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Using evidence of geomorphology, experimental and analytical hierarchy analysis in karstification (in Kalat mountain in the North East of Iran)

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ABSTRACT

The Identification of Karsticity degree of a karstic basin is very important for the management of water resources and tourism in a region. The purpose of this research is to identify the degree of karsticity of a karstic basin using geomorphologic, empirical, and hierarchical analysis. The research tool includes a topographic map of kalat 1: 50000, a geological map of kalat 1: 100000, aerial photographs of 1: 40000, Google Earth satellite imagery, ARC GIS software, GPS device, meter, compass, Hammock Smith and a digital camera. The results of the study showed that using field evidence, the diversity of landforms is relatively low, there are no cave deposits, and caves are not developed. In the evolutionary stages of karst using the Waltham and Fookse method, the basin is in a young stage. Using a Cvijic Karstic method, it is in the transitional phase. Using the empirical Corbel equation, the karstic erosion indicates a semi-evolutionary condition of the karst. Calcium rate, in the ICP method and weight percentages of lime in carbonate formations, indicating relatively low calcium purity in the carbonate formations of the basin, indicating the degree of development of karst is towards the young. Finally, using the hierarchical analysis model, the total area of the Kalat basin was 19.04% in the less developed class, 24.57% in the undeveloped class, 42.88% in the middle class and 14.38% in the developed class it has been found that due to the small extent of the developed areas of the basin, it shows the young stage. Using the results obtained from different methods and combining this information, Kalat mountain basin can be developed from the perspective of karst development in the less developed category and the karstization of this basin is at a young stage.

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1. Introduction

Karst is a geomorphic and hydrological system formed by dissolving dissolved gems such as limestone, dolomite and gypsum (Ozyurt et al. 2014). karstic landforms are formed mainly in regions with carbonate bedrock soluble by chemical dissolution of water with low acidity (Palmer 2007). Various factors and processes affect the evolution of karst, topography, lithology and tectonic properties act as passive agents, and other processes such as active land-making, climatic hydrological processes, biodegradation, dependent on environment and geomorphologic processes, weathering, slope, drainage and freezing are actively involved in the development of karst forms (Calic 2011).

From geomorphologists' point of view, the amazing regions formed in carbonate, dolomite, and evaporative rocks in each area are karstic phenomena of terrestrial sets of real karst shapes (Lamurex 2007). Wide areas of dry and semi-arid non-glacial planets Earth is susceptible to carbonate formations, covered and more or less 20 to 25 percent of the Earth's population is dependent, more or more generally, on its sources of work (Ford and Williams 2007). About 20 percent of the world's dams are covered with karstic rocks (Ford and Williams 2007) (Milanovich 1981).

In 2013, 28 percent of the world's population used water resources. According to the latest research, about 13% of Iran's area is carbonate formations, about 8% of Iran's water resources are used by water resources, which play a very important role in supplying drinking water to the country (Behniyafar and Qanbarzadeh 2016). Due to the importance of karst areas, relatively comprehensive research has been conducted in the world on karst development. Transformation studies of karst zones using RS and GIS techniques to show fracture zones for cave development (Hong et al., 2002, Chenini and Mamo, 2010) or using hydro geomorphological and hydrogeological maps to calculate water resource potential (Rao et al., 2009). Are sentences, Chenini and Mamo in 2010 studied geographic information system and numerical models of groundwater resource recovery capability in arid regions. Use of remote sensing data and GIS technique is used to determine geological, land use and geomorphic characteristics of karst areas (Mishra et al., 2010). In the 2013 paper, empirical techniques can be used to investigate the extent and severity of karst erosion using environmental and field data (Gun, 2013). Studies show that the karstification process, usually followed by carbon release, causes climate change (Zheng et al., 2016), which usually increases in cold and humid environments (Kerkel et al., 2016). Also, the karstification process can pose various hazards and require thorough surface and subsurface surveys using geophysical and remote sensing methods (Quinn et al., 2017). Khezri et al. (2018) In their research, evaluated and zoned the Karst evolution of the Sahulan Cave in Mahabad Basin (Zagros maintain in NW Iran) using a hierarchical analysis method. Zanganeh Asadi et al. (2018) evaluated the karstic erosion using field and experimental methods in Fahlian Fars (Zagros maintain in W Iran) calcareous basin, which estimated the annual rate was 48 millimetres per thousand years . Since no complete studies have been done on the evolution of karst and the degree of karstification in the stone units of northeastern Iran (Kalat mountains), and the other hand, common and border water resources between Iran, Afghanistan and Turkmenistan are some of these resources. Therefore, in this research, an attempt has been made to study and present this issue with the help of various methods (field, laboratory and hierarchical). It is hoped that the information obtained will be used in land management programs in the region.

2. Material and Methods

2.1. Study area

The study area is Kalat Mountain in Kopeh Dagh basin, located in the highlands of the thousand mosques and northeastern parts of Iran. Kopeh Dagh means many mountains located in northern Iran and includes part of the southern mountain range of Turkmenistan and northern Afghanistan. These heights are formed in the Alpine-Himalayan folds. These heights are northwest-southeast and are geologically similar to the Zagros Mountains in western to southern Iran. Their most important features are rich water resources, calcareous formations, water erosion and the existence of karst phenomena. This basin in Iran has an area of 168.37 square kilometres, with the highest elevation of 2709 meters and a minimum height of 620 meters. Timely mathematical 59 ° 39 ´ to 59 ° 47 ´ east longitude and 36 ° 52 ´ to 36 ° 57 ´ north latitude. According to the climate of the coupon, the climate of this basin is semi-arid. The average annual temperature of the region is 16.49 degrees Celsius and the average annual rainfall of the basin is 314 mm (figure 1).

2.2. Materials and methods

This paper relies on field, library and documentary methods. First for field study, using the topographic maps, the study area was determined. Topographic maps kalat 1: 50000 and geology kalat 1: 100000, aerial photographs 1: 40000 block 1 and Mashhad, were used for identification of complications and formations (Figure 2). Then, the geological map of the area was prepared and the potential formations were identified and separated (Figure 3). Also, GPS, meter and compass devices were used to determine the coordinates and geometry of the complications. To understand the degree of karsticity and evolution of karst, we used Cvijic (1925) and Waltham and Fookes (2010) methods. In the Sweeting method (1972) and in the Waltham method determinates karst evolution. Determine the karst erosion of the basin using corbel-squeezing and Sweeting formula (1972) to which according to the adaptation Standard tables has little erosion (described in detail in the Results section).

