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Relationship between Lithology Factor and landslide occurrence based on Information Value (IV) and Frequency Ratio (FR) approaches — Case study in North of Iran

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ABSTRACT

This study was conducted on the Land sliding areas in the southern part of the city of Sari. Due to the important role of Lithology in the study area, an attempt was made to determine the potential land sliding areas. Consequently, a digital mapping and of the location of these Landslides in the region were performed. Then, using statistical methods, density, frequency and information value of the types of geology formation in the study areas were evaluated. As a result, it became clear that the Paleocene and Plio-Miocene formations were the most important formations of land sliding and as compared to other litho types; they possess the highest marl contents which are of unstable nature. These rock types constituted a major part of foundation of these villages in the areas.

KEYWORDS: Landslide, Lithology, Statistical bivariate approach.

INTRODUCTION

Slope stability processes are the product of local geomorphic, hydrologic and geologic conditions; the modification of these by geodynamic processes, vegetation, land-use practices and human activities; the frequency and intensity of precipitation and seismic (Soeters and Van Westen 1996). Natural hazards such as land sliding are the probabilities of occurrence of a potentially damaging phenomenon within a specified period of time and within a given area (Varnes1984).

Landslide susceptibility is defined as a quantitative or qualitative assessment of the classification, volume (or area), and spatial distribution of landslides, which exist or potentially may occur in an area. Susceptibility may also include a description of the velocity and intensity of the existing or potential land sliding. Although it is expected that land sliding will occur more frequently in the most prone areas, in the susceptibility analysis, time-frame is explicitly not taken into account.

Landslide susceptibility includes landslides which have their source in the area, or may have their source outside the area but may travel onto or regress into the area IUGS (1997). There were several different methods for landslide susceptibility assessment that can be found in literature (Soeters and Van Westen (1996), Leroi (1996), Carrara et al.(1995,1999),Guzzetti et al.(1999),Aleotti and Chowdury (1999), Van Westen (2000), Chung and Fabbri (1999), Lee and Min (2002), Lee et al. (2002), Carrara, A., and Pike, R.,(2008) . Safaei et al. (2010) summarized these methods based on frequently application by different authors that including heuristic, inventory (probabilistic), deterministic and statistical approaches. Several statistical can be used to calculate weighting values for each factor. In this study we used information value method and densities for evaluate the influence of bedrock lithology in occurrence land slide in the study area.

In general, factors causing landslides are two types; external and internal factors. The most important internal factors of this geological phenomenon are found in the steep slopes of central of Alborz mountain range located in north of Iran. It is widely recognized that geological parameters greatly influence the occurrence of landslides, because lithological and structural variations often lead to a difference in strength and permeability of rocks and soils (Pradhan and Lee 2010). Among determinant factors (such as slope angle, slope aspect, distance to roads and faults, land use and land cover), lithology with respect to type, physical and chemical characteristics and mineralogy play a significant role. Lithological condition most frequently considered in the international literature (Rodriguez-Otriz et al.1978; Hansen 1984; Guzzetti et al.1996, 1999; Ayalew and Yamagishi 2004). Safaei (2002), in the process of analyzing landslide materials reviewed a number of landslides that had taken place in the Mazandaran province. They classified those types of materials involved in landslides into 11 categories with the strongest in the first place and the weakest in the tenth categories. The studies of Feyznia et al. (2005), lithology is one of the most important factors caused landslides in the Southern Sari Hillslope areas. Safaei (2002) in the process of his analysis on the causes of landslides in the Gillan province showed that most prominent sediment found was Paleocene sediment with maximum area and number density of landslide occurrences of the area of the litho type's class (60% of the landslide areas) .Furthermore, An analysis of the distribution of about 422 landslides locations in the Mazandaran province indicates that more than 37 percent of landslides related to Miocene marl formations [Safaei (2002)]. On determining and evaluation of the role of lithology in the area of destructive landslides and its distribution in the litho types of area under study, the important geological formations and the potential land sliding indicators could be classified. The first step would be the provision of an appropriate geological map of the zones of the region. In the study area with the aim of assessment influence different types of lithology on occurrence landslide two bivariate statistical analyses were performed between the inventory of landslides and lithological factors.

