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# Studying the causes of landslides in LEILE basin area in Javanroud-Iran

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**Abstract**

Landslides or mass movements are the phenomena, occurred by geomorphologic deforming. These phenomena are some kind of destruction, which is formed in the result of reaction among inner & outer land forces. This study has been carried out with the aim of recognizing & revealing the causes of landslides, their effect on structures, their shape in the related basin area and finally providing the applied maps for environment recognition & management of this area. Having studied the geologic qualities, climate, geomorphology, slope, physiography, hydrology, soil and vegetation cover, also by field studying of the basin area and reveling together with analyzing the effective causes of landslides, they have been gone under study in view of forming & developing. Meantime, the important role of man as a reinforcing stimulant of landslides and erosions should not be ignored. In this region, the faults effects can often extend 1 KM far around, so that more than 50% of landslides have been occurred in this district. In addition, many other landslides have occurred alongside SALAS-JAVANROUD road, which in turn reveals the man's interference in nature. In this region, molehill, alluvial cones and the river terraces are the most landslide bearing morphologic units. Cases like ruin of farmlands, reinforcement of destructive torrents, ruin of riverside gardens, debris falling in mining and building projects, road destruction, etc. are samples of resulted effects on the life of related residents.

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## Introduction

Landslides are occurred via different factors including primary factors and secondary factors resulting from primary ones. The landslides of LEILE basin damage the rural and urban residences, farmlands, communication routes, economic departments and the drainage systems. In addition, in long period, these landslides can bring about unrecoverable damages to the soil resources of the related region. Using the data of the showers and the daily sediment load of Annapurna basin of Nepal Himalaya, Gabt & his colleagues (2004) could find the effects of rainfalls and hillside slope on landslide occurring in the related basin in time of monsoon rainfalls. They found that every time the shower rate exceeds 860 mm in time of monsoon rainfalls, then sliding movements occur (E. J. Gabet *et al*,. 2004).

Ocakoglu & his colleagues studied the dynamics of mass movements resulted from heavy rainfall in Dagoy, Turkey. The data analysis in hours, days and long periods, demonstrated that man, as a stimulant, has an effective role in land sliding. Slope, tree density and moving thick soil onto marl soil, have got effective role in occurring different kinds of sliding (Faruk O *et al*,. 2002).

Anbalagan ( 1992), has identified the effective factor of landslide occurring in GATGODAM – NAINITAL mountaineer region of Himalaya mountains among which, lithology, geologic structure, slope and land use ratio, with 2 more grades comparing with other factors, had got the most effective role in occurring the land slides of this region (R.Anbalagan,1992).

The high slope of basin together with structures that are related to second and third geologic ages and are sensitive to erosion (marl& shale) and also streaming the muddy fluids into the valleys, have increased the probability of landslide occurring, destruction & torrent happening. An active fault in basin area (like ZAGROS new fault) and the fact that the basin has been located in a region with high probability of earthquake bearing, are threats to mass moving& landslide happening. Besides these natural factors, the erosion caused by human, cutting foot slope for road making, cutting precious oak trees, ruin of pastures, farming high slope lands, etc. are sample of other disasters related to basin.

According to the above mentioned issues, the importance of basin studies in view of sliding, in which the man's role is so obvious, will be conspiques due to its influence in correct understanding of natural conditions and the rules dominant on environment which in turn lead to optimal use of environmental facilities for permanent development and correct planning. So, in this article, we have been studied the role of effective factors like topography, geology, morphology, slope, canals and geomorphologic units in LEILE basin.

## Materials and methods

*The area of study*

The area of study has been located in the west part of the country, in the western & southwestern slope of northwestern ZAGROS range of mountains with longitude of eastern $46^{o},17'$ to $46^{o},36'$ and latitude of northern $34^{o},40'$ to $35^{o}$. The maximum north to south lengthening of the related basin is over 39 $km_s$ and in east to west direction is around 30 $KM_S$. This basin is limited to SHAHO range of mountains from the east and northeast side, to RAVANSAR basin from the south and to GARMZNA, KOSHTEH and BANDGAZ mountains from the west and North West side (Fig. 1.).

