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Assessing Earthquake Risk in North-eastern India Through Python and Geospatial Analysis

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ABSTRACT

North-eastern part of India is among the regions that experience the highest seismic activities in the country. These include Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and parts of northern West Bengal. North-eastern India is close to area where the Eurasian Plate and Indian plate meet. Seismic activities in the region occur due to tectonic movements within the region. Since this region experiences high levels of seismicity, it is important that preparations are to be optimal to cope with potential earthquakes. Preparations involve setting up building laws to guarantee the constructions can withstand the pressure exerted by the quakes and planning on how to respond to an earthquake when it occurs. It is also important for the inhabitants of this area to understand the seismic hazard in their locality and apply ways that will reduce the impact of earthquakes. Accordingly, this article will utilize of statistical analysis and Arc GIS Software for assessing the earthquake risk potentiality in the North-Eastern India.

KEYWORDS: Coping capacity; Vulnerability; Hazard; Risk map.

1. INTRODUCTION

The North Eastern Region (NER) of India, lying within the Eastern Himalayas, falls under the highest-risk category in the seismic zones of India (seismic zone V) according to the IS-1893 (2016). Therefore, this area can be termed as being among the most seismically prone zones in the world (Das et al., 2012). There is a lot of seismic activity in this area. The geologically complicated and tectonically sophisticated nature of the region arises from the converging plate boundary formed by the Indian Plate with the Eurasian Plate in the northeast, which has resulted in the formation of the Himalayan fold mountains, and further leads to the subduction taking place underneath the Indo-Burmese ranges trending North-Northeast-South-Southeast (NNE-SSE) (Agrawal et al., 2022; Baro et al., 2018). Hazards can have different effects on environmental, physical, and socio-economic losses within a given time and space (Agrawal et al., 2021). Numerous major earthquakes have caused significant loss of life and property damage in these regions. Two major earthquakes happen in this region are Shillong earthquake in 1897 and the Assam earthquake (magnitudes >8.0) in 1950 (Bilham & England, 2001; Mrinalinee Devi & Bora, 2016; Thingbaijam et al., 2008).

2. OBJECTIVES

The primary goals of the current study were as follows:

- To assess North-East India's risk zone and coping capacity measures.
- To look at the estimation of priority and rank for each vulnerability parameter.
- To determine the main seismic zones in north-eastern India.

