Flood Exposure and Social Vulnerability during 2020 Assam Floods

Nirdesh Sharma[1], Apoorva Singh[1], Anagha P[1], Manabendra Saharia[1], and Dhanya C T[1]

[1]Indian Institute of Technology Delhi

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Abstract

The state of Assam, primarily in the Brahmaputra basin, is one of the most flood-prone states of India, with devastating floods occurring every year. Rapid urbanization in the floodplains and inadequate water management have further exacerbated the human and infrastructural exposure to floods. Despite efforts in organizing relief camps and setting up safe houses, flood losses in terms of life and property have increased. This study presents a novel dataset and an approach that uses a combination of satellite and ground-based data to assess the population's vulnerability to these floods. The Sentinel-1 SAR data and India Meteorological Department (IMD) rainfall data are used to determine areas in Assam that suffered from floods during July 2020. Additional datasets employed include the population density maps obtained from Facebook, road density maps from the Global Roads Inventory Project (GRIP), relief camp data from the state government, and infrastructure data from a new national dataset sourced from the Pradhan Mantri Gram Sadak Yojna (PMGSY). These geo-tagged datasets are utilized to develop a vulnerability map that would help the policymakers identify vulnerable regions and accordingly strategize infrastructure and disaster preparedness for floods.

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Nirdesh Sharma, Apoorva Singh, Anagha P, Manabendra Saharia, Dhanya CT

Indian Institute of Technology Delhi

HydroSense
IIT Delhi

PRESENTED AT:

ABSTRACT

Floods are an annual occurrence in Assam. In recent years due to the increase in magnitude and frequency of rainfall, rapid urbanization and inadequate water management practices, the impact of floods has increased.

In this study, we present a novel approach using a combination of satellite and ground-based datasets to identify vulnerable areas during the 2020 Assam floods. The vulnerability is modelled as a function of exposure and resilience.

Here we use a combination of IMD rainfall data and Sentinel 1 SAR data to identify flooded areas; then, we develop an exposure map using population data along with inundation data. The exposure maps show the population density exposed to floods. The resilience is then modelled using social, ecological and connectivity features in an unsupervised learning framework using KMeans clusterin. In order to identify the vulnerable areas, the scaled resilience values are subtracted from exposure values. The vulnerability maps help us identify areas where development needs to be done to increase resilience to floods.

These datasets are presented as maps to help policymakers and humanitarian organizations strategize for better flood management.

STUDY AREA

Assam is a state in the northeastern part of India. It is located between 89° 42′ E to 96° E longitude and 24° 8′ N to 28° 2′ N latitude and has an area of 78,438 km. The physiography coupled with highly dynamic monsoons lead to floods every year in the region of Assam., causing widespread loss of life and property

