Iraqi Geological Journal

Journal homepage: https://www.igj-iraq.org

Flood Hazard Assessment Using Multi-Criteria Analysis and Remote Sensing Data in Dwiridj Basin, Maysan Governorate, Southeastern Iraq

Yasir A. Aldabbagh[1*]

[1] Department of Administrative and Finance Affairs, Al-Muthanna University, Al-Muthanna, Iraq

[*] **Correspondence:** Yasir.Aldabbagh@mu.edu.iq

Received:
8 December 2025
Accepted:
5 August 2026
Published:
30 September 2026

Abstract

A Flood Hazard Assessment of the Dwiridj Basin area (approximately 3,537 km^2 in the Maysan governorate of southernmost Iraq was done by the use of an expert-based, multicriteria, GIS-based approach that used Geographic Information Systems for spatial analysis. The five selected controlling criteria included Elevation, Slope, Mean Monthly Precipitation (2014-2024), Drainage Density, and the Topographic Wetness Index. All criteria were normalized by the application of fuzzy membership functions, and then all normalized criteria values were combined using a Gamma Fuzzy Overlay Operator within ArcGIS to create a Flood Hazard Index. An evaluation of the flood hazard index resulted in classification into four levels of flood hazard. Area statistics were generated by each level. The results indicated that 20% (707 km²) of the basin had little or no flood hazard potential; 45% (1592 km²) had low flood hazard potential; 25% (884 km²) had moderate flood hazard potential; and 10% (354 km²) had high flood hazard potential. The resulting map offers a practical foundation for prioritizing mitigation and preparedness within the basin.

Keywords: Flood hazard; Fuzzy logic; Multi-criteria analysis; Remote sensing; GIS; Dwiridj basin

1. Introduction

Floods damage infrastructure, agricultural land, and human safety. Flood impact is often enhanced in semi-arid regions where high-intensity storms produce short-lived but destructive flow peaks (Abdo, 2020; Al-Omari et al., 2024). This issue is not limited to urban centers. Flood waves can cause damage to roads and bridges, damage agricultural lands, interrupt cross-border transportation, and threaten downstream settlements during flash-flood seasons.

Remote sensing (RS) and Geographic Information Systems (GIS) provide an efficient framework for flood hazard assessment by providing consistent data on basin-scale terrain characteristics, drainage features, and rainfall indicators. Multicriteria analysis (MCA) has been extensively used to integrate these indicators into hazard indexes. Fuzzy logic offers a practical approach to handle gradual transitions and uncertainties at class boundaries (Allafta and Opp, 2021; Shawky and Hassan, 2023; Abdo et al., 2025).

Geospatial hydrologic analyses and water management applications in Iraq support the general use of RS/GIS methods for planning of resources and hazards including basin morphometry, water harvesting and runoff simulation (Ali, 2018; Abdulrazzaq and Aziz, 2025; Jawad and Abdul Wadud, 2019; Sufiyan et al., 2018; Al-Taani et al., 2023; Amen et al., 2023; Askar et al., 2022; Al-Shwani et al., 2025). However, many studies are specific to the basins they study, have limited criteria, or do not

account for uncertainty in the integration step, which reduces the reliability of zonation maps for planning purposes.

The Dwiridj Basin in Maysan Governorate, with upstream contribution from Iran, is vulnerable to flash flooding owing to its drainage configuration and rainfall variability. Despite this vulnerability, no detailed basin-scale hazard zonations exist for Dwiridj. The Dwiridj Basin contains irrigated lowland agricultural areas surrounding the city of Al-Amarah and along the Dwiridj and Al-Teeb rivers where flood waves pose a direct threat to croplands, local road networks, and local infrastructure.

This study applied expert-based MCA within a fuzzy standardization framework to develop a flood hazard zonation map for the Dwiridj Basin. The objectives were to (i) prepare key flood-controlling factors using RS/GIS datasets, (ii) integrate them into a flood hazard index (FHI) using fuzzy membership and fuzzy overlay, and (iii) quantify the areal distribution of hazard classes to support mitigation and preparedness planning (Table 1).

