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REMOTE RETRIEVAL OF ECOLOGICAL INDICATORS FOR DETECTING FOREST DROUGHT AND WILDFIRE

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学位論文要旨

Abstract of Doctoral Thesis

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論文題目：森林の干魃と火災を検知する指標のリモート抽出に関する研究

Title of Thesis：REMOTE RETRIEVAL OF ECOLOGICAL INDICATORS FOR DETECTING FOREST DROUGHT AND WILDFIRE

論文要旨：
Abstract：
Events of drought-induced forest mortality and forest fire have been occurred all over the world and will be exacerbated in the future due to rising temperature. Both forest disturbances have substantial influence on the global hydrological and carbon cycle. How to remotely and quantitatively monitor and assess both disturbances have not been effectively addressed until now. Remote sensing provides a reliable and practical means to assess forest disturbances by the retrieval of related indicators. In this study, four indicators, relative water content (RWC), equivalent water thickness (EWT), fluorescence–based quantum yield of PSII (ΔF/F'm) and fuel moisture content (FMC) were retrieved with hyperspectral indices for detecting forest drought and fire, respectively.

Leaf water status information is highly needed for monitoring plant physiological processes and assessing drought stress. In **Chapter 2**, a leaf dehydration experiment was designed to obtain a relatively comprehensive dataset with ranges that were difficult to obtain in field measurements. RWC and EWT were chosen as the surrogates of leaf water status. Moreover, five common types of hyperspectral indices including: single reflectance (R), wavelength difference (D), simple ratio (SR), normalized ratio (ND) and double difference (DDn) were applied to determine the best indices. The results indicated that values of original reflectance, reflectance difference and reflectance sensitivity increased significantly, particularly within the 350-700 nm and 1300-2500 nm domains, with a decrease in leaf water. The identified best indices for RWC and EWT, when all the species were considered together, were the first derivative reflectance based ND type index of dND (1415, 1530) and SR type index of dSR (1530, 1895), with R^2 values of 0.95 ($p<0.001$) and 0.97 ($p<0.001$), respectively, better than previously published indices. Even so, different best indices for different species were identified, most probably due to the differences in leaf anatomy and physiological processes during leaf dehydration. Although more plant species and field-measured datasets are still needed in future studies, the recommend indices based on derivative spectra provide a means to monitor drought-induced plant mortality in temperate climate regions.

The information of photosynthetic status is greatly required for better understanding forest drought stress. ΔF/F'm is a commonly used indicator of photosynthetic status. In **chapter 3**, ΔF/F'm was retrieved with leaf origin reflectance and first derivative reflectance ranging from 400 nm to 800 nm because leaf water content and dry mater content had minimal impact on these bands. Results showed that the changes of ΔF/F'm could not be traced by the published indices of NDVI and PRI. There were no significant correlations between ΔF/F'm and between ΔF/F'm and NDVI when all species were considered. The identified best indices for estimating ΔF/F'm was dND (533, 686) across different type of indices, with an R^2 of 0.88 and an RMSE of 0.11. The wavelength of 533 nm which is near xanthophyll-cycle-related 531 nm and 686 nm is near one of the emission peak of chlorophyll fluorescence, 690 nm. dND (533, 686) may incorporates the information of both chlorophyll fluorescence and xanthophyll cycle, and therefore it is suitable for the estimation of ΔF/F'm under water stress.

FMC, the water content either in dead (DFMC) or live fuels (LFMC), is a critical parameter in fire behavior prediction. Although remote sensing is an efficient way to estimate the spatial and temporal variations of FMC, most of the existing spectral indices are oriented to LFMC, while estimation of DFMC is commonly done using weather indices instead, and is therefore severely limited by the availability of meteorological stations. In **chapter 4**, dehydration experiments were designed for both live and dead fallen leaves in order to determine the best hyperspectral indices for different fuel types by tracking the time-varying water contents of both fuel materials. Meanwhile, PROSPECT model was used to simulate a dataset with a wide range of input parameters. The results showed that the reflected spectra from 400 to 1200 nm were quite different between green live leaves and fallen litters with decreasing FMC, while the changes of reflected spectra in the domain of 1200 to2500 nm were similar, with dry matter bands gradually appearing. The identified best index for FMC including both fuel types was a derivative spectra-based index of dND(1900, 2095) with an R^2 of 0.85 and an RMSE of 32%, although it was failed in simulated dataset by PROSPECT. Two fuel types were well separated by normalizing dND (1900, 2095) with a combination of NDVI ((dND-NDVI)/(dND+NDVI)), which had an R^2 of 0.85 and an RMSE of 21% for FMC in green live leaf fuels and a lower R^2 of 0.45 and RMSE of 69% for FMC in dead fallen leaf fuels. The decreased R^2 for FMC in dead fallen leaf fuels was primarily caused by the different NDVI values of different species, suggesting that the recommend indices should be validated with more plant species in the future.