

FLOOD PRONE AREAS MAPPING USING REMOTE SENSING AND GIS TECHNIQUES IN KALAL BADRAH BASIN, WASIT, EAST OF IRAQ

Athraa Abbas Kadhim¹, Marwa Razzaq Aya^{2*}, Zainab N. Jasim³

Southern Technical University, Technical Institute of AMARA, Iraq¹

Institute of Genetic Engineering and Biotechnology for Postgraduate Studies, University of

Baghdad, Baghdad, Iraq²

Department of Surveying Engineering, College of Engineering, University of Baghdad,

Baghdad, Iraq³

athraa.kadhim@stu.edu.iq¹, Marwa.r@uobaghdad.edu.iq^{2*}, z.jasim@coeng.uobaghdad.edu.iq³

Received: 23 November 2025, Revised: 06 April 2026, Accepted: 07 April 2026

*Corresponding Author

ABSTRACT

Floods are considered one of the most dangerous natural disasters globally due to the damage they cause, impacting lives and damaging property, infrastructure, and economic activities. Despite the increasing frequency of flash floods in Iraq, particularly in the eastern regions, as a result of climate change, high-resolution spatial assessments remain limited. This study addresses this research gap by integrating the latest Landsat 9 satellite imagery and rainfall data from the Global Precipitation Measurement System (GPM IMERG) within a multi-criteria framework based on geographic information systems (GIS) for the Kalal Badra Basin. The scientific contribution lies in providing a local sensitivity map with a 30-meter resolution that classifies the basin into three risk zones, offering a vital tool for disaster mitigation in data-poor semi-arid environments. The study guides methodology based on DEM SRTM, Landsat image, GPM data. The approach described integrates remote sensing and GIS techniques. Various thematic layers such as slope, elevation, Normalized Difference Vegetation Index (NDVI), drainage density and precipitation were employed to delineate flood prone zones in the Kalal Badra watershed in Iraq. The individual flood susceptibility maps of each thematic layer were combined with equal weights within the GIS environment to generate the overall flood susceptibility map of the study area. The final map classified the study area to three classes: No flood risk, low flood risk, and high flood risk area according to the selected criteria.

Keywords : Hazard, Geospatial, Flood, Fuzzy, Risk

1. Introduction

Flooding causes heavy socioeconomic damage worldwide, raising issues such as water scarcity and pollution (Tahir et al., 2026; Umali et al., 2023; Ucheje & Balafama, 2025). Safeguarding life and property require the identification of flood-prone zones (Allafta and Opp, 2021). Natural disasters not only cause loss to human life but also damage assets, infrastructure, agriculture, and environment. Millions of people across the world are vulnerable to the consequences of environmental disasters with limited resources and capacities to cope (Ullah & Zhang, 2020). Floods occur due to climate change, rainfall, dam break, and heavy storms (Wadeea and Jaber, 2021). Natural disasters not only cause loss to human life but also damage assets, infrastructure, agriculture, and environment (Thakur et al., 2023). Many disastrous floods have occurred over the last decade in the region, adversely affecting human lives, property, agriculture, and infrastructure (Al-Zubaidi and Abed, 2024; Merz et al., 2021; Angelakis et al., 2023). The most severe events took place in 2005, 2010, 2014, and 2016 while climate change has accelerated rainfall variability posing a threat of floods. Vulnerability to floods in the region is enhanced by a number of factors such as complex topography, limited water flow, and pronounced socioeconomic fragility (Ahmed et al., 2023).

Previous mapping efforts in Iraq often relied on outdated static datasets or lacked the spatial integration of high-resolution satellite-derived precipitation. This study fills this gap by using the newest Landsat 9 images (launched in September 2021) and the GPM (Global Precipitation Measurement) IMERG dataset. These datasets have better temporal and spatial resolution than older missions like TRMM or NOAA AVHRR. Utilizing contemporary datasets, this research provides a more dynamic and precise delineation of flood-prone areas in a semi-arid basin.

Numerous studies have applied remote sensing and GIS techniques to flood hazard mapping in different contexts (Ejenma et al., 2014; Gunathilaka & Fernando, 2022; Harshana & Gunathilaka, 2023; Ali, 2018; Yousef & Jaber, 2023). Amen et al (2023) used remote sensing and a geospatial methodology to identify flood-vulnerable areas of the central district of Duhok, Iraq, based on analytical hierarchy process (AHP) to give relative weights to 12 contributing parameters in order to calculate the Flood Hazard Index (FHI). Fatah and Mustafa (2022) assessed flood-prone locations in the Akre, Iraqi Kurdistan Region, fundamental for susceptibility mapping was undertaken using geographic information systems, remote sensing, and an analytic hierarchy process model. Flood monitoring, evaluation, and susceptibility mapping in China employed NOAA AVHRR data alongside geographical information systems and ensemble weights-of-evidence coupled with support vector machine models. Satellite SAR interferometry facilitated ground subsidence monitoring in Hong Kong, while flood hazard assessments in Bangladesh utilized NOAA AVHRR imagery. Analytical approaches integrating the Analytic Hierarchy Process and GIS generated groundwater potential maps in Iran. Landslide susceptibility in the same country merged support vector machines with GIS-based modelling. Maximum flood-prone area evaluations in Malaysia drew on RADARSAT images, and flood inundation simulation utilised raster-based methodologies. Near-real-time satellite imagery further supported flood modelling and verification (Rastogi et al., 2018; Copăcean et al., 2025).

