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Utilizing GIS and Remote Sensing for Flood Risk Analysis in the Kosi River Basin

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Abstract- This case study examines the flooding in Kosi River in Bihar. Using sential to temporal flood inundation pattern. Sential 1A,2B which used Synthetic Aperture Radar (SAR) to capture high resolution images. SAR image source from the Alaska Satellite Facility to map flood inundated areas across Kosi River basin. Pay load at satellite capture may across 13 band of spectral spanning the visible, near infrared (NIR) and short-wave infrared region (SWIR) is naming multispectral instrument (MSI). Land use land cover (LULC) identify and map feature like urban are water bodies, farmland information. LUCL study in accuracy 10 m NIR, red and green band distribution land cover type. To analyse rain, fall intensity trend using CHIRPS satellite precipitation data to analysis rainfall trends helps understand the temporal and spatial variability. Understanding the elevation and slope variation within a river basin used ALOS PALSAR Digital Elevation Mode (DEM). The DEM Data Acquisition we have find slope and elevation extraction. Slope and elevation in GIS software then we find flood risk modelling.

Keywords— Kosi River Basin, Flood Risk Analysis, Remote Sensing, GIS, SAR Imagery, Land Use Land Cover (LULC), CHIRPS Rainfall Data, Digital Elevation Model (DEM)

1. INTRODUCTION

Flooding in the river Kosi of Bihar geographically in north direction due to heavy monsoon rain in Himalayan sediment load. Course shift and flat plain overflow in month of July and September. Origination place is Nepal riverbeds siltation due to upper catchment rainfall, poor drainage, flood spains due the uncheck land used exacerbate the issue. some districts like madhepura, supaul, khagaria.

2. OBJECTIVE

Using sential-1to assess temporal flood inundation patterns for year 2015 to 2020

The Sentinel-1 mission, operated by ESA, includes two satellites sentinel-1A and 1B. which use Synthetic Aperture Radar (SAR) to capture high-resolution images regardless of weather or lighting conditions. Revisit Frequency- 10 days per satellite; 5 days combined. Radar Type: C-band (wavelength ~5.6 cm), Acquisition Modes: Strip Map, Interferometric Wide, Extra Wide, and Wave Mode, Spatial Resolution: Varies by mode-5×5 m, 5×20 m, and 20×40 m.

In this study, SAR images from July–August (2015–2020) were sourced from the Alaska Satellite Facility (ASF) to map flood-inundated areas across the Kosi River Basin sentinel contains twin earth observation satellite name as sentinel 2A and 2B orbiting in sun synchronous polar path with phase of 180 degrees apart is name as sentinei-2. Each satellite complete revolution in each 10 days. Bur combined constellation of full coverage in at equator in every 5 days at mid latitude. Payload at satellite capture image across 13 band of spectral spanning the visible, near infrared (NIR) and short-wave infrared region (SWIR) is naming a multispectral instrument (MSI).