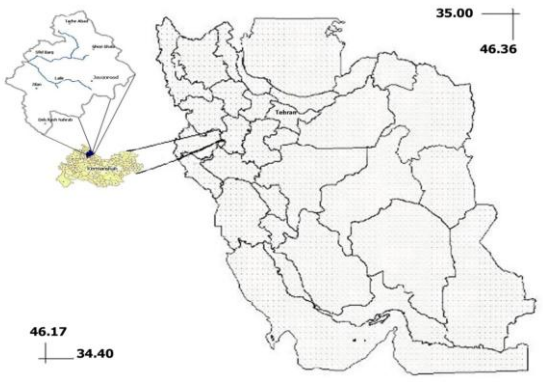


**Fig. 1.** The position of the area of study.

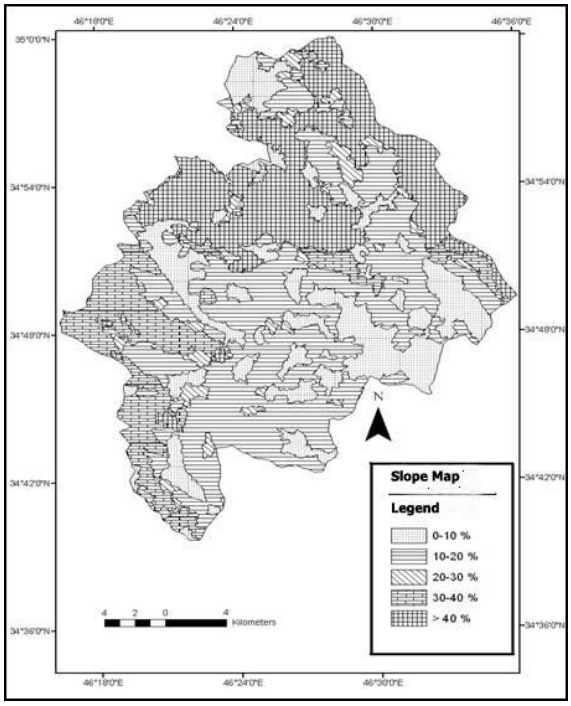


**Fig. 2.** Slop map.

Climatically viewpoint, this basin is mountaineer and a variant one having Mediterranean to semi moist climates. LEILE River as a main drainer of the basin has got irregular regime & monsoon overflows and has been faced to the western winds and Mediterranean atmosphere system because of its special geographic strategy. In cold seasons, there will be high rainfall in the river but in hot seasons, because of being dominated by subtropical high-pressure atmosphere, it is dry (Alijani B, 2000). The maximum rate of rainfall in winter and autumn is in the second rank. In DOMARTON classification, the related climate has been classified as Mediterranean climate, in COPEN classification as moist climate and in AMBREZHEH climograph classification as semi moist climate.

Geologically viewpoint, the area of study has been located in northwest end of ZAGOROS geologic unit between zones of high ZAGOROS and folded ZAGOROS. The main part of the basin has been composed of limestone related to cretaceous age. Marl and shale (related to second and third ages) which are in the west and center parts of the basin, are structures so sensitive to erosion. The massive limestone of BISETOON, related to cretaceous age, is the oldest and kovaterner alluviums located in the riversides and some parts of southeast are the newest structures of the basin. This region is tectonically active and has got different faults. The main fault of the basin is ZAGOROS new fault namely over thrust located in east and northeast of the basin that distinguishes the borders of BISETOON lime and radiologist structures (center and east part of the basin) with other structures. Except this main fault, there is other by- fault along west side of over thrust. The direction of basin faults, following the common directions in ZAGROS, is from North West to southeast.

