Slope stability analysis using safety coefficient in Mawt-Sulaymaniyah

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Abstract

The research includes examining the natural factors that impact how seriously slopes are taken and how stable they are. Using geographic information systems (Arc Gis 10.8) methods and the field investigation data determined the safety coefficient and speed of material flow on certain slopes. A map was then made to show these estimates. As for the speed of movement of materials on slopes, figures varied between the greatest speed of sector (6), which amounts to (19.3 m/s) and the lowest speed of sector (10), which is (9.9 m/s). The investigation revealed three degrees of stability for the analysed sectors.

The Research Problem

1- Do the natural characteristics of the study area have a role in determining the degree of stability of slopes and increasing the speed of materials on them?
2- What is the level of safety and stability of the slopes of the study area?

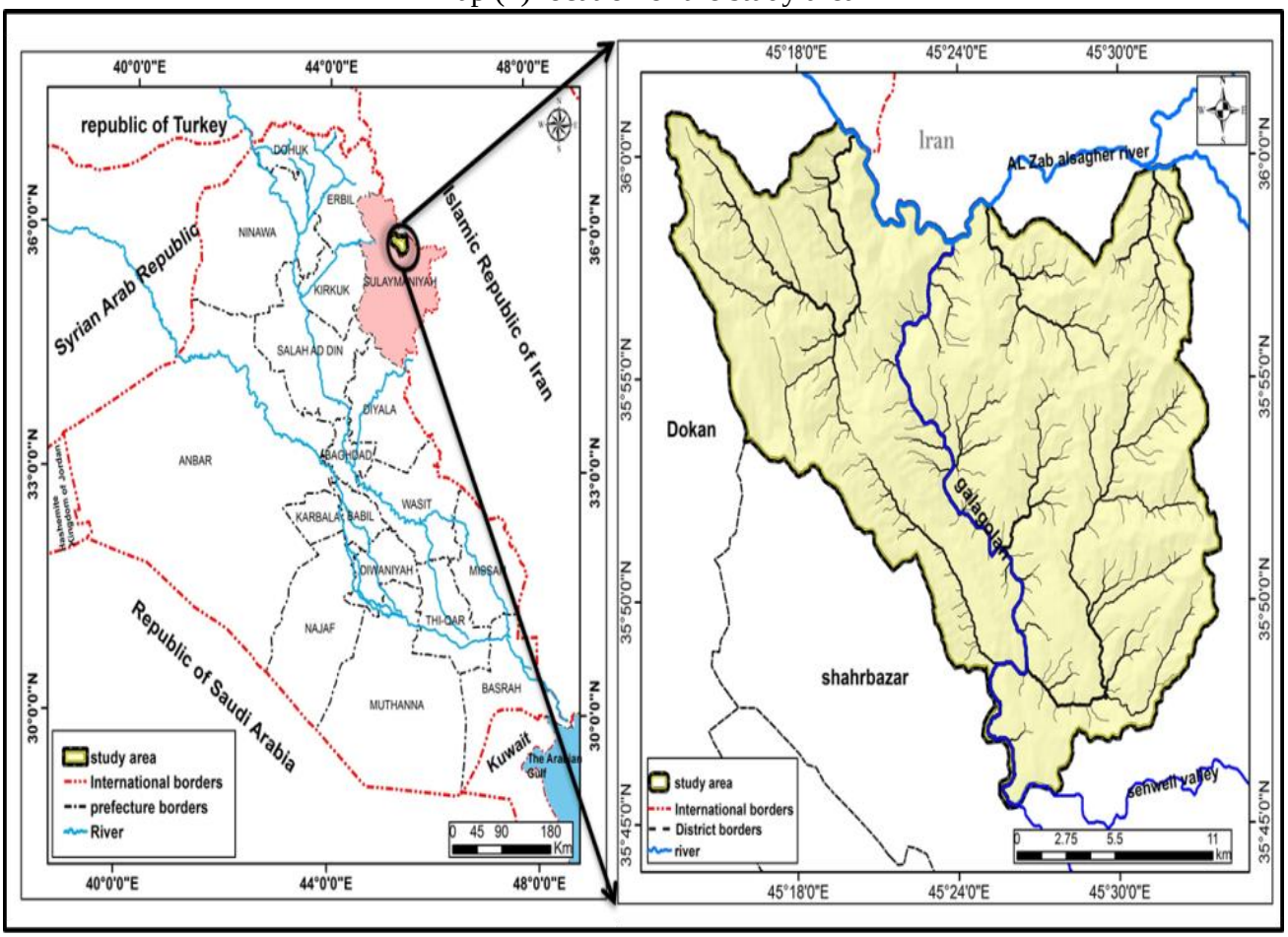
Research Hypothesis

1- The natural properties have an important role in determining the stability of slopes and increasing the speed of materials
2- There are three levels of the stability risk of the slopes of the study area

