

Comparison precision of Classical Methods and Analytic Hierarchy Process (AHP) in evaluating parameters affecting flood risk (Case study: Dezful flood, April 2020)

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Abstract

This research compares two methods for evaluating parameters affecting flood risk in Dezful area: the Analytic Hierarchy Process (AHP) and the classical method (simple average). The parameters under consideration include soil permeability, drainage density, distance from the river, elevation, slope, and aspect. The AHP method utilize pairwise comparisons to weight the parameters, whereas classical method assigned equal weights to all parameters. The results calculate based on these respective methodologies.

To assess the accuracy of the results, the Modified Normalized Difference Water Index (MNDWI) is extracted from the Landsat8-OLI sensor dated April 8, 2019, as the ground truth map, and Euclidean distance is used as the evaluation criterion. The results indicate that AHP has greater validity, with a Euclidean distance of 21.2, compare to 25.9 to classical method. The Mann-Whitney U test ($U=12034.5$, $p<0.05$) statistically confirms this difference. The findings demonstrate that AHP, in comparison to the classical approach, more accurately identifies distinct risk categories (ranging from vulnerable to critical) and achieves a more balanced classification of vulnerability levels. Furthermore, it mitigates the tendency toward extreme assessments observed in classical method. This study confirms that weighting parameters within the AHP framework significantly enhances the precision of flood risk assessment.

1. Introduction

In the process of environmental decision-making and spatial planning, choosing an efficient method for data analysis and prioritizing criteria is of paramount importance (Malczewski, 2006). Conventional (classical) methods, which are primarily based on assigning equal weights or using local experiences, may be less accurate and flexible compared to modern methods such as the Analytic Hierarchy Process (Saaty, 2008).

Although classical methods are still used due to their simplicity and ease of implementation (Hopkins, 2007). ignoring the complex relationships between criteria and subjective weighting is considered one of their fundamental weaknesses. In contrast, AHP, with its hierarchical structure, allows for more precise weighting based on pairwise comparisons and mathematical calculations (Saaty & Vargas, 2012).

Numerous studies have been conducted on the application of these methods in flood-related studies. For instance, the Flood Hazard Index (FHI) in the Allahabad region of India has been examined by weighting the criteria and integrating parameter scores (Dash & Sar, 2020). In that study, the validity of the method was confirmed through comparison with a satellite flood map and the Normalized Difference Water Index (NDWI), serving as a model for integrating satellite data with multi-criteria analysis in flood risk assessment.

Flood hazard mapping and risk assessment for the sustainability of Segamat Port were addressed using the Analytical Hierarchy

Process (AHP), examining criteria such as rainfall distribution, land slope, distance from the river, land use, drainage density, and road density (Sulaiman et al., 2015). AHP was introduced as an effective tool in this context, and the findings can assist authorities in developing flood mitigation strategies.

Similarly, flood risk in the Malda district of West Bengal, India, has been assessed using the Analytical Hierarchy Process (AHP) (Ghosh & Kar, 2018). The parameters used included natural factors—such as elevation, slope, distance from the river, and rainfall—and human factors, including population density, economic status, housing quality, and access to services. The northern and western parts of the region were found to be at high risk, accounting for 63% of the area, while the eastern part accounted for a small share of high-risk zones. The final flood risk map was validated with an accuracy of 87%.

Additionally, flood risk areas in Modjo watershed have been identified and mapped using this method (Bedada & Dibaba, 2025). The parameters considered included drainage density, curvature, rainfall, distance from the river, soil type, elevation, slope, topographic wetness index, land use or land cover, and the normalized difference vegetation index. The results clear that a substantial part of the catchment is at risk. The outcome was validated using 29 observed flood datasets, yielding an accuracy of 75% and an area under the ROC curve of 0.868.

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This research seeks to answer whether replacing AHP with classical methods can lead to more realistic and less error-prone results. In other words, the main issue of this research is the systematic comparison of these two methods in the context of flood risk assessment.

