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Remote Sensing and Geographic Information System Based Mapping of Flood Impact on Banana Orchards in Lower Gangetic Plains of Bihar, India

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ABSTRACT

Bananas are grown in the lower Gangetic plains of Vaishali, Bhagalpur, Purnea, and Katihar districts in Bihar, which suffer flooding during the rainy seasons. Prolonged water logging in lowlands provides a vulnerable zone for fungal and bacterial infestation in banana orchards, leading to a reduction in fruit yield. The assessment of flood inundation and vulnerability hotspots in banana orchards faced obstacles, such as the dynamic and complex nature of the monsoon, infestation in plants, and yield losses in fruits. Hence, multispectral, hyper spectral, and thermal data were utilized for visual interpretation, image processing, and extraction of geospatial information aimed at mitigation. The study provided valuable insights into the temporal changes in flooding and water logging in the specific area where banana orchards are at higher risk, contributing to the development of strategies for mitigating yield losses in flood-prone areas. Keeping these views in mind, the present study was carried out to assess the temporal changes in flood inundation during the monsoon using satellite data of the Moderate Resolution Imaging Specro-radiometer (MODIS V6, 2021) and to analyze the site-specific vulnerable hotspots where banana orchards may be badly affected due to floods. Results revealed that out of the total geographical area of Naugachhia subdivision (86982 ha), only 2541.36 ha (0.97%) are under banana orchards. The analyzed data shows that the maximum area under banana orchards was found in Kharik block (1157.83 ha), followed by Naugachhiya block (702.12 ha), Bihpur block (379.57 ha), Gopalpur (189.6 ha), Narayanpur (63.85 ha), Ismailpur (40.92 ha), and Rangra Chowk (7.47 ha), where, banana orchards were badly affected by bacterial and fungal diseases in Gopalpur (115.59 ha), Ismailpur (31.28 ha), and Rangra Chowk (1.25 ha).

Keywords: *Area estimation, Banana, NDVI, Remote sensing, Satellite data, Temporal change, Crop phenology and Water logging*

INTRODUCTION

Flooding, a pragmatic natural disaster resulting from prolonged water stagnation (up to 3 to 4 months), causes the loss of agricultural production [1]. In recent years, Remote Sensing (RS) and Geographic Information System (GIS) techniques have become extremely important for providing a cost-effective, reliable, and critical mechanism for managing seasonal crops during flood disasters. Satellite data, including multispectral and thermal imagery, have been utilized to approximate the duration of flooding. The cloud-penetrating capability of radar has long been an attractive feature for monitoring floods and standing crops in flood situations [2]. In flood-affected areas, the physiographic pattern, such as Tal and Diara lands (intensively cultivated for *rabi* crops), becomes waterlogged, leading to a treeless ecology [3]. Particularly in the lowland ecology of the lower Gangetic plains in Bihar, banana (Musa paradisica L.) stands out as an important fruit crop after mango. Bananas are rich in vitamins and minerals such as K, Ca, Na, and Mg, along with abundant starch, sugar, and vitamin C [4-5].

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Conversely, Bihar is the eighth-largest banana-producing state in India, contributing nearly five percent of the total production [6].

In recent years, remote sensing (RS) and Geographic Information System (GIS) have been employed to enhance horticultural crops. These technologies are used to develop site-specific strategies for overcoming biotic and abiotic stresses, monitoring them over large areas, and determining optimal deployment locations [7-8]. The swelling and shrinkage of clay, along with high bulk density, can affect proper drainage, consequently reducing crop yields. However, freely drained, deep, and fertile loamy soils are considered favorable environments for sustaining banana orchards [9]. Regarding the management practices of horticultural fields, an assessment of flood risk areas using visual interpretation of satellite data and considering temporal changes in crop phenology has been conducted. The Normalized Difference Vegetation Index (NDVI) was employed to map stress conditions due to floods and explore mitigation options [10-11].

The banana is cultivated in the Bhagalpur district, which falls under lowland ecology, experiencing floods and prolonged waterlogging. Constructive measures to minimize crop yield loss due to floods are currently lacking. Hence, the present study was carried out to map banana orchards and their topographical settings, assess temporal changes in waterlogging due to floods, and analyze their impact on standing banana crops.