The present study focuses on the use of approaches for flood-prone area mapping in Kalal Badrah Basin in Wasit province depends on remote sensing data, includes; precipitation from Global Precipitation Measurement (GPM), STRM DEM, and Landsat 9 images.

2. Materials and methods

2.1. Study area

Kalal Badrah Basin is located in the eastern Wasit Governorate of Iraq. In an independent study the basin was analyzed in quantitative morphometric detail using Shuttle Radar Topography Mission (SRTM) digital elevation data to extract key environmental aspects. The drainage basin comprises six hierarchical Strahler orders and incorporates dendritic, parallel, and deranged forms, indicating a mixed morphometric character. The topography consists of an alluvial basin, exhibiting similar solid geological structural properties throughout most areas. The drainage network is aligned with discrete lineaments and fracture traces and is indicative of a geomorphic phase beyond the youthful stage (A Jawad and Abdul Wadud, 2019).

2.2. Methodology

Floods are an important part of the global hydrological cycle (Liu et al., 2022; Al-Omari et al., 2024). They occur frequently and on a large scale, causing human and material losses annually throughout the world; these disasters are particularly prevalent in mountainous regions (Tiwari et al., 2020; Shaban, 2023). The past years have witnessed an unprecedented increase in the magnitude and frequency of floods, resulting in spatial and temporal changes in river flow characteristics under the influence of various climatic factors (Abdulrazzaq and Aziz, 2025; Li et al., 2026). Rivers and their basins are the factors influencing these changes (Zheng et al., 2021; Mohammed & Jawad, 2024). The river flow pattern depends on the characteristics of the basin (Yang & Cao, 2021).

Satellite Remote Sensing Technique is used to map and understand many earth and environmental aspects (Hussein & Alwehab, 2024; Jawad, 2024). Most of the phenomena on the Earth's surface can be studied. Remote sensing coupled with Geographic Information System (GIS) and Digital Elevation Model (DEM) techniques can be effectively used in finding the flood prone area regions and future mitigation (Al-Saady et al., 2016). The main objective of this research is to identify the flood prone areas, map these areas within the study area and point out these zones on the map by using Satellite images (LANDSAT), GPM precipitation data and DEM data.

The general steps of this study:

- **Data Preprocessing and GIS Workflow**

Before analysis, all multi-source datasets were standardized to ensure spatial consistency. The SRTM DEM, Landsat 9, and GPM IMERG data were projected to the UTM Zone 38N (WGS 84) coordinate system. To maintain a uniform spatial grain, the GPM precipitation data (originally at 0.1° resolution) was resampled to a 30-meter resolution using the Bilinear Interpolation method to match the pixel size of the Landsat and DEM layers. This confirms that the overlay analysis captures localized topographic differences accurately.

- **Generation of Thematic Layers Slope and Drainage Density**

Using the Spatial Analyst toolset in ArcGIS, the slope map was made directly from the SRTM DEM. To find drainage density, we first used Fill, Flow Direction, and Flow Accumulation operations to get the stream network. Then we used the Line Density command to show how many stream channels there are per unit area (km/km²).

- **Compute NDVI**

The NDVI was calculated from Landsat 9 imagery using the following formula:

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)} \quad (1)$$

This layer serves as a proxy for surface roughness; areas with lower NDVI values indicate sparse vegetation and higher runoff potential.

- **Rationale for Equal Weights Overlay**

Some studies use the Analytical Hierarchy Process (AHP) to give weights, but this one used an Equal Weights Overlay method to reduce bias and subjectivity. In the distinctive semi-arid setting of the Kalal Badrah Basin, both topographic elements (slope/elevation) and meteorological factors (GPM precipitation) exert a synergistic and equally critical impact on the occurrence of flash floods. By assigning equal weight to each of the five parameters, the model provides a balanced physical representation of the watershed's susceptibility without over-relying on weighted assumptions that may vary by season.

- **Classification and Risk Categorization**

The final flood susceptibility index was categorized into three risk levels (No, Low, and High) using the Natural Breaks (Jenks) classification method. This statistical approach was chosen because it identifies real classes within the data by minimizing the variance within classes and maximizing the variance between them, making it more accurate for non-uniformly distributed hydrological data than manual or equal-interval slicing.