In high mountains, the basin soil is shallow and its texture varies from light to medium (sandy loam). The soil of hilly points is shallow. In high slope and soilless point, the soil texture is medium. The plateaus have got deep to very deep soil and very heavy texture (salty clay). In slope plains, the soil varies from deep to very deep and the texture varies from heavy to very heavy ones. On the whole, mesic thermal regime and xeric moist regime are subgroups of Inceptisols.

The plant types are often Astragalus – Bromus, Astragalus Festuca, Astragalus psatatyros with canopy of 47% to 54% and mean tendency down to negative. The forests (mainly oak) are located at 1000 to 2200 m height; pastures are usually located in height of 2200 m. More than 60% of this district of basin area is covered with these forests. On the whole, in this basin, in view of forest study, the oak trees are most distinguished ones.

*The method of research*

In this research, the borders of the related area have been clarified via 1: 50000 topographic maps, 1: 250000 geologic map, aerial photos and satellite images. These maps then were drawn via GIS software. Afterwards, via field operation for several times in different seasons, terrain and the shapes of maps & photos were compared with environment condition. With studying the library resources & climatic dates of the related area, have been

accomplished the climatic and hydrologic analysis together with studying and explanation of the area landslides.

The area of related basin was measured via digital Planimeter on 1: 50000 topographic maps. The circumference of basin also was calculated by use of Arc GIS software via scanned and digital topographic map. The basin slope has been measured through the Horton method & its harmony slop through the GIS method. The slope ratio of different layer was calculated together with relative & absolute area of different orientation. The basin canals also were classified according to Estaler method.

To recognize the most landslide bearing parts of the related basin, by considering the most important causes of landslides, zonation related to this potentiality alongside with map preparing in GIS via empirical method, was accomplished by the use of geologic layers, slope, the main rivers, roads .faults and the map related to areas sensitive to earthquake has been prepared in 3 scales of high, normal and low risk (Fig.8.).

**Results and discussion**

*The hydrology of basin*

The area of related basin was measured as 576 $km^2$ via digital Planimeter and 574 $km^2$ via Arc GIS software. According to area classification of different kinds of basins, this one belongs to the medium group (100 to 1000 $km^2$). The circumference of the basin also was measured as 137 $km^2$. The maximum height of basin is 3390maltitude in the northeast and the minimum height is 1000 m in the exit point of the basin. The mean height of the basin is 1850 m. the main drainer of the basin is LEILE River .It is 34 $km$ long from the main canal to the basin exit point (Fig.3.).

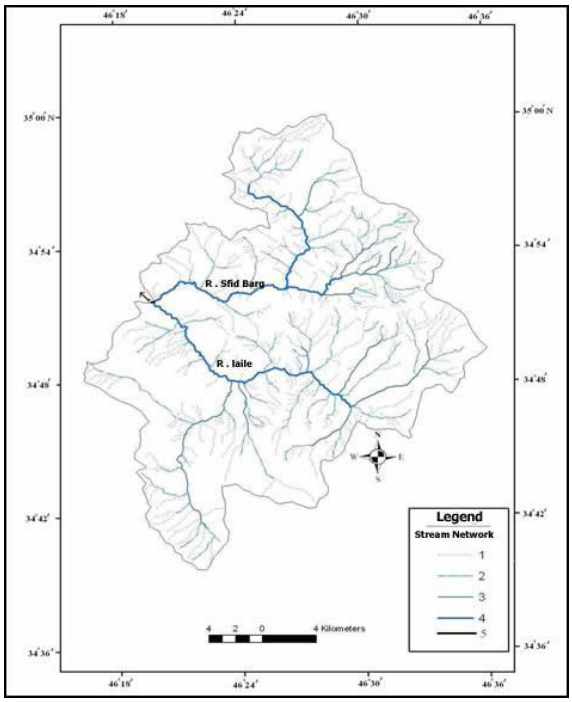


**Fig. 3.** Surface waters network map.

In mountaineer region (like LEILE basin), the high slope causes the rainfalls to be accumulated quickly which in turn leads to fatal torrents and also penetrating deep into the soil and finally causing the destructive landslides. The soil formation, vegetation cover, permeability, slope movement and ... are affected by slope. Accordingly, due to the high slope, there will be more landslides too. The basin slope was calculated as 14.8% via Horton method and harmony slop as 16.3% via GIS. This shows the quick accumulation of runoff & the high current speed of surface fluids in this basin and that this basin is capable of different kinds of landslides.

