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Locating Suitable Sites for Bandsar Construction with BWM and GIS

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Abstract
Bandsar is a traditional large plot, which is built by creating an embankment on the level lines in the plains around ephemeral rivers, or is built across the waterways like small dams in the hill region, and directing and maintaining the flood or runoff of the hillslopes and uplands. So, it is a solution for harvesting rainwater in arid and semi-arid areas. Therefore, the purpose of this research is to locate and prioritize the suitable areas of the Bandsar in the watersheds of the Qaenat region to control floods, recharge the Qanats, wells, and springs in arid areas with the Best-Worst Method (BWM) and Geography Information System (GIS). In order to determine and locate suitable sites for the construction of Bandsar from 12 different criteria, including slope, distance from rivers, distance from villages, distance from Qanats, distance from roads, distance from faults, distance from wells, geomorphology, geology, permeability, available source, and land use has been used. Criteria were weighted using the BWM method, and the priority of each criterion was determined. Results showed that among the considered criteria, distance of river with a weight of 0.214 has the first rank, permeability with a weight of 0.151 has the second rank, and slope with a weight of 0.1123 has the third rank. The study area divided into 12 zones based on natural resource priority, that named the English alphabet (A-J). Finally, region B with a score of 0.63 is the best region and region J is the worst region with a score of 0.15.
Keywords: Bandsar, BWM, Flood, Priority, Qanat, Qaenat Region.

1. Introduction
Most of Iran has an arid and semi-arid climate and has always faced a water shortage. The need for water is increasing daily with the increase in population, and to meet this need, the extraction of underground water has increased, and we have faced a negative balance in underground water. The people of arid and semi-arid areas, faced with sudden water shortage problems, found solutions to harvest rainwater. Bandsar is an example of their efforts in this direction, which is very common in Khorasan province (Dastorani et al., 2017).

Traditional flood harvesting systems in Iran are several thousand years old (Arabkhedri et al., 1997; Alinia et al., 2022). In many water-scarce areas of Iran, farmers know the importance of water and soil resources and try to protect them. (Tavasoli and Hoseinnia, 2015). Bandsar is a traditional structure with several main goals such as: cultivation, flood mitigation, erosion control, water harvesting and infiltration, flood water spreading and groundwater recharge (Dehghani et al., 2021; Arabkhedri et al., 2021), Improving vegetation and increasing production of agricultural products (Dastranj et al., 2021). In recent decades, the problems caused by the occurrence of droughts on the one hand and destructive floods on the other hand, have led the country's water resources managers and those involved in the implementation of flood spreading and artificial recharge projects have more attention (Monavari et al., 2012).

Therefore, the sustainability of groundwater resources is a critical issue. Sustainable management of surface and underground water is essential to ensure the stability of surface and underground resources of the watershed (Khashei-Siuki et al., 2012). In order to investigate the physical characteristics of Bandsar structure and measure its effectiveness in managing the optimal efficiency of water and soil resources in Birjand plain, with remote sensing methods, they concluded that by constructing Bandsar can controlling floods and sediment. Flood control in the upstream Bandsars causes the Qanat discharge to increase over time, so that the excess water created can used to irrigate the downstream lands, this method is a suitable model for solving recent crises such as erotion, reducing the level below cultivation area, reduction of fine dust, expansion of deserts and solving the problem of unemployment (Sharifikia and Mozafari, 2013).

As a result, considering the countless advantages and the extraordinary importance of the Bandsars, in the development of this region, this production method based on local and strategic knowledge is evaluated as compatible with the scarcity of water in the Birjand Plain (Peyrowan et al., 2019). The government's investment in this strategy can bring a lot of environmental benefits, continuity of life and production, employment, preventing the migration of villagers to cities, and a fantastic income without the need to worry about water supply for farmers through planting jujube trees and summer rain-fed agriculture (Yadollahi, 2018).

local and native structures play an essential role in the daily life of the people of great Khorasan; therefore, sharing local ecological knowledge in the field of natural resources as social systems, can play a crucial role in improving the adaptive capacity of social-ecological systems in dealing with perform with dehydration. Some traditional structures such as Bandsar and Khoshab help to survive in these areas and do not harm the environment, which have been customary since ancient times and are helpful for protecting water and soil as much as possible, and they are also a way to control floods. Modern science can help strengthen these structures. Strengthening these structures can improve the living conditions to some extent and prevent the migration of villagers to cities. (Dastorani and Safaei, 2018).

