COMPUTATIONAL RESEARCH PROGRESS IN APPLIED SCIENCE & ENGINEERING (CRPASE)

CRPASE: TRANSACTIONS OF CIVIL AND ENVIRONMENTAL ENGINEERING

Journal homepage: http://www.crpase.com

CRPASE: Transactions of Civil and Environmental Engineering 7 (2) Article ID: 2297, 1–8, June 2021 ISSN 2423-4591

Research Article

Evaluation of Groundwater Resources Potential using Analytical Hierarchy Process (AHP) and Remote Sensing Geographic Information System (GIS), a Case Study: Garmsar's Catchment Basin

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Keywords

Analytical Hierarchy Process (AHP), Geographic Information System (GIS), Groundwater Resources, Crisis Management.

Abstract

Iran is currently experiencing serious water-related issues. Frequent droughts combined with over-abstraction of surface and groundwater through a large network of hydraulic infrastructure and deep wells have brought the country's water situation to a critical level. Symptoms of this condition include drying of lakes, rivers and wetlands, declining groundwater levels, land subsidence, water quality degradation, soil erosion, desertification and dust storms. For example, the agricultural sector of Garmsar and Aradan counties has been damaged due to the lack of a coherent and codified plan, so that now, in addition to the problems of soil erosion and water salinity, farmers' motivation to work in this productive sector has decreased. Using experts' views in the field of water engineering and resources, the main factors affecting feeding of the Garmsar groundwater aquifers were identified and each one was classified and evaluated, then using a two-by-two comparison method known as the AHP, each of these factors was weighted and by means of the Arc GIS software, the identified factors were implemented in layers on the digital map of the Garmsar region. The overlap of the obtained layers of each factor in each of the mentioned methods leads to reaching the potential area of the region, i.e. The area where the probability of precipitation is higher and the risk of flooding is lower, and comparing the obtained area with the catchment area indicates the accuracy of the calculations. Now, by identifying the potential groundwater area as well as the flood prone areas, it is possible to propose solutions and suggestions to prevent wastage of water flow or reduce its effects, one of the advantages of which is the filling of groundwater aquifers.

1. Introduction

The 2006 United Nations report, which focuses on the government's issues as the core of the water crisis, states that "there is enough water for everyone" and that "water shortages are often due to mismanagement, corruption, lack of proper institutional bodies, and bureaucratic weakness and there is a lack of investment in both human capacity and physical infrastructure." The official data also represent a clear link between access to safe water and the ratio of GDP to per capita income. In addition, the economists have claimed that the current state of water, due to the lack of property rights, government regulations and subsidies in the water sector, causes very low prices and excessive consumption [1-3].

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Received: 11 March 2021; Revised: 20 May 2021; Accepted: 26 May 2021
https://doi.org/10.52547/crpase.7.2.2297

Please cite this article as: M. Naseri, G.R. Shobeyri, A. Rajabi, A. Sadeghpour, Evaluation of Groundwater Resources Potential using Analytical Hierarchy Process (AHP) and Remote Sensing Geographic Information System (GIS), a Case Study: Garmsar's Catchment Basin, Computational Research Progress in Applied Science & Engineering, CRPASE: Transactions of Civil and Environmental Engineering 7 (2021) 1–8, Article ID: 2297.

The vegetation and wildlife, primarily depend on the freshwater resources. Accordingly, the swamps and coastal areas depend on the sustainable water resources, but if access to water is reduced, forests and other ecosystems will be equally at risk of major changes. In the case of wetlands, with the expansion of the human population, a significant area of wildlife has been taken to be used for food resources and housing. However, the other areas are affected by the gradual depletion of freshwater because upstream branches are used for human use of water resources. In seven US states, more than 80% of all historic wetlands were filled in the 1980s, when the US Congress passed the "no net loss" law to protect wetlands. Similarly, in Europe, there has been a widespread loss of wetlands and consequent loss of biodiversity. For example, many swamps in Scotland have expanded or decreased as the human population has grown. In this respect, the examples are Portlethen Moss and Aberdeenshiree [4-7].

