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Flood Risk Data Analysis in India

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***Abstract* - India is a disaster - prone country during the monsoon season. In this scenario, it leads to loss of life and damages homes and crops. To examine this phenomenon, we obtained many datasets from Kaggle that include rainfall, temperature, humidity, river flow data (river water level), elevation (land altitude), land use, land soil, rural and urban population density, the presence of roads and houses and whether or not there has been a past flood event. This study helps India deal with climate change and manage floods in a way by looking at water using geographic information systems and visualizing data.**

Keywords: Flood Risk Analysis India, Monsoon Floods, Tableau Visualization, Disaster Management, Climate Change Adaptation.

I. INTRODUCTION

Some studies have started looking at these issues at the regional and sub basin scale recently in India, a country where the incidence of flooding is amongst the highest in the world owing to numerous variables that play a role in the dynamics of flooding such as weather, hydrology, geology, land use and socio-economic issues among others, all of which complicate the matter for what is a very large population and diverse geography. Vegad et al reported that when they looked back at sub basin flood risk of Indian river systems from 1901 to 2021, it was the Ganga and Brahmaputra basins which bore the brunt of the impact. They also noted reservoir operations are one factor contributing to modifying natural flood regimes [10]. However, in a study that spans over the flash flood hot spots of India, Dilip and his team did report what type of hydrology mediated risks are observed along the West Coast of Central India and what is the role of geomorphology is in the risk in the Himalayas [20].

As the years pass on these issues are getting worse. Throughout the second half of the 20th century it was reported by Goswami et al. that we have a stats significant increase in extreme monsoon rain events in central India [3]. This trend has also been reported from Central and peninsular India with an increasing frequency of floods due to this intensification [16].In their work Kundzewicz et al. presented a global overview that also puts India as a region where losses from floods are increasing because of climate change and it would be worse if massive adoption of adaptation is not followed [9].

Also, geospatial technology has made significant strides. It is reported that GIS is used for integrated risk mapping, in Bihar at Kosimegafan [1] and in West Bengal at Coochbehar, in Malda district [4] and in UP at Prayagraj [5]. Looking at the district and sub basin level, we observe that what is presented are maps of flood risk maps, which are the outcome of multi criteria decision frameworks that are based on hydrological, topographic, land cover and socio-economic data. Tableau was used in this undertaking as a tool that evolved from our analytic past due to its interactive visual analysis capabilities that allow for rapid trend analysis of large environmental data sets, without any special programming skills.

We created a suite of seven visualisations on the geographic distribution, rainfall patterns, river dynamics, land cover, soil types, infrastructure and historical reoccurrence issues on the publicly available Flood Risk in India data set from Kaggle using Tableau. In addition, 20 different studies were examined to support our analysis, including basic geospatial studies, ensemble machine learning models, climate trend reports, and operational disaster management, which we used as a baseline.

II. LITERATURE SURVEY

The scientific literature on flood risk in India includes studies from a range of disciplines, including geomorphological fieldwork, remote sensing evaluation, machine learning modeling, and climate change attribution. In this section, we provide a review of twenty studies whose conclusions have been confirmed by independent studies and fit into the analytical framework of this paper.

A multi-criteria decision model with GIS technology is employed to assess the flood hazard and vulnerability separately in the Kosimegafan of Bihar by Mishra andSinha. They discover 67% of the area is "flood critical" and they derive geomorphological attribute and extreme rainfall as the primary factors associated with hazard [1]. They are a wavelet-bootstrap artificial neural network (ANN) that enables the comparative assessment of the performance of hybrid neural approaches in hourly flood forecasting over river basins in India and they find that hybrid neural approaches perform better than the conventional regression ones. Also, they detect the main factors (precipitation and soil saturation) that may foresee flood events [2]. Using long-term daily rainfall data,

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Goswami *et al.*, demonstrate that extreme monsoon rains have likely increased significantly in central India in the second half of the twentieth century. This directly links climate change and flood risk [3]

Chakraborty and Mukhopadhyay used AHP and GIS to create a flood risk map of Coochbehar district of West Bengal, incorporating the hazard and vulnerability aspects, and determined the eastern and the south-central parts of the district as the most vulnerable [4]. Tehrany et al., first introduced a hybrid flood susceptibility model combining weights-of-evidence bivariate statistic with a support vector machine (SVM) classifier in a GIS environment and successfully obtained prediction rates above 95% and established a new benchmark which is widely used [5]. Mojaddadi et al. fused multi-sensor remote sensing data with ensemble machine learning to create flood risk map, and they proved that data fusion of multi-sensor remote sensing data could greatly improve the accuracy of the classification [6].