The slope direction also is the other effective factor in fluids regime and also creating different geomorphologic shapes of the hillside with different direction of which the landslide is one kind. As an example, the north angled slopes are moister and have got denser plant coverage. Accordingly, they are more resistant against erosion and there are fewer landslides there. While the south angled hillsides are relatively barer and are faced greater risk of erosion and landslides.

The network of surface fluids is composed of streaming waters, canals and the rivers of the basin. The density of network of canal arrangement and its general templates, in condition that it is not resulted from the tectonic activities, are geomorphologic ally important specially in determining erosion processes. The study of these templates will provides us with valuable information about permeability rate, stone material, and geomorphologic structure (Ramesht, MH, 20005).

Based on the carried out calculations, the total number of canals is 483 branches and their total length is 721 $km$.It is clear that the density of networks of surface fluids is high. It has been obtained by dividing the length of canals on the basin area rate which equals to 1.26. It means that for every 1 $km^2$ of basin area there is 1.26 $km$ surface fluid.

For clarifying the condition of canal branches of a basin or to compare the conditions of canal networks of two basins, bifurcation ratio can be used. The following formula offered by Horton has been used in LEILE basin.

$$Rb = \frac{Na}{Nu+1}(\frac{1}{u-1})$$

$$Rb = \frac{370}{88}+\frac{88}{16}+\frac{16}{2}+\frac{2}{1}(\frac{1}{5-1}) = 4.9$$

This value (4.9) shows that the basin has got many branches and the hydrograph should have a lying state and the concentration time should be long due to increase of water temporary accumulation in canals network.

*The basin geomorphology*

By a glance, we can divide the LEILE basin into 3 morphologically resemble units, namely mountains, molehill and plains. Through these units, mountains &molehill have occupied more space comparing with plains. With closer observation, we can also add other units like pediments and flood plains. Therefore, we have 5 under study units in this basin. The mountaineer unit is mainly on the surrounding lines of the basin and is the most identifier part of the basin. the highest mountain of KERMANSHAH province namely SHAHO, has been located in east & northeast part of the basin and the water separator line which distinguishes this basin from the eastern basins, is running through this mountain (fig. 4.).

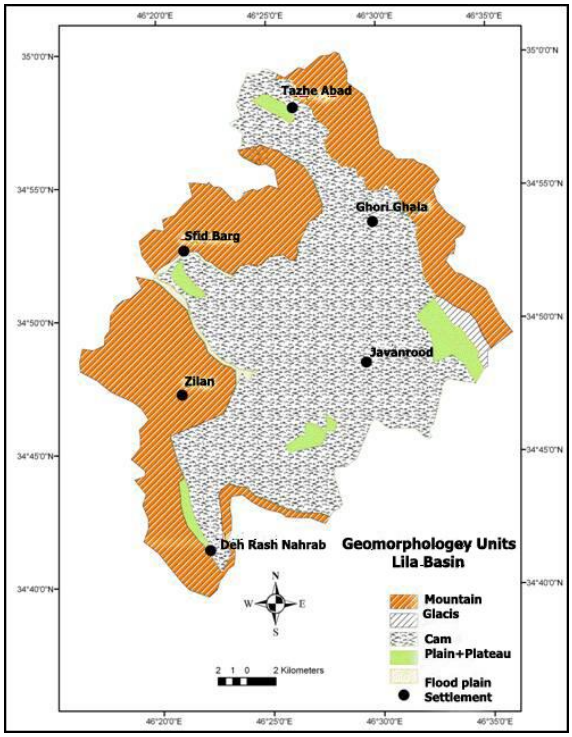


**Fig. 4.** Geomorphology units in Leile basin map.

These lime mountains, by getting a high showers and passing it through its plenty of slots, is the main source of surface & underground water of the basin. The mirages and springs of this mountain slopes (like springs of KAWAT & GHOURY GHALAE caves) are the main feeders of LEILE & SEFIDBARG Rivers.