The Location of the Study Area

The study area is located astronomically between two latitudes (36° 1′ 0″ - 35° 45′ 00″) north and arcs of length (45° 33′ 20″- 45° 17′ 20″) east, and geographically it is located in the northeast of Al-Araq within the Sulaymaniyah province, and it is bordered to the north by Iran, and from the east, southeast, south and southwest, by the districts of Shahrbazar, and from the west and northwest by the two sides of Surdash and Bankard of the district Dokan, map (1), the area of the study area is (485.3 km2).

Map (1) location of the study area



Source: The researcher based on the map of Iraq, and the map of the administrative governorate of Sulaymaniyah at a scale (1:100000) for the year 2017, and using the program (Arc Gis 10.8)

First: the natural characteristics of the study area

The natural characteristics of the study area (geological structure, climate, elevation characteristics, slope, natural vegetation,) play an important role in determining the degree of severity of the slopes of the study area and the movement of materials in it, so the impact of these factors will be studied and analysed as follows

1- Geological structure

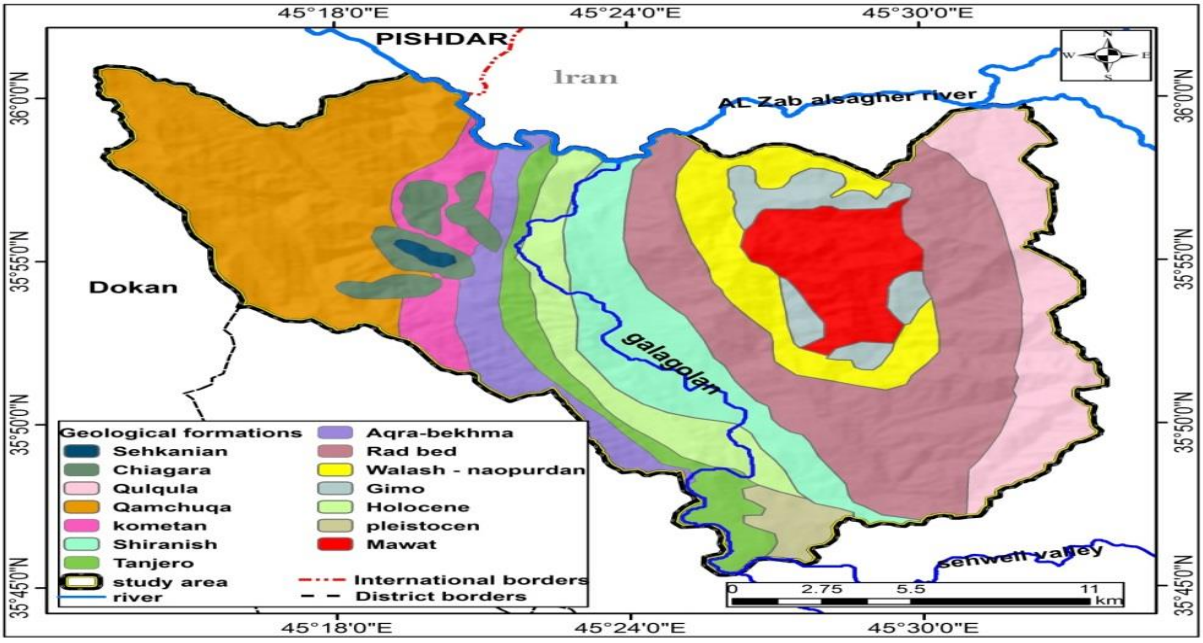
The geological formations and the degree of resistance of the rocks are among the most important variables on which it depends in classifying the degree of gravity of the movement of ground materials. In general, the study area is located tectonically within two main zones, namely, the eruption zone and slip faults to the east, and the unstable zone within the secondary zone (Sulaymaniyah - Zakho) to the west, and it is clear from Table (1) and map (2) The discovery of many formations consisting of several rocks with various characteristics, according to the geological times in which they were formed, namely (Sikanian, Giakara, Qolqa, Qamjouga, Mawt, Komitan, Shiranch, Tangro, Aqra-Bakhma, Jimo, Lash-Nuperdan, the red layers, precipices sediments, floodplain sediments). The formation of the red layers occupied the largest area (103.1) and (21.24 percent) of the total area of the area, while the formation Sehkanian occupied the smallest area, amounting to (1.6 km2), with a percentage of (0.32%) of the area

