APPLICATION OF REMOTE SENSING, GIS AND AHP POTENTIAL WATER SOURCES (A CASE STUDY ANTICLINE SHYROGOUN)

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ABSTRACT: *Currently, with regard to quantitative and qualitative constraints on alluvial sources in some areas of the world, karst sources are considered as the most important water supply in various consumption areas (such as drinkable water, agriculture,…). Therefore, the first step to reach reliable management of karst water sources is searching the location and potential mapping of this resource. Researchers used remote sensing and GIS to combine various layers to explore karst water sources. In this study, eight effective profiles are proposed for karst hydrogeology to determine areas with high potential of groundwater in karst areas in northeast of Khozestan (anticline shyrogoun). Maps of precipitation criteria (P), fracture density (D), fracture blanks (B), temperature (T), slope (o), Topography (TG), lithology (G), and vegetation are prepared by using available data and analytic functions of GIS. In order to assign weight to main criteria, analysis hierarchical procedure was used by following in consistency standard rate. Then, main criteria and sub-criteria entered geographic information system to analyze the location. Through combining all weighted values, appropriate limits and ranges were determined in terms of ground water, potential in the form of map. According to final map, 36 percent of studied areas are located in the area with high potential, and 13 percent of the area is located in the area with medium potential. 29 percent and 22 percent of the area are respectively located in the area with low potential and very low potential of discharge.*

Keywords: karst sources, potential mapping and positioning, GIS, Karst hydrogeology, hierarchical analysis, Anticline shyrgoun.

1. INTRODUCTION

1.1 Karst

This word was used for the first time to describe dry rock views in northwest of Yugoslavia. According to karst word, upper part of continents mainly formed by old marine sediments rise up so fractures, wrinkle and faulting are observed in these parts. After million years and after joints and fractures' erosion, large channels are gradually created due to dissolution process in soluble rocks and stones. Where these channels develop completely, the result is making surface and sub-surface forms, rivers drainage and surface streams. Finally, a special morphology is created in the area that is called "Karst" [1].

Due to wide ground water channels and their complex connection with ecosystem, there are many problems in karst systems. Due to these problems, there are some problems in managing karst water sources and construction projects. Hence, in order to reach reliable management of karst water sources, it is essential to investigate feeding and power source, effective factors of karst, its development and finally its effect on aquifer output appearing in the form of spring.

1.2 Karst advantages

The most reliable method to explore karst ground water sources is to carry out geoelectric studies, but they are very costly and time-consuming, so this method cannot be used in wide constraints. In this case, other tools should be used. Since potential mapping is a type of positioning and location, and it is placed in location modelling, all used data are considered in that location.

Therefore, using GIS in potential of groundwater is inevitable. Also, with regard to that area width, using remote-sensing data is a valuable resource for obtaining data [2]. In order to determine an appropriate location and place to excavate well in karst areas, it is necessary to carry out centralist studies. In other words, in order to decrease costs of studies and suitable narrow down method, disposed areas must be detected by executing simpler methods with low costs. Then, by performing some studies, exact location and place of big drilling must be determined by using more accurate methods that are often more costly, complex and time-consuming. Also, continuous limitations of target are, must be considered. It clearly involves performing studies in terms of potential of karst water sources, geophysics studied and performing excavation [3].

2. Literature Review

In 1996, Krishnamurthy and his colleagues, used GIS and remote-sensing technology to determine suitable areas for ground water source in the south of India.

They studied geology, topography, faults and fractures, surface waters, drainage, stream density and slop. They classified above mentioned mapped on the basis of groundwater importance to super, extremely good, good, medium and poor classes. At last, a weight was assigned to each factor on the basis of their importance. They were integrated by step-by step method. Finally, fitness map was obtained. The results showed that suitable areas are quartz range (weathered fault) and slopes lower than 5 percent [4].

Ghaydhary and Saraf used remote-sensing and GIF technology along with weighting information layers effective for possitioning in 1998 to determine potential weights of ground water and artificial feeding areas. Above mentioned layers involve geology, geomorphology, lineament, and slopes [5-6].

Shahid and his colleagues performed modeling of ground water sources in soft rocks of Midmapur with the width of 163km located in west Bengal state of India by using remote-sensing and GIS. In this research, at first, layers of lithology, geomorphology, soil, feeding, stream density, slope and surface water masses were prepared. Except feeding and slope layers, other layers were obtained by using remote-sensing data. They determined weights assigned to prepared thematic maps on the basis of layers importance to predict groundwater potential mapping, and then integrated them in

GIS environment. The results of this model have higher accommodation with real data [1].

