RETRIEVING BIOPHYSICAL DATA FROM AIRBORNE MULTISPECTRAL IMAGERY OF RICE CROPS

Sarah SPACKMAN, Gary McKENZIE*, David LAMB, John LOUIS
CRC for Sustainable Rice Production, Charles Sturt University, Wagga Wagga, NSW Australia
*Spatial Analysis Uni, Charles Sturt University, Wagga Wagga, NSW Australia
sspackman@csu.edu.au
gmckenzie@csu.edu.au
dlamb@csu.edu.au
jlouis@csu.edu.au

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ABSTRACT

Calibrated airborne multispectral imagery has been used to retrieve and map biophysical parameters, specifically biomass, in a rice crop (*Oryza sativa)*. Considerable amounts of image preprocessing, including correcting for image shear, camera misalignment and geometric and radiometric distortion was required. Conversion of image pixel digital numbers (DNs) to ground reflectance (R) was also necessary to combine data extracted from multi-temporal imagery, as was rectification to map coordinates using a selection of ground control points (GCPs).
This paper outlines the processes undertaken to generate calibrated surface reflectance data within the growing season of a single rice crop to support the retrieval and subsequent mapping of crop biomass at four stages during the growing season.

1 GENERAL INTRODUCTION

In agricultural crops knowledge of the variability within a field will allow more effective management to improve productivity (Cook & Bramley, 1998). Only now is within paddock variability being considered in Australian irrigated rice (Heermann *et al.,* 1998). Many ricegrowers aim to maximise yield by pre-sowing nitrogen (N) to whole fields, followed by a mid-season blanket application of N. MaNage Rice™ is a predictive crop yield model used by farmers to estimate crop growth potential and estimate mid-season fertiliser applications (Williams & Angus, 1994, Williams & Angus, 1997). This model utilises in-field measurements of various biophysical parameters including plant N, water level and shoot density at panicle initiation, and predicts crop growth, biomass and potential yield values based on various N applications and weather conditions. These parameters are randomly collected and averaged across entire rice fields.

Recently, harvest yield maps and airborne multispectral imagery of rice fields has demonstrated that rice crops are not homogeneous. Consequently, the ability to run predictive growth models separately in zones defined by differences in biophysical parameters would allow more efficient targeting of crop inputs, or at least by defining different zones within the growing season to which sampling could be directed.

Remote sensing has been used to estimate rice biophysical parameters such as leaf area index (LAI), chlorophyll content, percentage ground cover and biomass (Patel *et al*., 1985, Shibayama & Akiyama, 1989, Cassanova *et al.,* 1998). Maps of such parameters derived from imagery could conceivably be used to validate, and if necessary modify, the progression of predictive growth models like maNage Rice™.

Retrieval and mapping of biophysical parameters using airborne multispectral imagery of agricultural crops requires a high degree of image pre-processing to eliminate geometric and radiometric errors inherent in the camera system, and subsequent image calibration to on-ground reflectance and rectification to map coordinates (Neal & Crowther, 1994, Pearson *et al*., 1994).

2 THE AIRBORNE VIDEO SYSTEM

The high-resolution imagery is acquired using a 4-camera airborne video system (ABVS) (Louis *et al.,* 1995). Each CCD monochrome camera has a 740 x 576 pixel array and is fitted with a 12 mm focal length lens. The camera altitude above ground level governs image pixel size, and therefore to obtain 1 m image resolution (1 m x 1 m pixel) the cameras need to be at an altitude of 1524 m providing a footprint of 43.2 Ha (740 m x 576 m).

Each camera has a preset spectral band, specifically selected for vegetation analysis, governed by an interchangeable 25 nm band-pass interference filter. The vegetation filters used in this study include 440 nm (blue), 550 nm (green), 650 nm (red), and 770 nm (near infrared) bands. An on-board IBM compatible 486 computer, fitted with a 4-channel frame-grabber board, captures and digitises 4-band composite images from the cameras, creating 8 bit data.