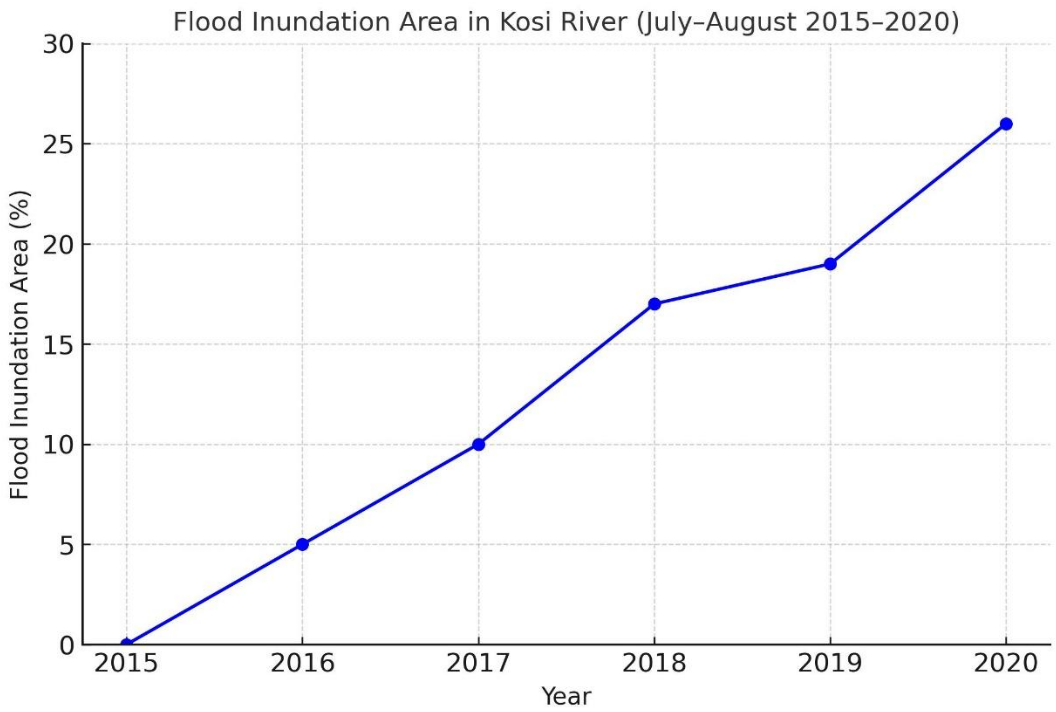

Figure 1 Flood inundation in Kosi River (July-August 2015-2020)

The detail monitoring of land cover like water bodies, vegetation, land cover and flood these band provide spatial resolution of 10m,20m and 60m. it provide detail monitoring of vegetation, land cover water bodies and flood event high resolution sentinel 2, land used land cover identify and map feature like urban area water bodies, farmland information.

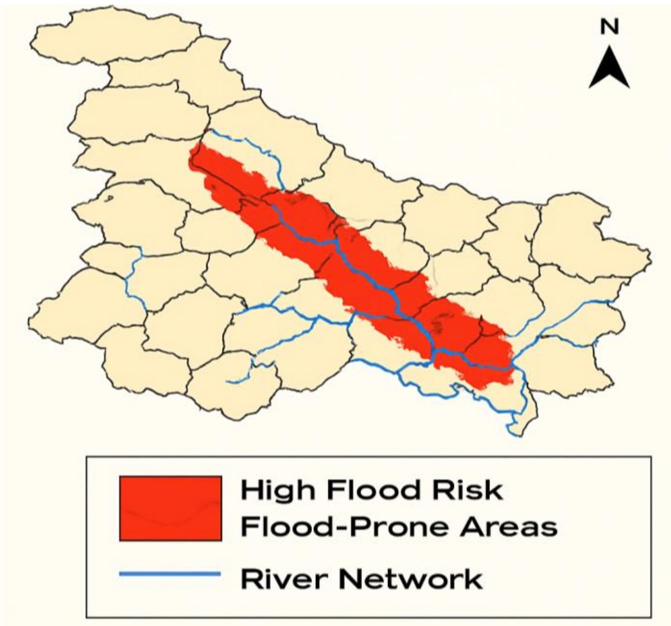

Figure 2: Flood inundation map of the Kosi River Basin showing high-risk zones with district boundaries and river system.

This information is very crucial for flood prone zone. LULC map was create in Kosi River in 2020. The LULC Study is accuracy 10 m NIR, red and green band distributing land cover type and the process involve atmospheric correlation and cloud masking. further enhance classification accuracy, land use planning and flood exposer. the reflectance of band decided water bodies, built up area, vegetated area and agricultural land.

Analysing these three bands, the project produced an accurate LULC classification essential for flood risk modelling. Red shades represent flooded zones, Underlying land cover (such as crops, settlements, forests) is mapped beneath, showing which land types were inundated. The river's course and floodplain boundaries are visible, highlighting areas most frequently submerged during July–August floods.

3. CHIRPS satellite precipitation data analysis rainfall intensity

Kosi river basin rainfall intensity is main reason of flood especially in monsoon. intense precipitation often leads widespread inundation. study of CHIRPS data base (Climate Hazards Group Infrared Precipitation with Stations) examine both temporal and spatial trends in rainfall in KRB. High resolution (0.05°) gridded precipitation series spanning from 1981 to present. Situ gauge observation based blending satellite infrared. CHIRPS offer trend detection and regional analysis with help of accurate daily rainfall data.