Gung and others, in 2002, pointed out the effective role of remote-sensing in karst studies and caves in the article entitles analysis based on GIS and remote sensing in karst development in suoimoui in Vietnam. They took into account data extracted from satellite images. By using special techniques of image processing, they extracted lineaments and fractures from these images. Then, they showed the connection between fractures and caves development in karst area by using GIS analysis. They concluded that there is very high accommodation between caves development and main tectonic structures in considered area [8].

In 2003, Jaiswal and his colleagues studied groundwater potential mapping by using remote-sensing and GIS in the areas of Gorna and Maldhya Paradesh in India. In this research, lithology layers, geology structures, find use, drainage channel, soil characteristics and slope were integrated in GIS environment, and the map of ground water potential was prepared for considered area. The results of this study are used to detect suitable areas to extract drinkable water for rural population [9].

In this research, anticline shyrogoun is selected in northeast of khouzestan for potential mapping of karst groundwater. In current study, areas where there are ground waters are detected by integrating techniques of remote-sensing, GIS and AHP. They are introduced for geoelectric studies. By using this method, groundwater potential can be quickly evaluated in the area scale.

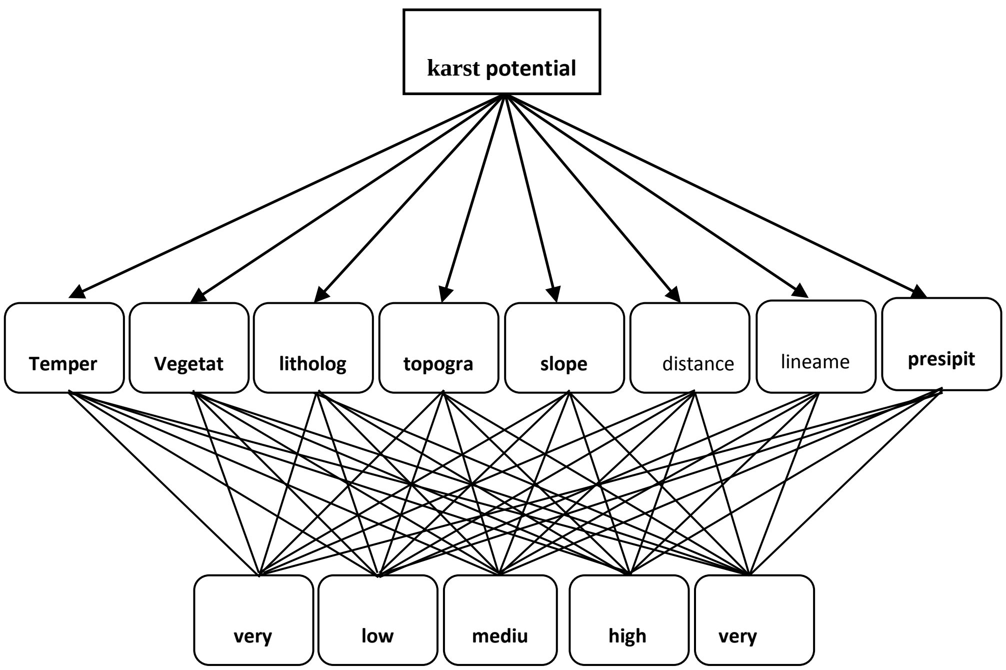

Figure 1: hierarchical structure to study karst potential

3

MATERIALS AND METHODS

3.1 Studying the role of structural factors in karst potential of anticline shyrogoun by using AHP, GIS and RS techniques

