Doi: 10.61186/jorar.16.4.205

Prioritization of Flood Vulnerability Criteria in Qirokarzin City, Fars Province, Iran

Seyedeh Fatemeh Hosseini[1], Mohammad Hemmati[2], Mahtab Jafari[3], Alireza Estelaji[4]

Date of submission: 26 May 2024 ***Date of acceptance: 20 Oct. 2024***

Original Article

Abstract

INTRODUCTION: Flood is a natural hazard with the highest frequency and the widest geographic distribution around the world. Indiscriminate exploitation of forests and pastures, changing the land use and turning them into unsuitable agricultural lands, along with the indiscriminate construction of residential areas, have caused an increase in floods. This article is done with the aim of prioritizing flood vulnerability criteria in Qirokarzin city in Fars province, Iran.

METHODS: In this descriptive-analytical research, priorities and effective criteria were selected through library studies, examining various sources, as well as the Delphi technique, then, the opinion of experts and specialists was asked and prioritization was done using a questionnaire.

FINDINGS: The findings of the research indicated that 12 effective criteria in the occurrence of floods in the study area are: land use, streets and public roads, distance to the river, soil texture, amount of precipitation, not respecting the boundaries and development of urban areas towards the rivers, high runoff coefficient in the areas residential, low width of the communication network, population density, type of building materials, slope of the land and overall capacity of flood control. In the following, for each criterion, the graph of importance percentage and degree of importance was drawn, and finally, based on that, the priority of the effective criteria in the study area was determined.

CONCLUSION: According to the results obtained, appropriate structural and non-structural measures should be taken to minimize flood damage as much as possible. Therefore, managers and executives should consider appropriate management plans to reduce flood damage and include its results in regional development planning programs.

Keywords: Flood; Qirokarzin; Delphi method; Prioritization.

How to cite this article: Hemmati M, Hosseini SF, Jafari M, Estelaji A. **Prioritization of Flood Vulnerability Criteria in Qirokarzin City, Fars Province, Iran**. Sci J Rescue Relief 2024; 16(4): 205-212.

Methods

Flood can be considered as one of the costliest natural hazards in developing and developed countries around the world (1&2) and is one of the main threats to the development of human society. (3&4)

According to the Emergency Events Database (EM-DAT), flood was the second deadliest disaster after earthquake in 2023. Apart from the loss of life and physical damages, flood has caused about 400 billion dollars in damages from 2000 to 2022. (5) Recently, it has increased in areas that have not had a history of heavy rainfall and subsequent flooding. (6)

In many studies, factors such as increased urbanization due to rapid population growth and increased migration of villagers have been identified as the main cause of increased peak flow and increased risk of flooding in many cities around the world. (7) Urban land use changes are one of the important factors of increasing flood

1. PhD Student, Department of Geography and Rural Planning, Science and Research Branch, Islamic Azad University, Tehran, Iran.
2. Associate Professor, Department of Geography, Yadegar-e-Imam Khomeini (RAH) Shahre Rey Branch, Islamic Azad University, Tehran, Iran.
3. Assistant Professor, Department of Geography, Faculty of Humanities, Chalous Branch, Islamic Azad University, Chalous, Iran
4. Professor, Department of Geography and Rural Planning, Yadegar-e-Imam Khomeini (RAH) Shahre Rey Branch, Islamic Azad University, Tehran, Iran
Correspondence to: Mohammad Hemmati, Email: hemmati2051@gmail.com

[DOI: 10.61186/jorar.16.4.205]

sensitivity. The increase of urban impervious surfaces such as roads, buildings, parking lots and other paved areas strongly affects the amount and speed of runoff during high intensity rainfall events (8). In recent decades, the frequency and total amount of extreme precipitations have been increasing in the United States (9), China (10) and Iran (11), and decreasing in West and Central Africa (12), Mediterranean regions (13) and India. (14) Significant changes in precipitation can intensify the effect of floods and droughts on agriculture (15); therefore, the issue of urban floods has been raised as a serious issue in big cities and its consequences have also affected sustainable urban development.

