Assessment of cyclone induced flood using microwave Synthetic Aperture Radar (SAR) data in four blocks of East Midnapore district, India

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Abstract

East Midnapore district is one of the flood prone regions of West Bengal, India. Geomorphological character, topographic nature and geographical location are the main causes of such kind of flood extensiveness in this region. Four most flood prone blocks of East Midnapore district are considered in this study to analyse, monitor and estimate the flood consequences. Flood intensity, duration of water logging, frequency, interval of flood and measurement of the vulnerability are the important parameters to assess the flood risk. Synthetic Aperture Radar (SAR) data has its distinct character to collect the data at the flood time even in bad weather and it can also penetrate the cloud cover and can avoid weather caused signal attenuation. European Space Agency's (ESA) Sentinel-1 SAR before and after flood data (2021) of Vertical transmit and Vertical receives (VV) polarization has been used to monitor and detect the flood extension and assess the inundated areas. The decibel (dB) value is mentioned and speckle noise correction is applied before and after both images.

By applying the threshold dB values on both images, the flood inundated areas are detected and extracted from the natural water bodies. A village wise water logged condition of this region was observed for a long time and the study reveals that total 11612.28 ha. areas are submerged due to flood inundation. For the development of the agriculture and aquaculture in terms of the local economy a special care should be taken in this low land flood, affected region.

Keywords: Flood assessment, Cyclone induced flood, Satellite remote sensing, SAR data, Speckle noise filtering, VV polarization.

Introduction

Natural calamities like cyclone induced flood are considered to be the biggest challenges that need to be monitored at regional and local level. Climate change is also a factor that increases the frequency, magnitude and the seasonality of extreme events such as flood.[11] The vital information in the form of GIS maps like inundated areas, depth of the flood, planning of evacuated route, risk and safe zone marking, selection of shelter point is very much needed to carry out disaster response and relief operations effectively.[20] Rapid urbanization within low flood plain area causes higher run off and thereby decreasing the carrying capacity of the river. The impact of frequency and magnitude of flood would lead to casualty and huge economic cost.[17]

Gayen et al[12] mapped the flood risk zone by considering the flood frequency and vulnerability of the people as flood risk components in East Midnapore district. Keleghai river basin area is one of the most flood prone regions in East Midnapore district experiencing flood almost every year. Storm and rain water overflow the banks and fill the adjacent low-lying lands, producing significant social, economic and environmental impacts when the river exceeds its storage capacity. The break of several dykes and embankments as well as over spilling of river caused such kind of huge flood during the cyclone time. Barman et al[8] evaluated the water logging situation due to tidal flood and rain-water flood in the coastal blocks of the district. The advanced satellite remote sensing techniques are the best option to monitor and assess the water resources and flood time scenario to make an effective decision for proper planning of the affected area.[1,3]

By implementing flood prevention or mitigation strategies, decision makers and planners should take action to protect the exposed population and assets. The advanced Google Earth Engine (GEE) platform is cost-effective, efficient and faster at calculating with enhanced precision. This is the most popular and accepted big GIS data processing platform, facilitating the different scientific process by providing free access to numerous remotely sensed datasets.[6] The outcomes of this study will aid in the management of cyclone-induced hazards.

Study Area

East Midnapore district is the southernmost coastal region of West Bengal State. The geographical location of the district is 21°36'35" to 22°30'44" north latitude and 87°25'37" to 88°12'30" east longitude[3] (Fig. 1). The four flood prone blocks of the district i.e. Patashpur-I, Patashpur-II, Bhagwanpur-I and Bhagwanpur-II lie between 21°52'58.86" to 22°09'39.09" north latitude and 87°27'36.56" to 87°51'43.86" east longitude and extend over a span of 733 sq. km. area to assess the flood time circumstances. Keleghai river is the only major river situated in the upper portion of the Patashpur-1block and flows throughout the study area to join the Kansai at Tangrakhali under Mahisadal police station of East Midnapore district (https://en.wikipedia.org/, 2023). The upper portion of the river in the study area has a very low gentle slope causing more deposition of sand and silt.

