J. Appl. Environ. Biol. Sci., 5(8S)641-647, 2015

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Landslide Hazards Zonation in Sattar Khan Dam Watershed Basin, using Analysis Hierarchal Process Method

Somayeh Nemati[1,*], Naser Abdi[2]

1*-Responsible Author: Department of Geology, Ahar Branch, Islamic Azad University, Ahar, Iran
2- Department of Geology, Ahar Branch, Islamic Azad University, Ahar, Iran
Received: March 8, 2015
Accepted: May 10, 2015

ABSTRACT

Landslide is referred to mass movement of stone or soil which happens naturally and influenced by different factors such as gravity at slopes, bearing extensive damages. Identification of places with higher landslide occurrence risk by different methods can be effective for prevention and reduction of damages caused by such natural phenomenon. One of these methods is landslide hazard zonation by Analysis Hierarchal Process (AHP) method. In this method, first, landslide maps of the area are prepared using aerial photos and field studies. Then, the controlling factors of lithology, level of slope, slope direction, land use, mean monthly rainfall, closeness to fault, distance from waterway and height, are selected based on their close relationship with landslide in underlying watershed basin, in order to provide schematic maps in GIS and to provide vulnerability maps. With expertise investigations of these factors in landslide, every factor divided into several classes. Then weights values are dedicated to raster layer and classes of each layer, respectively. In this study, AHP method was used for this aim. Finally through combining and overlapping schematic maps, the vulnerability map of the studied area was prepared by using weights obtained from above mentioned method. The results indicate, about 11.33% of total studied area has higher probability of landslide.
KEYWORDS: zoning, Sattar Khan Dam watershed basin, landslide, AHP

1. INTRODUCTION

Landslides are mass movements of rock or soil that happen naturally and as being influenced by several factors, especially by the force of gravity on steep slopes [1]. Landslides hazard zoning simply is dividing the study area into zones with nearly similar risk [2].

The study area is Sattar Khan watershed basin of Ahar, this dam is located in 15 km west of the Ahar city in east Azarbayejan province, in north-western of Iran and is located on Ahar-chai river. This watershed basin is limited from north to the Songoon mining of copper and the heights overlooking its south, from the south to the around the GooreDargh village and the heights overlooking the west of the village, from the east to the Masgharan village and the valley overlooking it, and from the west to the Alvigh village. This area is placed between latitude 38° 41' 23" to 38° 23' 31" north and longitude 46° 34' 16" to 47° 01' 32" east and the distance to Tabriz is about 110 km. In general, the area of the study region is 60188 hectares (equaling 601.8 square kilometers) and the approximate height of its highest point is 2760 meters and at lowest point is 1380 meters above sea level, its average height is 2067 meters above sea-level, with an average annual rainfall of 320 mm and an average temperature of 10.6° C has a semi-arid cold climate (Fig. 1).

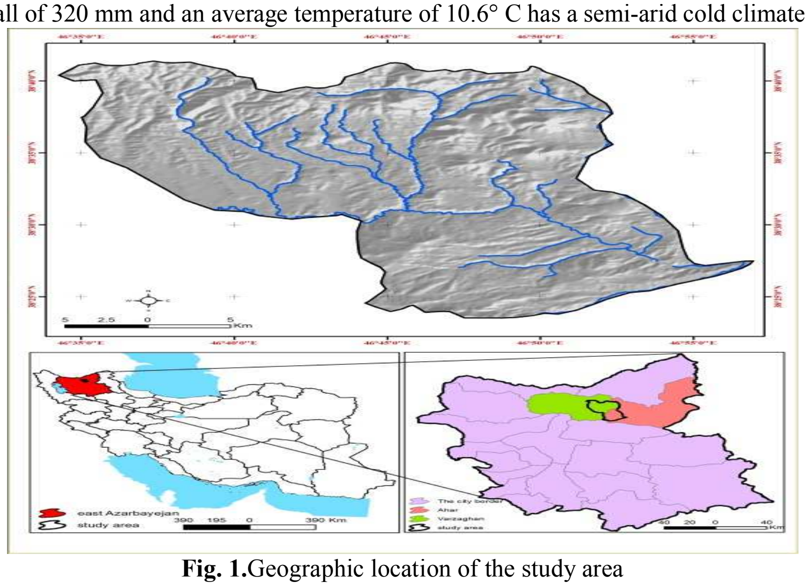

Fig. 1. Geographic location of the study area

Corresponding author: Somayeh Nemati, Department of Geology, Ahar Branch, Islamic Azad University, Ahar, Iran (somaye_6966@yahoo.com)