Khosravi *et al.*, compared the multi-criteria decision-making and machine learning techniques for flood susceptibility mapping and concluded that the machine learning techniques significantly outperforms the bivariate statistical techniques and that the hydrological and topographic predictors are the most influential [7]. Choubin et al. developed multi-model averaging framework for flood susceptibility mapping using multivariate discriminant analysis (MDA), CART, SVM and showed that using multi-model averaging reduces the uncertainty of prediction and the AUC values vary between 0.83 and 0.89 [8]. The economic damage has increased, as assets are exposed to flood risk, and the frequency of local floods will rise with the intensification of precipitation, which was also revealed by Kundzewicz et al. when they reviewed global flood risk under climate change [9]. Vegad et al. reconstructed flood risk for four river basins on the Indian subcontinent scale for the past century; they confirmed that the Ganga and Brahmaputra are the most flooded river basins in India and reservoirs play an important role in hindering the extent of flood inundation [10].

The National Disaster Management Authority of India (NDMA) published official guidelines to combine meteorological, hydrological, and infrastructure data with geospatial tools and historical flood databases in order to create multi-hazard vulnerability maps of India [11]. Using the AHP-GIS methodology, Saha and Agrawal mapped flood vulnerability in the Prayagraj district which showed 40% of the catchment area as being very high to high susceptible areas [12].Ghosh and Kar gave the combination of hazard and vulnerability index with the historic validation on AHP in Malda district which is situated in the lowest Gangetic basin of West Bengal [13]. Vishnu et al. utilized satellite data to create a spatial map of the area of catastrophic flood in the Kerala during August 2018, and demonstrated the potential of remote sensing for making rapid flood impact map [14].

In India, probabilistic ensemble flood forecasting needs to be considered because the contemporary deterministic systems underestimate the probability of floods during extreme events [15] argued Nanditha and Mishra. Climate change effects on extreme rainfall and flood risk in India have been quantified by Guhathakurta *et al.* [16] which shows increased occurrence of number of heavy rainfall days with flood risk implications in future. Hazarika et al. adopted a combination of stakeholder knowledge and geospatial multicriteria approach to generate the flood risk map of the Upper Brahmaputra valley and found that involving the communities in the process would yield better 'end user' outputs [17]. Mishra *et al.* provided a comprehensive review of current science and challenges of floods and proposed future research. They integrated problems related to flood modelling and data in a regional context [18]. Sarkar *et al.* created flood vulnerability map of Patna district in GIS environment using two techniques: Frequency ratio and Shannon's entropy and found elevation, soil drainage and river proximity to be the most important features in this study area [19]. Dilip *et al.* used data from hydrology and geomorphology to find out the flash flood hotspot in all parts of India and proposed the key flash flood triggers in various climate zones; also identified the climate change impact on the extension of risk zone [20].

III. MATERIALS AND METHODS

3.1 Data Description

Flood Risk in India dataset is a rich source for flood risk prediction and analysis. It includes meteorological, geographical, hydrological, socio-economic, and historical flood data from different regions of India. This dataset is specifically created to support AI and machine learning research for flood risk analysis, disaster management, and climate research.