According to global forecasts, in 2021, per capita water consumption will reach less than 1400 m3 per person per year, which means entering into a water crisis. According to the official statistics, Iranian experts believe that water is on the verge of crisis and in the coming years, water supply will become one of the biggest challenges in many provinces, cities, and regions. Geographically, Iran is located in the semi-arid and arid part of the world, so that the average rainfall in Iran is about 250 mm, while the global average is about 850 mm, which is more than three times greater than the rainfall in Iran [8].

In the following, the most important causes of water crisis in Iran is mentioned [9-10]:

Rapid population growth and dispersion, inefficient agriculture, mismanagement and excessive development thirst, inadequate water governance structure, multiplicity of stakeholders, uncoordinated management, and political weakness of the Environmental Protection Agency and lack of long-term attitude.

The solutions to this crisis are listed as follows:

Serious review of population growth and geographical distribution policies, prosperity of farmers and rural communities by granting more concessions and investment in the agricultural sector to increase the economic productivity of the agricultural sector by modernizing this sector, reviewing cultivation patterns across the country with regard to security National food and based on access to regional resources and economic productivity, increasing the price of energy and water carriers along with providing economic incentives to prevent economic and livelihood damage to farmers in the short term, establishing the cooperatives of agricultural management in each region and increasing the farmers' participation and collective capacities in water and agricultural management, water market creation, and water rights control, establishing a water savings account for the environment to preserve and rehabilitate the ecosystems by purchasing water from low-yield farms, shifting from crisis (passive) to preventive (active) management, reforming the water governance structure, and strengthening the environmental organization.

Due to the climatic changes in the last 20 years in Iran "and in the case of Garmsar city," which is followed by a decrease in rainfall (rain, snow, etc.), has led to excessive and unprofessional withdrawal of groundwater resources as well as depletion of the Hablehrood river. Another important issue is the existence of illegal wells and excessive withdrawal from the agricultural water wells, while lowering the groundwater level, their water quality has also changed and their salinity and minerals has increased, which has impacted the quality of the agricultural soils.

As a result, the gradual change of agricultural pattern and reduction of agricultural land cultivation and the decrease of villagers 'income level, and therefore the increase of villagers' desire to migrate to cities, all went hand in hand, causing destruction of agricultural lands and turning producing villages into the consuming villagers. This has caused the villages to become almost deserted and lose their nature, which has become one of the causes of unemployment and its consequences, which all the factors mentioned above led us to use the modern methods and technical and engineering knowledge can provide a logical and scientific solution to this problem [11-12].

After preparing the GIS maps, classified as standard maps, based on their relative importance, weight (AHP) criteria, these maps were classified using hierarchical analysis. In order to integrate the desired layers and potential zoning of existing water resources, benchmark maps were combined using the index overlap model. After preparing the groundwater potential map, in order to reduce the costs of geophysical studies and exploratory drilling, a layer called economic layer was applied to the final map and the economic zoning potential of the water resources of Birg anticline was obtained. Dariush Rahimi and Seyed Hojjat Mousavi [13] performed the potential of groundwater resources using AHP model and GIS technique in Shahroud-Bastam watershed. Mojgan Entezari and Majid Gholami [14] have identified potential areas suitable for groundwater recharge in the Romeshgan Basin (Kuhdasht - Lorestan). Taghizadeh Mehrjerdi et al. [15] in their paper have studied the methods of spatial interpolation to determine the spatial variation of the qualitative characteristics of groundwater in the Rafsanjan plain. Pourkermani et al. [16] have studied the structural effect of the gypsum castle salt dome on the salinity of groundwater in Daryoun plain.

This study tries to analyze the effective parameters in soil permeability and feeding of groundwater aquifers, through the hierarchical method and preparation of its raster layers, weighting and composition of layers and ARC GIS software environment, the best water resources Identify, determine, introduce and zoning in order to optimally exploit the water resources of the region and prevent their over-exploitation. In this research, we try to find new areas in terms of water resources in low water areas using remote sensing methods and statistical methods and direct these water resources to agricultural lands or by creating a town. Near new water resources, we can revitalize new villages and settlements, thus preventing the uncontrolled growth and density of cities, as well as providing employment opportunities.