The location and prioritization of the fence have been less studied, so most of the studies have investigated its construction and type, which are mentioned below.

Dehghani et al. (2021) determined the Role of the Bandsar in Flood Control, Infiltration, and Recharge of Water Resources, detected 435 Bandsar with 205 thousand cubic meters by using satellite images and field measurement, finally investigating the role of Bandsar in flood hydrographic characteristics, water harvesting and infiltration of water resources in Seyujan-Teghab plain of Khosf city in South Khorasan province, For this goal, using climate data (1982-2020 period), topography map, cover plant, land use, and features and capabilities of ArcGIS10.4 and HMS software.

The results showed that Bandsars control 100% of the runoff from rainfall up to a 10-year return period, and Bandsar output relative input hydrograph has two sharp characteristics: 1- lag to peak and 2- peak attenuation and 76.75% of the water harvesting is infiltration and recharge groundwater recourses.

Tabatabaei Yazdi and Aliabadi (2017), in a research on local runoff harvesting and climate change resilience in dry lands of Iran for agriculture in Bandsar in Sabzevar region. Bandarsar agriculture is known to be unique and sustainable due to several fundamental factors, such as the participation of owners, land use, and water resource management. Components, the methods of construction, operation, and maintenance of the Bandsar have been studied and summarized according to the information collected from field observations and face-to-face interviews with some of the most experienced dam owners. Results showed that crop yield can be significantly improved compared to dryland agriculture that does not use passive water harvesting, because water harvesting significantly increases soil moisture over a long period of time.

Nazari Samani et al. (2014), a research study of local knowledge and techniques of runoff harvesting (Bandsar and Khoshab) in arid and semi-arid regions of Iran. At first, the structure and advantages of the two methods, Bandsar and Khoshab, were investigated. An attempt made to explain the environmental conditions, the results of these techniques, and their side effects in decreasing soil erosion, flooding, and desertification, as well as increasing productivity in some areas of Iran. Results the research showed that the effectiveness of traditional knowledge is fully compatible with environmental conditions and socio-economic conditions of rural societies such as cooperatives. However, they can serve as a good option about new technological methods.

Native structures with small dimensions and more in number provide better runoff control at a lower cost, can be built on a large scale, and do not harm life either. On the other hand, with the help of modern science, it is possible to complete and update the traditional structures, which are effective, cheap, and reliable methods, and by solving their problems more and with higher efficiency, along with local participation and support, strive to protect water and soil. In the first step, it is necessary to know the different angles of these traditional methods for protection, restoration, and optimization.

The study area is the watershed of Farrokhi Dam in Qaen county, which has been used by Bandsar for producing water and preventing runoff for a long time. In this research, attempt to determine and prioritize the appropriate location of Bandsar using the best-worst method in the geographic information system environment.

2. Materials and Methods

The studied area of the Farrokhi Dam watershed is 379,836.4 hectares, and is located in Qaen County, South Khorasan province, Iran. The geographical coordinates of the study area are from 58°34'14" to 59°42'14" east longitude and 33°12'15" to 34°1'7" north latitude (Fig 1). The highest altitude of the area is 2843 meters, and the lowest altitude is 1139 meters above mean sea level. In the area of the studied watershed, and there are 70 geological units with outcrops, which are in the age range between Precambrian and Cenozoic. From the geological point of view, these geological units often belong to the Lut block geological zone. There are relatively diverse morphological facies in the plain, among which we can mention bare plain, erosional plain, playa clay plain, hill, and mountain facies (Kheslati, 2023).

