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# Investigation of Role of Slope, Aspect and Geological Formations of Landslide Occurrence Using Statistical Methods and GIS in Some Watersheds in Chahar Mahal and Bakhtiari Province

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## ABSTRACT

This study aimed to determination of the topographical effects of slope, aspect and geological factors (type of formation) on the landslides occurrence in the Ardal, Bazaft and Koohrang basins located in Chahar Mahal and Bakhtiari province using statistical method was performed, therefore using available data in the Arc Gis[1] software the slope maps in three classes and the aspect maps in four classes were provided, from the geological formations in each basin two formations with the most landslide number were elected as well, and with overlapping maps homogenous regions were obtained, to be possible using factorial experiments and randomized complete block, three replications from each homogeneous were measured, Thus 72 sliding surfaces were investigated in total and determined their occurring landslides number which they were used in the statistical analysis using analysis of variance and mean comparison using Duncan's multiple range tests, Based on the obtained results the role of slope and aspect in the landslides occurrence were significant at the level 0.01,Also over mean comparison for these factors, the south aspect and low slope (0 to 10%) has highest mean (8.333 and 10.292 landslide, respectively) and consequently they had the most role in landslide occurrence.

**KEYWORDS:** Factorial experiments, Duncan's multiple range tests, analysis of variance, SAS[2], GIS

## INTRODUCTION

Knowledge of nature, its characteristics and its actions and reactions because it is considered as human life environment, it has utmost importance. One of the interesting phenomena and also natural hazardous has occupied scientists mind, especially the earth science scientists and made them to investigate landslide occurrence. Lee and et al [19] over a study in Jin Bu area which is located in Korea, attempted to zonate landslide occurrence hazard using EBF[3]method and with consideration of topography, geology, soil and forest cover, evaluated good accuracy of the desired method. Grosevski and et al [14] studied the factors affecting landslide and using logistic regression model and GIS software have modeled landslide hazard. They expressed important factors in creating landslide are heavy rain, melting snow and forest road construction. Murat and et al [18] in the North West of Turkey attempted to zonate landslide hazard using multivariate statistical, geometric, fuzzy logic and geomorphologic methods and slope, aspect, land use, climatic conditions and height factors. The obtained results imply that the prepared map have a good adaptation with occurred landslides. Ashghali Farahani [1] using bivariate statistical techniques (density level and information value), linear multivariate statistical technique, discriminate analysis, logistic regression with discrete and continuous data and fuzzy logic, the landslide occurrence potential at Rudbar region in Gilan province using geographic Information System and ILWIS software has zonated. The used information layers include lithology, distance to the fault, vegetation, land use, precipitation and the maximum earthquake acceleration, based on the results of the statistical multivariate analysis, logistic regression shows the highest accuracy. Fatahi Ardekani [5] zonated Latyan dam watershed using two statistical methods information value and Nilsson, Based on the results, he determined that Information value method is more accurate. Kahy Mianji [8] using multivariate regression statistical and expert judgment methods, geographic information system and ILWIS software has zoned Taleghanroud watershed and accordingly, he has concluded that the factors aspect, vegetation, 24-hour rainfall intensity, average annual

[1]Geographic Information System
[2]Statistical Analysis System
[3]Evidential belief functions