There are many problems to detect groundwater sources in karst such as insufficient information and the higher cost of collecting information (surface and subsurface techniques). In these conditions, techniques of remote-sensing (RS) and geographical information system can be considered as suitable and efficient tools to study mentioned groundwater sources (Moor, 1982), satellite data present basic information quickly and effectively about various factors like geomorphology, slope, land use, lineaments pattern and etc that are directly or indirectly controllers of ground water streams. In addition, GIS provides a very effective framework to study large and complex location information to manage natural sources [10]. Recent studies show that there is no method with complete standard for potential mapping of water sources by using GIS and RS techniques [11]. Recently, many researchers have found out that multi-criteria decision making provides efficient tools for water management by adding structure, clarity and precision to decision-making [12]. Analytic hierarchy process is one of MCDM methods used widely in water source engineering. This method was presented by Thomas L.Saati for the first time in 1977. Then, this method was widely used in natural sources and managing water sources and environment [13019]. AHP process integrates different choices in decision making, and provides the sensitivity analysis of criteria and sub-criteria. In addition, paired comparison facilitates judgment. Also, consistency and inconsistency degree of decision shows that this technique is useful for multi-criteria decisions. Determining developed areas of karst is also a multi-criteria decision making and some criteria must be considered like topography slope, lithology, fractures density, precipitation, temperature and vegetation so that developed areas of karst can be determined. When different criteria are not same, decision must be made in multi-dimensional space [20]. In this research, weight is assigned to criteria to study karst potential of anticline shyrogoun on the basis of information defined in AHP method and detecting geology conditions of the area. AHP method can be executed in Expert choice software. In this software, the target is considered as the main hierarchical branch, while criteria are considered as sub-branches of that target. Main criteria that are effective for target sub-branch in tree diagram (that are determined by the software) enter the software (figure 1). Several sub-criteria can be defined for each sub-criterion. After defining criteria and sub-criteria, weight must be assigned to them. It can be performed in several forms like numerical paired comparison, graphical and conversational comparisons in software [21].

In this research, numerical paired comparison is used for assigning weights among criteria. In these comparisons, decision maker, use expert judgments. If elements of i and j are compared, decision maker can state that the priority of i in comparison to j is one of modes shown in table 1.

Table 1: preferred values for paired comparisons

Value	preferences (expert judgment)
9	extremely preferred
7	very strongly preferred
5	strongly preferred
3	moderately preferred
1	equaly preffered
2,4,6,8	preferences between distances

During paired comparison for each set, inconsistency index of decision is performed by the software. Consistency rate in AHP method is an index showing comparisons consistency. This rate indicates precision and appropriateness of valuations in paired comparisons. If mentioned rate is equal to 0.1 or lower than 0.1, then valuations and comparisons are appropriate; otherwise, they must be improved [20].

Consistency rate is obtained by computing consistency index (CI) and equation 1.

$$CI = \sum \frac{\lambda_{max} - n}{n-1} \quad (1)$$

In above equation, λmax is eigenvector, and n is the number of criteria. Eigenvector is obtained by equation 2.

$$\lambda_{max} = \frac{weights\ column * criteria\ weight}{matrix\ row\ of\ valuation} \quad (2)$$

λmax must be computed for all of them on the basis of criteria number. CI is obtained after summing then in equation 1. Another required index is random index (RI) obtained on the basis of criteria number in table (2). At last, consistency rate is computed in equation 4-5.

$$CR = \frac{CI}{RI} \quad (3)$$

In order to convert the real maps to criteria maps, vector layers are firstly converted to Raster layer by using analytic function. Then, by applying computed weights to obtained layers in GIS software and integrating them by using index overlapping method, karst potential map of the area was studied.

3.2. Preparing information layers

The layers prepared to study karst potential in anticline of shyrogoun were respectively as follows:

3.2.1. Precipitation

Since the water is the main factor to develop karst, and it is the main variable to control erosion and dissolution, and anticline of shyrogoun is often snowy, this area is highly preferred to study karst potential. This layer is presented in figure 3.

3.2.2. Lineament layer

As it way mentioned before, with regard to considerable performance of tectonic, shyrogoun anticline has higher density of fracture, so this factor has considerable role in developing karst process in studied area. Therefore, fracture map is mainly prepared in terms of lineament density and

Table (2): Random index criteria

The number of criteria	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.45

The procedures of karst potential are shown by using the methods of GIS, AHP and RS in figure (2).

