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Binod Kumar Vimal
Assistant Professor, BAU,
Sabour, Bihar, India

Piyush Kumar
M.Sc. Scholar, BAU, Sabour,
Bihar, India

Sushmita Ranjan
M.Sc. Scholar, RLBCAU,
Jhansi, Uttar Pradesh, India

Kumar Ashish
Ph.D Scholar, BAU, Sabour,
Bihar, India

Anshuman Kohli
Professor, BAU, Sabour,
Bihar, India

Sneh Prabha
Assistant Professor, BAU,
Sabour, Bihar, India

Ragini Kumari
Associate Professor, BAU,
Sabour, Bihar, India

Corresponding Author:
Ragini Kumari
Associate Professor, BAU,
Sabour, Bihar, India

Mapping of flood affected agricultural land of Kahalgaon sub division of Bhagalpur district, Bihar

Binod Kumar Vimal, Piyush Kumar, Sushmita Ranjan, Kumar Ashish, Anshuman Kohli, Sneh Prabha and Ragini Kumari

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Abstract

Flood water poses negative impact on standing crops during rainy season. Hence, the present study was carried out to assess the site specific flood impact on agricultural land and the actual condition of the same lands in *Rabi* season. To achieve this objective, thematic maps were prepared using the satellite imageries of Land sat 8 and Shuttle Radar Topography Mission (SRTM) data. Results revealed that alluvial plains in northern part of Kahalgaon and Pirpanti blocks were found to be flood affected during *Kharif* season caused by having gentle slope and meandering of the Ganges. However, the same lands were observed with a full swing of *Rabi* crops during winter and summer season, and the Southern part of the study area represented medium to up lands having no evidence of flood inundation, help to grow rice and maize during rainy season, and some patches of hillocks were observed as degraded forest land in the analysed Normalized Difference Vegetation Index (NDVI) image. Results may also be helpful to use as supplementary data source for further land use planning.

Keywords: Agricultural land, geographical information system, flood and remote sensing

Introduction

The land, being a finite and non-renewable resource, plays a vital role in sustaining agriculture and livelihoods, especially in regions prone to natural calamities such as floods. Floods, as recurrent events in the Gangetic plains, drastically alter the agricultural potential of affected areas, disrupting cropping patterns and soil properties. The increasing frequency and intensity of floods, possibly exacerbated by climate change, call for robust land resource management to ensure food security and rural resilience (FAO, 1976; Halder, 2013) ^[7, 8].

In this context, remote sensing (RS) and geographic information systems (GIS) have emerged as pivotal tools for spatial analysis and resource management (Bodaghabadi *et al.*, 2019) ^[3]. Their integration allows for dynamic monitoring, risk assessment, and planning by utilizing satellite-derived information alongside topographic and soil data (Dwivedi, 2001; Kalra *et al.*, 2010; De la Rosa, *et al.*, 2004) ^[5, 9, 4]. Thematic maps over flood affected lands played a crucial role in aiding agricultural planners by providing essential information, ultimately contributing to the reduction of land degradation and facilitating assessments of sustainable land use. In supporting data base and within the framework of digital soil mapping, Multi Criteria Decision Making (MCDM) model was employed to establish connections between soil observations and auxiliary variables (Manna, *et al.*, 2009) ^[11]. Auxiliary variables necessary for these models can be sourced from digital elevation models (DEM), remotely sensed data (RS), and other geospatial data sources (Mosleh, *et al.*, 2017) ^[12]. Hence, remote sensing and GIS techniques were used to prepare soil resources maps by using the satellite data of IRS-P6, LISS-IV, Cartosat-1 and Cartosat-2 for their database (Pereira, *et al.*, 2022) ^[13]. However, GPS receiver was employed to collect soil samples from various locations together with their latitudes, longitudes, and other geospatial features to create soil fertility maps under the RS-GIS domain (Rawal, *et al.*, 2018) ^[14].