2.1 Data collection

Multispectral images were collected at four sampling periods during the growing season. For each date the imagery was collected between 11am and 2pm Australian Eastern Standard Time with 1 meter pixel resolution. Four different reflectance canvas calibration panels (6 m x 6 m) were positioned on the ground the day of the flight and were imaged before and after the paddock images were taken. During each flight over the panels ground spectral measurements were taken of each panel with a calibrated PSII field radiometer (Analytical Spectral Devices, Boulder, Colorado, USA). The spectral reflectances of the panels were measured relative to a spectralon panel. This data allowed analysis to be performed on the reflectance changes throughout the day on the calibration panels. For the flight acquisition period there was no relationship between time of day and reflectance however aperture was significantly correlated with change in reflectance. Therefore analysis proved that for these image acquisition periods individual panel reflectance did not significantly vary over time at a particular aperture, so the panels were established to be standard.

2.2 Image pre-processing

Raw images acquired by the ABVS require the application of four fundamental corrections. The corrections are for shear, vignetting, geometric effects and band to band registration.

<u>Shear correction</u>

The COHU cameras used in the ABVS are interlaced. Interlaced cameras capture the odd and even lines of an image separately, with a delay of 20 ms between. Shear correction is required to compensate for the forward motion of the aircraft that effects the capture of the odd and even scan lines of the image. For example at 1524 m the forward movement of the aircraft could offset the horizontal pixel alignment by one or less commonly two pixels between the odd and even image frames.

<u>Vignetting and geometric correction</u>

Vignetting and geometric correction are required due to lens geometry (Ray, 1988). An image of a uniform target, even by illumination, should result in a uniform image. In addition, an image of a regular grid should constitute only straight lines. In reality the further from the centre of these images the lower the brightness of the pixel and the more curved the grid line. Geometric and vignetting corrections are required to eliminate these effects. Laboratory experiments were set up to remove these errors.

<u>Band to band registration</u>

As the ABVS is a four-camera system the alignment of the cameras is not absolutely precise. The cameras are aligned mechanically and it is difficult to achieve precise band to band registration this way. Consequently, a final band to band shift was applied using software.

<u>Conversion of digital numbers to reflectance</u>

After the internal issues of the camera system were addressed the conversion of DNs to reflectance was performed. Using a procedure similar to Richardson *et al*. (1992), the findings of Edirisinghe (1997) were adapted to develop a program that transformed the images into reflectance images using two on-ground reflectance measurements per image to adjust for camera gain and offset (Stow *et al*., 1996). Regression analysis was used to relate image DNs with ground radiometer measurements.

It was established that the dark target was not the darkest object in the image, usually this was water. This discrepancy caused initial problems, such as null values in the red band in particular. To resolve this problem the darkest pixels were established and used as the dark target for calibration. Linear regression equations were calculated for each image enabling DNs to be converted to reflectance. Using this method of calibration the atmospheric effects on the radiation transfer between the target and the sensor are accounted for in the calibration procedure.

2.3 Image pixel extraction

To correlate image reflectance values with ground measurements, pixel values were extracted from the imagery. It was considered that ground samples accounted for a surrounding five meter area. Geometric correction is used to locate areas within the image with respect to a known reference system (geodetic datum) (Billingsley *et al*., 1983). To preserve radiometric quality the imagery was not rectified to a geodetic datum. Instead, the GPS locations of the sample sites were transformed into image coordinates. This procedure ensured that image pixels were not re-sampled and interpolated which would affect the radiometric integrity of the imagery.

3 GROUND SAMPLING

To establish links with the maNage Rice™ model total plant biomass (dry weight), plant nitrogen (N) content, LAI, grain measurements and yield information were collected in the field. Four paddocks were selected with the same rice variety (Amaroo). From each paddock 50 sampling points were established using a Trimble ProXL differential global positioning system (dGPS) (Trimble, Sunnyvale, Claifornia, USA), on a 100 m grid. Sampling was scheduled at four stages within the growing season to correspond with major phenological periods within the rice field; mid-tillering, panicle initiation (PI), flowering and pre-harvest. Image collection was conducted on the 8th December 1998, 5th January, 3rd March and 30th March 1999 and ground sampling began on the day of imaging.

4 IMAGE REFLECTANCE AND GROUND DATA COMPARISON

The biomass field samples were correlated with the extracted airborne derived crop reflectance values and regression of the data was performed. In addition the extracted cluster of pixel reflectance values were converted into the normalised differential vegetation index (NDVI) (Rouse, 1974) and regressed with ground biomass measurements. Analysis was completed separately for each of the four sampling periods (mid-tillering, panicle initiation, flowering and maturity). Table 1 is a summary of the logarithmic regression analysis.