2. Materials and Methods

2.1 Study Area

The project area is located between the coordinates of 32°13' to 32°28' North latitude and 48°27' to 48°15' East longitude. This region is located in the north of Khuzestan province, between the cities of Shush, Andimeshk, and Dezful, with Dezful city situated in the north of the region. The main land use in the region is forest or agriculture, which accounts for approximately 60% of the area. It flows east of Dez River region and west of Balarud. Dez River is one of the most important rivers in Khuzestan province, originating in the central Zagros Mountains and reaching Khuzestan plain after passing through mountainous areas. Considering the flood that occurred on April 7, 2019 in Dez and Balah Rood rivers, and in order to compare the accuracy of assessment methods for this hazard, Landsat-OLI-C2L2 sensor images is used in this study. This sensor has 9 spectral bands with a spatial resolution of 30 meters (except for the panchromatic band with 15 meters). Images from this sensor before and after the flood hazard, dated March 7th and April 8th, is downloaded and used from the USGS Earth Explorer website. Moreover, in this research, ENVI 5.6 and Arc GIS 10.8 is used for processing and analyzing the results.

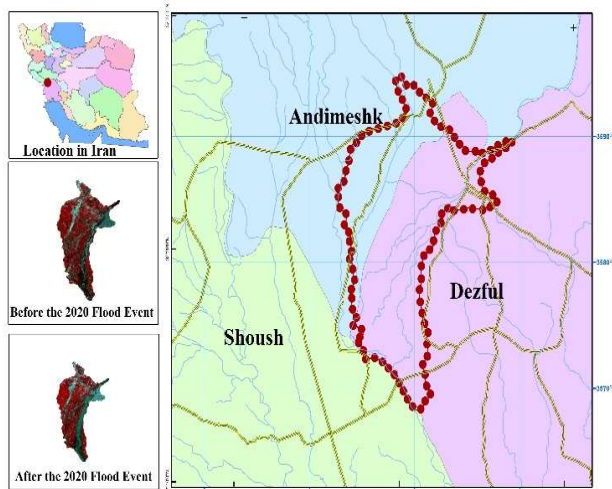


Figure 1: Location of the study area

2.2 Method of operation

In remote sensing studies, the quality of the results is directly dependent on accuracy of image preprocessing and the initial quality of the data. In this study, Level 2 (L2) data from the C2 (Collection 2) dataset, which has previously undergone radiometric and atmospheric corrections by USGS Earth Resources Observation and Science (EROS) center, is used.

Therefore, the image is of suitable quality for processing. In order to determine the flood-prone land status, six parameters were examined: soil permeability, drainage density, distance from the river, elevation, slope, and aspect (Tehrany et al., 2014). To create a topographic map of the land, a 30-meter digital elevation model (equivalent to the spatial resolution of the Landsat image) was used, and based on this, a slope and aspect map was prepared. The soil permeability class map was prepared based on publications from the Soil and Water Research Institute. In order to determine the drainage status of the area, it was first divided into several basins, and the waterways of each basin were extracted. Then, the drainage density index was calculated based on the total length of the watercourses in each sub-basin divided by the total area of the sub-basin, and this information was used as the basis for creating the distance from the river layer.

In the next step, each layer was categorized into three levels of impact: low, medium, and high (**Error! Reference source not found.**)

Description	Low impact	Medium impact	High impact
Soil permeability	I, V	IIS, IIST, IIT, IIIS, IIIST	VS, IVST, VI/RB, VI/T, VI/U
Distance from the river(m)	>500	200-500	0-200
Drainage density (km/km ²)	<5	5-7	>7
Height (m)	>130	100-130	69-100
Slope (%)	>5	2-5	0-2
Slope direction	S, SE, SW	NE, E, NW	N, W

Table 1: Classification of parameters affecting flood risk

- I (Sandy soils with excellent drainage)
- VA (Sandy-clay soils with good drainage)
- IIS (Sandy Loam)
- IIST (Sandy-clay loam)
- IIT (clay loam)
- IIIS (silty loam)
- IIIST (silty-clay loam)
- VS (Poorly drained silty clay)
- IVST (silty clay-clay)
- VI/RB (shallow stony soils)
- VI/T (Eroded sloping soils)
- VI/U (Boggy or saturated soils)

2.2.1 Classical Method

In this method, all parameters influencing flood risk assessment (including soil permeability, drainage density, distance from the river, slope, elevation, and slope direction) are considered with

equal weight (Malczewski, 2006). In other words, each parameter, regardless of its actual impact on the flood phenomenon, has an equal contribution to the final calculation as other parameters. This method is considered as the baseline method in this research.