Due to a very low run off at the monsoon time, Keleghai river is characterized by heavy flood discharge within a very short span of time.[16] The study area having a subtropical monsoon climate with an average annual rainfall is 116 mm. The highest intensity of rainfall is observed during June to September.[19]

Due to the monsoon and different cyclonic activities, the total amount of rainfall in these four months accounts for more than a half of the total amount of the yearly rainfall in this area. The study area is distinguished for its geographical attitude, physiographic variance, agro-climatic surrounding, cultivation and social composition.[2]

Material and Methods

The purpose of this study is to develop an accurate and updated flood risk maps of the study area of East Midnapore district which has a high frequency of flood events and great damage due to lack of flood protection systems and infrastructure.[9] A standardized technique and high precision scale data are essential for precisely mapping flood inundation areas with water logged region. The microwave satellite imagery of European Space Agency's Sentinal-1A SAR data (Table 1) has been considered to extract the flood submerged areas.

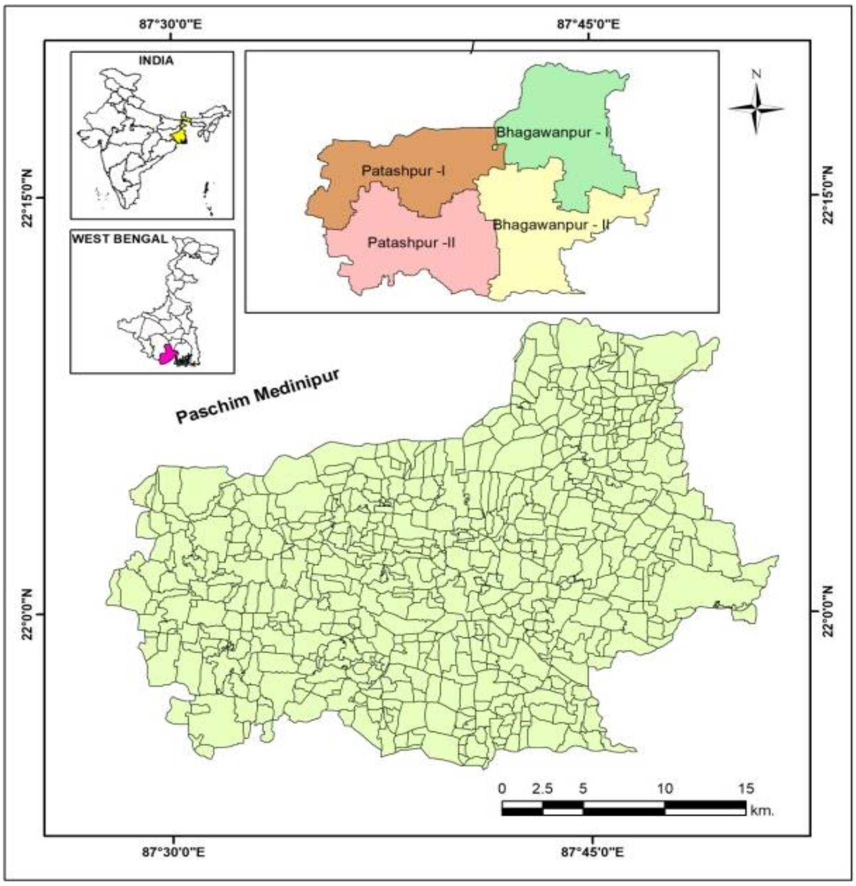

Fig. 1: Location Map of the study area

Table 1
Specification of Sentinel-1A SAR data

Product Type	**Level-1 Ground Range Detected (GRD)**
Imaging Frequency	C band (5.4 GHz)
Mission	Sentinel-1A
Acquisition Mode	IW
Polarization	VV,VH
Swath Width	251.8 km
Antenna Pointing	Right
Pass	Descending/Ascending
Pixel value/Spatial Resolution	10 meter
Repeativity/Temporal Resolution	12 days
Source	https://sentinel.esa.int/

https://doi.org/10.25303/174da040047

Table 2
SAR Polarization

Polarization Code	Transmitted Signal	Return/Received Signal
VV	Vertical	Vertical
VH	Vertical	Horizontal
HV	Horizontal	Vertical
HH	Horizontal	Horizontal

