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INVESTIGATION OF ERODIBILITY AND SEDIMENTATION IN GOYJAH BEL BASIN

INVESTIGAÇÃO DE ERODIBILIDADE E SEDIMENTAÇÃO NA BACIA DE GOYJAH BEL

Ramin Karbalaei Amini[1]

Mohammad Reza Noura*[2]

Sara Nakhjiri[3]

Ahad Habibzadeh[4]

ABSTRACT

Goyjah Bel basin is located 10 km south of Ahar city with an area of about 7462.8 hectares, where the occurrence of erosion is remarkable. This study is based on library studies, field studies, and the use of empirical models of erosion and sedimentation estimation. For estimation of the intensity of erosion in these units, and classification of lands based on quantitative criteria, PSIAC method is used with a comprehensive view of all the determinants. Estimation of erosion by this method in geomorphological units proves that the hypotheses on speed and accuracy, identification of the most important erosion factors and the most critical areas of sedimentation, and determination of relations and distribution of erosion in the region is correct. Here, the experimental MPSIAC model, which considers the most effective parameters in erosion and sedimentation, is used, and environmental parameters are evaluated. Finally, the results are compared with neuro-fuzzy model. The results indicate that MPSIAC model works good in this basin. It should be noted that the estimated sediment is in erosion class of 4, and in terms of qualitative classification, the erosion was in a high class. Therefore, according to the definition of this class, it can be said that in this basin, the transfer of soil particles is to an extent that implementation of soil and water conservation programs is necessary and prior, and the use of land must be so limited.

Keywords: Basin; Erosion; Weathering; Sedimentation; PSIAC; MPSIAC.

[1]PhD student, Department of of Geology, Science and Research Branch, Islamic Azad University, Zahedan, Iran. ra_k_amini@yahoo.com ORCID: https://orcid.org/0000-0002-0608-6306

[2]Assistant Professor, Department of Geology, Zahedan Branch, Islamic Azad University, Zahedan, Iran. *Corresponding author. noura706@yahoo.com ORCID: https://orcid.org/0000-0002-0866-0455

[3]Assistant Professor, Department of Geology, Zahedan Branch, Islamic Azad University, Zahedan, Iran. sara_nakhjiri@yahoo.com ORCID: https://orcid.org/0000-0002-3939-1550

[4]Assistant Professor, Soil Conservation and Watershed Management Department Agriculture &Natural Resources Research Center of East Azerbaijan, Tabriz,Iran. a.habibzadeheh@tabriz.ac.ir ORCID: https://orcid.org/0000-0002-6995-1010

RESUMO

A bacia do Goyjah Bel está localizada a 10 km ao sul da cidade de Ahar com uma área de cerca de 7.462,8 hectares, onde a ocorrência de erosão é notável. Este estudo é baseado em estudos de biblioteca, estudos de campo e no uso de modelos empíricos de estimativa de erosão e sedimentação. Para estimativa da intensidade da erosão nessas unidades e classificação das terras com base em critérios quantitativos, é utilizado o método PSIAC com uma visão abrangente de todos os determinantes. A estimativa da erosão por este método em unidades geomorfológicas prova que as hipóteses sobre velocidade e precisão, identificação dos fatores de erosão mais importantes e das áreas mais críticas de sedimentação e determinação das relações e distribuição da erosão na região estão corretas. Aqui, o modelo experimental MPSIAC, que considera os parâmetros mais eficazes em erosão e sedimentação, é usado e os parâmetros ambientais são avaliados. Finalmente, os resultados são comparados com o modelo neuro-fuzzy. Os resultados indicam que o modelo MPSIAC funciona bem nesta bacia. Deve-se notar que o sedimento estimado está na classe de erosão 4, e em termos de classificação qualitativa, a erosão foi em uma classe alta. Portanto, de acordo com a definição desta classe, pode-se dizer que nesta bacia a transferência de partículas de solo é na medida em que a implementação de programas de conservação de solo e água é necessária e prévia, e o uso do solo deve ser tão limitado.

Palavras-chave: Bacia; Erosão; Intemperismo; Sedimentação; PSIAC; MPSIAC.

INTRODUCTION

The outer surface of the earth as a dynamic system has always undergone processes that change its face gradually and permanently. In this process, rock and soil as the outer cover of most of the land are affected by various changes that result in their production or destruction. According to Bennett (2015), it usually takes about 300 years to reach 25 mm of surface soil in the intact condition; during a severe rainfall, this amount of soil may erode, transported to rivers, seas, and shores, and so get out of reach. The phenomenon of erosion not only causes inaccessibility of soil, but also leads to short time and long time adverse effects.