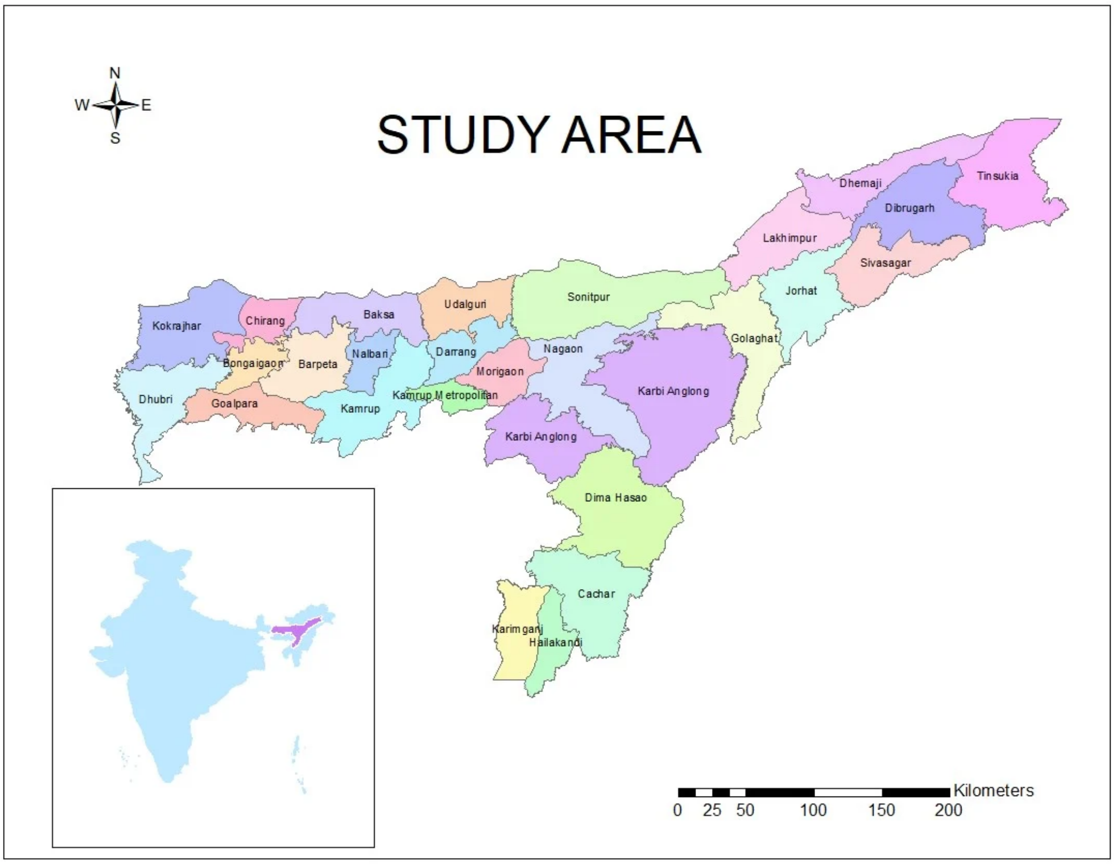

Fig 1: Study Area

METHODOLOGY

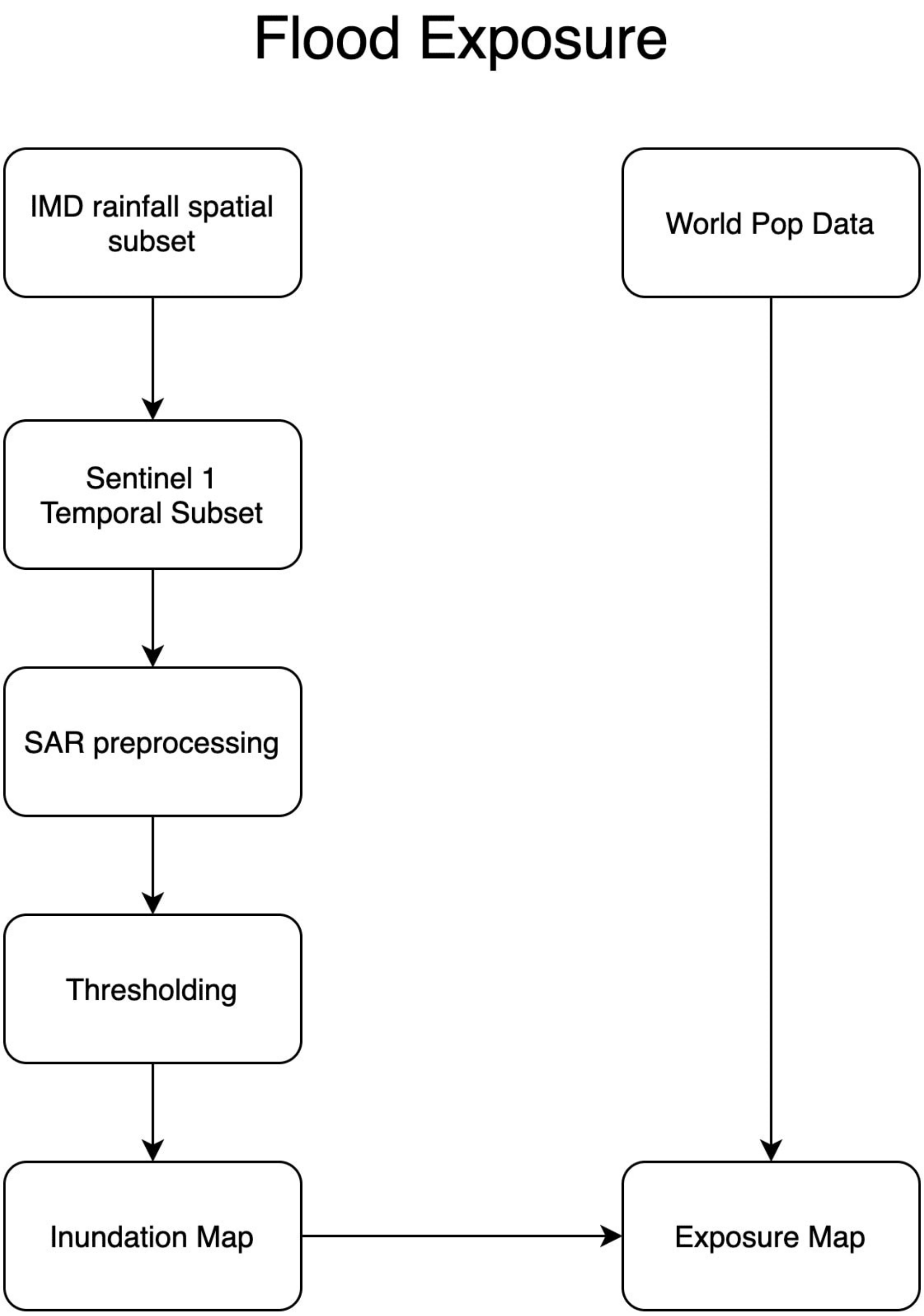

Fig 2: Flood exposure methodology

1) Generate rainfall intensity curve over Assam using IMD data:

To identify the starting date of floods, IMD rainfall data is subset to the location of Assam using the python IMD library, then the rainfall hyetograph for Assam for the year 2020 is generated as shown in Fig 3. Using visual inspection of the hyetograph and cross verification with online resources 10 June 2020 was selected as the date of onset of the flood.