PROCEDURE

GEOGRAPHIC LOCATION AND ACCESSORY WAYS

The areas under study were the slopes of the foothills overlooking the plains of southern Sari in the range of 53 East to 30-53 and 10-36 to 30-36 to the north. Location of the area under study has been shown in Figure1.

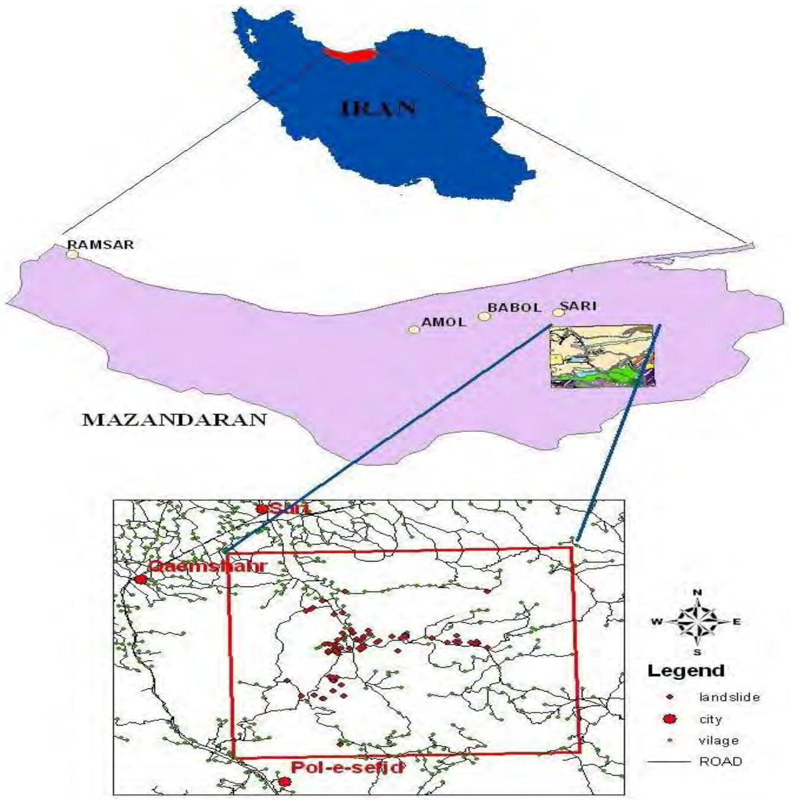

Figure 1: Location of the area under study.

Tajan River and its branches is the most important network of drainage area. The area is covered with broad-leaved forest with arable land and garden, which have emerged from deforestation during the past years. The average annual temperature of the region is 16-12 ° C and the amount of rainfall is700-1000 mm per annum. Several springs with a solid foundation and an average water content of 15-10 liters discharge based forms the channel. Furthermore, for access to the area is through a Kiasar road to Sari and Dodangah route from north to south. Area of research located in the central Alborz range in northern Iran is presented in Figure 2.

Figure 2: Area of research located in the central Alborz range in northern Iran.

STRATIGRAPHY OF THE STUDY AREA

The field studies for investigation of lithology and Stratigraphy indicate the spread of Mesozoic and Cenozoic deposits. Deposits of Mio - Pliocene are the main deposit spread in the area which includes continental series and marine molasses and sediments. Frequent changes in environmental conditions of deposits in the late Miocene sedimentary and early Pliocene caused an extraordinary diversity in lithology of formation of destructive colloidal in this period. In general, the sediments in the northern slopes of Alborz, including thick layers of conglomerate sediments with sandstone and Mudstone, Chelkan series with a lithology of brown and red sands and calcareous clays and marine sediments, limestone and Akchagel marls. The sediments were folded and faulted under the influence of the Pasadanian orogenic phase. The upper Cretaceous sediments of marl and limestone units, which generally change with lithology were gradual and were expanding. This sediment, including upper Cretaceous sediments is situated in the form of dissident's sharp mountain slopes with the lower Cretaceous sediments under the influence of phase strain. Their dominant lithology consisted of limestone marl rock units and is divided into four sections, which are consistent with litho Stratigraphy.