Table (1) Sediments and geological formations

time	sediments and formations	Area/km2	Ratio %		rock components
the fourth	Floodplain sedimentation	27.8	5.72	permeable, not resistant	Fine sand and gravel, lime lenses
the fourth	precipitation of mountains	8.2	1.68	permeable, not resistant	cut rocks, pebbles
Third	Red Bed	103.1	21.24	Average permeability and resistance	sandstone, shale, shale, limestone, mudstone
Third	Walash - Naopurdan	32.3	6.65	Medium transmittance, resistive	Basalt, volcanic eruptions, limestone, sandstone, shale
Third	Gimo	16.8	3.46	impermeable, resistant	Marble, limestone, metamorphic basalt
Second	Mawat (ophiolite)	29.4	6.05	impermeable, resistant	basalt, capro, metamorphic schist
Second	Tanjero	24.2	4.98	Low permeability, resistant	Marl, sandstone, rubble, limestone, silt
Second	Shiranish	48.1	9.91	Average permeability and resistance	Marl, limestone
Second	Kometan	15.9	3.27	permeable, medium resistance	limestone, limestone, marl
Second	Qamchuqa	95.5	19.67	permeable, not resistant	dolomite, limestone, limestone
Second	Aqra-Bekhma	22.8	4.69	permeable, not resistant	limestone, dolomite
Second	Qulaqula	45.4	9.35	Medium transmittance, resistive	compactors, flint, limestone, child, mudstone
Second	Chiagara	14.2	2.92	Average permeability and resistance	limestone, dolomite, shale, child
Second	Sehkanian	1.6	0.32	permeable, not resistant	dolomite, limestone
	the total	485.3	99.9		

Source: The researcher based on the Ministry of Industry and Minerals, the General Establishment for Geological Survey and Mining, a geological map of Sulaymaniyah Governorate, scale (1:250,000), for the year 2014, using the program (Arc GIS 10.8)

Map (2) of the geological formations in the study area



Source: The researcher based on the Ministry of Industry and Minerals, the General Establishment for Geological Survey and Mining, a geological map of Sulaymaniyah Governorate, scale (1: 250000), for the year 2014, using the program (Arc GIS 10.8)

The Climate

Climate has a prominent role in activating the movement of materials on the slopes and determining their stability, and accordingly, the basic elements of climate were studied based on the climatic data of the two stations (Dukan, Jawarta). The great variation in temperature has an important role in the activity of weathering processes and thus increasing the possibility of being exposed to the risks of precipitation and rockslide. From table (2) it is clear that the temperatures in the study area rise in summer, as it reached the highest average temperature in the month (August) (43°C) in Dukan Station (35.8 م°) in Juwarta Station, while in the winter the temperatures drop, and the month of January recorded the lowest degree of 9.1 م°) in Dukan Station and (6.3 م°) respectively in Juwarta Station. Rain also plays a major role in increasing the activity of materials movement and the occurrence of rockslides, and from table (3) it is noted that the annual total of rainfall reached (618.3 mm) in Dukan Station and (934.3 mm) in Jawarta Station. Movement of materials and the effect on the stability of slopes in the region From table (4) it is noted that the annual total amount of snowfall amounted to (498.2 cm) in Dukan station and (726.4 cm) in Jawarta station

Table (2) Monthly and annual averages of maximum and minimum temperatures and range (°C) in Dukan and Jawarta stations for the period (2009 - 2020)

Months	Dukan Station				Guarta Station			
	Max	Min	Range	Ave.	Max	Min	Range	Ave.
January	9.1	3.7	5,4	6.4	6.3	1	5.3	3.6
February	12.3	4.6	7.7	8.4	9.4	2.6	6.8	6
March	17.4	8.8	8.6	13.1	14.2	5.9	8.3	10.0
April	30.5	12.6	17.9	21.5	24.6	9.4	15.2	17
May	32.4	18.2	17.5	25.3	28.1	11.2	16.9	19.6
June	38.6	24.9	13.7	31.7	30.1	17.5	12.6	23.8
July	42.1	27.6	14.5	34.7	32.4	23.3	9.1	27.8
Father	43	27.3	15.7	35.1	35.8	24.6	11.2	30.2
September	37.3	23.4	13.9	30.3	33.2	20.3	12.9	26.7
October	29.4	18.7	10.7	24.0	25.1	16.4	7.8	20.7
November	18.7	10.3	8.4	14.5	15.7	7.6	8.1	11.6
December	11.1	5.5	5.6	8.3	9.2	3.2	6.2	6.2
annual rate	27	15.4	11.5	21.1	21.4	11.9	10	16.9