In this regard, a research was conducted to assess flood vulnerability using Delphi and fuzzy TOPSIS methods in South Korea's Han River in three stages. In the first stage, evaluation of the criteria (hydrological, economic and social) and their weight using the Delphi technique, in the second stage, experts were surveyed about the criteria and their weights using the Delphi technique. In the last step, flood risks were measured in different parts of the river and its adjacent basins using the fuzzy TOPSIS approach. The results showed that among the examined criteria, the hydrological criterion is particularly important. (16)

In addition, in another research that was conducted using the Delphi method, the prioritization of flood vulnerability in the Taquari-Antas basin showed that the highest scores are related to the aspects of the ability to deal with the vulnerability and exposure to floods of infrastructure and people. Overall, in this research, the focus was on the stage before the disaster. (17)

Another research in Brazil aimed at prioritizing and zoning floods in the river basin (Juqueriquere) using Delphi and AHP methods. The results showed that even if the initial rating scores were in a limited range, the Delphi method can adequately distribute these scores in the final scale from 1 to 10. (18)

A research was conducted in Malaysia with the aim of valuing residential properties according to the level of flood exposure using the Delphi method. The results of this method, four categories of characteristics are environmental, spatial, structural and economic. The findings showed that the valuation approach in Malaysia will change the identification of the value of residential properties at risk of flooding. (19)

In a research, the Delphi technique has been investigated in detail in terms of its history, definition, types, goals and applications, conditions of use, main components, process, advantages and limitations, and suggestions for better use of the Delphi method. (20)

Locating the flood spread in the Eiver watershed in North Khorasan province, using the Delphi method, showed that indicators such as soil infiltration, flood quality, soil texture, slope and presence of aqueduct and sub-criterion of water, aquifer and topography and infiltration criterion are important respectively. (21)

The prioritization of effective criteria in reducing the stability of the agricultural ecosystem in West Azerbaijan province using the fuzzy Delphi technique showed that among the ecological, economic and social criteria, the economic criterion had the greatest effect in reducing the stability of agricultural production in the province. Meanwhile, the sub-criterion of high production cost and low income of farmers with a relative weight of 0.27 was the most important. (22)

The prioritization of flood vulnerability of Azimiyeh Karaj using 17 criteria showed that the transmission capacity of the main channel, flood control operations and drainage density were identified as the most important criteria in the study area. The Delphi technique is considered a suitable and acceptable mechanism to show the vulnerability of cities against floods (23).

A research on flood susceptibility map in Haraz watershed in Mazandaran province was prepared by using Artificial Neural Network (ANN), Frequency Ratio (FR) and Evidential Belief Function (EBF) models. The results showed that the lower elevations and near the river have a high probability and sensitivity to flooding. (24)

Also, Sanaifard et al (2023) in their research showed that the dams on the north side of the city do not match with the existing channels in Sabzevar city. So that the network of urban roads plays a role in guiding the urban flood more than the network of Sabzevar canals. (25)

In fact, identifying and prioritizing criteria to reduce flood vulnerability is very important, and the Delphi method is a suitable method for doing this.

The advantages of Delphi can be mentioned: cheap, versatile, objective, non-threatening, easy to identify and understand, highly flexible approach, application in different disciplines and the

[DOI: 10.61186/jorar.16.4.205]

possibility of being used on a wide geographical level, no need to train interviewers, anonymity, presenting open discussions, identifying and understanding the underlying theme. (26-28) This technique prevents wasting time and energy for irrelevant or biased decisions because Delphi predictions are made with an analytical and systematic method. (29)

Qirokarzin city has experienced many floods in the historical periods in 1986, 1991, 2001, 2013, 2016, 2017, 2019 which caused casualties and damages in the city. In the present study, with the aim of identifying the most important criteria of flood occurrence in Qirokarzin city, it was tried to prioritize the criteria according to their degree and percentage of importance and using the Delphi method.