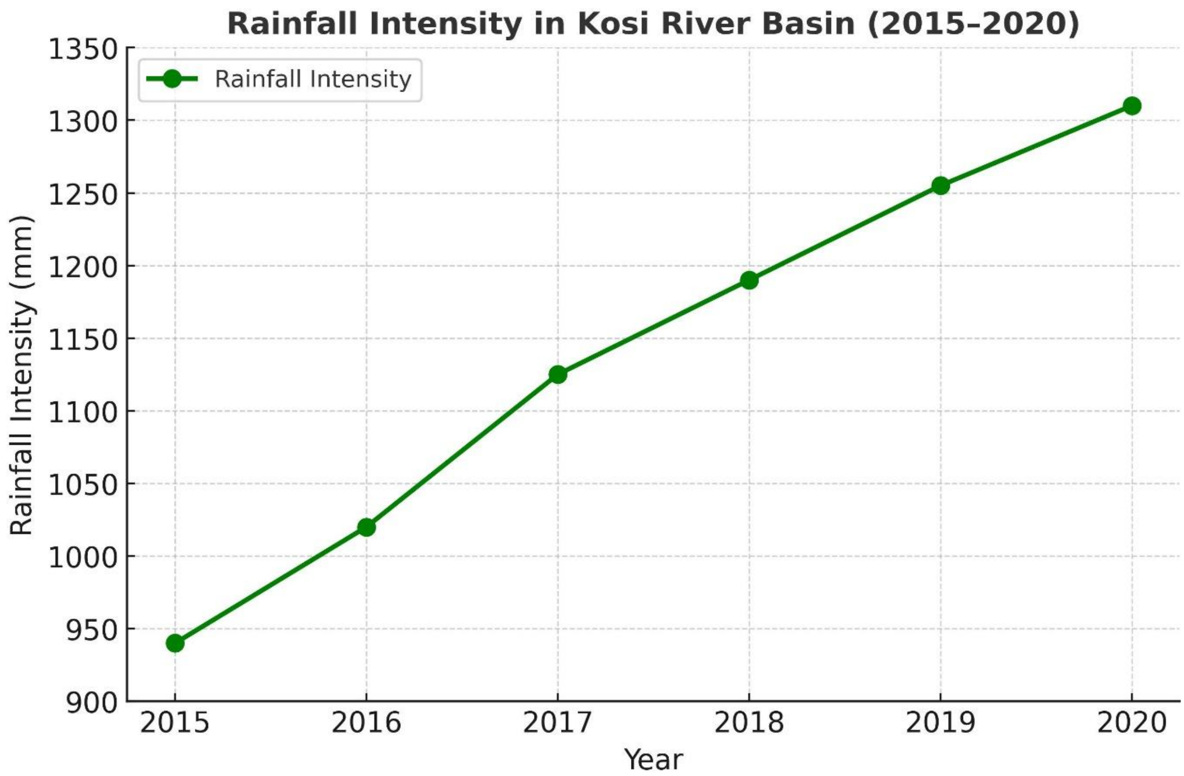

Figure 3 Flood Inundation Map of Kosi River Basin (2015–2020), showing affected districts and major flood-prone areas along the river course.

4. ALOS PALSAR DEM:

Determine the influence of topography factor including slopes and elevation. Flood behaviour is significantly depended on topography. Steeper slops encourage rapid runoff while flat and low lying appreciates water accumulation. High resolution digital elevation model (DEM) source from ALOS PALAR a radar-based system gives effective map flood prone area within the Kosi River basin. This system provide terrain data upto12.5 m of pixel size and also extracting slope metrics and elevation from the DEM. We can identify accurately zones likely to retain water during heavy rains and flooding events.

ALOS PALSAR DEM stand for Advance Land Observing Satellite-phased Array type L-band synthetic Aperture Radar Digital Elevation Model. It’s generated by Japan aerospace Exploration Agency (JAXA) and built using radar data to create high-precision terrain maps. Offer high resolution terrain data, typically 12.5m to 30 m, depending on the processing level and model. Utilizes L-band SAR which penetrates vegetation and is unaffected by cloud cover. Ideal for all-weather terrain mapping. Provides Radio metrically Terrain-Corrected (RTC) Geo TIFF data suitable for direct use in GIS workflows Low zones near the river are likely to accumulate floodwater. Elevated zones are relatively safer.