Advanced geostatistical methods, including Inverse Distance Methods (IDW), variogram, krigging, and nugget algorithm was used for grid based soil resource mapping and their database generation (Rentschler, *et al.*, 2019) ^[15]. GIS-based mapping of flood inundation, elevation and cultivated lands under lowland ecosystem were mapped for sustainable crop production, and better management of soil resources (Sys, *et al.*, 1991) ^[16].

Tools like Landsat-8 imagery and Shuttle Radar Topography Mission (SRTM) elevation data facilitate the accurate delineation of flood-affected zones and their topographic vulnerability, while MODIS-NDVI helps detect vegetative recovery post-flood (Liu *et al.*, 2018). Recent advancements in digital soil mapping (DSM) and decision-support systems viz. Multi-Criteria Decision Making (MCDM) geospatial models have enabled more precise spatial correlation between environmental variables and land suitability for agriculture (Behrens & Scholten, 2006; Mosleh *et al.*, 2017)^[1, 12]. These methodologies also aided in transforming raw geospatial data into actionable insights for land use planning, mitigation, and restoration strategies (Manna *et al.*, 2009; Pereira *et al.*, 2022)^[11, 13].

In Bihar, particularly in Bhagalpur district, flood-prone areas such as Kahalgaon and Pirpainti blocks require tailored interventions for sustainable agricultural management. Hence, the present study is based on RS-GIS tools to map the flood-affected lands, interpret spatial variability in elevation and slope, and identify agricultural land use transitions from Kharif to Rabi seasons. These insights are crucial not only for current land use planning but also for guiding future development strategies under stress conditions. Keeping of these facts in mind, the present study was carried out to trace out the flood prone areas and their temporal change in cultivated land for *Rabi* season.