2. DISCUSSION

Given the region's susceptibility to landslides and large landslides in the region, the need to identify factors contributing to the occurrence of this natural phenomenon appears a necessary and obvious matter. Therefore, to perform this important goal, we started to identify and evaluate the landslides occurred in the study area and the important parameters in the occurrence of landslide were evaluated and extracted.

From general point of view, we can classify the factors affecting the occurrence of landslides into three main categories [3], that these factors are: 1- geological factors 2- morphological factors 3-human factors. Each of the above factors, affect the landslides occurrence through different ways.

By examining factors affecting the landslides occurrence and in order to prepare the vulnerability map of the area, 8 controlling factors were extracted in the study watershed basin based on their relationship with the landslide occurrence and these factors include lithology, level of slope, slope direction, land use, mean of monthly rainfall, closeness to fault, distance from waterway and height. The factors which are affecting landslide, are as following:

2.1. Factors affecting landslide

2.1.1. Lithology

Because lithological changes often lead to differences in resistance and permeability of rocks and soils, therefore, the influence of lithology on the landslide occurrence is widely accepted. In this study the basic information used to prepare the main geological map with vector format from the available geological maps published by the Geological Survey of Iran was obtained at a scale of 1: 250,000. In preparing the geological map, all rock groups including igneous, metamorphic and sedimentary and not consolidate deposits by taking the resistive, physical, formation conditions, and tissue indexes were classified into 10 groups (Fig. 3). And finally the area of each landslide occurred in each unit was calculated (Fig. 2) and (Table 1).

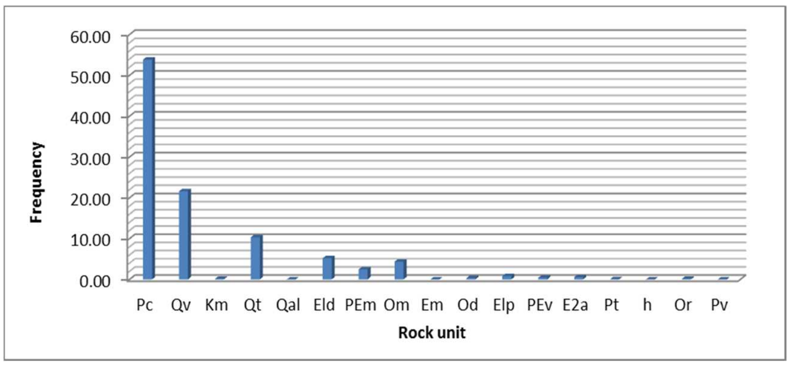

Fig. 2. Diagram of the frequency of landslides in different rocks

Table 1. Classification of intrinsic sensitivity of rock and soil units

Sign	Lithology description	Class name	Class
Pc	Conglomerate and siltstone	Ultra weak	9
Qv	Alkali and esiteand basalt	Weak	7
Km	Marl, molasses and sandstone	Very weak	8
Qt	Siltstone, conglomerateand travertine	Ultra weak	9
Qal	Recent alluvium	Quietly loose and detached	10
Eld	Dacite, trachyandesiteandignimbrite	Average	5
PEm	Marl, limestoneandsandstone	Weak	7
Om	MicroMonzoniteand related trachyandesitic dykes	Average to weak	6
Em	Marland nummulitelimestone	Weak	7
Od	Dasitic breccia	Average	5
Elp	Megaporphyriticlalite	Average to resistant	4
PEv	Submarine volcanics_pyroxeneandesite,analcimetephrite and trachyte	Average to resistant	4
E2a	Latiteandandesite	Average to resistant	4
Pt	Trachyandesitic dome	Resistant	3
h	Hydrothermalalteration zone	Average	5
Or	Rhyolitedomesandignimbrite	Resistant	3
Pv	Volcano_sedimentary conglomerate	Highly resistant	2
E2l	Latiteandignimbrite	Highly resistant	2
Pi	Ignimbrite	Ultra resistant	1

