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Abstract

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Keywords

Spectral, spatial, variation, leaf, patch, scale, invasive, wetland, weeds

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

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SPECTRAL AND SPATIAL VARIATION AT LEAF AND PATCH SCALE OF INVASIVE WETLAND WEEDS

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ABSTRACT

The establishment of invasive weeds in wetland environments is a prominent threat in Australia with adverse impacts on native flora. Current management is hindered by the lack of information available on which to base and justify management interventions, in particular, mapping of weed distributions. Remote sensing is a possible solution to difficulties of this type as illustrated by its successful application to wetland mapping in general. This paper explores the potential of multiscale spectral reflectance to discriminate between two particularly offensive, invasive woody weeds, bitou bush (*Chrysanthemoides monilifera* ssp rotundata), and lantana (*Lantana camara*). Spectral reflectance at the leaf and patch-level scales was measured at multiple sites using a field spectrometer. Derivative analyses of spectra as well as t-tests were used to evaluate spectral separability between species across scales. Results suggest further analysis is warranted at the patch level where species are intermixed and structural factors more complex.

Index Terms— spectral reflectance, weeds, spatial scale

1. INTRODUCTION

While a number of threats and management problems have been identified in wetland environments, the establishment of introduced weeds is a prominent threat with adverse impacts on native flora [1]. In Australia, current management is hindered by the lack of information available on which to base and justify management interventions. The paucity of information on wetland weed infestation can be attributed to the fact that the physical characteristics of wetlands make fieldwork expensive, time consuming and often inexact [2]. These factors limit fieldwork in wetlands to small areas and restrict the usefulness of the data for extrapolation [3]. Remote sensing is a possible solution to difficulties of this type as is illustrated by its successful application to wetland mapping in general [2]. The use of remote sensing for wetland mapping has well-known tradeoffs between spectral and spatial resolution using current remote sensing platforms. Aerial photography has been a widely used remotely sensed data source for wetland mapping [4], but restricted spectral capabilities limit the ability to discriminate different vegetation types that are often spectrally similar in wetland environments [5, 6, 7]. Within the past five years there has been a steady increase in the application of airborne hyperspectral (many and narrow spectral bands) datasets to the analysis of vegetation (eg 8, 9 10] showing increased accuracies in estimating quantitative biophysical characteristics of vegetation when compared with the present generation of satellite systems. A number of researchers have demonstrably shown that the narrow-wavebands typically found in hyperspectral datasets are crucial for providing additional information in quantifying biophysical characteristics of vegetation and to discriminate between vegetation species [11, 12, 13]. Differences in plant size, maturity and colour at certain times of the year may aid discrimination, in particular, major spectral differences often occur when target plants flower [e.g. 14]. As essential component of research into spectral weed discrimination is the identification of key stages of growth of characteristics to determine when they can best be discriminated from other similar vegetation types. The tendency for weeds to grow in distinct patch distributions has been found to assist their discrimination [13]. In Australia, examples of the application of remote sensing in wetland weed detection specifically are limited with literature dominated by weed detection in agricultural crops [e.g. 15, 16], where crop seasonality allows relatively simple discrimination of living vegetation against non-living vegetation or stubble. It has been shown that on-ground spectral measurements have the potential to discriminate among some crop-based weed species in addition to discriminating weeds from crop [17]. Other research indicates that relatively simple analysis such as "data thresholding" can discriminate and map weeds when discrete patches in cover type are present [18]. The primary objective of this study was to determine investigate spectral reflectance wavelengths at the leaf scale (6 x 6 cm) most discriminative of selected weed species invasive to Australian coastal landscapes. A secondary objective was to examine spectral variation at the patch scale (1 x 1 m) to determine how the spectral signal of these species changes from the leaf to the patch scale. Outcomes are expected to improve understanding of species discrimination and the influence of weed patch size on spectral and spatial resolution thus identifying the prospects and problems in using hyperspectral imagery for quantifying and mapping weeds.

2. METHODS

2.1. Site and species selection

This research was conducted in wetlands significantly impacted by weed infestation with site selection based upon a comprehensive wetland mapping inventory completed for the Illawarra Wetlands Project [19]. These wetland groups have particular relevance to local wetland management plans and thus to local governmental organisations, and contain a wide range of weeds of varying spatial distributions. After preliminary inspection of many sites and literature review, four wetlands significantly impacted by weed infestation were defined for study: Bellambi Gully wetlands, Korrongulla Wetlands (Primbee), Frazer Creek Wetlands, and Koonawarra Wetlands.