Source: The researcher based on the Kurdistan Region of Iraq, Meteorological Department, Dukan station, Jawarta station, unpublished data, 2020

Table (3) The monthly and annual total of rainfall (mm) in the two stations of the study area for the period (2009-2020)

Months	Dukan Station	Guarta Station
January	168.1	181.5
February	94.6	123.7
March	86.3	170.1
April	56.7	89.6
May	25.6	49.1
June	_	_
July	_	_
Father	_	_

September	1	1.9
October	12.4	26.4
November	60.8	118.3
December	112.8	173.2
Annual total	618.3	934.3

Source: The researcher based on the Kurdistan Region of Iraq, Meteorological Department, Dukan station, Jawarta station, unpublished data, 2020

Table (4) Annual total of snowfall thickness (cm) and number of snow days in the two stations of the study area for the period (2009 - 2020)

the years	Dukan Station		Guarta Station	
	Thickness (Cm)	The number of days	Thickness (Cm)	The number of days
2009	42	4	18.5	3
2010	33.2	5	43.7	6
2011	33	5	26.6	4
2012	42.5	4	67.8	8
2013	32.9	6	84.9	14
2014	40.9	4	63.1	10
2015	16.3	3	28.4	5
2016	15.6	3	28.2	5
2017	66.8	5	93.3	10
2018	55.6	6	96.5	12
2019	52.4	5	94.8	10
2020	67	5	83.3	8
Annual total	498.2	55	726.4	95

Source: From the researcher's work based on the Kurdistan region of Iraq, Meteorological Department, Dukan station, Jawarta station, unpublished data, 2020

Height characteristics

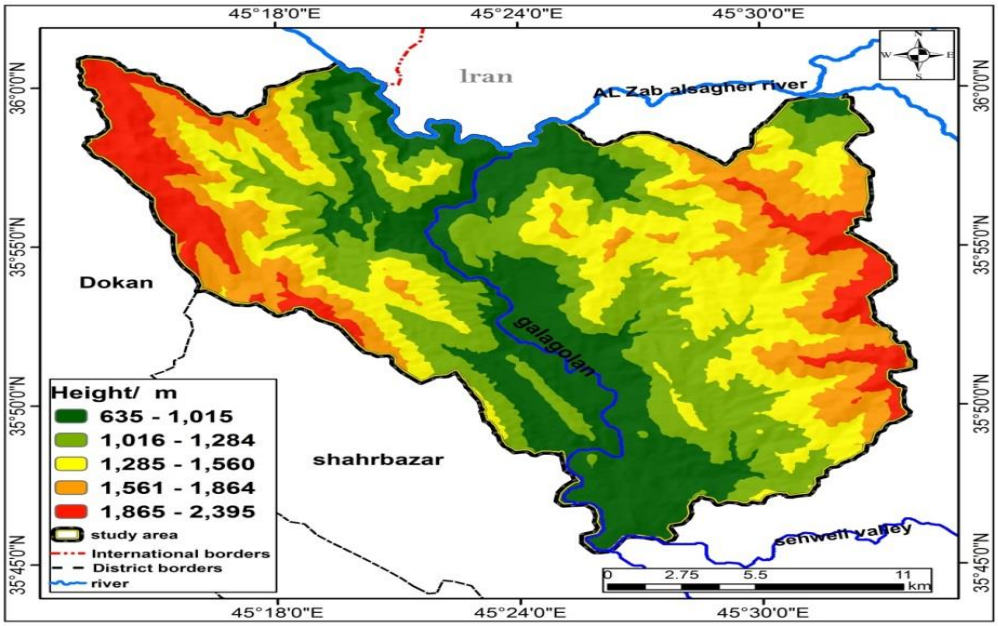
The topographical aspect plays an important role in the activity of the movement of materials and determining the degree of their speed, as well as its influence in determining the degree of stability of slopes. From Table (5) and Map (3), it appears that the study area consists of five terrain sections with different areas according to their different heights, namely (the area of high-rise mountains, The medium-altitude mountain region, the low-rise mountain region, the hill region, the plain region).