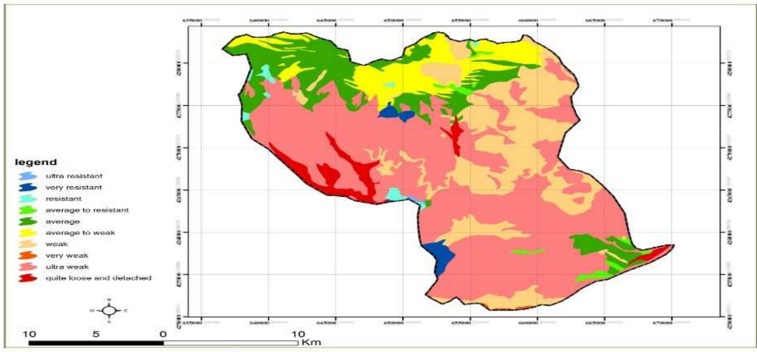

Fig. 3. The sensitivity map of lithological units classified in the basin

2.1.2. Slope level

The main parameter of stability analysis of slope is the angle of slope [4]. Because the slope level is directly involved with landslide occurrence, it is often used in the preparation of a landslide hazard zoning map [5], [6], [7], [8]. It controls the slope of the speed and flow of underground water and also the rate and content of soil moisture. As the slope increases, the tension and cut in the cover of disconnected soils increase in overall. The slope level in the study area changes between 0/01 to 35/5 degree and the levels were classified into the following five classes: a) Very light: 0/01 to 4 ° b) light: 4 to 12 ° c) Medium: 12 to 24 ° d) steep: 24 to 32 ° e) precipice: more than 32 ° (Fig. 5). About 63% of landslides occurred on slopes between 4 to 12 ° (Fig. 4).

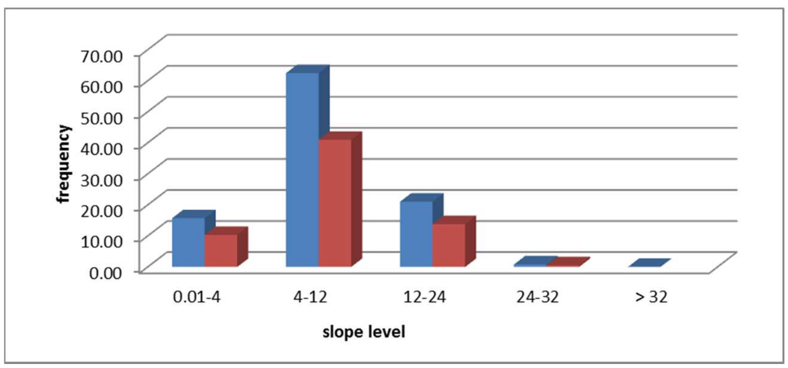

Fig. 4. Diagram of area and frequency of landslides occurrence in different slopes

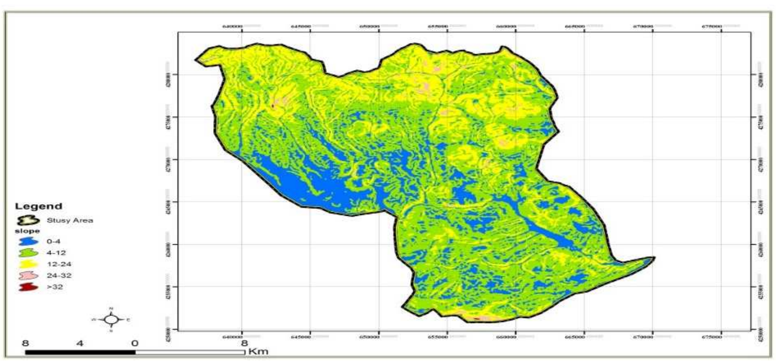

Fig. 5. Classification map of topographical slope

2.1.3. Slope Direction

As the slope direction is related with the parameters such as the percentage of sunlight absorption, drying winds and rain, is considered as a significant factor in preparation of vulnerability map of landslide [9], [10].