Then for library study, first for determine the dissolution rate of carbonate rocks using calcimeter (for this, used calcium Bernard) was measured the amount of carbon dioxide resulting from a certain amount of calcium carbonate in a given amount of sedimentation. If a lime content is added to a certain amount of chloride, then the decomposition of the lime in the sediment will be boiled and the Co^2 gas will be released. By determining the volume of gas produced, it can indirectly determine the percentage of calcium carbonate or lime in the sediment (Bagheri Seyed Shokri et al., 2016).

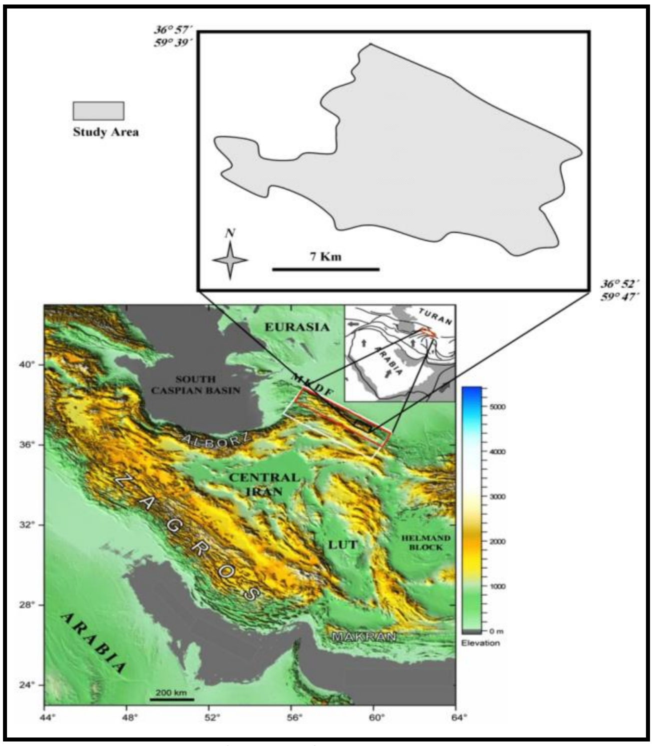

Fig. 1. Map the location of the study area. Shaded relief image of the Iranian plateau (GTOPO30 digital topographic data) showing its general morphology together with the main tectono-structural divisions. The red rectangle marks the area of Kopeh dagh and The black rectangle marks the area of Kalat. The map on the upper right shows the location iran in the Arabia-Eurasia collision framework.

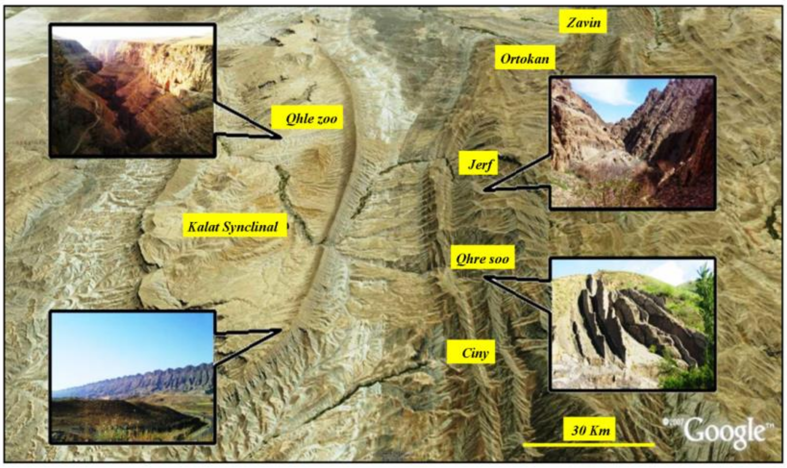

Fig. 2. Aerial photograph of the study area and a number of field images marked on it

ICP method (Induction coupled plasma), this method is one of the most important methods of elemental analysis. This method can be used to measure approximately 70 elements from a periodic table with a range around ppb detection in a variety of samples such as soil, water, metals, ceramics, and organic samples. Samples were taken from various formations and sent to the Acme Laboratory in Canada for testing.

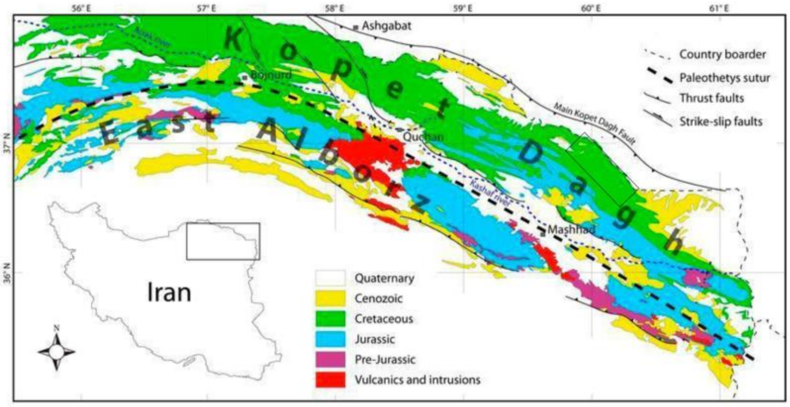

Fig. 3. Map the geology of the Kopeh dagh. The black rectangle marks the area of Kalat (Adapted from, Ruh et al., 2019).

Weight percentages or weighing the calcium technique is a simpler method to grind a kilogram of limestone, weigh it again to determine its milling fraction, weigh out some acid solution and weigh it. Boil the milled limestone in acid. In this way, the remaining limestone is completely dried in the oven. If the remainder is zero, its meaning is that the limestone has 100% lime, and if the remaining dry weight, for example, is 300 grams, it means that the limestone of the sample has 70% lime (Moghimi and Mahmoudi, 2004; Mahmoudi, 2005) (Figure 4). Using a hierarchical analysis model (AHP), the karstic development of the basin in four zones was obtained by combining the layers of altitude, slope, the direction of slope, rain, temperature, geology, distance from the fault, distance from the river. Based on field studies and the opinion of experts and consultants in the doctor's thesis, the lithology factor was chosen as an important parameter in the development of the karst. After that, the distance from the fault was selected considering its important role in the development of the fissure and gap. The climate and then the elevation are factors that have been selected as the important and influential factor on rainfall, evapotranspiration and temperature in this study. Subsequently, layers, slope, distance from the river were selected for slope and land use. To provide a potential karst development model, the information layers were introduced into Arc GIS 10.3 software. Different layers of information have been categorized into standard layout and field visits by applying expert judgment to each stratum. The above information layers are classified as standard maps and according to the importance of each of the parameters, a rating of 1 to 9 was given based on the Saaty method (Saaty, 1980). After assessing different classes, each layer was given a qualitative weighting based on the export method and the AHP method which indicates the effect of each factor on the degree of karst development. It should be noted that the sum of weights was considered to be 1. According to the obtained weight, a map of the zoning of karst development is obtained.