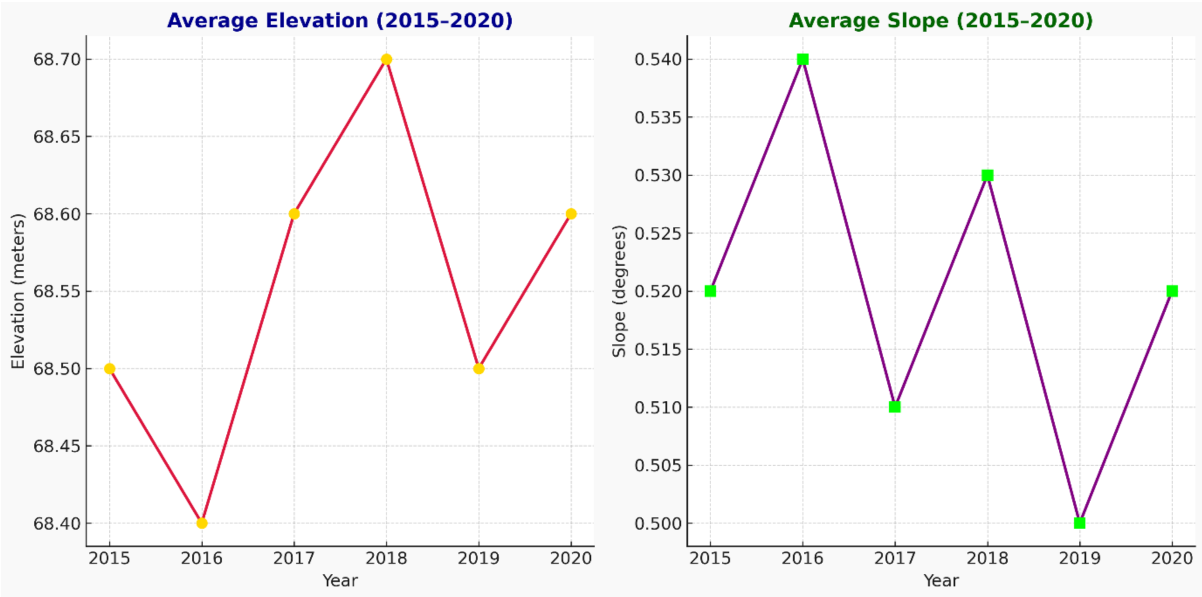

Figure 4 Topographic map showing elevation and slope variations in the Kosi River Basin, derived from Alos Palsar Dem to identify flood-prone lowland area

5. GIS Analysis:

The slope and elevation layers were created using Spatial Analyst tools in GIS software. These layers were later integrated with other flood-contributing factors (like rainfall, LULC) in flood risk modelling using Analytical Hierarchy Process (AHP)**.**

6. Drainage Network Data

Drainage networks including rivers, streams, and tributaries form natural pathways for runoff in a river basin. Proximity to these channels is a critical factor in flood risk models: areas closer to drainage lines are at higher risk of flooding, especially during intense rainfall or monsoons. We extracted the drainage network from 2020 Sentinel-2 derived LULC maps and calculated the Euclidean distance of each land parcel from the nearest drainage channel. These distance measurements were subsequently integrated into the AHP-based flood-risk model alongside other geospatial indicators to enhance the spatial precision of risk mapping and pinpoint areas of elevated vulnerability.
Measuring how close settlements or farmland are to drainage channels enhances flood exposure assessment areas within 200-500m are especially vulnerable, while risk decreases significantly beyond 1 km. This distance factor was integrated into the AHP model to boost the spatial precision of flood-risk zoning.

Analysis of drainage network data: Using Sentinel-2 imagery, we first classified land cover into water bodies, agriculture, settlements, and forest to delineate rivers and streams as the drainage network. We then created buffer zones at 0–500 m, 500–1000 m, and beyond to assess proximity to waterways, recognizing that closeness to drainage influences flood risk. Areas within 0–500 m were flagged as high-risk zones and, along with data on rainfall, elevation, and slope, were integrated via an AHP-weighted overlay in a GIS environment to generate a comprehensive flood susceptibility map for the study area.