Goyjah Bel area with an area of 74 hectares is located 10 kilometers southwestern Ahar city. This basin is part of Aharchay River Basin. Goyjah Bel basin is divided into three independent hydrological units called G1, G2 and G3, and an independent hydrologic unit called G-int, with its G3 unit being divided into seven sub-units.

Based on Nabavi (1976) divisions, the studied basin is part of the Western Alborz Zone. The diversity of rocky-sedimentary units is very high in Goyjah Bel basin, so that a set of volcanic and sedimentary rocks along with alluvial units are located together. The southwest of the basin is composed of sedimentary units similar to Flysch, its southern part consists of volcanic and pyroclastic rocks and are found near each other in the north of the combined basin of these two units. The central, eastern and western parts of the basin include the conglomerate PlQC unit and the alluvial unit with agricultural and horticultural use (Gharib-Gorgani et al. 2017; Baratian et al. 2018; Bina et al. 2020; Baratian et al. 2020; Yazdi, Sharifi Teshnizi 2021; Jehangir Khanet al. 2021). The volcanic and pyroclastic units of the north of the basin, like sedimentary units, show a consecutive age sequence of units, which can be adapted to the southern units of the basin. The under-study section consists of nineteen lithology units, which will be described in the following.

In this study, the exact identification of major and minor faults around Goyjah Bel area are carried out using satellite images of Google Earth and Sasplanet, and processing the data of Landsat-7 ETM+ satellite (p165r35 [03.06.2010]) (http://glcfapp.glcf.umd.edu:8080/esdi/) with the help of the ER Mapper 7 software. In order to better distinguish the rock units, and so identify the landslides, weathering, and erosion, various color combinations (Red, Green, and Blue (RGB)) have been used. Making stretch or transfer in the histogram of the data lets use of the whole range of numerical values of the data. One of the stretches used in this study is to make a stretch by uniformizing the graph. One of the other processes implemented for image reconstruction in some areas is the application of different formulas, including the use of band ratio. In order to identify different erosion phases and due to effective factors in their identification, mostly spatial filters are used. The filters used in this study are high pass filters, edges filters, and sun angle. Using these filters, the boundaries of different lithology units got more obvious and linear trends, including faults and important fractures of the area were identified. ETM30 satellite

images were used for identification of erosion and IRS images for accurate examination and identification of rock units and faults (figure 1).

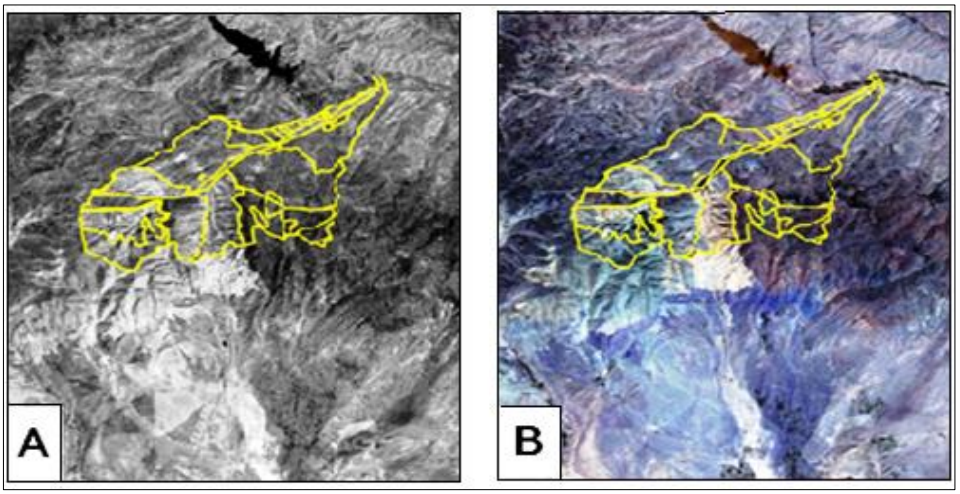

Figure 1. (A). IRS satellite image, (B). ETM30 satellite image, and the determined study área. Source: Authors (2021).

