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Landslide variation with morphometric factors using the GIS techniques: The case of Shaqlawa Forest

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ABSTRACT

This study deals with the application of geographical information system (GIS) datasets and methods to assess the landslide susceptibility in Wadi Hujran. The area has a rocky terrain and belongs to the Shaqlawa district of the Kurdistan Region of Iraq. The region is placed towards the Northeast side of Erbil city. The region covers an area of 18.56 Km^2 (1856.1 ha) and consists of rough broken and stones. The watershed area is surrounded by North latitudes 36° 21' 53.514" to 36° 17' 49.7796" and East longitudes 44° 17' 5.658" to 44° 20' 9.06". Three factors, namely the morphometric, geological, and environmental, were used to prepare the landslide susceptibility index. The study made use of AHP method and prepared a landslide susceptibility map. Data related to geology, topography, hydrology, rainfall, and land use were used to prepare the map. Physical and statistical methods were used to validate the map. A heuristic approach was incorporated to produce the final susceptibility map. ArcGIS software was used to generate the landslide zones. A total of five landslide zones were generated, which varied from very low landslide zones (80.5) to very high landslide zone (84.5). The zones also included low landslide zone (1262.2), moderate landslide zone (1505.9), and high landslide zone (566.8), and the ratio of consistency in the present study was 0.06 AHP less than 1, and all the five zones in the study were compiled landslide zonation estimated.

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تباين الانـهيار الأرضي مع العوامل المورفوميترية باستخدام تقنيات نظم المعلومات الجغرافية ضمن غابات شقلاوة

سارة هيمان زكي/قسم الغابات/كلية الزراعة /جامعة صلاح الدين /اربيل
جيهان محمد شيخ سليماني /قسم الموارد المائية/كلية الهندسة /جامعة صلاح الدين /اربيل ,اربيل

الخلاصة

تتناول هذه الدراسة تطبيق مجموعات بيانات ونظم المعلومات الجغرافية والطرائق التي تستخدم لتقييم قابلية الانهيار الأرضي في وادي حجران.المنطقة تتصف بكونها صخرية تنتمي الى منطقة شقلاوة ضمن اقليم كوردستان العراق, تقع المنطقة باتجاه الجانب الشمالي الشرقي من مدينة أربيل. تغطي المنطقة مساحة 18.56 كم^2 (1856.1 هكتار) وتتكون من حجرمتكسروخشن حوض مستجمعات المياه في المنطقة محاط بخطوط العرض الشمالية 36° 21 '53.514" إلى 36° 17 '49.7796" وخطوط الطول 44° 17 '5.658" إلى 44° 20 '9.06" شرق خطوط الطول. استخدمت ثلاثة عوامل هي المورفومترية والجيولوجية والبيئية لإعداد مؤشر قابلية الانهيار الأرضي .استخدمت الدراسة طريقة عملية التسلسل الهرمي التحليلي وأعدت خريطة قابلية الانهيار الأرضي. واستخدمت البيانات المتعلقة بالجيولوجيا والتضاريس والهيدرولوجيا وهطول الأمطار واستخدام الأراضي لإعداد الخريطة. تم استخدام الطرق الفيزيائية والإحصائية للتحقق من صحة الخريطة وقد ادرج نهج الاستدلالية لانتاج خريطة الحساسية النهائية. تم استخدام برنامج نظم المعلومات الجغرافية لانشاء مناطق على الجانب الارضي وتم التوصل الى وجود خمس مناطق قسمت حيث قابيلة حدوث الانهيارات الارضية تراوحت بين مناطق الانهيارات الأرضية المنخفضة جدا (80.5) إلى منطقة الانهيارات الأرضية العالية جدا (84.5). وشملت المناطق أيضا منطقة منخفضة للانهيارات الأرضي (1262.2) ومنطقة انهيار ارضي معتدلة (1505.9) ومنطقة انهيار ارضي مرتفع (566.8) حيث ظهرتالمناطق الخمسة المرئية في الموقع في تطابق مع نسبة الانهيارات المقدرة في المنطق

1.INTRODUCTION

The mass movement of land on slope involves debris flow, rockfall, sliding, and topples. The main force behind the mass movement is gravity. Landslide happens as a consequence of different situations, such as saturated clay materials on the impermeable layer-specific in the steep slope areas. Soil moisture, with many factors, contributes to increasing the pore water pressure and leads to land movement.

The most common disaster that occurs in mountainous areas is landslides causing huge damages directly or indirectly. There are several studies about landslides estimating the risks of landslide hazards [6]. According to [12], in the study, there are five cases of landslides. These types are named: Falls, Topples, Slides, Spread, and Creeps. Each type of landslide occurs in specific conditions such as geological, topographical, or hydrological circumstances. The study also showed that the causes of landslides hazard are classified into geological, human, and morphological causes. The study of [7]. was applied to the delineation of high landslide risk areas based on three factors which include the elevation, rock types, and land cover.

[13]. Assessed the effect of landslide on the roads network and the economic development of the study area through trade, tourism, and social sector.[3]. And [2]. Conducted a study using freely available remote sensing products and GIS to determine landslide hazard maps, including geology, topography, land use, and climate data: frequency Ratio Model (FRM) and Analytical Hierarchy Process Model (AHPM). The study was based on the topographic data (slope, aspect, elevation), lithology, climate data (rainfall), land cover, and distance from roads, drainages, and fault. Integrating three models in a GIS environment are considered good estimators of landslide risks.

There are many locally conducted studies displaying the landslide hazard in different areas. [1]. conducted a study to estimate the index for Landslide Possibility Index (LPI) for rock slope. [4]. landslide risk based on the field samples of a slope, soil, and geological data. [14]. the study displayed different models to estimate landslide susceptibility Index (LSI), Compare Frequency Ration (CFR), Weight of Evidence (WOE), Logit Regression (LR), and Probit Regression (PR) models were integrated with new geomorphological records to gauge the avalanche hazard planning.

