Plant Archives Vol. 26, Supplement 1, 2026 pp. 3414-3423 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.457

REVIEW OF FLOOD INUNDATION MAPPING AND FLOOD-PRONE ZONE ASSESSMENT USING DEM AND RAINFALL DATA: A CASE STUDY APPROACH FROM BANDA DISTRICT, BUNDELKHAND REGION OF INDIA

Krishnanand Yadav[1], Raghvendra Kumar Kushwaha[1*], Deo Kumar[1], Arpit Yadav[2], Anurag Mishra[1], Neha Yadav[1] and Bhoomika Gupta[3]

[1]Department of Soil Science & Agricultural Chemistry, Banda University of Agriculture and Technology, Banda, U.P.- 210001, India.

[2]Department of Agronomy, Banda University of Agriculture and Technology, Banda, U.P.- 210001, India.

[3]Department of Soil Science, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250 110, UP., India.

*Corresponding author E-mail: rkk182000@gmail.com

(Date of Receiving : 04-11-2025; Date of Acceptance : 17-01-2026)

ABSTRACT

Flooding is one of the most frequent and destructive natural disasters, especially in regions like Banda district of the Bundelkhand region, where unplanned land use, irregular rainfall patterns, and inadequate drainage infrastructure increase vulnerability. The aim of this study is to review and analyze flood inundation mapping techniques and assess flood-prone zones using Digital Elevation Models (DEM) and rainfall data, specifically within the Banda district context. The methodology involves the integration of GIS and remote sensing techniques to evaluate topographical and hydrological parameters. Shuttle Radar Topography Mission (SRTM) DEM data is utilized to assess terrain features and drainage networks, while rainfall data sourced from the Indian Meteorological Department (IMD) is used to identify high-intensity rainfall events that could trigger flooding. The combination of these datasets supports hydrological modelling and spatial analysis for accurate flood-prone zone delineation. This approach is important for disaster risk management in data-scarce and ecologically sensitive regions like Bundelkhand. The results indicate that flood vulnerability in Banda is highest along low-lying riverbanks and poorly drained zones, particularly during peak monsoon periods. DEM-based modelling proves effective in simulating inundation extents and identifying hazard-prone zones. In conclusion, the review highlights that the integration of DEM and rainfall data is a reliable, low-cost, and scalable approach for flood risk assessment. The findings can assist local authorities, planners, and disaster management agencies in implementing early warning systems, infrastructure planning, and long-term flood mitigation strategies in vulnerable regions.

Keywords **:** Flood-Prone Zone, QGIS, NDVI, Satellite Data, Banda District.

Introduction

The project "Mapping Flood-Prone Zones using DEM Analysis and Rainfall Thresholds" aims to identify and mark areas that are especially susceptible to flooding and water inundation by analyzing historical rainfall patterns and topographic elevation data. Advanced Geographic Information System (GIS) techniques and remote sensing tools are used to analyze spatial and temporal environmental data, thereby achieving this aim. The main aim of the project is to analyze Digital Elevation Models (DEMs) to understand the drainage patterns, flow accumulation, and topographical characteristics of the selected study area. Hydrological investigation pinpoints natural depressions and low-lying areas that are more prone to the accumulation of floodwater. By examining historical rainfall data, one can determine the intensity, frequency, and spatial distribution of extreme precipitation events that often lead to flooding. Flooding is one of the most common, immediate, serious, recurrent, and damaging natural disasters. They pose a grave threat to the economy in various regions worldwide, as well as to human life and the environment Sunu *et al.* (2024). Floods, which rank among the most devastating natural disasters globally, adversely affect ecological and socioeconomic systems. They affect the ecological distribution of provisional and regulatory services (Manyika & Kambeu, 2024). By integrating these variables, the study generates a flood susceptibility model that pinpoints regions where high rainfall and topographical risk coincide. This comprehensive approach offers a scientific basis for improving the accuracy of flood-prone region predictions. The end aim is to produce a flood inundation map that can be used by policymakers, urban planners, and disaster management authorities for emergency planning, infrastructure development, risk assessment, and sustainable land use planning. The initiative bolsters community resilience by enhancing preparedness and response to flooding through data-informed decisions and early warning systems.

Material and Method

Study Area

Fig. 1: Area of Interest (AOI) in Banda District, Uttar Pradesh This map illustrates the area of interest (AOI) for the Banda district, as extracted and displayed through QGIS. To conduct a spatial analysis of flood-prone areas, the district border is overlaid on base layers. To carry out flood inundation mapping, terrain analysis, and hazard assessment, DEM and rainfall data will be clipped to this AOI. This limited focus enables a precise investigation of the effects of changes in elevation and hydrological behavior on flood susceptibility. To ensure dependable and uniform outcomes, the map guarantees that all subsequent geospatial studies are confined to the administrative boundaries of the district. Floods are devastating natural disasters that pose a significant threat to ecosystems and human lives worldwide. During the monsoon season, floods frequently occur in Indian districts (Saha & Agrawal, 2020).