Areas of slope direction were classified into eight classes that based on the analysis of the relationship between slope and the occurred landslides it was revealed that the most landslides have occurred in the north direction and fewest landslides in the south west direction. (Fig. 6).

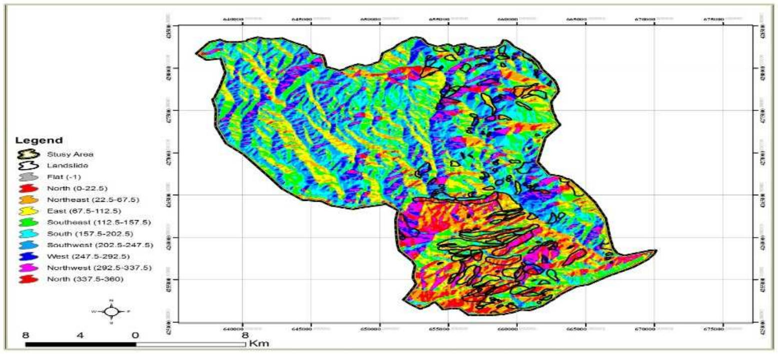

Fig. 6. Classification map of topographical slope direction

2.1.4. Landuse

The effect of soil coverage on slope stability can be explained by its hydrological and mechanical effects. Soil coverage serves as a shelter and decreases the soil vulnerability to erosion, landslide and the amount of received water from rain. Vegetation changes the soil hydrology by increase of water accumulated between leaves, infiltration and evaporation and transpiration to a great extent. Water accumulated between leaves and evaporation and transpiration reduces the amount of water that reaches the soil and get stored in it. During short-term heavy rainfalls the soil cover does not have a vital function because it generally triggers shallow landslides, but in the long-term rainfalls the water evolution in the soil is important. Roots increase soil permeability and thus increase the transudation rate and hydraulic conductivity that causes more accumulation of water in the soil during two short-term and long-term rainfall periods. Vegetation also through strengthening of the soil and loading on the slope, changes some of its mechanical features and increase of soil resistance, due to strengthening of the root, has great potential for reducing the rate of landslides occurrence [11]. By preparing the land use map by satellite images and aerial photos, the study area was divided into eight different uses (Fig. 7).

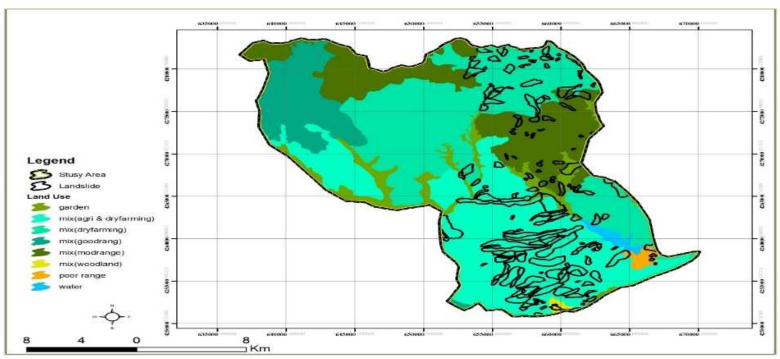

Fig. 7. Landuse map of the study area

2.1.5. Rainfall

The rainfall data related to 22 stations in the region and its neighborhood were collected and analyzed for investigating of the effect of rainfall on the increase of the risk of instability, No significant difference was found in the rainfall amounts of the area and it has relatively minor changes by increase of height and in the high mountain area of the region it reaches more than 500 mm. Taking this factor in the study area into account, its thematic map was prepared and was classified into 7 different classes with different monthly rainfall average rate (Fig. 8). Potentially, more rainfall rate provides more favorable conditions for landslide occurrence. The impact of rainfall has been specified both on soil moisture increase, resulting in increase of landslide occurrence potential, and as a factor starting landslides in the condition of heavy and long term rains.