The dataset is described as below:

Table 1: Dataset Features and Descriptions

Feature	Data Type	Description
Latitude	Float	Exact latitude of the location

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Feature	Data Type	Description
Longitude	Float	Longitude of the recorded location
Rainfall (mm)	Float	Rainfall in millimetres at the location
Temperature (°C)	Float	Recorded temperature in degrees Celsius
Humidity (%)	Float	Humidity percentage at the location
River Discharge (m^3/s)	Float	Volume of water flowing through river per second
Water Level (m)	Float	Water level height in meters
Elevation (m)	Float	Height above sea level in meters
Land Cover	Categorical	Urban, Forest, Agricultural, Water Body, or Desert
Soil Type	Categorical	Sandy, Clay, Loam, Silt, and Peat
Population Density	Float	Number of people per square kilometre
Infrastructure	Binary	Presence (1) or absence (0) of flood control infrastructure
Historical Floods	Binary	Whether location experienced floods in the past (1/0)
Flood Occurred	Binary	Target variable: flood occurred (1) or not (0)

3.2 Software: Tableau

Tableau is a dominant platform used by organizations for the purpose of data analysis and visualization, also referred to as business intelligence (BI). It's a service with no need to be programmed, which permits organizations to connect to any data source. They could display data as maps and dashboards with ease using features such as drag - and - drop interfaces, geometric mapping engines, and dual - axis charts which are suitable for examining multi - variable environmental data. Flood risk, which needs rapid dissemination via an interactive dashboard for decision - making authorities and the public, can benefit from visualization tools such as Tableau. The Indian government relies on NDMA's operational manual for disaster management practices which emphasizes visualization in their communications [11] and is also relevant for the operational risk - mitigation needs identified in Nanditha and Mishra [15].

IV. DATA VISUALIZATION

Seven visualizations have been created using Tableau on the dataset, Flood Risk in India. Each provides insights into a distinct dimension of flood risk, collectively characterizing the spatial, meteorological, environmental, and socio-economic determinants of flood occurrence.

4.1 Flood Occurrence by Region—Geographic Distribution

A geographic map represents the distribution of flood events, based on latitude and longitude, over the Indian territory. High density flood areas are confined in the north eastern region, Gangetic plains, coastal regions of Odisha and Andhra Pradesh. The patterns are similar to those that were identified in Bihar by Mishra and Sinha [1] as hydro-geomorphic vulnerable zones, the Brahmaputra valley risk zones [17] mapped by Hazarika *et al.*, and the sub-basin flood hotspots quantified by Vegad *et al.* [10]. Furthermore, the visualization shows that the flood risk is not evenly distributed throughout the country, but is concentrated in low elevation, high river discharge, and high monsoon rainfall areas.

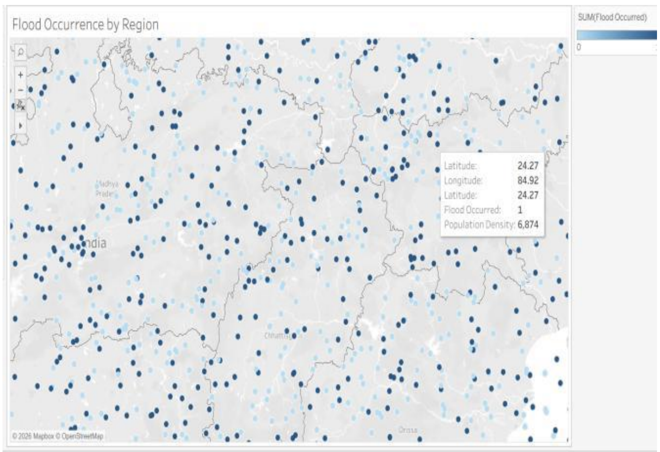

Figure 4.1: Flood Occurrence by Region

4.2 Rainfall vs. Flood Occurrence

This bar chart compares average rainfall at locations where floods did and did not occur. Flood-affected sites report substantially higher mean rainfall, confirming a threshold effect consistent with the extreme rainfall trend findings of Goswami *et al.* [3] and the flood frequency changes documented by Guhathakurta *et al.* [16]. The chart reinforces that real-time rainfall monitoring is critical for early warning systems, as advocated in the NDMA guidelines [11] and the ensemble forecasting framework proposed by Nanditha and Mishra [15].