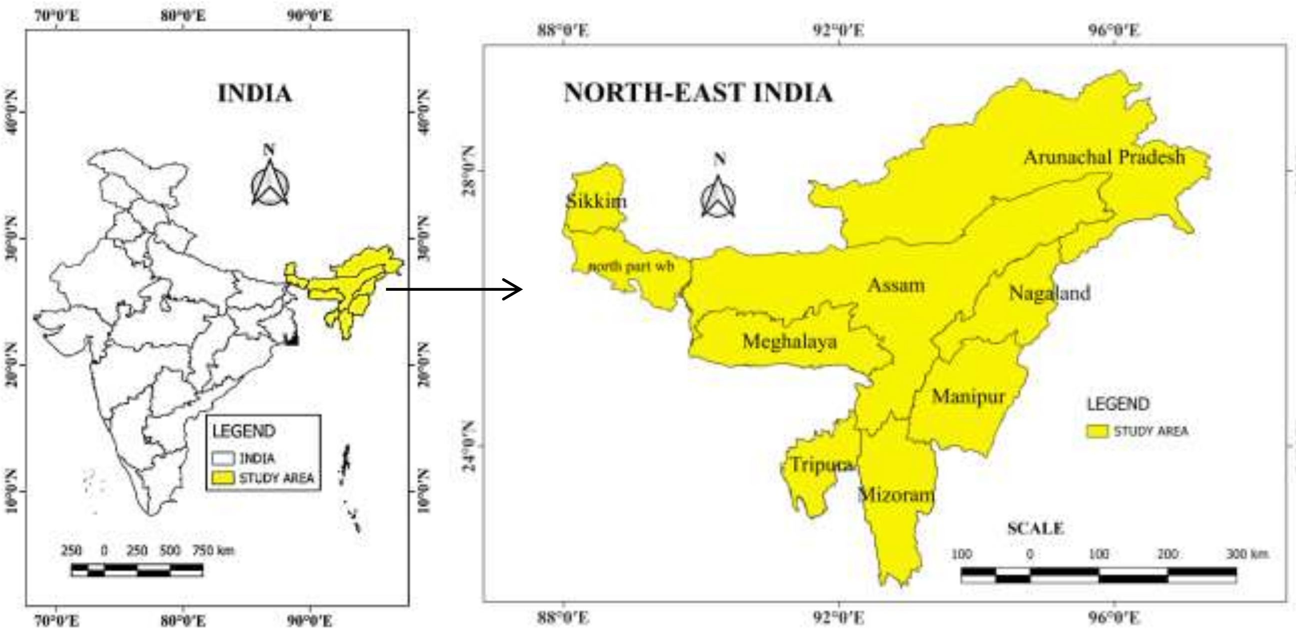

Fig. 1. Location map of the study area

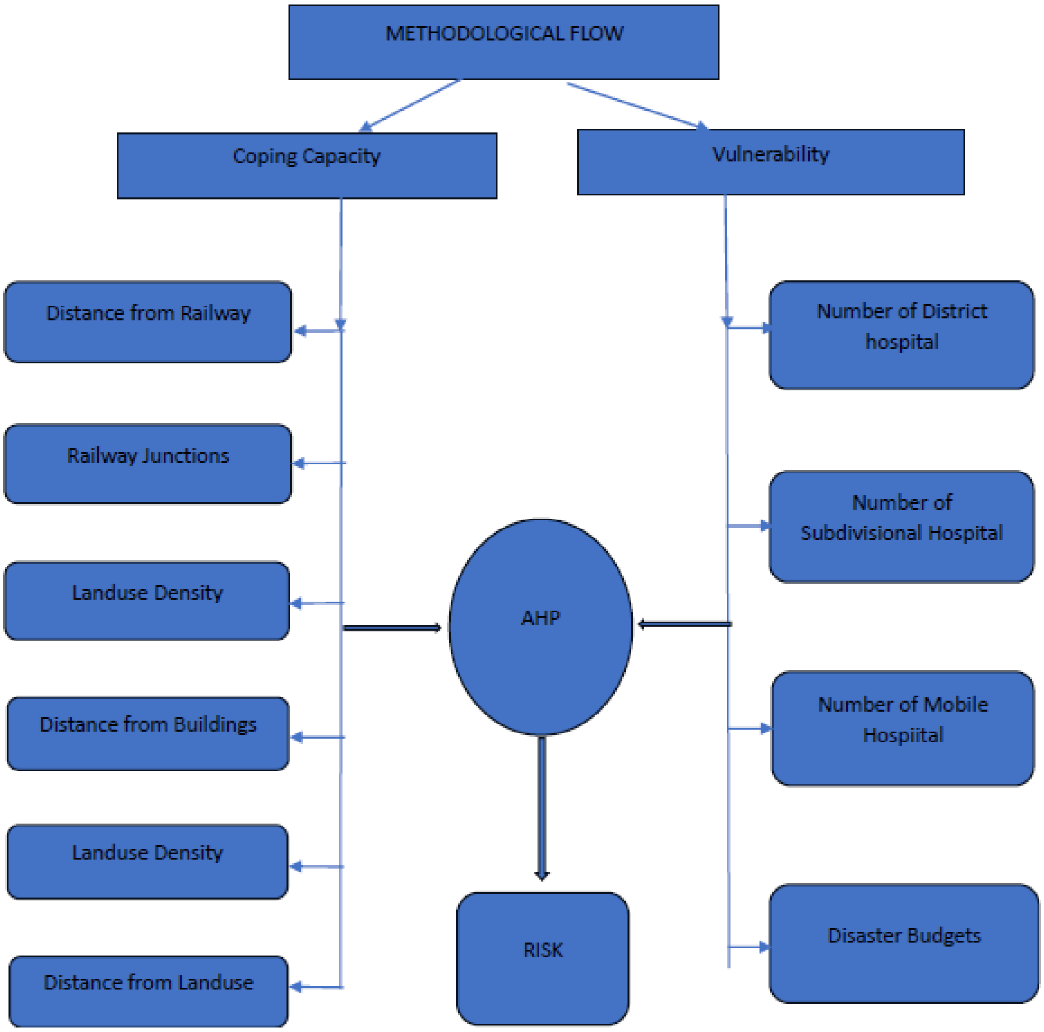

Fig. 2. Schematic diagram of the study design

3. STUDY AREA

The term "NE India" describes the region in north-eastern India that comprises the states of Assam, Meghalaya, Arunachal Pradesh, Manipur, Nagaland, Sikkim, Mizoram, and Tripura. The total population of Northeast India is 45772188, and the region is roughly 262230 km² (Fig. 1). North-eastern India is composed of three major plates: the Indian, Burmese, and Eurasian Plates. This area is very prone to earthquakes. Numerous earthquakes with maximum magnitudes of 8.0 > Mw > 7.0 have occurred.

4. METHODOLOGY

Earthquake data were gathered from various databases, including the United States Geological Survey (USGS) for NE India, for historical occurrences between 1980 and 2024, and used to train and validate the Python code. Maps of hazards, vulnerabilities, and risks were created using GIS-created databases. Several risk assessment layers were developed using a variety of methods, including spline, buffer, Euclidean distance, and Inverse Distance Weighting (IDW) (Fig. 2).

5. RESULTS AND DISCUSSION

5.1. Coping Capacity

The coping capacity map for the NE India disaster was made using two different kinds of data. The overall risk was calculated by combining coping capacity with the hazard and vulnerability indices. The integrated coping ability risk map was then developed by classifying 5 groups mentioned in the risk section (Fig. 3). The weighted sum technique was used to assess the overall capacity in Northeast India, taking into account the disaster fund (50%), mobile (20%), district (15%), and sub-divisional hospitals (15%) weights. Coping skills in Northeast India vary by state. Some states have low to very low levels of coping ability, while Assam, Sikkim, and Arunachal Pradesh are among those with moderate to high levels. On the other hand, Manipur is a very high-hazard state. Manipur and Tripura are areas of extreme vulnerability and coping capacity.