Nine weed species were selected for measurement and analysis, defined by growth form and occurrence: caster oil, lantana, moth vine, fire weed, madeira vine, privet, bitou bush, coastal morning glory, and blackberry. In addition, casurina and kikuyu grass were included as both are found in common occurrence with the weeds, creating a mixed patch effect. This paper isolates analysis and further discussion to comparison of lantana and bitou bush.

2.2. Data collection and processing

The spatial distribution at one metre patch level of all species was mapped for two sampling periods: November 2003 (26 – 28 Nov, spring) and March (27 Feb, 1 and 9 March, autumn) using a Palm Data Assistant (PDA) running ArcPad GIS software. Representative samples of reflectance spectra between 350 and 2,500 nm at 2-nm sampling intervals were measured for (i) at the leaf scale in the laboratory and (ii) *in situ* patch samples in the field, using an ASD-FR spectroradiometer (Analytical Spectral Devices, Boulder, CO USA). Spectra were standardized to reflectance using Spectralon (Labsphere, NH, USA). The patch *in situ* spectra were collected between 0.5 and 1m above the top of the taret using a 22 degree field of view with all spectra were collected within 2 h of solar noon. The total number of spectra for each species was 25 for field and 40 for the laboratory specimens. Spectra of flowering weeds were collected during the November sampling period. Spectra data smoothing, and analyses were performed using the Spectral Analyser, a series of customised scripts developed in SPlus to automate processing. A moving t-test [12] was used to compare pairs of mean spectra to determine gross spectral differences between the species and statistical significance at the leaf and patch scales. Derivative analysis was performed to compare differences in the shape of the reflectance curves which are not necessarily evident in the original spectrum, Prior to analysis, spectra were smoothed in the Spectral Analyser using a 5 point moving average [20] which provides consistently smooth derivative spectrum.

3. RESULTS AND DISCUSSION

3.1. Leaf scale

Visual examination of the mean leaf spectra for individual samples for each species show the characteristic patterns of green vegetation yet within-species variation was generally high. When comparing between the two species, bitou bush had considerably higher reflectance visible and NIR reflectance than lantana, but lower SWIR reflectance.

Derivative analysis indicates several spectral regions possibly indicative of differences between biophysical properties of the species, in particular the region associated with the chlorophyll absorption maximum and the red-edge where there is a rapid change of slope between the red and near-infrared regions.

As in the mean reflectance spectra, the first derivative curves of the species show similar features, with inflections and extremas occurring at roughly the same wavelengths. Further analysis indicated several wavelength intervals related to distinguishing features. In several wavelength regions, the location of the curves may be used to distinguish between species.

3.2. Leaf vs patch scale

Comparison between mean spectra at the leaf and patch scale for both species indicates spectral contrast between regions of absorption and scattering at the patch scale. Patch-scale spectra for bitou bush had lower visible, NIR and SWIR reflectance (virtually all wavelengths) similar to that found by other researchers [21, 22]. In contrast, patch-scale spectra for lantana had lower visible and NIR reflectance, but higher SWIR reflectance, again with comparable results to other studies [21]. The moving t-test compared pairs of mean spectral to determine spectral separability suggesting that separability existed between the species within the visible and NIR regions, confirmed by derivative analyses.

4. CONCLUSIONS

Preliminary analysis indicates that bitou bush and lantana have distinct spectral differences at the leaf scale likely related to differences in structural and pigment variation which may enable discrimination despite high variation. Derivative analysis suggests species confirms discrimination may be possible at the leaf level. However, comparisons between leaf and patch scales clearly indicate that spectral features change with the scale of the measurement [21] where quite different variables become important in differentiating species. Further analysis with the larger dataset acquired will assist comparison of: (i) seasonal spectral reflectance to evaluate the impact of flowering; (ii) other plant materials and species being incorporated into the measurement as spatial scale increases from leaf to patch scale, (iii) similar analyses for the remaining weed species, and (iv) patch metrics allowing contrast of weeds versus natural vegetative cover as represented in a mixed patch effect. At this stage it is yet to be established whether species-level differences are most significant at the leaf or the patch scale. Variability at the weed patch level where patch size and extent of weeds interwoven with non-weed species occurs may limit weed species discrimination from an airborne platform. However, it is suggested that weed flowering may provide a means for spectral discrimination between similar species at specific scales of observation.

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