Study area

Qirokarzin is one of the cities of Fars province with Qir city as its center. Geographically, it is located between longitude 52 degrees 6 minutes and 53 degrees 13 minutes east to latitude 28 degrees 32 minutes and 28 degrees 54 minutes north (Figure 1). The area of Qirokarzin city is 339,473 hectares, its height is 750 meters above sea level, and its average annual precipitation is 319.6 mm in a statistical period of 20 years. The highest rainfall in February and the lowest rainfall in June are 86.6 and 0 mm, respectively. The average highest and lowest temperatures are reported 34.1 and 12.4 in July and December, respectively. According to Dumarten climate index, the study area is classified as dry areas. The maximum height of the study area is 2187 meters in the north of the city and the minimum height is 314 meters in the south and center of the city. The most important rivers of Qirokarzin city, the Qareaghaj River enters Qirokarzin plain from north to south. The main channel of Mobarakabad, which comes from the east, and the channel of Dutoulghaz, which enters the eastern part of the plain from the south-west of Qir, feed the plain during floods. (30)

Most of the soil in the study area is of Entisol type. According to the census of 2016, the population of Qirokarzin city was 71,203 people.

Methods

In this descriptive-analytical research, priorities and effective criteria were selected through library studies, examining various sources, as well as the Delphi technique, and by using the opinion questionnaire of experts and specialists. The Delphi method is a structured process for gathering and summarizing knowledge from a group of experts using a set of questionnaires with controlled feedback. (31)

Table 1. The percentage and degree of importance of the vulnerability criteria of Qirokarzin city against floods based on the Delphi method (research findings, 2024)

Criterion	Importance degree	Importance percentage
Land use	6.4	25.5
Streets and public roads	6.6	26.6
Distance to the river	7.8	31.5
Soil texture	7	28
Amount of precipitation	7.3	29.4
Ignoring the river boundary & development of urban areas towards the ravine	8.5	34.2
High runoff coefficient in residential areas	7.2	29
Low width of the communication network	6.5	25.9
Population density	5.8	23.5
Type of building materials	6.6	26.3
Land slope	7.9	31.5
The overall ability to flood prevention	8.2	32.8

[DOI: 10.61186/jorar.16.4.205]

