Estimating tree growth rates using UAV-based optical remote sensing method

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Optical remote sensing provides rich information to monitor forest ecosystems and assess their role in carbon cycling. Forests are a major terrestrial carbon pool, and accurate estimation of tree growth and carbon uptake is essential for sustainable forest management and climate studies. While many previous studies have focused on estimating forest biomass or carbon stocks using vegetation indices, optical remote sensing methods often suffer from saturation at high biomass levels, limiting their ability to capture growth dynamics. At the same time, tree growth is closely linked to leaf functional traits, which can be inferred from spectral reflectance. We hypothesize that hyperspectral data can therefore be used to estimate tree growth rates, and that these relationships may vary with tree size. Focusing on tree growth rate may thus provide an alternative way to assess forest productivity and growth dynamics, particularly in dense forests.

This study proposes a new approach to estimate tree growth rates using hyperspectral data acquired from a UAV-mounted spectrometer to identify appropriate spectral bands for future remote sensing satellites. Moreover, this study shows the potential of hyperspectral data to classify tree species in a temperate forest. We conducted a UAV-mounted spectrometer measurement in the Hokkaido University Uryu experimental temperate forest, on 31 July, 2025. The target forest covers 100 m ×80 m area including eight dominant tree species. The forest inventory includes annual measurements of diameter at breast height (DBH), tree species, and tree location collected by forest experts from 2007 to 2024.

The hyperspectral data captured by the small spectrometer consist of 180 spectral bands in the range of visible (~400 nm) to near-infrared (~840 nm) with a spatial resolution of 8 m/pixel. For tree species classification, we used a support vector machine (SVM) algorithm with a linear kernel, and the input features were standardized prior to analysis. Using all spectral bands, we achieved an overall balanced classification accuracy of 70% for eight tree species.

Tree growth parameters, including diameter, height, and volume growth, were derived from 17 years of field inventory data. Relationships between growth rates and spectral information were examined using normalized difference spectral indices (NDSI) derived from all band combinations. Results show that correlations between spectral indices and growth rates differ by species and tree size. As a preliminary analysis, we focused on Quercus crispula species because of its dominance in the study area. Small Quercus crispula trees showed positive correlations between growth parameters and NDSI derived from red-edge (710nm) and near-infrared bands (770nm), whereas larger trees showed weak to moderate correlation between the growth parameters and NDSI derived from blue (460-490 nm) and red bands (660nm). These preliminary results suggest that hyperspectral data contain useful information for estimating tree growth rates. However, the weakening relationship observed in larger trees may reflect changes in growth strategy with increasing tree size. Overall, this study shows that UAV-based hyperspectral data can support analyses of tree growth rates and highlights the importance of considering tree size when interpreting spectral data and growth rate relationships.

Keywords: remote sensing , tree species classification , tree growth rate , hyperspectral data , UAV