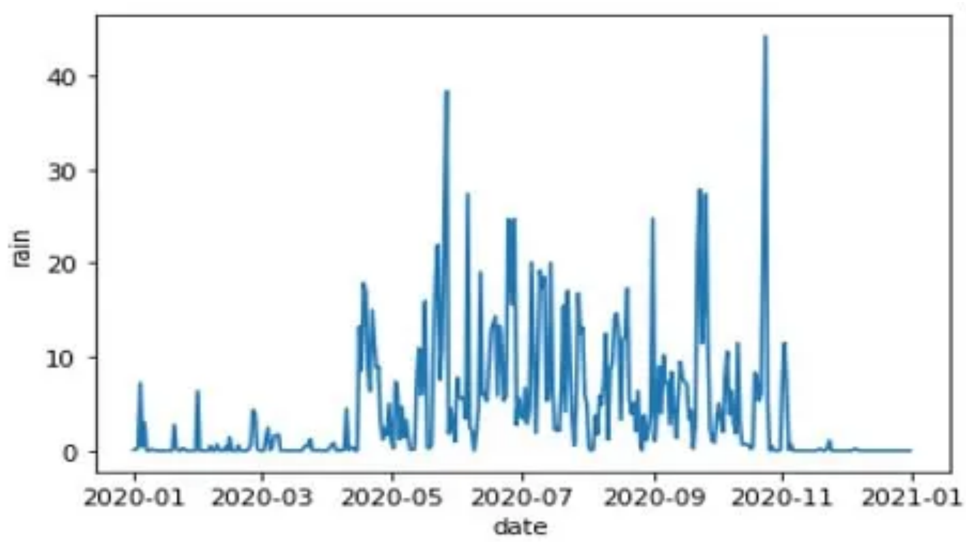

Fig 3: Rainfall hyetograph for Assam

2) Identify flood inundated areas using Sentinel SAR data

Since water reflects SAR waves in a specular way, there is very little backscatter; thus, SAR can help identify flooded areas. To generate a flood map we use a change detection technique where a prior (before floods) and a posterior (after floods) map of the area is used. The difference between the maps is used to identify the areas which were flooded due to extreme rainfall.

The SAR images are preprocessed, and a mosaic of pre-flood and during floods images is created for Assam. To identify the location of flooded pixels, a threshold is determined by creating spatially heterogeneous water layer vectors and then plotting the histogram of pixel values. The 98% confidence level, which comes out to be -10dB, is selected as the threshold. Using this threshold a binary water map is prepared for pre and post floods scenarios. The maps are subtracted to generate a flood inundation map such that the flooded region has a pixel value of 1, and non-flooded regions have a pixel value of 0, as shown in Fig 4