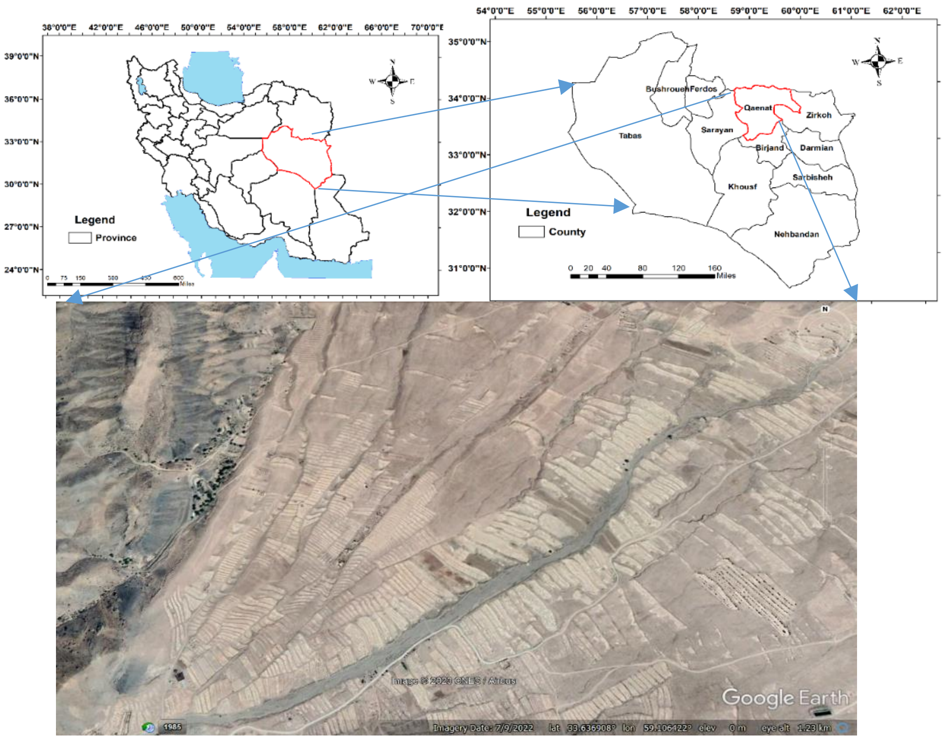

Fig. 1. Geographical location of the research site in South Khorasan province

2.1. Method

By reviewing the previous studies and the background of the research, 12 criteria identified for determining the construction areas of Bandsar. To standardize these factors, 15 experts who worked in the Qaen Natural

Resources and Watershed Department were used (Table 1). A questionnaire based on a Likert scale of 1-5 (1=very little importance, 2=low importance, 3=moderate importance, 4=high importance, 5=very high importance) was prepared to score each criterion and completed by experts. The average score of each criterion calculated; if the average score of a criterion was less than 3, it was removed. In the end all criteria were approved by experts. The average of all criteria is higher than 3. Therefore, the criteria were used (Table 2).

Table 1. Experts work experience

Service record	frequency	frequency percentage
5 to 10 years	4	30
10 to 15 years	8	50
More than 15 years	3	20

In this research, 12 different indicators, including slope, distance from the river, distance from the village, distance from the aqueduct, distance from the road, distance from the fault, distance from the well, geomorphology, geology, permeability, loan resources, and land use have used. After confirming the criteria, the effect of the criteria on the location of Bandsar was examined, because, in nature, the effect of the criteria is not the same; on this basis, the weight and priority of the research indicators calculated using the Best-Worst Method (BWM). The BMW, one of the new multi-criteria decision-making techniques, was used.

2.2. Best worst method

Here, we briefly describe the steps of BWM that can used to derive the criteria weights (Rezaei, 2015).

Step 1: Determine decision criteria.

In this step, the decision-maker identifies n criteria {c1;c2;···;cn} used to make a decision.

Step 2: Determine the best (e.g., most desirable, significant) and the worst (e.g., least desirable, least important) criteria.

Step 3: Determine the preference of the best criterion over all the other criteria, using a number between 1 and 9. The resulting best-to-others (BO) vector would be:

AB = (aB1, aB2, …, aBn),

where aBj indicates the preference of the best criterion B over criterion j. It is clear that a BB = 1.