2. Materials and Methods

2.1. Study Area

The Dwiridj Basin (which has an area of 3537 km2) is a seasonal water collection basin that is seasonal. It is situated in the Maysan Governorate, which is in southeastern Iraq. The basin continues upstream into Ilam province, which is in southwestern Iran, as shown in Fig.1. The basin is roughly located at latitudes of 31°02′26″ – 32°00′37″N and longitudes of 47°01′05″E – 47°03′05″E.

Climate-wise, the basin can be described as having semi-arid climate characteristics. Most of the rain falls from November to April when it is cooler. Dry seasons continue for a long period each summer. Morphologically, the lower end of the basin transitions to the Mesopotamian alluvial plains, and the dominant geomorphic features of this region include alluvium deposited in the last few thousand years and sediment deposited on the floodplains. In contrast, the upper portion of the basin reflects the effects of the transition zone or foothills along the Iraqi-Iranian border. Agriculture and grazing land cover most of the basin, and there are a small number of rural communities and irrigation networks; therefore, flooding occurs primarily due to loss of crops and/or damage to rural roads and community infrastructure located in the lowest areas of the basin.

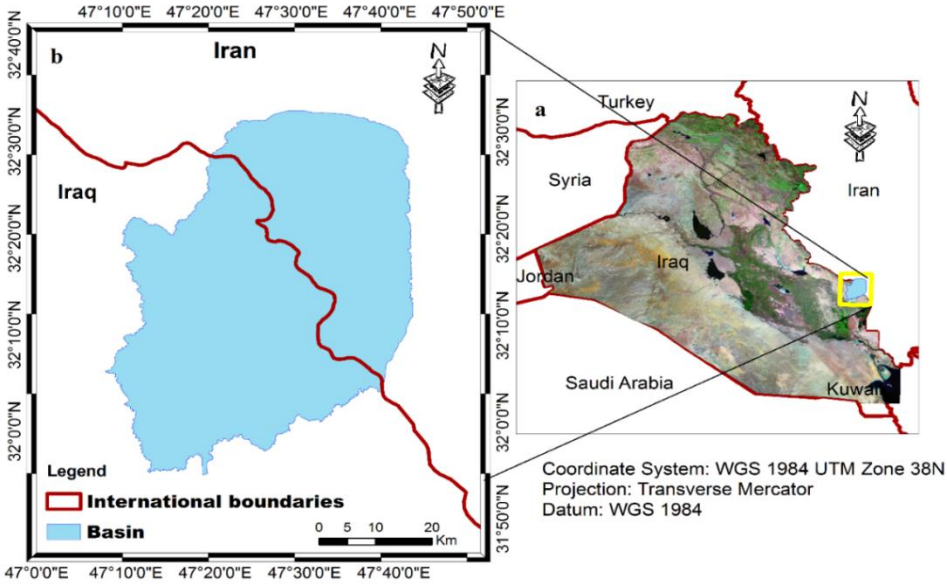


Fig. 1. a) Regional location of the Dwiridj Basin in Maysan Governorate, southeastern Iraq, and southwestern Iran; b) basin boundary within the transboundary setting

2.2. Data Sources and Preprocessing

Two major data sets were utilized within this research. One was a Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) at a 30-meter horizontal resolution (Farr et al., 2007). The other dataset was from GPM's Global Precipitation Mission via satellite during the time period of 2014-2024 (Huffman et al., 2020). The DEM was applied to determine slope, elevation, drainage networks, drainage density (Dd), and topographic wetness index (TWI). All thematic layers were then transformed into UTM Zone 38N, WGS84 datum, and resampled to 30-meter pixels so that all spatial processing could be performed consistently. GIS analysis and raster-based calculations were conducted utilizing ArcGIS software version 10.5.

