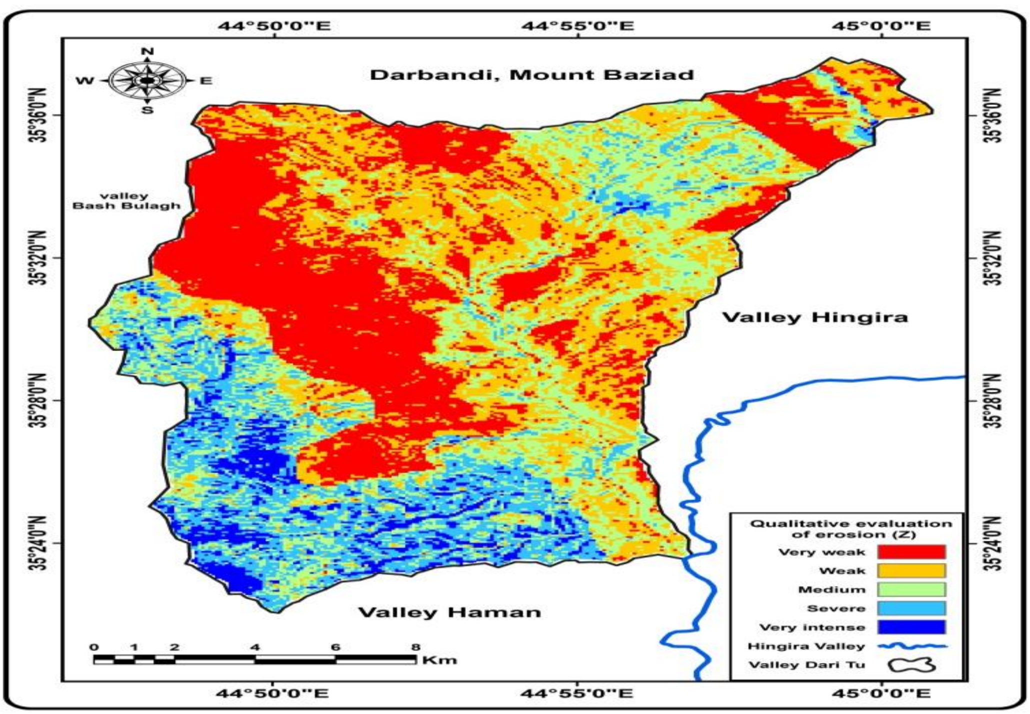
I. I. Blinkov and Trendafilov, 2008).

$$Z = Y^{*} Xa^{*}(\varphi + \sqrt{Ja})$$

And its values range between (0-1) or exceed one in the case of very severe erosion. High values indicate the severity of erosion. It is worth noting that the equation does not take into account rainfall or temperature indices. After applying the equation, a map of potential erosion was derived for the Dari to watershed, as shown in Map (9) and Table (7). The area was divided into:

- Very light erosion (0.19 - 0.01), covering an area of (97 km²) or (28.9%) of the total watershed area. This type predominates in the plain areas of the watershed covered with dense vegetation, and it is the most prevalent type in the basin in terms of area.
- Light erosion with an erosion coefficient (0.20 - 0.40), covering an area of (93 km²) or (27.7%). This type accompanies very light erosion.
- Moderate erosion, covering an area of (74 km²) or.(%22.0)
- Severe and very severe erosion, prevalent in the mountain peaks with steep slopes. The combined area of severe and very severe erosion is approximately (71 km²) or (21.1%). This type of erosion dominates rocky edges with sparse vegetation cover.

Map (9): Erosion Qualitative Evaluation Index (Z) for the Wadi Dartu Basin.



Source: Arc Map 10.8 Output.

Table (7): Levels, Area, and Percentages of Erosion for the Dari to Basin According to the Value of the Erosion Coefficient (Z).