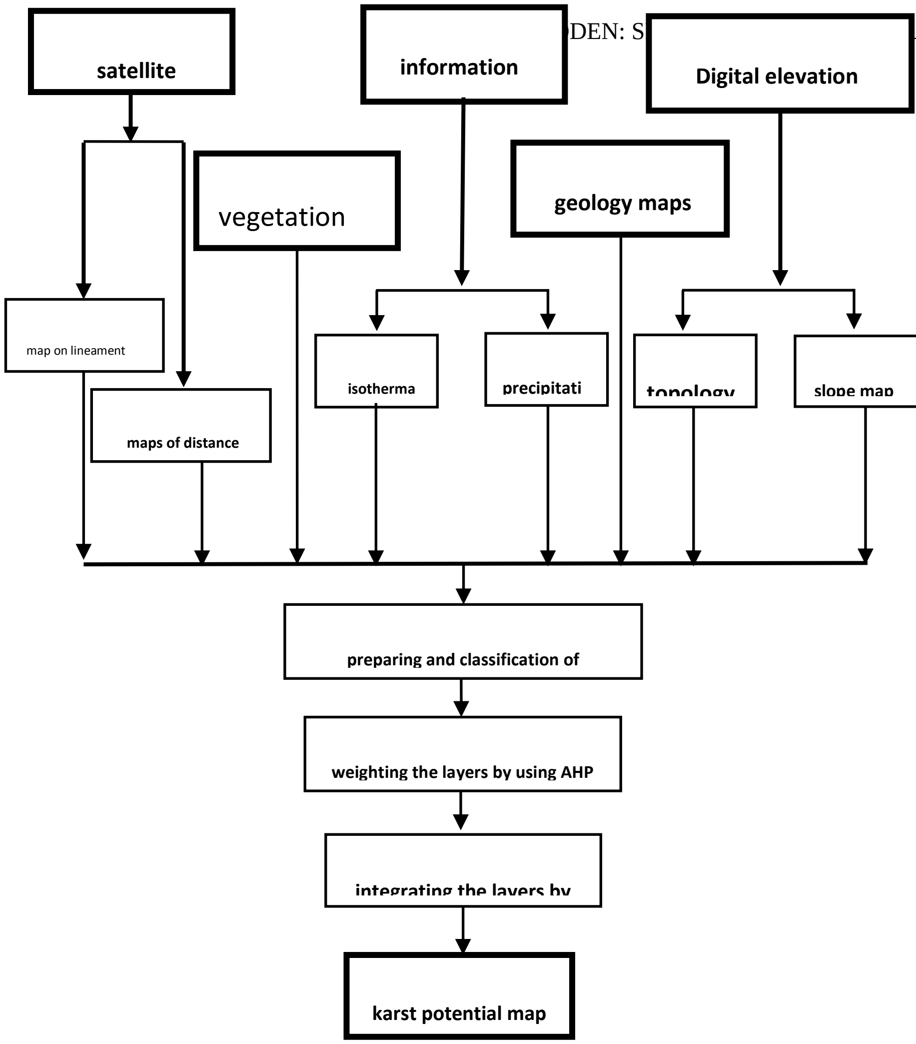

Figure (2): flowchart of preparing karst potential map by using AHP, RS and GIS methods