From the geomorphologic shapes of the mountaineer part is karstic forms in lime structures of the eastern mountain, namely SHAHO. In this mountain, besides polje, we can observe other karstic steps from the formation of small holes to formation of wells, blind valleys, suspending valleys, caves and underground rivers. The stones of the related basin are sedimentary and in most parts are limestones .Carbonate rocks like lime and dolomite are transformed into different shapes under different climatic conditions. In most regions of the related basin, many karstic forms like dolines and poljes and

lime caves (GHOURY GHALAE and KAWAT) are observable. While in dry regions, the matter is totally different.

The main factor in karst effect is lime break up. $CACo_3$ in Shape of Kalsit or Aragonite is almost not soluble in waters with no $CO_2$. But the existence of $CO_2$ (even a small amount) in water will increase the solubility of CaCo and MgCo (the tectonic slots & ….increase the permeability of water into lime masses in advance).

*On the whole, the karstic forms are as follow*

Lapis: the most important kind is line lapis that is plentifully observable in Bisetoon lime formation in the east and northeast part of the basin (Fig. 5.).

**Fig. 5.** Lapis upon Bisetoon lime stone.

These rifts are formed in the consequence of lime structure break up that is occurred by the water with carbonic acid within.

Close pits: the most apparent & informative surface karstic forms, are small or big holes and the most important ones are dolines & poljes. These shapes are observe especially in SHAHO Mountain in the east part of the basin from which the nomad ranchers in the old times used to store water and snow for themselves and their animals too.

The cave can be considered as the final shape of karstic forms development. In this area of study, there are two caves (GHOURY GHALAE and KAWAT); both are in the east part of basin with 2200 m far from each other. These caves are watery type. GHOURY GHALAE cave has got beautiful stalactites & stalagmites (Fig. 6.).

**Fig. 6.** Beautiful stalactite & stalagmite.

In hillock unit especially in the central & western part of the basin, there are shapes resulted from slope process like debris flow, sliding, creeping, mudflow& …which most of the times are shaped as a result of the effect of outer dynamic forces on the slopes.

Materials sliding over the slopes are one of the most common shapes that have been developed more in the central & western part of the basin. Being close to active fault, the existence of fine soil, being close to river, sedimentation over slopes and the mechanical forces, leading to destruction of slope foot, are the most effective causes of landslide happenings. 49 landslides have been observed in LEILE basin of which five are more important and are located on the north angled slopes close to the rivers. The biggest landslide has been ever observed, was occurred alongside SALAS – JAVANROUD road and near to KANIGAOHAR village which has led to the destruction of the road (Fig. 7.).

**Fig. 7.** Landslides creation by human.

There is another landslide in the related basin that is occurred in the Valley of BANILWAN Mountains. This landslide is three $km_s$ far from the east side of JAVANROUD and has led to obstruction of related mountaineer valley and also formation of Season

Lake called Goom. By beginning spring torrents, this lake will overflow with water and until the end of summer (sometimes the whole year), it has got water. The area of this lake is about 3000 $m^2$ .

To recognize the most landslide bearing parts of the related basin, by considering the most important causes of landslides, zonation related to this potentiality alongside with map preparing in GIS via empirical method, was accomplished by the use of geologic layers, slope, the main rivers, roads & faults and the map related to areas sensitive to earthquake has been prepared in 3 scales of high, normal and low risk (Fig.8.).

