MAPPING THE SPECTRAL AND SPATIAL CHARACTERISTICS OF MOUND SPRING WETLAND VEGETATION IN SOUTH AUSTRALIA: A NOVEL SPECTRALLY SEGMENTED PCA APPROACH

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ABSTRACT

The Australian Great Artesian Basin mound springs are unique wetland ecosystems of great ecological, scientific, economic importance and culturally significant for indigenous Australians. In recent decades the ecological sustainability of the springs has become uncertain as demands for this precious water resource increase. Research methods are being developed using hyperspectral remote sensing for mapping and monitoring the sensitivity of spring vegetation to mining and pastoral water allocations and land use. The aim of this paper is to evaluate the use of Spectrally Segmented Principal Component Analysis (SSPCA) with airborne hyperspectral data to map the extent, distribution and diversity of mound spring permanent wetland vegetation.

HyMap airborne hyperspectral imagery was acquired in March 2009 coinciding with a field campaign of spectroradiometry measurements and botanical survey. SSPCA was applied to NDVI masked vegetation portions of the HyMap imagery with wavelength regions spectrally segmented for VIS-NIR, 450-1,350 nm, SWIR1, 1,400-1,800 nm, and SWIR2, 1,950-2,480 nm.

VIS-NIR PCs 2, 3 and 9 identified key vegetation discrimination wavelength features, i.e., green peak at 555 nm, chlorophyll absorption at 685 nm, and VIS-NIR and red-edge contrasts. SWIR1 PC 3 mapped the invasive species *Phragmites australis*, with notable loadings at 1,450, 1,645-1,715, 1,815, and 1,825 nm associated with water, lignin, and cellulose absorptions, respectively. PC 3 mapped *Phragmites* successfully, coinciding with *Phragmites* in survey field plots verified with 30 cm digital aerial photography. The results suggest that SSPCA is capable of revealing considerable spectral variation within spring wetland vegetation, providing a good basis for discriminating communities.

INTRODUCTION

The Australian Great Artesian Basin (GAB) mound springs (Figure 1) support a unique and diverse range of rare and relic endemic flora and fauna. They also provide a vital source of water in the arid inland heart of Australia (Mudd, 2000; Badman, 1996; Boyd, 1990). In recent decades the ecological sustainability of the springs has become uncertain as demands on the GAB for this precious water resource increase. The impacts of existing water extractions for mining and pastoral activities along with their land use impacts are unknown. This situation is further compounded by the likelihood of increasing demand for extractions in the future.

Previous mapping and monitoring of wetland vegetation associated with selected mound springs has relied on visual interpretation of aerial photography and considerable field work. This approach is particularly limiting for discriminating wetland plant communities, perennial from ephemeral wetland plants and from dryland vegetation.

This paper focuses on the development of research methods for mapping and monitoring the sensitivity of mound spring vegetation to mining and pastoral water allocations and land use using hyperspectral remote sensing. Hyperspectral remote sensing provides the spectral detail necessary to discriminate wetland vegetation and has shown great potential in previous studies for mapping wetlands vegetation (Torbick and Becker, 2009; Hestir et al., 2008; Zomer et al., 2009). The aim of this paper is to determine the capability of Spectrally Segmented Principal Component Analysis (SSPCA) applied to airborne hyperspectral imagery to map the extent and distribution of mound spring permanent wetland vegetation communities.