Step 4: Determine the preference of all the criteria over the worst criterion, using a number between 1 and 9. The resulting others-to-worst (OW) vector would be:

AW = (a1W, a2W, …, anW) T,

where ajW indicates the preference of the criterion j over the worst criterion W. It is clear that aWW =1.

Step 5: The optimal weights (w^*_1; w^*_2; …; w^*_n) (Jiancheng et al., 2023).

Calculations of the best-worst method are performed in Lingo software. Finally, using GIS software, all the maps of the previous stage were integrated according to the weight of the criteria and using the overlap index, and a new classified map was prepared, which will represent the areas with priority for the construction of flood spreading.

2.3. Calibrate and validate

In this research, for calibrating the result of BWM, a field survey and Natural Resource Admonitory data were used for 11 zones of Bandsar location in the study area (Fig 2).

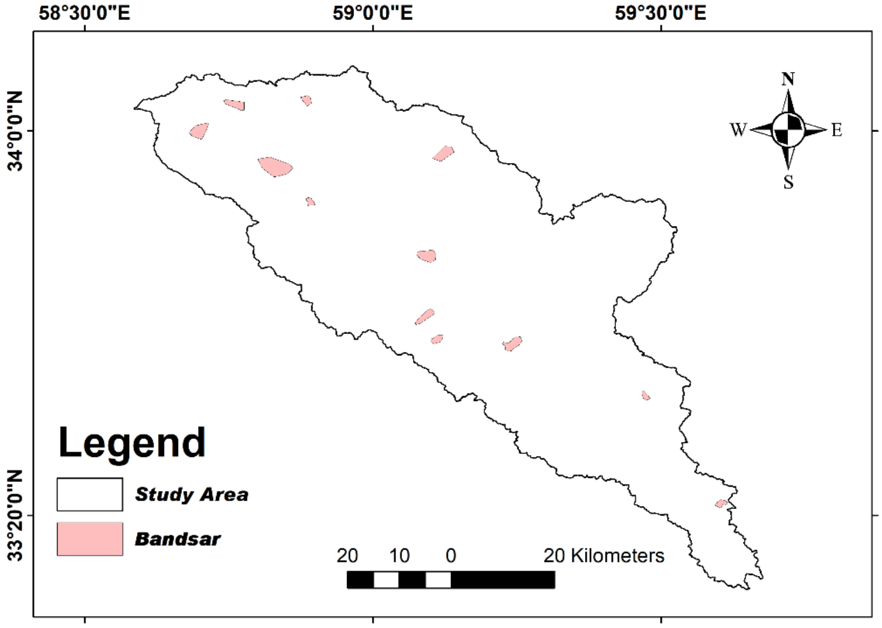

Fig. 2. Bandsar location in the study area

3. Results and Discussion

All the criteria of the research based on the opinion of the experts in the Likert method have an average higher than 3, so they have obtained the necessary points and are confirmed. The results are shown in Table 2.

Table 2. The results of the criteria evaluation

Criteria	Score
Distance of Road	3.8
Distance of Village	3.5
Distance of source	3.2
Soil Permeability	4.2
Slope	3.7
Geology	3.5
Geomorphology	3.5
Land Use	3.3
Distance of Fault	3.7
Distance of Qanat	4.1
Distance of Well	3.2
Distance of River	4.3

The results of Table 2 showed the distance from river, soil permeability, and distance from Qanat criterion obtained the highest score in the evaluation of the criteria, which shows the importance of this criterion in determining suitable areas for Bandsar based on the opinions of natural resources and watershed management experts.

Examining the status of criteria and indicators in the studied area and the method of valuing and standardizing them in the range of 1 to 9 was scored based on the impact of each class, so that the distance from the Qanat divided into five classes and each class based on the influence. For example, according to experts, the closer these structures are to the Qanat, the more points they get, and the distance from 0 to 200 gets the most points. Meanwhile, the values and intervals for each of the indicators according to the criteria and opinions of experts are listed in Table 3.