2.OBJECTIVES OF THE STUDY:

1. To estimate the effects of morphological, geological, and lithological factors on landslide
2. To determine the probability of landslides happening in our study area.
3. To validate and investigate the capability of GIS techniques and the AHP approach in landslide mapping.
4. To identify the areas posing a risk of the potential landslide.

3.NOVELTY OF THE WORK

The motivation for this study is: There are extensive impacts of land sliding, loss of lives and social disruption, destruction of built infrastructure, damage to land, and loss of natural resources. Landslide material can also block rivers and increase the risk of floods. Unfortunately, thus investigations in the study area have never been done before, and this study advances the knowledge in this field. There is a little type of researches that has been done on landslide zonation mapping in the region, and the findings of the previous studies most are manual, and the source of data is from site investigation only.

Morphometric factors

Morphological features are extracted using DEM.

1. Elevation (DEM)
2. Slope
3. Slope Aspect
4. Slope Curvature

NDVI

NDVI is used to assess the live green vegetation on the target. This is the primary method used to assess the land cover's impact in the vent of landslide hazard assessments. The method has proved significant in predicting landslides.

STUDY AREA

The site has been visited, and the image has been collected by (GPS). The study area is located in the north-eastern part of Iraq within in Kurdistan Region. The study area is situated in the Erbil governorate within the Salahaddin district. It is located in the northeast of Erbil city, the capital city of the Kurdistan region, as shown in figure (1) and figure (2). The watershed of the study area follows under 36° 21' 53.514" to 36° 17' 49.7796" North latitudes and 44° 17' 5.658" to 44° 20' 9.06" east longitudes. The study area occupied an area of 18.56 Km^2 (1856.1 ha), which lies wholly in the mountainous terrain area and consists of rough broken stone, where the characteristic of the mountainous area consists of shallow lithosolic soils in limestone, steep slopes, rock-crop, and deep valleys as the description in soil map of Iraq by Buringh 1960. The elevation of the study area varied between 837-m to1534-m above sea level (ASL). The higher elevation areas are in the north part, while the lower elevation areas are in the south part of the study area, as shown in the Digital Elevation Model (DEM) of the study area. The climate of the study area is the Mediterranean climate region, cool snowy in winter and warm dry in the summer. The rainfall average in the watershed is around 679 mm, which starts from October to May.

The geology of the study area consists of four formations; Tanjero, Shiranish, Qamchuqa, and Kolosh formations. The lithology includes sandstone and claystone with conglomerate, well-bedded limestones, and blue mari, mainly massive limestones and dolomites, and finally, the lithology of the study area also consists of black claystone, siltstone, and sandstone as depicted in the Geologic map of Iraq and field data collection. Land use and land cover of the watershed include different types of land classification. The land is covered by grassland, trees, cropland, pastureland, shrubland, built up and bare soil. [10]. Five locations in the study area were observed by site and recorded land sliding, which their coordinates were measured by GPS, and they were in good agreement with the findings of this study by using AHP techniques and GIS tools

4.MATERIALS AND METHODS

DEM was downloaded from the USGS website. DEMs values are arranged in a matrix data with defining coordinate system which has geo-reference according to UTM-WGS-84-zone-38N projected coordinate system. As shown in Figure (1).

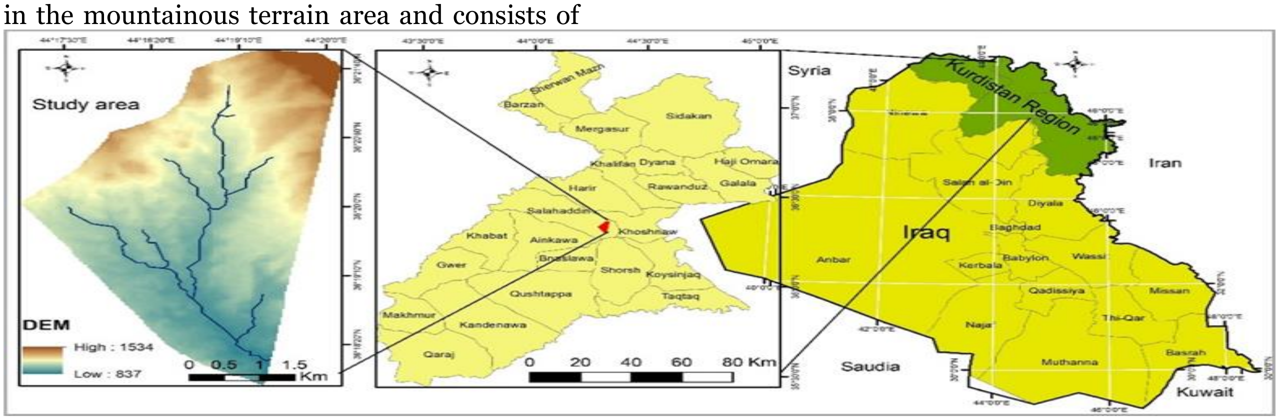


Fig.1. Digital Elevation Model (DEM) of the study area

The study area was visited, and Five locations were selected to compare the results of sliding with the findings in this study using AHP techniques and GIS tools.
The DEM on the study area was recorded in 30-m resolution. The study depends on different thematic layers to estimate the landslide risk, including slope value, rainfall, geology, land use, slope aspect, elevation, normalized difference vegetation index (NDVI), distance to drainage network, and distance to roads. All thematically produced layers were combined using the weight of criteria, which was identified by the Analytic Hierarchy Process (AHP) model to extract the landslide susceptibility map. GIS has powerful tools to integrate different types of the layer from various sources by the combination of the weighted linear combination (WLC) method.