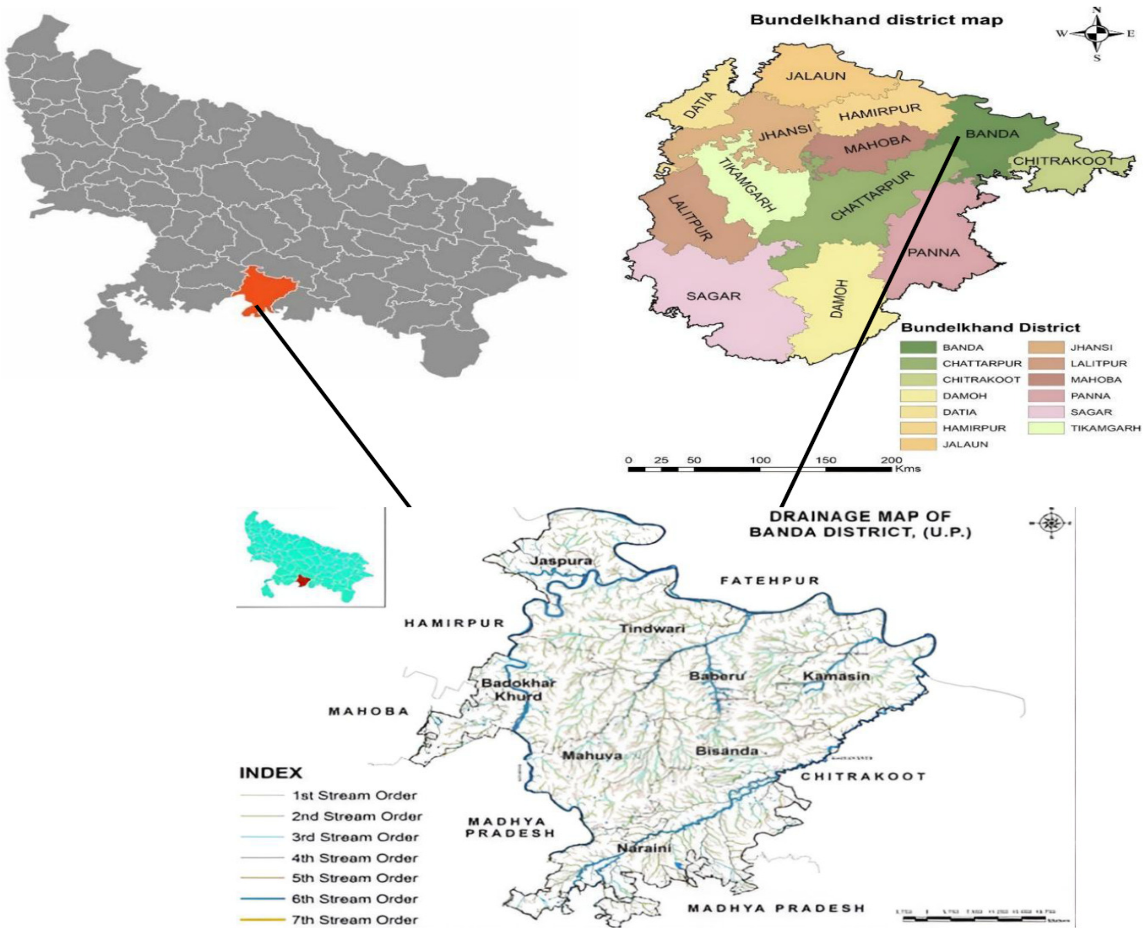

Fig. 1 : Insert a map QGIS / GEE screenshot showing the Area of Interest.
Source (VectorStock, 2025; Bundelkhand Index, 2025; Central Ground Water Board).

Area : Banda District, Bundelkhand region, Uttar Pradesh, India.

Location and Overview:

The Bundelkhand Region, a semi-arid plateau in central India, comprises six districts in Madhya Pradesh (M.P.) Datia, Tikamgarh, Chhatarpur, Panna, Damoh, and Sagar as well as seven districts in Uttar Pradesh (U.P.) Jhansi, Jalaun, Lalitpur, Mahoba, Hamirpur, Banda, and Chitrakoot Jain *et al.* (2021). Despite being tropical, Uttar Pradesh's climate varies due to variations in altitude Shakeel & Shazli (2021). The Banda district, situated in the semi-arid Bundelkhand region of southern Uttar Pradesh, has increasingly become vulnerable to flood-related risks in recent years. Although Bundelkhand is mainly known for its persistent drought, certain districts like Banda are also at risk of water shortages and occasional floods, particularly in the rainy season. The physiographic, hydrological, and climatic characteristics of Banda contribute to its increasing flood risk profile and justify the selection of the area as a key site for flood inundation mapping.

Geographical and Hydrological Context

The Bundelkhand region, covering an area of 71,619 km², is situated between latitudes 23°08′ N and 26°30′ N and longitudes 78°11′ E and 81°30′ E Thomas *et al.* (2015). Banda is situated at coordinates 25.29° N latitude and 80.20° longitude, covering a total area of 4,413 km². According to the 2011 census, the population of Banda District was 19,79,541. Banda consists of four Tehsils: Nairani, Baberu, Attara, and Pailani, along with eight blocks (Dwived 2017). The Baghein River flows through the district in a south-west to north-east direction. Significant rivers include the Ken River in the east and the Yamuna to the north (District Banda) (Government of Uttar Pradesh 2025). The hydrological dynamics of Banda district are significantly influenced by the Ken River and its tributaries, including the Bagian, Ranj, and Birma rivers. Throughout the region, there are alluvial plains and rough terrain, while slopes facilitate considerable surface runoff in times of heavy rain. Additionally, the area is intersected by a number of small seasonal streams called nalas. These streams often flood during monsoon periods, resulting in localized inundations.