2.3. Criteria Identification

A key component for generating dependable flood maps that allow for better flood prevention and flood control is selecting the appropriate set of input parameters. Elevation, slope, precipitation, drainage density, and TWI are used as the primary parameters since these are widely recognized for their impact on flood generation and have been studied and are available.

The DEM was obtained from the Shuttle Radar Topography Mission (SRTM) at 30-m resolution in GeoTIFF format. Slope, drainage density, and TWI were derived from the DEM. Precipitation data were obtained from the Global Precipitation Measurement (GPM) mission (Huffman et al., 2020) for the period 2014–2024. Each criterion layer was prepared in vector or raster format and converted to raster datasets with a consistent projection, coordinate system, and resolution (UTM Zone 38N; WGS84 datum; 30-m pixel size) using ArcGIS 10.5.

2.4. Standardization and Analysis

In the fuzzy membership phase, the criteria were transformed into continuous membership data that change between 0 (not contributing at all to flood hazard) and 1 (maximum contribution). Slope and elevation linear membership functions were employed, whereas sigmoidal functions were used for precipitation and drainage density. The fuzzy overlay operator was subsequently used to combine the standardized criteria in a single flood hazard index (FHI).

The drainage network was extracted from the DEM using the flow direction and flow accumulation procedures. A flow accumulation threshold was selected through iterative testing to obtain a realistic stream pattern that matched the basin geomorphology and visually recognizable drainage lines.

The Fuzzy Overlay Tool in GIS was used to integrate the layers into a single layer for use as input data. Each layer was normalized to a common scale (between 0-1) and then combined using the fuzzy overlay tool with a Gamma Operator. This will give you an index that is somewhere in between being conservative and liberal. For example, if TWI = -5, then it would be converted to 0 because $As/\tan\beta < 1$. The fuzzy overlay tool has built-in methods for converting negative numbers to positive ones. It does this by first normalizing each value to a number between 0 and 1, and then using those values to create the final flood hazard index.

$$TWI = ln(As / tan\,\beta) \quad (1)$$

3. Results

3.1. Criteria Analysis

Estimation of slope is a very important component in assessing the potential risk from flooding. A reliable estimate of the watershed slope is required to make an accurate forecast of floods (Ahmed et al., 2023).

The slope has a direct impact on the rainfall-runoff response and is a major factor in the generation of flood runoff (Ahmad et al., 2024). The slope attribute of the Dwiridj Basin watershed was derived from a 30 m SRTM DEM. The slope values range from 0° to 24°, as shown in Fig. 2a.