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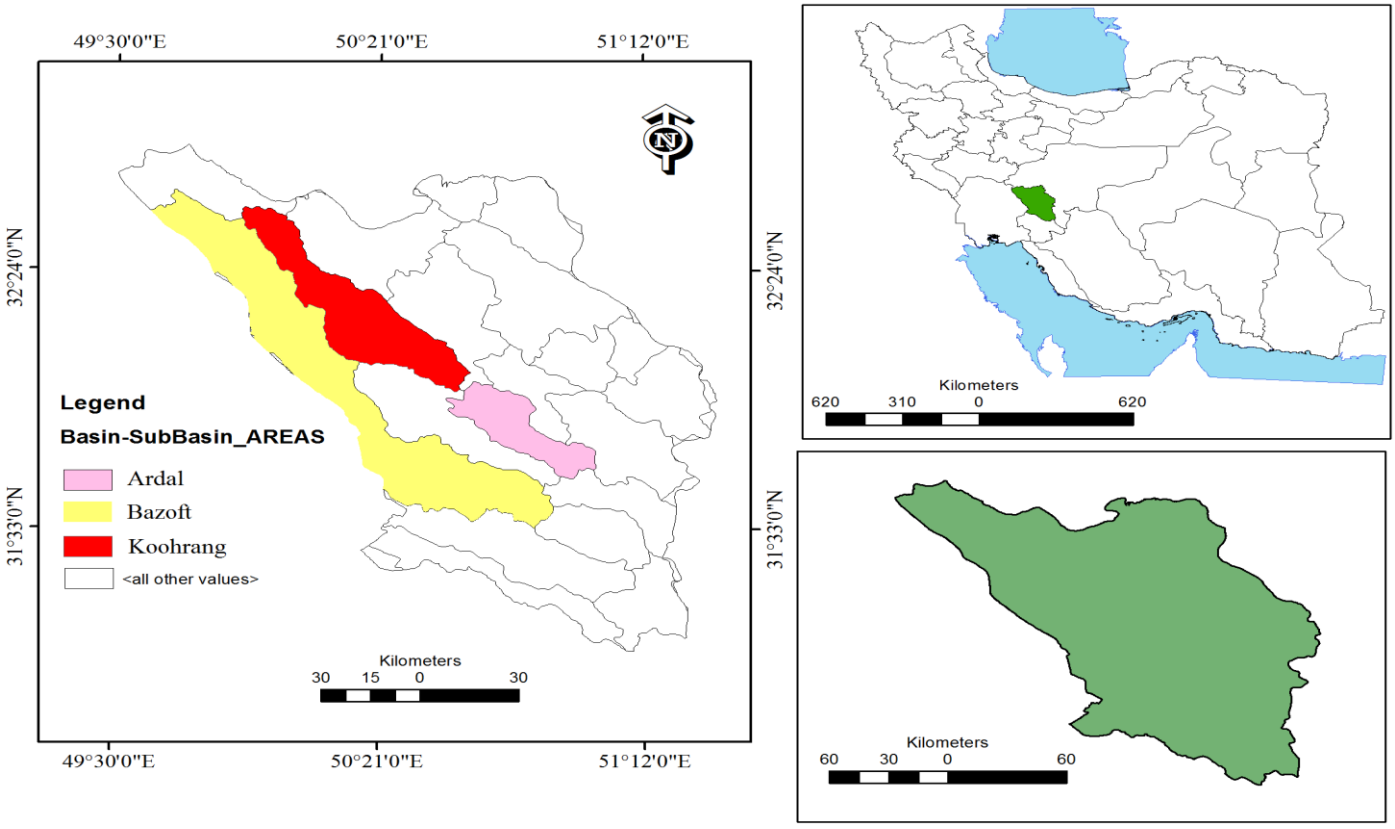
rainfall height and type of geological formations are the most important effective factors in the landslides occurrence in the research area.

## METHOD AND MATERIALS

The Ardal watershed is located in southwest Chahar Mahal and Bakhtiari province and its area is approximately 2578.5 square kilometers and it is 1980 meters above sea level. The climate of this region according to the Ambreje classification is cold. The basin in terms of tectonic-deposits units is located in the territory of the Zagros (the High and folded Zagros) and according to the geomorphology classification based on the land consists of mountains unit and hills unit. The scope of activities of numerous large and small faults, such as Ardal and Duplan faults with North West and South East directions exist in this region. In terms of Hydrology main branches of the primary rivers of the country i.e. Karoon and zayanderood are located in this region. The other studied basin is Bazaft watershed which is one of the major basins of Karoon with an area of 2973 square kilometers and located in the central part of it. This basin is completely mountainous and high altitude so that 2924 square kilometers of its area is formed by heights. In the basin the minimum height is 891 meters and the maximum height is 4091 meters above the sea level which they are in the northern parts of it. This mean height in this region is 2115 meters above the sea level. The third basin is Koohrang watershed with an area of 1230 square kilometers which is located in the West and North West part of Chahar Mahal and Bakhtiari Province, the Koohrang city. The mean height of the basin is 2790 meters. This region due to its particular topography and heavy snowfall at its parts, is the most wet areas of the country so that the source of one of the major rivers of the country i.e. Karoon is located there. In terms of geological this basin heights have




consisted of limestone formations in Cretaceous period. Due to appropriate climatic situation and relatively high rainfall, vegetation situation is appropriate and mostly consists of steppe rangeland and semi-dense forests.