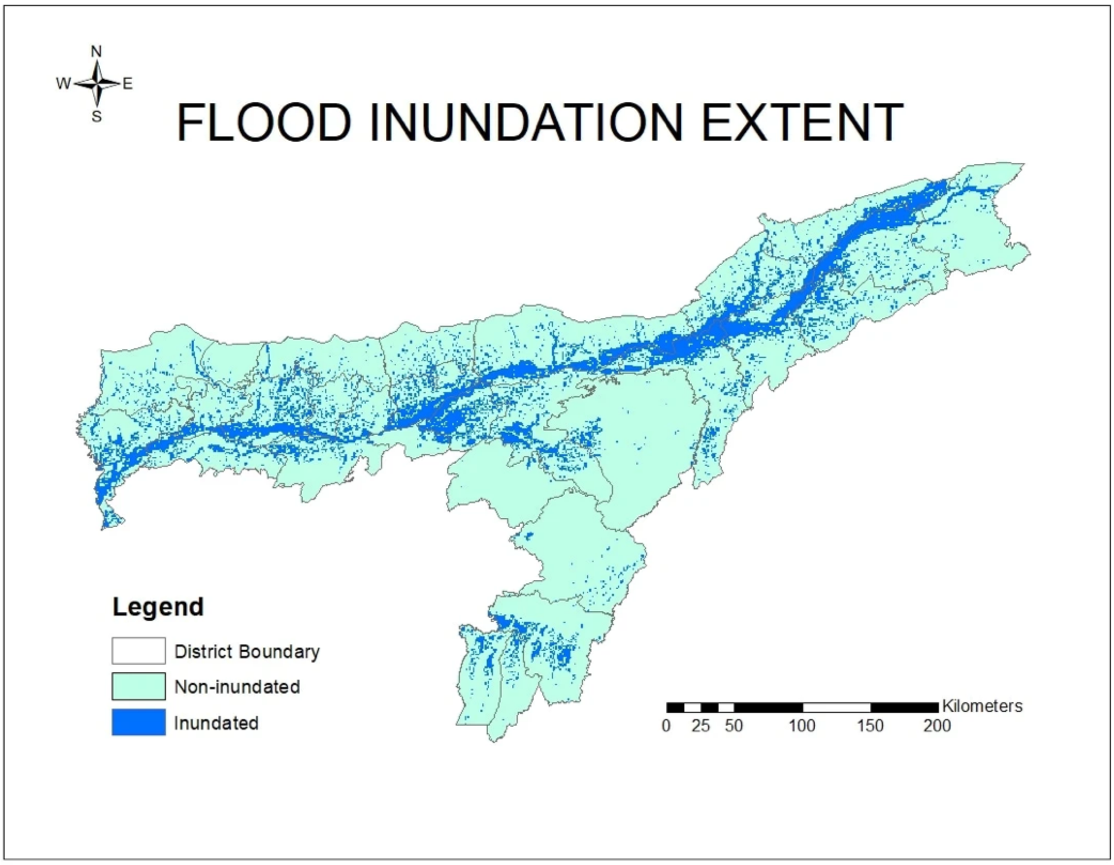

Fig 4: Flood Inundation Extent using SAR

3) Develop a flood exposure map using a flood inundation map and high-resolution population data.

The population density is used as a proxy indicator for exposure. The larger the population density greater is the exposure of human lives to floods. The population data adapted from World pop Data is used in combination with inundation data to generate exposure map. The resulting map, as shown in Fig.5, helps to distinguish the regions with high population exposure to floods from ones with low population exposure.

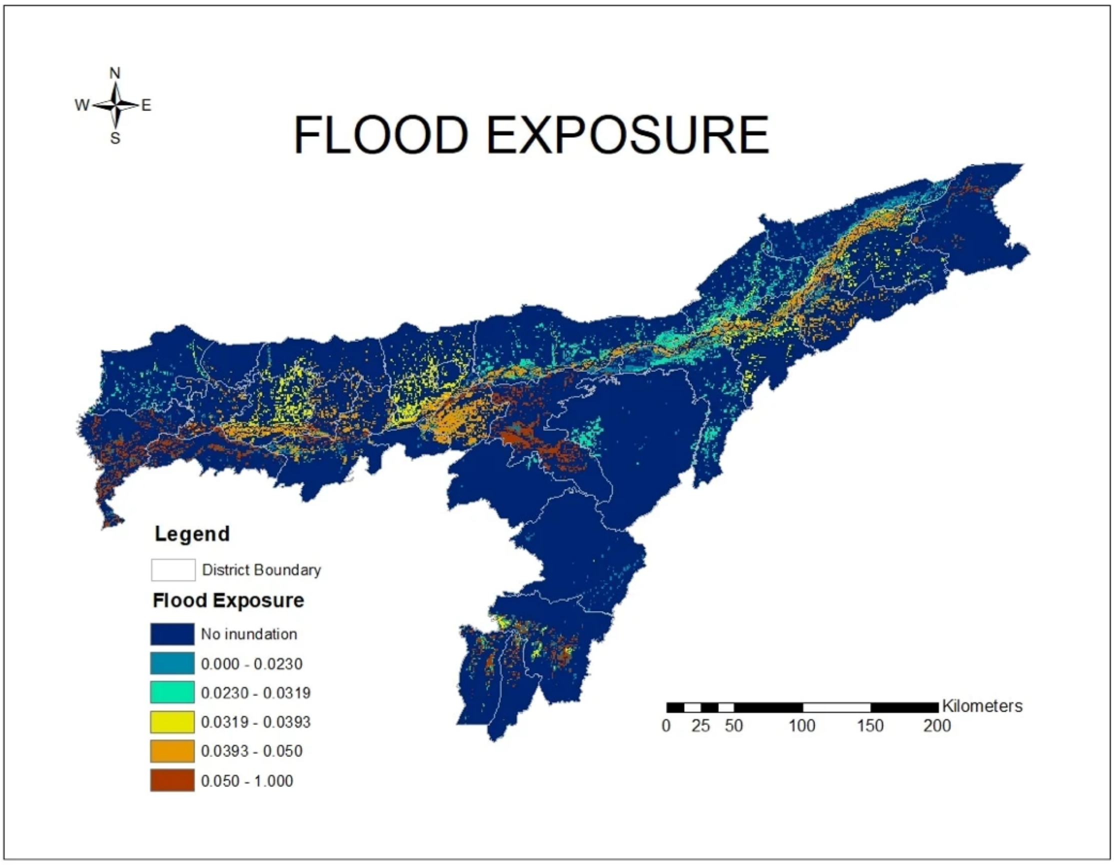

Fig 5: Flood Exposure map

4) Develop resilience maps using unsupervised learning on ground-based and satellite data.

Resilience is used to describe how people deal with environmental stressors. Flood resilience shows the ability of humans to absorb the change and return to pre-flood conditions.

Here we have developed a methodology (Fig 6) using unsupervised machine learning techniques on novel datasets to show the resiliency of Assam against floods.