Table (5) of the topographical sections, their heights, area and percentages in the study area

the description	height \ m	Area \ km2	Percentage
plains	635-835	40.5	8.3
hills	836-1035	93.7	19.3
medium altitude mountains	1036-1335	138.2	28.5
high altitude mountains	1336-1635	109.6	22.6
high altitude mountains	1636-2395	103	21.3
the total		485.3	100

Source: From the researcher's work based on the DEM digital elevation model, and using the Arc Gis . program

Map (3) elevation of the study area



Source: the researcher based on the digital elevation model DEM and using Arc GIS 10.8)

Slope

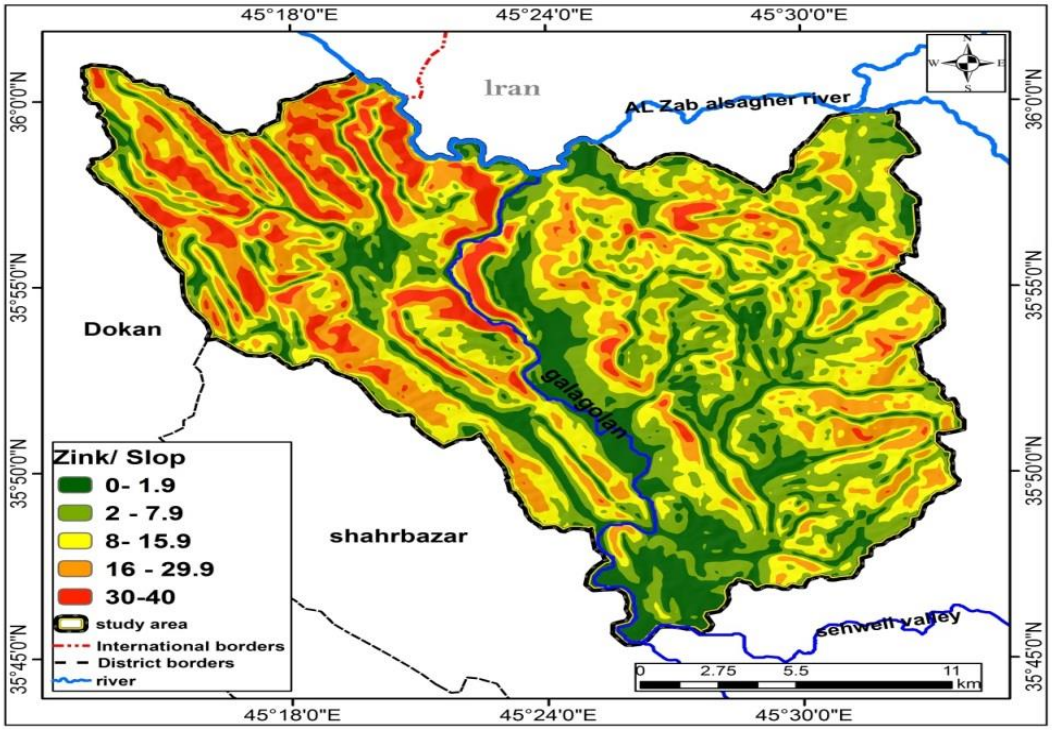
Regression is among the most important factors that contribute to the activity of the process of landslides and landslides, and the degree of gradient determines the quality and unity of these processes. The slopes of the study area were divided into five categories with different areas, namely (plains and valleys, feet of mountains, low hills, high hills, mountains).

Table (6) Regression categories, land surface levels, area and percentages in the study area according to zinc classification

Category	gradient	Area \ km2	percentage
plain, valley	1.9-0	88.8	18.2
plain, feet of mountains	7.9-2	135.7	28
low hills	15.9-8	125.5	25.9
high hills	29.9-16	92.2	19
mountains	30<	43.1	8.9
the total		485.3	100

Source: From the researcher's work based on the Zink classification, and using the Arc Gis 10.8 . program

zink(4) regression map



Source: the researcher based on the digital elevation model (DEM) and using the program (Arc Gis 10.8)