The effect of location criteria for determining suitable areas for the construction of Bandsar is not equal. In this research, the BWM was used to obtain the effect of the criteria. Results of the final weight of the criteria are shown in Table 4.

Table 4 showed that the criterion of distance from the river, permeability, and distance from Qanat, with a respectable score of 0.214, 0.151, and 0.118, had the most excellent effect in prioritizing suitable areas for constructing Bandsar in the BWM. Instead, the criterion of distance of sources has had the most negligible impact, with a relative importance of 0.017. Because Bandsar is built next to the river or inside waterways 3 and 4 river order, whatever areas are near the river are given priority.

Table 3. Value of criteria

Index	Intervals	Score	Description	Source
Distance of Qanat	0 to 200 meters	9	suitable	opinions of relevant experts
	200 to 500 meters	7	Fairly suitable	
	500 to 800 meters	5	medium	
	800 to 1000 m	3	rather unsuitable	
	> 1000 meters	1	unsuitable	
Distance of Road	0 to 1000 meters	1	unsuitable	opinions of relevant experts
	1000 to 1500 meters	3	rather unsuitable	
	1500 to 2000 meters	5	medium	
	2000 to 2500 meters	7	Fairly suitable	
	>2500 meters	9	suitable	
Distance of Village	0 to 1000 meters	1	unsuitable	opinions of relevant experts
	1000 to 1500 meters	3	rather unsuitable	
	1500 to 2000 meters	5	medium	
	2000 to 2500 meters	7	Fairly suitable	
	>2500 meters	9	suitable	
Distance of Fault	0 to 1000 meters	1	unsuitable	opinions of relevant experts
	1000 to 2000 meters	3	rather unsuitable	
	2000 to 3000 meters	5	medium	
	3000 to 4000 meters	7	Fairly suitable	
	>4000 meters	9	suitable	
Distance of River	0 to 500 meters	9	suitable	opinions of relevant experts
	500 to 1000 meters	7	Fairly suitable	
	1000 to 1500 meters	5	Medium	
	1500 to 2000 meters	3	rather unsuitable	
	>2000 meters	1	unsuitable	
Distance of Well	0 to 1000 meters	1	unsuitable	opinions of relevant experts
	1000 to 2000 meters	3	rather unsuitable	
	2000 to 3000 meters	5	Medium	
	3000 to 4000 meters	7	Fairly suitable	
	>4000 meters	9	suitable	
Slope	0 to 5%	9	suitable	opinions of relevant experts
	5 to 15%	7	Fairly suitable	
	15 to 20%	5	medium	
	20 to 25%	3	rather unsuitable	
	> 25%	1	unsuitable	
Distance of source	>2000 meters	1	unsuitable	opinions of relevant experts
	1000 to 2000 meters	5	medium	
	0 to 1000 meters	9	Suitable	
Permeability	Very low	1	unsuitable	opinions of relevant experts
	Low	3	rather unsuitable	
	Medium	5	medium	
	High	7	Fairly suitable	
	Very High	9	suitable	
Land Use	utilization of residential areas	1	unsuitable	opinions of relevant experts
	Irrigation land	3	rather unsuitable	
	Rain fed	5	medium	
	Good Range	7	Fairly suitable	
	Bad Range	9	suitable	
Geology	Unresistant	1	unsuitable	opinions of relevant experts
	Resistant	9	suitable	
Geomorphology	Mountain	1	unsuitable	opinions of relevant experts
	Hill	5	medium	
	Plain	9	suitable	

Table 4. Value of criteria in BWM

Criteria	Value
Distance of Road	0.047
Distance of Village	0.041
Distance of Source	0.0179
Permeability	0.151
Slope	0.112
Geology	0.082
Geomorphology	0.0914
Land Use	0.0414
Distance of Fault	0.0504
Distance of Qanat	0.108
Distance of Well	0.0402
Distance of River	0.214

The results of each model must be validated to be acceptable. In this research, 11 districts of Bandsar were used to validate the results of the method. These data were prepared by field investigation and natural resources reference data. The results showed that ten zones are in the appropriate area, fifty percent of one zone is in the appropriate area and, fifty percent is in the middle class of the appropriate area. Validation of the BWM model showed that this model had good results.