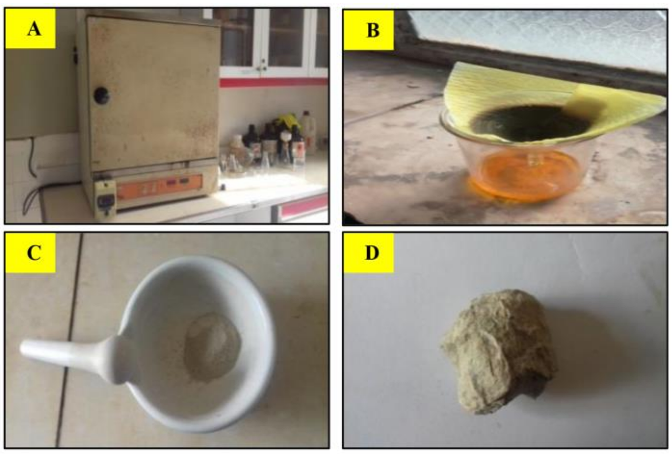

Fig. 4. Weighing the calcium technique A), oven, B) hydrochloric acid, C) powdered rock, D) calcite.

3. Results and discussion

To identify the degree of karstification of the basin with field evidence, empirical and hierarchical analysis model, the following are cited separately:

3.1. Field evidence

Field evidence includes Cvijic methods (1925), Waltham and Fookes (2010), and geomorphologic evidence. The following is a summary of the field evidence:

3.1.1. Classification of Karstic forms of kalat basin based on the method of Cvijic

In this classification; karst is divided into three categories according to the following table:

Table 1. The division of karst forms based on the Cvijic methods (1925)

karst development	Karst forms	Face of earth surface	Rock type	Kind of karst
Very high	Surface and deep-seated phenomena	Rocky and without vegetation	Limestone with high dissolution	Holokarst
Very little	Defective karstic forms are the lack of macro karst	Vegetation - non-calcareous soils	Non-crude stones, low purity lime	Merokarst
The expansion of underground forms, the formation of Karren and the lack of expansion of Polje	Underground karst, Microkarst, Defective Doline, Lack of Polje	A combination of lime and other formations - Dispersed vegetation	A combination of calcareous layers between thin layers of non-calcareous formations	Transitional karst

3.1.2. Division of karstic forms based on Waltham and Fookes methods (2010)

Another categorization of karsts was made by Waltham and Fookes (2010), which is based on the classification of maturity and the rate of evolution of karst. According to this categorization, the karstic forms created in carbonate rocks can be from the young stage to the full aged stage or the largest evolution. The criteria and indicators of this classification are shown in Table 2.

3.1.3. Evidence of Karst geomorphology of Kalat mountain basin

One of the other techniques for recognizing the degree of karsticity in the karstic areas of field evidence and geomorphology is that in the studied basin several times in 2018, these visits took place.

3.2. Experimental formulas of karst

In general, empirical formulas are a very good criterion for understanding the karstic erosion and the degree of karst evolution. Two well-known corbel formulas and a combination for determining the degree of erosion of karst and degree of evolution of karst have been used in this research.

3.2.1. Corbel equation

One of the most suitable equations for determining the rate of erosion dissolution is the corbel equation, which is presented as (Eq. 1):

$X = 4ET / 100 = 4 \times .7\times 845/100 = 23.66$ (1)

In which X: the amount of limestone dissolution in millimeters per thousand years ($m^3km^{-2}a^{-1}$), E: runoff value (dm), T: average volume of $CaCo_3$ of water to (mgl^{-1}). This equation, especially in areas where surface contamination is present, is one of the most suitable methods for calculating the erosion rate of dissolution in each karstic basin. In order to use the formula, it should be noted that the density of carbonate rocks is between 1.5 and 2.9. For dolomite, it is necessary to measure the hardness of water and temperature so that the amount of dissolution through precipitation can be obtained and to determine the sulfate rocks, the Ca^{2+} The hardness of carbonate rocks is measured.

3.2.2. The Sweeting equation

Various calculations have been made to determine the level of lowering the level of karst through dissolution. These calculations, regardless of the deep dissolution and the presence of organic acids (that is, according to the Dalton artistic law on gas adsorption), is one of the most commonly used ones (Chorley et al., 2007) (Sweeting, 1972) (Eq. 2).

$X=FQTN/ (\mathbf{10^{12} \times AD})$ (2)

$= 1000 \times 105000000 \times 845000 \times .39 \times 1012 \times 37/168 \times 59.1 = 12.92$ mm per thousand years

Here, X = the dissolution value in millimeters per thousand years at a given time, Q = drainage per m^3, A = drainage area in km, T = drainage hardness (per million or PPM), D = rock density, 1 / n = part of the basin where the lime is exposed, F = constant-coefficient which depends on unused units (in the metric system, this coefficient is constant equal to 1000) (Table 3).