GEOLOGICAL SETTING AND CLIMATIC CONDITIONS OF THE STUDY AREA

Goyjah Bel study unit with an area of 7462.8 hectares is located 10 kilometers southwest of Ahar city (figure 2). This basin is part of Aharchay River Basin which is located from 46° 47' 21.26'' E to 46° 56' 53.64'' E, and from 38° 21' 42.13'' N to 38° 27' 39.4'' N. The maximum height of the basin is 2495 meters and the minimum height at the outlet of the basin is 373.1 meters above sea level.

According to Amberje method, Goyjah Bel basin has a cold semi-arid climate, with an average rainfall of 342.2 mm/year. This basin is part of the Aharchay River Basin which connects to Aras River after joining Ghareh Sou River. The villagers in the region mainly live through agriculture, animal husbandry and handicrafts. Its main agricultural products include wheat, barley and tree fruit.The main road to access this area is the main road of Tabriz-Ahar. This road enters the basin defile from the south to the north and exits from the north-east (figure 2). The residential centers of Goyjah Bel Basin include the villages of Damanabad, Goorehdaraq, Zanjeer Balagh, Yaijiloo and Gemsh Abad.

METHOD OF STUDY

In this research, it is benefited from library method and data collection including the study of the literature, books and publications, articles, geological maps, aerial photographs and satellite images. In addition, field visits are used to observe various erosion, topography, geology, vegetation and land use of the study area. Also, due to the lack of statistics and information on soil erosion of Goyjah Bel basin, MPSIAC experimental methods have been used to estimate soil erosion and sediment production. In this method, nine effective factors in soil erosion are investigated.

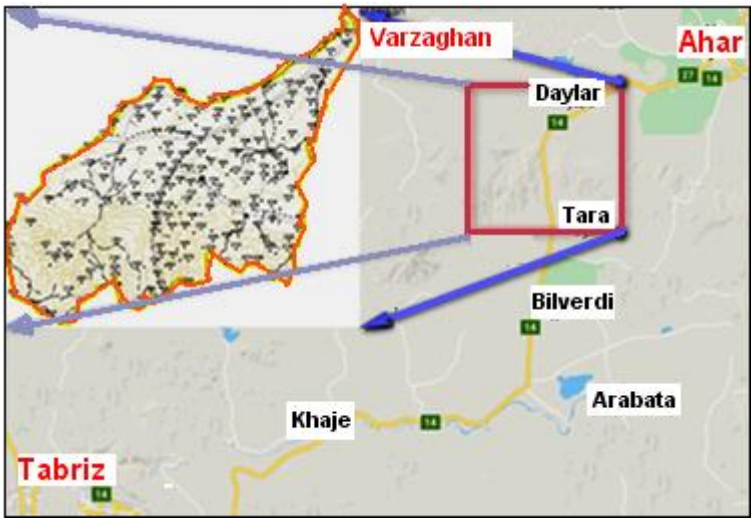

Figure 2. The communication paths of the study área.
Source: Adapted from Roads Atlas of Iran (2011).

STRATIGRAPHY OF THE STUDY AREA

The studied basin, based on the Nabavi (1976) divisions is part of the western Alborz zone, but according to Stöcklin (1968), and also the most recent sedimentary-structural zonation of Iran which is presented by Aghanabati (2004), this area is located in the central zone of Iran's Plateau (figure 3). The study area, from the point of view of tectonics events, during the Paleozoic period, like Central Iran and Alborz has had a platform state, during which continental moraine sediments accumulate therein. The main factor for creating this condition can be the stability of Bikalin basement due to the Catanga orogenic phase. The

deposition continued until after Jurassic, and only epirogenic movements caused degradation in sedimentation, which dates back to Ordovician, Silurian, and Carboniferous periods. The volcanic rocks of the area are mostly andesite and trachyandesite with various types of pyroclastic materials with the Eocene age, which is caused by the Pyrene phase, and is probably part of the Sahand-Bazman volcanic belt.