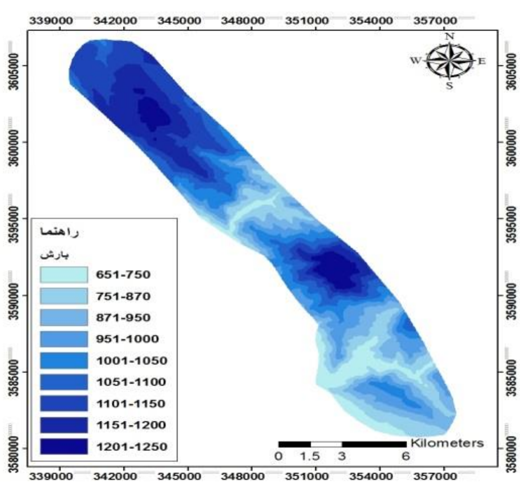

Figure 3: precipitation layer

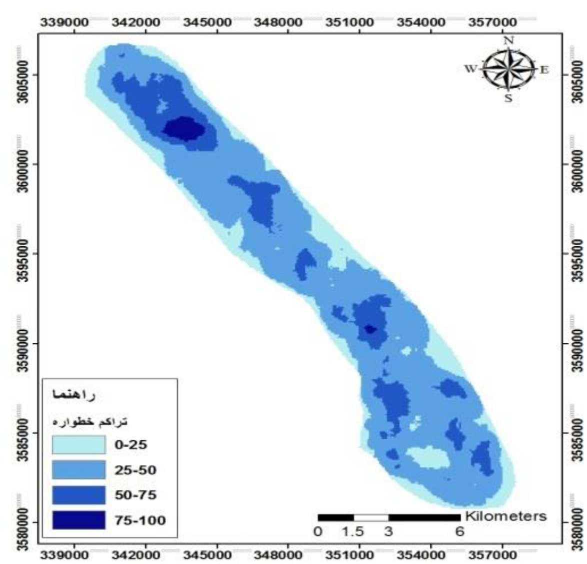

Figure 4: Lineaments density layer

distance from lineament in GIS environment (Figure 4 and 5). The effects of these two factors are clear with regard to their nature. when the distance from lineaments is smaller, lineaments density is higher, and the probability of becoming karst is higher.

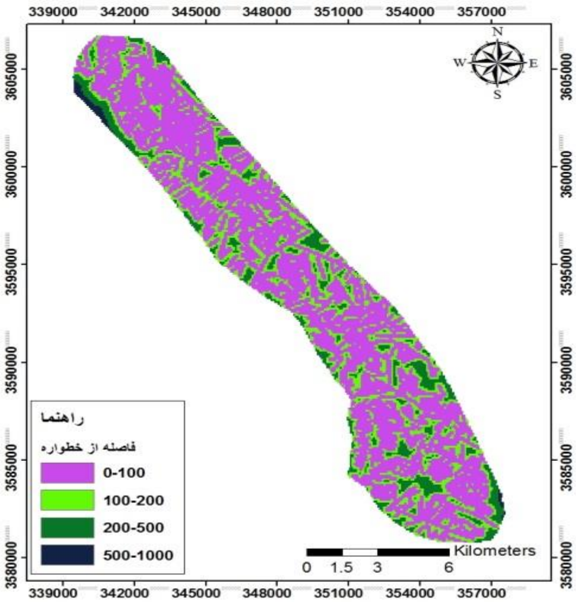

Figure 5: layer of distance from lineament

3.2.3. slop layer

slope has important role in the speed of water stream. This factor controls water penetration and aquifer feeding. In the area where the slope is moderate, surface runoff provides more opportunity for penetration of rain. In the areas where runoff stream is quicker, it causes reduction of rain penetration [13]. The slope map of considered area has been prepared by using digital elevation model (DEM) and GIS software (figure 6).

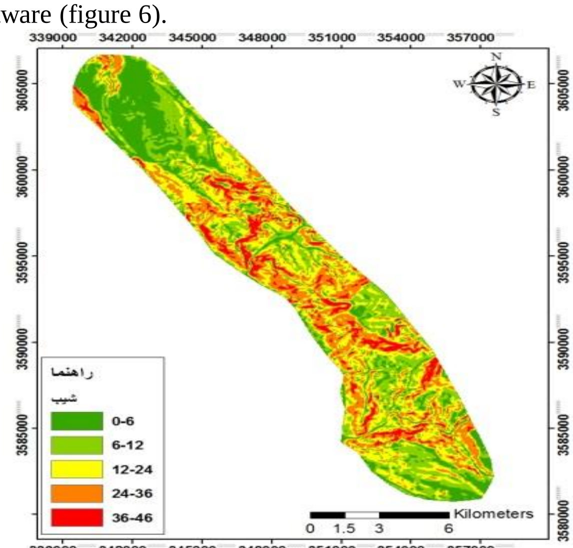

Figure 6: slope layer

3.2.4. Topography layer

In order to prepare topography layer, digital maps prepared by topography organization in 1:25000 scale where used. These maps have elevation data of areas. By using RIVER Tools software and topography data, digital elevation model (DEM) was presented in the area, and it was presented in figure (7)