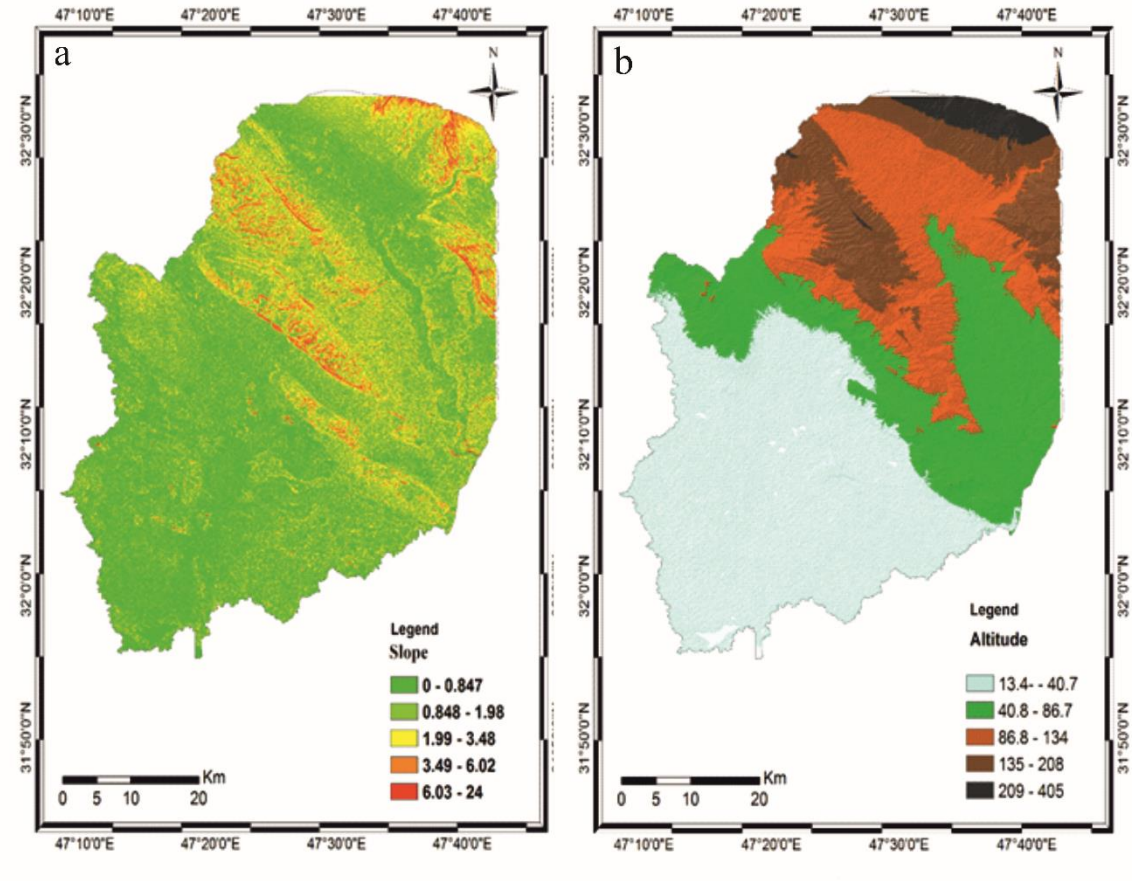


Fig. 2. a) Slope map, b) Elevation map for the Dwiridj Basin study area

Elevation is one of the most important parameters in assessing flood susceptibility since low-lying areas tend to collect runoff and have greater potential for flooding. Fig. 2b shows the elevation distribution across the Dwiridj Basin, derived from the SRTM DEM, with near-flat alluvial plains in the downstream reaches transitioning to higher terrain toward the upstream boundary.

Precipitation plays a significant role in the water cycle. In addition, precipitation is one of the most common inputs into hydrologic modeling.

Monthly total precipitation (in mm/month) averaged over the entire decade 2014 – 2024 is illustrated in Fig. 3a. The decade that we have used as our time frame is the length of the GPM satellite data record that exists for the drainage area. Therefore, it reflects the most recent climate changes, but also provides us with more years of data on which to base our statistical evaluation than if we had based our study on a shorter period of time.

Drainage density (Dd) is defined as total stream length divided by total area of the basin. It describes the density of the drainage network and provides insight into infiltration and surface runoff characteristics (Mattivi et al., 2019). Since Dd is a product of a static DEM-extracted drainage network, it can be viewed as a morphometric property of the basin rather than an annually changing variable. The drainage density map created based upon this calculation is illustrated in Fig. 3b.

The Topographic Wetness Index (TWI) defines the relationship between topography and hydrological processes. As such, TWI is used to illustrate the relative flow accumulation and tendency

towards wetness due to the local topography. The TWI was developed using Equation (1) (Mattivi et al., 2019) and is depicted graphically in Fig. 4a.