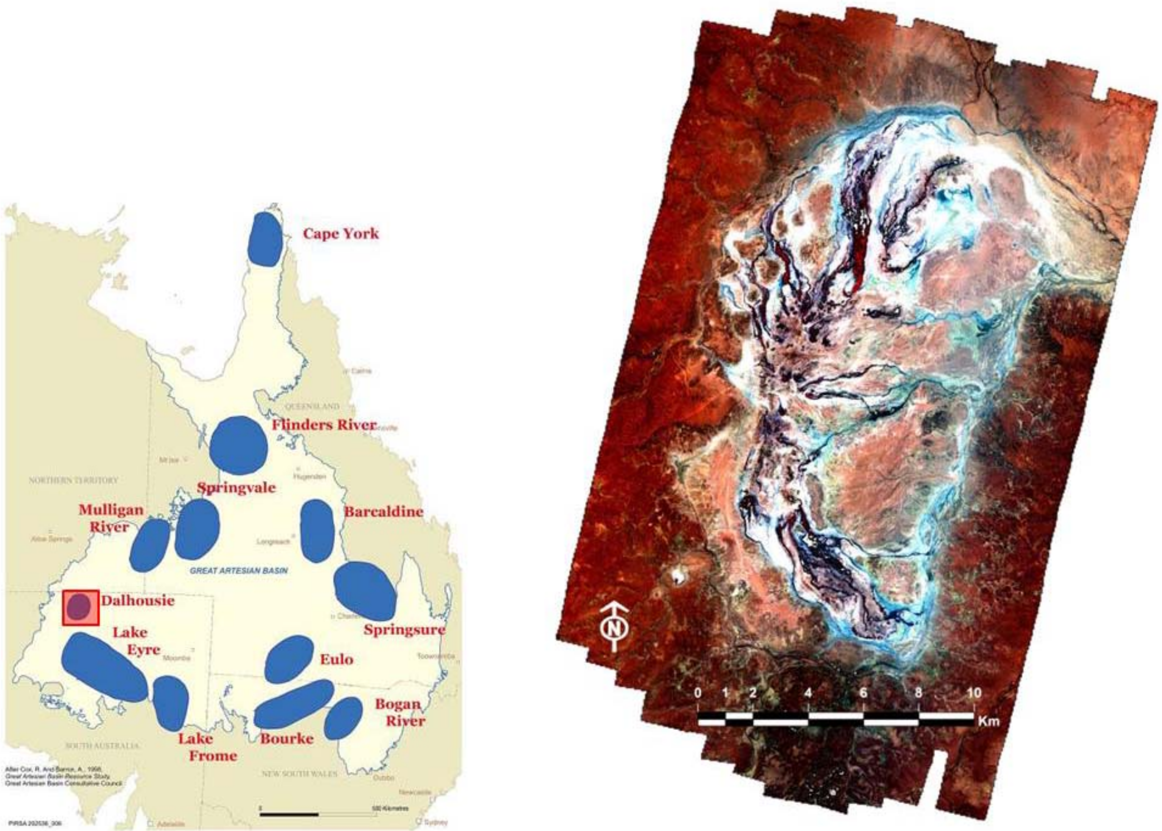

Figure 1. Location of Australian GAB spring groups (graphic courtesy of Travis Gotch, South Australia Arid Lands Natural Resource Management Board) and a false colour composite (blue: 467 nm; green: 559 nm; red: 890 nm) mosaicked HyMap image of the Dalhousie spring group study site.

METHODS

Data Collection and Pre-processing

HyMap airborne hyperspectral imagery was acquired in March 2009 for regions surrounding selected mound spring groups. The imagery comprised 126 wavebands with a bandwidth of ~15 *nm* and wavelength range of 450 - 2,500 *nm* (Kruse et al., 2009; Cocks et al., 1998), with a 3 m spatial resolution and swath width of 1.5 km. Pre-processing of the HyMap imagery by HyVista Corporation included radiometric correction with the HyCorr atmospheric correction model (a modified version of the Atmospheric Removal (ATREM) algorithm; refer to Gao et al., 1993, for details) and Effort polishing, with geometric correction and colour balancing of swaths to form a seamless mosaic. Digital aerial photography at 30 cm ground resolution was acquired concurrently with the HyMap imagery, primarily for image analysis validation purposes.

The analyses reported in this paper were performed on mosaicked HyMap imagery over the Dalhousie Springs group located in northern South Australia on the Northern Territory border (Figure 1).

The HyMap image acquisition coincided with a comprehensive field campaign of field spectroradiometry measurements and a botanical survey. The botanical survey used a modified version of the Braun-Blanquet relevé method. Sample plots of 9 × 9 m were recorded, to allow for geolocation errors and point spread function effects of the HyMap sensor (Schmid et al., 2005). Five roaming target spectra representative of the vegetation within each of the 9 x 9 m sample areas were acquired using an analytical Spectral devices (ASD) FieldSpec® Pro full range (FR) spectroradiometer, together with reference panel measurements . Vertical digital photographs were also acquired for each field spectroradiometer target, capturing the top of canopy instantaneous field of view (TOCIFOV) of the spectroradiometer to quantify vegetation cover.

Hyperspectral Analytical Techniques

Prior to conducting advanced hyperspectral analyses a normalised difference vegetation index (NDVI) was applied to the HyMap imagery. The NDVI was used to mask the HyMap image, selecting only vegetated regions for the SSPCA analysis (values ≥ 0.2 associated with the presence of photosynthetic vegetation). Applying an NDVI mask ensured that the SSPCA focussed on spectral variation within types of wetland vegetation, rather than separation of plants from other land cover types, such as substrate and diffuse discharge zones. A similar approach was adopted by Andrew and Ustin (2008) who constrained an area of the Cosumnes River Reserve to encompass vegetation within NDVI ranges to spectrally separate *Lepidium latifolium* (perennial pepperweed) from other sparse vegetation.