Figure-1: Location of the studied area in Iran and Chahar Mahal and Bakhtiari province

## RESEARCH METHODS

After preparation and obtaining initial data from the related organizations, the data were analyzed using Arc GIS software. In this way that the slope map into 3 classes, low (0 to 10%), moderate (10 to 20%) and high (above 20%) and aspect map into 4 classes North, East, West and South were classified [22] , [13], [11], [3].From the available formations in Geological maps in each basin, two types of formations sensitive to the landslides (based on number of occurred landslide) were chosen [3]. Then obtained maps for each basin were interrupted by spot map of landslides. In the following, by sampling, 72 homogeneous sliding surfaces were

determined and the numbers of occurred landslides in each of them were specified. The obtained results in this stage provided onset of Statistical analysis in SAS version 9.2 and SPSS[4] version 20 software which for this purpose of the analysis of variance and mean comparisonwere used.

## DISCUSSION

To evaluate the influence of three factors slope, aspect, and geology in occurrence of landslides statistical methods were used, this mean that after a series of primary operations in GIS environment and obtaining landslides abundance in each samples of the studied area, statistical software SAS and SPSS were used. The results of this section can be divided into two parts:1-Results of variance analysis to investigate which of three factors: slope, aspect and geology have significant effects on the occurrence of landslides.2-Results of mean comparisons which investigate significant influence levels of each factor separately. Based on Results of variance analysis, influence of slope and aspect in occurrence of landslides was significant but the influence of geological factors (type of formation), unlike the above two factors was not significant (Table 1).

Table-1: Results of variance analysis

| Source | Freedom degree | Mean squares of occurred landslides | Pvalue |
|---|---|---|---|
| Aspect | 3 | 119.754630 | 0.0013** |
| Slope | 2 | 787.180556 | 0.0001** |
| Geology | 1 | 17.013889 | 0.3568 |
| Aspect / Slope | 6 | 31.254630 | 0.1705 |
| Aspect / Geology | 3 | 7.087963 | 0.7817 |
| Slope / Geology | 2 | 8.013889 | 0.6674 |
| Aspect / Slope / Geology | 6 | 3.087963 | 0.9867 |

** Significant at the 0.01 level

To determine how the quadruple Aspects impact on the occurrence of landslides, Duncan multiple range tests was used which based on the obtained results north direction has significantly less influence than other directions in occurrence of landslides; because the mean of this direction was less than the mean of other directions (Table 2).

Table-2: Mean comparison of occurred landslides in different directions in the studied region

| Aspect | Mean |
|---|---|
| South | 8.333a |
| East | 7.944a |
| West | 7.333a |
| North | 2.778b |

Means with the same letter are not significantly different at the 0.01 level

Being less the north mean announces less landslides occurrence in the direction, this result is unexpected of course because it is expected in the Iran due to being located in the northern hemisphere receives more shade and thus more moisture, North directions have a higher hazard for landslide occurrence. Jamali [3] also in a research to zonate landslide occurrence potential Watershed adjacent to Firoozkoohusing GIS and decision techniques has conducted, with the same reasoning, the most points for the influence on landslide occurrence, given to the North directions. In this regard researchers such as Pajm [2], Kahymianji [8], Sakar and et al [20] Lan and et al [17] and Samad Zadeh and et al [21] have investigated the role of aspect in landslides occurrence in the same approach. NikAndish research results [11] in the middle Karoon Basin indicates further influence of the south and southwest directions on the landslides in this regard his results are same as the results of present study. Including reasons that is notable for this unexpected result is reduction of aspect role in landslide occurrence due to other effective factors and environmental conditions. For example, it is possible northern skirts which there are expectance of having more landslides occurrence according to the foregoing reasons, there was not soil mass volume or sensitive formations to landslide or they are located in low slopes. For example, the map of occurred landslides in the Ardal basin, one of the three studied basins has shown in Figure-1.According to the obtained statistics for the occurred landslides in this basin, it is observed that the maximum value of the occurred landslides per unit area is related to the East direction (Diagram 1).