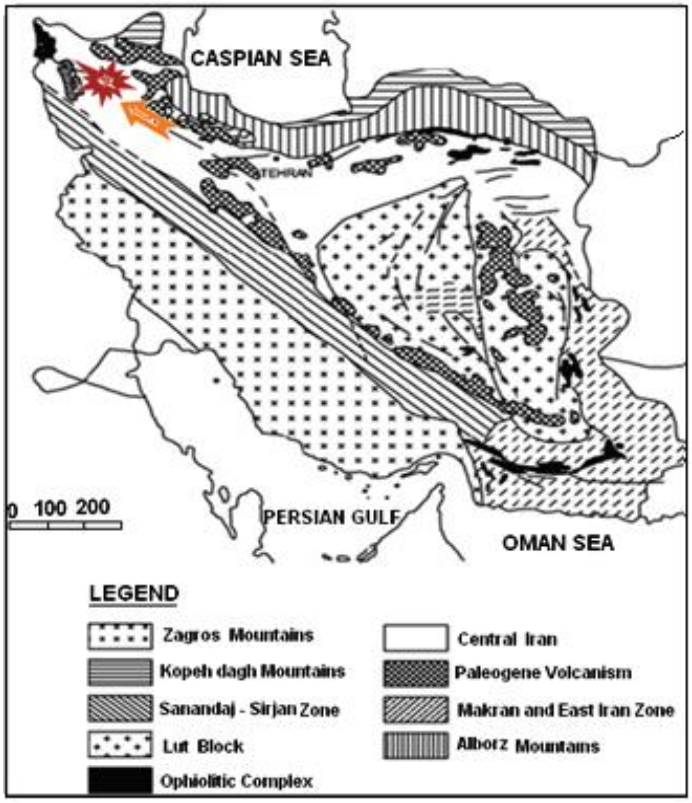

Figure 3. Structural Zones Of Iran.
Source: Stöcklin (1968).
(The study area is located in the Central Iran zone, which is indicated by the red arrow).

The diversity of rocky-sedimentary units in Goyjah Bel basin is very high, with a set of volcanic and sedimentary rocks along with alluvial units. The southwest of the basin is composed of sedimentary units similar to Flysch; the southern part consists of volcanic and pyroclastic rocks; in the north of the basin, a combination of these two units is seen adjacently.

The central, eastern and western parts of the basin include PlQC conglomerate unit and the alluvial unit with agricultural and horticultural use. The volcanic and pyrogenic units of the north basin, similar to sedimentary units, show a consecutive age sequence of units, which can be adapted to the southern units of the basin.

At the boundary between the Miocene-Pliocene sediments, there is an apparent unconformities that is dependent on the Mio-Pliocene movements. These movements, are accompanied by the exhaust of volcanic material, as lava and cut. In the interval between Plio-Pleistocene, the Pasadenian tectonic event ends the evolutionary course of sedimentary basins. After this tectonic event, all movements have acted as epeirogenic and caused the precipitation of Quaternary sediments. Figure 4 shows the rock-stratigraphic units of the studied basin and their area in hectare. Below the characteristics of these units are examined.

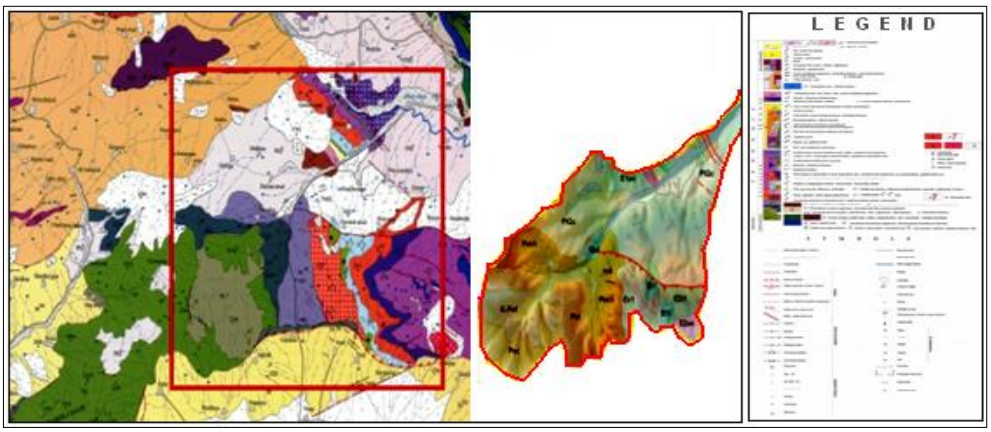

Figure 4. Extension and distribution of each rock and sediment unit classified by hydrologic units (area in hectare). Adapted from the map of Geological Servey and Mineral Exploration of Iran.
Source: Stöcklin (1968).

AN EXAMINATION OF EROSION IN GOYJAH BEL BASIN

Erosion includes all materials that result from weathering of rocks or waste of soil (Faiznia, 2008). Soil erosion is one of the important environmental problems; millions of tons of sediment accumulate annually in rivers, lakes, reservoirs and dams, and a heavy cost is spent for dredging lakes, reservoirs, and dams (Goldman , 1964). Also, frequent flooding, by destroying and washing roads and agricultural lands, and contaminating drinking water,

cause irreparable damage to humans and the ecosystem. Soil erosion is an inevitable phenomenon that human activities can reduce or increase it.