Materials and Methods

Study area

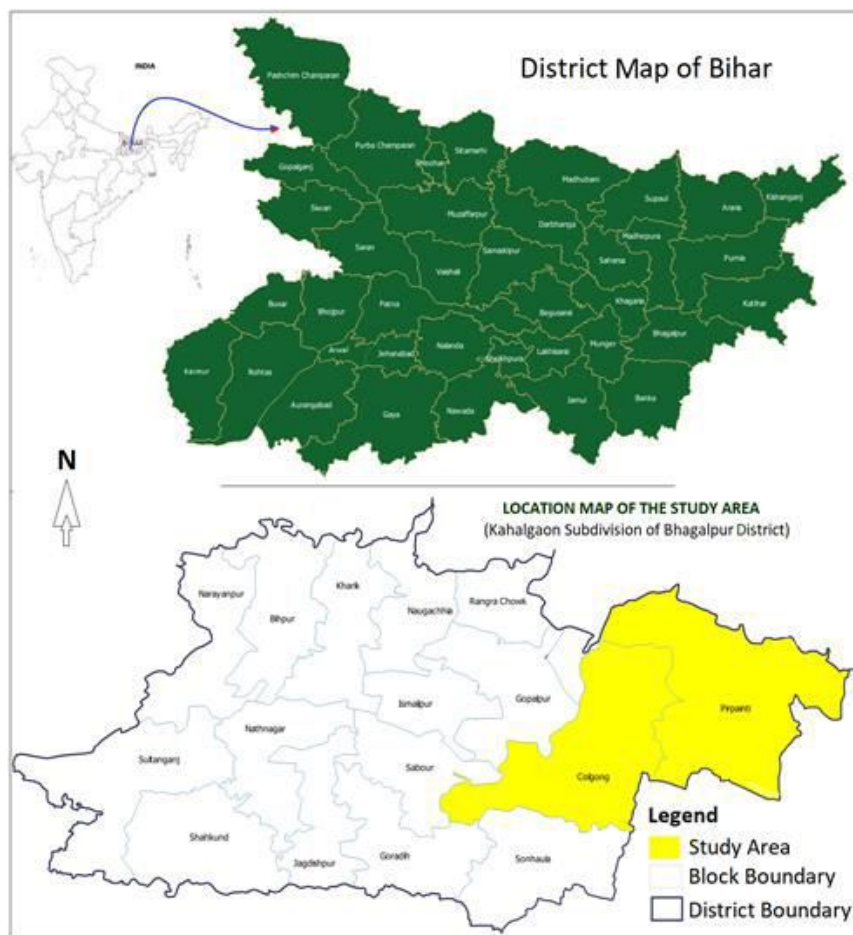


Fig 1: Location map of the study area

Kahalgaon subdivision of Bhagalpur district, Bihar consists the geographical area of 683.90 km² having latitudes and longitudes extensions of 25.19551° N to 25.39942° N and 87.12213° E to 87.52806° E. The elevation varies from 25 to 61 m above mean sea level falling in a part of the Gangetic plains just before an extension of Rajmahal hills near the border of Bihar and Jharkhand. The Ganges flow from west to east fills various ponds, lakes, and oxbows among other water bodies, underlain by mostly younger alluvial deposits in a broadly flat plain especially in low land ecosystem (north side).

Satellite images, hard ware and software used

The multi spectral images of Landsat-8, MODIS V5 and SRTM data were used to map the flood affected lands,

elevation, slope and water logged condition of the area of interest. However, the administrative boundaries of the area of interest were traced out using topographical sheets with scales of 1:250000 and 1:50000, and the GPS receiver was used to ground truth and validation of data. In context of digital image processing, the computer system (HP Platinum 4 core processor) and QGIS software (Version 3.8.2) were used for the visual interpretation of satellite imagery, digitization and mapping. In order to validate the derived data, soil survey reports, topographical maps and auxiliary data were also used as references.

Methodology

In context of preparation of different thematic maps, satellite data of land sat 8 (2024) and Shuttle Radar

Topographic Mission (SRTM) for elevation and slope analysis were downloaded, layer stacked and visually interpreted by using visual interpretation keys for the characterization of different land features and their mapping. However, digital image processing was applied for unsupervised classification, spectral enhancement and NDVI generation. In terms of analysis of crop response and

water bodies analysis, spectral enhancement techniques were applied and mapped the flood affected area and related attributes. Finally, all the geodatabase were assessed, evaluated and ground truth for final map reparation towards assessment of the flood inundation and crop land. Hence, details of the methodology is summarized in a flow chart.

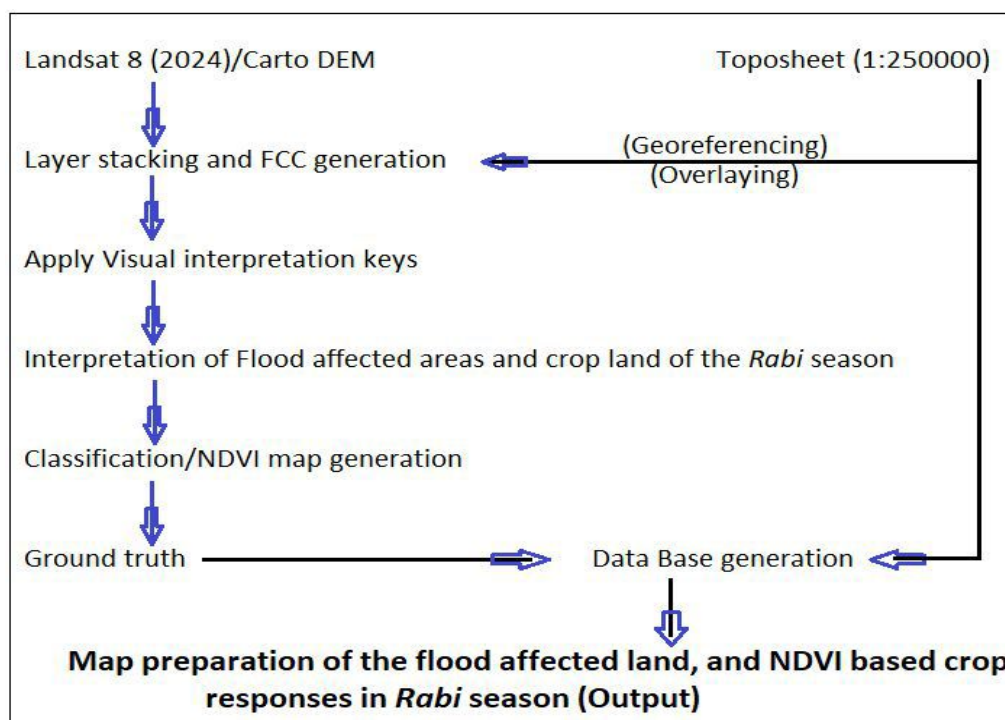


Fig 2: Flow chart of the methodology

Results and Discussion

The spatial analysis revealed that the Kahalgaon subdivision (Kahalgaon and Pirpainti blocks) encompasses a heterogeneous terrain ranging from 25 to 61 meters above mean sea level.