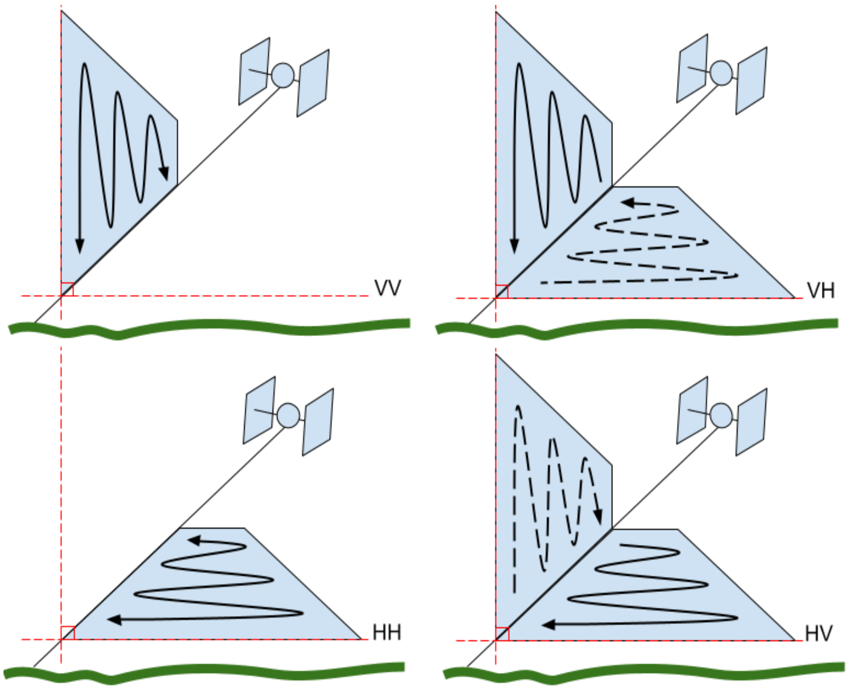

Fig. 2: Four most possible polarization combination (VV-Vertically transmitted and vertically received, VH-Vertically transmitted and horizontally received, HH- Horizontally transmitted and horizontally received, HV-Horizontally transmitted and vertically received) Source: Alaska Satellite Facility[5] (https://asf.alaska.edu/)

SAR data is preferred over optical image for flood mapping and real-time monitoring for its unique characteristics of obtaining data in all weather conditions. It is proven from the previous studies that VV polarization (Table 2) images are the best option to delineate flood water bodies in respect of its accuracies.[4] In this study, VV-polarized (Fig. 2) Sentinel-1 SAR images were used to produce flood inundation maps.[7]

Thresholding technique has been applied to determine the flood mapping through Sentinel-1 data. Before and after flood event images were used to discriminate the submerged areas from the natural water bodies. High resolution satellite imagery from ESA sentinel-2B and Google earth data has also been used to delineate the permanent water body in the study area.[3] Data obtained from the Indian Meteorological Department (IMD) for the month of September 2021 has been analysed to understand the influences and extensiveness of the precipitation in this particular duration. Microwave SAR images were obtained from Sentinel-1A sensor in both descending and ascending passes of 01-09-2021 to 05-09-2021 for pre-flood data and 15-09-2021 to 30-09-2021 for post-event images to find out and assess the submerged areas. Based on the date of filter, the area of interest is extracted for both before and after event images.

Mosaic function is applied for all the available images in this time frame and db values are mentioned to extract water and non-water pixels. To remove the speckle noise, speckle filtering function is applied.[18] The refined 'Lee filter' reduces the speckle noise by applying a spatial filter to each pixel of the image which filters the data based on local statistics within a square window. The centre pixels value is replaced by a value calculated by the neighbouring pixels. The Lee filter is used to smooth speckled data that has an additive or multiplicative component. The dB values of the images are converted to natural and then refined lee function is applied as well as converted back to the dB to smoothen the images in GEE platform.

Value of filtered pixel = LM + K * (PC - LM)

where K (weight function) = LV / (LV + AV) PC is Centre pixel value of window, LM is Local mean of filter window, LV is Local variance of filter window and AV is Additive noise variance.

After filtering the images, the two set of data's for after and before event appeared much more smooth than raw image data (Fig. 3).

Threshold rules were basically used and it is observed from the images that <-20 dB value is water body for both images and dB value of >-20 is before image and after image <-20 dB value is flood pixel. Now geometry calculation function is applied for calculating the area of flood pixels in hectares' unit. Village wise flood inundated areas are estimated thoroughly and a final report was made on this analysis.