2. Study Area and Data

Garmsar is one of the eight cities of Semnan province and is located in the west of this province. Garmsar city is limited from the north to Firoozkooh and Damavand cities, from the east to Aradan city and Sorkheh city from the west to Garmsar city and Qom province and from the south to Aran and Bidgol cities. The distance from the Garmsar city to the center of the province is 110 km and to Tehran is 95 km. The area of Garmsar city is 10686 square kilometers. Garmsar is geographically located between 34°and 28” and 30’ north latitude and between 51° and 52” to 52° and 55” east of the Greenwich meridian. Garmsar is located on the alluvial fan of Hablehrood, one of the permanent rivers of this city, and is surrounded by mountain ranges in three directions, and only its southern side is open due to the desert. The average altitude of Garmsar is 856m above sea level. Garmsar city is the junction of the northern (Gorgan) and Mashhad railways and the main Tehran-Mashhad road is located next to it. The length of Garmsar plain is 48 km from east to west and 27 km from north to south. The agricultural sector of Garmsar and Aradan counties has been damaged due to the lack of a coherent and codified plan, so that now, in addition to the problems of soil erosion and water salinity, it has reduced the motivation of farmers to work in this production sector [17-19].

3. Research Methodology

The main stages of this research are summarized in 5 steps, which are:

- Determining effective criteria in finding groundwater potential.
- Two-by-two comparison of each of the main criteria of AHP method.
- Overlap of groundwater potential evaluation criteria in Arc GIS software.
- Comparing the actual and predicated results
- Providing solutions and suggestions to control water shortage management and reduce flood and urban planning risks.

First, the effective factors in finding the potential of groundwater and then processing each of them together are introduced. There are several factors that affect the potential of groundwater. Among the most important cases: annual rainfall, topography, vegetation density, land slope, land slope direction, grain size and soil type, urban constructions, uncontrolled felling of trees, unevenness of land surface, destruction of flood control structures such as dams. At this stage, a number of questionnaires were distributed among water resources and water engineering experts, the main question of which is to introduce the effective parameters in groundwater potential. By summarizing these questionnaires, the effective factors are: ground slope, direction of ground slope, vegetation density, type, and grading of soil, rate of annual rainfall [20].

These selected factors should be evaluated separately. The method of valuation is that the part that has the greatest potential in creating groundwater aquifers has more value than the other parts. After comparing and evaluating the criteria, it is time for the maps to overlap. The purpose of overlapping multiple maps is to combine inputs based on a set of rules and values that define the output map class from the input map classes for each location. The ultimate goal of most GIS projects is to combine spatial data types from different sources so that their interactions can be described and analyzed. With the help of these hybrid models, predictions are made that are the basis for decision makers. Now, in order to obtain and prepare data for entering the GIS environment, the effective factors in the design must be entered in different layers. Input layers for modeling are determined based on a set of criteria about the importance of each layer, and the more layers there are, the more comprehensive the design decision will be. However, this amount of layers should not be too much because they make the decision-making process difficult. They are more than the other layers. The values used to overlap these layers were prepared with the consultation and consensus of 5 experts. It should be noted that this was done by special forms that were prepared for this research. After completing the evaluation forms for the layers, weights are assigned to each layer using Analytic Hierarchy Process (AHP) [20-23].

4. Study of Main Criteria and Weighing

As mentioned in the previous section, five criteria (Table 1) were introduced as a factor and effective in the occurrence of water flow, which we will now briefly review each of them and evaluate them.

Table 1. Extraction of the criteria

Criteria	Extraction method
Ground slope	By digital elevation map of the area (DEM)
Direction of ground slope	By digital elevation map of the area (DEM)
Vegetation density	Through surveys of geological maps and aerial photographs
Type and grading of soil	Through surveys of geological maps
Rate of annual rainfall	Meteorological Organization rain stations

In the sloping of Garmsar region, the slope of the region is from 0 to 87° and is divided into 4 classes (Table 2). According to studies conducted in the slope angles of the region, angles greater than 30 degrees in the region are related to excavations and embankments in the region. Preliminary studies of the slope have shown that the study area in most areas includes up to 10° of slope for design. The first class has the highest value because it has the lowest slope and increases the potential and has a value of 10. Similarly, with increasing slope, which increases the speed of water movement, the second class has a value of 7 and the third class has a value of 4. The fourth class also has a very steep slope because the speed of water movement reaches its highest level, so its value is 1, which is a limiting factor for water absorption.