2.2.2 Multi-Criteria Weighting Method (AHP):

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making technique that structures complex problems, determines weights of criteria, and evaluates alternatives based on pairwise comparisons (Saaty, 2008)

In this method, pairwise comparisons using a scale of 1 to 9 were employed, where 9 indicates very high importance and 1 signifies equal importance of the two criteria. Finally, the eigenvector and the consistency index are calculated, and if this index is less than 0.1, the evaluation is acceptable

In this study, after preparing the raster for each layer in a suitable format, AHP and classic method (without applying the impact coefficient of the layers on the hazard) were used to integrate these layers. The final raster layer was divided into five classes based on the statistical parameters of minimum and maximum: no impact, vulnerable, moderate, critical, and high critical.

In order to evaluate accuracy of the results obtained, MNDWI index was calculated on April 8, 2019, from the Landsat sensor image using the following formula, and this index was also divided into 5 classes (Dash & Sar, 2020)

$$MNDWI = (Green - SWIR) / (Green + SWIR)$$

In the results evaluation stage, Euclidean distance between the outputs of the two classical methods, Analytical Hierarchy Process (AHP) and MNDWI, which served as the ground truth map, was calculated. To examine the statistical significance of the differences, the Mann-Whitney Test was used.

3-Results

In order to determine the effective parameters on the flood, a pairwise comparison matrix is created based on *Table 1*, and the weight of each parameter is determined. (CR = 0.07)

	P1	P2	P3	P4	P5	P6	P7
P 1	1	2	3	5	7	8	0.36
P 2	0.50	1	2	4	6	7	0.28
P 3	0.33	0.50	1	3	5	6	0.20
P 4	0.20	0.25	0.33	1	3	4	0.09
P 5	0.14	0.17	0.20	0.33	1	2	0.05
P 6	0.13	0.14	0.17	0.25	0.50	1	0.02

Table 1: Pairwise Comparison Matrix and Final Weight of Each Parameter

- P1: Drainage density (km/km²)
- P2: Soil permeability
- P 3: Distance from the river (m)
- P 4: Height (m)
- P 5: Slope (%)
- P 6: Aspect
- P 7: Final weight

In order to determine the effective parameters on flooding using AHP in the next stage, the raster layer of factors affecting the hazard is prepared for input into AHP.

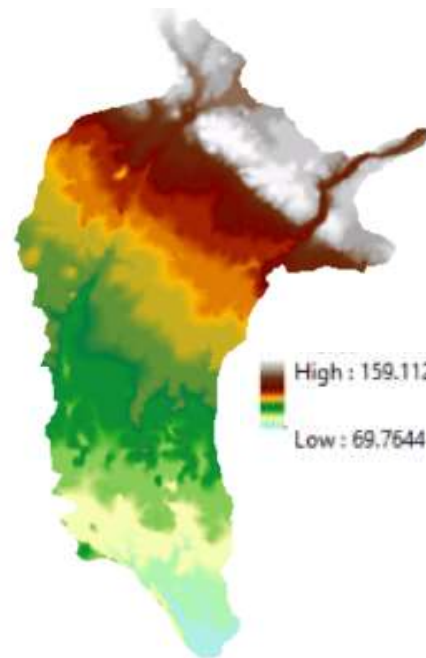


Figure 2 Dem: Parameters used in AHP.