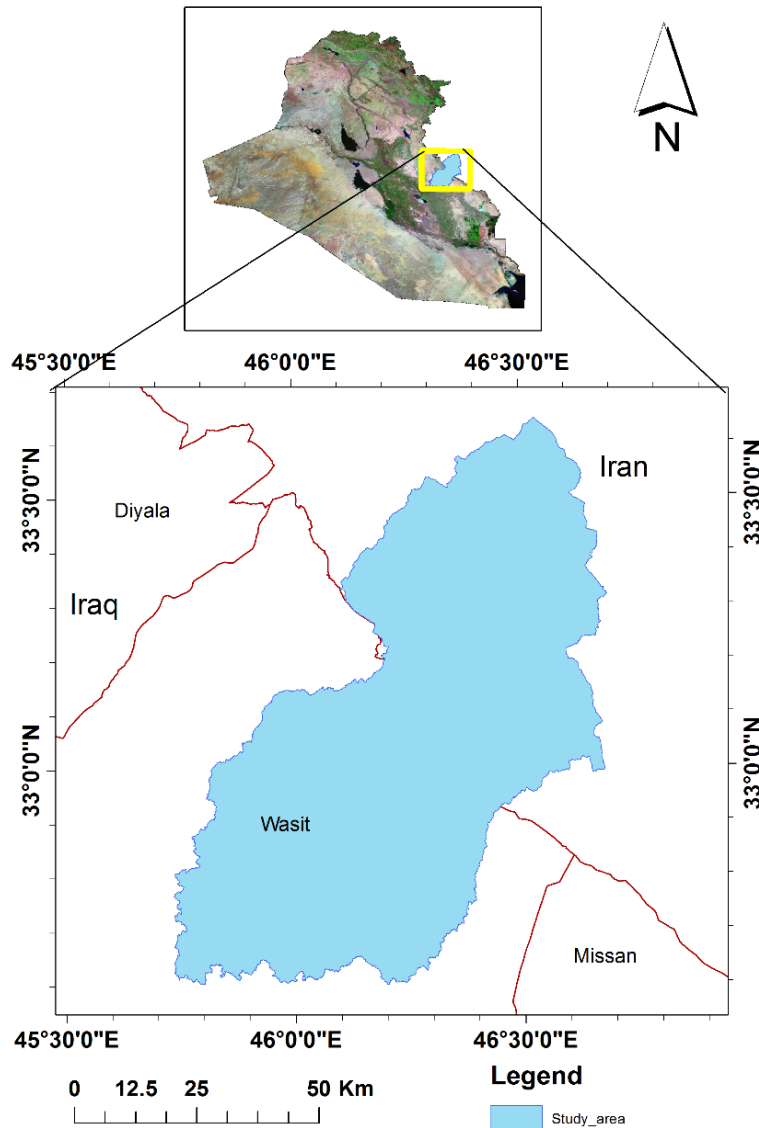


Fig. 1. Location of the study area.

2.3. Data Collection

To map flood-prone areas, it is necessary to collect and analyze data pertaining to the governing factors (Al-Hussein et al., 2023). Low-lying, low-slope, and floodplain areas experience the greatest risk of flooding. Satellite data combined with topographical information an appropriate database for this purpose. precipitation data provide information about regional rainfall and discharge (Abood et al., 2025).

The Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) for the Kalal Badrah basin was downloaded from the Earthdata Center (<https://earthdata.nasa.gov/>). A 30-m resolution SRTM DEM was downloaded to delineate the catchment boundary of the Kalal Badrah basin and extract its stream network, channel slope and other geomorphological characteristics. The basin boundary was defined in ArcGIS and selecting the flow direction to finally cure the outlet points. Delineation of the drainage network began by defining the flow-accumulation threshold to optimize the results according to the known drainage densities obtained from the topographic map (Amen et al., 2023).

Satellite-derived precipitation estimates enable regional rainfall analysis. Within the availability period of combined satellite precipitation and auxiliary data, the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) tool offers valuable

information on the spatial and temporal distribution of precipitation. Version 7 of the TMPA provides the long-term GPM IMERG precipitation dataset for assessing global flood damage. IMERG extends the TMPA product by combining observations from radar, microwave, and infrared sensors with high temporal and spatial resolution.

LANDSAT 9 is the latest satellite from the Landsat program, developed to continue the long history of Earth observation spanning over five decades. It was launched into a near-polar, sun-synchronous orbit at 705 km altitude on 27 September 2021, with an equatorial crossing time of 10:00 a.m. Landsat 9 was used in this study to drive the NDVI layer.

2.4. Remote Sensing Techniques and GIS

Remote sensing techniques provide valuable data for flood-risk mapping. To delineate flood extent in satellite images, a two-stage approach that combines thresholding with auxiliary contextual information is used (Aziz et al., 2024). In a flood-prone region, floodwaters damage standing crops and valuable properties annually. Remotely sensed imagery and geographic information systems (GIS) are widely used to measure the areal extent of flooded areas. Water resource and flood-risk management requires an accurate notion of the topographic elevation of riverbed and floodplain. Flood inundation mapping is one of the most important contemporary applications of remote sensing (Shamkhi and Al-Badry, 2021).