Goyjah Bel basin in the southwestern part of Ahar (figure 1), due to natural conditions, the existence of erodible formations, human activities, agriculture, livestock, active faults, unstable slopes of hillsides, regional slip and, most importantly, weathering has a high precipitation potential. Estimation of precipitation rate and zoning of erosion-sensitive areas in order to protect soil in this region seems necessary. Due to the presence of reservoirs or watercourses in the study area, there was no accurate and complete information on annual sediment volume. Therefore, the use of appropriate experimental methods seems necessary for estimating the severity of soil erosion and precipitation. Since the weathering factor plays an important role in the erosion of region, this factor is described in detail.

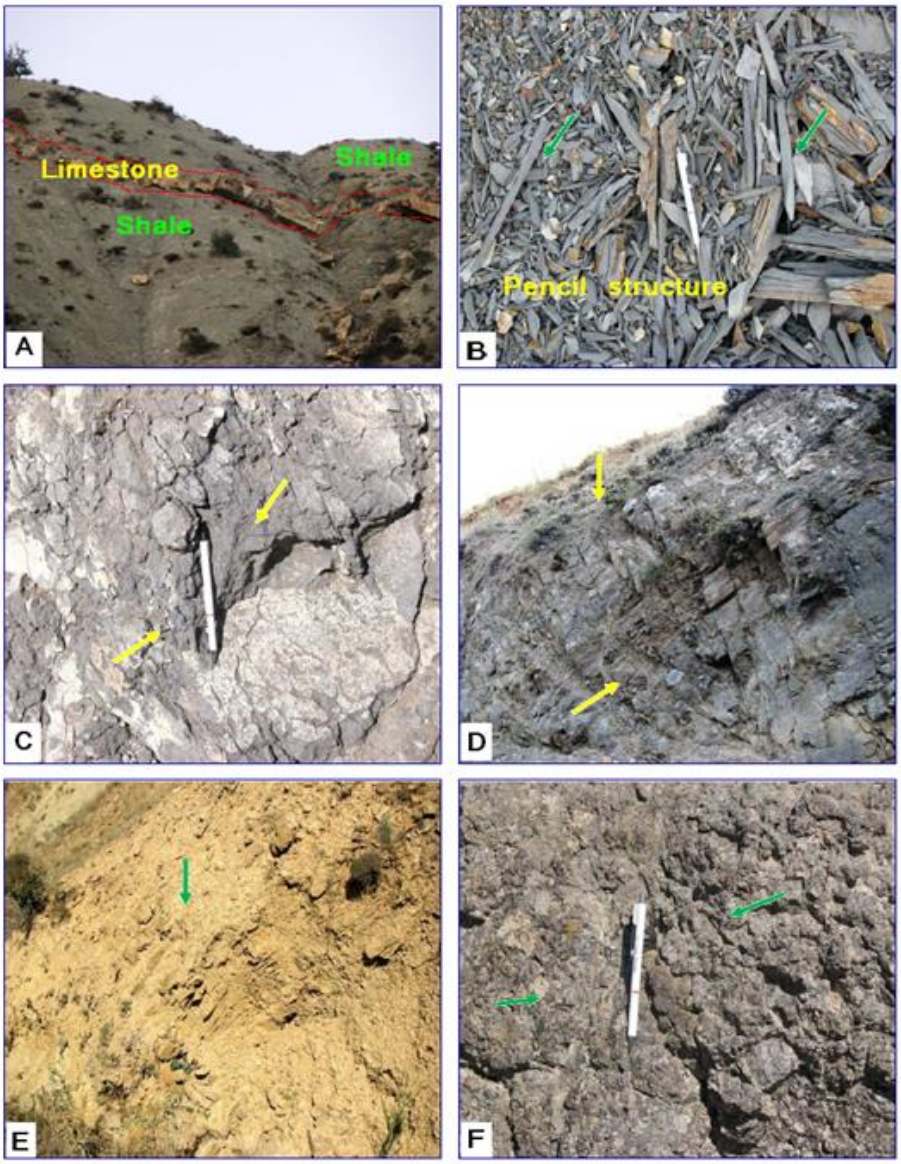

Figure 5. (a). Goyjah Bel shales along with the calcareous layer (Pe^{sh} unit) in Goyjah Bel Defile; *(b)*. Pencil shales of Pe^{sh} unit; *(c)*. Andesitic lava of E_1^{an} unit in the north of the basin; *(d)*. Pyroclastic unit with layering (E_1^{t2}) in the west of Gemsh Abad Village; *(e).* Destructive unit E^11 in west of Gemsh Abad Village. *(f)*. Andesitic lava of E_2^{an} unit in the north of the basin.
Source: Amini (2020)