To determine the direction of the slope in the area, it is divided into 9 main directions. The divisions made with 45 degree angle differences for each side. The queen operator consists of 6 vectors with three horizontal vectors and three vertical vectors to interfere with the 8 pixels around the main pixel in the orientation, and thus in all 8 main directions, the orientation will be done. Valuation of directions due to the

Table 2. Extraction of the criteria

Criteria	Valuations								
Ground Slope	Slope (°):	0 -10	10 -20	20 -30	30 <				
	Value:	10	7	4	1				
Slope Direction	Slope direction:	South	North	North-East	North-west	East	West	South-East	South-west
	Value:	10	8	6	6	4	4	2	2
Ground cover	Ground cover:	Garden and pasture	Low density pastures	Agriculture	Barren				
	Value:	10	7	4	1				
soil grading	Soil type:	Gravel	Sand	Silt	Clay				
	Value:	10	7	4	1				
Annual Rainfall (mm)	Rate:	1	3	4	5	7	8	10	
	Value:	100-50	150-100	200-150	250-200	300-250	350-300	400-350	

general direction of the earth slope from north to south should be as follows:

That is, the further south it goes, the faster the water moves, the less water is absorbed, and the lower the score. By averaging the valuations performed, the values of these 8

classes were determined in terms of direction. Thus, the north class has the highest value after flat ground, i.e. 8, and the value of the northwest and northeast class was determined to be 6. The values of the East and West classes also have a value of 4. The value of the southeast and southwest classes also includes a numeric value of 2. The south direction is the least absorbed direction during water flow, therefore it has the lowest value.

Examining the geological maps of the Geological Survey and aerial photographs taken from the area and referring to these maps with a map prepared by the Modis satellite of the area, it was determined that the predominant vegetation of this area is the coniferous family, Aras, Cedar and barberry shrubs and above the area a lot of turmeric trees can be named.

The ground cover layer is divided into 4 different classes, each of which has its own value. Areas to barren cover are among the worst coverings because they do not prevent the flow of water from increasing and controlling the flow of water, so it has the lowest weight. The class of agricultural area is more valuable than the class of the barren, and the reason is that the soil of these lands has a low cover but shows more resistance to water flow. The next class are gardens and pastures that have the highest value in terms of valuation. Because such coverings, due to the presence of numerous trees and plants in their area, control the flow of water and reduce the risks of this phenomenon. The higher the density of these coatings, the more valuable they are and have a significant effect on water absorption.

The more fine-grained the soil, the less water penetrates into it, so in areas with clayey and sticky soils, raindrops, due to impact on the soil, cause compaction and adhesion of the surface layer of the soil and the ability to absorb Soil and water penetration decreases in depth and as a result rainwater does not penetrate into the soil and flows. On the other hand, the intensity of rainfall causes the soil grains to move and moves these grains with them, and the suspension of these soil particles increases the volume of runoff and water flow. So, the classification is divided into four classes of sand, silt, silt, clay.

The annual rainfall in Iran, according to the statistics of the Meteorological Organization is about 100 to 800 mm every year.

It can be seen that the rate of intensive rainfall is mostly in the provinces of Guilan, Mazandaran, Ilam and the northwestern basin of the country. Moreover, Yazd, Sistan-Baluchestan and Kerman provinces have the lowest rainfall [24].