Climatic and Rainfall Characteristics

The climate of Banda is characterized as semi-arid to sub-humid, with monsoon rainfall that varies greatly. The district receives an average of 850 to 950 mm of rain annually, most of which occurs from June to September. Annual mean precipitation fluctuates between 514 and 1260 mm. The climate is typical of subtropical regions, marked by long and intense summers. The south-west monsoon accounts for roughly 80% of the annual precipitation. In August, the relative humidity peaks at around 85%, while it reaches its lowest point in April (Government of Uttar Pradesh 2025). The pattern of rainfall is unpredictable and inconsistent, exhibiting extreme variability. Banda district has recorded a maximum temperature of 47 ℃ and both Banda and Chhatarpur districts have recorded a minimum temperature of 6 ℃ Yadav *et al.* (2025). The pattern of rainfall is increasingly unpredictable, characterized by short but intense precipitation events. These convective storms, resulting from monsoonal instability, heighten the risk of flooding, especially in areas that are low-lying and lack proper drainage.

Justification for Selection

The Banda district exemplifies the effective use of remote sensing and GIS for flood risk assessment. Due to its combination of natural flood causes (like river overflow and heavy rainfall) and human-induced vulnerabilities (such as land use changes and inadequate infrastructure), it serves as a valuable study location for the application of digital elevation models (DEMs) and satellite-derived rainfall data. Moreover, the availability of open-access datasets such as SRTM DEM, CHIRPS rainfall, and Sentinel-1 SAR images enables thorough mapping and validation of flood inundation. Due to these traits, the Banda district is considered a high-priority region for the planning of mitigation strategies, flood hazard analyses, and the establishment of data-driven early warning systems.

Drainage and Morph metric Features

The district features a well-developed drainage system network. The perennial and primary drainage systems in the district are the River Yamuna and Kenand Baghain. The Ken and Baghain rivers are components of the Yamuna River system. Other streams observed in the district include Banganga, Karauli, Garhara, Turi, and Madron Nadi, as illustrated in fig. 1. The majority of the streams are classified as second or third order. Throughout the whole district, only a small number of streams are classified as first-order or fourth-order. In the northern part of the district, the River Yamuna splits Banda from Fatehpur. Throughout the district, the River Yamuna moves in an eastward direction from the west. At Chilla, the River Ken converges with the River Yamuna. In the southeast, the River Baghain splits Banda from Chitrakoot (Central Ground Water Board).

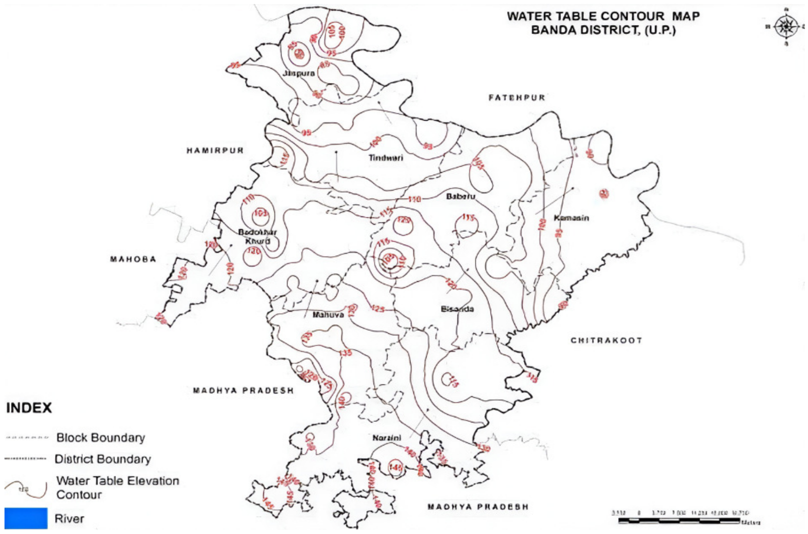

Fig. 2 : Water Table Elevation-Banda District.
Source : Central Ground Water Board.

The map (Fig. 2) depicts the contours of groundwater table elevation throughout Banda district. It shows the levels of the water table with contour intervals (measured in meters above mean sea level), demonstrating spatial differences in groundwater depth. Major blocks like Naraini, Badokhar Khurd, and Tindwari are emphasized, along with adjacent districts and rivers. The river networks are depicted in blue, with block boundaries indicated by dashed lines and district boundaries by solid lines. The central and southern areas of the district show concentrations of higher groundwater elevations, indicating possible recharge zones.