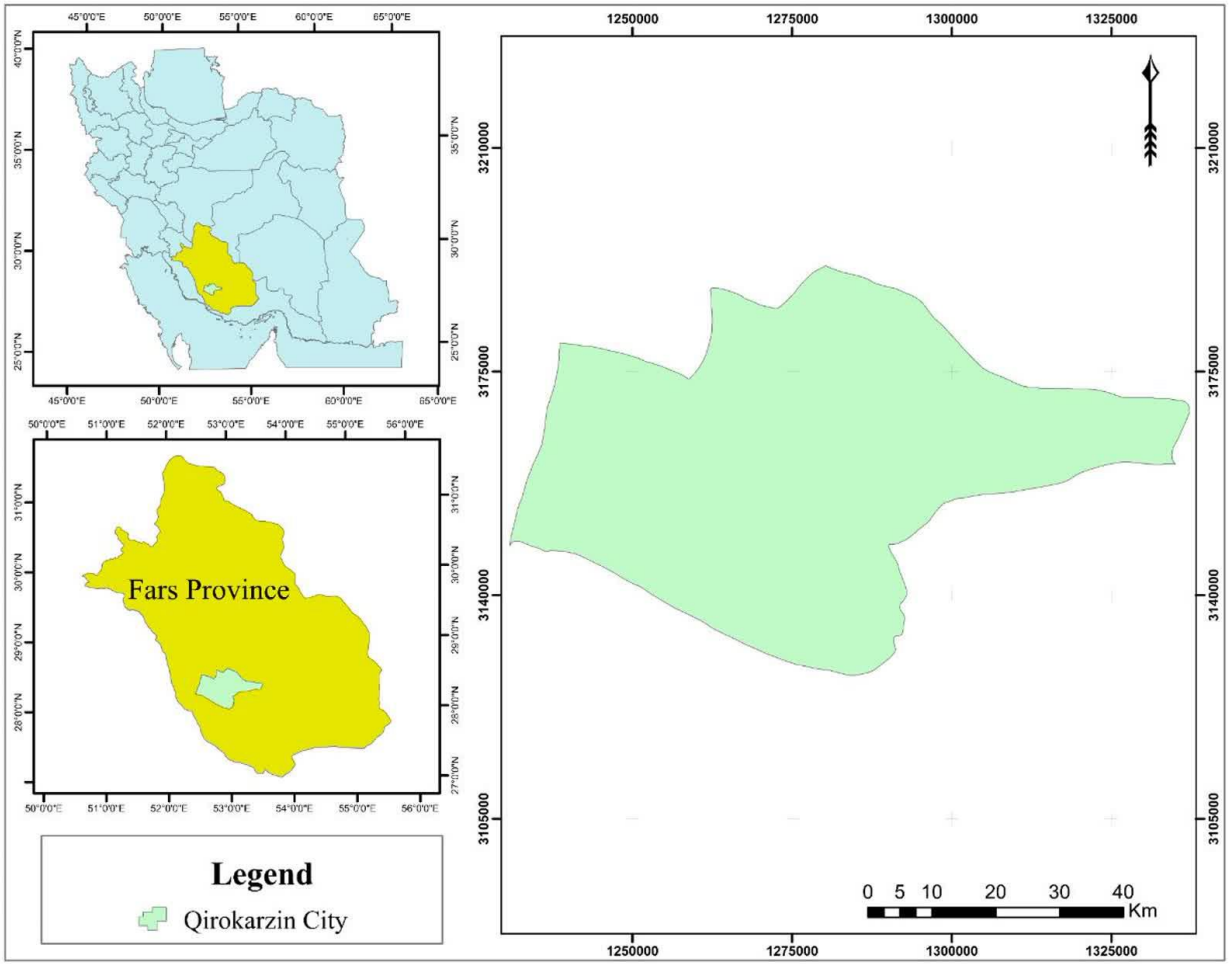


Figure 1. Location of Qirokarzin city in Fars province (research findings, 2024)

Findings

In order to select the desired criteria, the criterion importance chart was set and 12 effective criteria on flood vulnerability of Qirokarzin city are obtained. To select the most appropriate criteria, the best percentage of importance and the best degree of importance were used. Since all the examined criteria are more than half of the maximum percentage of importance and more than half of the degree of importance; therefore, all criteria are important in the vulnerability of Qirokarzin city against flood. The importance percentage of the criteria is another component to measure the importance of the criteria, which is presented in Table 1.

However, ignoring the river boundary & development of urban areas towards the ravine (with an importance degree of 8.5 and an importance percentage of 34.2), the overall ability to flood prevention (with an importance degree of 8.2 and an importance percentage of 32.8), the slope of the land (with an importance degree of 7.9 and an importance percentage of 31.5) and distance to the river (with an importance degree of 7.8 and an importance percentage of 31.5) are the most important criteria; while population density (with an importance degree of 5.8 and an importance percentage of 23.5) and land use (with an importance degree of 6.4 and an importance percentage of 25.5) are among the least important measures of flood vulnerability in Qirokarzin city. Finally, in order to measure the research criteria more appropriately, the priority percentage of the investigated criteria in Qirokarzin city in flood vulnerability is presented based on the percentage of importance, from high to low importance (Figure 2 & Table 3).

The number of choices made for each degree of

[DOI: 10.61186/jorar.16.4.205]

importance (n) was considered as its score.

The weight of the criteria was considered in the range between zero and 10, and each degree of importance represented a range of weight. Using equations 1 and 2, for each criterion, two statistical components, including the percentage and degree of importance of the criterion, were calculated in order to provide the importance of the criterion based on the graph (33).