MATERIAL AND METHODS

Study Area

The Naugachhiya subdivision of Bhagalpur district in Bihar consists of an area spanning 86,982 hectares, situated near the Ganges River, with latitude and longitude extensions ranging from 24°30'N to 25°06'N and 86°03'E to 87°07'E, as illustrated in Figure 1. The physiographic pattern in this region is locally classified into Tal, Diara, and Oxbows, found in low-lying areas.

The Diara land, formed through the periodic erosion and deposition of sediments (alluvium) in flood-prone areas, is recognized as one of the most valuable natural resources in Bihar and Orissa [12]. The Tal, characterized by a saucer-shaped structure, develops due to the accumulation of backwater during floods in low-lying areas. Oxbows, forming semi-circle or curve-shaped physiographic structures, result from the cutting off of wide meanders from a stream or river, creating lakes locally known as "Moun" in the Gandak River basin in Bihar [13]. Several oxbows with abundant water were observed in Narayanpur, Bihpur, Kharik, Naugachhiya, Gopalpur, Ismailpur, and Rangra Chowk blocks using visual interpretation and ground truth verification of satellite images from Landsat 8 and MODIS in 2021 (Figure 1).

The climate of the study area is semi-humid to humid. The summer season starts from March to early June, followed by the rainy season from mid-June to the end of September, and winter from November to February. The mean daily maximum ambient temperature in summer is close to 43°C, and in winter, it is around 8°C. The southwest monsoon is active from mid-June to the end of September, with the maximum rainfall recorded at 2194 mm. Additionally, above 80% humidity was reported during the monsoon period from July to September in 2021. Southwest monsoon actives from mid-June to September end having maximum rainfall (2194 mm), and above 80% humidity was reported during monsoon period from July to September in 2021.

Satellite images, computer hardware and software used

In the present study, Landsat 8, MODIS V6 (2021), and Shuttle Radar Topography Mission (SRTM) data were utilized for visually interpreting vegetation, water bodies, streams, and topographic undulation. Additionally, Google Maps and the Bhuwan portal were employed as supporting references for delineating and characterizing the banana growing area. The analysis of soil texture, waterlogged, and moist lands was conducted through the visual interpretation of satellite images from IRS LISS III and documented soil reports. Topographical sheets at scales of 1:250,000 and 1:50,000 were employed to trace out the block boundaries of Bhagalpur district. For digitization, image processing, and mapping, a computer system with an HP Intel® Core(TM) i5-4210U CPU (4 cores) and QGIS software (Version 2.8) were utilized.

METHODOLOGY

In May-June 2020, a field survey was conducted for the identification and visual interpretation of banana orchards, coinciding with Landsat 8 and Google Maps for further interpretation and information extraction. Shapefiles (.shp files) for different blocks were generated by tracing topographical sheets, and necessary information was filled into the attribute table.

In addition to these activities, temporal data of the Normalized Difference Vegetation Index (NDVI) from MODIS V6 were utilized to analyze the encroachment of floodwater, loss of greenness, and the development of treeless ecology (see Fig. 3, 4, 5 & 6). NDVI, calculated as the difference between the near-infrared (NIR) and red bands (RED) normalized by the sum of those bands, was employed to characterize vegetation, agricultural and horticultural land units [11]. All thematic layers were superimposed to analyze vulnerable hotspots. A detailed summary of the methodology is provided in the flow chart (see Fig. 8).

