Investigating 3-D distribution of bio-chemical traits in tree canopy using UAS-based LiDAR and hyperspectral data

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Abstract

Quantifying three dimensional structure of individual tree canopy is proven to be critical for precision tree cultivation and sustainable forest management. Hyperspectral imagery has been used in species classification, biomass estimation, and bio-chemical traits measuring. However, due to the limitations of the hyperspectral instrument and the lack of fusion algorithm considering sensor imaging mechanism within vegetation community, combining the three dimensional structure and hyperspectral data to explore the spatially variations of bio-chemical traits in the tree canopy is sparse. Therefore, with the 3D distribution of bio-chemical traits to provide supports for physiological activity monitoring and nutrition diagnosis have attached little attention. In this study, high-density LiDAR point cloud and high-spatial resolution hyperspectral imagery from unmanned aerial system (UAS) platforms were used in combination, to quantify and analyze the three dimensional distribution of bio-chemical traits in individual tree canopy. A DSM based fusion method considering attenuation effect in radiative transfer process was developed to integrate the three dimensional LiDAR point cloud with hyperspectral imagery. A radiative transfer model was used to estimate the bio-chemical traits hierarchically. The horizontal and vertical distributions of bio-chemical traits in individual tree canopy were quantified using ANOVA analysis and Duncan's multiple comparison post hoc tests. Three dimensional distribution of bio-chemical traits in individual tree canopy were accessed and their correlation with accumulated solar radiation were analyzed. We found that the radiative transfer model had a strong ability to estimate bio-chemical traits, and most of the canopy structural had little effect on the accuracy of estimation. Horizontally, the portion of canopy that received solar radiation directly had a slightly lower bio-chemical traits, which means that the southern canopy portion has a lower bio-chemical traits for the individual tree located in the northern hemisphere. Vertically, the bio-chemical traits gradient was negatively correlated with the increase of tree height, because of being affected by shadows from the canopy of oneself and neighboring trees. This study explored the three dimensional bio-chemical traits distribution of individual tree canopy on the basis of mechanistic fusion of high-density LiDAR point cloud and high-spatial hyperspectral imagery. The methods and findings indicate a great potential of deep fused LiDAR point cloud and hyperspectral imagery in investigating solar-induced physiological activities, as well as nutrition diagnosis and productivity enhancement, which have wide application for precision forestry and ecology.

Keywords: LiDAR, hyperspectral data, bio-chemical traits. UAS, 3-D distribution

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