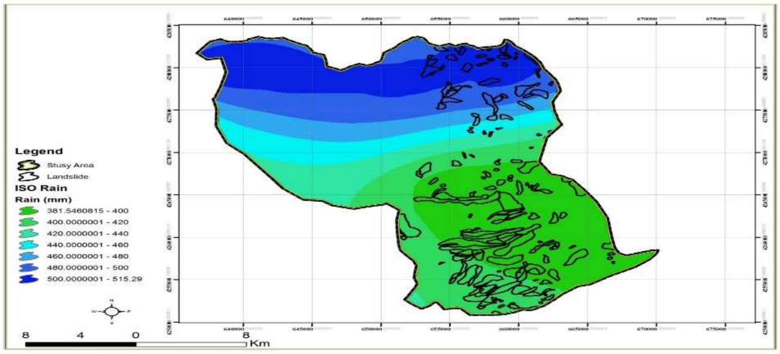

Fig. 8. Map of the areas with the same rain in the study area

2.1.6. Distance from the waterway

Nearness of the slopes to drainage structures directly affects the degree of materials saturation and slope stability. The drainage network can have negative effect on the slope stability through erosion of slopes or by materials saturation of lower part of domain which in turn leads to the stagnation level rise [12].

The main waterways of the study area were divided to six spaces with a range of 0 to 200 meters, 200 to 400 meters, 400 to 600 m, 600 to 800 m, 800 to 1000 m and more than 1000 m (Fig. 9). Generally, with increase of the distance from drainage network, the risk of landslide occurrence reduces. Studies showed that the highest percentage of the available landslides have occurred in the distance 0 to 200 meters of the waterways (Table 2).

Table 2. Area and frequency of landslides occurred in different spaces of the waterways

Space (meter)	Area of total landslide	The frequency of landslide
0-200	12.3	31.44
200-400	8.9	22.71
400-600	7.18	18.33
600-800	5.69	14.53
800-1000	5.08	12.97

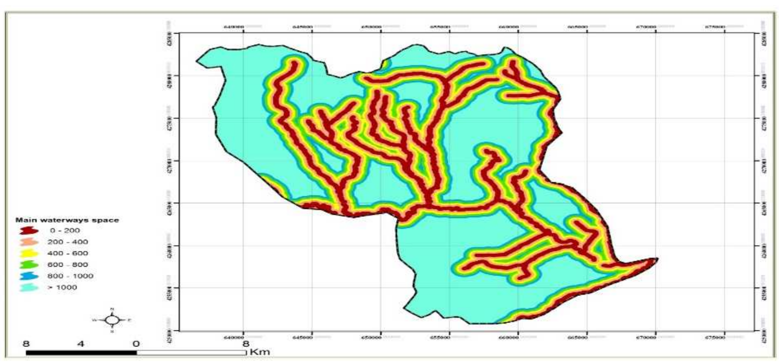

Fig. 9. Map of distance space from the main waterways

2.1.7. Distance from faults

Fault zones, by creating steep slopes, weak shear areas and fractured rocks, increase the potential of landslide occurrence. Landslide is caused by placing permeable rocks at the top and rocks or formations with low permeability at the bottom, that this process is usually diagnosed by the spring. Main faults and thrusts of the study area were extracted and numbered through geological maps and was appointed as a vector layer. On this layer, the distance function was applied as space zones along structural discontinuities and six buffer zones were created each with 400 meters distance (Fig. 10). Studies show that structural phenomena have a significant impact on landslide occurrence as with increasing distance from tectonic lineaments, the frequency of landslide decreases.