Various thematic layers such as slope, elevation, Normalized Difference Vegetation Index (NDVI), drainage density and precipitation were employed to delineate flood prone zones in the Kalal Badrah watershed in Iraq. Relative frequency ratio was applied to establish the relationship between each flood causative factor and the flood locations, as determined by analysis of Landsat-8 (OLI) satellite imagery, Digital Elevation Model (DEM), and precipitation. All thematic layers were retrieved as raster grid values with cell sizes of 30 m to ensure homogeneous spatial resolution. A natural breaks classification method was then applied to group the relative frequency ratios into five categories, ranging from very low to very high susceptibility. The individual flood susceptibility maps of each thematic layer were combined with equal weights within the GIS environment to generate the overall flood susceptibility map of the study area.

2.5. Criteria identification

The criteria identification process considers various factors pertinent to the generation of flood-prone area maps. Elevation is a major factor because lower altitudes tend to collect water and are more likely to flood (Rasn et al., 2021). The slope of the land affects how surface runoff flows. Areas with gentle slopes hold water better, while areas with steep slopes let it drain quickly. Drainage density, which is the total length of streams per unit area, shows how well the drainage system works and how likely it is that surface water will build up. Land use and land cover have a big effect on how quickly water can soak into the ground and how quickly it can flow off the surface. For example, urbanized or deforested areas make surfaces that don't let water through, which makes the risk of flooding worse. Moreover, proximity to channel banks and the occurrence of active channels are critical, as regions adjacent to overflowing rivers are inherently flood-prone. These factors, nominated according to prior studies (Hoque et al., 2019; Zehra & Afsar, 2016), are incorporated into the model to accurately delineate flood-prone zones in the Kalal Badrah basin.

2.5.1 Elevation

Digital Elevation Model (DEM) is a critical component in hydrologic, hydraulic modeling, and remote sensing applications, providing elevation data in a raster format (Ahmed et al., 2023). A raster layer comprises a grid of cells, each representing a particular spatial unit on the Earth's surface. Models simulate water movement within the raster domain, where flow direction for each cell depends on adjacent cells' elevation (Shamkhi and Abdul-Sahib, 2020). The 3D nature of a DEM differs significantly from a 3D vector dataset, as it depicts surface elevation without point or node connectivity, making direct measurements of slope, aspect, or flow direction impossible (Sufiyan et al., 2018).

2.5.2. Precipitation

In this study, annual time average map for the last ten years from 2014 to 2024 from GPM dataset was used. The GPM data indicates variability in annual and monthly precipitation.

2.5.3 Drainage Density

Drainage density, defined as the total length of per unit area within a basin, governs the response of a drainage basin to runoff and is affected by several meteorological and physiographic factors. Major and minor streams were extracted using the stream order tool in ArcGIS software. The minor and major catchment boundaries of the Kalal Badrah Basin were delineated using ArcGIS 10.3 software and base maps.

2.5.4 Slope

Slope is an important topographic factor that affects the speed of overland flow, how much erosion it can cause, and how well soil can hold water. Steeper slopes usually mean that water runs off the surface faster and erodes the soil more, which makes flooding more likely (Mzuri et al., 2024). To assess the influence of slope on flood risk in the Kalal Badrah Basin, a high-resolution Digital Elevation Model (DEM) was obtained from the Shuttle Radar Topographic Mission (SRTM), featuring a spatial resolution of approximately 30 meters. The DEM makes it easier to find important morphological parameters, such as slope gradient and flow direction, that are used to figure out how likely a flood is to happen. Slope is computed using SRTM DEM data using ArcGIS, surface function in the spatial analyst tools.

2.5.5 Landcover (NDVI)

Normalized Difference Vegetation Index (NDVI) analyses are widely employed in floodplain mapping and hazard assessment (Gumma et al., 2019). The index capitalizes on the spectral difference in red and near infra-red bands for monitoring vegetation health, and consequently surface water. In actively flooded environments, healthy vegetation often cannot be sustained over long durations, so NDVI serves as a valuable proxy indicator of floodplain extent. In substantially de-vegetated flood plains (e.g., around many semiarid rivers) an NDVI approach is precluded. In this study, NDVI was derived using ArcGIS 10 based on Landsat 9 image.

3. Results and Discussion

Flood mapping helps to identify risk areas and is therefore regularly applied in flood management surveys. Five main factors influence flood: drainage density, elevation, slope, NDVI, and precipitation as shown in Figure 2. Flood susceptibility mapping is essential for future flood management. The resultant flood hazard map delineates three zones: high, low, and no flood risk, as shown in Figure 3. Approximately 20% of the area is classified as highly flood-prone, with elevated risk concentrated in mid, southern, and western sectors characterized by gentle slopes, flat curvature, low elevation, high topographic wetness, and dense drainage networks. Flood hazard assessment constitutes a vital component of disaster risk management. Utilizing various remote sensing and GIS techniques for susceptibility mapping aids in pinpointing vulnerable areas. Combining these methods improves the assessment of flood risk and makes and planning mitigation efforts more effective.