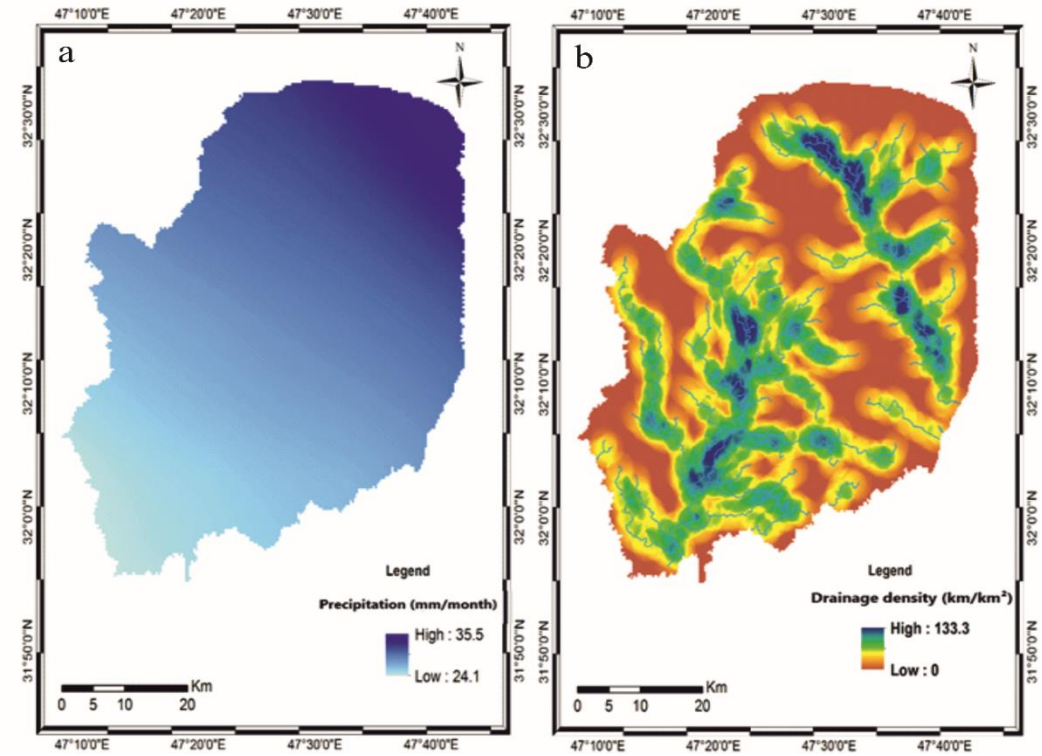


Fig. 3. a) Mean monthly precipitation (mm/month) averaged over 2014–2024, b) Drainage density (km/km²) for the study area

