Proc. of the 9th International Symposium on Geotechnical Safety and Risk (ISGSR)
Edited by Zhongqiang Liu, Jian Dai and Kate Robinson
Published by Research Publishing, Singapore. ©2025 The Author(s), CC-BY 4.0 licence.
doi: 10.3850/GRF-25280825_isgsr-056-P365-cd

A GEOSPATIAL APPROACH TO IDENTIFY LIQUEFIABLELOCATIONS IN KANCHANBARI, TRIPURA, INDIA

Hrik Chaudhury
Department of Civil Engineering, Indian Institute of Technology, E-mail: c.hrik@iitg.ac.in

Abhishek Kumar
Department of Civil Engineering, Indian Institute of Technology, E-mail: abhiak@iitg.ac.in

Rishikesh Bharti
Department of Civil Engineering, Indian Institute of Technology, E-mail: rharti@iitg.ac.in

Earthquake (EQ) is one of nature's most catastrophic disasters that has the capacity to destroy civilisation in an instant. One of the most impactful effects of an EQ is liquefaction of soil. State of Tripura, located in the NorthEastern (NE) part of India has experienced multiple significant EQs in the past due to the region's complex tectonic setting. Identifying liquefiable locations within the state is essential for understanding the vulnerable parts in the region. Conventional geotechnicaltestslike Standard Penetration Test (SPT) and Cone Penetration Test (CPT) aretypically performedto identify the liquefiable locations. Although these methods yield reliable results, their application often leads to the huge financial and geographical challenges due to inaccessibility, particularly in regions like Tripura. To overcome thesechallenges, the present study explores the use of geospatial technology to identify liquefiable zones. Tripura has experienced two major EQs in the past decade: the 2016 Imphal EQ (Moment Magnitude or M_w 6.7) on January 4th, and the 2017 Tripura EQ on January 3rd (M_w 5.7). Pre- and post-EQ optical satellite imagery corresponding to the above mentioned two EQs are usedto capture soil moisture changes in the affected areas utilizing three indices [two Normalized Difference Water Indices ($NDWI_{gao}$ and $NDWI_{xu}$) and the Temporal Difference Liquefaction Index (TDLI) and one statistical tool (Tasselled Cap Wetness Index)]. The study identifies common coordinates (locations) exhibiting the most significant soil moisture changes due to both the EQs using each of the above four geospatial indices individually. Additionally, two borelog dataarealso collected from the region, to validate the findings in terms of Factor of Safety against liquefaction.These borelog data locations match the identified locations from Tasselled Cap Wetness index, concluding that the Tasselled Cap Wetness Index is a reliable geospatial tool for preliminary investigation of liquefiable locations.

1. Introduction

EQs are among the most erratic and calamitous natural disasters. In recent times, over the past decade, their occurrence has significantly increased across various regions worldwide. One important induced effect of EQs is soil liquefaction, where the soil experiences a substantial loss inshear strength. Mapping the potentiallocations to liquefaction is pivotal for implementing appropriate strategies for design and planning.While traditional field investigations like SPT and CPT provide dependable observations, they mostly demand substantial resources in terms of time and cost, and can be infeasible in areas with inaccessibleterrain such

as NE India. To overcome these challenges, the present study develops a geospatial approach to detect liquefiablespotsin Tripura using pre and post-EQ LANDSAT 8 OLI imagery with respect to 2016 Imphal EQ and 2017 Tripura EQ.