Results and Discussion

Different multi-dated sentinel-1 images were taken and image pre-processing was done. A backscattering analysis is processed on VV polarization in GEE platform to identify the cyclone induced flood inundated areas.[21] The image pre-processing is most important step to get the noise free better resolution smoothen dataset and to analyse the pre and post flood events as well as to estimate the inundated areas, permanent water bodies and wetland.[10] The pre flood images were obtained in between 01-09-2021 to 05-09-2021 and within this time frame, the derived images are mosaic into a single image and post flood event dates are considered during the time of flood and water standing time period (15-09-2021 to 30-09-2021).

The same process has been applied to get a single image data. To get the precise information about permanent and natural water bodies, high resolution satellite imageries are used. Total 3923.99 ha. area of permanent water bodies was identified and estimated in this entire study area (Fig. 4).

The day wise rainfall data from Indian Meteorological Department (IMD) has also been derived to assess the amount of rainfall during this period. It was observed from the study that a significant amount of rainfall was caused during this month and maximum rain was noticed within the time of 15 to 21st of September (Table 3, Fig. 5). Total 11612.28 ha. of sub merged areas is measured in four most flood prone blocks of the district. A detail analysis of block level and village wise inundated areas has also been executed to understand the vulnerability scale of the villages in these blocks.

It is revealed from the study that Bhagwanpur-I and Patashpur-I blocks are having the highest flood inundated areas with an area of 3178.19 ha. and 3069.54 ha. respectively during this phase (Fig. 6 and 7). The others two blocks Patashpur-II and Bhagwanpur-II were inundated with an area of 2840.74 ha. and 2523.81 ha. respectively.

A detail investigation on village wise inundated areas has also been carried out to find out the vulnerability scale of the villages as well as to take preventive measures. The villages in the study area have been categorised into five classes according to their cyclone induced flood inundated areas. After that a village wise flood inundation map was prepared and Shankarpur, Selmabad, Sandalpur, Palpara, Nilkanthapur, Mathura, Mangraj, Mallikpur, Laoa, Lalua, Kotmukha, Kismat Bajkul, Itabaria, Gokulpur, Dhankar, Chandankhali, Bibhisanpur, Baruipur, Bara Hat, Bal Gobindapur, Bahadurpur villages were recognized as most prone to flood (Fig. 8). The overall result shows that the microwave SAR data with simple thresholding method is competent to generate high accuracy mapping and proved its efficiency in detecting the flood and water logged areas.