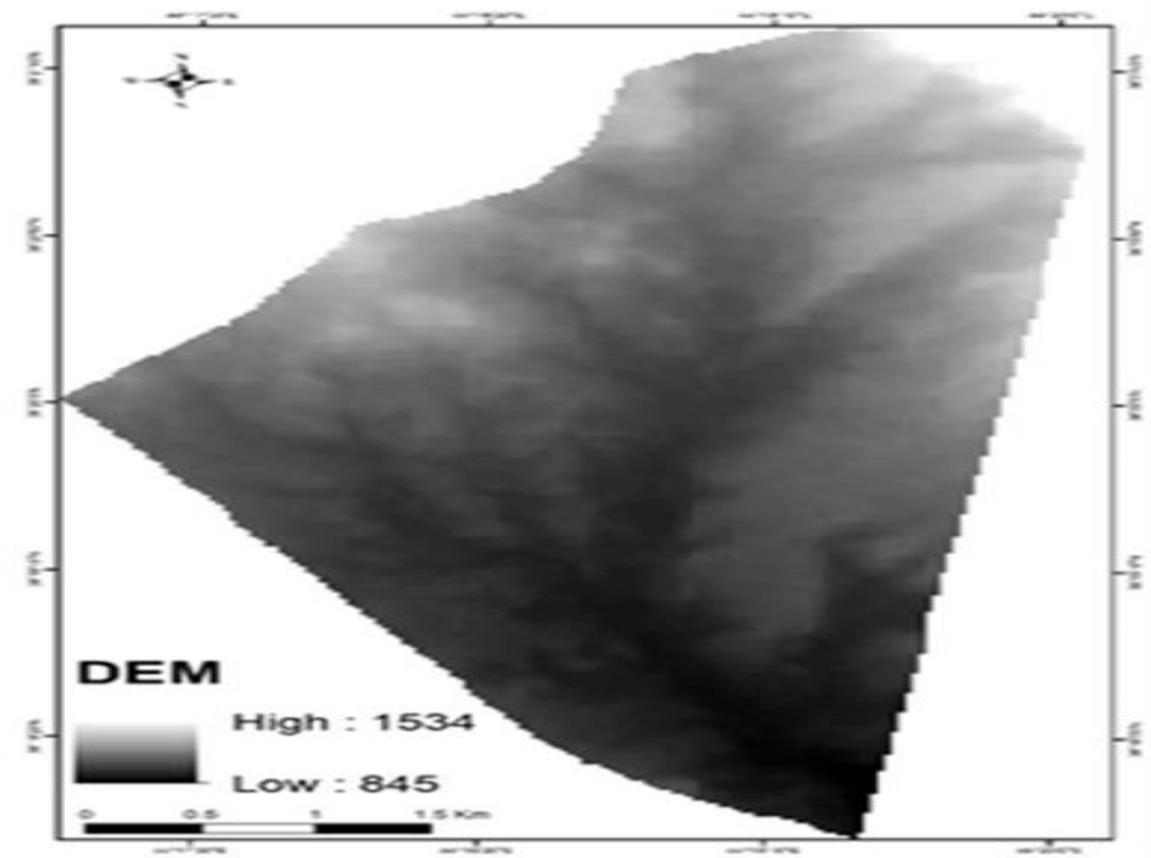


Fig.2. Digital Elevation Model of the basin

Calculating algorithm of downhill slope of the pixel depends on the 3 × 3 widows around the processing of center cell

Slope in radians = ATAN (√ ([dz/dx]2 + [dz/dy]2) (1)

Slope in-unit degree uses the algorithm of formula (2)

Slope in degrees = ATAN (√ ([dz/dx]² + [dz/dy]²)) * 57.29578

Aspect

[dz/dy] = ((g + 2h + i) - (a + 2b + c)) / 8 (3)

Where [dz/dy] is the rate of aspect in the y-direction

Aspect = 57.29578 * atan² ([dz/dy] - [dz/dx]) (4)

Normalized difference vegetation index (NDVI)

NDVI = (NIR - R) / (NIR + R) (5)

where, NIR = Near Infrared band and R is the red band.

NDVI values are represented as a ratio ranging between -1 to 1. Negative and zero values of NDVI values refer to a water body, built up, bare soil areas, while positive values represent the amount of green biomass.