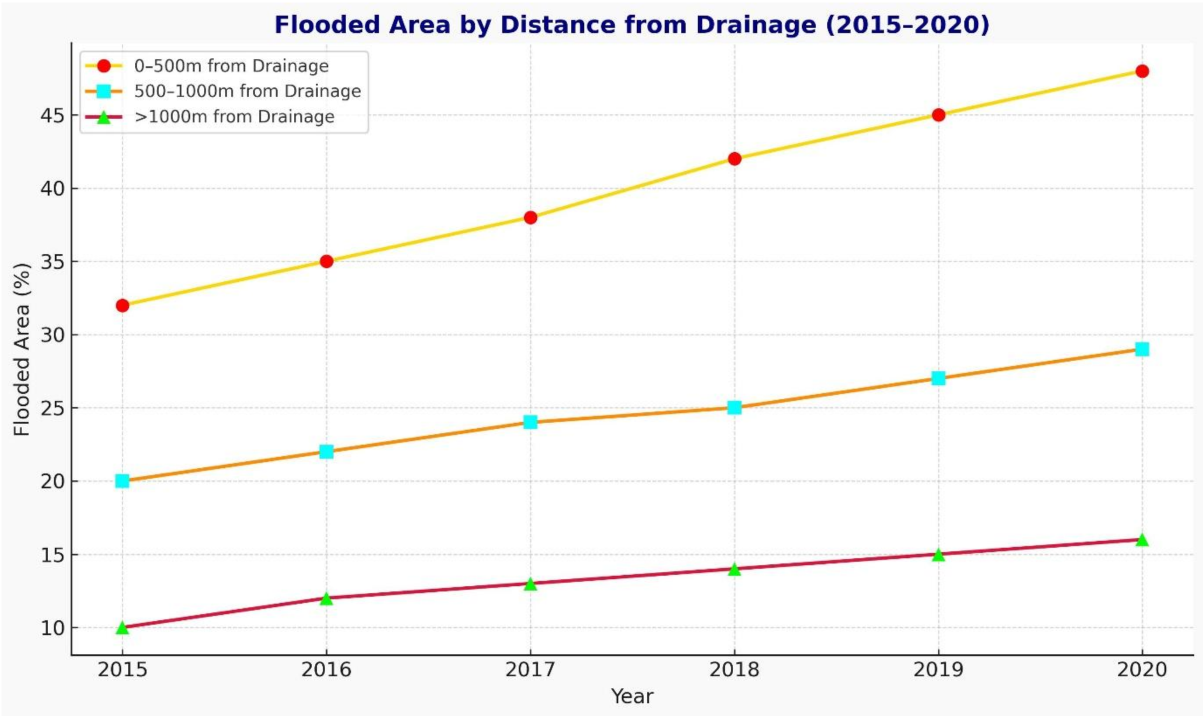

Figure 5 flooded area by distance from network (Kosi River basin ,2015-2020)

7. Methodology:

The methodology adopted in this study consists of five major components:

i. Data Pre Processing:

Sentinel-1 SAR imagery underwent rigorous pre-processing including radiometric calibration to convert raw data into calibrated backscatter, speckle filtering (typically using Refined Lee or similar methods) to suppress granular noise, and terrain (Range-Doppler) correction to correct geometric distortions and align signals with ground elevation and slope via DEMs At the same time, Sentinel-2 multispectral images were atmospherically corrected often using the Sen2Cor (Level-2A) algorithm to remove effects of clouds, humidity, dust, and aerosols, yielding surface reflectance data essential for accurate land-cover classification

ii. Flood Mapping:

Using Sentinel-1 SAR imagery (July–August from 2015–2020), flood detection in the Kosi River Basin was achieved through a two-fold approach: thresholding and backscatter analysis**.** In the thresholding method, pixels in SAR images with backscatter values below a predetermined cut off typically in the range of –15 to –24 dB for VV polarization—were classified as water, leveraging the fact that calm water surfaces reflect radar energy away from the sensor and appear dark. This contrast in backscatter allows clear separation between water and dry land. The validity of this SAR-derived flood map was confirmed by comparing it to historical flood records from government agencies and previous field-based studies, ensuring the flood extents derived were accurate and reliable.

iii. Sential-2:

Satellite image supervised classification in LUCL gives land cover and land used images. Maximum likelihood Algorithm applying in NIR, Green, Red spectral band. Landscape into major classes categorized by this process such as water bodies, agricultural area, built up region and forest, offering vital insights into surface characteristic. This LULC data play the ket role in dertmine how water behaves impacting runoff, water retention and infiltration. Flood modelling significantly improves the reliability of vulnerability assessment when LUCL data has been used. Flood risk analysis in Analytical Hierarchy Process(AHP) LUCL serves important factor. Runoff rates. Changes in land cover, such as deforestation or urban expansion, can affect the rate of runoff, modify peak flow levels, and, in turn, influence the flood risk, exposure, and vulnerability throughout the region. A technique called supervised classification was used. This involves selecting training samples for each land cover type and then using an algorithm to classify the rest of the image based on those samples. The algorithm applied here is the Maximum Likelihood Algorithm, which is one of the most widely used methods for satellite image classification. It calculates the probability of each pixel belonging to a particular class based on the statistical characteristics of the training data.