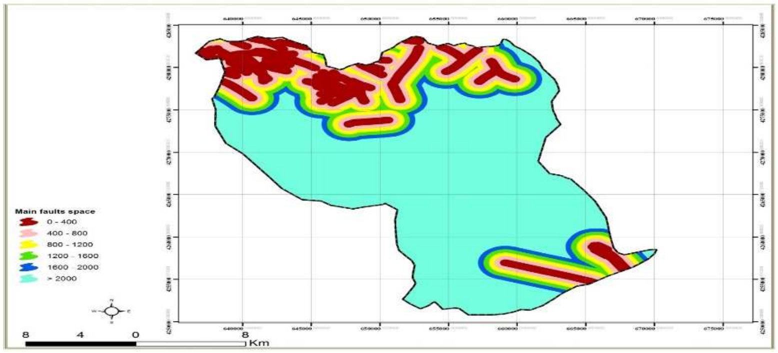

Fig. 10. Distance space from major faults

2.1.8. Height

Height changes affect the degree of weathering of rock units as with increasing of height and humidity, chemical reactions get accelerated that results in increase in weathering and possibility of landslide occurrence. According to the range of height changes in the study area, thematic map of height was divided to eight classes with the ranges of 200 meters (Fig. 11) and the results show that about 65 percent of the landslides occurred in the height range of 1550 to 1950 meter (Table 3).

Table 3. Area and frequency of landslides occurred at different heights

Height (meter)	Landslide area	Frequency in percentage	Cumulative frequency
>1350	0.00	0.00	0.00
1350-1550	8.93	13.58	13.58
1550-1750	27.28	41.46	55.04
1750-1950	16.14	24.52	79.56
1950-2150	6.07	9.22	88.78
2150-2350	5.7	8.66	97.44
2350-2550	1.54	2.33	99.78
2550-2750	0.15	0.22	100

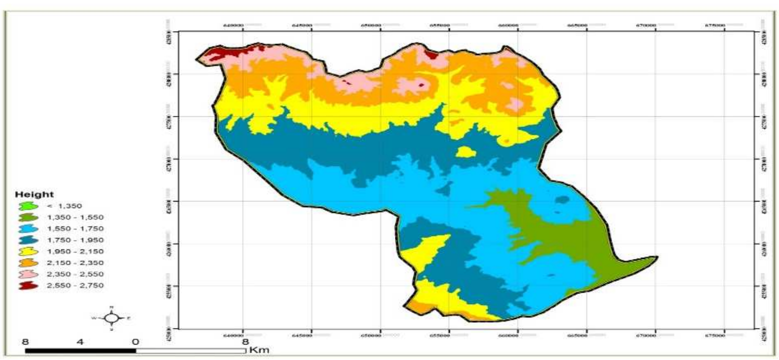

Fig. 11. Height classification of the study area

2.2. Integration and modeling

Integrating data layers is the key section of landslide hazard zoning because not using the correct way to integrate data, can result in confusion and lack of access to the correct results. First the factors affecting landslide were selected. Then each factor was classified into multiple classes. In the next step weight values were allocated respectively to raster layers (factors) and classes of each layer and for this the method of Analytical Hierarchy Process (AHP) was used. To determine the priority of the classes related to layers affecting landslide, after preparing the said map by GIS software, the percentage of landslides area occurred in each class was calculated. Therefore, prioritizing for the properties of landslides occurred in that area is carried out by this method and as a result it is obvious that the final result will be closer to reality.

Finally, by overlapping thematic maps by means of Raster Calculator, we integrated the effective layers identified in landslide that led to preparation of vulnerability map of the study area using the weight obtained from the mentioned method (Fig. 12).

(“lithology” × 0.3129)+ (“slope” × 0.2289)+ (“fault” × 0.1737)+ (“river” × 0.1098)+ (“landuse” × 0.0733) + (“rain” × 0.0642) + (“height” × 0.0216) + (“aspect” × 0.0153) / 100

(1)