GEOLOGICAL SETTING

The area under study as per the Iranian construction plan is situated in the central Alborz zones and consists of all the features related to this zone. Alborz Mountains range expands from the northern part of the orogenic part of the Alps to the western Himalayas in Asia.

The first major tectonic movements that led to the folds in the Alborz were in the final phase of early Paleocene under the Laramid phase. This led to the formation of the Alborz mountain range in the early Cenozoic era. Pyrenees in the early phases of orogenic in the late Pliocene caused the formation of the earth's current from the Alborz Mountain. As a result of these fault movements and high corrosion, Alborz accumulated in its height. Within the area of study, a large section of the heights overlooking the city of Sari and some central parts of the area, the folding portions of Meo- Paleocene, the southern parts of upper Cretaceous in the core of anticline and syncline or are in contact with protruding faults.

Disruptive and displaced folds of solid anticline and syncline are the tectonic features of this area. Geological map of southern Sari is illustrated in Figure 2.

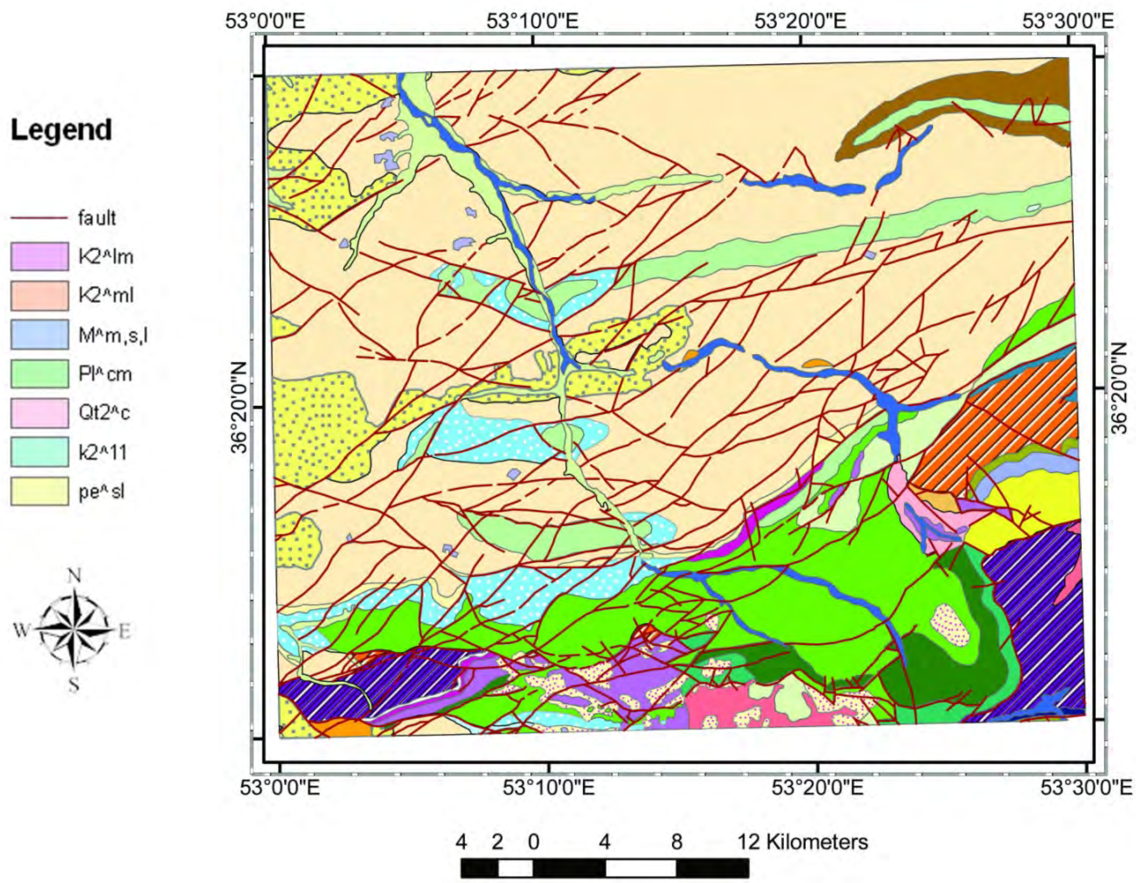

Figure 3: Geological map of southern Sari

Lithology formations involved in the landslide hit area from the previous to the latest analysis include:

$\mathbf{K^{ll}_2}$: Upper Cretaceous rock units (lower section), with thin-medium bedded limestone layers

$\mathbf{K^{ml}_2}$: Lower-Upper Cretaceous rock units (middle section), including marl - silty marl, calcareous marl, marly limestone, limestone

$\mathbf{K^{lm}_2}$: Upper Cretaceous rock unit (upper section) consisting of marly limestone, calcareous marl, marl.