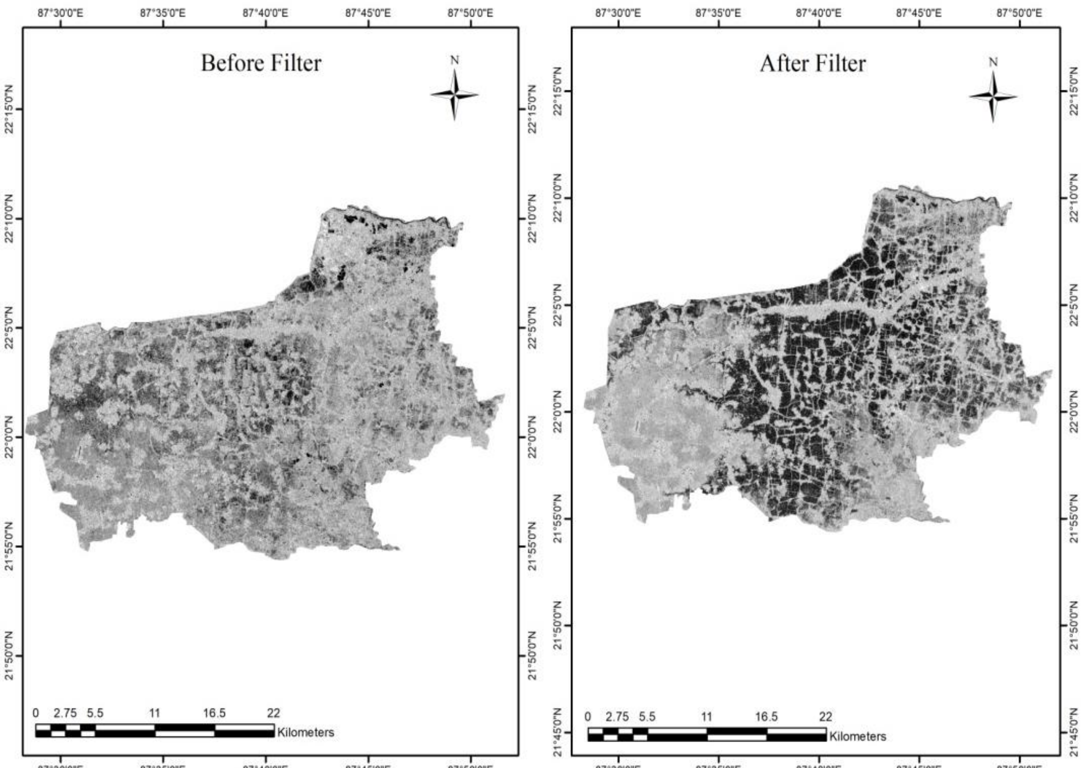

Fig. 3: Speckle Filtered SAR image

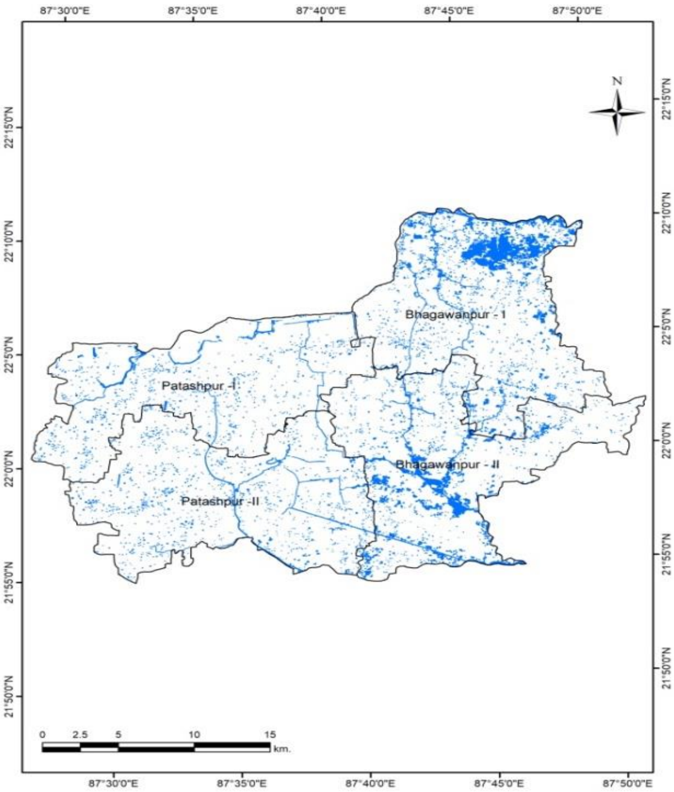

Fig. 4: Permanent water bodies in the study area

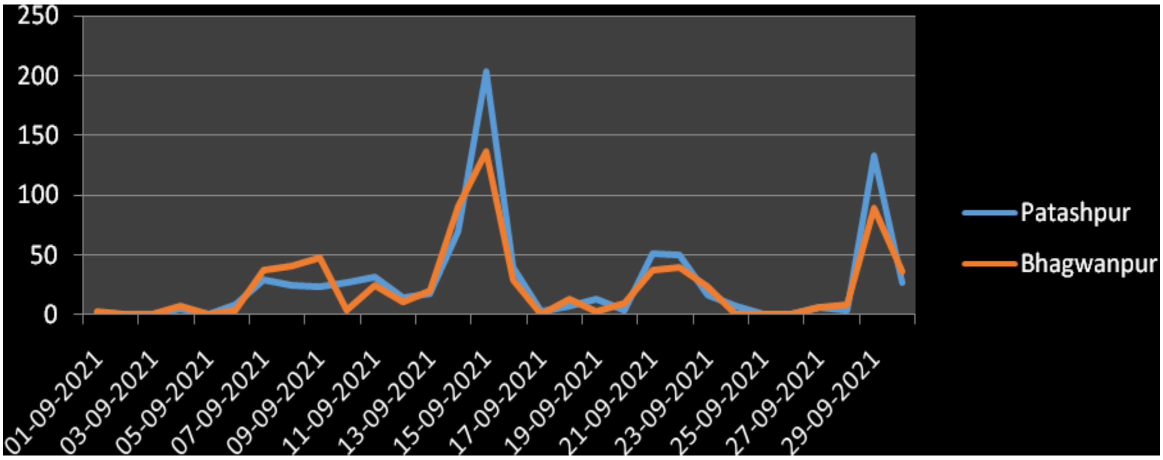

Fig. 5: Graphical presentation of day wise rainfall (mm.) in the month September 2021 in Patashpur and Bhagwanpur block