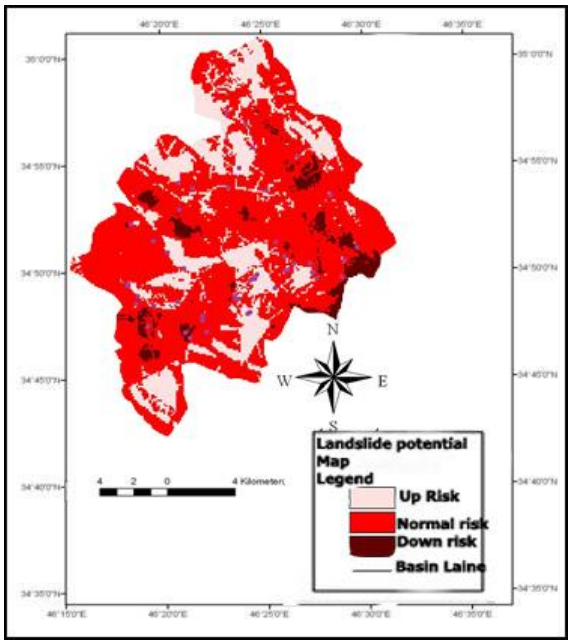


**Fig. 8.** Zonation of areas with landslide potentiality in Leile basin.

**Fig. 9.** Gully erosion landforms.

Solifluction is another geomorphologic shape of slopes. Of conditions necessary for occurring this phenomenon, water interference, the existence of fine sediments, permeability of debris and the slope factor are some examples.

**Table 1.** Slop Surfaces transmittal in LEILE basin area (JAVANROUD).

| Slop class | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Slop THESAURUS (%) | | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | 70< |
| space (km²) | 192 | 200 | 121 | 43 | 9 | 1 | 1 | 7 |

**Table 2.** Orient slop Surfaces transmittal in LEILE basin area (JAVANROUD)

| orient slop | NE | E | SE | S | SW | W | NW | N | F |
|---|---|---|---|---|---|---|---|---|---|
| space (km²) | 41 | 39 | 67 | 82 | 62 | 46 | 42 | 59 | 131 |
| Relative space (%) | 7 /1 | 6 /8 | 11 /7 | 14 /3 | 11 /2 | 8 /0 | 7 /4 | 10 /3 | 22 /9 |

**Table 3.** Surface flow network of Leile basin

| DEGREE | Streams number in DEGREE | LENGTH Streams |
|---|---|---|
| 1 | 370 | 405721 |
| 2 | 88 | 199560 |
| 3 | 16 | 61182 |
| 4 | 2 | 52812 |
| **5** | 1 | 47 |

This phenomenon has been occurred more in western part of the basin in which there are looser formations and ZELAN village is the main point which possesses that necessary condition for this phenomenon. Debris forms have been resulted from the effect of mechanical destruction over high slope stone hillsides, and mainly are amorphous and angular pills available more in sandstones.

Avalanche phenomenon has been observed more in northern slopes in which 30% of showers, due to relatively considerable height and also winter cold climate, is in shape of snow and the whole condition is prepared for avalanche occurring. The landform

meaty erosions have been observed over slopes with fine soil.

Close is a shape occurred by water deep probing uprightly onto the liner axis of folds. It is the proof for no conformity between geomorphologic structure & canal network. SEFIDBARG River is a sample of a Close that has cut the folds of GAROUDGIR radiolarian formation related to cretaceous period, at an east to west direction and also has made valley cliffs through its direction (over 200m in NOEL valley is an example). The valley of this river is narrow and V-shaped. The Close of GEDAR spring in the west side of the basin is a sample that has cut ZELAN mountain perpendicular on linear axis.

In foot valleys, there are various features that are mainly under the effect of river & streaming water processing; hitch meaty erosion or hydrosphere features are some samples. In the past times, these features were considered as the developed shape of water canal erosion, but nowadays as a result of very complicated process. Factors like breaking up, the existence of primary cavity for water penetration, development of underground canal, and ... are considered necessary for gully formation. These valleys are deeper and more extended than groovy meaty erosion features and their depth is different from $30cm_s$ to several meters. In this state, the parent rock appears on the base. The meaty erosion features are v-shaped in thick lands of clay and marl formation but in formation with less thick lands are loose and the destruction continue down to a hard layer; consequently they appear in U-shape (Asyaee M & Javanmard S, 2004).