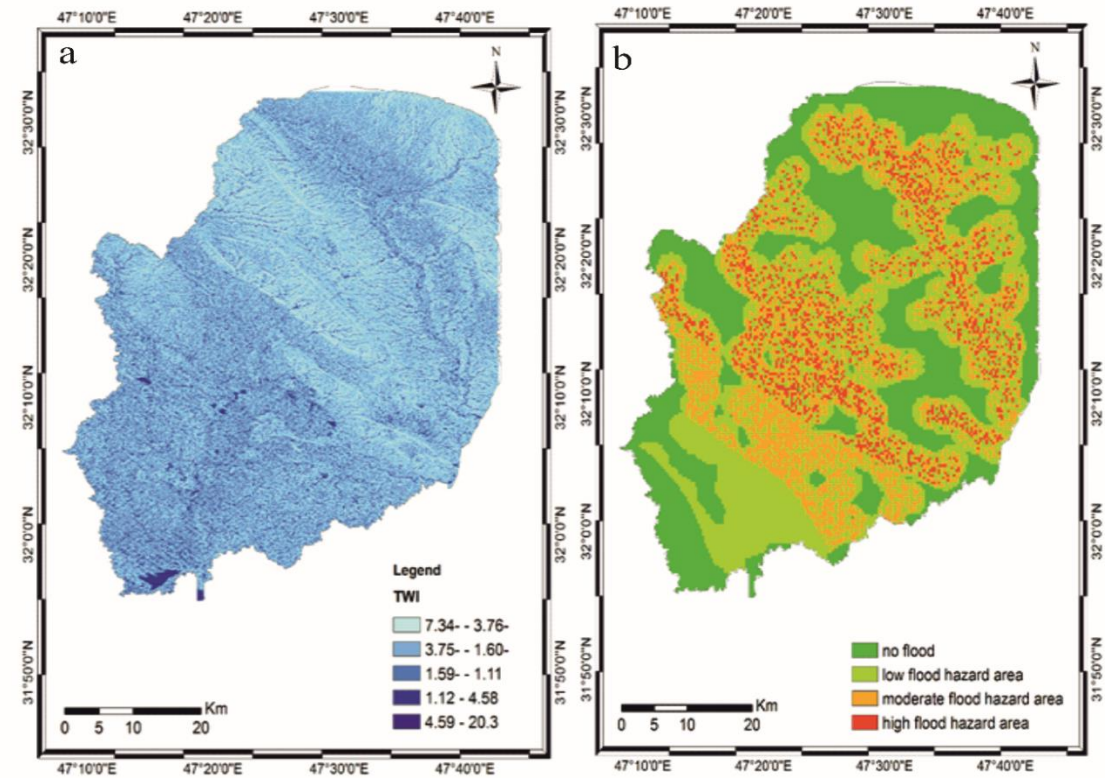


Fig. 4. a) Topographic Wetness Index (TWI) map, b) Final Flood Hazard Index (FHI) map for the Dwiridj Basin (no hazard = 20%, low = 45%, moderate = 25%, high = 10%)

3.2. Flood Hazard Mapping

Initially, each thematic layer was standardized to a [0–1] scale to reduce bias among criteria, and then fuzzy logic techniques (fuzzy membership and fuzzy overlay) were applied to integrate the factors. The resulting flood hazard index was classified into four hazard zones (no, low, moderate, and high) using natural breaks (Jenks) on the FHI values.

FINAL HAZARD MAP RESULTS

Fig. 4b illustrates a continuous transition from one hazard class to another and no abrupt changes between them. Hazard Classes A and B are located primarily in the central part of the low-lying area of the basin, as well as in those portions of the central part that have drainage lines converging toward one location. These two factors combined with low elevations and high precipitation increase the likelihood of flooding occurring in this area. Hazard Class C is associated with the steep slope upstream areas of the upper reaches of the tributaries to the main stream and also those peripheral upland areas which have low flow accumulations.

Moderate-to-high hazard zones cover 35% of the basin area and are mainly concentrated in the central low-lying parts of the basin.

Table 1. Areal distribution of flood hazard classes in the Dwiridj Basin

Flood Hazard Class	Area (km²)	Percentage of Basin (%)
No hazard	707	20%
Low hazard	1,592	45%
Moderate hazard	884	25%
High hazard	354	10%
Total	3,537	100%

4. Discussion

The flood hazard assessment of the Dwiridj Basin showed that approximately 35% of this region falls into either the moderate- to high-hazard flood zones. This susceptibility is driven primarily by low-lying terrain in the downstream and central parts of the basin, combined with dense drainage pathways that concentrate runoff rapidly. These findings are consistent with established understanding of flash flood behavior in arid and semi-arid settings, where topography and rainfall intensity exert the strongest influence.

Fuzzy overlays were used in order to assess the degree of uncertainty that occurs when determining the boundaries of flood hazard zones. Fuzzy overlays provide a "fuzzy" transitional boundary that better represents reality than a simple true/false (crisp) decision based upon Boolean logic (Rasn et al. 2021). Although there is relatively little urbanized land within the Dwiridj Basin, damage can occur to agricultural lands, rural roadways, irrigation systems, and other structures/facilities due to flood wave impacts. Additionally, people who live along streams, rivers or creeks may be unable to travel during times of peak flow. Therefore, the identified high-hazard zones can serve as a useful tool for planners to identify where they need to implement controls relative to land use, protect their infrastructure, and otherwise mitigate potential flood damage. One limitation is that there is no direct evidence supporting the model that uses observed hydrologic conditions (i.e., measured discharge at gauging stations, historical documents describing past flood inundation), so while it can be used to guide future studies/planning, ultimately the modeled flood magnitudes and return intervals will require both additional hydraulic modeling and/or physical verification.

