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Mapping tree health using airborne laser scans and hyperspectral imagery: a case study for a floodplain eucalypt forest

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Airborne laser scanning (ALS) and hyperspectral imaging (HSI) are two complementary remote sensing technologies that provide comprehensive structural and spectral characteristics of forests over large areas. In this study we developed two algorithms: one for individual tree delineation utilizing ALS and the other utilizing ALS and HSI to characterize health of delineated trees in a structurally complex floodplain eucalypt forest. We conducted experiments in the largest eucalypt, river red gum forest in the world, located in the south-east of Australia that experienced severe dieback over the past six decades. For detection of individual trees from ALS we developed a novel bottom-up approach based on Euclidean distance clustering to detect tree trunks and random walks segmentation to further delineate tree crowns. Overall, our algorithm was able to detect 67% of tree trunks with diameter larger than 13 cm. We assessed the accuracy of tree delineations in terms of crown height and width, with correct delineation of 68% of tree crowns. The increase in ALS point density from $\sim$12 to $\sim$24 points/m2 resulted in tree trunk detection and crown delineation increase of 11% and 13%, respectively. Trees with incorrectly delineated crowns were generally attributed to areas with high tree density along water courses. The accurate delineation of trees allowed us to classify the health of this forest using machine learning and field-measured tree crown dieback and transparency ratios, which were good predictors of tree health in this forest. ALS and HSI derived indices were used as predictor variables to train and test object-oriented random forest classifier. Returned pulse width, intensity and density related ALS indices were the most important predictors in the tree health classifications. At the forest level in terms of tree crown dieback, 77% of trees were classified as healthy, 14% as declining and 9% as dying or dead with 81% mapping accuracy. Similarly, in terms of tree crown transparency, 15% of trees were classified as high-density, 81% as medium-density and 4% as sparse or defoliated with 70% overall accuracy. Finally, Landsat derived flooding frequency map for over 12 years showed that trees in areas that were flooded less than 5 times and more than 30 times were most susceptible to dieback. Similarly, sparse and medium-density tree crowns were concentrated in areas that were flooded less than 15 and more than 30 times, respectively. Our results provide two algorithms that accurately delineate and classify the health of trees in a structurally complex forest, enabling us to prioritize areas for forest health promotion and biodiversity conservation. This study is novel in using airborne remote sensing to assess the health of structurally complex individual trees on a relatively large scale.