I LEILE basin, these kind of features are found in valleys & flood plains especially where the accumulated sediments & flood flows stream strongly over the mountains. The steep slope of basin & the heavy rainfall also can lead to high formations of these features.

Lateral erosion is more observable alongside the main rivers of the basin. In this type of erosion, water flows ,especially muddy water having gravels, sands & ..., can wash out both sides of river bed and accordingly carry away more materials. Consequently, the bedside lands lose their solidity sediment transport. On the other hand, the weight of water, down to the dissolved materials, will increase and its destroying power will increase in turn.

In the lands with loose soil, this kind of erosion will develop more and where it is accompanied with human interferences alongside the rivers in shapes of gardening and cultivating in the flood plains and narrowing the river runways for other uses, it can be destructive as well.

The flood plain is an alluvial surface that is connected to stream canal and is often covered with water. The size of flood plain depends on the amount of water discharge of the river (Chourli R & colleagues, 2000). However, the role of other factors should not be ignored. The rate of linear slope of the mainstream canal, the sediment rate of torrent flood and the topographic structure of river valleys, are samples of other causes in development process of the flood plains. On the other word, the accumulated materials in flood plains of riversides are washed out from upside, and are disposed by slope decreasing and also decreasing in power of rivers. This is while the streaming flows exit from the basin with no considerable decrease in strength & speed. Flood plains are not so extended in LEILE basin due to the steep slope of riverbed and also narrowing of valleys.

In fact, the erosion is a natural phenomenon that occurs inevitably and is not controllable. Accordingly, the mechanical operations for this purpose are not so helpful. But what is more considerable now is accelerated erosion that is occurred in result of excessive use of some part of a land. This kind of erosion is controllable by human being but comparing with past, the role of human being in developing the erosion rate has been more distinguished by development of sciences. Nowadays erosion control is focused & emphasized on in all communities (Fig. 10.).

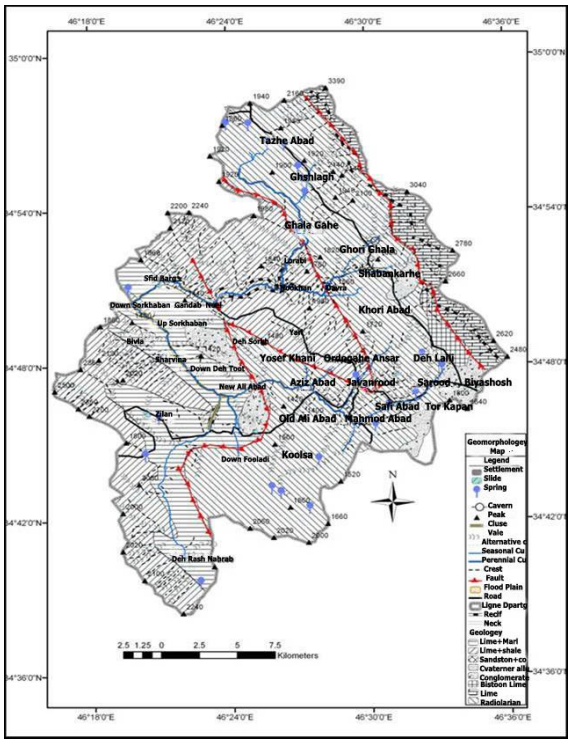


**Fig. 10.** Geomorphology map.

In the related area of study, due to the shortage of lands and the people's economic dependence on environmental resources, the limited resources are in danger of ruin. For example, the development of gullies, expanding of villages, the ruin of riverside gardens, the animals overfeeding in pastures of slop hillsides and the ruin of oak forests, all have led to increase of sediments and have made the rivers muddy and the floods more strong.