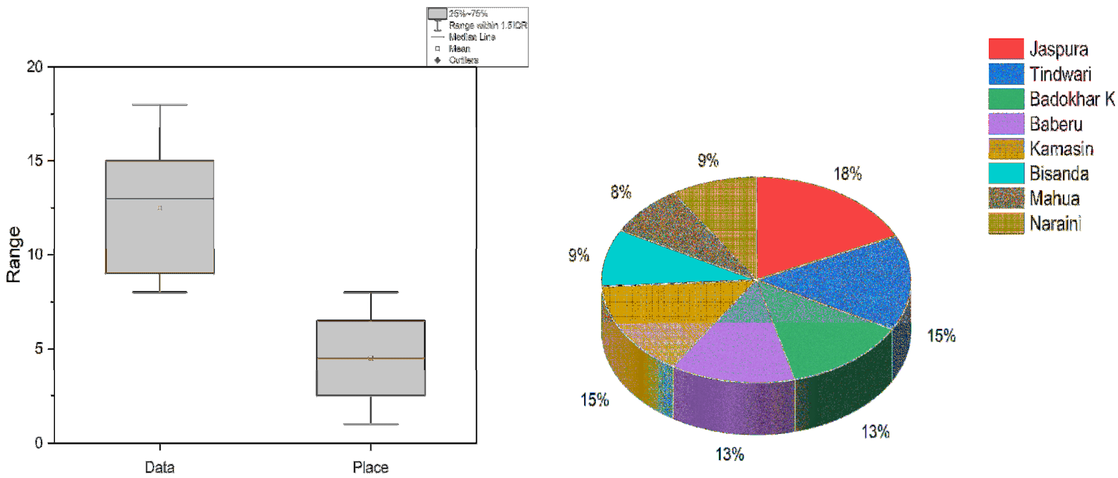

Fig. 3 : Contribution of Ground Water in Irrigation (%)
Source : Central Ground Water Board.

Data Used in Banda District, Uttar Pradesh

Satellite Used

Imagery necessary for the analysis in Banda district was supplied by the Sentinel-2 satellite, which is operated by the European Space Agency (ESA) within the framework of the Copernicus Program. Another option is Landsat-8 from NASA/USGS, but Sentinel-2 offers a higher spatial resolution of 10m, which is suitable for detailed land cover and use mapping.

Source URLs

- **Sentinel-2 Data**: https://dataspace.copernicus.eu/ (ESA Copernicus Open Access)
- **Google Earth Engine**: https://code.earthengine.google.com/
- **Landsat-8 Data (alternative)**: https://earthexplorer.usgs.gov/

Bands

- **Band 4 (Red)** – 10 m resolution
- **Band 3 (Green)** – 10 m resolution
- **Band 2 (Blue)** – 10 m resolution (Utilized for natural color composite visualizations)

Table 1 : Climatic and Topographic Features of the Banda Region

Parameter	Value / Observation	Source / Reference
Average annual rainfall (district)	~850 mm	Banda district official site; Government of Uttar Pradesh 2025
District geography / rivers	Rivers: Baghein, Ken, Yamuna; irregular uplands & lowlands subject to flooding	Banda district official geography page; Government of Uttar Pradesh 2025
Elevation / topography	Min ~78m, Max ~428m, average ~137m (for Banda region)	Banda topographic map, elevation, terrain. (topographic-map.com)
Monthly average precipitation pattern	Jan ~14 mm, Feb ~10 mm, Jun ~87 mm, Jul ~323 mm, Aug ~260 mm, Sep ~199 mm, etc. (based on 2017–2022 climatology)	Monthly climate in Banda, India; (Nomadseason 2025)
Long-term average rainfall & variability	Annual average of ~806 mm for Banda (1981–2022), with considerable year-to-year variation	Prakash *et al.,* 2024

Methodology

Flood-prone areas in the Banda district were identified using rainfall data and the Digital Elevation Model (DEM). Initially, the border of the study area was determined and trimmed using the SRTM 30m DEM. Hydrological study involving sink filling, flow direction, flow accumulation, slope, and elevation mapping was conducted to identify areas that are low-lying and prone to water accumulation. Rainfall data from sources like CHIRPS or IMD (2010–2023) was analyzed to determine extreme rainfall thresholds. Areas characterized by high flow accumulation, gentle slope, and abundant rainfall were identified through the overlaying of the DEM and rainfall layers. The regions were classified into three categories of flood risk: high, moderate, and low. Finally, the results were illustrated using GIS tools, and historical flood records were optionally utilized for validation.

Separate the methodology into QGIS-based and GEE-based.

QGIS-Based Methodology

Flood-prone zones in the Banda district are delineated through a QGIS-based methodology that involves the importation of district boundaries and the extraction of relevant statistics. After sink filling, a 30m SRTM DEM is processed to create elevation, slope, flow direction, and flow accumulation layers to ensure hydrological accuracy. Flood risk thresholds serve to assess and categorize rainfall data from CHIRPS or IMD. To identify areas at risk of flooding, these layers are combined using overlay analysis with the Multi-Criteria Evaluation or Raster Calculator. To facilitate reporting and decision-making, the finalized flood risk zones are classified into high, moderate, and low categories, and displayed using the map layout features of QGIS.

Study Area Setup

- Bring in the shapefile that outlines the boundaries of Banda district.
- Clip all datasets (DEM and rainfall layers) to the AOI.

DEM Processing

- Get the 30m SRTM DEM from USGS Earth Explorer.
- Use the following QGIS tools:
  - Fill sinks using the (r.fill.dir under Processing Toolbox > GRASS)
  - Flow Direction and Flow Accumulation (utilizing the TauDEM plugin or GRASS tools)
  - Raster > Slope and elevation layers of terrain analysis.

