学 位 論 文 審 査 の 要 旨

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学 位 論 文 題 名

Synergy of multi-source remote sensing and multi-model approaches for understanding post-disaster vegetation dynamics and terrain characteristics in Hokkaido, Japan
（北海道における災害後の植生動態と地形特性の理解に向けたマルチソースリモートセンシングとマルチモデルアプローチのシナジー）

In recent years, the frequency and severity of natural disasters, such as typhoons and earthquakes, have significantly impacted ecosystems and the environment. This research addresses the urgent need for efficient post-disaster environmental monitoring and assessment by presenting five case studies, particularly in the context of the increasing frequency and intensity of natural disasters in Japanese mountain ecosystems. By advancing remote sensing applications, this work highlights innovative methods for post-disaster damage assessment, with a focus on Hokkaido, Japan.

The first case study investigates forest damage from three typhoons in Hokkaido in 2016. This study compared existing forest damage estimation techniques with the goal of identifying their respective advantages and suitable use cases. Using Landsat 8 imagery, vegetation indices, machine learning classifiers, and the CLASlite software, various approaches to damage estimation were compared. Machine learning classifiers, especially Random Forest (RF) and Support Vector Machines (SVM), demonstrated high accuracy (80.36% overall accuracy) when using Fractional Cover as a predictor. Among vegetation damage indices, Difference Normalized Difference Vegetation Index (DNDVI) showed better performance to identify forest damage areas. This analysis revealed that forest damage was more severe on windward slopes and higher elevations, emphasizing the role of landscape features in damage distribution.

The second case study examines topographic changes and vegetation dynamics in areas affected by the 2018 Mw 6.6 Hokkaido Eastern Iburi earthquake. High-resolution digital elevation models (DEMs) and multi-temporal satellite imagery from Sentinel-2 and Planet were used to map landslide activity and vegetation regrowth as an indicator of stability. Results showed significant topographic steepening due to

the earthquake, with slow vegetation recovery, indicating ongoing vulnerability to debris flows and gully erosion. These findings highlight the need for long-term monitoring to assess landscape stability after seismic events.

In the third and fourth case studies, high-resolution topographic changes in landslide-affected areas following the 2018 earthquake were analyzed using LiDAR-derived DEMs. Changes in slope, relief, and texture were examined, and comprehensive volume estimates of shallow landslides were compared with global area-volume relationships, highlighting uncertainties in scaling earthquake-induced landslides. By compiling an inventory of 1,719 landslides for 2018 Mw 6.6 Hokkaido-Iburi earthquake epicentral region, this study estimates that the volume of soil landslides can be estimated by $\gamma = 1.15$. The total volume of eroded debris from Hokkaido-Iburi catchments based on this new scaling relationship is estimated as 64–72 million m3. Findings suggest that the earthquake not only steepened the topography but also generated debris volumes exceeding typical uplift rates, providing valuable insights to co-seismic uplift and erosion processes.

The final case study utilizes UAV-LiDAR data to capture microtopographic changes in the Iburi region, focusing on rill erosion dynamics in areas with minimal vegetation regrowth. This case study presents a UAV-LiDAR based data collection and processing workflow to capture the microtopography of a post-landslide area. A flow-accumulation based method for automated detection of rills is proposed and evaluated. Multi-year acquisitions were analyzed to assess changes in rill-density, width and depth dimensions, and sediment volume loss. A Zenmuse L1 LiDAR sensor was used for data acquisition. DEMs with a spatial resolution of 1 cm were generated from the LiDAR point cloud processing. A flow-accumulation algorithm with a threshold value of 5,000 could detect rill network accurately (Producer & User accuracies > 86%). Vertical cross-sections of the individual rills showed an increase in the depth and width of rills over one year. This study demonstrates that a UAV-LiDAR system can effectively capture microtopography in a post-landslide landscape and facilitate analysis of small-scale rill characteristics and the progression of rill erosion over time.

Collectively, the methodologies and findings presented in this thesis demonstrate the effectiveness of integrating multi-source remote sensing data and advanced processing techniques to enhance post-disaster damage assessment. These insights can guide future monitoring and risk assessment efforts in disaster-prone regions, supporting more resilient environmental management strategies.

The Ph D committee recognized that this research developed various methodologies useful for monitoring vegetation and topographic changes caused by typhoons and earthquake-induced landslides. The integration of multi-source data and multi-model approaches can overcome various limitations in post-disaster impact assessment. In addition, Mr. Chen Xinyu maintained a strong academic record throughout his Ph.D. studies and publications. Based on this evidence, the committee concluded that he is eligible for the degree of Doctor of Philosophy (Environmental Science).