学位論文内容の要旨

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学位論文題名

Application of remote sensing for characterization of windthrow and landslides at multiple scales in forest landscape

（マルチスケールでの風倒地・崩壊地の特性把握―森林景観におけるリモートセンシングの応用―）

Due to climate change, the frequency, size, and intensity of natural disturbances are increasing, leading to increase damage to forest ecosystems. Proper management of these disturbed areas is critical for the resilience of forest ecosystems. Remote sensing is used for disaster management as it can provide essential information for post-management of damaged areas, reducing the need for manual inspection of hazardous sites. However, remote sensing has some challenges, such as the influence of elements like atmosphere, clouds, topography, and sun position, generating noise in the output data. The remote sensing community is addressing these challenges and developing new techniques to improve scientific understanding. Still, there is a discrepancy between technical development and application of remote sensing in the management of forest landscapes, due to the need for interdisciplinary skills involved. Since rapid and accessible information at multiple scales on damaged areas are critical, straightforward approaches are required to support forest managers.

This thesis proposed three different approaches to facilitate the implementation of remote sensing to characterize windthrow and landslides at three different scales: regional scale, forest stand scale, and single tree scale. The first approach compared three different classification methods at a regional scale to identify windthrow and landslides using high temporal/ spatial resolution satellite data: the normalized difference vegetation index (NDVI) filtering method, spectral angle mapper (SAM)

method, and support vector machine (SVM) method. The results showed that the NDVI filtering method was better to identify landslides, while the SAM method was better to identify windthrow; supporting forest managers to choose appropriate methods to identify windthrow and landslides.

The second approach compared a red green blue (RGB) UAV with a Multispectral UAV to characterize landslides throughout the months at a forest stand scale. The results showed that the RGB UAV was able only to monitor vegetation growth, while the Multispectral UAV, due to the higher spectral resolution, could monitor different characteristics: vegetation, bare soil, and dead matter over the months. Both systems, due to the high spatial and temporal resolution, were able to deliver an understanding of the potential vegetation recovery process in a landslide at a forest stand scale. The third approach was based on full motion video (FMV) technology to identify fallen and snapped trees, at a single tree scale. The results showed that FMV was able to identify fallen and snapped trees in a windthrow area, even with the presence of vegetation. The higher context-awareness provided by the video and the simpler workflow showed the potential to overcome the limitations of the UAV structure from motion photogrammetry.

In conclusion, the study provided specific approaches in three different scales for the use of remote sensing in the management of disturbed forest areas. As climate change advances, the need to take quick actions to mitigate damage and sustain resilience in forest ecosystems is essential. Remote sensing will continue to develop and play an important role in forest management after natural disasters. However, more research needs to be conducted on facilitating the implementation of remote sensing techniques and training forest managers to take full advantage of remote sensing for forest management after natural disasters.