Resilience Methodology

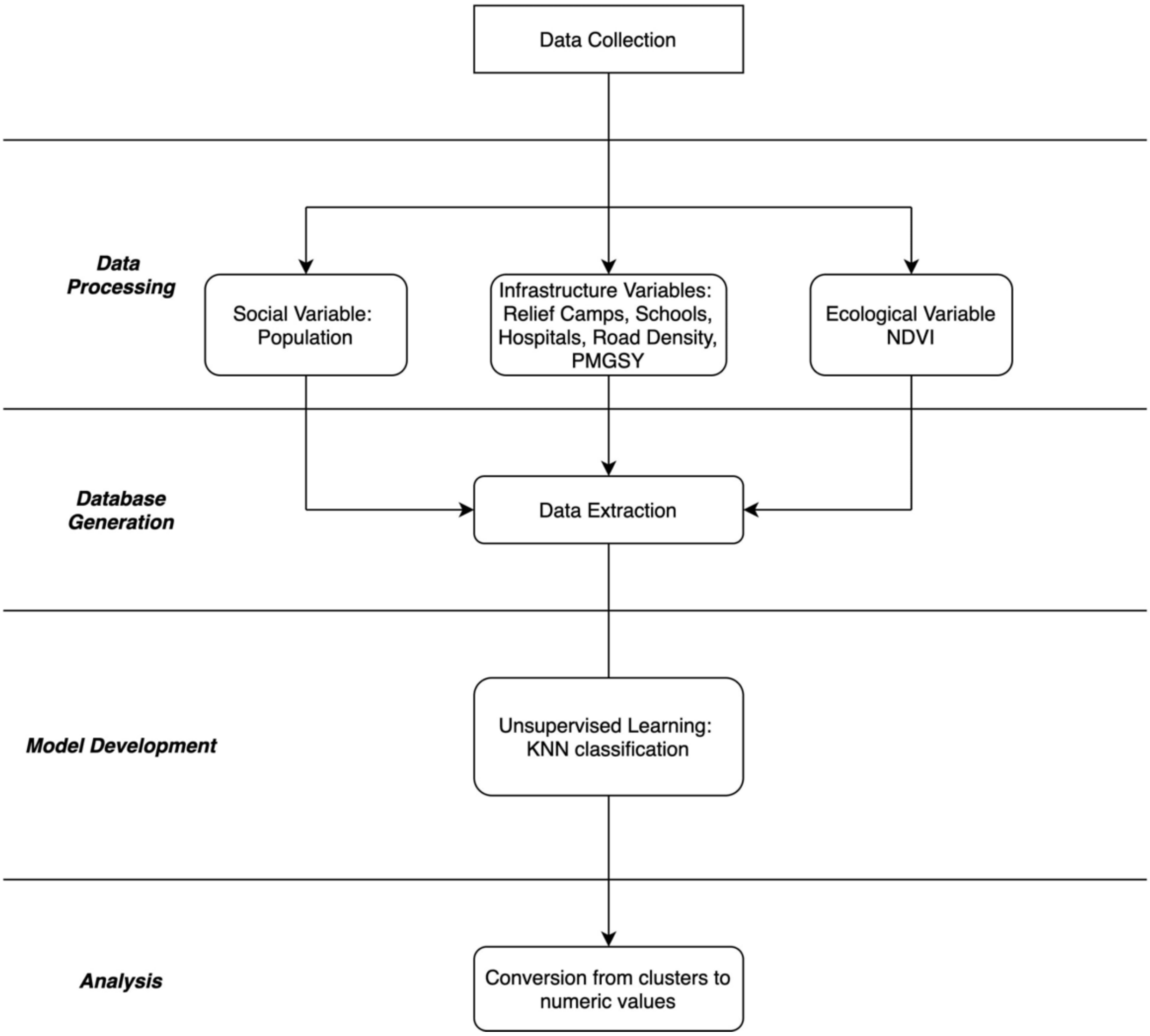

Fig 6: Resilience methodology

The variables used to measure resilience are divided into three major categories.

a) Social variable: Social variables include the area's population density. The higher is the population density in a flooded area, the more exposed will be the people to floods, thereby decreasing resilience. Therefore World pop data is used in the resilience model

b) Infrastructural Variables: Well-developed government and private infrastructure are essential for flood management. The relief camps, schools, ITI can be used to provide temporary accommodation to affected people as well as store supplies. Hospitals nearby flooded areas (contained in PMGSY data) help stop the spread of water-borne diseases. All-weather roads maintain the connectivity of flood-affected areas, thus increasing the area's resilience to floods. To account for Infrastructure data; Relief camps data from the Assam administration; Schools, hospitals, and other infrastructure from PMGSY and Road density data from the GRIP roads database are used.

c) Ecological variable: Ecological variable includes vegetation. Vegetation acts as a barrier to floodwater and reduces the speed of the water. and increase the infiltration, thereby increasing the resilience. Therefore Modis NDVI during flood time is used as an input in the resilience model