$\mathbf{P_e^{sl}}$: Paleocene rock units, calcareous limestone, sandy-marly limestone

$\mathbf{M^{msl}}$: With the dominant lithology marl, calcareous limestone, sandy-marly limestone and locally with conglomerate that sometimes together gypsum intercalation.

$\mathbf{PL^{cm}}$: Unit includes Pliocene conglomerate, marl, and silt marl with layers of coarse sandstone with clay cement and matrix

$\mathbf{Q^{c}_{t2}}$: Quaternary sediments in the form of erosion materials of clay and silt in the form of thick layer of soil covering the stone. These young deposits are also exposed to surface erosion.

Overall, the most important characteristic lithology of this area is the dominance of destructive materials and colloidal carbonate and marl lithology.

In this study, in the process of field operations, all information on the old and new earthquakes in the area 914 square kilometers of region **A** was identified by GPS. Subsequently, on the lithological thematic map, in the area scale 1:250000 were spotted and coordinated based on a geological map from the Geological Survey of Iran (GSI). Ratio of total surface area of each lithological formation is presented in Figure 4.

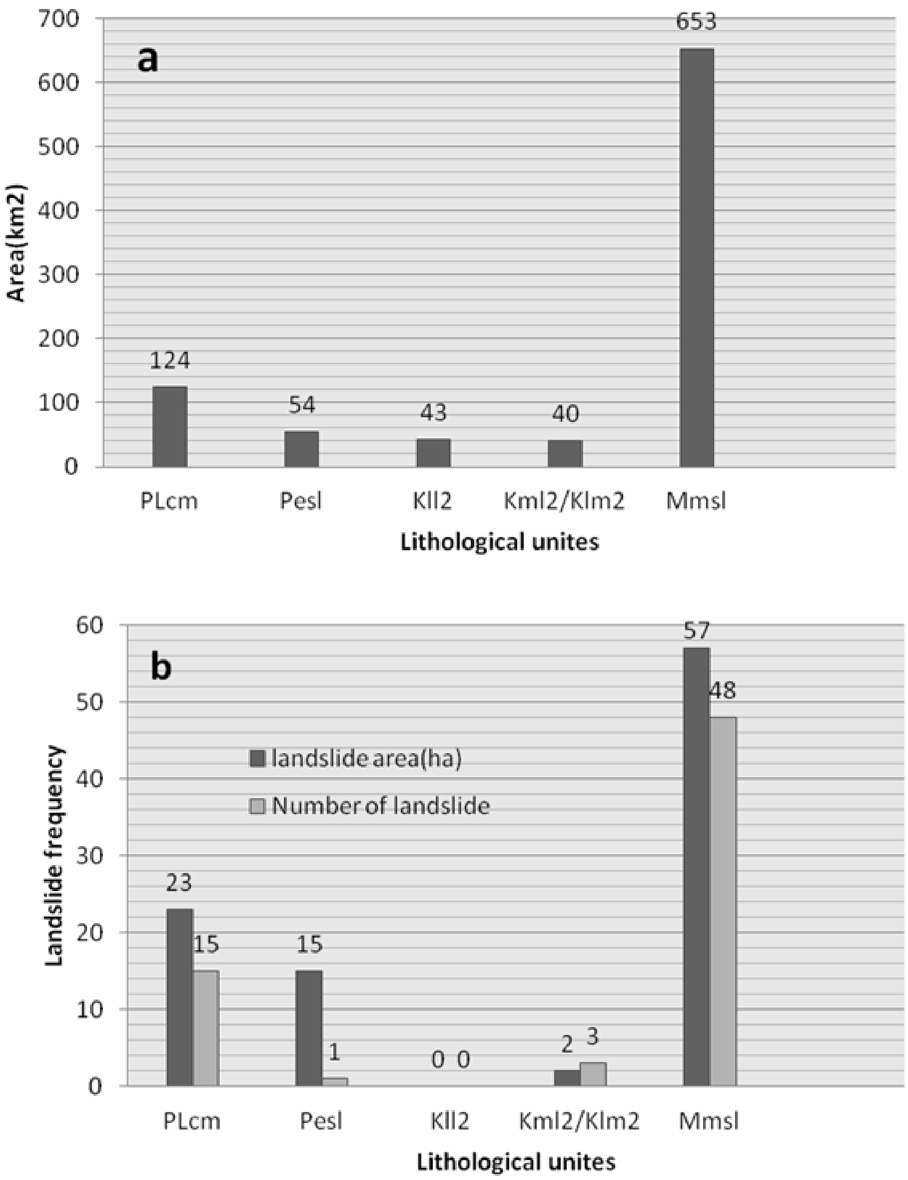