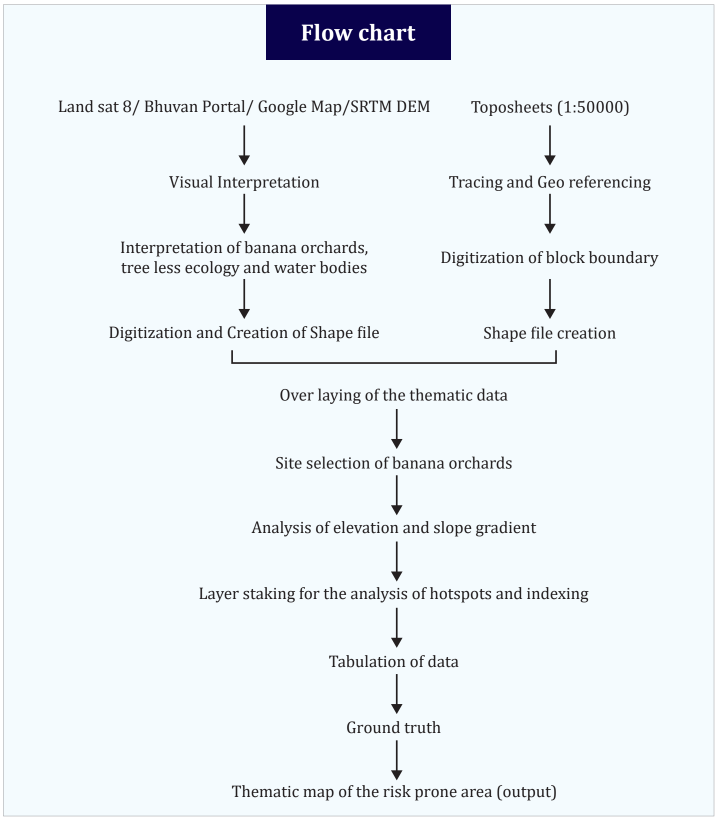

Fig.8. Flow chart of Methodology

RESULTS AND DISCUSSION

Out of the total geographical area of Naugachhiya subdivision (86,982 ha) in Bhagalpur district, only 2,541.36 ha (0.97%) of the land was covered under banana orchards. The highest area under banana orchards was found in Kharik block (1,157.83 ha), followed by Naugachhiya block (702.12 ha) and Bihpur block (379.57 ha) (Fig. 2). Banana orchards in Rangra Chowk, Naugachhiya, and Ismailpur blocks were severely affected by Galwa Rog, caused by prolonged floodwater with low elevation from neighboring sites (Fig. 4 & 5). Eighty-five percent of the geographical area of the banana orchards was situated on elevated plains (stable Diara) of the Kosi River and the Ganges, which are mostly free from prolonged waterlogging. Such plains indicated lower infestation from the surroundings (Fig. 3).

MODIS V6 NDVI images for the months of July, August, and September 2021 revealed the signature of waterlogging in banana orchards. Tal and Diara lands in the month of September were also encroached by floodwater, exhibiting a tree-less ecology (Fig. 4, 5 & 6). Temporal changes in NDVI from August to October 2021 indicated that banana orchards in Rangra Chowk, Ismailpur, and Gopalpur blocks were damaged early due to waterlogging (Fig. 4). In October 2021, the maximum floodwater had drained out from Narayanpur, Bihpur, Kharik, and Naugachhiya blocks, but it may have provided a convenient environment for the spread of bacterial and fungal attacks in banana orchards (Fig. 6).

An integrated understanding of RS-GIS techniques in the area of interest, aimed at promoting precision agriculture and orchards, helped suggest to farmers the application of judicious amounts of fertilizer and pesticides in the affected areas [12]. IRS LISS III data was used to feasibly test and discriminate fully damaged late blight potato fields from healthy ones [13]. Remotely sensed data (IRS-1-C) were utilized for the detection, monitoring, and mapping of affected rubber plantations caused by Corynespora and Gloeosporium fungi, which are responsible for leaf spot and leaf fall diseases [14].

CONCLUSION

Remote sensing and GIS have been instrumental in monitoring waterlogging across different topographies, aiding in the formulation of strategies to drain stagnant water from banana orchards. The digitization process has proven valuable in mapping banana orchards, providing a reliable data source for future planning. The topographical setup and flood inundation behavior in lowlands, flood-affected areas, along with supporting data, contribute to the identification of susceptible zones prone to pest and disease attacks in the lower Gangetic plain of Bihar.

FUTURE SCOPE OF THE STUDY: The results of the studied area revealed that temporal changes in waterlogging could be traced using the interpretation of satellite images in the RS-GIS domain. RS-GIS technology provided an opportunity to assess the geospatial features that directly or indirectly aided in analyzing the problem, developing a decision support system, and formulating a contingent plan for the area of interest. Such findings facilitated a rapid and highly accurate survey of the study area, contributing to the development of a perspective land-use plan in the vulnerable area.

CONFLICT OF INTEREST: The authors declare that they have no conflict of interest.