SSPCA was subsequently applied to the NDVI-masked vegetation portions of the HyMap imagery with wavelength regions being spectrally segmented for the VIS-NIR, 450-1,350 *nm*, SWIR1, 1,400-1,800 *nm*, and SWIR2, 1,950-2,480 *nm*. These specific wavelength regions correspond with the four sensors housed within the HyMap airborne instrument and those of the ASD Field Spec Pro FR radiometer (used for field data collection). These different sensors, particularly those of the ASD field spectroradiometer, are known to differ in their field of view of ground targets such as vegetation. Adopting the SSPCA approach ensures that differing fields of view within different wavelength regions corresponding with these sensors do not bias the PCA. Moreover, SSPCA takes into account the higher variances in short wavelength bands in the VIS-NIR region, inherent in hyperspectral data. Thus, SSPCA was deemed an appropriate technique to determine the spectral separability of spring wetland vegetation communities and to identify the key wavelengths conveying the most variation within the spectra.

RESULTS AND DISCUSSION

The SSPCA revealed considerable spectral variation within spring wetland vegetation. VIS-NIR PCs 2, 3 and 9 identified key vegetation discrimination wavelength features, in particular, the green peak at 555 *nm*, chlorophyll absorption feature at 685 *nm*, VIS-NIR and red-edge contrasts (Figure 2). The SWIR1 PC 3 mapped the native, but invasive species *Phragmites australis*, with notable loadings at wavelengths 1,450, 1,645-1,715, 1815, and 1,825 *nm* associated with water, lignin, and cellulose absorptions, respectively (Figure 3). The PC 3 mapped *Phragmites* successfully (lighter pixels coinciding with *Phragmites*), coinciding with *Phragmites* in botanical survey field plots and verified with 30 cm digital aerial photography for a wide range of springs (Figure 4).

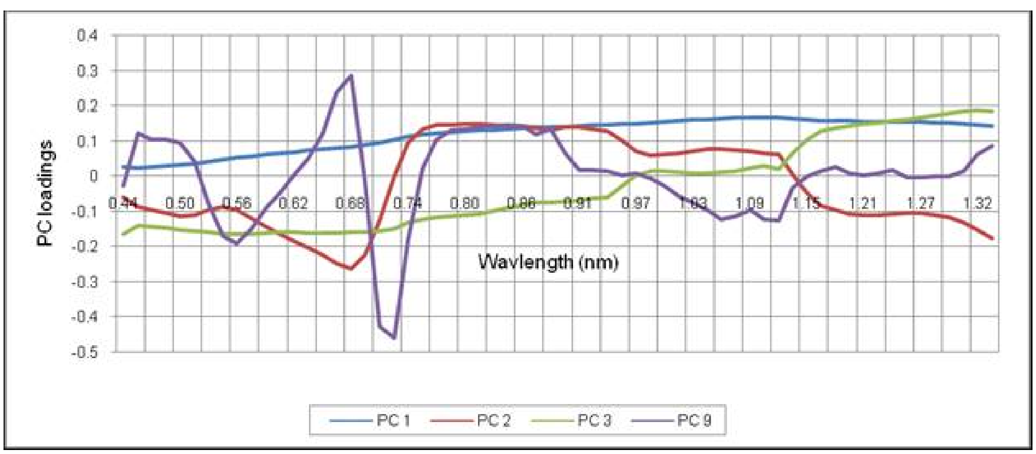

Figure 2. VIS-NIR eigenvector values by wavelength for PCs 1, 2, 3 and 9.