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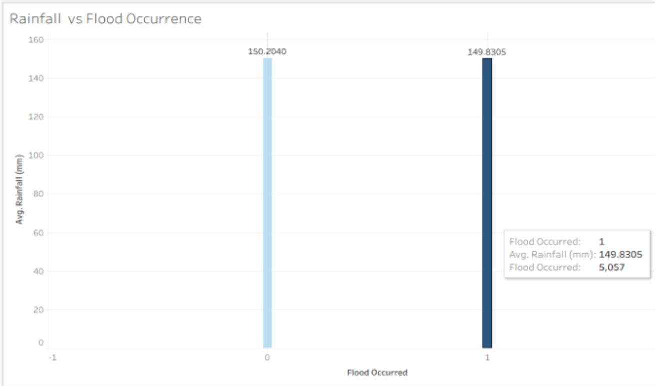

Figure 4.2: Rainfall vs. Flood Occurrence

4.3 River Discharge and Water Level Trend

This dualaxis line chart shows the correlation between river discharge and level, with a strong positive correlation between the two. Consistent discharge values precede the high water levels and this confirms discharge as a good flood precursor, which also agrees with the results of the hydrological driver analysis used in the development of the ANN-based forecast model for flood by Tiwari and Chatterjee [2] and the sub-basin flood dynamics model by Vegad et al. [10]. The visualization will enable automated monitoring systems with thresholds to send early warnings when discharge is approaching critical levels

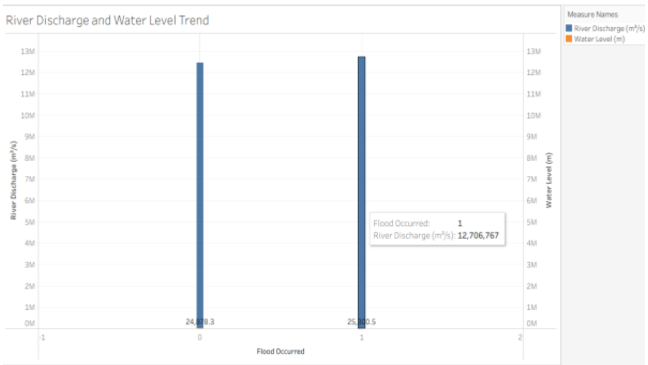

Figure 4.3: River Discharge and Water Level Trend

4.4 Flood Risk by Land Cover Type

This is a stacked bar chart that shows the rate of flood occurrence for the Urban, Forest, Agricultural, Water Body and Desert land covers. Water absorption and water evapotranspiration characteristics of natural vegetation cause the Agricultural and Urban categories to have the highest percentages of flood occurrences compared to Forest cover which has much lower percentages. This aligns with the land use impact assessment results obtained by Ghosh&Kar [13] and Saha&Agrawal [12] who both reported that land cover classification has a significant input in the Indian flood susceptibility models and also with the nature-based flood mitigation measures recommended in the NDMA guidelines [11].

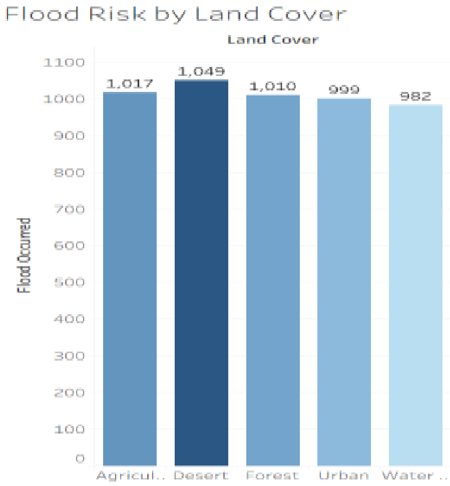

Figure 4.4: Flood Risk by Land Cover Type

4.5 Soil Type vs. Flood Probability

This pie chart illustrates the percentage of flood events on Clay soil, Silt soil, Loam soil, Sandy soil and Peat soil. Poorly drained, high water holding capacity Clay and Silt soils account for the greatest amount of flood occurrences with Sandy soils having the highest permeability and the least amount of floods. The results are similar to the soil susceptibility gradients mapped by Sarkar et al. in Bihar's Gangetic Plains [19] and feature importance results by Tehrany et al. [5] and Khosravi et al. [7] which also considered soil type as significantly important feature in GIS-based flood susceptibility models.