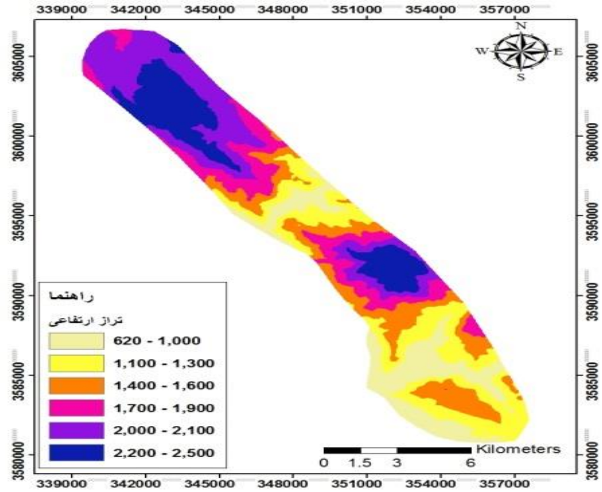

Figure 7: Topography layer

3.2.5. Litholography layer

with regard to the sever effects of rock and stone type on water penetration and various capacities of water retention, this profile is taken into account. Geology elements are classified to two groups according to karst perspective: A) Line formation of Ilam-Seroule with high capacity of karst, By pabdeh and kazhadom formation and current sediments that are considered as Natrava, and they lack capacity of becoming karst (figure 8).

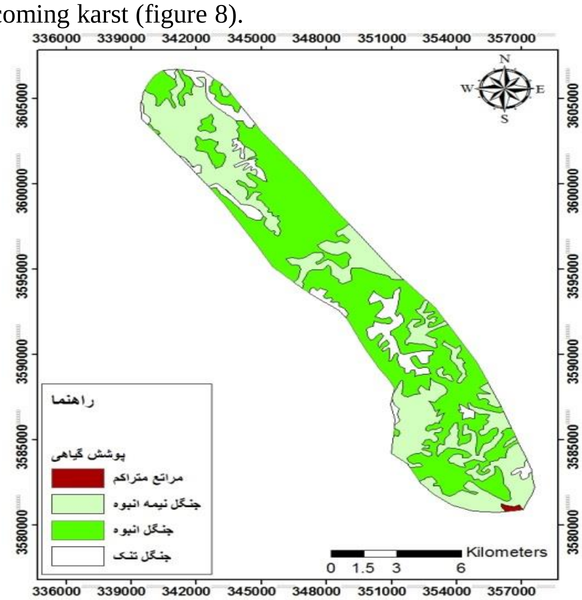

Figure 8: Lithology layer

3.2.6 Vegetation

Vegetation of studied area is a combination of dense forests, semi-dense forests, this forests and dense pastures. Vegetation has considerable role in karst development [22]. Surface materials and vegetation pattern control penetration and surface runoff [23]. In the areas where there are coil on stone surface, water of ran has acid composition, and limestone mass dissolution increases due to presence of CO2 in soil formed by plant decomposition. Due to plants leaves, the soil humus increases, and permeability increases as well.

Also, pressure of plants roots causes destruction and fracture of rocks and stones, and it is an effective factor to increase permeability and dissolution. On the other side, when vegetation density is high, runoff created by sever rains is prevented. In this way, required time is provided to penetration of atmospheric rains. The map of khouzestan vegetation was used to present the conditions of plants and vegetation in the area.

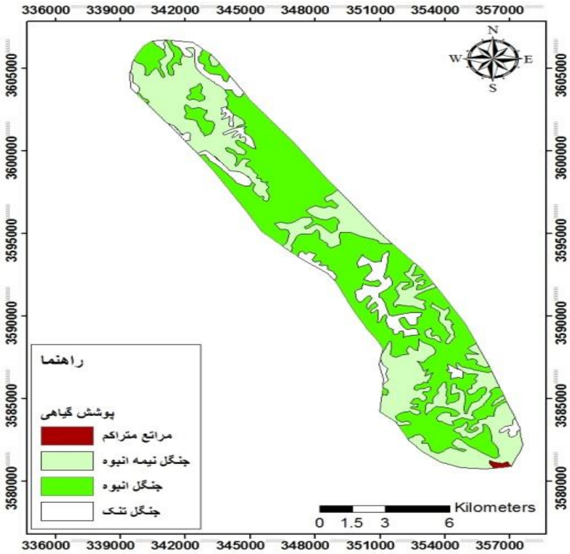

Figure 9: Vegetation layer

3.2.7 Temperature

The role of temperature is mainly proposed for water. when the environment temperature decreases, the water temperature decreases as well. By decreasing the water temperature, CO_2 uptake is higher, and dissolution occurs

3.3. computing the weight of factors effective for karst potential

The matrix of paired comparison of criteria explained above and weights of these comparisons computed in expert choice software are respectively presented in table 3 and figure 11.

Since prepared maps have different scales like meter for distances, percent for density and degree for slope, in order to integrate them, they must be scalable. For this purpose, with regard to expert knowledge, all maps are valuated in the range of 0-9 values by using re-classification function. Selected values are presented in table 4.