According to the vulnerability outputs, the south-northern (SE) regions are considered to be moderately to highly vulnerable to earthquakes because of their close proximity to active faults. However, lower elevation, higher population density, moderate slope, higher rail numbers, and higher land use-land cover (LULC) are the reasons for the extremely high susceptibility in the designated zones. The highly vulnerable regions are thought to be caused by a number of factors, including a high land use density, a high proportion of dependent individuals, land use that is close to the epicentres and a population that depends on railroad roads. They are located in close proximity to seismically significant areas. Due to their planned built-up areas, hospitals, mobile hospitals, and first-rate educational systems, Assam, Sikkim, and Arunachal Pradesh have a strong capacity to recover from the devastating effects of multiple earthquakes and active faults. High-risk areas in north-eastern India are defined as having a high fault density and epicentre, low elevation, steep slopes, dense land use and population, and magnitude distribution with a lower coping capability index. None the less, due to their ability to mitigate status and appropriate planning, certain high-risk locations may be reduced to low risk (Hoque et al., 2019; Jena & Pradhan, 2020).

5.2. Vulnerability Priority and Rank Estimation

5.2.1. Vulnerability Analysis

Six levels were considered for vulnerability evaluation due to data scarcity and consistency issues with the AHP technique (Jena and Pradhan, 2020). The strata are described in the table. The relative significance of the parameters used in the pairwise comparison is shown in Table 1. The normalizing process was then used to determine each layer's weight and rank. A number of factors were used as input data to evaluate the LULC and community vulnerability (Figs. 8 to 9). An earthquake vulnerability mapping was made and divided into 5 sections using the quartile classification methodology (Fig. 10). The table chart indicates that very low-risk areas cover 0.04% of the territory. The vulnerability index was created by processing the five criteria. High and very higher vulnerable zones cover about 22.54% (63620.3 km²) and 0.16% (458.68 km²) of the entire area, respectively. However, moderate covers 55.09% (155532 km²) and 22.17% (62584.2 km²) of the area, respectively (Table 2).