The fact that 20% of the basin is a high-risk area, especially in the southern and western parts, shows how important it is to build specific hydraulic structures right away. This geospatial method gets around the problems with sparse ground-based monitoring in the Wasit Governorate. As a result, the maps that were made give local governments a scientific basis for using "non-structural" flood management strategies like zoning land use and giving priority to early warning systems. The latest flood susceptibility map clearly shows that the Kalal Badra basin is characterized by significant spatial diversity. High-risk areas constitute approximately 20% of the total basin area, with the majority of this area concentrated in the western and southern parts. This is due to the low elevation and gentle slope (less than 2%) in these areas, which facilitate water

stagnation during periods of heavy rainfall as recorded by the GPM. In contrast, the No flood risk area covers 27% of the basin area, mainly concentrated in the elevated eastern border. This is because the topography enhances the steepness of the slope and promotes rapid surface runoff rather than water accumulation.

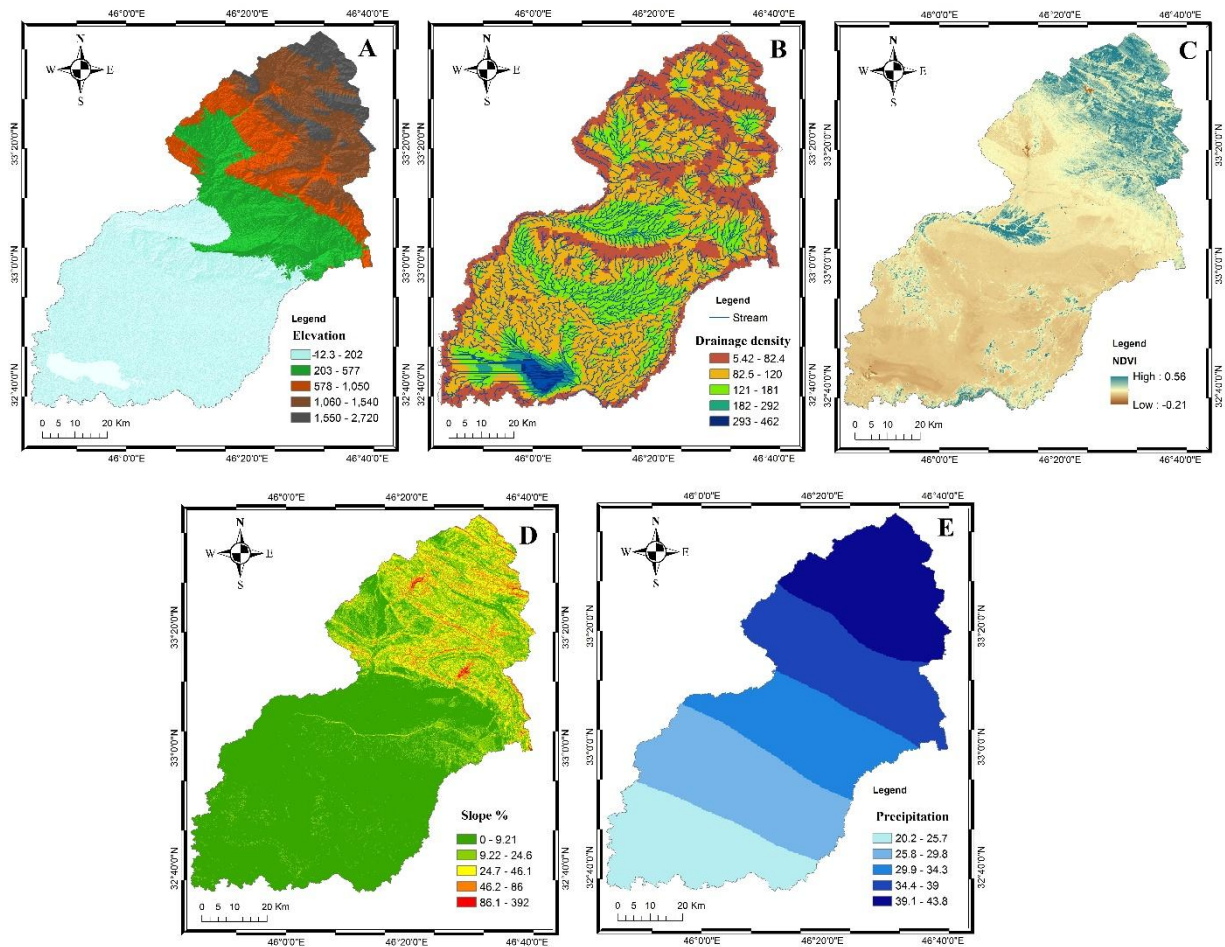


Fig. 2. The criteria used in this study. A) Elevation, B) Drainage Density, C) NDVI, D) Slope, E) Precipitation.