Table 2. Classification of karstic forms based on Waltham and Fookes (2010)

Karst class	Locations	Sinkholes	Rockhead	Fissuring	Caves	Ground investigation	Foundations
kI **Juvenile**	Only in deserts and periglacial zones, or on impure carbonates	Rare NSH <0.001	Almost uniform; minor fissures	Minimal; low secondary permeability	Rare and small; some isolated relict features	Conventional	Conventional
kII **Youthful**	The minimum in temperate regions	Small suffusion or dropout sinkholes; Open stream sinks NSH 0.001-0.05	Many small fissures	Widespread in the few metres nearest surface	Many small caves; most <3m across	Mainly conventional, probe rock to 3 m, check fissures in rockhead	Grout open fissures; control drainage
kIII **Mature**	Common in temperate regions; the minimum in the wet tropics	Many suffosion and dropout sinkholes; large dissolution sinkholes; small collapse and buried sinkholes NSH 0.05 - 1.0	Extensive fissuring; relief of <5m; loose blocks in cover soil	Extensive secondary opening of most fissures	Many <5m across at multiple levels	Probe to rockhead, probe rock to 4m, microgravity survey	Rafts or ground beams, consider geogrids, driven piles to rockhead; control drainage
kIV **Complex**	Localised in temperate regions; normal in tropical regions	Many large dissolution sinkholes; numerous subsidence sinkholes; scattered collapse and& buried sinkholes NSH 0.5 – 2.0	Pinnacled; relief of 5-20m; loose pillars	Extensive large dissolutional openings, on and away from major fissures	Many >5m across at multiple levels	Probe to rockhead, Prove rock to 5m with splayed probes, microgravity survey	Bored piles to rockhead, or cap grouting at rockhead; control drainage and abstraction
kV **Extreme**	Only in wet tropics	Very large sinkholes of all types; remnant arches; soil compaction in buried sinkholes NSH >>1	Tall pinnacles; relief of >20m; loose pillars undercut between deep soil fissures	Abundant and very complex dissolution cavities	Numerous complex 3-D cave systems; galleries and chambers >15m across	Make individual ground investigation for every pile site	Bear in soils with geogrid, load on proven pinnacles, or on deep bored piles; control all drainage and control abstraction

Table 3. Solubility of calcium carbonate (CaCo3) mg / L (Chorley et al., 2007)

Climates /Rock Type	Oregano (uncoated)	Between soil and stone
Cold	45	100
temperate	50	114
Warm and dry	90	85

3.3. Laboratory Techniques to Review the Dissolution of Basin Karst

Laboratory techniques are widely used to understand solvent erosion and degree of evolution of karst. The three most important laboratory techniques used in this study are calciometry, weighting and ICP method.

3.3.1. Measurement of lime in sediment by calcicometric (volumetric) method with Bernard calcium

Calcareous deposits are the most abundant chemical deposits and are often found in other materials, especially clay or sand, and very low in pure form. Like dolomite, this is a mixture of lime and magnesium. The basis of the measurement of lime is its dissolution in chloride-acid and, as a result of the gas produced by Co2, the amount of lime in the sediment is shown (Eq. 3).

$$CO3Ca + 2ClH = Cl2 + CO2 + H2O \quad (3)$$

It is necessary before testing with .3 The pure and dry calcium carbonate controlled the amount of gas and then determined the percentage of lime in the sample.

In this study, in order to study the annual erosion in the study area, we needed laboratory analysis. In order to calcium and the amount of lime in the sample of limestone, from the limestone formation of Tirgan, Sarcheshmeh, Kalat and mozduran 2 from each of the Formation of a rock sample with Smith Hammer from the walls. Then a certain amount of lime was poured in laboratory mites and then weighing 5.5 grams pure of it in a special calciometry Erlen and add some hydrochloric acid to measure the volume of gas produced in the Bernard calcium device. Calcite percentage was determined in a calcium test based on the following equation (Eq. 4).

$$K=V*100/N*224 \quad (4)$$

The value of V is the CO2 released from the sample tested, N is the sample weight of the sediment to the grams. If the amount of calcium carbonate is 100 g, the CO^2 gas generated by the Avogadro Act will be 22400 cubic meters. The mean amount of lime purity and calcite content calculated from the samples of four formations of rock formations was 36.3%.

3.3.2. ICP Method (Induced Coupled Plasma)

An induced coupled plasma spectrometer is one of the atomic spectroscopy methods in which the atomization of elements (atomization) occurs through the hot plasma environment. This method is more sensitive than other methods, with better detection limits and repeatability. In order to perform the experiment, four rock samples were taken from four important limestone formations of the basin of the ICP technique and analyzed in the laboratory and the results are as follows:

3.3.3. Weighting method

weighting the Calcium technique is a simpler method to grind a kilogram of limestone, weigh it again to determine its milling fraction, weigh out some acid solution and weigh it. According to this experiment in sedimentology laboratory, 4 samples of Tirgan, Mozduran2, Kalat and Sharcheshmeh formations indicate the average amount of lime in the sample is 56.3%.

3.4. Analytical Hierarchy Model

Another technique for recognizing the degree of karst evolution is a hierarchical analysis model basin. The basis of this model is the comparison of the parameters Couple and ultimately the zoning of the karstic transformation. Considering the role of the various factors and the development of the karsts of the region in the past, and considering the different paleoclimate of the past region with the current situation and the role of the various factors in the development of eight-layer karst Information was selected. After assessing different classes, each layer was given a qualitative weighting based on the export method and the AHP method which indicates the effect of each factor on the degree of karst development. It should be noted that the sum of weights was considered to be 1. According to the obtained weight, a map of the zoning of karst development is obtained (Table 5).

Table 4. Calcium (Ca) element content in Kalat Mountain basin divided by four formations percent

Formation	Calcium content in percent
Tirgan	38.90
Mozduran2	38.43
Sharcheshmeh	38.41
Shorijeh	0.7

Table 5. Information layer weights by AHP method and application of expert opinion in Kalat Basin

Name of layers	Final Weight
Geology (lithology, distance from fault)	0.53
Climate (precipitation and temperature)	0.22
Topography (aspect of slope, elevation, slope)	0.24
Hydrology (distance from the river)	0.041
Human factors or land use (garden, agriculture, land, road, village)	0.1
Total	1

In the beginning, the graphical model of the hierarchical analysis model was drawn up about the priority of each of the criteria and sub-criteria affecting the development of karst in the study area. According to the findings of the study, among the criteria for the development of karst: geological, climatic and topographic criteria with final weights of 0.33, 0.22, 0.24, respectively, were considered as the most important and most effective criterion in relation to development potential Karst was identified in the Kalat Basin. Finally, all of the mapped maps in the GIS environment were called, and, using the Raster Calculator, each parameter was weighted in the Expert Choice software, and the Karst Development Zonation Map was obtained, which was developed based on the goal to four classes, Moderate middle class, developed class and undeveloped class (Figure 5). The environmental parameters that were studied influenced the Karst region development and the adaptation rate was % 5 Obtained. Based on this, the discussion of environmental parameters influencing the Karst region's development, including the following, is addressed:

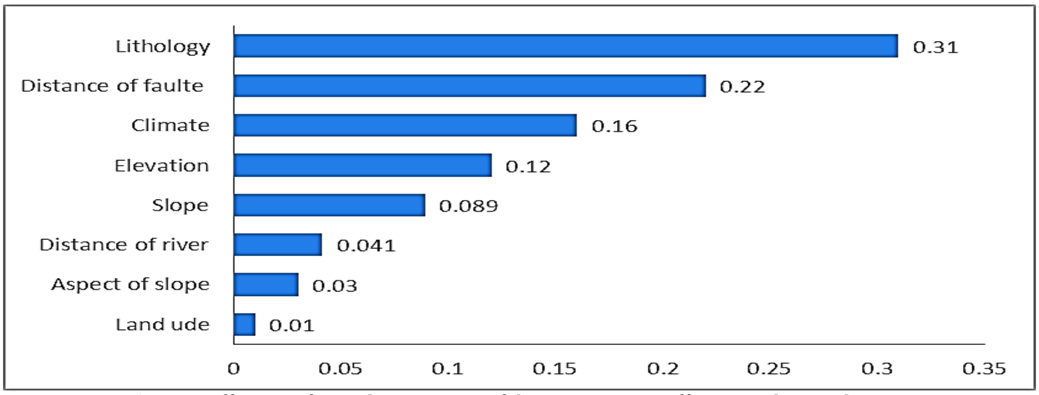

Fig. 5. Coefficients of Paired Comparison of the Main Criteria Effective in the Development of Karst Process of Analytical Hierarchy

3.4.1. Lithology

The earliest outbreaks of these units are related to the Jurassic period (the Chaman bid Formation) and the widest outbreaks of the outcrops belong to the Mozduran2 and Shurijeh formations. The major calcareous formations of the studied basin are Tirgan, Mozurdan2, Kalat and part of the Sarcheshmeh. The studied basin is a total of 13 lithuaul units. Geological studies in karst regions are of great importance due to the high role of lithology in karst development. The presence of soluble rocks with proper thickness is one of the preconditions for the development of karstic lands. In the present study, geological units are classified into 13 classes. According to the classification of Thicken Lime Thicken Lime, Mozurdan2 Lime and Kalat for the Karstification Potential has the highest weight. Subsequently, they originated in the following areas: Chaman Bid, Neyzar, Abderaz, Ab talkh, Pesteh ligh, Losses and Quaternary Alluvial Plants. Table 6 shows the distribution of carbonate and non carbonate formations in area and percentage (Figure 7A).

Table 6. Distribution and Carbonate and Non-carbonate Formation in Kalat Mountain Basin

row	Formation	Area of Formation per Km	Formation Area to Percent
1	Chaman bid(JCh)	10.10	5.99
2	Mozduran2(Jmz2)	35.75	21.23
3	shorijeh(JkS)	36.61	21.74
4	Tirgan(KT)	18.18	10.79
5	Sharcheshmeh(KSR)	4.86	2.88
6	Sanganeh(KSN)	6.95	4.12
7	Atamir(KAT)	6.08	3.61
8	Abderaz(KAD)	7.22	4.28
9	Abtalkh(KAB)	13.15	7.8
10	Neyzar(KNY)	6.95	4.12
11	Kalat(KK)	8.97	5.32
12	Pestehligh(Ps)	.019	.011
13	Losse(QL)	12.93	7.67
14	Terraces(Qt)	.65	.36

3.4.2. Distance from fault

In the weighting of the fault layer, the main assumption is that the development of karst in areas close to the fault is greater and more weight is allocated, and areas far away from the lines of the fault have a lower weight (ghobadi, 2010; Ghobadi and Behzad tabar, 2016). The distance from the fault in five floors is provided for the study area, which has the highest weight to the distance of 100 meters and is more prone to karst development, with a distance of more than 300 meters and the lowest weight. That is, the least potential in the region is for the development of karst (Fig. 7B).

3.4.3. Rainfall agent

The more rain it is, the better the conditions for the development of the karst. In other words, rainfall above 300 mm has favourable conditions for the development of karst in a region. Because rainfall in karst development and potential of karstic waters plays an important role, the information layer was prepared. In the studied basin, the rainfall layer is divided into four well-suited floors with rainfall exceeding 400 mm, suitable for precipitation of 400-300 mm, appropriately proportional to rainfall of 200-300 mm, and unsuitable with rainfall of 200-100 mm.

3.4.4. Temperature agent

Another important factor in the development of temperature karstic is the development of high scores. The lower the temperature, karst development is more. The temperature layer is divided into four classes, which has the highest score of 0 to 10 degrees. After that, 10-20 ° C, then 20-30 ° C and 30 ° C, respectively, provided the rest of the points in the development of karst (Fig. 7C).

3.4.5. Height agent

As the height increases, a potential karst development potential increases due to the increase of the hydraulic gradient. The greatest change in karsticity is observed at high altitude levels with the condition of lime purity. Therefore, it plays a large role in the development of the Karst process (Zarvash et al., 2015). Raster map of the elevation classes of the basin was studied in 9 classes (Fig. 7D). The maximum altitude, with the largest area, is 97.93 square kilometers, at altitudes of 1,300-1,000 meters above sea level. The minimum area of the altitudes is less than 2500 meters, with an area of 4,444 square kilometers (Fig. 6).

3.4.6. Slope agent

The slope rate also plays an important role in the amount of runoff from the rainfall, as well as in the amount of water penetration into the ground and the action of dissolution by precipitation. The final slope map of the study area was classified in 9 floors from class 2 to more than 40%. According to theoretical foundations, slopes and flat areas have the greatest potential for karsticity (Zarvash et al., 2015). In the studied basin, slopes of 15-0 are low in the territory of the slope.

The expansion of the karstic phenomenon is due to the increased contact of water with lime and the dissolution phenomenon in these slopes is intensified. In weighting, because the slope has a higher penetration potential, more value was given (Fig. 7E).