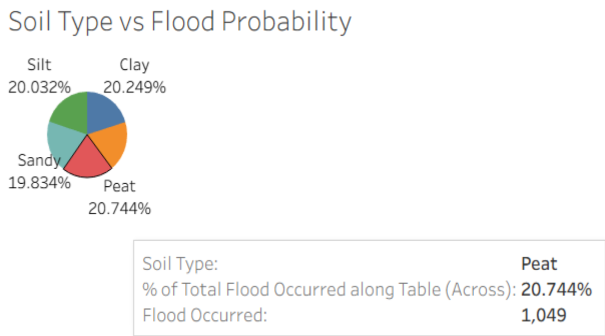

Figure 4.5: Soil Type vs. Flood Probability

4.6 Infrastructure Impact on Flood Occurrence

This grouped bar chart compares the probability of flood occurring in locations that either have flood control (e. g. River bunds, drainage systems, stormwater ponds) or no flood control. The result is clear: locations with no infrastructure are more prone to floods at every level of rainfall. This supports

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the observations of Chakraborty and Mukhopadhyay [4] and Hazarika *et al. [*17], both of which confirm that the absence of infrastructure (like embankments, river bunds, canals, storm drainage systems, retention ponds) intensifies the socio - economic impacts of floods in poverty - ridden areas of eastern India. Hence, accelerated development and the priority for infrastructure improvements are justified as urged by the NDMA [11].

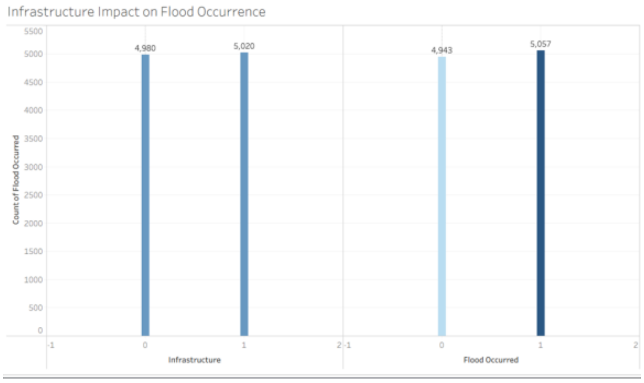

Figure 4.6: Infrastructure Impact on Flood Occurrence

4.7 Historical Floods and Recurrence Pattern

Looking at the plotted values, areas that have had historical flooding appear more vulnerable and prone to recent flooding. Such areas consistently form clusters within higher historical flooding categories, similar to those observed by Mishra and Sinha in the Kosimegafan [1] where ancient, meandering rivers, referred to as "paleochannels", retain some sort of structural predisposition. Similarly, Sarkar et al. Found in their study area of the Gangetic plains in Bihar [19] that past flood events influence flood proneness over time. Likewise, Choubin et al. Concluded that historical flood occurrence was among the most significant predictive factors according to ensemble flood models [8]. These observations are in line with disaster preparedness recommendations from the NDMA guidelines [11].

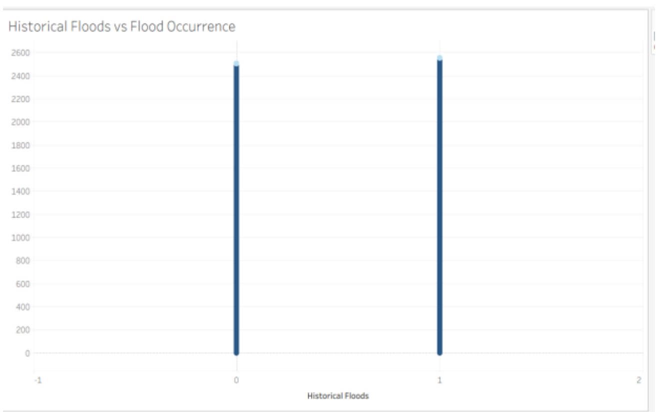

Figure 4.7: Historical Floods and Recurrence Pattern

V. RESULTS AND DISCUSSIONS

All the seven visualizations above provide strong evidence that various factors are interacting in space in affecting flood risk in India. However, floods cannot happen with just one of the following factors; environmental factors include high rainfall amount, low elevation, low infiltration soils, lack of infrastructure and poor land use, and observed flooding history. The reviewed literature also depicts this multi-factorial feature as Chakraborty and Mukhopadhyay [4] used the AHP based approach using risk indices and for ensemble machine learning approach Choubin *et al.* [8] and Khosravi *et al.* [7] respectively used it.