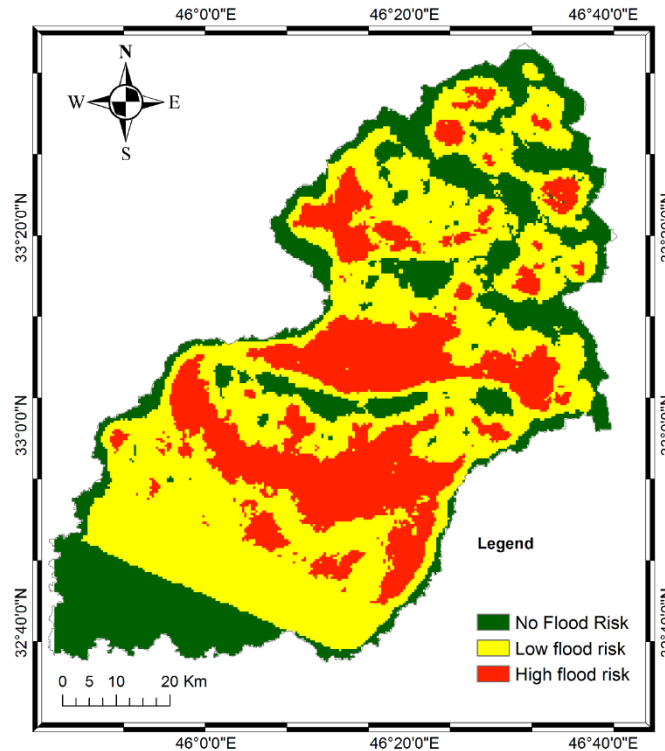


Fig. 3. The Final flood prone areas map.

4. Conclusion

Flood hazard maps help find places that are at risk and help plan ways to reduce that risk. Identifying areas that are likely to flood lets you figure out which ones need protection or special land-use rules, even if you don't have complete flood-frequency data. This study successfully achieved its objective of delineating flood susceptibility zones in the Kalal Badrah Basin using an integrated RS and GIS framework. The research contributes to the regional hydrological literature by providing the first high-resolution (30m) risk map for this basin using Landsat 9 and GPM IMERG data. This context offers a cost-effective tool for disaster managing in data-scarce transboundary areas, enabling authorities to prioritize infrastructure protection in identified high-risk flood area. A flood hazard map of the Kalal Badrah Basin was generated by integrating GIS and remote sensing techniques with a recognized geomorphologic-depression data. Five criteria were used such as slope, elevation, Normalized Difference Vegetation Index (NDVI), drainage density and precipitation to delineate flood prone zones in the study area. The final map classified the study area according to inherent flood hazard level namely; no flood, low, and high flood risk. Approximately 20% of the area is classified as highly flood-prone, with elevated risk concentrated in mid, southern, and western sectors characterized by gentle slopes, flat curvature, low elevation, high topographic wetness, and dense drainage networks. Determining flood risk levels can minimize the economic impact of a flood event. All flood-prone areas have a high risk of flooding, but the actual risk of damage in such an area depends on economic, social, environmental, and physical factors.

References

- A Jawad, L., & W Abdul Wadud, H. (2019). The Al-Abiadh Valley Drainage Basin Environmental Aspects Extraction Using Quantitatively Morphometric Analyses of Shuttle Radar Topographic Mission Data. *Baghdad Science Journal*, 16(1), 13. <https://doi.org/10.21123/bsj.2019.16.1.0097>.
- 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*, 1-11. <https://doi.org/10.1007/s42108-025-00351-1>