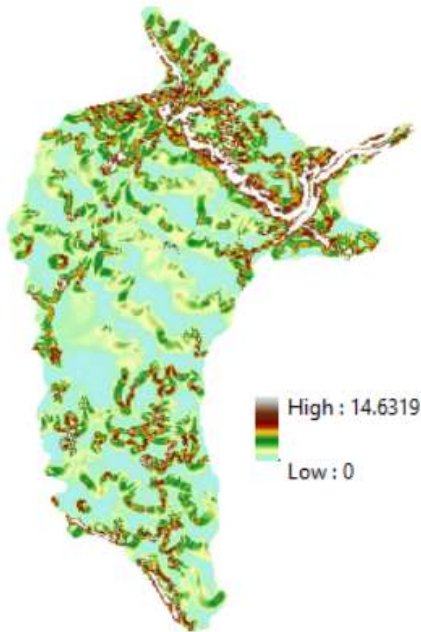


Figure 3 Slope: Parameters used in AHP.

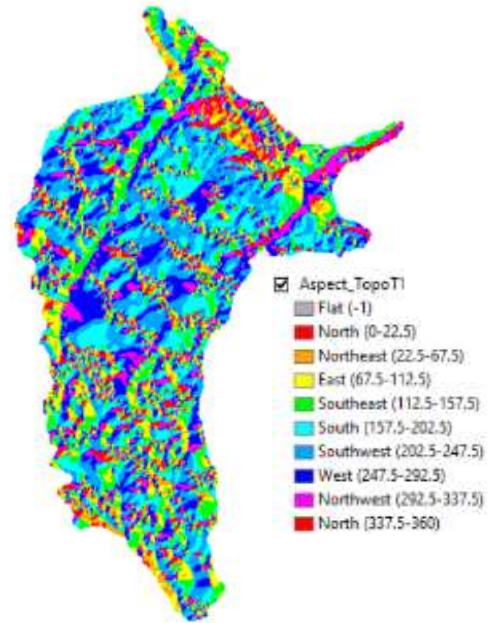


Figure 5: Aspect parameters used in AHP.

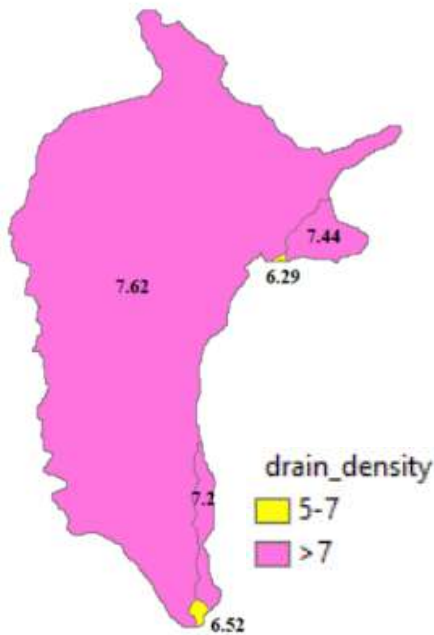


Figure 4 Drain density factor used in AHP.

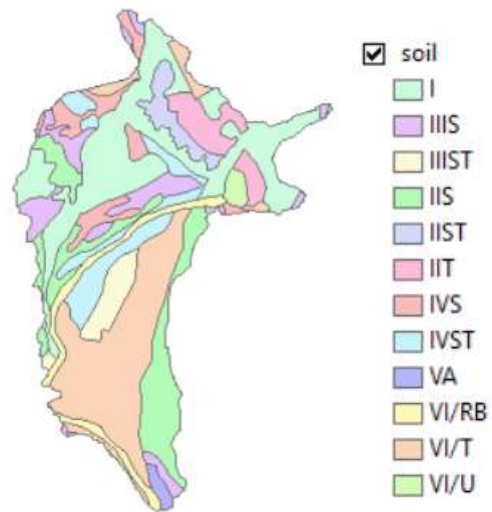


Figure 6 Classification of the soil

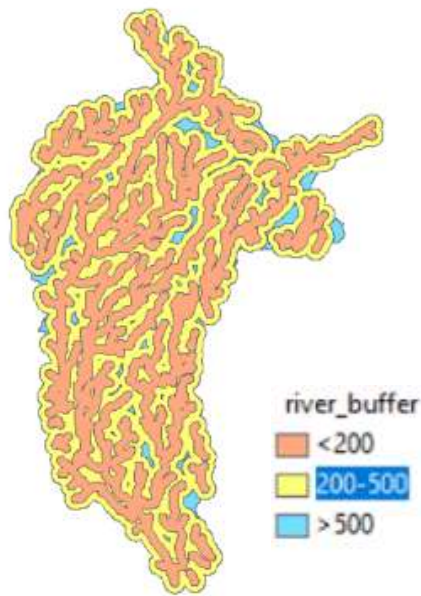


Figure 7: classification of river distance

In the next step, the obtained weights were applied to each of components, and the final raster layer is prepared. The minimum and maximum risk classes and the area of each class in each of the methods is calculated (Table 2, Table 3)