[4]Statistical Package for the Social Sciences

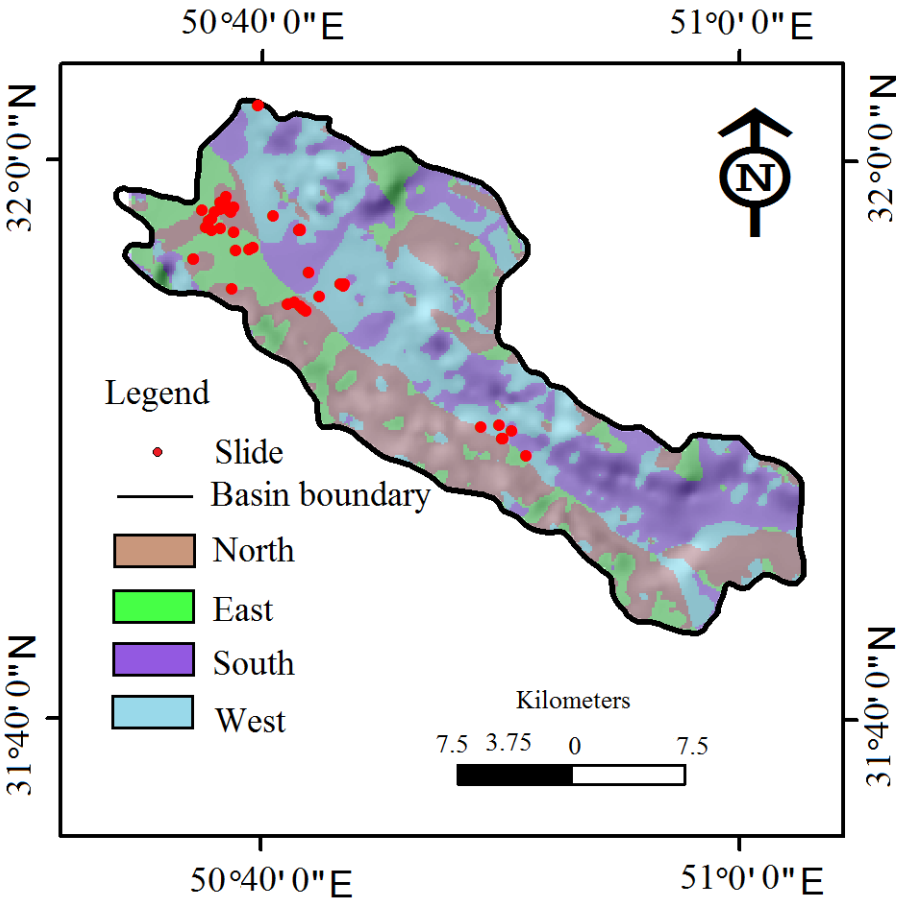



Figure-1: positions of occurred landslides in the map of Ardal basin

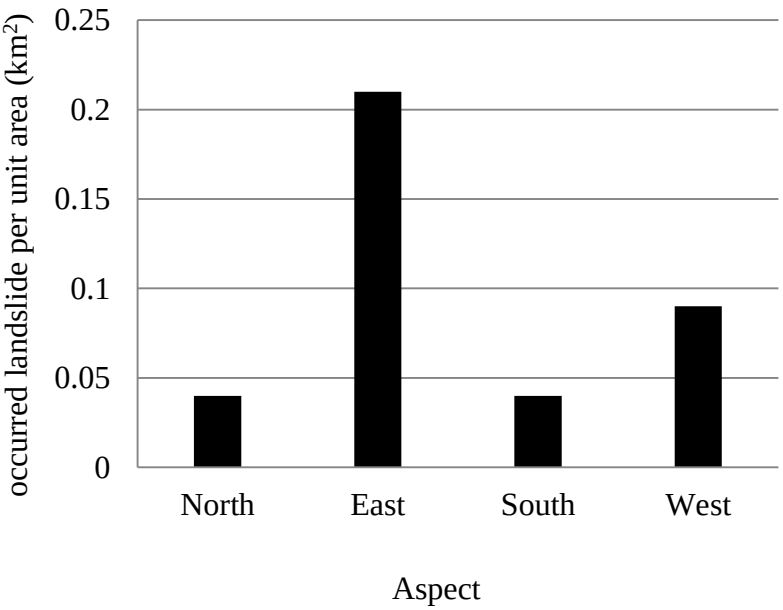



Diagram-1: occurred landslide per unit area in different directions of the Ardal basin

The mean comparison for slope factor has been done using Duncan method as well. According to the obtained results, the mean of steep slopes significantly has been lessened to average of low and moderate slopes; in other words, the slope in high class has been less effective in landslide occurrence than the other two classes namely moderate and low classes (Table 3).

Table-3: Mean comparison for slope classes in the studied region

| Slope | Mean |
|---|---|
| Low | 10.292a |
| Moderate | 9.500a |
| Steep | 0.000a |

Means with the same letter are not significantly different at the 0.01 level

Based on the scientific principles and carried out research findings about the landslide, this result is unexpected as well; because by increase in the slope the inertia and establishment of materials in hillside has been reduced and probability of landslide occurrence increases which results of researches such as Jamali [3], Moradi and et al [9] Farhadi Nejad and et al [6], Sarolee [22], Murat and et al [18], Lan and et al [17] and Lallianthanga and Laltanpuia [16] also confirm this Content. In this regard NikAndish [10] in a study at middle Karoon basin, Dymond and et al[13] at the region in New Zealand and Terhrost and Neuhauser [20] in a region located in the southeastern of Germany have obtained the effective slope in landslide occurrence is 20 to 50 percent and often30 to 40 percent,5 to 30 percent and 11 to 26 percent, respectively. These results confirm the positive role of increase in the slope in landslide occurrence. Of course this has accepted extreme at extreme steep slope due to receiving less moisture conditions for the occurrence of landslide are not favorable, but the point is not only in extreme steep slope class but also in steep slope class, no landslide has occurred in the studied region. To state the reasons of this result, same reasoning which were stated about the cause of aspect factor also we can state environmental conditions and interaction of other factors. For example, it is possible in the steep slopes in the studied region there is not sensitive formations to landslide or soil mass with sufficient volume. For example, according to the position of occurred landslides in the Bazoft basin (Figure 2) and the obtained results of occurred landslides per unit area (Figure 2), it is observed that maximum value of occurred landslide per unit area is devoted to the low slope class.