a. Agricultural Areas: These sections exhibit high reflectance in both the green and NIR bands, signalling the presence of healthy crops or exposed soil typical of cultivated fields
b. Water Bodies: Rivers, ponds, and flood zones appear dark across multiple spectral bands, as water strongly absorbs light, particularly in the green and NIR regions
c. Built-Up or Settlement Zones
   Urban and developed land displays unique spectral signatures, often with heightened red band reflectance due to the prevalence of concrete and rooftops
d. Forested Regions: Areas with dense tree cover reflect strongly in the NIR band, distinguishing them from agricultural fields or sparse vegetation

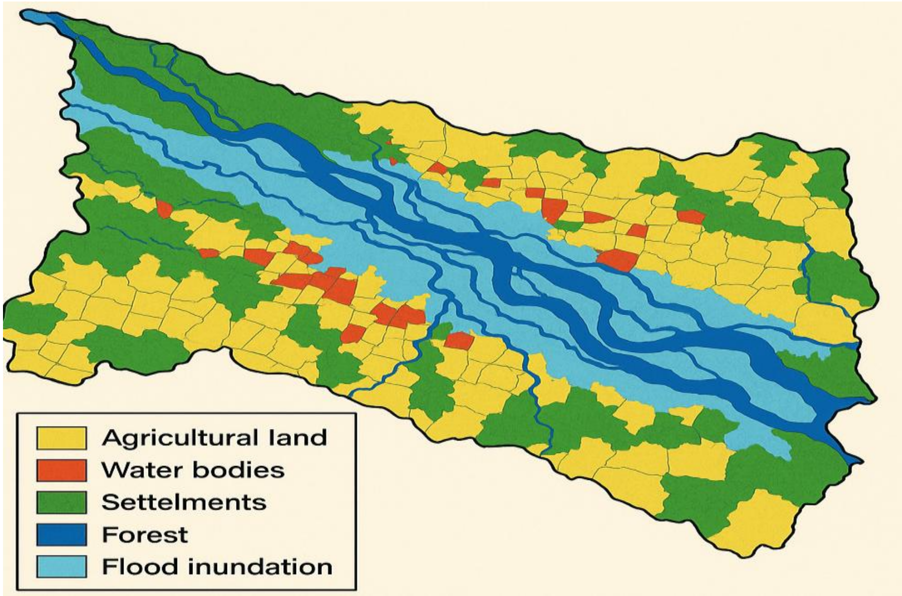

Figure 6 LULC map of the Kosi River Basin showing agricultural land, water bodies, settlements, forests, and flood zones. It helps in understanding flood impacts across different land uses for better planning.

8. Topographic and Rainfall Analysis:

DEM was processed to extract slope and elevation maps. CHIRPS data was used to generate rainfall intensity maps, normalized for each year.

i. Elevation and Slope Extraction

Using the ALOS PALSAR Digital Elevation Model (DEM), elevation and slope data were generated with GIS Spatial Analyst tools. DEMs are essential for terrain-based hydrological modelling high-resolution models significantly improve flood depth accuracy compared to coarser alternatives

Terrain's steepness calculated by slope map that is measure in degrees. This giver idea to how water flow across landscape. Like how water trends in flatter region, water tends to accumulation and how quick water drainage in steeper region.

The area near riverbank which has been flood prone zones elevation map highlighted the area which low elevation. Approximately less than 50m and higher terrain.

ii. Analysis intensity of Rainfall

CHIRPS Annual rainfall data was analysed for period of 2015-2020. Satellite observation with ground based data when high resolution daily precipitation data set has been combining. This fusion identifying perfect rainfall trends. This monitoring long term change and flood risks assessing in different areas.