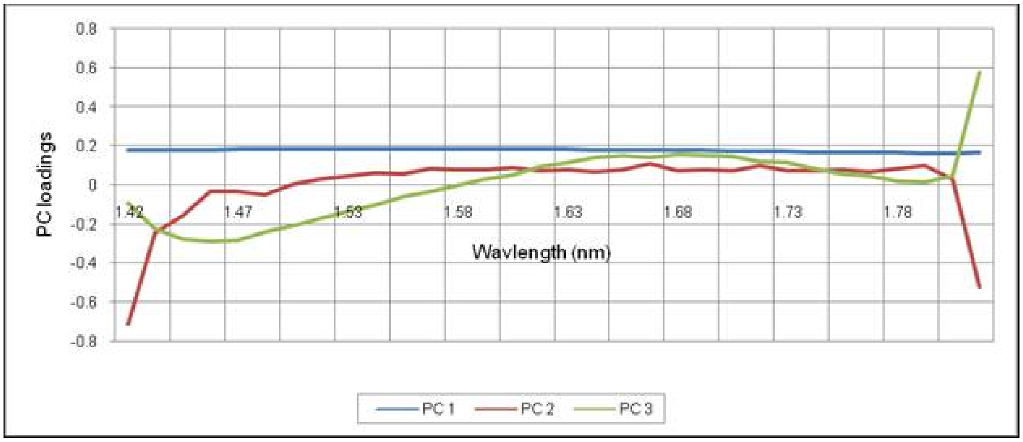

Figure 3. SWIR 1 eigenvector values by wavelength for PCs 1, 2 and 3.

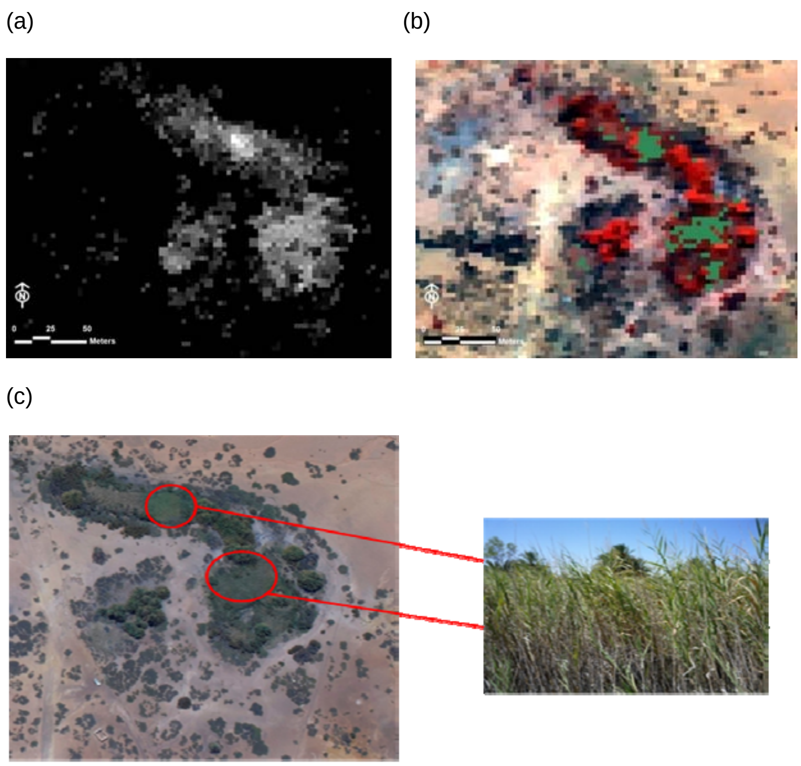

Figure 4. Mapped SWIR1 PC 3 coinciding with *Phragmites* at Dalhousie Ruins: (a) grey scale image of SWIR1 PC 3; (b) NIR false colour composite with density slice overlay of SWIR1 PC 3 in green; and (c) verified with 30 cm digital aerial photography and field botanical survey.

The SSPCA results provide a good basis for discriminating species and communities within the spring permanent wetland vegetation within the HyMap imagery. There is considerable spectral variation within the wetland communities, some of it related to dominant plant species. Current research efforts are focusing on applying SSPCA to the field spectra to assess spectral variation and separability of the wetland plant species. The results of these analyses will be compared with those of the HyMap image analyses: differences between the two data sets may indicate influences associated with spatial heterogeneity within the 3 x 3m pixels of the HyMap imagery.

CONCLUSIONS

Our results suggest that the SSPCA approach is capable of revealing considerable spectral variation within mound spring wetland vegetation, providing a good basis for discriminating species and communities. The key wavelengths identified from the SSPCA for the VIS-NIR and SWIR1 wavelength regions will be used to inform hyperspectral image classification techniques with targeted wavelengths, i.e., spectral angle mapper and mixture tunned matched filtering. A targeted hyperspectral image classification approach will enable expedient image processing to produce maps of wetland vegetation extent and specific spring species such as *Phragmites*.

Moreover, this research, funded by the Australian National Water Commission will ultimately determine the sensitivity of mound spring permanent wetland vegetation to water allocations, thus influencing and improving the effectiveness of water allocation plan management decision and associated policies.

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