Figure 4: Areas of lithological unite (a) and landslides frequency in each litho types in the study area.

On analyzing all landslides on a geometrical perspective, the factors and types of soil compositions involved in landslides were determined. After preparing and coordinating the landslide distribution maps, it was decided to determine the lithological factors affecting instability slopes. The most important of these factors include: the area of each landslide in each composition, the percentage of total surface landslide area to any unit or lithology composition and the number of or the frequency of sliding in each of the litho types. Then, the analysis of the lithological cause and the ranking of the region's litho type were done by two weighting methods base on bivariate statistical approach. Figure 5 shows overlapping the geological and landslide inventory maps of the study area also this Figure shows most landslides occurred in Miocene and Pliocene formations as well Figure 6n shows' landslide number per unit area of each lithology.

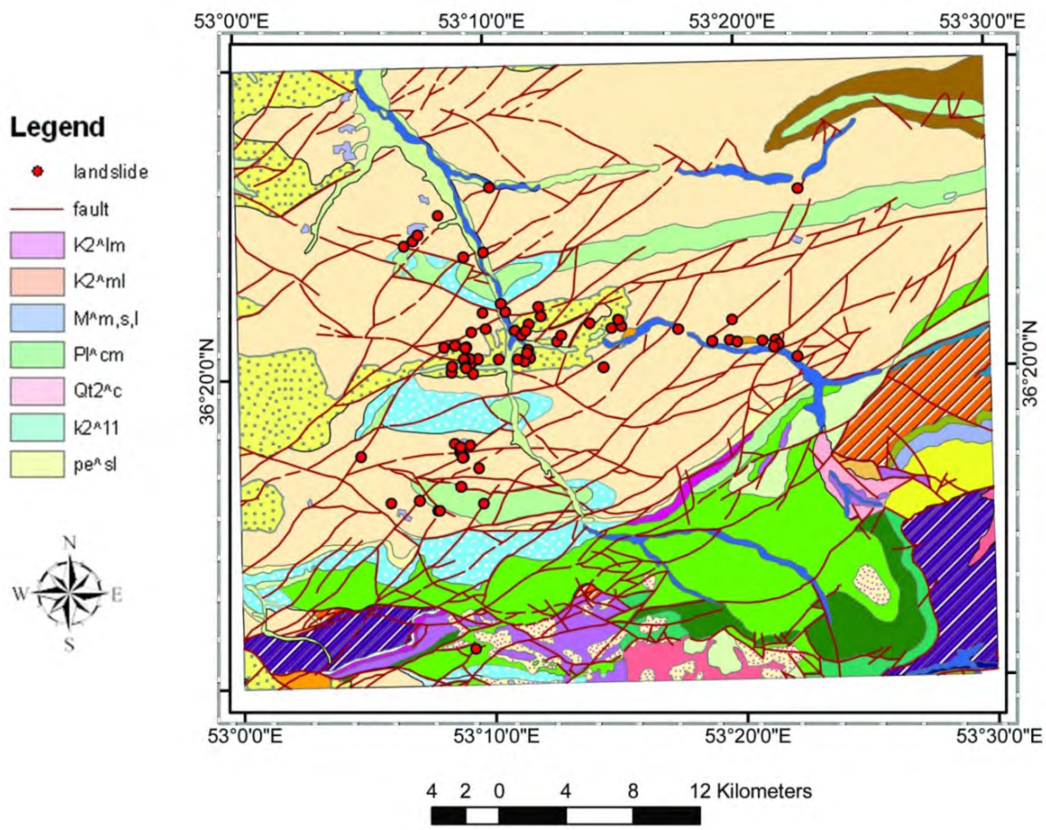

Figure 5: Overlapping the geological and landslide inventory maps of the study area (That shown most landslides occurred in Miocene and Pliocene formations).