To determine the importance percentage, first the weighted score of each class was obtained, then the adjusted weight coefficient (Yi) was calculated by dividing the weight of each class into the total weight of each criteria with a score, and finally, using this coefficient and the weight of each criterion, the weighted score was calculated. (Zi) was obtained. In the last step, the importance percentage of each criterion was obtained by dividing the total weighted score of each criterion by the maximum weighted score obtainable for each criterion. To calculate the degree of importance of each criterion, the weighted average of the importance of each criterion was calculated from the sum of the points multiplied by the weight and finally divided by the total number of points (equal to the total number of respondents).

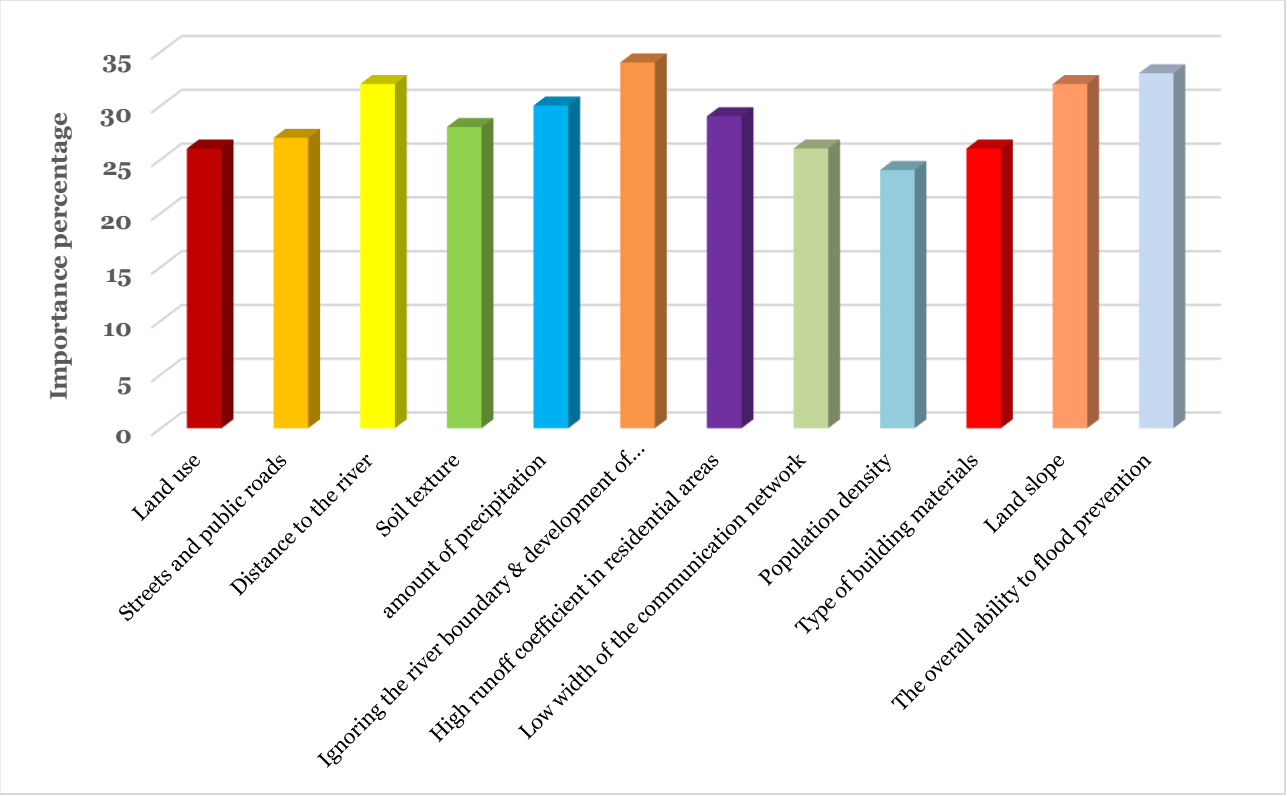
Equation 1: $$Yi = \frac{xi}{\sum xi}$$

Equation 2: $$zi = \frac{\sum(xi \times n)}{N}$$

Xi= the initial weight,
n= is the number of people who voted for each importance level,
Yi= is the adjusted weight,
Zi is the weighted score.