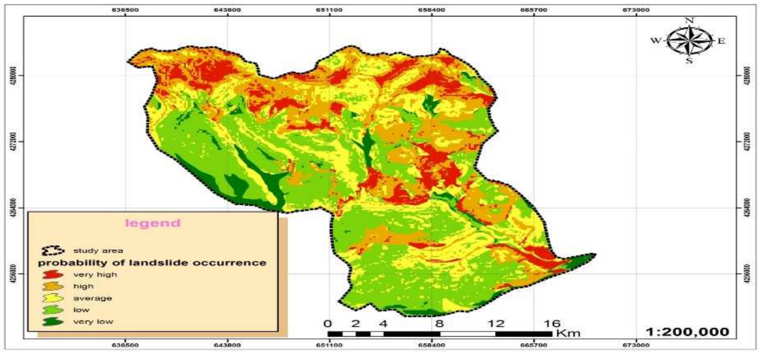

Fig. 12. Zoning map of possibility of landslide hazard

3.Conclusion

Investigating the vulnerability map of the area reflects the fact that:

1. Most of the basin area(about35.84%) has possibility of low landslide occurrence and very small part of the study area has low landslide occurrence probability (Fig.13).
2. Among the8factors which are affecting landslides, the factors of slope level, lithology and land use are the most effective in controlling landslides, respectively.

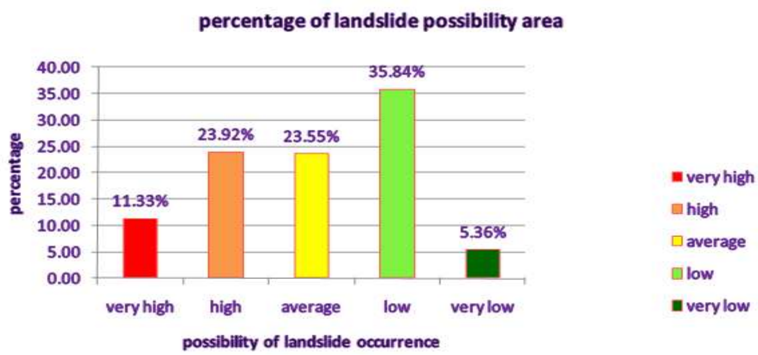

Fig.13. Diagram of the area percentage of zones with the different landslide possibility in the study basin

REFERENCES

1. Ahmadi, H., Mohammadchan, S., 2003, Investigation of some parameters of mass movements, Case study: Taleghn watershed, Iranian J. natural Resources, 55, 455 436.
2. Brabb, E., Pampegan, E. H. & Bonilla, M. G., 1972, Landslide susceptibility in Sanmateo county, California, U.S Geological Survey map, Miscellaneous field studies, map MF-360, scale 1:62,500.
3. Carrara, A., 1983. A multivariate model for landslide hazard evaluation. Mathematical Geology 15, 403–426.
4. Dai, F.C., Lee, C.F., Li, J., Xu, Z.W., 2001. Assessment of landslide susceptibility on the natural terrain of Lantau Island, Hong Kong. Environmental Geology 43 (3), 381–391.
5. Dearman, W.R. 1974, The characterisation of rock for civil engineering practice in Britain; Centeraire de la societe Geologique. Colloque, Geologie de L' Ingenieur, liege, 1-75.
6. Ercanoglu, M., Gokceoglu, C., 2004, Use of fuzzy relations to produce landslide susceptibility map of a landslide prone area (West Black Sea Region, Turkey). Engineering Geology 75 (3–4), 229–250.
7. Ghobadi, Mohammad Hossein. 2011, Principles of Engineering Geology (especially for students of Geology), Hamedan, Publication of Bu-Ali Sina University, third edition.
8. Hafezi Moghaddas, Nasser& Ghafoori, Mohammad. 2009,EnvironmentalGeology, Shahrood: Publication of Shahrood Industrial University, first edition.
9. Komac, M., 2006. A landslide susceptibility model using the analytical hierarchy process method and multivariate statistics in perialpine Slovenia. Geomorphology 74 (1–4), 17–28. Engineering Geology 76 (1–2), 109–128.
10. Mathewson, 1981, An Interodation to engineering geology wiley and sons.
11. Savarenskii, P.F., 1937, Inzhenernaya geologiya, Moskva.
12. U.S. Geological Survey, 2004, Land Slide Type and Processes, Fact Sheet 2004-3072-July.