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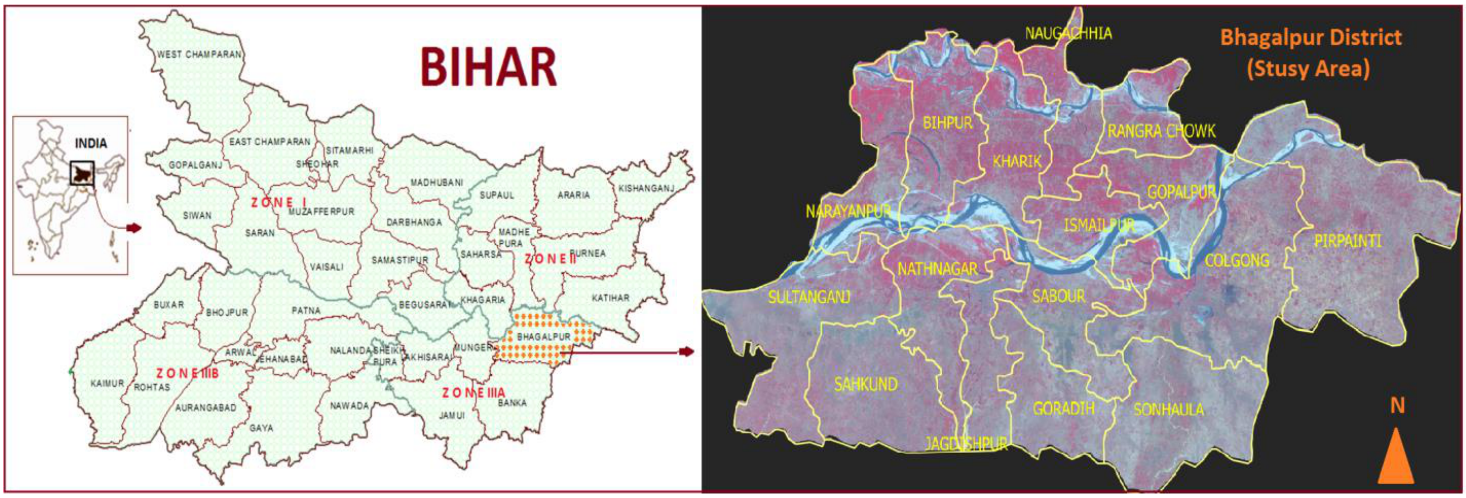