- Abood, R. H., Hameed, I. A., & Alrikabi, A. S. (2025, September). Mapping flood vulnerability in Wasit province, Iraq, using enhanced AHP-GIS techniques. In IOP Conference Series: Earth and Environmental Science (Vol. 1543, No. 1, p. 012002). IOP Publishing.
- 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(1), 11919. <https://doi.org/10.1038/s41598-023-39290-4>.
- Al-Hussein, A. A., Hamed, Y., Rezaq, S. R., & Bouri, S. (2023). Application of analytical hierarchy process and frequency ratio model for predictive flood susceptibility mapping using GIS for the Khazir river basin, northern Iraq. *The Iraqi Geological Journal*, 118-138.
- 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.
- 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.
- Al-Saady, Y. I., Al-Suhail, Q. A., Al-Tawash, B. S., & Othman, A. A. (2016). Drainage network extraction and morphometric analysis using remote sensing and GIS mapping techniques (Lesser Zab River Basin, Iraq and Iran). *Environmental Earth Sciences*, 75(18), 1243.
- Al-Zubaidi, S. A., & Abed, B. S. (2024). Studying and assessing surface water use of Shuwaija Marsh within Wasit Governorate-Iraq. *Journal of Engineering*, 30(03), 159-176. <https://doi.org/10.31026/j.eng.2024.03.11>.
- Angelakis, A. N., Capodaglio, A. G., Valipour, M., Krasilnikoff, J., Ahmed, A. T., Mandi, L., Tzanakakis, V. A., Baba, A., Kumar, R., Zheng, X., Min, Z., Han, M., Turay, B., Bilgiç, E., & Dercas, N. (2023). Evolution of Floods: From Ancient Times to the Present Times (ca 7600 BC to the Present) and the Future. *Land*, 12(6), 1211. <https://doi.org/10.3390/land12061211>
- Aziz, N. A., Alwan, I. A., & Agbasi, O. E. (2024). Integrating remote sensing and GIS techniques for effective watershed management: a case study of Wadi Al-Naft Basins in Diyala Governorate, Iraq, using ALOS PALSAR digital elevation model. *Applied Geomatics*, 16(1), 67-76. <https://doi.org/10.1007/s12518-023-00540-9>.
- Copăcean, L., Man, E. T., Cojocariu, L. L., Popescu, C. A., Vilceanu, C. B., Beilicci, R., ... & Herban, S. (2025). GIS-Based Flood Assessment Using Hydraulic Modeling and Open Source Data: An Example of Application. *Applied Sciences (2076-3417)*, 15(5). <https://doi.org/10.3390/app15052520>.
- Ejenma, E., Amangabara, G. T., Chikwendu, L., & Duru, P. N. (2014). Analysis of Patterns of Encroachment on Flood Vulnerable Areas by Settlements around River Kaduna, Kaduna South LGA, Nigeria. *risk management*, 4(13). [Online]. Available: <https://www.iiste.org/Journals/index.php/JEES/article/view/14223>
- Fatah, K. K., & Mustafa, Y. T. (2022). Flood susceptibility mapping using an analytic hierarchy process model based on remote sensing and GIS approaches in Akre District, Kurdistan Region, Iraq. *The Iraqi Geological Journal*, 123-151.
- Gumma, M. K., Thenkabail, P. S., Teluguntla, P., & Whitbread, A. M. (2019). Indo-Ganges river basin land use/land cover (LULC) and irrigated area mapping. <https://doi.org/10.1016/b978-0-12-812782-7.00010-2>.
- Gunathilaka, M. D. K. L., & Fernando, S. L. J. (2022). Accuracy Assessment of Unsupervised Land Use and Land Cover Classification Using Remote Sensing and Geographical Information Systems. *International Journal of Environment, Engineering and Education*, 4(3), 76–82. <https://doi.org/10.55151/ijeedu.v4i3.73>
- Harshana, W. T. S., & Gunathilaka, M. D. K. L. (2023). The Implementation of the Mangrove Quality Index: A Way to Overcome Overestimation and Classification Concerns in

- Detecting Mangrove Forest Cover. *International Journal of Environment, Engineering and Education*, 5(1), 1–8. <https://doi.org/10.55151/ijeedu.v5i1.85>
- Hoque, M. A. A., Tasfia, S., Ahmed, N., & Pradhan, B. (2019). Assessing spatial flood vulnerability at Kalapara Upazila in Bangladesh using an analytic hierarchy process. *Sensors*, 19(6), 1302. <https://doi.org/10.3390/s19061302>
- Hussein, O. D., & Alwehab, A. (2024). Environmental Monitoring of Changes in the Flooded Areas of the Marshes and Their Relationship to Water Quality Using GIS Techniques. *Iraqi Journal of Science*, 4112-4123. <https://doi.org/10.24996/ij.s.2024.65.7.44>
- Jawad, L. A. (2024). Horan Valley Environmental Monitoring Based on its Digital Elevation Model to the 2023 Year. *Iraqi Journal of Science*, 7325-7334. <https://doi.org/10.24996/ij.s.2024.65.12.42>
- Li, X., Cui, P., Shen, P., & Zhang, X. (2026). Unraveling scale-dependent flood responses to changing climate extremes over the Tibetan Plateau. *Communications Earth & Environment*, 7(1). <https://doi.org/10.1038/s43247-026-03413-2>
- Liu, J., Feng, S., Gu, X., Zhang, Y., Beck, H. E., Zhang, J., & Yan, S. (2022). Global changes in floods and their drivers. *Journal of Hydrology*, 614(128553), 128553. <https://doi.org/10.1016/j.jhydrol.2022.128553>
- M Amen, A. R., Mustafa, A., Kareem, D. A., Hameed, H. M., Mirza, A. A., Szydłowski, M., & M. Saleem, B. K. (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.
- Merz, B., Blöschl, G., Vorogushyn, S., Dottori, F., Aerts, J. C. J. H., Bates, P., Bertola, M., Kemter, M., Kreibich, H., Lall, U., & Macdonald, E. (2021). Causes, impacts and patterns of disastrous river floods. *Nature Reviews. Earth & Environment*, 2(9), 592–609. <https://doi.org/10.1038/s43017-021-00195-3>
- Mohammed, M. J., & Jawad, L. A. (2024). The Morphometric and Hydrological Analysis of the Largest Valley Basin in the Western Plateau of Iraq. *Iraqi Journal of Science*. <https://doi.org/10.24996/ij.s.2024.65.10.43>
- Mzuri, R. T., Fatah, K. K., & Mustafa, Y. T. (2024). Identification of Flood-Prone Areas Using Geo-informatics: A Case Study of Erbil City, Kurdistan Region, Iraq. *The Iraqi Geological Journal*, 277-295. <https://doi.org/10.46717/igj.57.2c.19ms-2024-9-27>
- Rasn, K. H., Nsaif, Q. A., Al-Obaidi, M. A., & John, Y. M. (2021). Designation of flood risk zones using the geographic information system technique and remote sensing data in wasit, Iraq. *Geomatics and Environmental Engineering*, 15(3). <https://doi.org/10.7494/geom.2021.15.3.129>
- Rastogi, A. K., Thakur, P. K., Rao, G. S., Aggarwal, S. P., Dadhwal, V. K., & Chauhan, P. (2018). Integrated flood study of Bagmati river basin with hydro processing, flood inundation mapping & 1-D hydrodynamic modeling using remote sensing and GIS. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 4, 165-172. <https://doi.org/10.5194/isprs-annals-iv-5-165-2018>
- Shaban, A. H. (2023). Flood Scenario of Tigris River in Baghdad City. *Iraqi Journal of Science*, 3717-3724. <https://doi.org/10.24996/ij.s.2023.64.7.46>
- Shamkhi, M. S., & Al-Badry, H. J. (2021). Assessment of groundwater recharge potential depending on morphologic analysis in East of Wasit, Southeastern Iraq. *The Iraqi Geological Journal*, 138-154. <https://doi.org/10.46717/igj.54.2d.11ms-2021-10-30>
- Shamkhi, M. S., Azeez, J. M. R., & Abdul-Sahib, A. A. (2020). Morphologic and engineering characteristics of watersheds (a case study: East wasit watersheds that feed the al-Shewicha Trough-Iraq). In *IOP Conference Series: Materials Science and Engineering* (Vol. 870, No. 1, p. 012115). IOP Publishing.. <https://doi.org/10.1088/1757-899x/870/1/012115>
- 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>
- Tahir, H., Din, A. H. M., & Hussein, T. S. (2026). Future Coastal Inundation Risk Map for Iraq by the Application of GIS and Remote Sensing. *Earth*, 7(1), 8.