For the sake of valuation, the part-to-whole method is used, which first evaluates the criteria against each other. The purpose of the two-by-two comparison method is to compare the criteria together and in pairs and show their superiority over each other, with a number from 1 to 9, and this method in order to facilitate decision-making on. The basis of empirical information as well as the judgment of decision makers was presented. In this method, complex problems are analyzed and graphically expressed in a hierarchical format. This technique can systematically incorporate both quantitative and qualitative factors into the decision model. This method is based on pairwise comparisons. In such a way, all the criteria are quantified and the weight of the criteria is calculated with the help of the presented techniques. The analytical hierarchical process is one of the most comprehensive systems designed for decision making with multiple criteria, because it is based on a strong and comprehensive mathematical methodology and obvious principles and is considered as an input in the two-by-two comparative method and the relative weights are generated as output. For this purpose and to determine the percentage of the effect of the main criterion, special forms were prepared and provided to a group of 5 design engineers and specialists, and these specialists gave a value to each of the criteria by a two-by-two comparative method. Hierarchical processing (AHP) method was used to determine the effect of criteria by percentage. The following is how to evaluate the criteria in this study. By averaging all the values obtained from the collection of forms, and the value of their ratio has been prepared through the hierarchical processing method [25-29].

4. Data Collection

A number of questionnaires were distributed among water engineering and water transfer experts, the main question of which was to introduce the effective parameters in the occurrence of water flow compared to other parameters. After reviewing the questionnaires, five factors were selected as the most effective factors. Now, the two-by-two comparison and evaluation of each of the main criteria was done by experts using the following questions.

1. What is the priority of the land slope criterion compared to the direction of the land slope for gaining more weight?
2. What is the priority of land slope criteria over vegetation density for gaining more weight?
3. What is the priority of the land slope criterion over the soil type and grain size of the soil for gaining more weight?
4. What is the priority of the land slope criterion compared to the annual rainfall for gaining more weight?
5. What is the priority for the slope of the land compared to the density of vegetation for gaining more weight?
6. What is the priority of the criterion for the slope of the earth in relation to the material and grain size of the soil for gaining more weight?
7. What is the priority for the slope of the land compared to the annual rainfall for gaining more weight?
8. What is the priority criterion for vegetation density compared to soil type and soil granulation for gaining more weight?
9. What is the priority of vegetation density criteria over annual rainfall for gaining more weight?
10. What is the priority of the soil type and grain size of the soil in relation to the annual rainfall for gaining more weight?

Using the results of the above questionnaire, Tables 3 and 4 are formed based on the AHP decision method.

Table 3. Valuation of the effective factors on the flood

Main criteria	Expert No.					Mean
	1	2	3	4	5	
Ratio of land slope to slope direction	3	4	3	4	2	3.2
Ratio of ground slope to vegetation density	1	2	2	3	2	2
Ratio of ground slope to type and grading of soil	3	2	2	3	2	2.4
Ratio of ground slope to rate of annual rainfall	1	1	2	1	1	1.2
Ratio of vegetation density to ground slope direction	2	3	2	2	1	2
Ratio of soil type and grading to ground slope direction	1	2	1	2	3	1.8
Ratio of rate of annual rainfall to ground slope direction	2	3	2	2	3	2.4
Ratio of vegetation density to soil type and grading	1	2	1	2	1	1.4
Ratio of rate of annual rainfall to vegetation density	2	1	2	3	1	1.8
Ratio of rate of annual rainfall to the soil type and grading	2	1	2	2	3	2

4. Overlapping of Criteria in GIS

By determining the number of criteria and sub-criteria, the first part of the research goal was performed. In the second stage, these criteria and sub-criteria must be entered into the GIS environment, so there is a need for modeling. ArcGIS software has the ability to perform the relevant modeling according to the index overlap method. By first forming an overlap model for each relevant criterion and then combining these overlapping models and as shown in the diagram below, the overlap model obtained the total index.