3.4.7. Agent of distance from the river

One of the important factors in the potential of karstification, hydrology, water drainage and faeces is that the higher the flow rate and the distance from the river, the greater the extent of the development and destruction of the karst (Sepand et al., 2007). Weighing is due to the fact that in areas with high waterway congestion and low river distance, more weight is due to the greater extent of the karstic collapse, and the longer the distance from the river and the lower the density, the extent of the development and destruction of karst It will be less. The distance from the river to the studied area is classified into five categories: the longer the distance from the river is, the greater it is. The distance from the waterway to 100 meters has the highest weight, that is, it is more prone to Karst development, and the distance is more than 300 meters is the least weight, that is, the least potential in the region is for the development of karst (Fig. 7F).

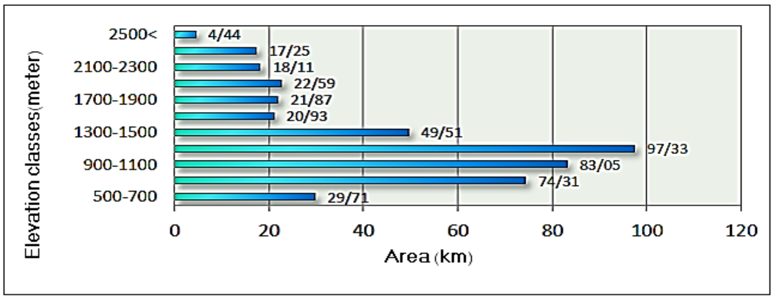

Fig. 6. Range of elevation classes in Kalat mountain range, in meters from sea level

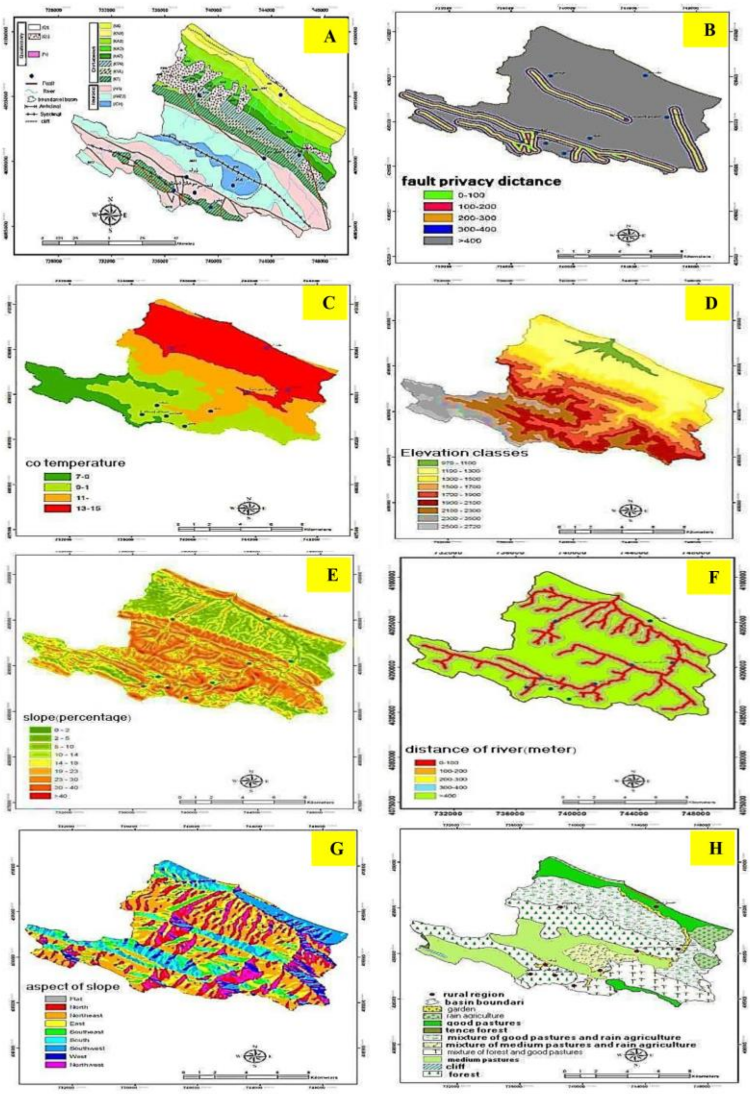

Fig. 7. A) geological maps, B) distance from faults, C) co temperature, D) elevation, E) slope, F) distance from the river land use, G) aspect of Slope, H) land use.

3.4.8. The aspect of slope

The effect of slope on vegetation diversity and some hydrological processes such as snow melting is important (Alizadeh, 2010). The best directions for karstic development are back-to-sun directions. Due to the importance of the quality of sunlight in providing the required energy in the regions, the orientation of the domains plays an important role in this connection. According to theoretical foundations and other surveys and interviews with experts, slopes and flat areas have the greatest potential for karsticity. The areas with northern, eastern, and northeastern aspects have the highest score and weight, and the best aspects are for the development of karst. Backward aspects to the sun are less favourable due to less evaporation and longer shelf life due to lack of sunlight is more favourable ground for the development of karst (Yamani et al., 2014). In the final map, the same is taken into account. In the study area, the North East with 28.10% of the highest area and the flat area with 51.1% has the lowest area of the basin (Fig. 7G).

3.4.9. Land-use agent

A land-use map has been used to study the land cover capability and land use for the potential karsticity potential in the area. The highest weight was given to pastures, forests, agriculture, rock and gardens. According to their influence on karstification of the studied area, the lowest weight was given to the gardens and cliffs, agriculture, forest, and finally pasture, was the least weighed (Fig. 7H).