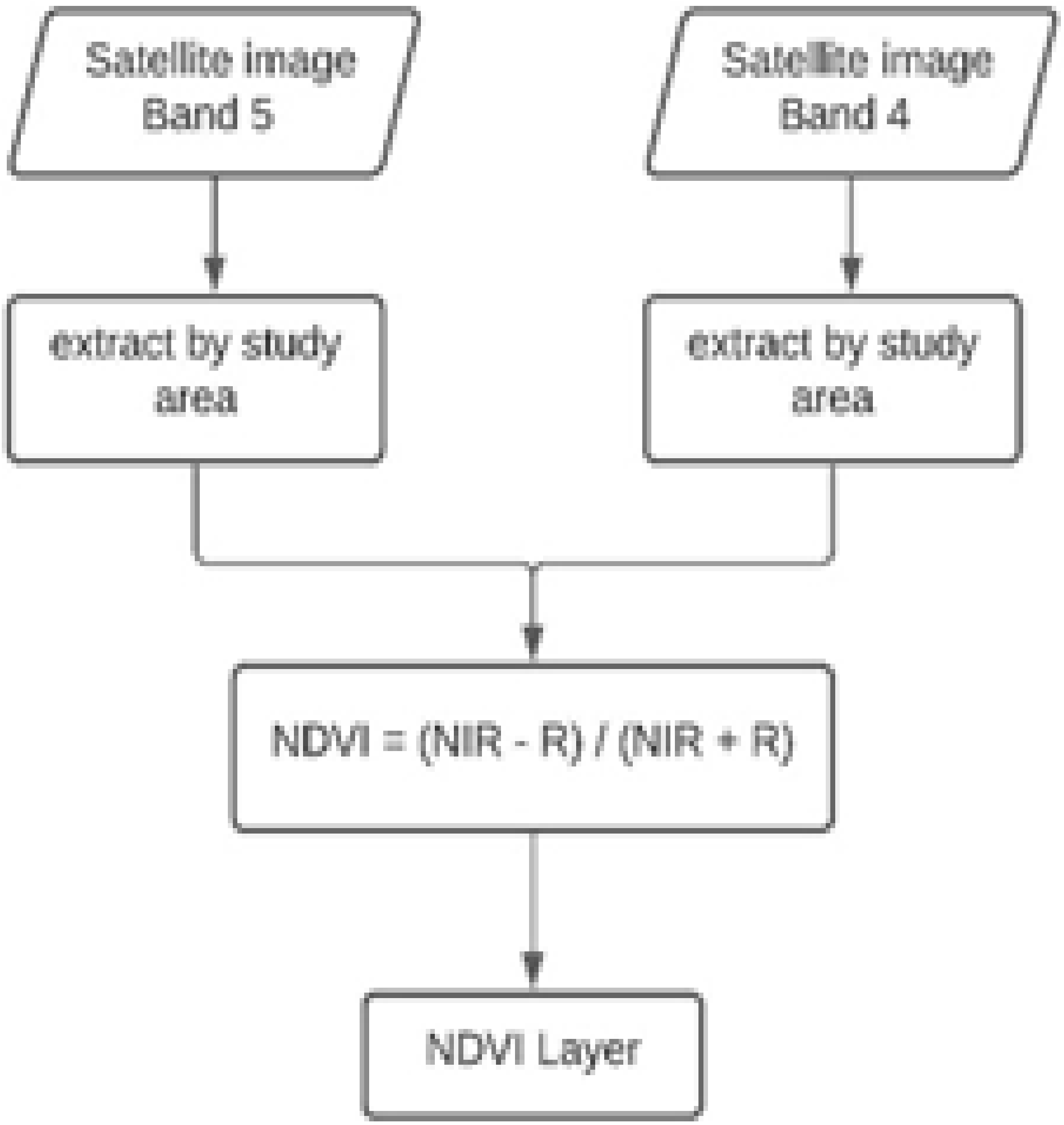


Fig.3. Schematic Diagram of NDVI

The study area by the site has been visited, and images have been collected by (GPS). Among 12 samples that have been collected (5), only was complies with landslide zonation estimated by this investigation. The landslide map was divided into very low landslide zone, low landslide zone, moderate landslide zone, high landslide zone, and very high landslide zone.

Figure (4) shows a flowchart of landslide processes.

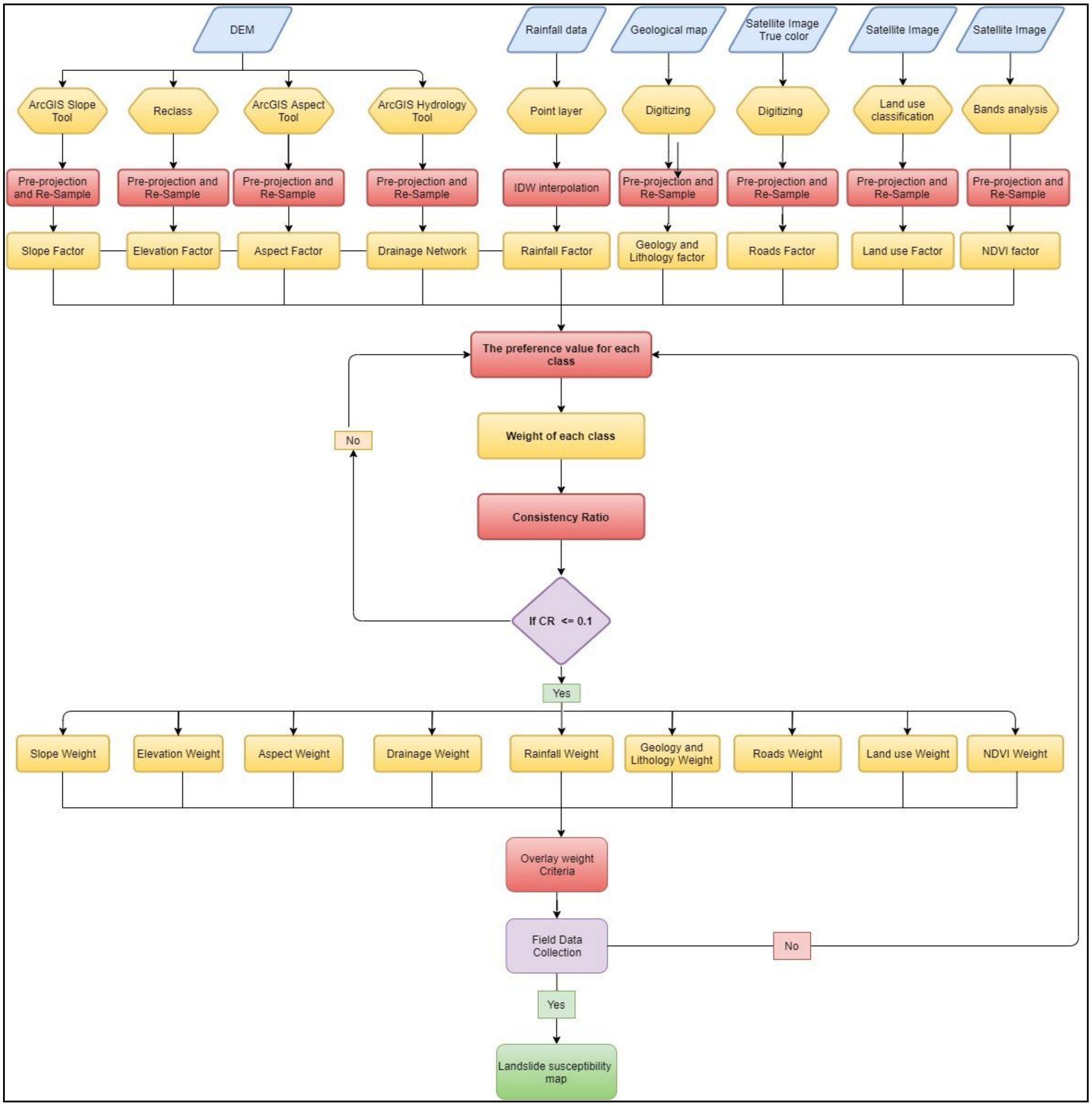


Fig.4. flowchart of landslide processes.