5.2.2. Hazard Analysis

In NER of India, the degree of regional variation in earthquake-prone zones is very high. As a result, an intensity level greater than five might be considered a dangerous area. The regions in the south-western corner of Arunachal Pradesh,

Table 1 Illustrates the Priority Check and Decision Matrix Data

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat	Priority	Rank	(+)	(-)
1 Building Density	34.5%	1	9.3%	9.3%
2 Distance from Building	26.4%	2	8.4%	8.4%
3 Landuse density	14.5%	3	7.3%	7.3%
4 Distance from Landuse	8.5%	4	3.4%	3.4%
5 Distance from railway	8.2%	5	3.5%	3.5%
6 Railway Density	8.0%	6	3.8%	3.8%

Number of comparisons = 15

Consistency Ratio CR = 6.7%

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3	4	5	6
1	1	2.00	3.00	4.00	4.00	3.00
2	0.50	1	3.00	3.00	4.00	3.00
3	0.33	0.33	1	3.00	3.00	1.00
4	0.25	0.33	0.33	1	1.00	2.00
5	0.25	0.25	0.33	1.00	1	2.00
6	0.33	0.33	1.00	0.50	0.50	1

Principal eigen value = 6.423

Eigenvector solution: 6 iterations, delta = 3.8E-9

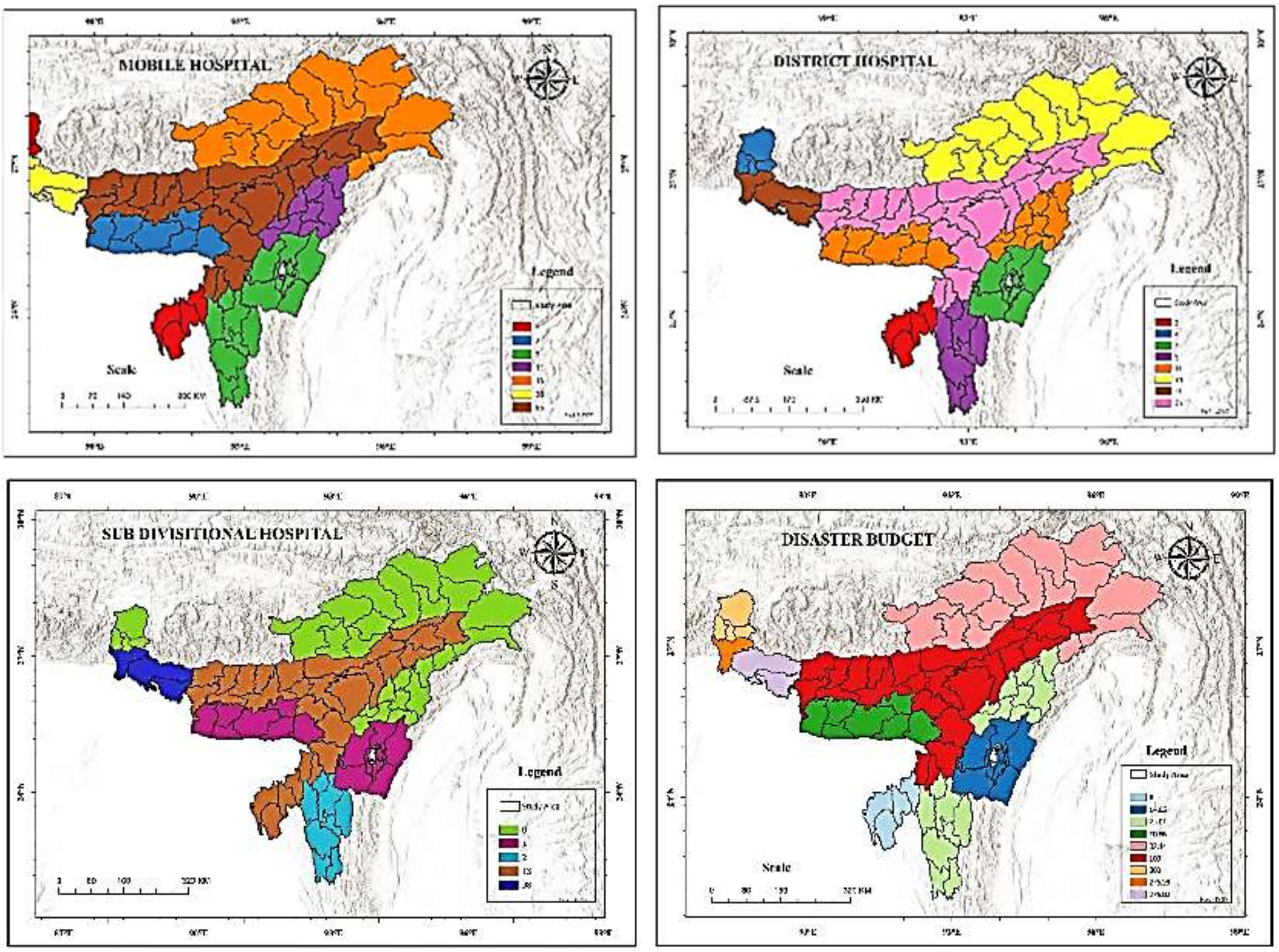

Fig. 2. Coping Capacity Maps

the southern part of Nagaland, the whole of Manipur, and the northern part of Mizoram have extremely high levels of intensity variation. While the NE and central parts of the region fall into the moderate to medium intensity variation. Very low intensity variation is found in Arunachal Pradesh and the Coochbehar district (Value <5). The hazard map was divided into five groups according to intensity variation: high (8–9), moderate (6–8), low (5–6), very low (<5), and very high (>9). Hazard data show that 68.14% (192458 area sq.km) of NE India is in a high-hazard zone and 7.6% (21452.6 area sq.km) is very high-hazard zone (Fig. 11) and (Table 2). The northern region and coastline of north eastern India were designated as high hazard zones on the hazard map due to a significant number of high-intensity, often occurring meteorological disaster. An extremely strong hazard zone is found in the states of Manipur and Nagaland. A very low hazard zone is occupied in Arunachal Pradesh. The moderate hazard zone indicates Coochbehar, Alipurduar, Jalpaiguri district, with a value of this zone 45942.5 Area Sq Km.