The studied area was divided into 12 zones based on the need of the region to construct Bandsar and named according to the letters of the alphabet (A, B, …, L). Then, the decision matrix was prepared for these zones based on the criteria (Table 5).

Table 5. Normalized matrix of BWM model for Bandsar priority

Zone / Criteria	A	B	C	D	E	F	G	H	I	J	K	L
Qanat	0.008	0.01	0.007	0.007	0.009	0.006	0.006	0.004	0.0054	0.002	0.0033	0.0042
Road	0.006	0.009	0.005	0.0045	0.007	0.0042	0.004	0.0038	0.004	0.002	0.0028	0.003
Village	0.009	0.011	0.008	0.007	0.01	0.0066	0.006	0.0055	0.0058	0.004	0.005	0.0052
Fault	0.005	0.007	0.0045	0.0044	0.006	0.004	0.0038	0.0033	0.0035	0.003	0.0033	0.0035
River	0.01	0.03	0.01	0.009	0.022	0.0088	0.0085	0.008	0.0083	0.007	0.0075	0.008
Well	0.05	0.06	0.04	0.033	0.055	0.03	0.025	0.022	0.024	0.01	0.015	0.02
Slope	0.05	0.08	0.044	0.04	0.061	0.035	0.033	0.025	0.03	0.012	0.021	0.023
Geology	0.015	0.04	0.011	0.01	0.032	0.0095	0.0092	0.008	0.0088	0.007	0.0073	0.0075
Geomorphology	0.04	0.07	0.032	0.03	0.058	0.025	0.018	0.022	0.025	0.01	0.012	0.015
Source	0.015	0.033	0.012	0.01	0.025	0.009	0.0085	0.007	0.007	0.005	0.006	0.0065
Permeability	0.05	0.08	0.044	0.042	0.07	0.038	0.033	0.027	0.03	0.02	0.022	0.024
Land Use	0.16	0.2	0.14	0.12	0.18	0.11	0.099	0.085	0.092	0.07	0.077	0.08

The normalized matrix was multiplied by the relative importance of the criteria obtained from the best-worst method, the weight matrix was prepared, and the final value of each zone was prepared, based on which the zones were prioritized (Table 6).

The BWM method is used to prioritize and determine the best area for constructing Bandsar (Fig 3). Results showed that B region is the best area, with a score of 0.63, and region J is the worst region, with a score of 0.15, and has been assigned the 12th rank for the implementation of Bandsars.

Table 6. Priority of Zones

Site	Value	Degree
A	0.41	3
B	0.63	1
C	0.35	4
D	0.31	5
E	0.53	2
F	0.28	6
G	0.25	7
H	0.22	9
I	0.24	8
J	0.15	12
K	0.18	11
L	0.19	10