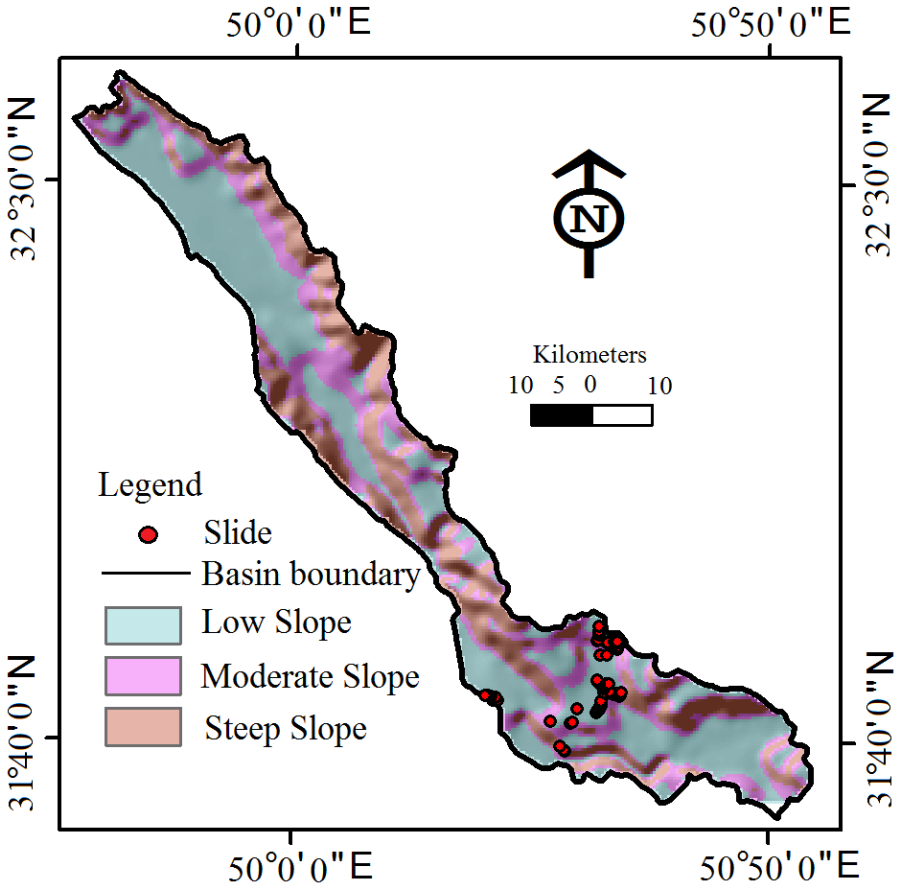



Figure-2: positions of occurred landslides in the map of slope in the Bazoft basin

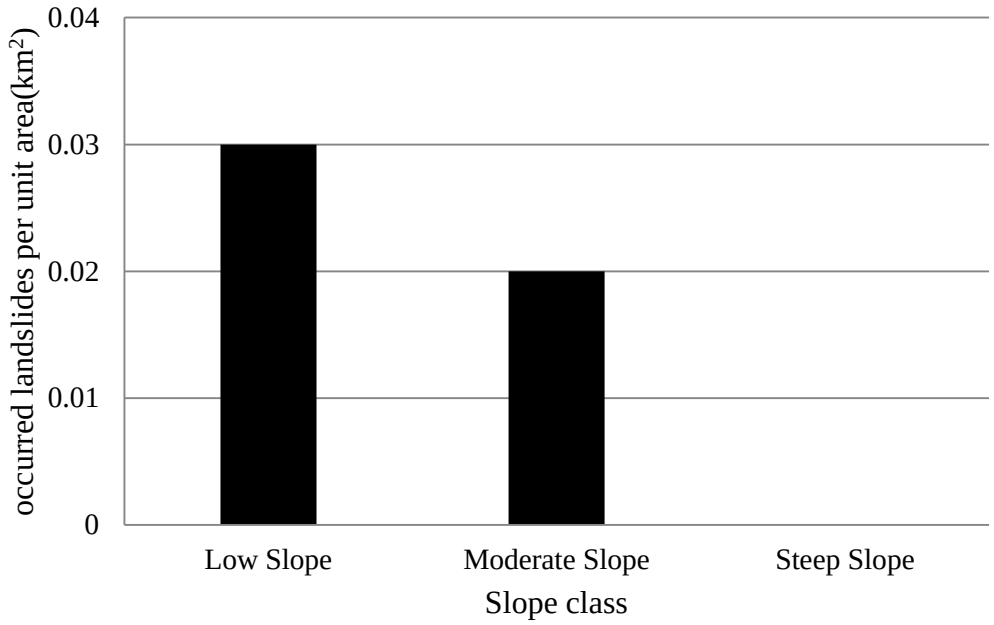



Diagram -2: occurred landslides per unit area in slope classes in Bazoftbasin

Significance effect of formation type on the landslide occurrence was investigated by comparing the mean using Duncan multiple range tests. Based on the obtained results none of formations had a significant advantage to each other in terms the mean. The results of the analysis of variance confirm the insignificance of the effect of geological factors on landslides occurrence (Table 4).