The elevation gradient showed a consistent decline from south to north, which aligns with the flow direction of the Ganges and makes the northern zones naturally more susceptible to flood water. Using Shuttle Radar Topographic Mission (SRTM) data, slope analysis categorized a significant portion of the land as having 0-1.5% gradient, indicated a gentle or flat terrain cause highly vulnerable to water stagnation during monsoons (Fig. 2 and Fig. 3).

Flood mapping based on Landsat-8 imagery from September 2024, which was analyzed using unsupervised classification and spectral enhancement techniques indicated that approximately 16.27% of the total area was highly flood-affected. A further 24.56% was moderately impacted. These zones were primarily located in the northern parts of Kahalgaon and Pirpainti blocks, where meandering of the Ganges, combined with low elevation and poor drainage, results in repeated inundation. Such patterns are consistent with findings from similar studies in other parts of the Indo-Gangetic plains (Kalra *et al.*, 2010; Rawal *et al.*, 2018) [9, 14]. Interestingly, post-monsoon NDVI imagery revealed the significant vegetative recovery in many of the flood-affected areas during the Rabi season, highlighting the resilience of alluvial soils and local cropping practices (Fig. 6). Crops such as wheat, lentils, and mustard were observed to grow in full swing on previously inundated fields, suggesting that

these lands, although seasonally affected, remain agriculturally productive with appropriate water management and crop scheduling (FAO, 1976; Bera *et al.*, 2017) [7, 2].

In contrast, the southern part of the subdivision exhibited higher elevation and more rugged topography, with medium to upland zones supporting *Kharif* rice and maize cultivation. These areas showed no signs of flood inundation, thereby indicating their potential as flood-resilient agricultural zones. Patches of degraded forest on hillocks in this region were also observed in NDVI imagery and could benefit from reforestation or agroforestry interventions to prevent further land degradation.

The use of geostatistical techniques such as inverse distance weighting (IDW) and kriging enabled the generation of soil fertility maps and flood vulnerability maps, which together provide a valuable decision-making tool for stakeholders. These maps can help in delineating zones for crop diversification, introducing flood-tolerant varieties, or developing community-based watershed management systems (Pereira *et al.*, 2022; Manna *et al.*, 2009) [13, 11].

Furthermore, the integration of satellite-derived data with ancillary sources such as topographic maps, soil surveys, and GPS-based field observations ensured the reliability and accuracy of the analysis. The thematic maps generated from this study not only support immediate disaster response but also aid in long-term land use planning, conservation agriculture, and sustainable development in flood-prone ecosystems (Behrens & Scholten, 2006; Mosleh *et al.*, 2017) [1, 12].