5.RESULTS AND DISCUSSION

Vegetation cover was derived from the NDVI method based on Landsat OIL-8. The study area was divided into six classes of dense vegetation in order to show the spatial distribution of vegetation in the study area, as shown in Table 1. [15]. NDVI factor was derived from Equation 1. No vegetation area represents water and built-up area which has covered around 1.35% of the land area, and less vegetation area refers to NDVI bare soil area occupying 7.38% area while 44.2% of the study area was occupied by less to moderate vegetation area. All these areas located within no vegetation, less vegetation, and less moderate vegetation are prone to occurrence failure soil and landslide susceptibility. These zones in the study area were assigned high values of ranking. Otherwise, dense and very dense vegetation spatial distribution occupied more than 3.39% of the study area, and theses area were assigned a low degree ranking to estimate landslide hazard, see Figure(5)

Table 1.
Distribution of vegetation cover

NDVI class	-0.138-0.092	0.092-0.229	0.229-0.313	0.313-0.385	0.385-0.452	0.452-0.548
Area(ha)	25.69	140.27	840.27	829.82	0.56	64.41
Area%	1.35%	7.38%	44.20%	43.65%	0.03%	3.39%
Land class	No Vegetation	Less Vegetation	Less Moderate Vegetation	Moderate Vegetation	Dense Vegetation	Highly Dense Vegetation
Ranking	9	8	6	4	2	1

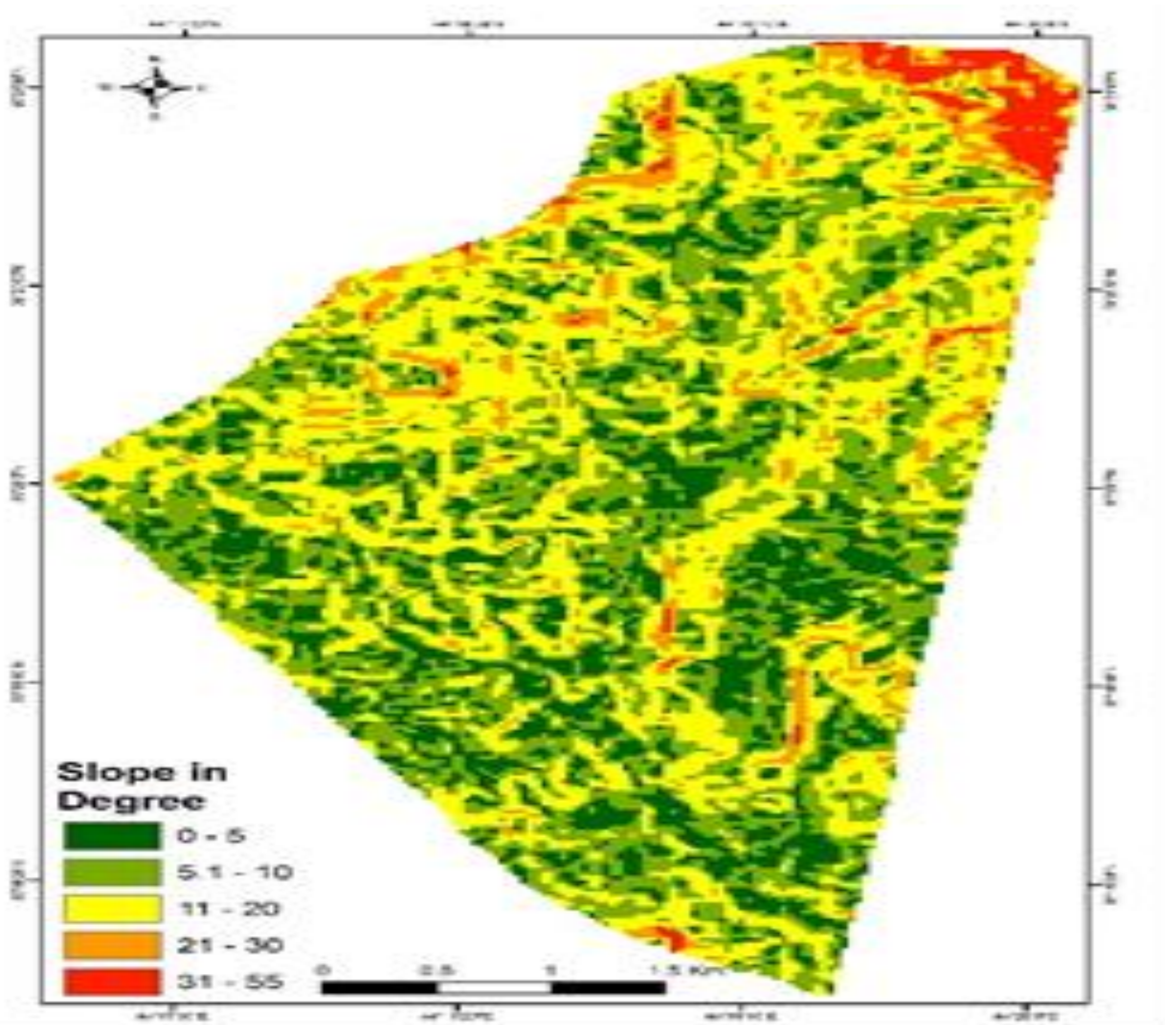


Fig. 5 distribution of vegetation cover

The vegetation is suitable in areas to increase infiltration rate and reduce the surface water, while the bare soil, roads network, drainage, and built-up areas decrease the infiltration and increase the rate of runoff (Souissi et al., 2020). The land use and land cover consist of buildings distribution, roads, drainages, shrubland, grassland, and bare soil, as shown in figure (6).