Table 4. Weighing the effective factors on the flood

Main criterion	Ground slope	Annual rainfall	Vegetation density	Slope direction	Soil type and grading	Weight vector
Ground slope	1	1.20	2.00	3.20	2.40	0.325
Annual rainfall	0.84	1	1.80	2.40	2.00	0.273
Vegetation density	0.50	0.56	1	2.00	1.40	0.167
Slope direction	0.32	0.42	0.50	1	0.56	0.098
Soil type and grading	0.42	0.50	0.72	1.80	1	0.137

Preventing flood hazards requires identifying and determining potential groundwater zones. Meanwhile, work units in the regions are determined and evaluated based on a number of factors affecting the groundwater potential of the basin. Spatial information system is used to prepare layers of spatial information as well as a combination of effective factors and the application of remote sensing to prepare a map of vegetation and soil and facilities and infrastructure. Potential zoning of groundwater in the basin can be presented based on the conceptual model and based on slope factors, land slope direction, rugged shapes, soil type and vegetation and land use. The results are analyzed and evaluated in a spatial analysis system using spatial analysis models, and the maps indicate the potential of groundwater and the determination of expandable areas in future plans taking into account the flood threat. The conformity of the results of this method with the study and application of models and spatial information system and the final interpretation of information can be confirmed by studying the natural conditions of the region.

In order to study the potential places of groundwater, the location map of residential centers along with basic information of population and population centers as descriptive data and the map of potential groundwater areas obtained from GIS analysis in a spatial analysis using related analyses such as zinc fusion to identify potential ranges. By examining the potential maps of groundwater and overlay, this layer and other distribution layers of the watershed population centers are more than 40% of the city at risk of water shortage. In addition to the maps presented in the next chapter, containing topographic spatial analysis and flooding areas using digital elevation model and slope and flood analysis Using digital elevation model and slope and flood analysis and also using regional model Water scarcity, endangered settlements have come.

5. Implementation and Discussion

In this part of the research, our goal is to reach potential water sites in the area for water extraction through information and maps obtained by the GIS system. Also, by implementing the evaluated scores of each factor of creating groundwater potential in Garmsar region by GIS and the overlap of these factors with each other, potential and investable parts in the region are identified and can be proposed by appropriate and appropriate plans. The region has largely diverted the region's high-risk water flow to low-potential areas for feeding and residential and urban construction to safer, less hazardous areas with the necessary water. The extracted results are presented in Figures 1 to 6.

Accordingly, it can be said that Garmsar urban areas, such as Aradan, Garmsar and Ivanki are located in potential groundwater areas. However, the important point of this map is related to the low potential parts of this city, which are prone to floods due to sudden and heavy rains due to the lack of water penetration into the ground. As a result, they are not suitable for the construction of towns and residential areas.

6. Conclusion

The studies presented in this study using spatial information systems indicate that after heavy rains in the regional watershed in Garmsar city, especially in the north, if the water is not successful in controlling and transferring it behind the dams. Feeding of aquifers causes severe water flow and also causes great damage to economic and infrastructural sectors such as buildings and facilities, farms and agricultural lands and also leads to casualties.

Therefore, the importance of using spatial information data in the present study has been revealed to us in two ways, one is to identify potential areas of groundwater, and the other is to pay attention to areas prone to floods. With the overlap of factors and information in GIS and analysis of the results obtained confirms the role of the following factors in groundwater potential:

- Land use changes in areas affected by rainfall and the direct correlation of these changes with the intensification of water flow.
- Lack of attention to topographic conditions and slope of areas in incorrect use of agricultural lands and unbalanced agricultural development regarding slope.
- Excessive grazing of livestock and destruction of land cover in pastures and increasing susceptibility to flooding.
- Heavy and unbalanced rainfall outside the normal rainfall patterns in short periods of time.
- Construction and development of unsuitable structures in unsuitable locations and non-engineered along rivers and flood-affected areas to transfer water.
- Instability and soil erosion on sloping and vegetation-free surfaces.

According to the specified zoning and determining the potential points of groundwater and effective factors, as well as the Garmsar watershed, in the case of Garmsar, the current potential finding is correct with high accuracy.

Reducing runoff damage is not limited to flood time activities. Rather, it is a combination of pre-rainfall, flood management, and post-flood reconstruction and function review. In the end, the profit of all this work goes back to feeding and filling the aquifers, so it is a kind of win-win game.

Pre-rainfall activities include:

1- Water flow risk management for the factors that cause floods.

