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| **Differentiating eucalypt tree species and provenances using UAV hyperspectral imagery and machine learning** |
| Understanding the genetic composition of natural and restored ecosystems is increasingly necessary for the effective management of biodiversity and ecosystem health in the face of global change. In the case of forests, trees are a foundation component of that biodiversity. The identification of tree genotypes to the species and provenance levels is increasingly important for the evaluation of the success of different seed-sourcing strategies aimed at climate change adaptation and resilience. Popular methods to achieve this, including pedigree tracking or molecular techniques, can be costly and in some cases prohibitively expensive. In this study, we explore the possibilities offered by advances in very high-resolution hyperspectral imagery, acquired from Unmanned Aerial Vehicle (UAV), to differentiate between species and provenances based on their unique spectral signatures.  Using a common garden restoration experiment, random forest classifiers were trained to discriminate between: (a) two focal eucalypt species (*Eucalyptus pauciflora* and *E. tenuiramis*); (b) *E. pauciflora* provenances from Tasmania and mainland Australia (’state’); and (c) ten different Tasmanian provenances of *E. pauciflora* (‘provenance’). We compared both object- (*i.e.,* tree) and pixel-based approaches; using the spectral information directly or as derived vegetation indices, both with and without 3D structural traits derived from Light Detection and Ranging (LiDAR).  Species were best classified when using he fusion of derived vegetation indices and LiDAR at the object-level, with an overall test accuracy (OA) of 87.6%. However, the object-level models performed poorly when differentiating the spectral differences between state (OA = 56.7%) and provenances (OA = 28.6%), with vegetation indices and the fusion of vegetation indices and LiDAR being the top models, respectively. While there was little gain in detectability of species at the pixel-level (OA = 88.1%), substantial gains were achieved in differentiating intraspecific spectral differences at the state (OA = 82.4%) and provenance (OA = 50.4%) levels. Employing a mixed odds-ratio and majority vote approach on the pixel affinities for each object, we were able to increase our ability to differentiate objects at all hierarchical levels: species (100% correct classification); state (92%); and provenance (95%).  We discuss the results within the context of applying these methods to broadscale monitoring of tree biodiversity at spatial- and genetic-scales relevant to natural resource managers. |