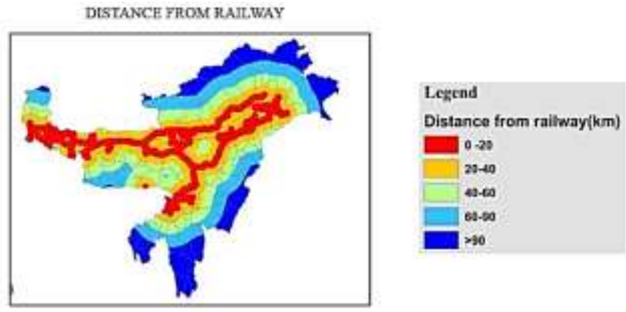

Fig. 4. Distance form Railway

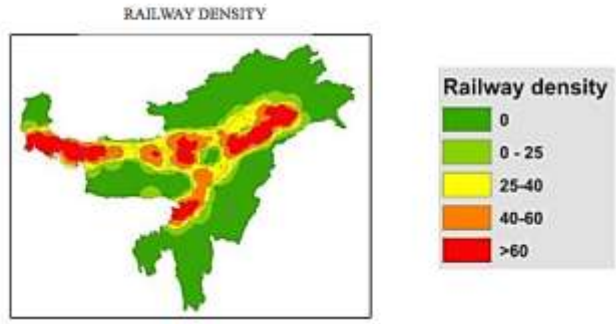

Fig. 5. Railway Density

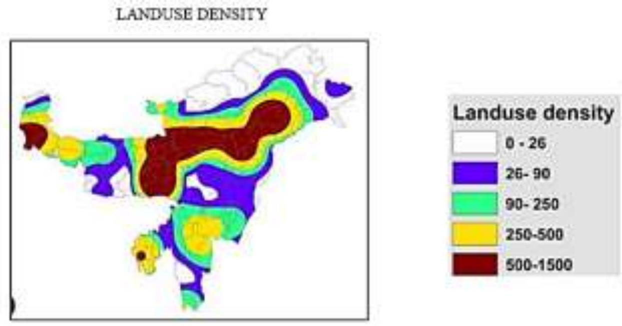

Fig. 6. Land-use Density

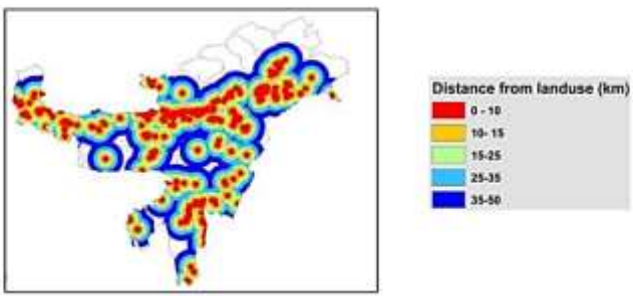

Fig. 7. Distance from Land-use

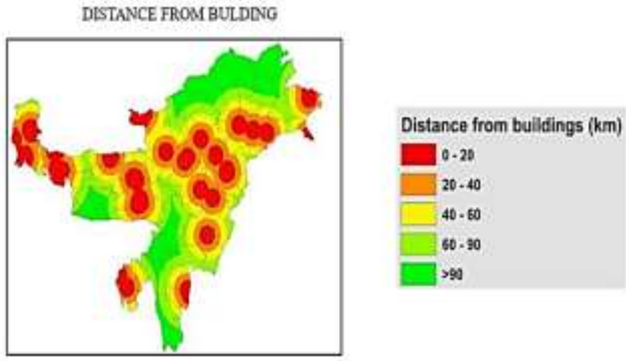

Fig. 8. Distance from Building

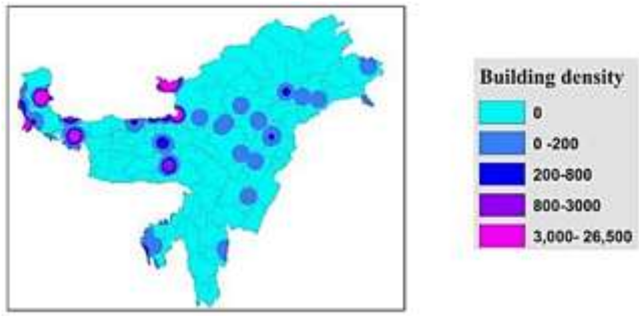

Fig. 9. Building Density

5.2.3. Risk Analysis

Figure 12 shows the estimated, mapped, and spatially represented earthquake risk. The risk map was displayed as very-lower, low, medium, higher, and very higher after it was categorized using quartile classification algorithms. The area's high-risk zone was made up of 22.51% (59256.3 km^2), while 12.71% (36148.6 km^2) of the territory was classified as extreme higher risk zone, according to the risk results. The areas classified as medium, very low, and low risk are roughly 30.98% (87458.3 km^2), 12.80% (35889.5 km^2), and 20.99% (63548.6 km^2), respectively (Table 2). Assam state may be classified as a moderate-risk zone, whereas certain areas of Arunachal Pradesh fall into a low-risk zone. The southern part of Assam indicates a very low risk zone (12.80%). The validation of the risk map is based on the work (Pandey, 2017), which displays the total incidents and dense clustering in North-east India. A high probability zone covers 249,070 km^2 of the North-east, according to the probability distribution research (Fig. 12).

The most popular multi-criteria decision-making (MCDM) technique in academia and business is AHP, which also offers the most suitable answer for priority output. The combined geospatial and AHP methodologies, which are

Table 2 Result of Vulnerability and Hazard Data

Classes	Class No.	Vulnerability Data		Hazard Data		Risk Data	
		Area (Sq. Km)	Area %	Area (Sq. Km)	Area %	Area (Sq. Km)	Area %
Very high	1	458.68	0.16	21452.6	7.60	36148.6	12.71
High	2	63620.3	22.54	192458	68.14	59256.3	22.51
Moderate	3	155532	55.09	45942.5	16.27	87458.3	30.98
Low	4	62584.2	22.17	1702.85	0.60	63548.6	20.99
Very low	5	105.68	0.04	20745	7.35	35889.5	12.80
Total		**282301**	**100.00**	**282301**	**100.00**	**282301**	**100.00**

