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Assessing Slope Failure Susceptibility in Volcanic Ash Terrain of Southeastern Hokkaido.

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1. Introduction

Slope failures in volcanic ash terrains pose a significant hazard in Hokkaido, especially in the Iburi prefecture, where a recent slope failure with volcanic ash materials was triggered by the 2018 Ibura-Tobu earthquake in the region (Kawamura *et al.*,2019). Up to 40% of the Hokkaido area is covered by pyroclastic materials (Machida *et al.*, 2002). Pyroclastic layers typically have lower strength than the underlying rocks, therefore, slope stability is compromised, leading to devastating consequences. Excessive rainfall or strong earthquakes collectively trigger the occurrence of these events. Slope failures occurring in such unstable volcanic ash terrains pose significant threats to human life, infrastructure, economic assets, and long-term damage to the regional ecosystem (Kawajiri *et al.*, 2024). Although there is a widespread application of GIS-based slope failure modelling in Japan (Kohno and Higuchi,2023), there is limited research focusing specifically on volcanic ash dominated terrains especially using AHP-based spatial analysis. This gap is critical given the unique geotechnical behavior of tephra deposits (volcanic ash) and their vulnerability during heavy rains or seismic events.

The study aims to:

(A) Derive topographic and hydrological factors using a Digital Elevation Model

(B) Assess and integrate the influence of volcanic ash characteristics (cohesion, shear strength, ash thickness factors contributing to slope failure.

(C) Map areas susceptible to slope failure in pyroclastic terrain.

(D) Develop a Web-Map service for geo-visualization.

2. Significance and Contribution

Our study aims to assess slope failure susceptibility in pyroclastic environments using a GIS-based AHP framework to support disaster risk mitigation. The results will clarify the relationship between rock and soil strength in relation to tephra deposits. Practical outcomes include: (a) tools for identifying high-risk areas for use by governments, planners, and developers, and (b) support for implementing early warning systems.

Future research may integrate additional data sources such as remote sensing and ground-based sensors.

3. Study area

The study area covers approximately 645 km², consisting of the towns of Abira and Atsuma in the Iburi Subprefecture, southwestern Hokkaido. The region is highly vulnerable due to its steep terrain, active tectonic features, and thick Quaternary tephra deposits overlying basement rocks.

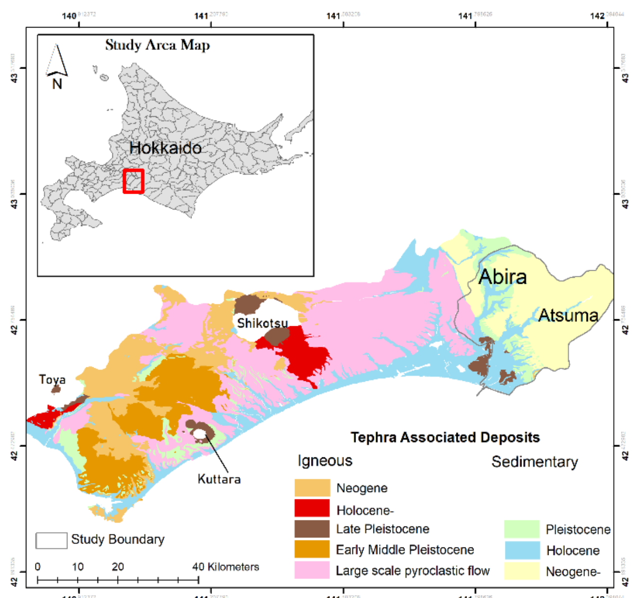

Figure 1: Study area map and associated volcanic fields, highlighting the Toya, Shikotsu, and Kuttara calderas.