Table-4: Mean comparison for two types of formations is sensitive to landslides in the studied region

| Sensitive formation to landslide | Mean |
|---|---|
| Formation of Type I (Ardal: Kkgp, Bazoft: Kbgp, Koohrang: E) | 7.083a |
| Formation of type II (Ardal: Qft2, Bazoft: Kgu, Koohrang: Kbgp) | 6.111a |

Means with the same letter are not significantly different at the 0.01 level

The result is unexpected as the results of the slope and aspect because despite formations sensitive to landslides (Gurpi, etc.) in the region, a defining and critical role for geological factors in landslide occurrence is expected; the reason for this also should be explored in other effective factors and environmental conditions. For instance, it is possible sensitive formations have been located in directions that landslide direction may not get sufficient moisture (according to have high absorption capability moisture). Ashghali Farahani [1], FaizNia and et al [7], Ayenew and barbieri [12], Li et al [19] and Khosravi Asl and Ramesht [15] in their study have mentioned geological factor as important and influencing factoron the occurrence of landslides. Talaii [4] also in a survey on the landslides-prone area in the southwest of Khalkhal came to the conclusion that landslides of the region are controlled by geological formations and in the research adherence of age and type of landslide movement from geology of the region has been completely proven as well.Similarly, based on NikAndish research results [11] in the middle Karoon basin in terms of geological deposits of the present era with the marl and gravel frequency and formations such as Sachoon, Gurpi and Pabdeh with the marl and marlylime stones frequency, have been deeply affected occurrence of landslides. It is observed that according to the position of occurred landslides in geological map of Koohrang basin (Figure 3) and the results of occurred landslide per unit area (Diagram3) number of occurred landslides in two sensitive formations of this basin is obviously more than other formations. But as we mentioned, in total in the studied area, effect of geological factor on landslide occurrence is insignificant.

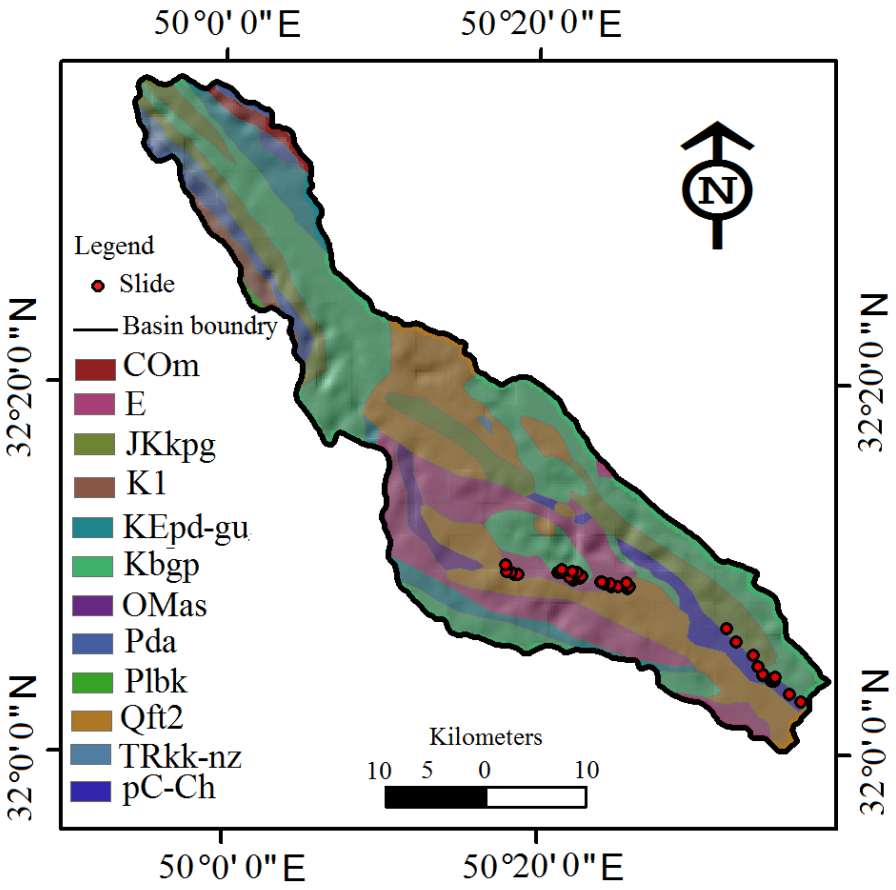



Figure-3: Occurred landslides location in the geological map of Koohrang watershed