Table 2. Determining the degree of importance of criteria (20)

Importance degree of the criterion	Very high	High	Average	Low	Very low
Numerical expression	9	7	5	3	1
Numerical scope of expression	8-10	6-8	4-6	2-4	0-2



[DOI: 10.61186/jorar.16.4.205]

Figure 2. The importance percentage of the vulnerability criteria of Qirokarzin city against floods (source: research findings, 2024)

Table 3. The priority of effective criteria in the vulnerability of Qirokarzin city against floods (research findings, 2024)

Criterion priority	Criterion
1.	Ignoring the river boundary & development of urban areas towards the ravine
2.	The overall ability to flood prevention
3.	Land slope
4.	Distance to the river
5.	Amount of precipitation
6.	High runoff coefficient in residential areas
7.	Soil texture
8.	Streets and public roads
9.	Type of building materials
10.	Low width of the communication network
11.	Land use
12.	Population density

Discussion and Conclusion

Many researches have been done in the field of prioritizing flood vulnerability criteria in different parts of the world due to the effects of floods on human societies. Among others, Pouresmaeel et al. (2021) believe that the transmission capacity of the main channel, flood control operation, drainage density, topography and land use are the most important vulnerability criteria of the Azimiyeh, Karaj region. (23) However, due to their findings, it can be acknowledged that it is consistent with the present research.

According to the research results of Alipour et al. (2015) (21), floodplains are located at lower elevations and low slopes and on the edges of rivers; considering the findings of the current research, the slope of the land and the distance from the river are relatively important, so it can be said that this research is consistent with the current research.(23)

According to the Madruga de Brito et al. (2017) (17) research, human factors and infrastructure were identified as the most important criteria of flood vulnerability in Brazil, which is consistent with the results of the current research, that is, the criterion of not respecting the privacy and development of urban areas towards the rivers is the first priority. However, this research is consistent with the results of Madruga et al. because they also concluded that the Delphi technique allows experts with different views to prioritize indicators in a systematic and transparent manner. In fact, the use of the Delphi technique in the current research enabled the researchers to prioritize the effective criteria in the flood of Qirokarzin city with collective agreement.

The results of the survey showed that according to the opinions of experts and specialists, the population density with the degree of importance of 5.8 and the percentage of importance of 23.5 had the least effect on the flood of Qirokarzin city. This is while ignoring the river boundary & development of urban areas towards the ravine with the degree of importance of 8.5 and the percentage of importance of 34.2 has had the greatest effect on the floods of recent years in the study area.

Considering that the results mentioned in this article are based on the effective measures of flood vulnerability of Qirokarzin city, it is suggested to minimize the damage caused by flood as much as possible with appropriate structural and non-structural measures. In addition, by using the results of this research, it is possible for managers and executive officials to consider suitable management plans to reduce the damages caused by floods and the results to be considered in regional development planning plans.

Compliance with Ethical Guidelines

[DOI: 10.61186/jorar.16.4.205]

All ethical principles have been considered in this article, and participants were informed of the purpose of the research and its implementation steps.

Funding/Support

This article is extracted from Seyedeh Fatemeh Hosseini PhD thesis entitled "Prioritization of Flood Vulnerability Criteria in Qirokarzin City, Fars Province" without any financial support at the Department of Geography, Islamic Azad University of Fars in 2024.

Author's Contributions

This article is based on Abbas from Seyedeh Fatemeh Hosseini PhD thesis at Department of Geography, Islamic Azad University of Fars who was responsible for conducting the research, collecting, and analyzing the data; and the first author, Mohammad Hemmati was responsible for the design and supervision, and Mahtab Jafari, Alireza Estelaji were responsible for the methodology. However, Seyedeh Fatemeh Hosseini and Hemmati were responsible for correspondence and editing the final manuscript submitted to the journal.

Conflict of Interests

The authors declare no conflict of interest.