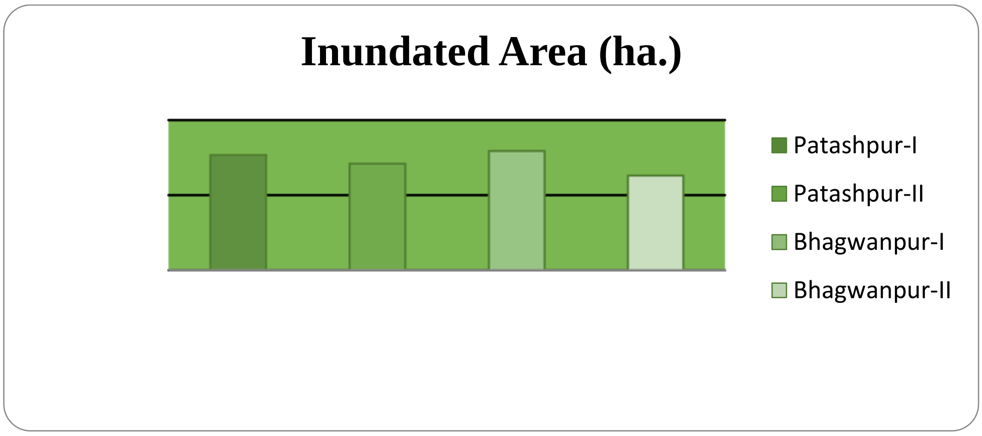

Fig. 6: Block wise area of submerged region

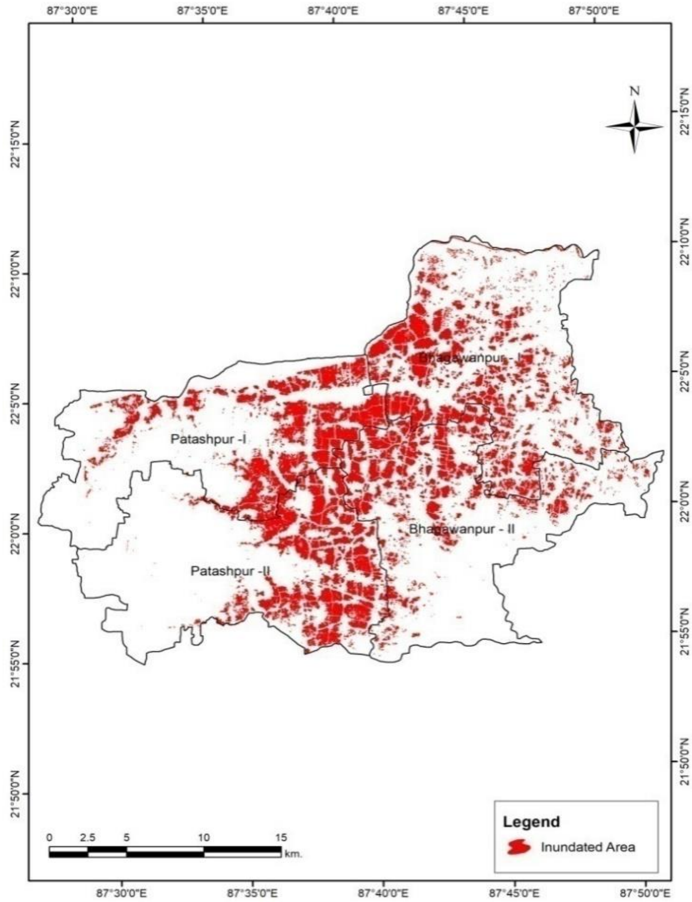

Fig. 7: Block wise distribution of flood inundated areas

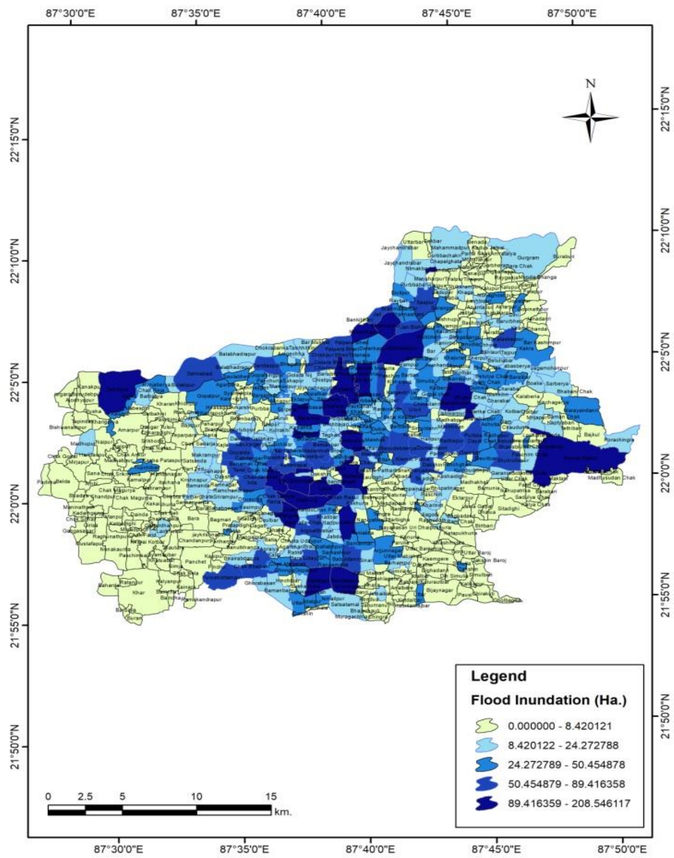

Fig. 8: Village level flood inundated areas

Table 3
Day wise rainfall (mm.) in the weather station of Patashpur and Bhagwanpur block

Weather Station	September 2021																													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Patashpur	1.14	0	0	4.71	0	7.99	28.5	23.74	23	26.38	31.10	13.73	17.29	69.95	203.8	39.2	2.18	7.15	13.10	3.56	50.63	49.51	16.52	7.24	0	0.18	5.67	3.95	132.69	26.79
Bhagwanpur	2.74	0	0	6.47	0.53	3.80	36.69	40.46	47.81	3.12	24.45	10.64	19.56	90.62	136.71	29.39	0	12.73	1.88	8.76	37.63	39.38	23.50	0.55	0	0.53	6.25	8.58	89.50	36.46

Conclusion

The rapid use of big geo data and the recent advancement in cloud computing and processing services through GEE platform are changing the trend and future of remote sensing analysis. GEE is now effectively useful for researchers, scientists and developers for precise extraction of required information from large remotely sensed datasets without the burdens of conventional techniques with a minimum time. It is understood and scientifically proven that Sentinel-1A VV polarized SAR data is much more efficient to capture data at day and night both time at any weather condition to produce the flood inundation mapping rapidly and easily. Vulnerability assessment is crucial for planning and development initiatives in flood prone areas to take the preventive measures at the right time in a swift way.

The flooding extent and spatial variation across the affected blocks of East Midnapore district has been analyzed. Micro level analysis of flood risk is essential for proper understanding the condition at village level of these flood prone blocks. Bhagwanpur-I appears to be most prone to flood and hazardous block in the study area, delineating the high exposure condition towards the negative impact of floods. It is observed from the study that Shankarpur, Selmabad, Sandalpur, Palpara, Nilkanthapur, Mathura etc. are some of the villages that were completely inundated during the time of flood.

The dredging of riverbeds, construction of concrete river banks at weak points, bifurcation of channels and construction of guard walls at lowland areas in the Keleghai river basin are urgent matters that need immediate attention. The evacuation route and shelter point during disaster should be planned for better management in the difficult situation. An early warning system should be imposed for awareness of the dwellers living in a risky low land area. The flood risk map would help the authorities in disaster preparedness, mitigation plan and make the evaluation of flood damages.

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