2- Construction of flood prevention structures in both physical and flood forecasting and warning systems.

3- Maintenance of flood resistance structures.

4- Applications and applied land management throughout the basin.

5- Preventing the unbalanced development of plain water flow.

6- Predicting the future river flow conditions from meteorological observation

Activities after rainfall are:

7- Relieve the people affected by this incident.

8- Reconstruction of buildings, flood structures that have been damaged.

9- Recycling and reconstruction of the environment and economic activities in the flooded area.

10- Review of the flood management activities to improve procedures and workflows for subsequent similar incidents.

According to the extraction of groundwater potential map in the project area, by providing solutions and formulating specific strategies, we will manage the risk in the flood zone, which also eliminates the nutritional weakness in low potential areas. These solutions can be in one of the following ways:

1- Land use management in flowing water and providing less vulnerable land uses.

2- Basin management to reduce flood vulnerability in the study area

3- Use of special structural and non-structural methods in different intervals to reduce flood risk.

Different solutions can be suggested to deal with water flow. These solutions are based on reducing flood damage, improving the catchment and improving the river route, which reduces flood damage is usually based on management or non-structural methods or based on structural systems. Structural methods usually have a water flow control perspective, these methods are more expensive than non-structural methods. Experience has usually shown that these methods are less efficient than non-structural flexible methods due to their low flexibility