The grassland area occupied 48.4% of the study area, while the built-up area, which consists of buildings region and roads network, covered around 0.7% area whereas other categories of land cover, including shrubland and bare soil, covered around 37.2% and 13.7% area respectively.

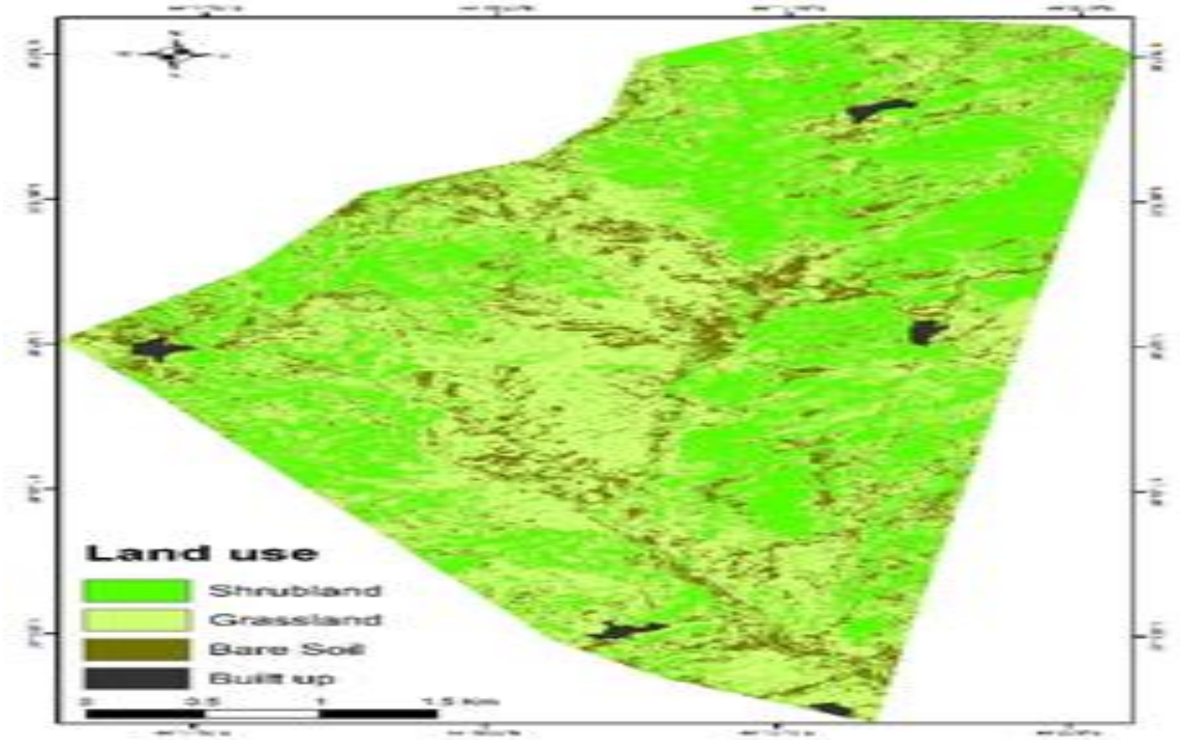


Fig.6. spatial distribution of land use and land cover

The saturation degree of the soil texture directly impacts the slope stability. Therefore, the slope degree of the drainage areas affects the landslide susceptibility, especially in the wet season(Ghanavati, 2018). Euclidean distance was used in Arc GIS to divide the study area into 9 zones, as shown in figure (7).

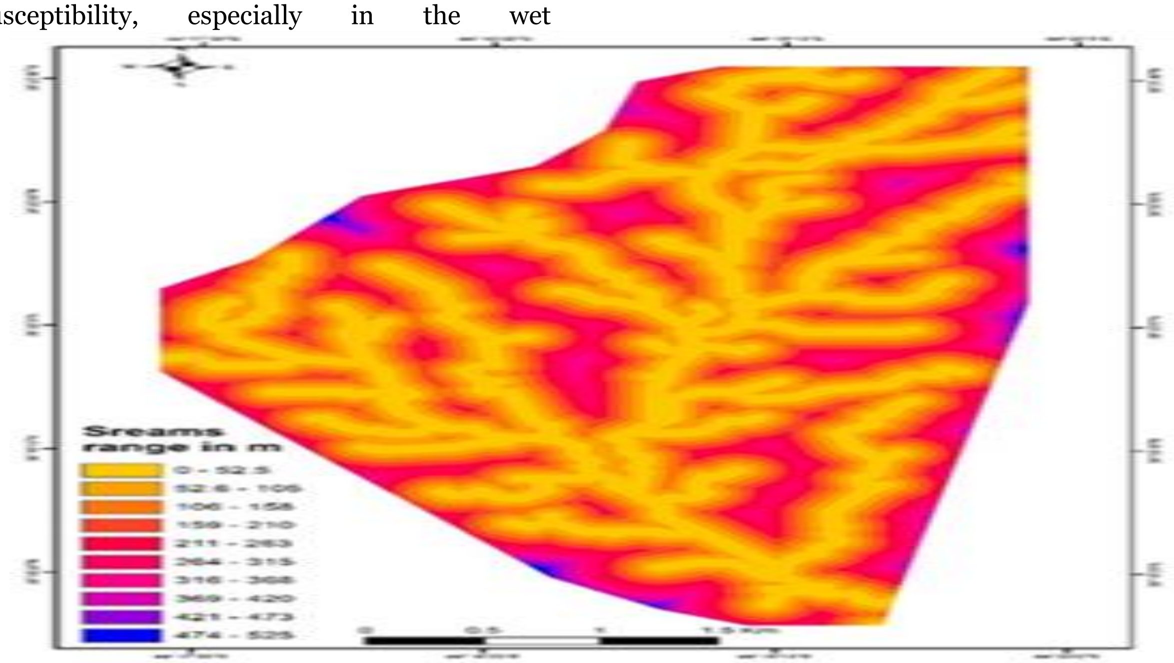


Fig.7. the spatial distribution of streams

Road's network is distributed on most of the study area, some of these roads are paved, and other unpaved, and these roads pass through slope areas as shown in Fig 8