Rainfall Threshold Analysis

- Vector or raster data on rainfall (from IMD/CHIRPS) should be imported.
- Employ a raster calculator to determine areas where rainfall surpasses flood-triggering thresholds (e.g., >100 mm/day).
- Utilize the Raster > Reclassify tool for the reclassification of rainfall layers.

Overlay and Risk Zoning

- Utilize the Raster Calculator to superimpose layers of flow accumulation, slope, elevation, and rainfall.
- Reclassify each layer and assign weights to them.
- Collaborate to develop a map of areas susceptible to flooding through the use of Multi-Criteria Evaluation (MCE) or Weighted Overlay.

Visualization

- Develop design layers for flood zones categorized as high, moderate, or low.
- Employing the Print Layout, generate the map layout that includes the legend, scale, and title.

GEE-Based Methodology (Google Earth Engine)

The GEE-based method for identifying flood-prone regions in Banda district utilizes satellite data and cloud computing for effective analysis. It takes the Banda border as a feature collection. Elevation and slope layers are derived by clipping the SRTM DEM data to the specified region. Rainfall data from the CHIRPS dataset is filtered by date and location before analysis to identify instances of heavy rainfall that exceed flood-triggering thresholds. To determine flood-risk zones characterized by low elevation, gentle incline, and significant precipitation, these layers are combined through logical methods. The flood-prone areas resulting from the analysis are shown on the GEE map interface and can be exported for future use.

Study Area Definition

- Import or draw Banda district AOI using ee. FeatureCollection.
  var banda = ee.FeatureCollection("FAO/GAUL/2015/level2")
  .filter(ee.Filter.eq('ADM2_NAME', 'Banda'));

DEM Analysis

- Load SRTM DEM in GEE:
  var dem = ee.Image("USGS/SRTMGL1_003");
  var elevation = dem.clip(banda);
  var slope = ee.Terrain.slope(dem);

Use existing scripts or custom hydrological functions to compute flow accumulation (this requires more advanced GEE hydrology scripts; use Hydro SHEDS when needed).

Rainfall Threshold Analysis

- Get CHIRPS precipitation data:
  var rainfall = ee.ImageCollection("UCSB-CHG/CHIRPS/DAILY")
  filterBounds (banda). filter Date ('2023-06-01', '2023-09-30').sum();
- Use a threshold (for instance, >300 mm during monsoon season):
  var heavyRain = rainfall.gt (300);

Risk Mapping

- Integrate layers of elevation, slope, and precipitation:
  var lowSlope = slope.lt(5);
  var lowElev = elevation.lt(150); // Adjust elevation threshold based on terrain
  var floodRisk = lowSlope.and(lowElev). and (heavyRain);

Visualization

- Add results to map:
  Map.centerObject(banda, 9);
  Map.addLayer(floodRisk.updateMask(floodRisk), {palette: ['blue']}, 'Flood-Prone Zones');
- Export result if needed:

```
Export.image.toDrive({
  image: floodRisk,
  description: 'FloodRiskMap_Banda',
  region: banda.geometry(),
  scale: 30
    });
```

Add screenshots of key steps (clipping, NDWI/NDVI formula, raster calculator, classification, layout, etc.)

To begin with, bring the Banda district border shapefile and satellite data into QGIS. The area of interest for the research can be extracted with the help of the "Clip Raster by Mask Layer" tool. Open the Raster Calculator to compute NDVI with the formula (NIR - Red) / (NIR + Red) and NDWI with (Green - NIR) / (Green + NIR). Use a pseudocolor ramp to style the output for displaying water or vegetation. Utilize the Semi-Automatic Classification Plugin or the "Raster Reclassify" tool to perform variable reclassification for classification purposes. Finally, use the "Print Layout" tool to create your map, making sure to add a title, scale bar, and legend. After that, export the map in image format or as a PDF. This carousel of four images depicts key QGIS stages for NDVI and NDWI calculations, clipping, viewing, and preparation for classification:

- **Image 1** – Initial setup for NDVI calculation and raster bands in the QGIS interface.
- **Image 2** – Input your NDVI/NDWI formula into the Raster Calculator dialog.
- **Image 3** – NDVI/NDWI output styled with a pseudocolor ramp.
- **Image 4** – NDVI illustration depicting alterations in vegetation density.