- Thakur, M. S., Maity, R., & Singh, V. P. (2023). Comparative assessment of machine learning and GIS-based multi-criteria decision-making for flood susceptibility mapping in data-sparse regions. *Journal of Hydrology: Regional Studies*, 47, 101389. <https://doi.org/10.1016/j.ejrh.2023.101389>
- Tiwari, V., Kumar, V., Matin, M. A., Thapa, A., Ellenburg, W. L., Gupta, N., & Thapa, S. (2020). Flood inundation mapping-Kerala 2018; Harnessing the power of SAR, automatic threshold detection method and Google Earth Engine. *Plos one*, 15(8), e0237324. <https://doi.org/10.1371/journal.pone.0237324>
- Ucheje, O. O. ., & Balafama, I.-W. (2025). The Impact of Environmental Hazards on the Academic Performance of Public Secondary School Students. *International Journal of Environment, Engineering and Education*, 7(1), 13–24. <https://doi.org/10.55151/ijeedu.v7i1.177>
- Umali, L. A. R., Recto, I. C., Lansangan, R. S., Torres, L. D. G., & Basilio, E. R. (2023). Modified Tricycles as Public Transport during Tidal Flooding Events: The Case of Tikling in Hagonoy, Bulacan, Philippines. *International Journal of Environment, Engineering and Education*, 5(2), 45–55. <https://doi.org/10.55151/ijeedu.v5i2.102>
- Ullah, K., & Zhang, J. (2020). GIS-based flood hazard mapping using relative frequency ratio method: A case study of Panjkora River Basin, eastern Hindu Kush, Pakistan. *Plos one*, 15(3), e0229153. <https://doi.org/10.1371/journal.pone.0229153>.
- Wadeea, K., & Jaber, H. S. (2021, June). Assessment of flood hazard areas and its management using remote sensing and GIS techniques: a case study of Tigris River-Salah Al-Din Governorate, Iraq. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1105, No. 1, p. 012104). IOP Publishing.
- Yang, H., & Cao, J. (2021). Analysis of basin morphologic characteristics and their influence on the water yield of mountain watersheds upstream of the xiongan new area, north China. *Water*, 13(20), 2903. <https://doi.org/10.3390/w13202903>
- Yousef, O. A. R., & Jaber, H. S. (2023). Studying the Environmental Changes Using Remote Sensing and GIS. *Iraqi Journal of Science*, 3705-3716. <https://doi.org/10.24996/ijs.2023.64.7.45>
- Zehra, S., & Afsar, S. (2016). Flood hazard mapping of lower indus basin using multi-criteria analysis. *Journal of Geoscience and Environment Protection*, 4(04), 54. <https://doi.org/10.4236/gep.2016.44008>.
- Zheng, Y., Yu, C., Zhou, H., & Xiao, J. (2021). Spatial variations and influencing factors of river networks in river basins of China. *International Journal of Environmental Research and Public Health*, 18(22), 11910. <https://doi.org/10.3390/ijerph182211910>