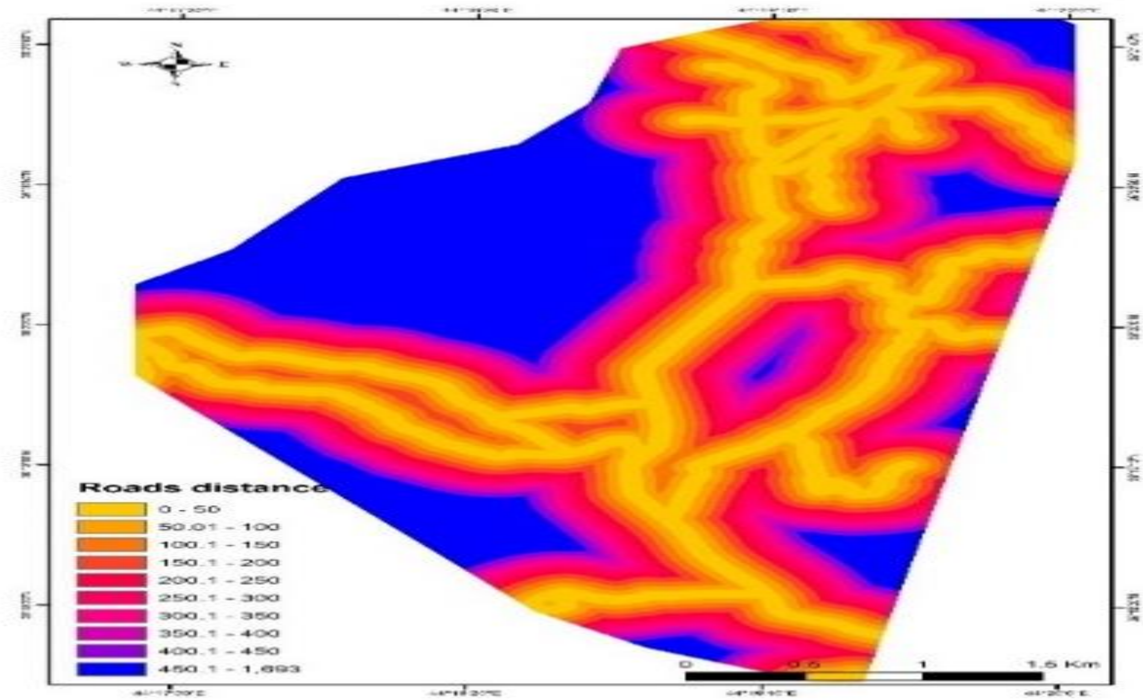


Fig.8. illustrates the road Euclidean distance method

Landslide risk zonation is classified into five zones, as shown in figure (9)

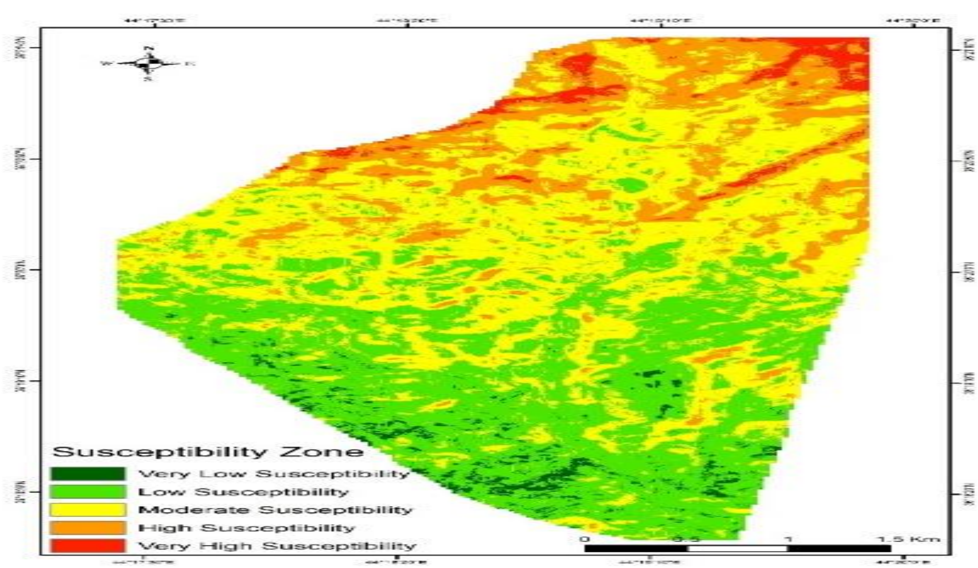
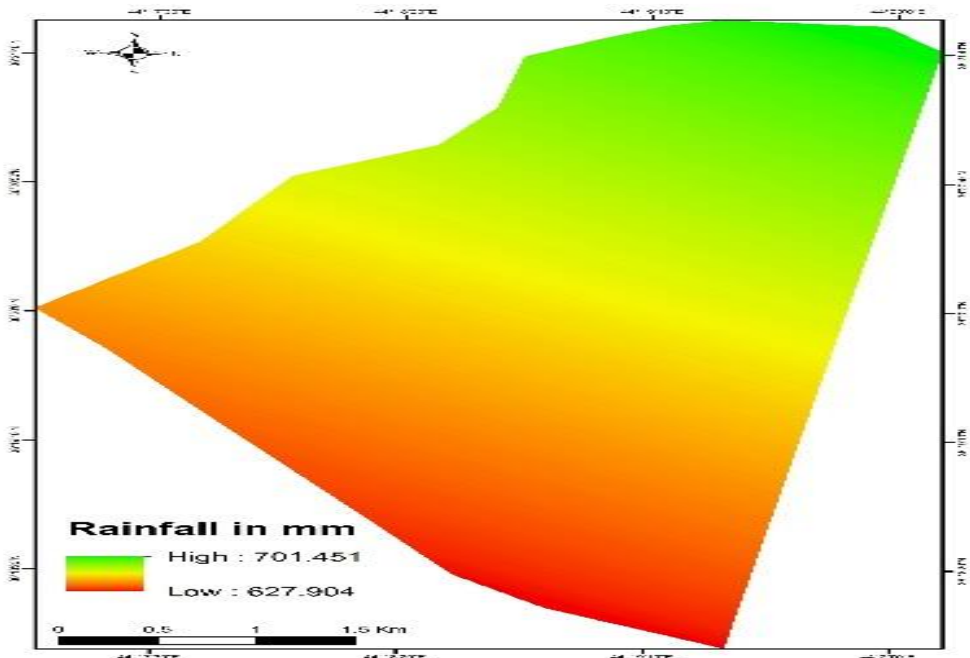