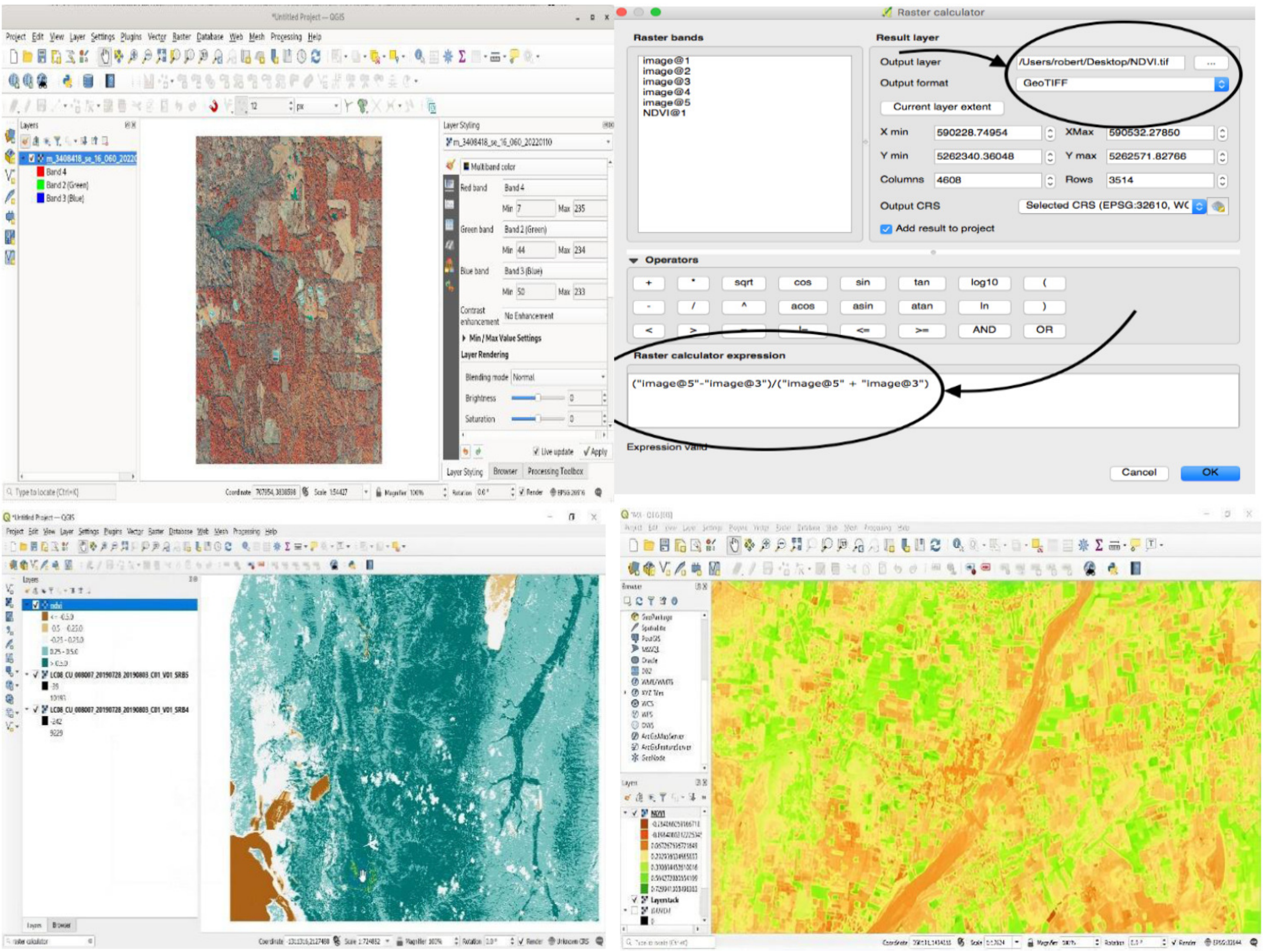

Fig. 4 : key steps in QGIS for calculating NDVI and NDWI, clipping, visualizing.
Source (North River Geographic Systems Inc.; MicaSense, 2024; MapScaping, 2024).

Walkthrough: QGIS Workflow for Banda District, Uttar Pradesh

Data Acquisition & Clipping

- Acquire multispectral satellite images with the necessary bands (Red, NIR, and optionally Green or SWIR) from Sentinel 2 or Landsat.
- Utilize your Banda border shapefile to clip the image to the Banda district by selecting Raster → Extraction → Clip Raster by Mask Layer. This will limit processing to the study area.

Raster Calculator – NDVI & NDWI

- **For NDVI**:

The NDVI (Running 1990; Myneni 1995) is calculated using the ratio of red to near-infrared reflectance: [NDVI= (NIR-RED)/ (NIR+RED), with NIR and RED representing the amounts of near-infrared and red light reflected by the vegetation as recorded by the satellite's sensor]. The formula relies on the principle that chlorophyll absorbs RED while the mesophyll leaf structure scatters NIR. NDVI values vary between -1 and +1, with negative values indicating no vegetation (Myneni 1995).

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Example, using Sentinel-2: ("B8"-"B4")/("B8"+"B4")

Visualization & Styling

After the calculation, the new layer appears in the Layers Panel. After accessing its settings, use the Single band pseudocolor renderer to apply a gradient colour ramp (for example, red/brown to green for NDVI).

Classification

Additionally, you can utilize semi-automated classification tools such as the Semi-Automatic Classification Plugin (SCP), which is ideal for categorizing land cover, or Process Toolbox → SAGA → Raster Reclassification to organize your raster into groups.

Layout & Map Export

Finally, generate your map with the help of Project New Print Layout by incorporating scale bars, titles, legends, and other elements typical of maps. Export to image files or PDF formats for inclusion in reports or presentations.