Fig. 1. Location map of the study area

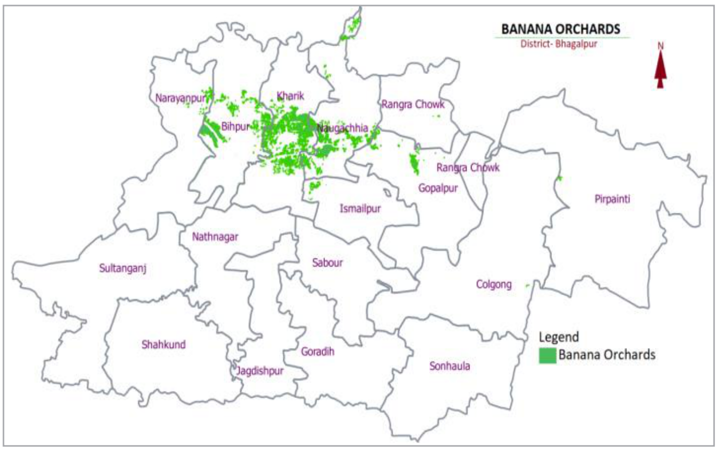

Fig. 2. Map showing banana growing area in Bhagalpur district

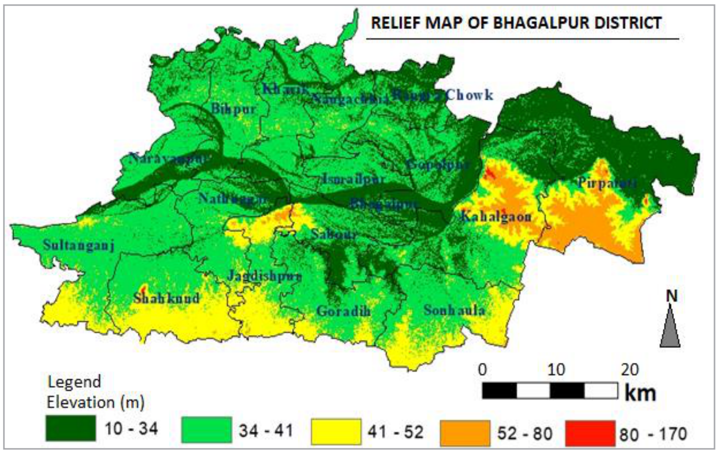

Fig. 3. Relief (Elevation) map of Bhagalpur District

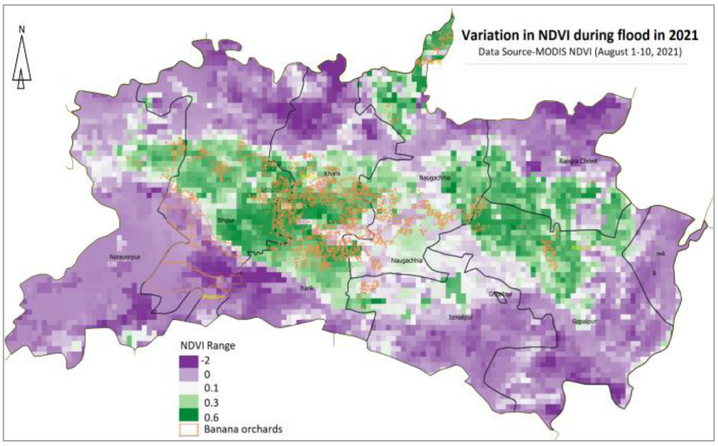

Fig. 4. Variation in NDVI during flood in the month of August, 2021

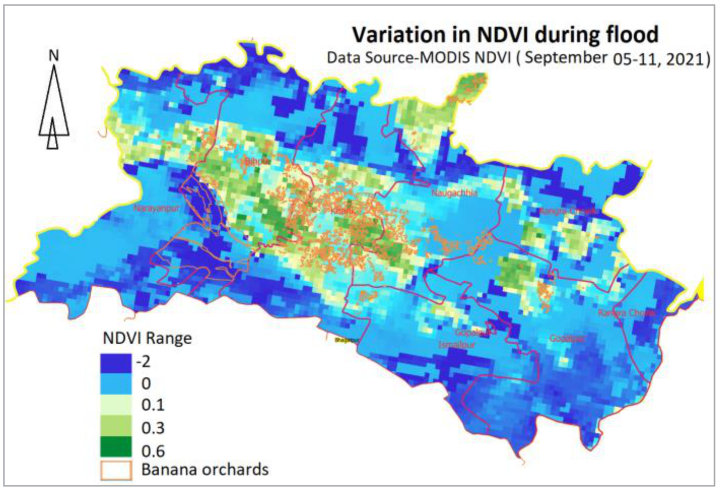

Fig. 5. Variation in NDVI during flood in the month of September, 2021

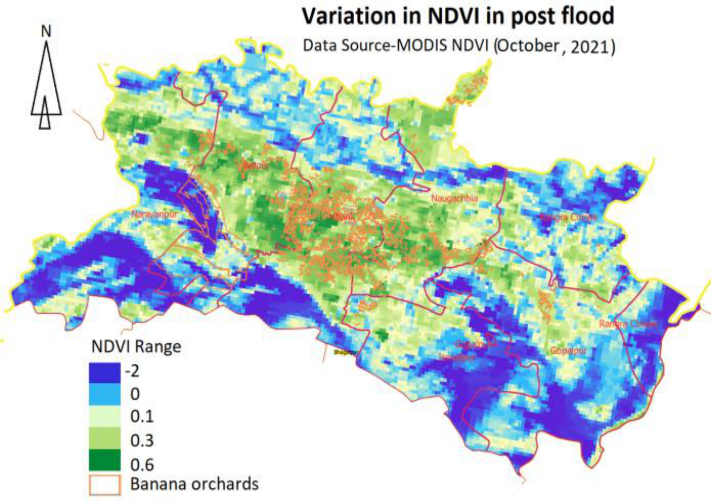

Fig. 6. Variation in NDVI after flood (October 2021)

Fig. 7. Field image of pest and disease infested banana orchards during flood

Table 1. Geographical area under banana orchards

S.No	C. D. Block	Total Geographical Area (ha)	Area under banana orchards (ha)	% age of banana	Area under disease infestation (ha)
1	Narayanpur	14427	63.85	0.024	10.35
2	Bihpur	15208	379.57	0.145	85.63
3	Kharik	13157	1157.83	0.443	380.57
4	Naugachhiya	10670	702.12	0.269	245.63
5	Rangra Chowk	11994	7.47	0.003	1.25
6	Gopalpur	13257	189.6	0.073	115.59
7	Ismailpur	8269	40.92	0.016	31.28
	Total	86982	2541.36	0.973	870.3

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