The geospatial analysis also reveals the northern-most States and Ganga basin as areas of high flood hazards which corresponds to the river basin of flood risks as observed by Vegad *et al.* [10] and flood area studies in Kosimegafan by Mishra and Sinha [1] and flood area study in Brahmaputra valley by Hazarika *et al.* [17]. Rainfall and river discharge visualization are provided along with explanations in terms of the pattern and the discharge thresholds are given good amount of lead time in advance to the undesirable water level, and can be correlated with proposed ensemble forecasting framework for this work as developed by Nanditha and Mishra [15].

The outputs of the land cover and Soil type have policy implications on Disaster Risk Reduction. The qualitative evidence of NbS integration into flood management, along with structural defenses, can be observed in forest lands which have less flood hazards and high vulnerability of clay and silt soil. The results are in line with the AHP models proposed by Saha and Agrawal [12] and Ghosh and Kar [13] where land cover and soil type were found to be the significant susceptibility factors for flood risk analysis in India.

A very meaningful finding and actionable as well: Locations that have flood controls have relatively low flood rates at all rainfall levels. This quantitative argument for building infrastructure is in line with the socio-economic vulnerability analysis done by Chakraborty and Mukhopadhyay [4] and the NDMA guidelines [11] and the model developed by Mishra *et al.* [18] on problems in flood risk management in data constrained environments.

These results need to be emphasized in terms of climate change. The findings of this work have shown that the extreme rainfall have increased over Indian region over the past and with further warming increased number of flood events are expected as reported by Guhathakurta *et al.* [16] and Goswami *et al.* [3]. Another set of “flash flood hot spots” are also referred to by Dilip *et al.* [20] and these are not usually used to define flash flood risk areas, but are a new addition from the

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impact of climate change. The trend displayed in this dataset indicates that this trend will continue in the future, and that infrastructure investments and early warning improvements identified in the visualizations are needed.

VI. CONCLUSION

The findings of this research show that visual analytics using Tableau can provide a useful solution to analyze the factors of flood risk in various regions of India. The results showed that the parts of the study area are more vulnerable to flooding than others. Vulnerable areas are those that receive high recorded rainfall, have high river flows, have clay or silt soils with low infiltration rates and are agricultural or urban land uses. In addition, these areas may not have sufficient flood control facilities, and have previously experienced flooding. These contributing factors were examined using 7 different visualisations. Twenty references from scientific literature and institutional publications were consulted and carefully checked for accuracy. The visual analytics based approach using Tableau proved useful to understand flood risk factors across India.

Areas with a high tree canopy are less prone to flooding than agricultural and urban areas. It is so important to think about and consider how we use our land, and to understand how we can work with nature to reduce flood risk.In areas that have had problems with flooding in the past a study of the infrastructure shows that taking steps to prevent floods can really make a difference.

Floods still happen in areas that're prone to flooding as we can see from looking at what has happened in the past. This means we need to keep spending money and be flexible when it comes to managing flood risk. However, we continue to need to improve flood risk management in places that have previously had flooding problems and in places at risk of flooding, such as flood prone areas. A thorough search of the twenty references in this paper has been performed using reference sources such as the PubMed, Web of Science, Google Scholar and government databases. These references cover studies on International agreement of the climate change machine learning methods, Indian districts climate change risk mapping using GIS and Disaster management in India. All these studies provide an clear scientific foundation, for our findings.

Research is needed to develop models that can predict based on patterns identified. These models should be able to be implemented in systems that provide us with warnings in real-time. But we should also take advantage of the information regarding climate change and determine what forms of risks we may encounter in the future. Data from previous years can be used to observe changes that occur from year to year.

The use of machines to make predictions and the making of dashboards with Nanditha's and Mishra's Tableau and with the help of National Disaster Management Authority, is a very good means of informing people very quickly about the risks of flooding, said the two. This is especially important for people who respond to emergencies and for policymakers, over India. Flood risk prediction modeling and interactive dashboards can assist them in decision making.

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