3.5. Discussion

According to the results obtained from different methods, the state of development and evolution of the karst in Kalat basin is described and then compared with each other and the degree of karst evolution in this region is determined. By analyzing the information obtained based on Cvijic method (Table 1), the cluster basin karsts are placed in the row of transition karsts, because in this basin, the dimensions of the caves are small and not very large. Polje, also known as karst areas, are not formed in this basin, and because of their slopes and inappropriate topography, they are not likely to be formed in the future. Doline does not have much to gain in the basin. Other forms of karats also have not evolved. The only problems that have evolved in the basin and are likely to be further developed in the future are Karren. In addition to the above, the weather conditions of the area have also been limited in the formation and expansion of karst forms of the area. The most suitable climate for the formation and expansion of karst forms is the wet weather. Because rainfall in this basin does not require moisture for formation and evolution of karst forms, and on the other hand, the lack of precipitation has caused the dispersion of vegetation. So, for the sake of categorization, karsts in the row of transfer karsts. The distribution of karst forms based on the methods of Waltham and Fookes (2010) is shown in Table 2. One of the indicators of this classification is the type of climate. According to the kopen classification, the climate of this basin is placed in a semi-arid climate. This type of climate is a dry season and a cold season, which has caused many restrictions for the formation and expansion of the karst forms of the basin in these two seasons. The dry season with decreasing moisture plays an important role in reducing the various karstic processes. In the cold season, decreasing vegetation, decreasing surface water due to freezing, snowfall and snow cover of the region, reduce the dissolution and decrease the karst formation in this basin. As a result, the karst of the basin is placed in the row of young karst. Also, the formation of imperfect Doline, small caves expansion, and the absence of polje are indications of the younger karsts of this basin. Also, since the dissolution of the rocks is usually carried out along the joints, faults or layers of surfaces with greater ease the absence of extensive seams and fractures in the limestone rock of the basin. The process of dissolution in these rocks is limited, and the karstic forms are not widely spread. This situation shows that the karstification in this region is in a young stage and has not yet evolved, therefore, about the evidence and classification proposed basin karsts are placed in the row of young karst (Fig. 8).

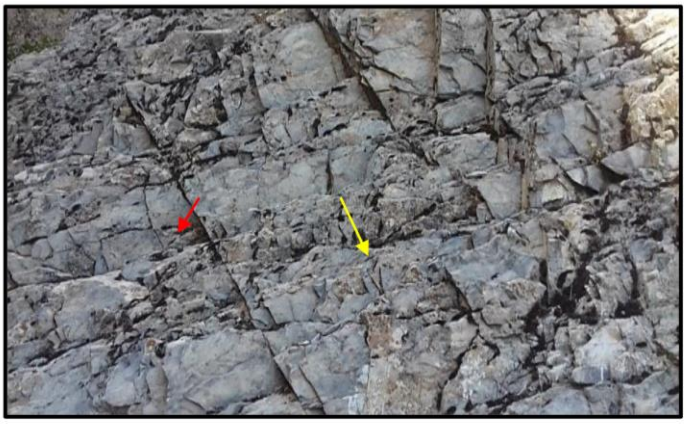

Fig. 8. Fissure and gap in Tirgan limestone, which are desirable.

Evidence of Karst geomorphology in Kalat mountain shows that since the degree of karstic characterization of a basin depends on the variety of terrestrial structures, the existence of cave deposits such as stalagmite and stalactite, cave development and karst hydrology (Bogli, 2009) because in the studied basin, the diversity of landforms is low due to field visits to the basin, and it lacks any cave deposits, and the cave does not exist in it, and the karst hydrogeology is not much developed. These reasons make the study of the studied basin more youthful to semi-evolutionary. Below are some examples of karstic landscapes in the basin studied (Fig. 9).

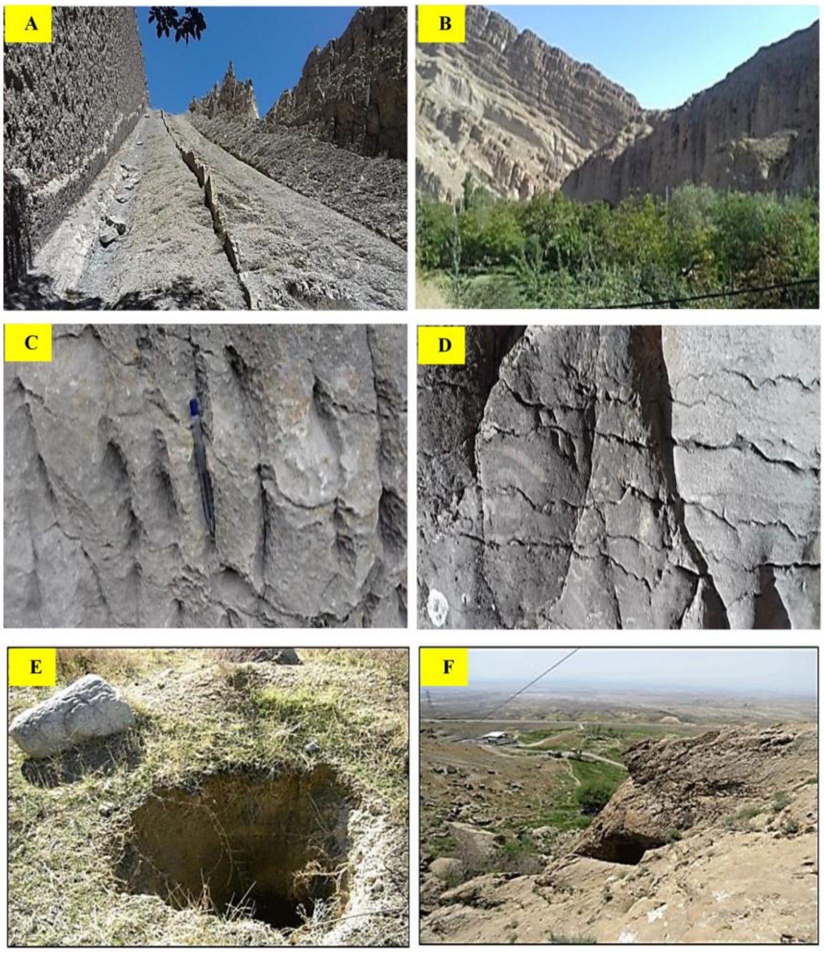

Fig. 9. A) Karstic corrodor, B) Gorge Karstic, C) Rillen karren, D) Meaner Karren, E) Doline, F) Cave in the Kalat Mountain Range.