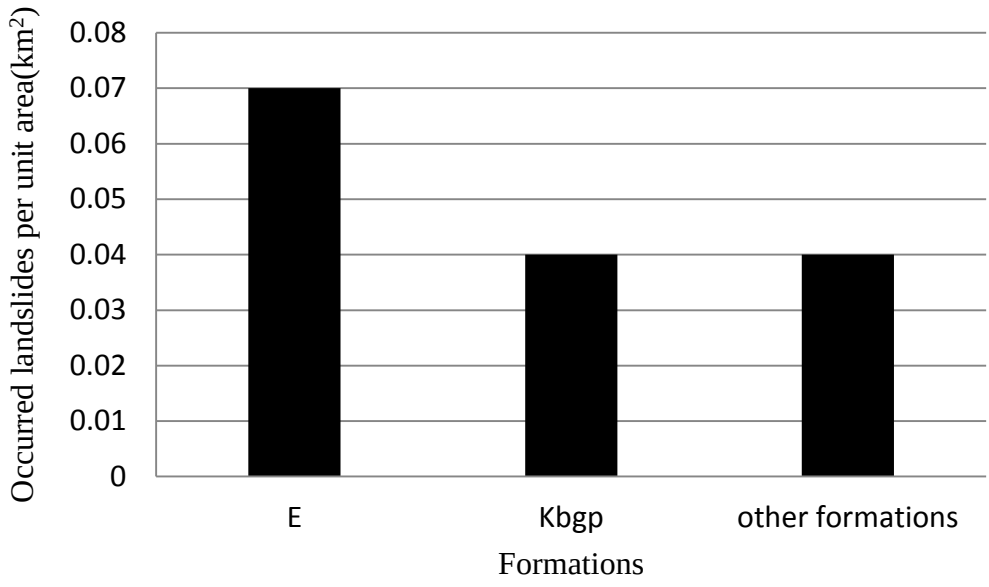



Diagram-3: Occurred landslides per unit area in the two sensitive Formations of Koohrang watershed

## Conclusion

From the obtained results of this study can be found that landslide phenomena can be due to several reasons that may in any particular case of this phenomenon, only some of these factors play a crucial role and be effective. In other words, the system approach would be to study this phenomenon; this means that several factors may play a role in landslide occurrence in a single system and Influenced by each other, and environmental conditions are effective in the occurrence of this phenomenon. So an important issue in the study of this phenomenon has a fundamental role, is the diagnosis of more accurate effective factors on occurrence of this phenomenon, consequently the selection of a suitable method for diagnosis of these factors is utmost of importance. Surely field studies and experts opinion is a great help on identification of the effective factors on the landslides occurrence but this method usually puts a large number of factors ahead of researcher that using all of them in the research process can take a lot of time and money. So it seems statistical analysis of occurred landslides in order to investigate their rate and how they are related to the specified primary factors is an appropriate method for identification of the factors with the greatest impact on the landslides occurrence. Another significant result was obtained in this study was lack of high slope class effect and the north direction in landslide occurrence were obtained by mean comparison using Statistical method (Figures 2 and 3).The unexpected result will mention two points in landslide studies, First, the researcher should not base on typical procedure influence of determinants on the landslide occurrence attempt to use them in their studies procedure; perhaps these factors, in some special cases, due to the advantage of other factors appear to act contrary to its procedure and Second, the use of statistical methods to understand influence of determinants and avoid wasting time and money in the research procedure is very effective in such cases. In general the result of the present study emphasizes on the correct understanding of the extent and impact of the various factors in the landslides occurrence and using really effective determinants, in the landslide study.

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