Fig 1: FCC image

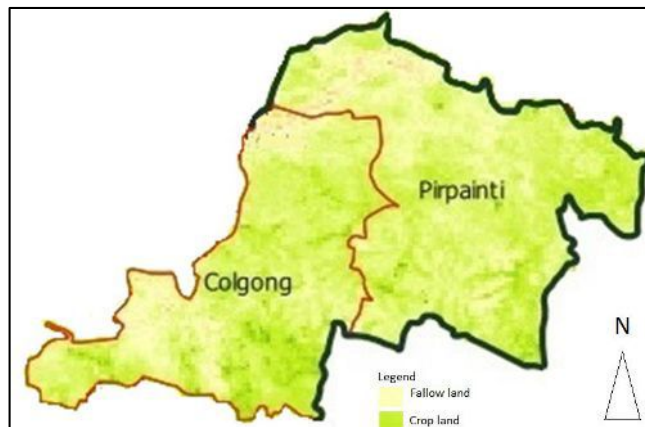


Fig 5: NDVI response of Rabi crops

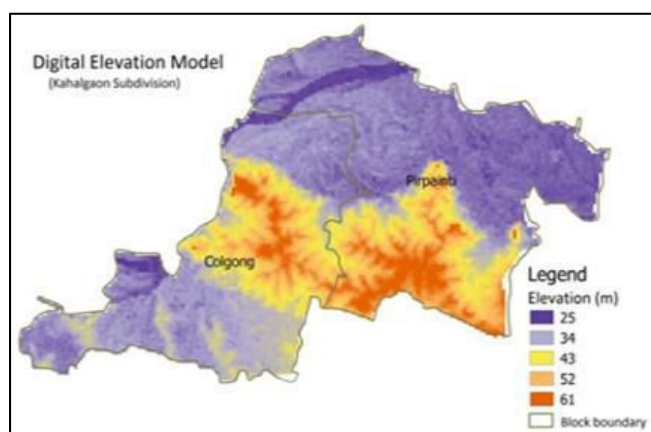


Fig 2: Elevation

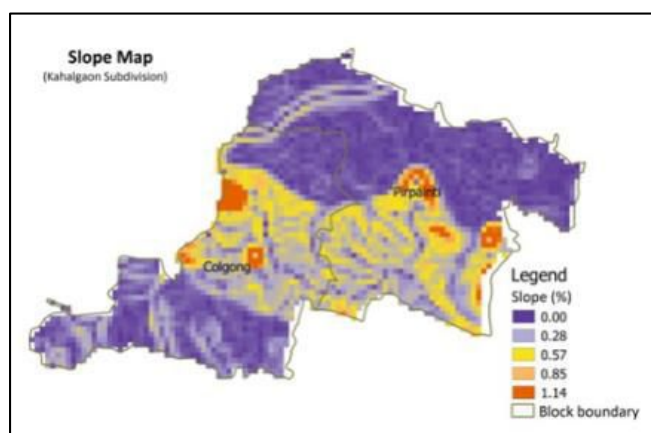


Fig 3: Slope

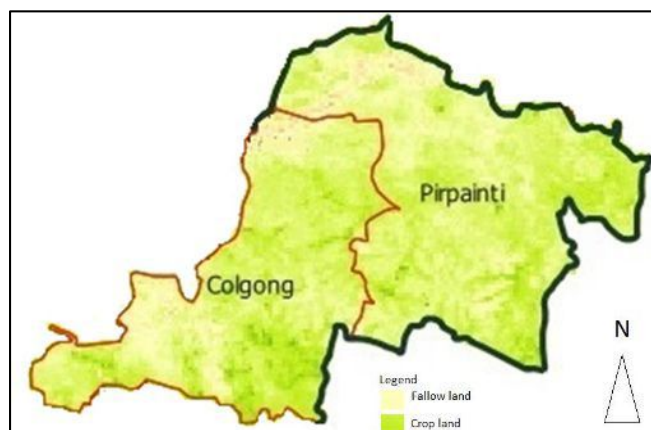


Fig 4: Flood affected land

Conclusion

The present study was conducted to analyse the flood inundation impact on agricultural lands of Kahalgaon subdivision using RS-GIS-techniques. Analysed topographical features, and flood inundated lands using the interpretation of satellite image of land sat 8 of September 2024, it was observed that 16.27% of the total area was found to be highly affected due to flood followed by was moderately affected (24.56%) and the rest of the land was not affected due to flood specially uplands of the Kahalgaon and Pirpanti blocks. The findings of this study can be also used by policymakers to develop an appropriate plan towards providing special agricultural incentive policies.

Future Scope of the Study

Research findings may be helpful to trace out the flood affected lands and their mitigation option through land suitability or land use planning. Outcomes will also be helpful to support to providing the supplementary data source for the initiation of the same type of research work in stressed land situation.

Conflict of Interest

The authors declare that they have no conflict of interest.

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