3.4. The map of potential karst and water power of the area

Final map of studied area involves 5 areas with karst potential involving very low, low, medium, high and very high. Final map is consistent with these two factors with regard to two important factors involving precipitation and lineament density for water retention and to increase the water power of that area.

[2]. Since studied area has considerable elevation, it has relatively lower temperature, and it helps the development of karst. In figure 10, the layer of temperature whose penetration procedure has been explained in the third section, is considered.

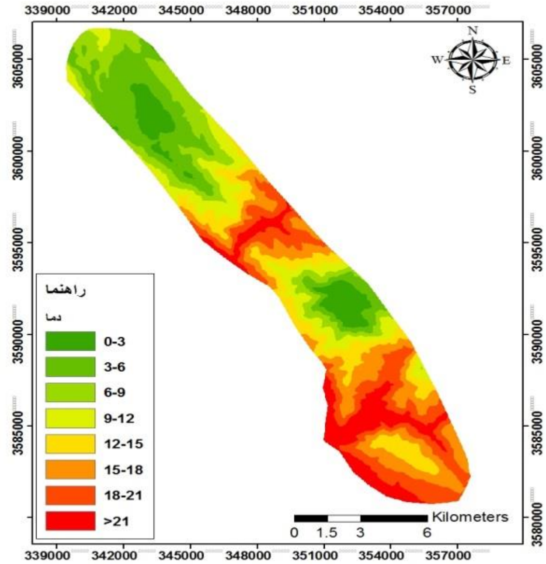

Figure 10: Temperature layer

3.5. Validation of the final layer with two factors involving precipitation and lineament

3.5.1. Precipitation layer

Since water is the main climatic factor in karst development and it is the main variable in terms of erosion and dissolution control, it is highly preferred to investigate karst potential of this area. According to prepared precipitation layer, the highest water power is considered in the area where the highest water power is considered in the area where the highest precipitation occurs. Precipitation layer validates our study (Figure 13).

3.5.2. Lineament layer

As it was mentioned before, studied area has higher development and density of fracture with regard to tectonic performance. Hence, this factor has considerable role in karst process development in studied area, Figure 14 shows the map in which extracted fractures are displayed on the final map of water power (figure 4).According to this map, the highest fracture is observed in the area where there is the highest water power and it validates our study.

Table 3: Matrix of paired comparison in hours for criteria effective for karst in anticline of shyrogoun

criterion	precipitation	lineaments density	distance from lineaments	slope	stream density	lithology	vegetation	temperature
precipitation	1	2	3	5	6	7	7	8
density		1	2	3	5	6	7	7
distance from lineament			1	3	3	3	4	5
slope				1	2	3	5	5
topography					1	2	3	4
lithology						1	3	3
vegetation							1	2
temperature								1

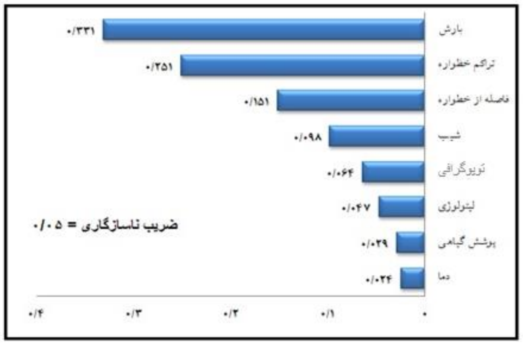

Figure 11: weights computed for criteria effective for karst process in anticline of shyrogoun