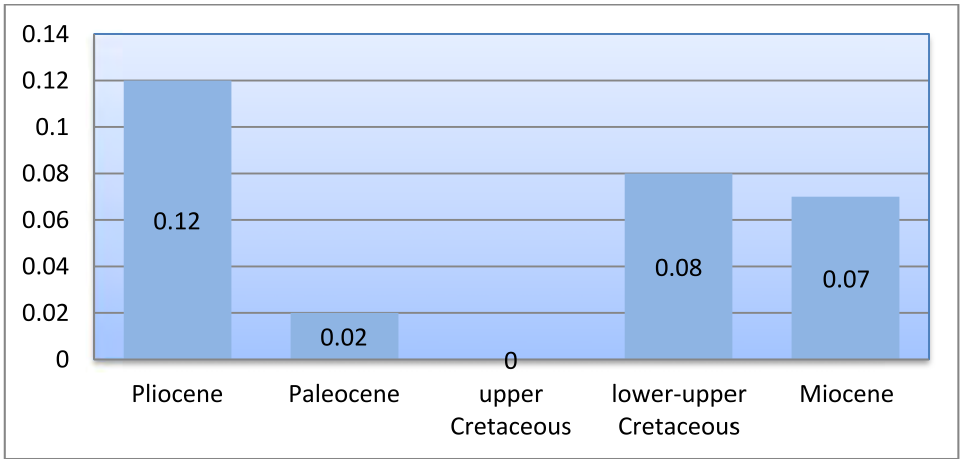

Figure 6: Landslide number per unit area of each lithology (Number/Area)

METHODOLOGY

This research has been used bivariate statistical methods for assessment lithological unites relative susceptibility of landslides has been occurred. In other to assess the importance of the lithology, a cross between lithological map and a landslide inventory map was prepared then for each lithology class two types of density's methods including area density and frequency of the ratio also information values were calculated.

INFORMATION VALUE METHODS

Mostly, this method has been used before applying any statistical models to find the influence of environmental factors in landslide occurrence. Information value is a simple technique to understand the statistical relationship is a conditional analysis, which attempts to assess the probabilistic relationship between landslide event and casual factors. The technique is based on Baye's theorem (Bayesian classifier) according to which frequency data can be used to calculate the probabilities that depend upon the knowledge of past landslide events.

The Information Value Method developed by Yin and Yan (1998), and was being applied to lithological units in the study. The calculation applied to this method was based on the following formula, as for the calculation the information value I_i for each variable class factor. The information value equation is expressed as the natural logarithmic ratio of class density to map density of landslide (1):

$$I = ln[(a / b) / (c / d)] \tag{1}$$

in which:
I-value = information value
a = area with landslide in a class (KM^2)
b = area in the class
c = total area of landslide in the map (thematic layer)
d = total area in the map

Density methods

1. Area density method is defined ratio of landslide area to variable class area that can be as a percentage or per millage content (2).

$$D_{area}=1000\ (a/b) \tag{2}$$

To estimate weighting of variable class can be calculated density area with overall density in the study area (3).

$$w_{area} = 1000[(a/b) - (c/d)] \tag{3}$$

2. Number density is defined ratio of the number of landslide per square kilometer of the area of the variable class area (4).

$$D_{Number}=\frac{Number\ of\ landslide}{Area\ of\ the\ variable\ class} \tag{4}$$

The calculated weighting for the number density based area on number per square kilometer is:

$W_{Number}=[\left(\frac{Na}{b}\right)-\left(\frac{Nc}{d}\right)]$

Na = number of landslide in each variable class

Nc = number of landslide in total area

FREQUENCY RATIO METHOD (FRM)