FORMS OF EROSION IN THE BASIN

Among various types of erosion processes, wind erosion has a lower role in the study area. Other erosions such as chemical and mechanical erosion has formed the overall geomorphology of the basin. Water erosion in the basin has had two main effects, physical

degradation of the constructive units and chemical dissolution of the shale and calcareous units. Below, types of erosive forms of the basin are described.

Qualitative class of erodibility	Erodibility score
Resistant to erosion	0-2
Relatively resistant to erosion	2-4
Fairly erodible	4-6
Erodible	6-8
Sensitive to erosion	8-10

Table 1. Qualitative classes of erodibility of lithological units.
The maximum number of each category belongs to that category ($\prec a \leq$).
Source: Authors (2021).

Rock unit	Symbol in geological map	The genus of different rock parts	Score of the rock unit in calculation of sedimentation through MPSIAC method	The average weight of the score	Qualitative description of rock units in terms of erodibility
Destructive unit	*K-Pe^{f}*	Sandstone	7	7	ERODIBLE
		Limestone	5		
		Shales	8		
		Siltstone	8		
Conglomerate	*Pe^{c}*	Conglomerate	6	6	RELATIVELY ERODIBLE
Calcareous unit	*Pe^{1}*	Limestone	5	5	RELATIVELY ERODIBLE
Goyjah Bel shales	*Pe^{sh}*	Shale	8	7.5	ERODIBLE
		Limestone	5		
Unclassified unit	*E^{V}1*	Tuff	6	5	RELATIVELY ERODIBLE
		Andesite	4		
		Dacite	4		
Pyroclastic and lava	E_1^{an}	Tuff	4	5.5	RELATIVELY ERODIBLE
		Andesite	4		
Lava	E_1^{da}	Dacite	4	4	RELATIVELY RESISTANT TO EROSION
Pyroclastic	E_1^{t2}	Tuff	6	6	RELATIVELY ERODIBLE
		Breccia tuff	6		
	E^{L}1	Lime	5	5.25	

Rock unit	Symbol in geological map	The genus of different rock parts	Score of the rock unit in calculation of sedimentation through MPSIAC method	The average weight of the score	Qualitative description of rock units in terms of erodibility
Limestone and conglomerate		Conglomerate	6		RELATIVELY ERODIBLE
Pyroclastic and lava	E_2^{an}	Andesite and basalt	4	4.4	RELATIVELY ERODIBLE
		Tuff	6		
Pyroclastic and lava	E_2^{ta}	Trachyandesite	4	4.4	RELATIVELY ERODIBLE
		Tuff	6		
Pyroclastic	E_2^{t2}	Tuff and breccia	6	6	RELATIVELY ERODIBLE
Tuff calcareous	E^L3	Tuff limestone	5	5	RELATIVELY ERODIBLE
Pyroclastic and lava	E^V3	Dacite	4	5	RELATIVELY ERODIBLE
		Tuff	6		
Dyke	*Md*	Microd*iorite*	4	4	RELATIVELY RESISTANT TO EROSION
Pliocene Conglomerate	PlQ^C	Conglomerate	7	7	ERODIBLE
Young conifer	Q^f	Gravel, sand and clay	8	2	ERODIBLE
Alluvial agriculture fields	Q^{t3}	Gravel, sand, clay and organic matter	8	2	ERODIBLE
River alluvial	Q^{A1}	GRAVEL, SAND, AND CLAY	0	0	RESISTANT TO EROSION

Table 2. Erodibility of lithologic units in Goyjah Bel Basin.
Source: Authors (2021)

RAINFALL EROSION

One of the most common types of erosion which is caused by the collision of rain drops with the surface of the soil. With the onset of precipitation, the effect is usually gradually increased due to the wetting of the earth and reaches to its maximum when the soil becomes saturated. In the studied basin the effect of this type of erosion is less, since most precipitations are snow. In the south of the basin, the rough topography intensifies the

effect of this type of erosion, so that particles separated from the soil are displaced by rainfall due to the high slope. The effect of rain erosion on calcareous units is considered as a karstic erosion.