	Vulnerable:	Medium	Critical	High critical	Total
Range	4-7	7-11	11-14	14-18	
Area(ha)	0	24.1	481.5	1805	2310.6
Area(%)	0	1	20.8	78.1	100

Table 2: Hazard Class, Area, and Percentage of Area in Each Class for classical Method

	Vulnerable:	Medium	Critical	High critical	Total
Range	1.4-1.8	1.8-2.2	2.2-2.6	2.6-3	
Area(ha)	9.5	198.7	374.8	1727.7	2310.6
Area(%)	0.4	8.6	16.2	74.8	100

Table 3: Hazard Class, Area, and Percentage of Area in Each Class for AHP Method

In order to evaluate the accuracy of the classical and AHP MNDWI extracted from Landsat data on April 8th is divided into 5 classes, and the results of the classes, area, and percentage of area in each class are presented in Table 4

	Vulnerable:	Medium	Critical	High critical	Total
Range	0.10-0.25	0.25-0.35	0.35-0.45	>0.45	
Area(ha)	12.0	25.0	78.0	215.0	330.0
Area (%)	3.6	7.6	23.6	65.2	100.0

Table 4: Classification of the flood hazard class for the April 2020 event based on MNDWI

In conclusion, considering MNDWI as the ground truth map and Euclidean distance as the evaluation criterion, AHP has higher validity with a Euclidean distance of 21.2 compared to classical method 25.9. The Mann-Whitney U test ($U=12034.5$, $p<0.05$) statistically confirms this difference.

3.1 Discussion and Conclusion

The results find out classical method strongly tends towards the upper vulnerability classes, with 78.1% of the area falling into the critical category and 20.8% into the hazardous category. No area is identified in vulnerable, and only 1% fell into the moderate category, indicating the method's bias towards high-risk classes.

In addition, this method, with a strong focus on the two high-risk classes (98.9% in total), showed greater uniformity but lower sensitivity, which is probably due to the lack of proper separation of criteria by this method. It should be noted that this method, due to the elimination of the vulnerable class and the focus on critical classes, may have less unrealistic estimates in the lower classes and may not be very suitable for risk management.

The Hierarchical Method (AHP) clears a wider distribution across different classes, with 74.8% of the area in the High critical class, 16.2% in the critical class, and 8.6% in the moderate class. This method identifies 0.4% of the area as a vulnerable class, which is not present in classic. This method clears greater flexibility in risk modeling by identifying all classes (even vulnerable ones), but it may have more unrealistic estimates in the upper classes (especially High critical). Additionally, this method creates a better balance in identifying different levels of risk (from vulnerable to critical). The significant difference in class percentages (ranging from 0.4% to 75%) may be due to the impact of hierarchical weighting on different criteria. Based on the results obtained, considering MNDWI as the ground truth map and Euclidean distance index as the evaluation criterion, AHP with a Euclidean distance of 2.21 has higher accuracy compared to classic with a distance of 25.9. The Mann-Whitney U test ($U=12034.5$, $p<0.05$) statistically confirms this difference.

3.2 Research Proposals

To improve the results of Analytic Hierarchy Process (AHP method), it is possible to review the hierarchical weights to reduce excessive focus on critical categories. To improve the results of classical method, it is suggested that more qualitative criteria be included in the model to increase its sensitivity to medium and low-risk classes. Future studies could explore a combination of weighted and non-weighted methods to achieve a more realistic risk distribution. This analysis shows that the choice of evaluation method has a direct impact on the results of

risk management and should be selected appropriately based on the study's objectives and the required accuracy.

4. References

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