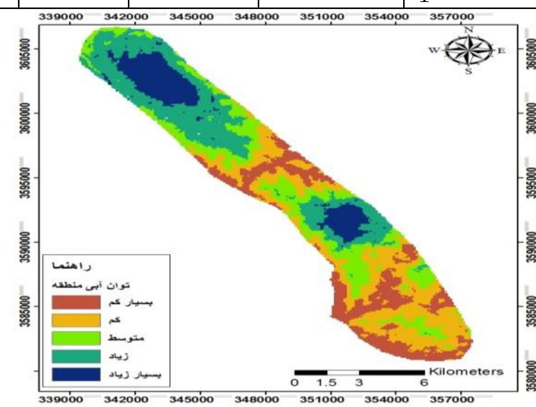

Figure 12: water potential map of shyrogoun anticline

Table 4: values, dedicated to considered layers

parameter	ranking	Parameter	ranking
precipitation (millimeter)		stream density (percent)	
651-750	1	0-25	2
751-870	2	25-50	4
871-950	3	50-75	7
951-1000	4	75-100	9
1001-1050	5	temperature (centigrade degree)	
1051-1100	6	0-3	1051-1100
1101-1150	7	3-6	1101-1150
1151-1200	8	6-9	1151-1200
1201-1250	9	9-12	1201-1250
lineament density (percent)		12-15	5
0-25	2	15-18	4
25-50	4	18-21	3
50-75	7	>21	0
75-100	9		
distance from lineament (meter)		Vegetation	
0-100	9	dense forest	9
100-200	7	semi-dense forest	7
200-500	4	thin forest	5
500-1000	2	dense pasture	8
>1000	1		
slope (degree)		lithology	
0-6	9	Ilam-serouk	9
6-12	8	other elements	0
12-24	7		
24-36	6		
36-46	5		
>46	4		

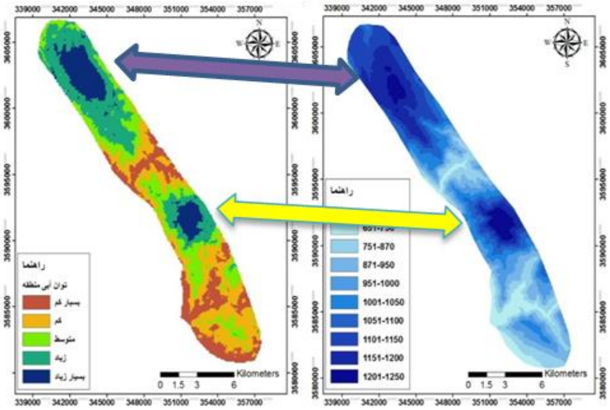

Figure 13: Precipitation layer (right) and water power map of area (left)

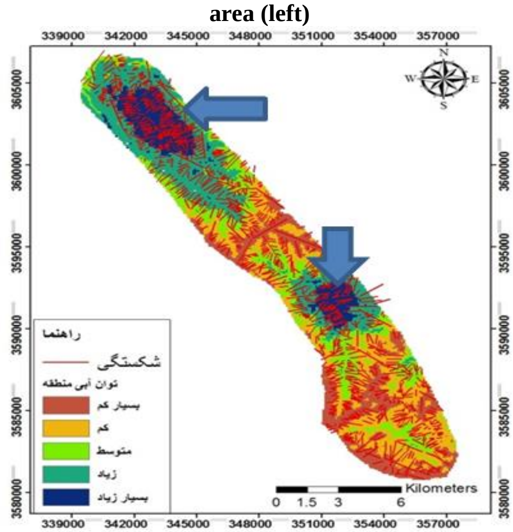

Figure 14: The map of fractures and water power of the area

4. CONCLUSION

The results show that precipitation and tectonic play respectively the main roles in forming groundwater in limestone structures of the area. With regard to lineament density layer, the highest lineaments are related to upper parts and a small part of down part of the area.

According to karst potential, 36 percent of studied area is located in the area with high potential, and 13 percent is located in the area with medium potential. 29 percent and 22 percent are respectively located in the area with low potential and very low stream potential.

Since different methods are used to combine bands of satellite information to study lithology in similar studies, 7*1 band combinations are considered more suitable for this purpose in this study.

Also, according to previous studies and researches, 7 input elements interfere in feeding of Sabzab spring. 5 elements are autogenetic, while 2 elements are allogenic. Autogenic elements involve lime streams of Ilam-Serouk kino, Mahal bekh and Hrean, of lime-dolomite of Pabdeh and kamaroun. Allogenic elements involve Taloug river and Shahid abbaspour lake. The first group of autogenic elements involving karst streams of kino, Mahal Bakh and shyrgoun has the main role in spring feeding because this group provide spring stream with more water and less delay time in comparison to the second group. In addition, among autogenic elements, karst streams of kin and streams of Mahal Bakh and shyrgoun have respectively the first and second importance in terms of feeding sabzab spring. karst appearances of the area are diverse and involve water sinkholes, different dissolution cavities, karn, ponor, care, waterfall, narrow valley, poulzheh and etc showing developed karst of the area. In addition, water sinkholes can be considered as suitable water sources in the area due to their width.

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