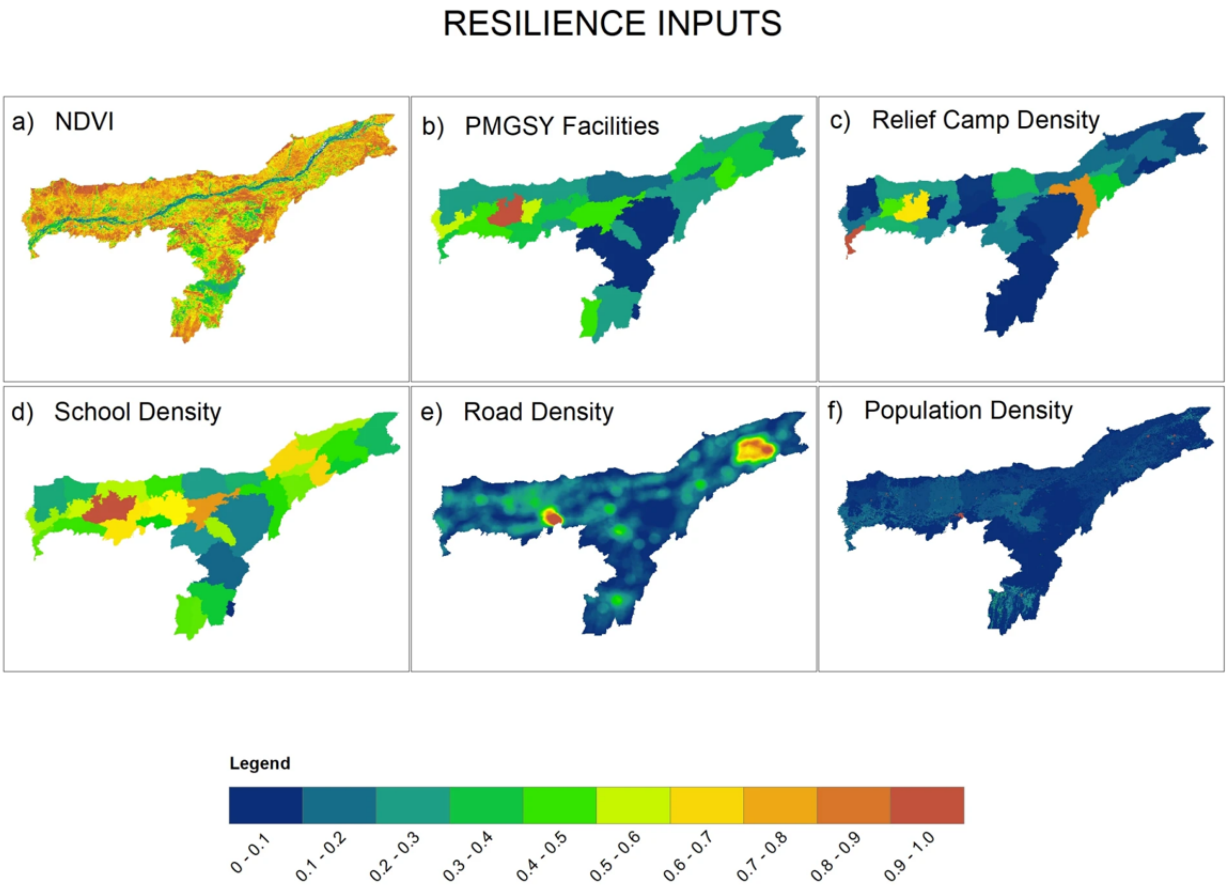

Fig 7: Resilience Inputs

All the resilience input datasets are converted into a numerical format at 100 m resolution to run an unsupervised clustering algorithm. The optimum number of clusters is found using the elbow method (fig 8)