Natural plant

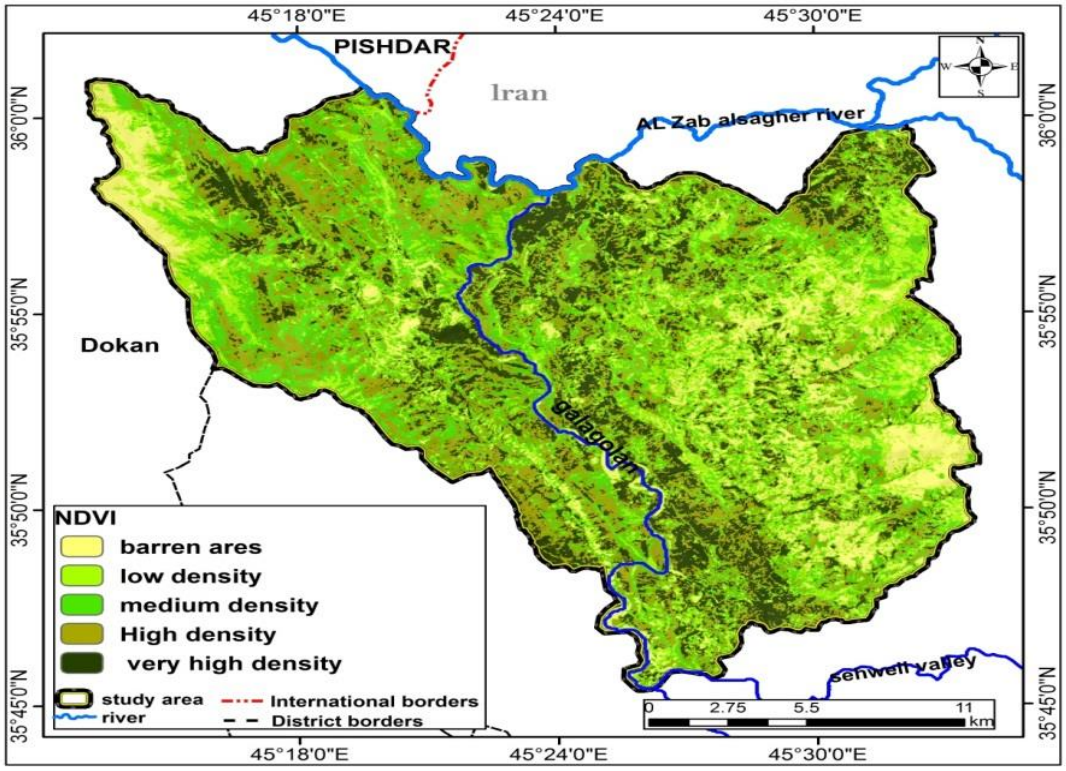
The natural vegetation in terms of its type and density has a medicine in influencing the movement of materials on the slopes. Empty slopes with few vegetation cover are more susceptible to the process of falling and collapsing, and the NDVI index was used to determine the density of the plant and accordingly the area was classified into five categories (barren lands, dense lands Weak vegetation, lands with medium vegetation density, lands with high vegetation density, areas), map (5). The medium density occupied the largest area (167.9 km2) and at a rate of (34.59%) of the area, while barren lands occupied the smallest area and amounted to (73.2 km2) and a percentage of (15.08%) of the total area of the region, table (7)

Table (7) Vegetation Coverage Index (NDVI)

the description	Area/km2	Percentage
bare soil	50.4	10.385
low density	92.7	19.101
medium density	126	25,963
High density	137.1	28.250
very high density	79.1	16,299
the total	485.3	99.9

Source: the researcher based on the program (10.8 Arc GIS)

Map (5) Vegetation Cover Index (NDVI) in the study area



Source: The researcher, using the satellite imagery (Landsat8), and using the Arc Gis10.8 program.

Second: Estimation of the safety coefficient of the slopes of the study area

The study of the safety coefficient aims to know the degree of stability of slopes, and to determine the surfaces prone to collapse and fall. This study is of great importance, especially with regard to engineering practices related to the construction of urban and residential facilities and transportation routes. The degree of stability of slopes in the study area can be calculated by studying the safety coefficient of the studied sectors, and the speed of movement Articles on it and as follows.

1- Safety factor

The safety coefficient is intended to calculate the stability of the studied slopes through the relationship between the degree of friction of the rocks that make up the slope and the average degree of the slope, through the following equation

Coefficient of safety = tangent of the degree of friction / tangent of the angle of the mean gradient of the slope If the result of the equation is less than (1), the slope is unstable, and if the result ranges between (1.25 - 1), the slope is almost stable, and if the result ranges between (1.5 - 1.25), the slope is closer to stability, but if the result increases from (1.5 The slope is stable.

After applying the equation to the slope sectors of the study area and through Table (9) and Map (6), it is clear that the values of the results of the safety coefficient ranged between (1.1-2.9), as the segments (5,6,7) recorded the lowest value of (1.1) This means that they are almost stable slopes, which indicates a great danger to the movement of materials in them, while the sectors (1,9) recorded an average value of (1.5) for both, and this means that they are slopes close to stability, while the sectors (2,3,4,8, 10) High numbers were recorded, amounting to (2.8, 2.4, 2.5, 2.1, 2.9), respectively, which means that they are stable sectors and that the risk of material movement in them is low.

