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3D Mapping of Forest Canopy Water Content using Dual-wavelength Terrestrial Laser Scanning

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Determining vegetation water status has significant importance in forest health monitoring. For example, it can serve as an indicator of stress and as an early indicator of wildfire risk or infection by pests and diseases. Vegetation water status can be quantified as the leaf Equivalent Water Thickness (EWT). Satellite hyperspectral remote sensing data has been widely used for estimating EWT in recent years, as a more efficient alternative to the traditional in-situ destructive methods. However, the satellite sensors can only observe the upper layers of a forest canopy and cannot deliver sufficient information about the lower layers or the understory vegetation, where most wildfires and many disease infections are believed to start. On the other hand, Terrestrial Laser Scanning (TLS) instrumentation can potentially provide such information, as such instruments record an intensity image of each scan in addition to a 3D high definition point cloud. The intensity image can be linked to the scanned target's reflectance with appropriate calibration, thereby enabling 3D estimates of EWT at leaf and canopy level. This study introduces a novel approach that combines data from two TLS instruments operating at complementary wavelengths in the shortwave and near infrared. A Normalized Difference Index (NDI) is used to generate 3D estimates of EWT at leaf and canopy level, both in a laboratory setting and a real-world forest environment. A strong relationship was observed between NDI and EWT at leaf level ($R2 = 0.94$). At canopy level, the average error in the EWT estimation was found to be < 8%. The approach has the potential to: overcome limitations of satellite hyperspectral estimation of EWT; provide midday and predawn EWT estimates; analyse the drying patterns of vegetation at high spatial and temporal resolutions; better understand the heterogeneity in biochemistry within forest canopies; and study and exclude woody material influences on EWT estimates.