Table 2 : Geospatial Image Processing Workflow for Banda District

Step	Task	Key Action
1	Clip imagery	Use Banda district boundary
2	Compute indices	NDVI: (NIR–Red)/(NIR+Red); NDWI: (Green–NIR)/(Green+NIR)
3	Style output	Utilize single-band pseudocolor
4	Classify	Utilize raster reclassification or SCP
5	Layout & export	Design print layout and export map

Results and Discussion

Creating NDWI/NDVI Maps for Banda District

This instance shows raster maps of NDVI (above) and NDWI (below) for a certain area, which can act as a visual template for Banda District in Uttar Pradesh. The arrangement, color palette, and design, while not exclusive to Banda, can assist in guiding your presentation:

- The NDWI maps (lower panels) illustrate surface water and potential flood areas,
- NDVI maps (upper panels) depict vegetation density and health.

Two spectral indices, NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index), are used to study these significant landcover changes effectively (Ahmed & Akter, 2017), To assess the health of vegetation and identify areas at risk of flooding in Banda District, NDVI and NDWI indices were generated from remote sensing data. This research investigates the application of eight remote sensing indices for delineating flood extents, with a focus on widely used indices such as the Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI), and Normalized Difference Vegetation Index (NDVI), NDWI, which is derived from (Green – NIR) / (Green + NIR), serves to emphasize water bodies and saturated regions. In contrast, NDVI is computed as (NIR – Red) / (NIR + Red) and indicates the vitality of vegetation Bormudoi *et al.,* 2024. This investigation utilized Sentinel-2 (Band 3 for Green, Band 8 for NIR) and Landsat 8 (Band 3 for Green, Band 5 for NIR) imagery. Below is the interpretation of NDWI values: Values between 0.2 and 1 denote water surfaces, values between 0.0 and 0.2 indicate wet or flooded surfaces, values between -0.3 and 0.0 represent dry land or vegetation, and values between -1 and -0.3 correspond to arid or barren areas. The imagery was processed using QGIS and ArcGIS, while Python (with libraries such as rasterio and NumPy) or raster tools were employed to compute the indices.

Green-to-brown color ramps and blue-toned NDWI layers highlighted regions that had been flooded in the resulting NDVI maps. Threshold values were analyzed using histogram plots to accurately categorize flood extents. To aid in spatial analysis and flood risk mapping for planning and mitigation, all outputs were generated at a high quality (300 dpi) Uddin *et al.* (2019).

Classified Layers – Flood-Prone Zones in Banda District, U.P.

Flood-prone areas were identified based on elevation, slope, and rainfall thresholds derived from DEMs. Zones were divided into:

- **High Risk:** Gentle slopes at low elevation, precipitation >150 mm
- **Moderate Risk:** Medium elevation and incline, precipitation 100–150 mm
- **Low Risk:** Greater altitude or precipitation <100 mm

Areas susceptible to flooding are marked on the produced map, mainly adjacent to lowlands and riverbanks. The distribution of flood risk throughout the various zones according to severity levels High, Moderate, and Low is shown in (Fig. 5). According to the data, there is a serious concern in these areas since 970 square kilometres, or 21.9% of the entire assessed area, are at high risk of flooding. About 1,480 square kilometres, or 33.5% of the total land, are in moderate flood risk zones. The majority 1,960 square kilometres, or 44.6%—is categorised as having a low risk of flooding, indicating areas that are comparatively safer. Planning flood mitigation techniques and setting resource allocation priorities in disaster management require this information.

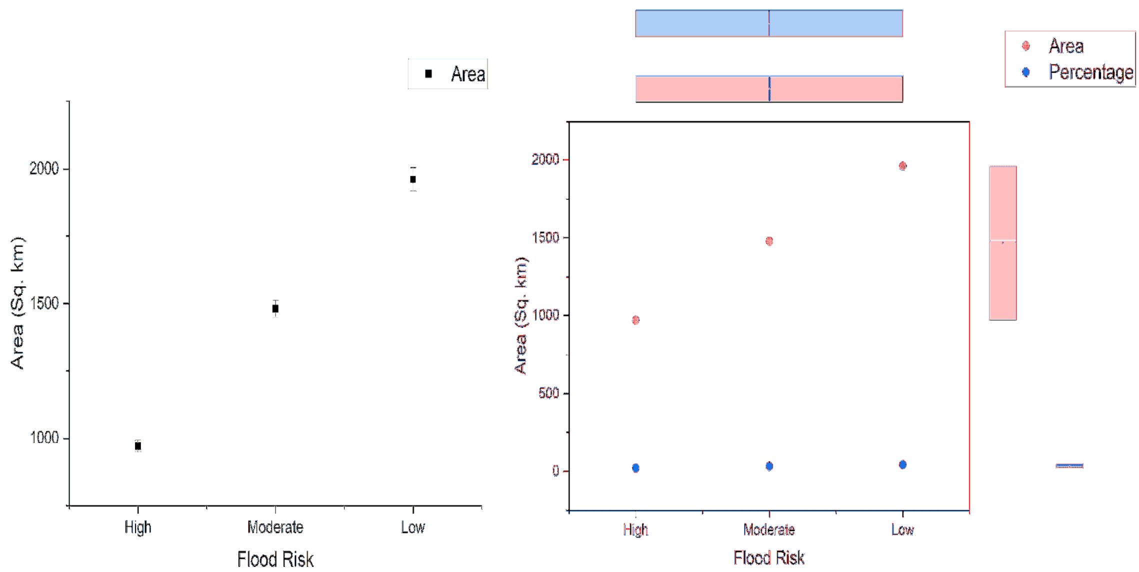

Fig. 5 This classification facilitates flood planning and management in the Banda District.