Table (8) coefficient of friction of some rocks on the slopes in the study area

rocks	degree of friction
Limestone	32
dolomite	27
marl + limestone	24
sandstone	24
basalt	31
admixtures	35
marble	31
Shale	27

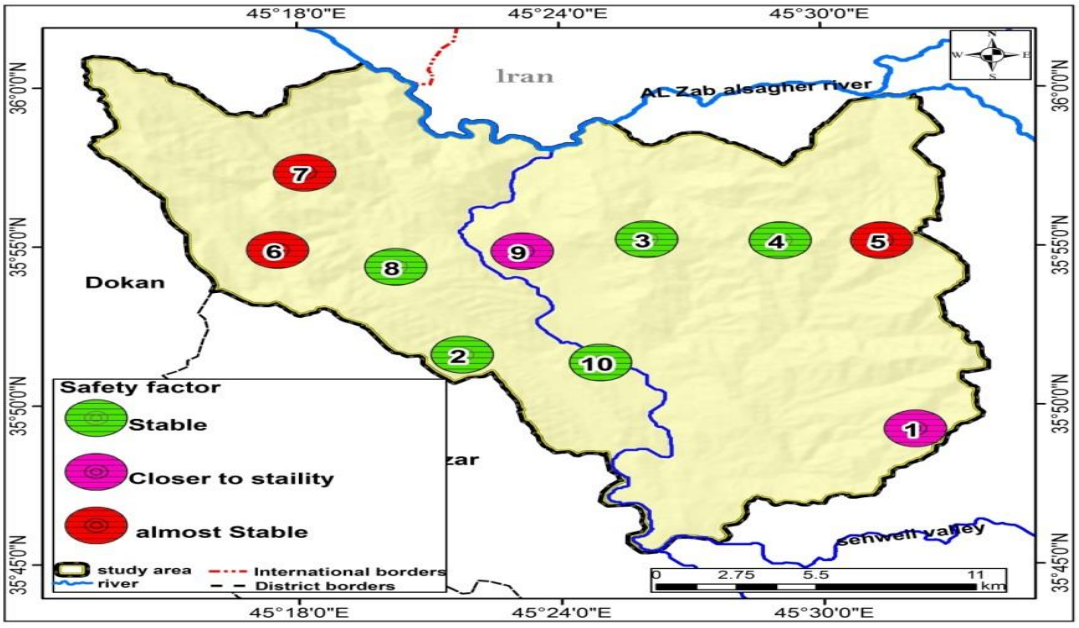
1-Shimelies Ahmed Aboye,2009, 2- B.Deoja ,M.Dhital ,B.Thapa, A.Wagner1991

Table (9) values of the safety coefficient and the speed of movement of materials on the slope sectors of the study area

sector	safety factor	Material movement speed m/s
1	1.5	14.2
2	2.8	10.1
3	2.4	10.3
4	2.5	10.5
5	1.1	16.5
6	1.1	19.3
7	1.1	18.7
8	2.1	12.6
9	1.5	13
10	2.9	9.9

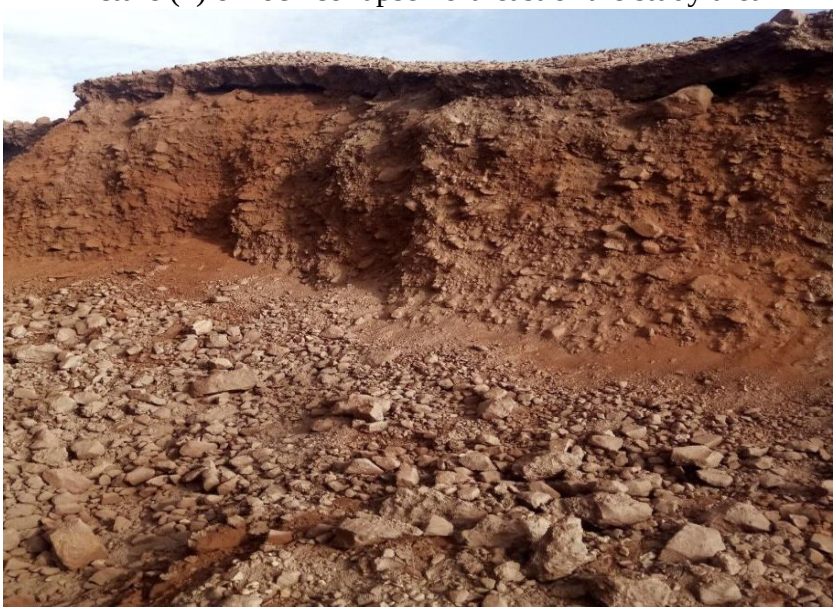
Source: The researcher based on the results of the safety equation, and the speed of movement of materials, and using the program (Arc Gis 10.8)