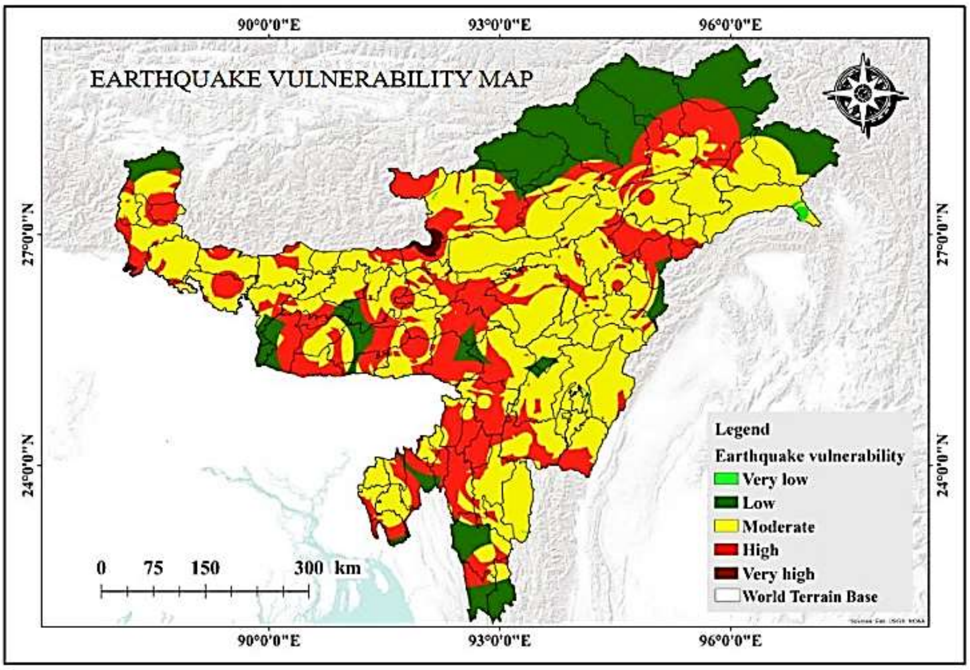

Fig. 10. Earthquake Vulnerability Map

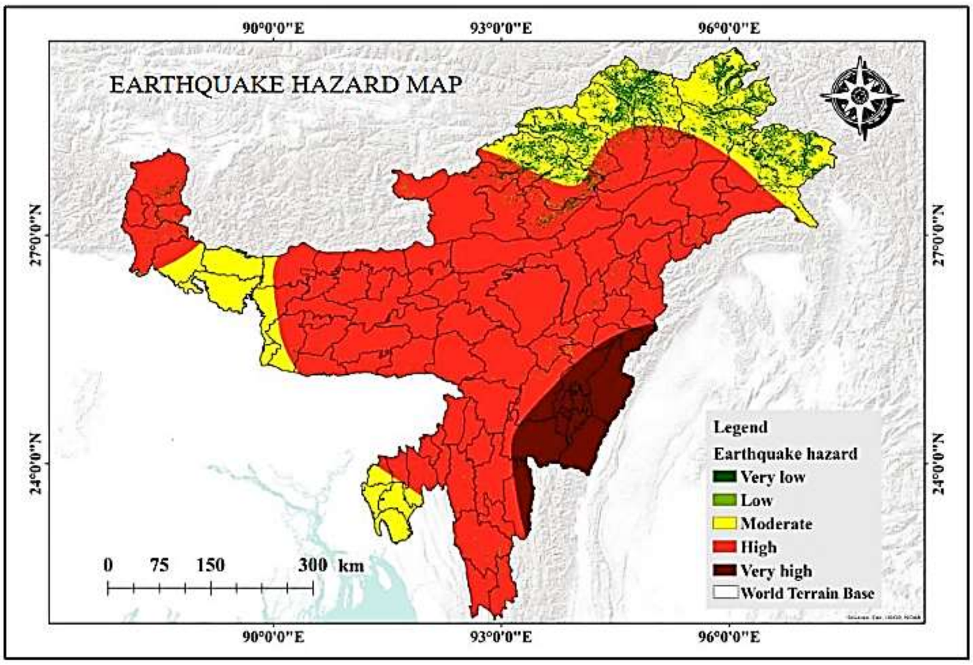

Fig. 11. Earthquake Hazard Map

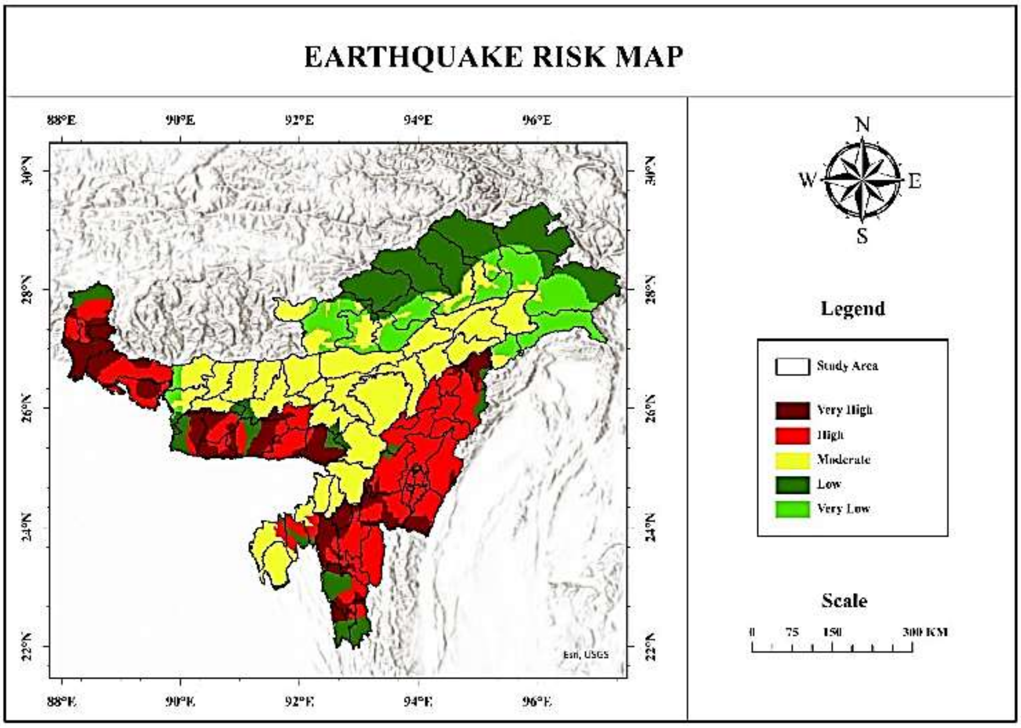

Fig. 12. Earthquake Risk Map

effective for risk analysis at regional scale to evaluate accurate data, are demonstrated in this work to provide a comprehensive risk assessment.

6. CONCLUSION

For Northeast India, the author uses the AHP (Analytic Hierarchy Process) model's earthquake risk-mapping mode, DEM (Digital Elevation Model), shape file data, and earthquake map spatial analysis. The risk results show that 15.64% (34,586.10 km^2) of the area was designated as extremely higher risk zone, and 26.15% (57,856.74 km^2) of the territory is within the SE and SW sections. In conclusion, because of its intricate tectonic setting, the NER of India is a higher-risk area for earthquakes. Proactive steps are necessary to reduce the risk of earthquakes, such as building structures that are earthquake-resistant, being prepared, and implementing early warning systems. Seismic-resistant design principles should be used when designing and constructing buildings and other structures to withstand earthquakes. The districts of Mon, Tuensang, Chandel, Bishnupur, Lurglei, Mamit, Kolasin, East Jaintia Hills, South Garo Hills, the northern portions of Coochbehar, Jalpaiguri, Darjeeling, Kalimpong, and East Sikkim are precisely identified by the author as extremely high-risk areas.

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CONFLICTS OF INTEREST/COMPETING INTERESTS

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