Vectorized output

To ensure precise spatial analysis, flood risk areas derived from rainfall data and DEM were converted into vector polygons. The vector layers represent areas at high, moderate, and low risk of flooding, making it easy to incorporate them with other GIS data for planning and decision-making purposes.

Area Statistics–Flood-Prone Zones in Banda District, Uttar Pradesh

Using DEM elevation, slope, and rainfall thresholds, flood-prone areas in Banda District, Uttar Pradesh were classified; these areas cover approximately 4,410 square kilometres. Zones with a significant risk of flooding, predominantly found along the banks of rivers in low-lying areas and within floodplains, constitute approximately 970 square kilometers or 21.9% of the district. About 1,480 square kilometers (33.5%) of areas classified as moderate risk are located in regions characterized by transitional elevation, moderate rainfall, and slopes. The rest of the area, covering 1,960 square kilometers (44.6%), is classified as having minimal flood risk. This land is typically situated at higher elevations and experiences lower levels of precipitation. These area data highlight the spatial distribution of flood susceptibility, providing crucial information for flood management, disaster preparedness, and land use planning in the district. Mapping and measuring flood-prone areas creates a scientific basis for resource allocation and priority-setting for flood mitigation efforts, helping to lessen the impact of flooding on infrastructure and communities.

Conclusion

By integrating DEM analysis with rainfall thresholds, areas susceptible to flooding in Banda District, Uttar Pradesh were effectively pinpointed. By combining elevation, slope, and precipitation data to generate a clear geographical representation of vulnerable areas, this method assists in flood risk evaluation and management. The high-risk zones, primarily located near riverbanks and low-lying agricultural areas, underscored the need for immediate attention to certain areas. However, the strategy has disadvantages. The accuracy of flood extent is influenced by the resolution and quality of rainfall data and DEM data; Minor terrain features may be overlooked by coarse data. Static rainfall thresholds may not account for extreme flood events and variability in rainfall over time. In addition, the absence of field validation and real-time hydrological data restricts accuracy. Possible future improvements include utilizing higher-resolution datasets, employing hydrological modeling, and integrating dynamic data on rainfall and river flow. Field research and validation through remote sensing would enhance reliability. Despite its disadvantages, this method offers a valuable framework for delineating flood risk in Banda District.

References

Ahmed, K. R., & Akter, S. (2017). Analysis of landcover change in southwest Bengal delta due to floods by NDVI, NDWI and K-means cluster with Landsat multi-spectral surface reflectance satellite data. *Remote Sensing Applications: Society and Environment*, **8**, 168–181.

Bormudoi, A. (2024). Common index-based methods of flood mapping by optical satellite sensors: A review of the merits.

Bundelkhand Index. (2025). *Bundelkhand Index*. https://x.com/Bundelkhand_idx

Central Ground Water Board. (n.d.). *Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, Government of India, Northern Region, Lucknow*. https://www.cgwb.gov.in/cgwbpnm/public/uploads/documents/1697522133630051832file.pdf

District Banda, Government of Uttar Pradesh. (2025). *Geography*. https://banda.nic.in/geography/

Dwived, A. P. (2017). Analysis of physico-chemical characteristics of soil from various locations of Banda City, Uttar Pradesh, India.

Jain, R., Chand, P., Agarwal, P., Rao, S., & Pal, S. (2021). Determination of agricultural infrastructural suitability in aspirational districts: A case study of Bundelkhand. *The Indian Journal of Agricultural Sciences*, **91**(7), 1020–1024.

Manyika, M. K. (2024). *Application of GIS techniques in flood extent mapping and management on Matebele flood plain in Shangombo district, Zambia* (Doctoral dissertation, The University of Zambia).

MapScaping. (2024). *Calculating NDVI with QGIS: A step-by-step guide; interpreting NDVI maps*. https://mapscaping.com/calculating_ndvi_with_qgis/

MicaSense. (2024). *Creating agricultural indices (NDVI, NDRE) in QGIS*. https://support.micasense.com/hc/en-us/articles/226531127-Creating-agricultural-indices-NDVI-NDRE-in-QGIS

Myneni, R. B., et al. (1995). The interpretation of spectral vegetation indexes. *IEEE Transactions on Geoscience and Remote Sensing*, **33**, 481–486.

NomadSeason. (2025). *Monthly climate in Banda: Monthly average temperatures in Banda, India*. https://nomadseason.com/climate/india/uttar-pradesh/banda.html

North River Geographic Systems Inc. (n.d.). *QGIS: Creating an NDVI image in QGIS (Software: QGIS 3.34.x)*. https://www.northrivergeographic.com/qgis-creating-an-ndvi-image-in-qgis/

Prakash, P., Mishra, P. K., & Mishra, H. (2024). Analysis of climatic variables and its implication on agriculture in the Bundelkhand region of Uttar Pradesh, India. *Journal of the Asiatic Society of Mumbai*, **98**(10), 45–61.

Running, S. W. (1990). Estimating terrestrial primary productivity by combining remote sensing and ecosystem simulation. In *Remote sensing of biosphere functioning* (pp. 65–86). Springer New York.