Map (6) the safety coefficient of the slopes of the study area



Source: the researcher based on the results of the equation of safety coefficient, and using the program (Arc Gis 10.8)

Picture (1) of rock collapse northeast of the study area



Field study on 1/6/2022

Picture (2) of the landing east of the study area

Field study on 3/6/2022

2- The speed of movement of materials on the slopes

The speed of material movement is one of the most important factors for measuring the degree of stability of slopes, and to measure this speed, a number of slope sections were selected within the slopes of the study area during the field study, map (7) and extracting the degree of elevation of the exposed surface by using the program (Arc Gis 10.8) and from Then extract the velocity of movement by the following equation

movement speed= $\sqrt[2]{2\text{exposed roof height}} \times 9.81$

After applying the equation and from Table (9), it turns out that the values of the movement speed of materials in the study area ranged between (9.9-19.3 m/s), as sector (6) recorded the highest value of

(19.3 m/s), which indicates the danger of a large movement and the reason is due to To the high altitude as well as the steepness, while sector (10) recorded the lowest value of (9.9 m / s) due to the lack of height and slope.

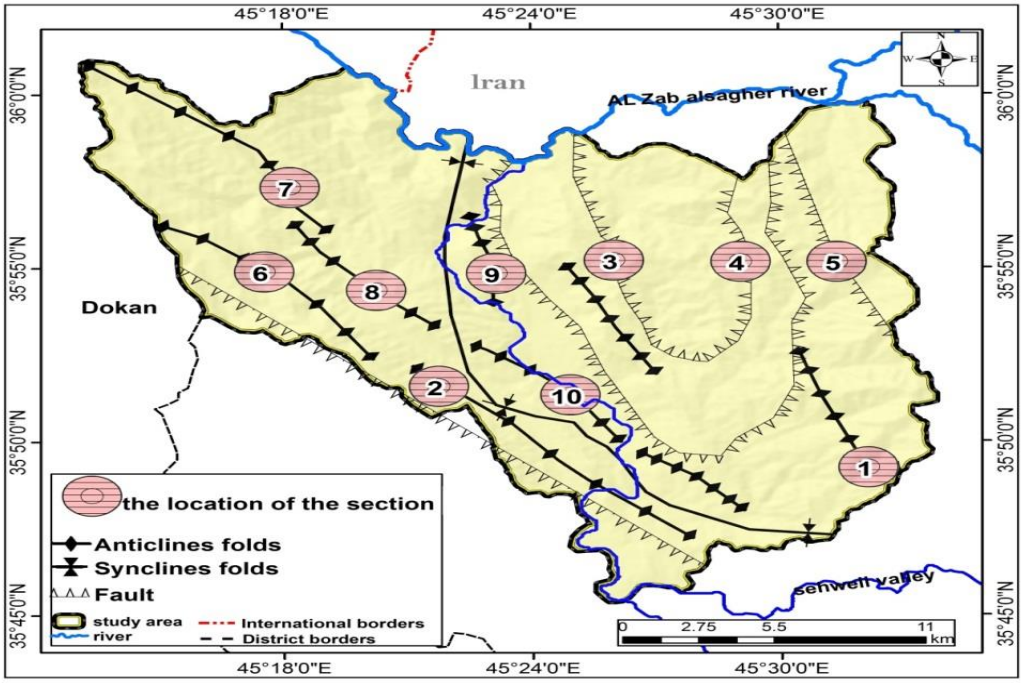
Picture (3) of the mudflow southeast of the study area

Field study on 1/2/2021

Picture (4) of the rock sliding southwest of the study area

Field study on 1/6/2022

Map (7) of the locations of the studied sectors



Source: the researcher based on the field study and the program (Arc Gis 10.8)

Conclusions

- The variation in the degrees of rock friction and the average slope led to the variation in the stability of the slopes of the study area between semi-stable slopes that are at risk of collapse and precipitation, and slopes close to stability, and stable slopes that are safe from the dangers of collapse.
- The variation in the geological structure, the degree of slope and elevation, as well as the density of the presence of natural vegetation, led to the variation in the speed of movement of materials on the slopes in the study area, between fast, moderate and slow movement.

Recommendations

- Surrounding steep slopes with weak rocks with iron nets to protect roads, residential areas, tourism and other activities.
- Planting trees in the slopes made of loose rocks to help stabilize the components of the slopes
- Cultivation of empty and few areas of natural vegetation with dense plants to reduce as much as possible the speed of movement of materials on the slopes of the slopes.

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