Frequency ratio method was used based on the assumption that future landslides will occur under circumstances similar to those of past landslides. This method is defined relationship between spatial distribution of landslide with each casual factor (environmental factors) and ratio of class density to map density of landslide for each variable class (Eq.5).

$$Fr_{=}\frac{DesClass}{DesMap} = [(a\ /\ b)\ /\ (a\ /\ b)] \tag{5}$$

In this study by the overlay of the landslide location map with lithological map using ArcGIS platform(Figure 5), the landslide susceptibility assessment as a function of the lithological setting as relative sensitivity to lithology unites of landslide occurrence in the north slopes of Alborz mountain range in northern Iran has been studied.

RESULTS

Table (1) shows that the Miocene composition and lithological composition of marl and calcareous sandstone are among the various compositions that compose the highest number landslide measured in the regional level and with the lowest, in the upper Cretaceous rock units of K_2^{lm}. The average levels of sliding in the different formation in different areas show those Paleocene as the highest with 15 hectares and Miocene with 1.2 hectares is in the second place. Lower Upper Cretaceous section (K_2^{ml}) has an average sliding of 0.6 hectares. The studies of Feyznia et al. (2005) showed that the geological factor and lithology are the most important factors for the cause of landslide in these parts of this area and among these formations; Miocene alone caused 59% of the sliding in the area under study. Taking the degree of density that caused sliding under consideration, or the specific level of sliding in each composition based on the relationship of the level of sliding with the level of composition or the number of sliding, the level of composition could be estimated. Weight values obtained for each of composition showed that Paleocene had the most unstable nature, while the upper Cretaceous had the lowest instability in nature.

Landslide occurrence in the study area for each lithological type was presented in Table1

Table1: Landslide occurrence in the study area for each lithological type

Ratio landslide Of the total area%	**land slide occurrence**			**Area covered**		**Code**	**Formations (lithology class)**
	%	**Area**$(km)^2$	**Number**	%	$(km)^2$		
23.72	0.19	0.23	15	14	124	P_e^{sl}	**Pliocene**
15.46	0.28	0.15	1	6	54	PL^{cm}	**Paleocene**
-	-	-	-	5	43	K_2^{lm}	**Upper Cretaceous**
2.06	0.05	0.02	3	4	40	K_2^{ml}	**Lower-Upper Cretaceous**
58.76	0.09	0.57	48	71	653	M^{msl}	**Miocene**
100%	-	0.97	67	100%	914		**Total**

Assessment of each lithology units by statistical analysis of information value and density area that make Paleocene information, with the highest instability, and then make Marl Cretaceous and Miocene formation with less instability and make the upper Cretaceous calcareous marl lowest instabilities are in the study area (Table 2).

Table 2: Calculation weighting and information value for each lithology class

Weight of density area(W_A)	**weight of density Number(W_N)**	**frequency of ratio**	**information value(W_{inf})**	**Code**	**Formations (lithology class)**
1.79	-0.61	1.75	+0.56	P_e^{sl}	**Pliocene**
1.74	-0.05	2.64	0.97	PL^{cm}	**Paleocene**
-1.06	-0.07	0	—	K_2^{lm}	**Upper Cretaceous**
-0.56	0.002	0.47	-0.75	K_2^{ml}	**Lower-Upper Cretaceous**
-0.19	0.001	0.82	-0.20	M^{msl}	**Miocene**

CONCLUSION

Lithology final assessment of sliding of the study area by calculating weighting and information values using methods applied that shown in Table 4 indicate that lithology Paleocene and marly upper Cretaceous are the respectively highest and lowest landslides of susceptibility.

Thus, make the most Paleocene and Mio-Pliocene formations and the sliding region compared to other rock units that have marl are unstable. These units make much of rural settlements in their place that during an intense rainfall cause destroyer landslide over the marl bedrock lithology, which destroyed several villages, mainly on the units has been Mio-Pliocene. Thus, the necessity Reviews Engineering Geology (REG) to determine the risk of landslides in the areas of Paleocene and Mio-Pliocene can prevent and control destructive geological phenomena playing a role in how should manage land area land sliding lead..

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