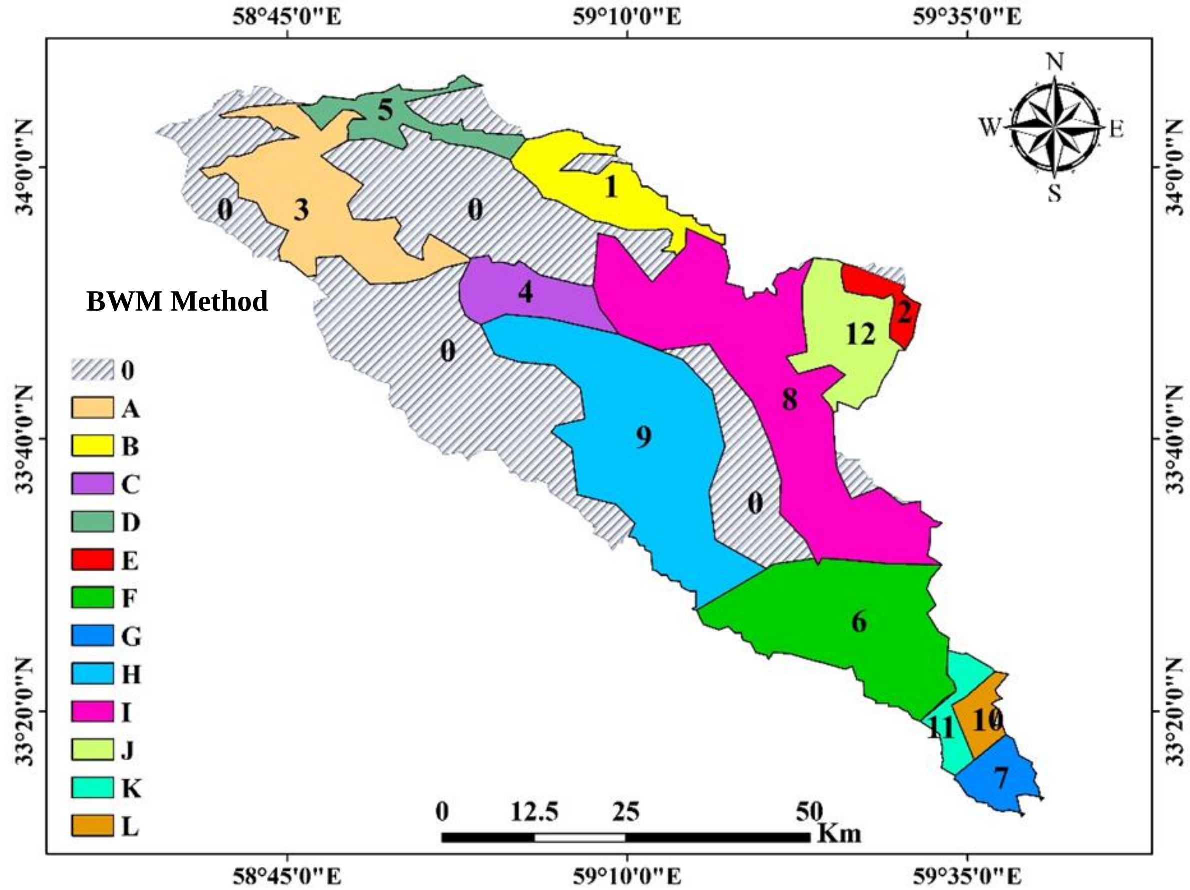

Fig. 3. Zones rank based on BWM

4. Conclusion

This research is an attempt to improve the output as much as possible by using experiences and relatively accurate criteria. In order to determine and locate suitable sites for the construction of Bandsar from 12 different criteria. Criteria were weighted using the BWM method, and the priority of each criterion was determined. Results showed that among the considered criteria, distance of river with a weight of 0.214 has the first rank, permeability with a weight of 0.151 has the second rank, and slope with a weight of 0.1123 has the third rank. The study area divided into 12 zones based on Natural Resource priority, which named the English alphabet (A-J).

Finally, region B with a score of 0.63 is the best region and region J is the worst region with a score of 0.15. The final results showed that it is possible to conduct extensive studies at the regional and national level with the data and experiences of experts by combining decision-making models and ArcGIS software. Acceptable results were obtained, thereby contributing of improving and rehabilitating groundwater levels, which are vast and precious resources. Rivers had the most significant impact on the construction of Bandsar, because these structures were used to control floods and optimize the use of floods for agriculture, strengthening the soil through sediments, etc. In the method of the BWM criterion of the distance from the river, the highest final value was obtained based on the expert's opinions, which shows the high accuracy of this method for locating and prioritizing Bandsar. In the end, Bandsars that are close to the river are prioritized with those that have higher permeability, because the higher the permeability, the more water reaches underground aquifers and recharge the aquifer or downstream Qanat.

Most essential restrictions are related to residential uses and impermeable and saline structures. A study for locating Bandsar by combining geographic information systems and decision-making models has not been done so far. Which can be checked in other research or other areas of this model with other models and different parameters.

5. Disclosure statement

No potential conflict of interest was reported by the authors.

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