Corbel (1959) concluded, following a detailed study, that the conditions for karstification in cold climates, often with snow, are faster than those with hot climates. According to the Corbel, erosion rates, both mechanical and chemical, in low-altitude Mountains with a rainfall of 1000 to 1600 mm, and under cold weather conditions, are 160 mm per 1000 years, and at the same time in warm weather conditions, this is 10 times lower and only 16 mm. In relatively flat areas with rainfall ranging from 300 to 350 mm and cold weather, the erosion rate is 40 mm per 1000 years, and in warm climates, this amount is only 4 mm per 1000 years (Zanganeh Asadi, 2018). Given the fact that the number obtained from the Corbel formula is 23.66, it is comparable to what the corbel has mentioned. Because solubility is only in calcareous formations and in other formations, there is little solubility. Therefore, the studied basin is in the young and semi-evolutionary stage. According to the number obtained in the Sweeting formula, this equation does not have relative efficiency and does not match the following table, because all the formations of the basin are not karstic and calcareous, and because of the erosion obtained, it shows a relatively low number. On the other hand, the major part of the basin is covered with naked and stony rocks. Therefore, the studied basin shows the young stage of karst. In the calciometric method, the average purity of lime and the percentage of calcite calculated from the samples of the stones of the four formations tested were determined to be 36.3%. According to the obtained number, the amount of calcium in the four formations with this technique shows the low number, which shows the youth and semi-evolutionary nature of the basin. According to the table 4 and based on the results obtained from the ICP method, the highest degree of lime purity is observed in the calcareous and thick layer of Tirgan, after which the Mozduran2 and then the source and finally the Shorijeh with the least amount of lime purity. According to the weighting technique of 4 stone samples related to Tirgan Formation, 2 mercenaries, Kalat and Sarcheshmeh, the average amount of lime is 39.3%, which is close to the calorimetric technique. This shows the semi-evolutionary state of karst and the low purity of lime in the region. The final map of Kalat mountain basin zonation using geological layers, distance from the fault, temperature, precipitation, land use, slope, aspect of slope, elevation and distance from the river. with the combination of weights derived from the hierarchical analysis method with each. Their layers and overlaps were obtained in the GIS environment. Based on the principles of karst bases and field observations, the final map was classified into four categories: undeveloped, less developed, medium and developed. Figure 25 shows the final mapping of the Karst development, and Table 7 shows the area and percentage of the Karst development classes using hierarchical analysis. The total area of the Kalat Basin was 19.04% in less developed class, 24.55% in Undeveloped class, 42.88% in the medium class and 14.38% in the developed class. Therefore, the lithology factor of the basin with the value of 0.53 is the most important weight and the most important factor controlling the potential of Karst development in the study area. The land-use factor has the lowest value of 0.01, which has the least effect on present karsticity Basin is dedicated. The results indicate that geological factors, climate, elevation, topography and distance from the river have the most important role in the current development of Karst. Considering that the development of karst in a region is more evolving, considering that about 14.38% of the area of the basin is located in the developed class of Karst, the studied basin is located at the young stage of Karst (Fig. 10). Since the studies conducted in different methods show young and underdeveloped or less developed karsts in the study area. In the meantime, only the method Cvijic to some extent, show less accuracy, so it is possible to ensure that each of the mentioned methods is relatively acceptable.

Table 7. Area and percentage of karstic development classes by AHP method

row	class	Area to Km	Percentage of classes area
1	Undeveloped	41.69	24.57
2	Less developed	32.38	19.04
3	Medium development	69.12	42.18
4	Developed	24.19	14.38

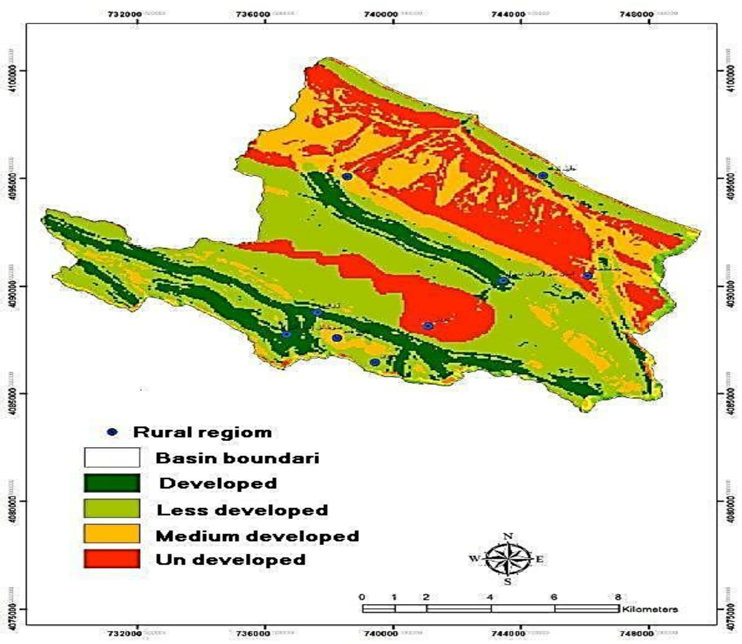

Fig. 10. Map of zoning of Karst development

4. Conclusion

Kalat mountainous basin is located in the north-eastern part of the Kopeh Dagh Zone, which has all the conditions for karstification. To understand the degree of evolution of basin karst, we investigated field, experimental and laboratory techniques and the hierarchical analysis model. In order to know the degree of karstfication and evolution of karst, we first used the Cvijic and Waltham methods. In the Cvijic method, karst evolution of the basin is a transient karst type and in the Waltham method of young karst type. Using corbel-squeezing and Sweeting formula to determine the erosion of the basin's karst which in the corbel formula is 23.66 mm / year and in the Sweeting method, it is 12.93 mm per thousand years, which according to the adaptation with standard tables, there is little erosion, which indicates the semi-evolving condition of basin karst. In the studied basin, the diversity of landforms is low due to field visits to the basin, and it lacks any cave deposits, and the cave does not exist in it, and the karst hydrogeology is not much developed. These reasons make the study of the studied basin more youthful to semi-evolutionary. Using Bernard calciometer, ICP, and weight percentages, the lime percentage in carbonate formations was 36.3%, 38% and 56.3%, respectively, indicating relatively low calcium purity in the carbonate formations of the basin, indicating the lower the purity of lime is, the degree of karst evolves towards young and semi-evolutionary. Using a hierarchical analysis model (AHP), the karstic development of the basin in four zones was obtained by combining the layers of elevation, slope, aspect of slope, precipitation, temperature, geology, distance from the fault, distance from the river and Land use obtained from the total area of the Kalat basin was 19.04% less developed, 24.57% in the undeveloped class, 42.88%in the medium class and 14.38% in the developed class. Therefore, the lithology factor of the basin with the value of 0.53 is the most important weight and the most important factor controlling the potential of Karst development in the study area. The land-use factor has the lowest value of 0.01, which has the least effect on present karsticity Basin is dedicated. Therefore, recognizing the degree of karstification of a basin in terms of water resources management and tourism is very important.

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