Because of poor yielding of farmlands, due to high slope and the natural hazards like cooling and droughts, the farmers, in order to supply themselves, have to farm more area of lands without fallow. It means that in order to cultivate more lands, they use the high slope lands too and because there will be no fallow in land cultivating, organic matters of soil will decrease and on the other hand the erosion possibility will increase instead.

Narrowing of river for agriculture purposes has led to increase in streaming speed of torrents and destruction of lands & gardens as well. Road making without road barriers, especially in slopes with alternation of hard layers (lime) and loose ones (shale & marl), in some cases has led to weakening of slope reliance surface and providing the necessary conditions for land slide occurring (The west & south west part of the basin).

**Conclusion**

LEILE basin, in west side of the country, has been located in a high slope mountaineer region in geologic zone of high folded ZAGROS, an active tectonic zone, and has got semi moist climate. The stones of basins are mainly in lime with mid layers of shale and marl between which are sensitive to erosion and landslide. Different factors like slope, canal network, geology, road makings, mining, other building operations by human being and ... have led to landslide occurring and genesis of different shapes of water erosion. Undoubtedly, the natural landslide & erosions are not controllable or this controlling will be more expensive. But the main wrong activities that lead to acceleration of erosion and landslides and ruin of soils and water resources can be controlled & prevented. The most important causes of landslides in this basin are the faults, slope, and mainly man's effects like road instruction in Javanroud - Salas road.

Sand taking from the rivers for building uses, Sometimes lead to walls creep into the river runway (in central parts of the basin) and also diversion of water streaming speed line and increasing of sediments.

Farmers & gardeners have made obstacles in the way of rivers to deviate the water into the farms & gardens. In springs when torrent floods are occurred, these obstacles deviate away the related floods into the flood plains that in turn cause the soil erosion and even ruin of riverside trees. The garbage that have been accumulated in rivers during the times of water loss, are carried away by floods in rainy seasons and sometimes deviate the path of floods.

The ruin of vegetation cover resulted from excessive grazing and slashing via animal husbandry has led to increase of soil erosion and sediments, mudding of rivers and also increase of rain in hillsides.

Water logging the farmlands with high slope most often has led to increase of landslides, formation of gullies, washing out the shallow soil of farmlands and appearance of deeper spalls and blocs.

The destruction of valuable oak trees for farming & fuel providing purposes have made slopes barer and have led to increase of river sediments and the threat of avalanches & landslides. These can in turn lead to increase of ruin and growth of resident's poverty.
About 60% of the basin area has been covered with precious oak trees that are preventing hills from erosion & landslide. The rich vegetation and pasture cover in forestless regions also can prevent erosion & landslide. But the measures like forest destruction, excessive grazing, cultivating slope lands, narrowing the river canals and wrong mechanical operations like road making ignoring geologic conditions have led to mass movement, landslides, flood flows , ruin of gardens and farmlands and subsequent economic and social problems. Undoubtedly by optimal management of resources, caring about the environment potentials and measures like supporting of gardening than of agriculture, job making employment in industry & services departments, thorough minding in fulfilling way constructing plans and fuel (oil & gas) providing for residents of related basin, can be more hopeful in improving environmental conditions and acceleration of landslide can be prevented.

*Proposals*

1. Considering the various causes of landslides, on time fuel providing for residents of basin, can prevent them from cutting bushes and forest trees of the basin, which in turn prevent landslides and its subsequent damages. The positive effects of this factor in stabilizing the slopes of LEILE basin is certainly due to this fact that in region with dense vegetation, bush and forest cover, no landslides has occurred.
2. The residences like Cheshmenezar and old Aliabad that are located on sliding mass are in priority for strengthening slopes via mechanical & biological methods. Otherwise, these residents are preferred to move in somewhere else. Thorough minding in fulfilling way-constructing road plans, supporting of gardening than of agriculture can be also useful.

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