SHEET EROSION

Another type of erosion which begins immediately after the collisions of the rain drops into the surface are the sheet erosion, resulting from the movement of water on the surface layer of the soil. In this erosion, particles that come from droplets collisions are carried. In Goyjah Bel basin, like all basins, this type of erosion exists.

RILL EROSION

When runoff moves on a slope, it tends to gradually choose its path from troughs of the surface of the earth, resulting in tiny waterways in the earth. These waterways are said to be erosive if they are skin-deep and are destroyed by cultivation. Shear erosion depends on shear force and water resistance.

In Goyjah Bel basin, the activity of this type of erosion follows the topography of the area; i.e., in the central and northern parts of the basin, which are rolling terrains, the slopes are very regular and the hills and valleys are sinusoidal. For this reason, the flow of water on the surface is uniform and flat and has not caused a lot of grooves. This situation can be observed in the northwestern rolling terrains of the basin which are semi-hard conglomerate (PlQC). One of the most prominent examples of this erosion can be seen in Goyjah Bel Defile, on the river's margin, which is created in the weathered section of Pesh shales (Fig. 6). This type of erosion is less observed in volcanic units of the basin, due to their almost homogeneous and hard lithologic texture.

Figure 6. Rill erosion in weathered sections of Pe^{sh} shales in Goyjah Bel Defile (west view). Source: Amini (2020)

TORRENT EROSION

This erosion is active at the time of severe rainfall that cause large flooding. In this type of erosion, water has a lot of erosivity and usually can carry coarse aggregate material. Due to the relatively low potential of the basin for sedimentation and the low area, no major flood occurs during severe rainfall. Effects of this erosion can be observed in the northern and central parts of the basin where the volume of floods is high.

RIVERSIDE EROSION

In this erosion, outer parts of the river bends, where the shear-force of water is high, are severely eroded. This erosion, in spite of the torrent erosion that is active only during the rain, is permanent. Due to the low water drainage and low energy of floods, this erosion is poorly seen in Goyjah Bel basin. This type of erosion can be seen on alluvial terraces in the center and north of the basin and in the valley walls (figure 7).

WATERWAY EROSION

If rill erosion is further developed in the area, waterway erosion may occur. In this case, damage to the waterway is high and the profile is V-shaped. Two important factors in this type of erosion are the severity of rainfall and the slope of the earth. Erosion of the

waterways can be caused based on various rocky outcrops in the form of parallel, dendritic, scaffold or abnormal. This type of erosion is also seen in Goyjah Bel basin, which is mostly in the form of the extension of the parallel waterway channel in the plain and the waterway channel in the altitudes. The shape of this type of erosion in different areas of the basin is dependent on the severity of rainfall and slope of the land, as well as on the type of rock and sedimentary units.

Figure 7. Erosion along the river in the alluvial terraces of Goyjah Bel River in the north of the basin.
Source: Amini (2020)

GULLY EROSION

The difference between rill erosion and gully erosion is that, in rill erosion, the width of the grooves is usually several times the depth, but in gully erosion the depth of the gullies is much greater than their width. Gully erosion is usually a much more advanced stage than the rill erosion. The size of gully varies from 25 centimeters to 50 meters. Gully is more developed in areas where the soil is loose and vegetation is poor and makes it difficult or even impossible to carry out agricultural operations.

In Goyjah Bel basin, in some parts of its territory, in which the ranges are covered by a thick destructive cover, there is potential for gully erosion, but a rich vegetation has

prevented this erosion. However, this type of erosion can be observed only in the tuff and lime tuff of EL1 unit and in areas where the vegetation is weak. Figure 11 shows an example of this erosion in the basin. As it is seen, vegetation has prevented the ditch from rising to the left.

KARSTIC EROSION

This erosion occurs when there are high solubility structures such as lime, dolomite, gypsum and salt in the basin. The higher the degree of lime purity, the faster the process of karstification. Karstic erosion can occur in both surface and underground, with underground forms are cave or sink hole, and its surface forms include kinds of Karren.

Since the erosion materials in Karstic erosion are transported in water-soluble form, it does not play a major role in sedimentation, but due to dissolution, pieces of lime may be removed and transported by flood as bed load or suspended load. This part of lime erosion, which is the result of karstic erosion, produces a high sediment load.