Qualitative assessment of erosion according to the value of the coefficient (Z)	Erosion coefficient	Area km2	Percentage %

Very light erosion	0.01-0.19	97	28.9
Light stripping	0.20 -0.40	93	27.7
Medium erosion	0.41 -0.80	74	22.0
Severe erosion	0.81-1.0	48	14.3
Very severe nudity.	More than 1	23	6.8
Total		335	100

Source: Based on the Map(9)

- After integrating the coefficient (Z) with climatic factors (H - T), in addition to the watershed area (F), according to the following equation (Blinkov, I., I Mincev, B. Trendafilov, 2008):

$$W= H * T * \pi * \sqrt{Z}^{3} * F$$

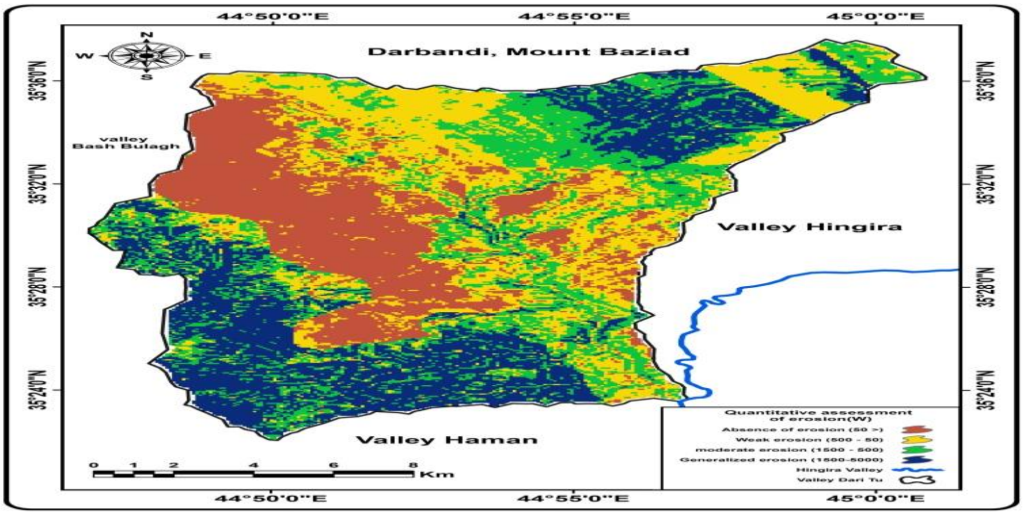
After applying the equation, the final erosion model (W) was derived, which is considered a comprehensive model as it considers all factors that either reduce or increase erosion processes. Thus, the coefficient (Z) was integrated with climatic factors (H) and (T) to yield erosion quantities measured in (m^3/km^2/year). Milevski and colleagues (MILEVSKY I. Al, 2008) suggest that annual erosion rates below 500 m^3/km^2/year indicate weak erosion, while rates exceeding 800 m^3/km^2/year indicate high erosion. Calculating the annual rate of water erosion, we find that the watershed falls within the category of weak erosion, with an area of 93 km^2, accounting for 27.7% of the total area. However, there is variation within the watershed, with severe erosion concentrated in the western and southwestern parts, as well as a portion of the northeastern area, covering an area of 80 km^2, representing 23.8% of the total area. Meanwhile, moderate erosion is concentrated in scattered parts of the watershed, covering an area of 85 km^2, representing 25.3% of the watershed area. With the addition of the annual rainfall (H) and temperature (T) values, the susceptibility of the watershed to erosion changed compared to when only considering the coefficient (Z).

Table (8): Quantities, areas, and rates of erosion (W)

Quantitative Assessment Index for Erosion (W)	Quantities of erosion (m3/km2/year)	km2	Ratio
Very weak nudity.	Less than 50	77	22.9%
Weak erosion	500 – 51	93	27.7%
Medium erosion	1500 – 501	85	25.3%
Severe erosion	5000 – 1501	80	23.8%
Total	-	335	100.0%

Source: Based on Map(10)

Map (10): Erosion Quantitative Evaluation Index (W)



Source: Relying on the Output of Arc Map 10.8.

4. Conclusions

1. Natural factors, such as geological structure, rock quality, climatic characteristics, temperature, and rain, affected the amounts of soil lost through water erosion.
2. The category of potential erosion (Z) is severe and very severe, with an area of 71 km2 and a rate of 21%. This category prevails in areas with erodible rocks and little vegetation.
3. When adding the rainfall index (H) and the temperature index (T), the susceptibility to water erosion in the basin changes from the way it was in the values of the coefficient (Z).
4. It represents a quantitative estimate of water erosion in the Daritu Basin (W), We find the basin within the classification of (51-500 m3/km2/year), as its area reached 93 km2, representing 27.7% of the total area of the basin, while the area of the severe erosion category was 80 km2, representing 23.8%.
5. Of the total pelvic area in various parts of the pelvis.

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