5. Conclusions

This study produced a flood hazard zonation map for the Dwiridj Basin (area of approximately 3,537 km²), based on an expert-based GIS multi-criteria decision-making method, utilizing five

parameters for determining flood hazards (slope, elevation, precipitation, drainage density, and TWI), and fuzzy standards for their combination. The results show that 45 percent of the area is characterized as having low flood hazard; 25 percent is identified as having moderate flood hazard; 10 percent as having high flood hazard; and 20 percent of the area has no flood hazard. The area within the basin that is characterized as having moderate-to-high flood hazard is generally located in the central lower-elevated areas. These outputs can support the prioritization of the protection of areas utilized for agriculture and transportation routes, and to identify potential locations where mitigation measures can be implemented.

Small, upstream "detention" or "check dam" structures can be designed in selected "sub-catchment" areas to decrease "peak flow", provided a full hydrologic (rainfall) design and environmental assessment are completed. The future will include validating the maps using an "observed record" of floods or field observation data, and improving the analysis with higher resolution rainfall and terrain data.

Author Contributions: CRediT

Yasir Abdulameer Nayyef Aldabbagh: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review and editing.

Declaration of Competing Interests

The author declares that he has no competing financial interests or personal relationships that could influence the work reported in this study.

Acknowledgments

The author thanks Al-Muthanna University for institutional support.

Funding Sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data Availability

SRTM DEM and GPM precipitation datasets used in this study are publicly available; processed layers can be shared upon reasonable request to the corresponding author.

ORCID

Yasir Abdulameer Nayyef Aldabbagh, https://orcid.org/0009-0009-2772-7596

References

Abdo, H.G., 2020. Evolving a total-evaluation map of flash flood hazard for hydro-prioritization based on geohydromorphometric parameters and GIS–RS manner in Al-Hussain River basin, Tartous, Syria. Natural Hazards, 104(1), 681–703. https://doi.org/10.1007/s11069-020-04186-3.

Abdo, H.G., Zeng, T., Alshayeb, M.J., Prasad, P., Ahmed, M.F.M., Albanai, J.A., Alharbi, M.M., Mallick, J., 2025. Multi-criteria analysis and geospatial applications-based mapping flood vulnerable areas: A case study from the eastern Mediterranean. Natural Hazards, 121(1), 1003–1031. https://doi.org/10.1007/s11069-024-06864-y.

Abdulrazzaq, Z.T., Aziz, N.A., 2025. Geospatial mapping of groundwater potential zones using multi criteria evaluation based AHP approach in semi-arid region of Babil, Iraq. International Journal of Energy and Water Resources, 9, 1437–1447. https://doi.org/10.1007/s42108-025-00351-1.

Ahmad, B.A., Salar, S.G., Shareef, A.J., 2024. An integrated new approach for optimizing rainwater harvesting system with dams site selection in the Dewana Watershed, Kurdistan Region, Iraq. Heliyon, 10(6), e27273. 10.1016/j.heliyon.2024.e27273

Ahmed, A., Al Maliki, A., Hashim, B., Alshamsi, D., Arman, H., Gad, A., 2023. Flood susceptibility mapping utilizing the integration of geospatial and multivariate statistical analysis, Erbil area in Northern Iraq as a case study. Scientific Reports, 13, Article 11919. https://doi.org/10.1038/s41598-023-39290-4.

Ali, K.A., 2018. Geospatial Hydrological Analysis in GIS Environment for Selecting Potential Water Harvest Sites: The Case of Badrah–Wasit. Journal of University of Babylon for Engineering Sciences, 26(2), 328–337. https://doi.org/10.29196/jub.v26i2.574.

Allafta, H., Opp, C., 2021. GIS-based multi-criteria analysis for flood prone areas mapping in the trans-boundary Shatt Al-Arab basin, Iraq–Iran. Geomatics, Natural Hazards and Risk, 12(1), 2087–2116. https://doi.org/10.1080/19475705.2021.1955755.