3.1 Data and Methods

Lithological data were obtained from the Geological Survey of Japan`s Seamless Digital Geological Map. The landslide inventory from the September 2018 earthquake created by Kita (2018) is available on (https://github.com/koukita/2018_09_06_atuma). The 10m Digital Elevation created in 2019 was obtained from the Geospatial Authority of Japan. This study will utilize a GIS-based multi-criteria decision analysis framework, employing the Analytical Hierarchy Process (AHP), to facilitate weighting of factors. There is no single factor that exclusively influences the event. Therefore, each factor will be weighed based on its importance. QGIS and Jupyter Notebook environment will be utilized to achieve objectives.

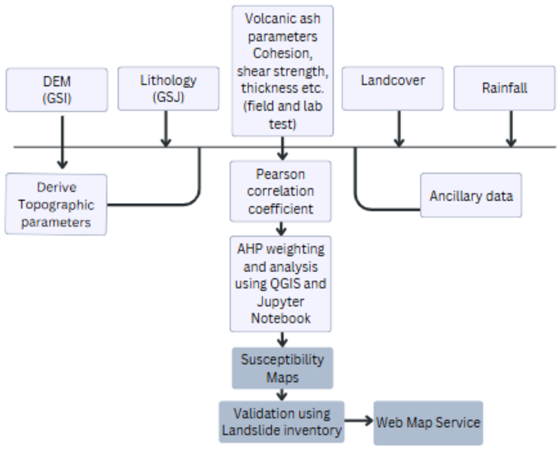

Figure 2: Methodology Flow Diagram

4. Preliminary results

The 10m resolution DEM was used to derive key terrain factors (1), specifically the Topographic Position Index (TPI), to identify landforms such as ridges and valleys. TPI values in Fig.3 range from -106 to 166m. Higher values correspond to ridge tops and peaks. In contrast, the strong negative values correspond to deep valleys. The mid-range values correspond to gently sloping terrain.

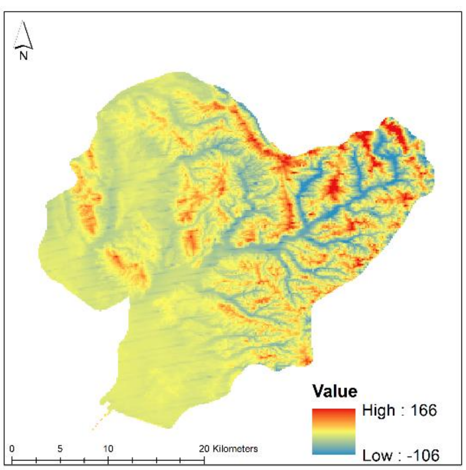

Figure 3: Topographic Position Index

(2) Topographic Wetness Index (TWI) was used to estimate potential water accumulation and soil saturation. As shown in Fig. 4, high TWI values are concentrated along river basins and low-lying terrain, indicating hydrological convergence zones where water tends to accumulate. These areas are likely to exhibit increased soil moisture and reduced shear strength, making them more susceptible to slope failures. In contrast, low TWI values, represented in blue, are predominantly observed on upper slopes, which are typically drier and thus less prone to saturation-induced failures.

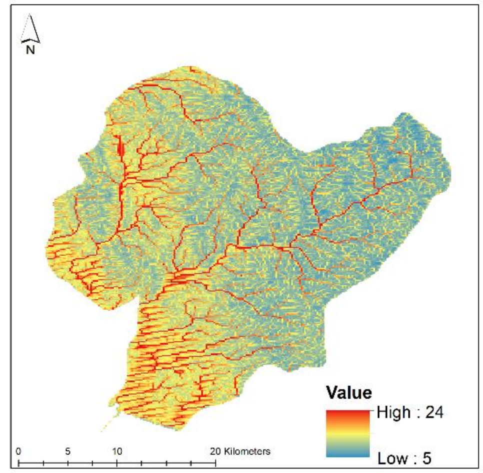

Figure 4: Topographic Wetness Index

5. Plan of Action

The next step involves collecting substantial data (geotechnical, etc.), refining and pre-processing it, and conducting fieldwork to collect samples, as well as performing laboratory testing.

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