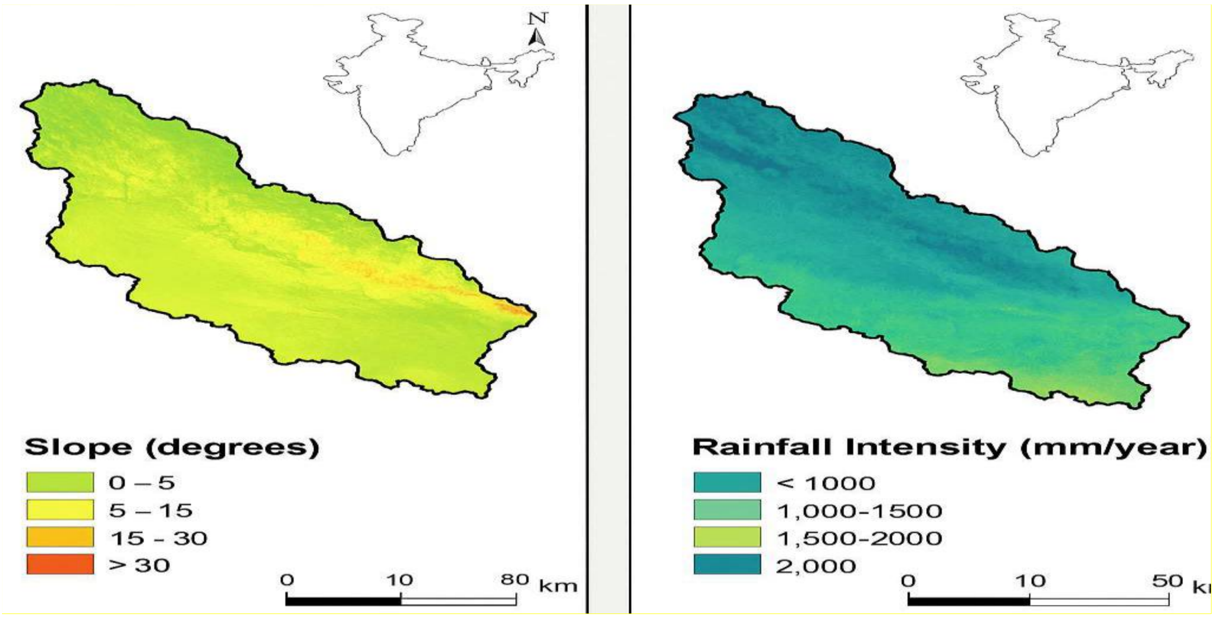

Figure 7 Maps showing rainfall intensity and slopes in the Kosi River Basin, emphasizing terrain slope and annual precipitation patterns key factors for evaluating flood risks.

iii. Flood Risk Mapping using AHP:

The Analytical Hierarchy Process was used to assign weights to six flood-contributing factors: elevation, slope, flood frequency, LULC, rainfall intensity, and proximity to drainage. Weighted overlay analysis was conducted in a GIS environment to generate composite flood risk maps.

iv. GIS Weighted Overlay:

Each flood-related factor layer was standardized and assigned weights based on AHP values. These layers were then combined using GIS overlay techniques, resulting in a composite flood risk map that classifies the area into high, moderate, and low flood risk zones.

9. Results and Discussion:

Occurrence and distribution of flood risk this finding reveal temporal pattern and distinct spatial.

Flood Inundation: The greatest flood inundation occurred in 2020 (27.92%), followed by 2019 (20.73%). In contrast, 2015 experienced the lowest inundation (4.13%). This pattern corresponds with years of heavy rainfall and insufficient drainage maintenance.

Flood-Prone Areas**:** Approximately 32% of the total land area (6526.2 km²) was classified as flood-prone.

Risk Zones**:** High-risk areas covered 1383.5 km² (7%), predominantly found in very flat, low-lying regions near the Kosi riverbanks. Medium-risk zones made up about 40%, while low-risk areas were estimated at 3820.8 km² (19.4%).

LULC Impact: The most vulnerable category is agricultural land that has been emerged due to its floodplains position. Inundation also has been faced by urban areas. Flood has been controlled due to development.

Slope and Drainage: Drainage Channel with gentle slopes the region which more prone to frequent inundation.

This result help to planning to build embankments, planning evacuations flood preparedness also selecting sites for relief infrastructure.

10. Conclusion:

This project effectively showcases the use of remote sensing and GIS techniques to assess flood risks in the Kosi River Basin. By combining satellite data with terrain and rainfall information, a comprehensive flood risk zoning was created. The resulting spatial maps are invaluable for disaster response planning, particularly in pinpointing the most vulnerable areas for timely intervention. Additionally, this model can be applied to other flood-prone river basins in South Asia, particularly those with transboundary features, like the Brahmaputra and Gandak basins. Overall, the study emphasizes the value of geospatial intelligence in both understanding and reducing the impacts of climate-related disasters.

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