Acknowledgments

None

References

1. Balica S. F, Popescu I, Beevers L, Wright N. G. Parametric and physically based modelling techniques for flood risk and vulnerability assessment: A comparison, Environmental Modelling & Software, 2013; 41: 84-92. https://doi.org/10.1016/j.envsoft.2012.11.002
2. Uddin K, Gurung D. R, Giriraj A, et al. Application of remote sensing and GIS for flood hazard management: a case study from Sindh Province, Pakistan. Geogr. Inf. Syst, 2013 https://doi.org/10.5923/j.ajgis.20130201.01
3. Easterling D.R, Evans J.L, Groisman P. Ya, et al. Observed variability and trends in extreme climate events: a brief review, Bull. Am. Meteorol. Soc, 2000; 81:417 425. https://doi.org/10.1175/1520-0477(2000) 0812.3.CO;2
4. Milly P.C.D, Wetherald R.T, Dunne K.A, Delworth T.L. Increasing risk of great floods in a changing climate, Nature, 2002: 415: 514-517 https://doi.org/10.1038/415514a
5. EM-DAT- the international disaster database. 2023 Disaster in numbers: a significant year of disaster impact. [10 May 2024] Available from: https://files.emdat.be/reports/2023_EMDAT_report.pdf
6. Hettiarachchi, S. Wasko C., Sharma, A. Increase in flood risk resulting from climate change in a developed urban watershed- the role of storm temporal patterns. Hydrology and Earth System Sciences, 2018; 22: 2041-2056 https://doi.org/10.5194/hess-22-2041-2018
7. Chang H, Franczyk J. Climate change, land-use change, and floods: toward an integrated assessment. Journal of Geography Compass, 2008; 2:1549-1579 https://doi.org/10.1111/j.1749-8198. 2008. 00136.x
8. Arnold C, Gibbons C. Impervious surface coverage: the emergence of a key environmental indicator. The American Planning Association, 1996; 62: 243-258 https://doi.org/10.1080/01944369608975688
9. Balling R.C, Goodrich G.B. Spatial analysis of variations in precipitation intensity in the USA. Theoretical and Applied Climatology. 2011; 104 (3&4): 415-421 https://doi.org/10.1007/s00704-010-0353-0
10. Shi J, Cui L, Wen K, et al. Trends in the consecutive days of temperature and precipitation extremes in China during 1961-2015. Environmental Research, 2018; 161: 381-391 https://doi.org/10.1016/j.envres.2017.11.037.
11. Modarres R, Sarhadi A, Burn D.H. [Changes of extreme drought and flood events in Iran (Persian)], Journal of Global Planetary Change, 2016; 144: 67-81. https://doi.org/10.1016/j.gloplacha.2016.07.008
12. Aguilar E, Barry AA, Brunet M, Ekang L, Fernandes A, Massoukina M et al. Changes in temperature and precipitation extremes in western central Africa, Guinea Conakry, and Zimbabwe, 1955-2006. Journal of Geophysical Research: Atmospheres. 2009; 27:114(D2). https://doi.org/10.1029/2008JD011010
13. Hertig E, Seubert S, et al. Changes of total versus extreme precipitation and dry periods until the end of the twenty-first century: statistical assessments for the Mediterranean area. Journal of Theoretical and Applied Climatology. 2012; 111: 1-20. https://doi.org/10.1007/s00704-012-0639-5.
14. Sharma Sh, Shukla A. D, et al. The Holocene floods and their affinity to climatic variability in the western Himalaya. Journal of Geomorphology, 2017; 290: 317-334. https://doi.org/10.1016/j.geomorph.2017.04.030
15. Zhang Q, Gu X, Singh V.P, et al. Flood-induced agricultural loss across China and impacts from climate indices. Global Planet Change, 2016; 139: 31-43. https://doi.org/10.1016/j.gloplacha.2015.10.006
16. Lee G, Jun K.S, Chung, E.S. Integrated multi-criteria flood vulnerability approach using fuzzy TOPSIS and Delphi technique. Journal of Natural Hazards and Earth System Sciences, 2013; 13: 1293-1312. https://doi.org/10.5194/nhess-13-1293-2013
17. Madruga de Brito M., Evers M., Höllermann B. Prioritization of flood vulnerability, coping capacity and exposure indicators through the Delphi technique: a case study in Taquari-Antas basin, Brazil. Journal of Disaster Risk Education. 2017; 24: 119-128. https://doi.org/10.1016/j.ijdrr.2017.05.027