Fig.9. landslide hazard zonation

The monthly rainfall average was used to estimate the spatial distribution of rainfall in the study area from 2004 to 2017, as displayed in figure (10).



"Fig.10." spatial rainfall distribution

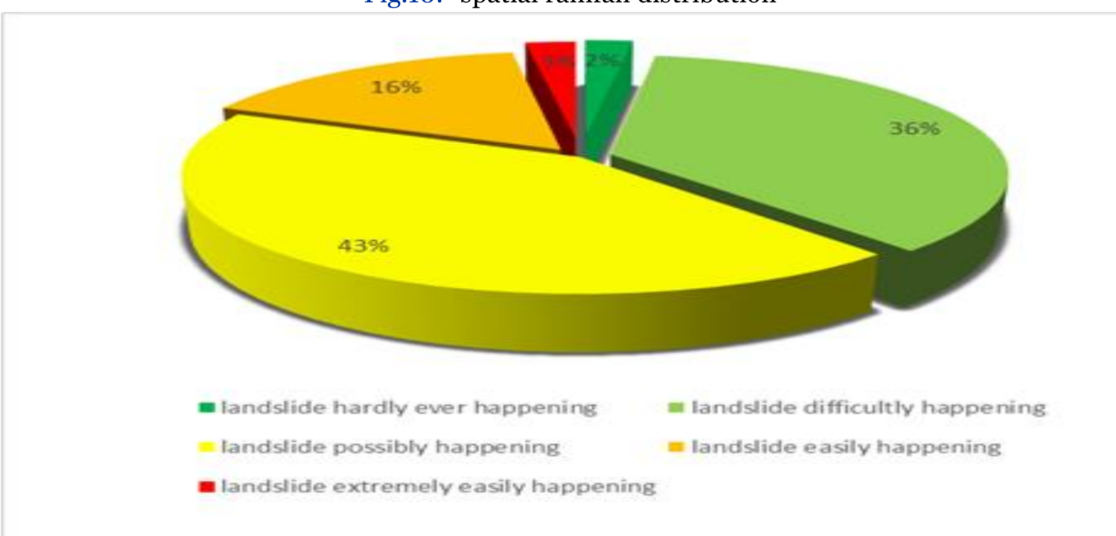


Fig.11. landslide percent

The study area by the site has been visited, and images have been collected by (GPS). Among 12 samples that have been collected, Five only complied with landslide zonation estimated by this investigation. Records of Five locations in the study area were observed by site and recorded land sliding, which their coordinates were measured by GPS, and they were in good agreement with findings of this study by using AHP techniques and GIS tools.

The landslide map was divided into very low landslide zone, low landslide zone, moderate landslide zone, high landslide zone, and very high landslide zone, as shown in Figure (12).



very low landslide zone **low landslide zone** **moderate landslide zone**


High landslide zone **very high landslide zone**

Fig.12. landslide susceptibly zones in the study area

6.CONCLUSIONS

In the present study, the following conclusions are summarized:

1. Predicted susceptibility map zonation agrees with the past landslide occurrences investigated in the site.

2. Integration of GIS techniques with an AHP developed by Saaty-(1987) provides a powerful tool for determining the susceptibility of landslides in the study area that does not have sufficient historical records and can help in mitigating the potential impact of morphometric geological and lithological factors on a landslide.

3. Impact of each criterion to estimate landslide hazard was assigned using the AHP model. Landslide zones were generated from Equation 2 to integrate criteria layers by ArcGIS software. Landslide risk zonation is classified into five zones.

4. Landslide risk zonation is classified into five zones; the landslide map was divided into very low landslide zone (80.5), low landslide zone 1262.2), moderate landslide zone (1505.9), high landslide zone (566.8), and very high landslide zone (84.5).

5. The ratio of consistency in the present study was 0.06 after applying Equation 4. The value of consistency ratio shows that the consistency between factors recognizes the weight of criteria as a parameter to estimate landslide susceptibility.

RECOMMENDATIONS

1- It is strongly recommended that the study of landslide zonation hazard mapping should cover the entire watersheds in the Kurdistan region
2- Landslides have some positive effects as creating new habitats, increasing biodiversity, providing raw materials and can be good tools for studying the

environment. The researcher strongly recommends studying.

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