Al-Omari, A.A., Shatnawi, N.N., Shbeeb, N.I., Istrati, D., Lagaros, N.D., Abdalla, K.M., 2024. Utilizing remote sensing and GIS techniques for flood hazard mapping and risk assessment. Civil Engineering Journal, 10(5), 1423–1436. https://doi.org/10.28991/CEJ-2024-010-05-05.

Al-Shwani, J.K.M., Saleh, S.A., Al-Manmi, D.A.M.A., 2025. Identifying Areas Exposed to Potential Flash Floods and Drawing Map for Them Using Multi-Criteria Decision-Making Depending on GIS and AHP for Erbil Sub-Basin, Northern Iraq. Iraqi National Journal of Earth Science, 25(2), 93–113. https://doi.org/10.33899/earth.2024.145160.1188.

Al-Taani, A., Al-Husban, Y., Ayan, A., 2023. Assessment of potential flash flood hazards concerning land use/land cover in Aqaba Governorate, Jordan, using a multi-criteria technique. The Egyptian Journal of Remote Sensing and Space Sciences, 26(1), 17–24. https://doi.org/10.1016/j.ejrs.2022.12.007.

Amen, M., Rahman, A.A., Mustafa, A., Kareem, D.A., Hameed, H.M., Mirza, A.A., Szydłowski, M., Saleem, B.K.M., 2023. Mapping of flood-prone areas utilizing GIS techniques and remote sensing: A case study of Duhok, Kurdistan Region of Iraq. Remote Sensing, 15(4), 1102. https://doi.org/10.3390/rs15041102.

Askar, S., Zeraat Peyma, S., Yousef, M.M., Prodanova, N.A., Muda, I., Elsahabi, M., Hatamiafkoueieh, J., 2022. Flood susceptibility mapping using remote sensing and integration of decision table classifier and metaheuristic algorithms. Water, 14(19), 3062. https://doi.org/10.3390/w14193062.

Farr, T.G., Rosen, P.A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D., Alsdorf, D., 2007. The Shuttle Radar Topography Mission. Reviews of Geophysics, 45(2), RG2004. https://doi.org/10.1029/2005RG000183.

Huffman, G.J., Stocker, E.F., Bolvin, D.T., Nelkin, E.J., Tan, J., 2020. GPM IMERG Final Precipitation L3 1 day 0.1 degree × 0.1 degree V06. NASA Goddard Earth Sciences Data and Information Services Center (GES DISC). https://doi.org/10.5067/GPM/IMERGDF/DAY/06.

Jawad, L.A., Abdul Wadud, H., 2019. The Al-Abiadh Valley Drainage Basin Environmental Aspects Extraction Using Quantitatively Morphometric Analyses of SRTM Data. Baghdad Science Journal, 16(1), 97–103. https://doi.org/10.21123/bsj.2019.16.1.0097.

Mattivi, P., Franci, F., Lambertini, A., Bitelli, G., 2019. TWI computation: a comparison of different open source GISs. Open Geospatial Data, Software and Standards, 4(1), 6. https://doi.org/10.1186/s40965-019-0066-y.

Rasn, K.H., Nsaif, Q.A., Al-Obaidi, M.A., John, Y.M., 2021. Designation of flood hazard zones using the geographic information system technique and remote sensing data in Wasit, Iraq. Geomatics and Environmental Engineering, 15(3), 129–140. https://doi.org/10.7494/geom.2021.15.3.129.

Shawky, M., Hassan, Q.K., 2023. Geospatial modeling-based multi-criteria decision-making for flash flood susceptibility zonation in an arid area. Remote Sensing, 15(10), 2561. https://doi.org/10.3390/rs15102561.

Sufiyan, I., Zakariya, R., Yacoob, R., Idris, M.S., Idris, N.M., 2018. SWAT subbasins parameters and flood risk simulations using 3D in Terengganu watershed. Earth Sciences Malaysia, 2(2), 10–15. https://doi.org/10.26480/esmy.02.2018.10.15.