18. Boulomytis V.T.G, Zuffo A.C, Imteaz, M.A. Detection of flood influence criteria in ungauged basins on a combined Delphi-AHP approach. Journal of Operations Research Perspectives, 2019; 6:100-116. https://doi.org/10.1016/j.orp.2019.100116
19. Zulkarnain S.H. Razali, M.N. The Delphi method to identify attributes for a valuation approach for residential property exposed to flood risk. Journal of Property Management. 2022; 40: 62-82. https://doi.org/10.1108/PM-10-2020-0067
20. Ahmadi F, Nasiriani, K, Abazari, P. [Delphi technique: a tool in research (Persian)]. Iranian Journal of Medical Education. 2017; 8: 175-185.
21. Alipour H, Malekian A, Kheirkhah Zarkesh M, et al. [Application of Delphi method and GIS in site selection flood water spreading (Persian)]. Journal of Desert Ecosystem Engineering. 2016; 4: 11-22. https://doi.org/10.22052/deej.2016.113629
22. Abdi S, Abedi T, Abedi R. [Prioritization of effective criteria in reducing the stability of agricultural ecosystems in West Azerbaijan province with the fuzzy Delphi technique (Persian)]. Journal of Agricultural Science and Sustainable Production. 2018; 29: 307-321
23. Pouresmaeel M., Salajegheh A., et al. [Prioritization of vulnerability criteria in Azimiyeh (Karaj) against the flood based on the Delphi method (Persian)]. Journal of Extension and Development of Watershed Management. 2021; 9 (33): 46-53.
24. Shahabi H. [Application of artificial neural network, frequency ratio and evidential belief function models in preparing of flood susceptibility map in Haraz watershed: a plan for urban flood risk studies (Persian)]. Journal of Research and Urban Planning. 2021; 12:181-202.
25. Sanaifard A, Amirahmadi A, Zanganeh Y. [Reducing the vulnerability of infrastructures against floods (case study: Sabzevar city) (Persian)]. Journal of Research and Urban Planning, 2023; 14(52): 1-16. https://doi.org/10.30495/jupm.2021.26428.3693
26. Walker AM, Selfe J. The Delphi method: a useful tool for the allied health researcher. British Journal of Therapy and Rehabilitation. 1996; 3:677-81. https://doi.org/10.12968/bjtr.1996.3.12.14731
27. Manca D P, Varnhagen S, et al. Rewards and challenges of family practice: web-based survey using the Delphi method. Journal of le Medecin de Famille Canadien. 2007; 53: 278-86, 277.
Landeta J. Current validity of the Delphi method in social sciences. Journal of Technological Forecasting and Social Change. 2006; 73 (5): 467-82. https://doi.org/10.1016/j.techfore.2005.09.002.
28. Jones J, Hunter, D. Consensus methods for medical and health services research. British Medical Journal Publishing Group, 1995; 311(7001):376-80. https://doi.org/10.1136/bmj.311.7001.376
29. Powell C. The Delphi technique: myths and realities. Journal of Advanced Nursing. 2003;41: 376-82 https://doi.org/10.1046/j.1365-2648.2003.02537.x
30. Adler M, Ziglio E. Gazing into the oracle: the Delphi method and its application to social policy and public health. Jessica Kingsley Publishers. 1st edition. 1996.
31. Haddadinia S, Danehkar A. [Prioritizing ecotourism criteria in desert and semi-arid ecosystems using Delphi method (Persian)]. Journal of Geography and Territorial Spatial Arrangement (GTSA). 2012; 2:17-30.

[DOI: 10.61186/jorar.16.4.205]