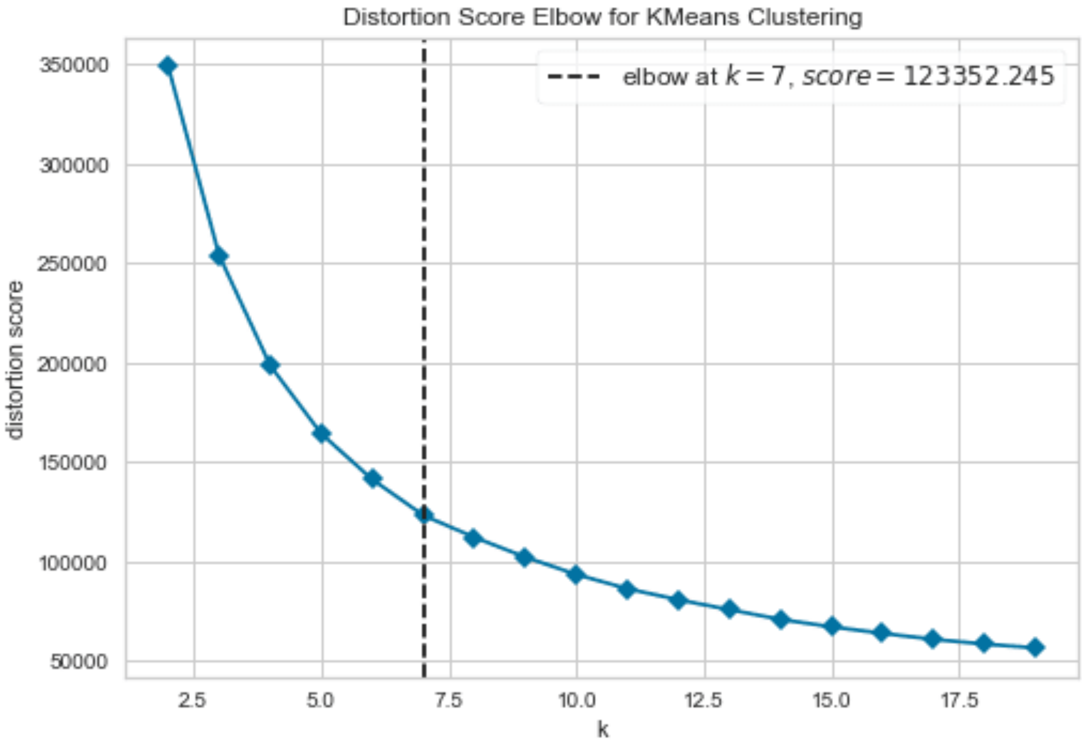

Fig 8: Optimum Clusters using elbow method

Kmeans clustering is run on the dataset to generate 7 clusters. The resilience values are allotted based on the median values of the clusters.

RESULTS

The areas having high populations and less infrastructure have low resilience to floods, as seen in Fig 9. These low resilience areas are mostly located in the floodplains of the Brahmaputra River. This is owed to the fact that the floodplains provide rich soils for agriculture, inland water transport, and abundant livelihoods.

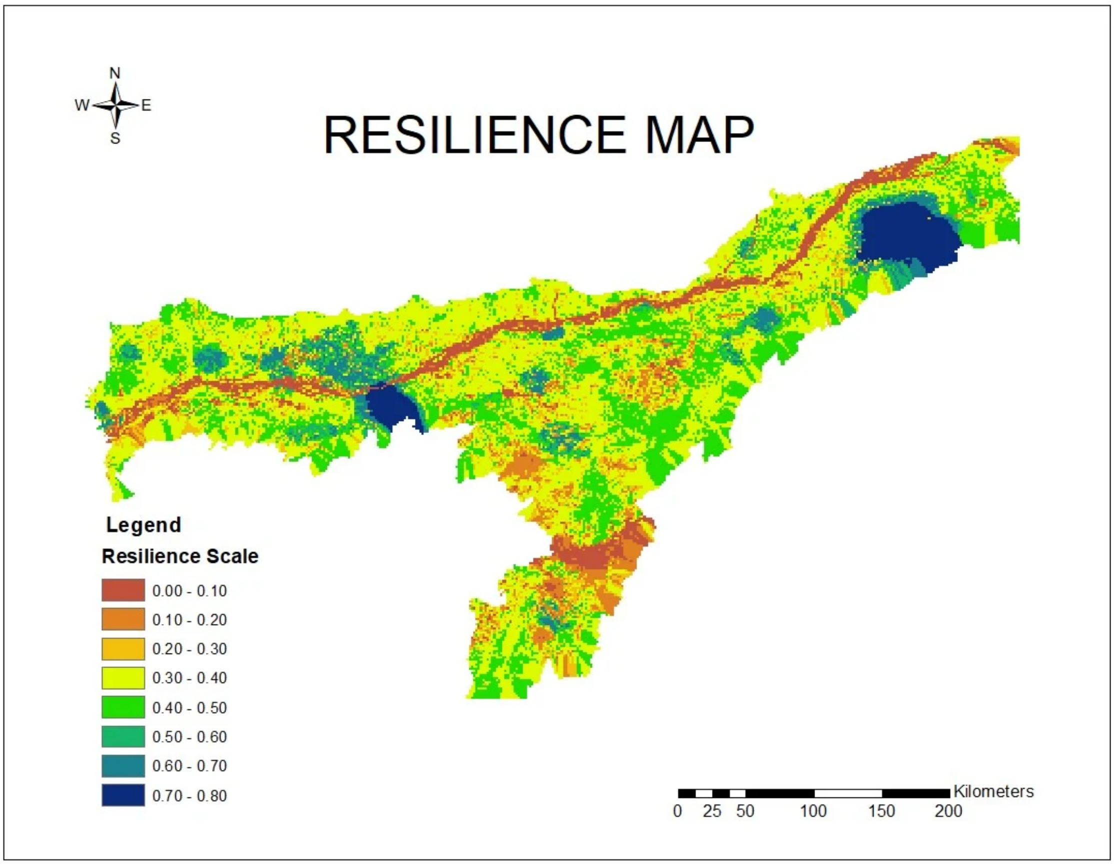

Fig 9: Resilience map

The vulnerability of the area is estimated by subtracting resilience from exposure. The vulnerability is divided into three regions.