2. Study Area

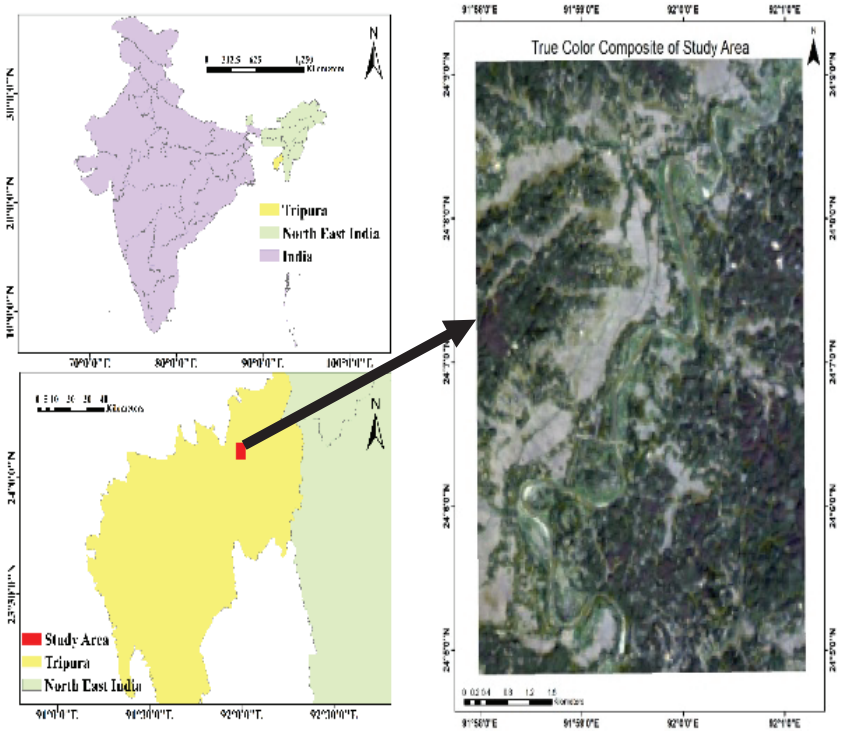


Figure 1: Study area within Tripura, India

State of Tripura, situated in NE India, is in close proximityto a complex tectonic setting and has recently experienced two significantEQs. The 2016 Imphal EQ, with a Mw6.7, occurredat 4:35 AM IST in Manipur's Tamenglong district (24.83°N, 93.66°E) on January 4th. It was widely felt across the region, resulting in 8 fatalities in India, 5 in Bangladesh, and injuring around 200 people (Rai et al. 2017). On January 3rd, 2017, anEQ(M_w 5.7)struck Tripura's Dhalai district at 2:39 PM local time. Though moderate in intensity, this EQcaused considerable damage, affecting 5,218 homes, severely damaging 1,467 homes, and destroying 42 homes, with one fatality and seven injuries reported (Chaudhury et al. 2022).Anareain Tripura, affected by the 2017 Tripura EQ, ischosen for this analysis. A reconnaissance survey by Anbazhagan et al (2017) reportedEQ effects along the Manu River, including soil liquefaction manifestations like sand boils in Kanchanbari, Unakoti district.

3. Dataset and Methodology

Liquefaction occurs when excessive pore water pressure develops in loose, cohesionless soil.This in turn increases the soil moisture.Locationsexhibiting

repeated soil moisture increase from two differentEQs suggest persistent susceptibility to liquefaction, making them potential liquefaction zones. Presentanalysisemploys four geospatial indices to identify locations in the study area with significant soil moisture increase with respect toboth the 2016 Imphal and 2017 Tripura EQs.

The data for this study is acquired from the LANDSAT satellite, which orbits at 705 km altitude with a 16-day temporal resolution. For the 2017 Tripura EQ, LANDSAT-8 OLI images from December 25, 2016, and January 10, 2017, are used. Similarly, for the 2016 Imphal EQ,LANDSAT-8 OLI images from December 23, 2015, and January 8, 2016 areused. Soilreflectance, altered by moisture levels, detects changes in soil moisture before and after anEQ using different band combinations.It should be noted here thatno rainfall occurred between the pre- and post-EQ image dates, as reported by the Center for Hydrometeorology and Remote Sensing (https://chrs.web.uci.edu/), ensuring observed soil moisture changes areonly EQ-induced.

There are a total of 2 Normal Differential Water Indices used ($NDWI_{gao}$(Gao (1996)) and $NDWI_{xu}$(Xu (2006))) which are given in equations 1 and 2 correspondingly,and one Temporal Difference Liquefaction Index (TDLI) (Baik et al. (2019)) is used which is given in equation 3 below.

$$NDWI_{(xu)} = \frac{Green_{550nm} - SWIR_{2200nm}}{Green_{550nm} + SWIR_{2200nm}} \tag{1}$$

$$NDWI_{gao} = \frac{NIR_{860nm} - SWIR_{1600nm}}{NIR_{860nm} + SWIR_{1600nm}} \tag{2}$$

$$TDLI = \frac{Pre_earthquake_SWIR_{2200nm} - Post_earthquake_SWIR_{2200nm}}{Pre_earthquake_SWIR_{2200nm} + Post_earthquake_SWIR_{2200nm}} \tag{3}$$

Another geospatial technique used for capturing the soil moisture change is Tasselled Cap Wetness Index. It is a statistical tool developed by Huang et al. (2002) to capture wetness on Earth'ssurface.Two borelog dataareanalysed using the Boulanger and Idriss (2014) method, confirming both locations as susceptible to liquefaction. Four geospatial techniques are then applied to compute soil moisture change using pre- and post-EQ images for both events. Differences in the images represent EQ-induced soil moisture changes.Subsequently, the image differences for both events are classified using quantiles. High-value pixels (in the highest class) indicating significant moisture increases are extracted, and common locations for both EQs are identified by dividing one classified image (corresponding to 2016 EQ) with the other (corresponding to the 2017 EQ). Multiple iterations are done to determine the most effective geospatial technique and corresponding optimal classification to get the common locations which align with borehole locations.