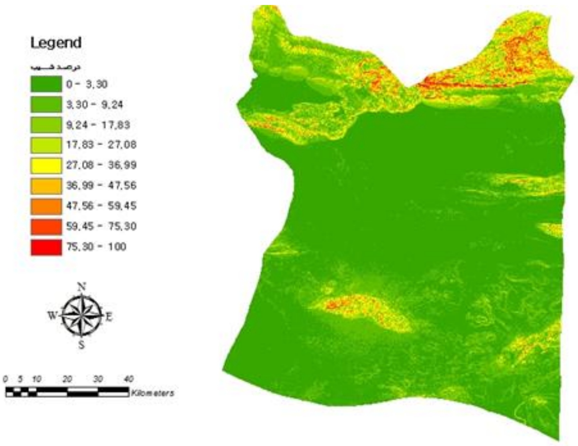

Figure 1. Digital Model of Garmsar Region

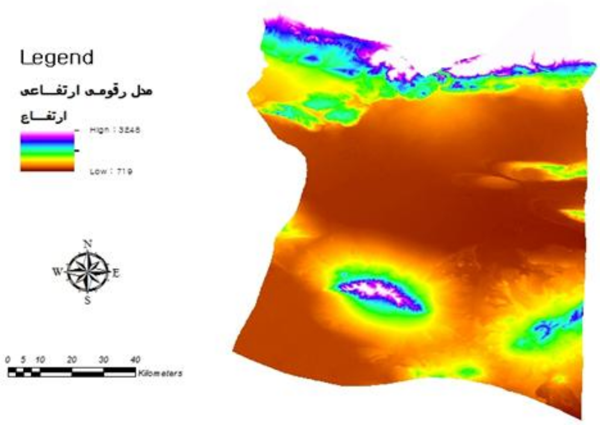

Figure 2. Ground Slope of Garmsar Region

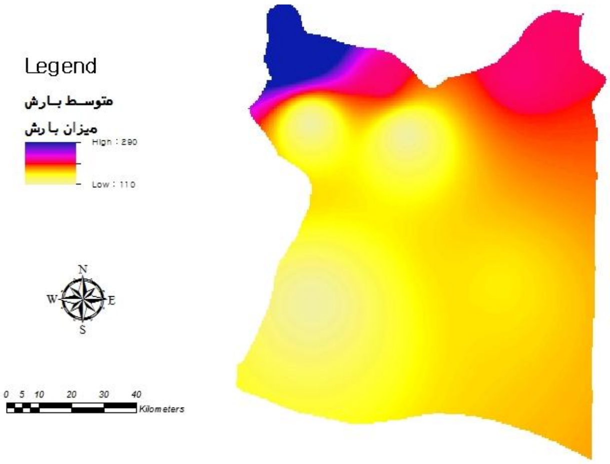

Figure 3. Rate of average rainfall in Garmsar region

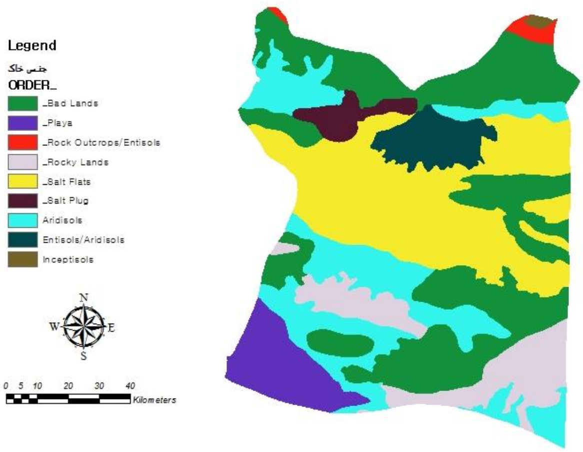

Figure 4. Soil Classification map of Garmsar Region

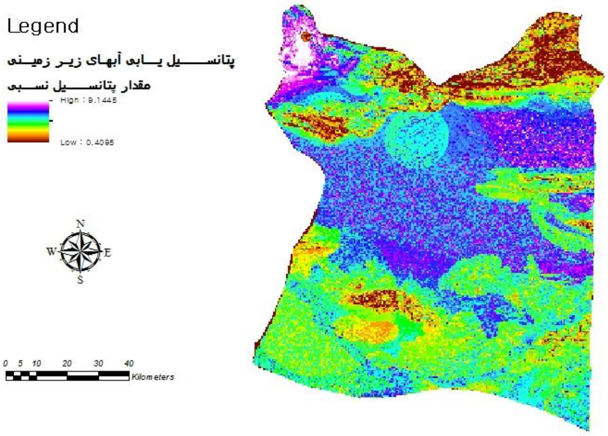

Figure 5. Valuation of the Region using the AHP method

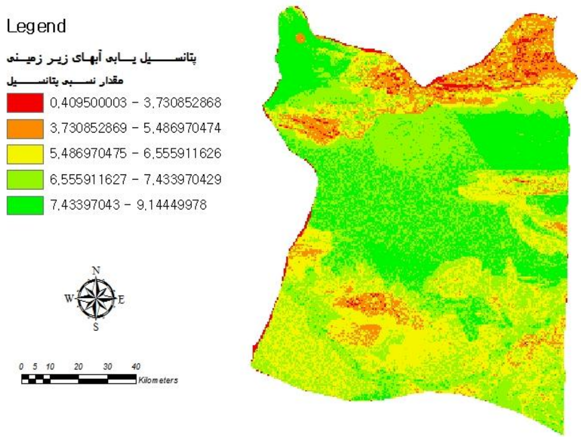

Figure 6. Potential of Groundwater resources

Methods are in which the main channel of the river is changed in such a way that the maximum volume of water flows through it in the shortest possible time. Of course, it should be noted that the transfer of large volumes of water downstream in a short time may cause damage downstream, and if the frequency of this water flow is high, there will be problems in the ecology and environment of the region.

In this method, measures are taken to control the risk of flooding before runoff enters the main channel of the river. By dividing the catchment into three areas of holding, delaying, and post, it tries to control the water flow. This method, like the previous method, may have ecological and environmental problems.

This method is very flexible and its selection is based on the desired area. It is based on the creativity of the previous two methods in such a way that over time it can be adapted to changes in the river or catchment. Various methods such as flood warning systems, land use control, waterproofing of buildings, education and public awareness, etc. are among these methods.

Given the fact that the lands around the rivers are valuable in terms of agriculture and industry and are always exposed to floods, we must always be prepared to accept the danger and plan for the time of occurrence of water flow as well as after this program. Its design and implementation can be based on risk management. That is, by identifying the effective factors in the risk and the degree of vulnerability of different points and available facilities to reduce the risk of failure of flood control methods.

Conflict of Interest Statement

The authors declare no conflict of interest.

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