Figure 8. Gully erosion at $E^{1}1$ unit.
(effect of vegetation on preventing the spread of this erosion is significant).
Source: Amini (2020)

In Goyjah Bel basin, Pe^{1} calcareous unit and calcareous parts in K-Pe^{f}, $E^{L}3$ and $E^{L}l$ units are affected by the karstic erosion. But other than Pe^{1} unit which is made up of calcisparite, in other units since the sandy limestone or tuff limestone , extension of karst

has not been high in them and only the surface forms have had a limited development. Of the surface forms of karstic erosion in lime in the region, Rain Pit and Karren can be mentioned. Rain Pits are the place where rain falls collide the surface of limestone, which is seen in the form of circles on the limestone surface with a few millimeter radius. These shapes are the onset to the formation of a variety of Karrens. Karrens are dissolved grooves on the limestone surface, varying from a few millimeters to several dozen centimeters. Unlike previous erosion forms, this type of erosion is more developed in cases where the limestone surface slope is low, because there will be enough time for the limestone to dissolve with its surface.

PRACTICAL SOLUTIONS TO PREVENT SEDIMENT TRANSPORT AND POSSIBLE RISKS

In Goyjah Bel basin, slope and slip factors have a major role in the transport of sediments. The tectonic factor is considered to be the driving force of the above mentioned factors; the tectonic factor firstly causes the formation of the elevations of the area and the slopes, and secondly, by making multiple earthquakes causes landslides in the area. The tectonic agent is not controllable, but its effects can be controlled. The most important of these are as follows:

(A) Destructive cover on the heights of the basin has caused the instability of sediments due to the high slope of these regions, and they can be planted for stability. Of course, due to the high slope and the climate of the region, appropriate tree species should be selected. This will prevent slippage on these slopes;

(B) The above option is not sufficient to stabilize the sediments and always part of the sediments is transported. In this case, it is necessary to proceed with the implementation of sediment control programs in the form of construction of gabion and mortar stone checkdams. These gangways should be created in the southern part of the basin and within valleys and waterways;

(C) In the event of a loose destructive coating on a solid volcanic rock, and slopes are steep, plowing should be perpendicular to the slope direction, and plowing along the slope will be extremely dangerous in sedimentation and extreme risk of slipping. Plowing along the slope is seen in many basin areas, which in addition to increasing the sedimentation of the basin, in the long run, will

exacerbate landslides. Of course, due to the high slope in some skirts, it is not possible to plow by tractor, and restoration of traditional plowing method with the help of a plow may have a positive impact on the process.

CONCLUSION

Goyjah Bel basin with an area of 7462.8 hectares is part of Aharchay River basin which is located 10 km southwest of Ahar city. The basin is located in the western Alborz zone.

The lithological units of the basin in the south-east and north, mainly include "volcanic lavas and pyroclasts of the Eocene Age". In the southwest, there are shale, lime, sandstone and conglomerate formations related to Cretaceous and Paleocene. At the center and part of the north of the basin, Pliocene conglomerate unit (PlQC) and the Alluvial unit (Qt3) has covered the above units. According to the studies, the study area has 19 lithology units.

In the study area, various factors such as the trend and activities of active faults, rainfalls, landslides, climate, topography, morphology and, finally, weathering are important in erosion and thus the sedimentation rate of the studied basin. Weathering plays an important role among these factors.

There are three types of weathering, namely physical, chemical and biological weathering in Goyjah Bel Basin, among which physical and biological weathering are significant.

In this research, MPSIAC method has been used to study the effect of surface geological factor in erosion. In this method, depending on the resistance of the stone to erosion, 5 qualitative and 10 quantitative degrees have been used. According to studies, the units in the area are in five erosion groups.

The highest sensitivity to erosion is attributed to young alluvial units (Qt3 and Qf) and Goyjah Bel shales (Pesh). Young alluvium units in the basin are located in the rolling

terrain area, and therefore, it is prone to erosion. Hence, erosion score of 8 is assigned to them.

Erosion in the basin is occurred due to both wind and water, but wind erosion plays a smaller role in the region. Erosion forms include rain, sheet, torrent, rill, riverside, waterway, gully and karstic erosions. The most important erosion in the study area is the rill erosion.

Among the stratigraphic and lithologic units of Goyjah Bel basin, Pesh, K-Pef and PlQC units have the highest potential for sedimentation because of their lithology type. On the other hand, calcareous units of the basin are also considered as the origin of alluvial deposits of the basin. Volcanic and pyrogenic units that form hard formations are mainly the origin of coarse-grained sediments and constitute the main parts of the basin's alluvial units.

The sediment transport factors in the study area are rainfall, wind, slope and landslide.

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