4. Results and Discussion

The framework discussed in Section 3 iscarried out, demonstrating that only the Tasselled Cap Wetness index successfully capturesthe common locations that have

seemed to experience increased wetness due to both the 2016 Imphal and 2017 Tripura EQs that align with the locations of two borelog data indicative of liquefaction susceptibility. These locations areshown in Figure 2. On the contrary, the other indices viz. $NDWI_{gao}$, $NDWI_{xu}$, and TDLI,cannot identify high soil moisture change's locations common to both EQsthat align with the borelog data. Moreover, it isfound that 32 quantile classes are required to achieve the desired outcome.

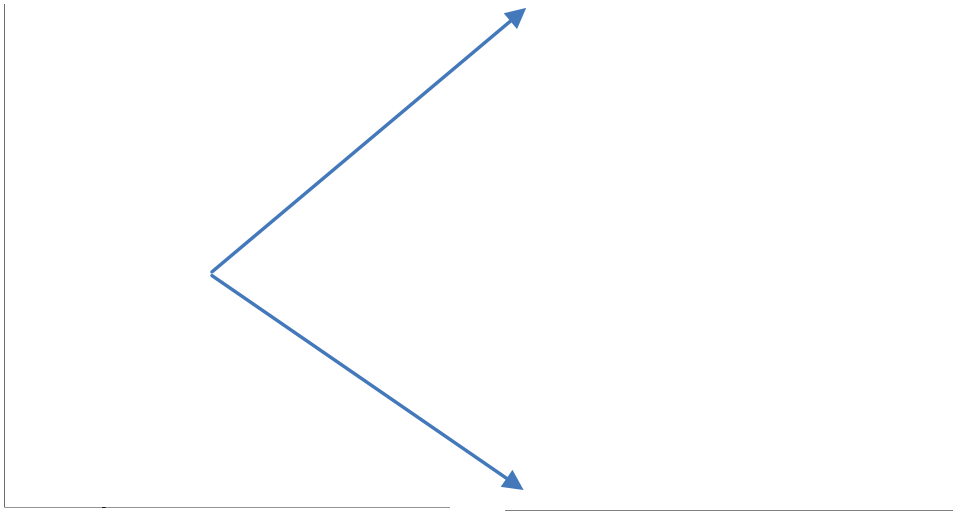


Figure 2: Common locations representing high moisture change due to both 2016 EQ and 2017 EQ using Tasselled Cap Wetness index

5. Conclusion

Two borelog data are collected from the state of Tripura.Cyclic Stress Ratio (CSR) and Cyclic Resistance Ratio (CRR) is calculated using the SPT-N value, soil type, unit weight and fines content from the borelog data. Factor of safety against liquefaction is calculated using the CSR and CRR following the process provided by Boulanger and Idriss (2014). It confirmed both locations aresusceptibleto liquefaction. Four geospatial indices viz. $NDWI_{gao}$, $NDWI_{xu}$, TDLI, and Tasseled Cap Wetness Index are used to analyse soil moisture changes before and after the 2016 Imphal and 2017 Tripura EQs. Among these, the Tasselled Cap Wetness Index identifies locations closely matching the borehole positions which indicate potential liquefaction zones. This approach narrows down search areas, though detailed geotechnical investigation is needed for accurate results. It is to be noted that the number of classes for identifying high-value pixels may vary depending on the study area. For Tripura the optimal number of quantile classes is found to be 32.

6. References

Rai, Durgesh C., Hemant B. Kaushik, and Vaibhav Singhal. "M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings." Current Science (2017): 2341-2350

Anbazhagan, P., et al. "Reconnaissance report on geotechnical effects and structural damage caused by the 3 January 2017 Tripura earthquake, India." Natural Hazards 98 (2019): 425-450.

Chaudhruy, Hrik, Abhishek Kumar, and Rishikesh Bharti. "Detection of Liquefaction Phenomenon from the 2017 Tripura Earthquake using Remote Sensing Data." IGARSS 2022-2022 IEEE International Geoscience and Remote Sensing Symposium. IEEE, 2022.
Wichtmann, T., et al. "Correlation of cyclic preloading with the liquefaction resistance." Soil Dynamics and earthquake engineering 25.12 (2005): 923-932.
Center for Hydrometeorology and Remote. Sensing. https://chrs.web.uci.edu/ (accessed 25th November 2024).
Gao, Bo-Cai. "NDWI—A normalized difference water index for remote sensing of vegetation liquid water from space." Remote sensing of environment 58.3 (1996): 257-266.
Xu, Hanqiu. "Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery." International journal of remote sensing 27.14 (2006): 3025-3033.
Baik, Hyunseob, Young-Sun Son, and Kwang-Eun Kim. "Detection of liquefaction phenomena from the 2017 Pohang (Korea) earthquake using remote sensing data." Remote Sensing 11.18 (2019): 2184.
Huang, Chengquan, et al. "Derivation of a tasselled cap transformation based on Landsat 7 at-satellite reflectance." International journal of remote sensing 23.8 (2002): 1741-1748.
Boulanger, Ross W., and Izzat M. Idriss. "CPT and SPT based liquefaction triggering procedures." Report No. UCD/CGM.-14 1 (2014): 134.