1) The regions indicated in black did not receive floodwaters during the flood event.

2) The regions marked in green were at risk due to flood inundation. Still, adequate development strategies have reduced the vulnerability, indicating that in case of a flood event, the exposed population will be able to cope with the impact of the floods.

3) The areas having medium and high vulnerability are shown in red and dark red. These areas are localised to the middle and lower course of the river. Despite being the regions that face high flood inundation every year, they have a high population density. Low resilience, high population, and proximity to water make the areas highly vulnerable to floods, as shown in Fig 10.

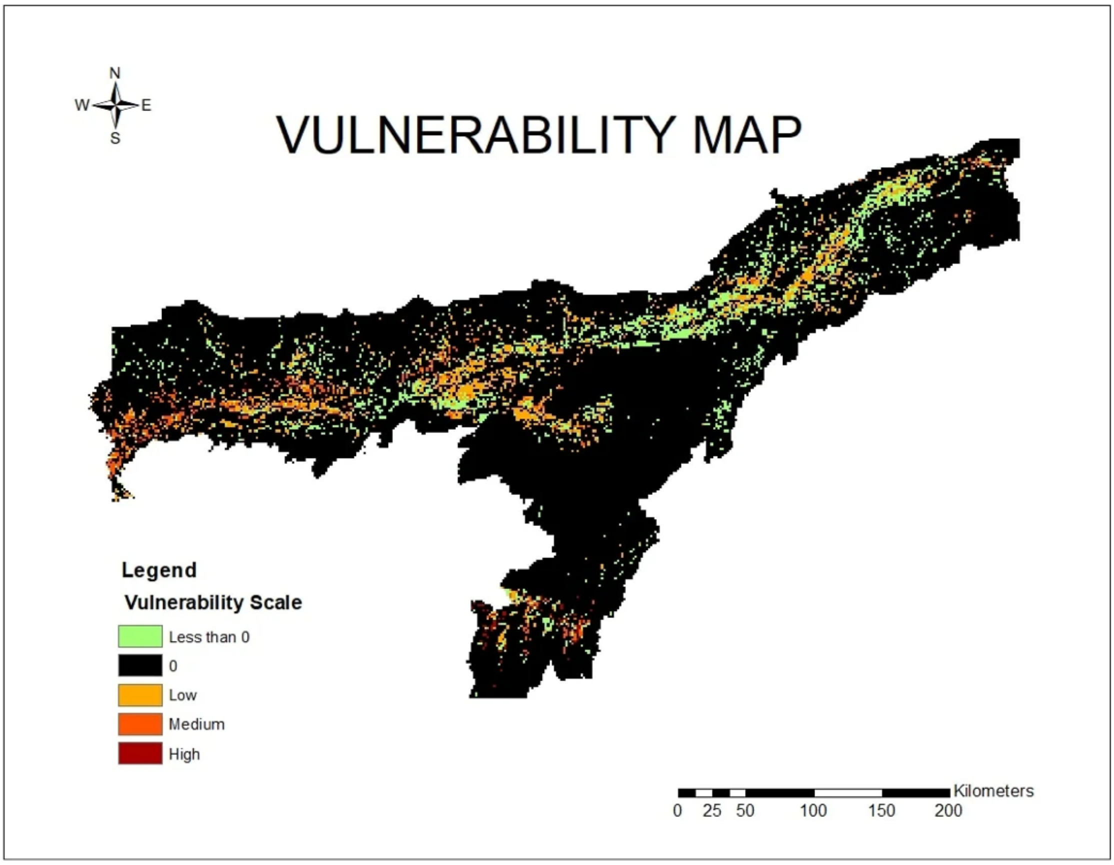

Fig 10: Vulnerability map

CONCLUSION

Flood Vulnerability Maps can help identify disaster-prone regions and take timely mitigation measures. People in the middle and lower course of the river Brahmaputra are more vulnerable to floods than people in upstream regions. This study will help the administration identify the available resources, develop new infrastructure in particularly vulnerable zones, and prepare for floods in advance.

ABSTRACT

The state of Assam, primarily in the Brahmaputra basin, is one of the most flood-prone states of India, with devastating floods occurring every year. Rapid urbanization in the floodplains and inadequate water management have further exacerbated the human and infrastructural exposure to floods. Despite efforts in organizing relief camps and setting up safe houses, flood losses in terms of life and property have increased. This study presents a novel dataset and an approach that uses a combination of satellite and ground-based data to assess the population's vulnerability to these floods. The Sentinel-1 SAR data and India Meteorological Department (IMD) rainfall data are used to determine areas in Assam that suffered from floods during July 2020. Additional datasets employed include the population density maps obtained from Facebook, road density maps from the Global Roads Inventory Project (GRIP), relief camp data from the state government, and infrastructure data from a new national dataset sourced from the Pradhan Mantri Gram Sadak Yojna (PMGSY). These geo-tagged datasets are utilized to develop a vulnerability map that would help the policymakers identify vulnerable regions and accordingly strategize infrastructure and disaster preparedness for floods.

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