Sampling period	Regression equation	R^2	F value
mid-tillering	NDVI = 0.239 log(DW)-0.534	0.73	82.8
panicle initiation	NDVI = 0.210 log(DW)-0.328	0.50	27.7
flowering	NDVI = 0.078 log(DW)-0.239	0.19	9.2
pre-harvest	NDVI = 0.147 log(DW)-0.438	0.45	36.7

Table 1. Summary of regression equations and R^2 values acquired at each stage of crop development (DW = dry weight biomass)

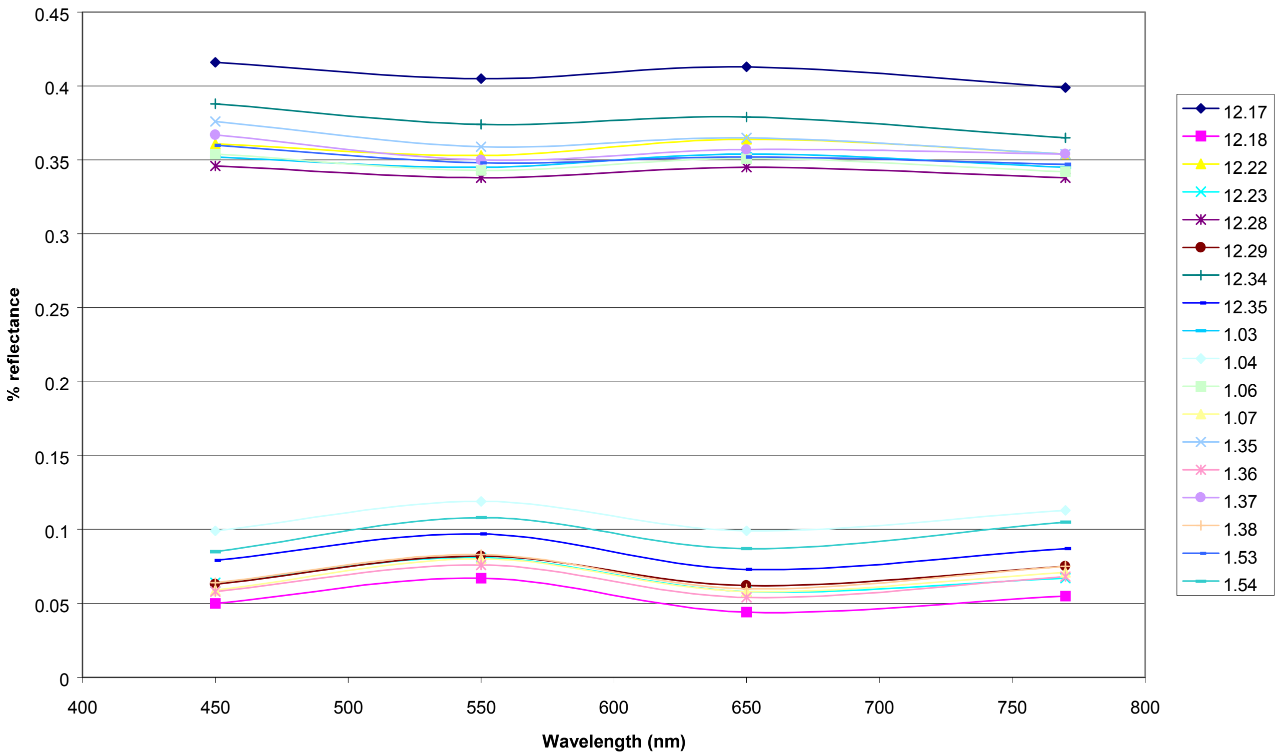
The mid-tillering regression analysis provides the highest R^2 value due to the developing crop contrasting with the underlying water signature and therefore a change in biomass greatly influences the reflectance in each pixel.

5 ACCURACY ASSESSMENT OF THE CALIBRATION

An assessment of the accuracy of the reflectance calibration was obtained by considering the variability of the panels reflectance. Graph 1 illustrates the variation in reflectance for the panels over all of the sampling periods and Table 2 shows the variation in the reflectance of the calibration panels for each band; green (550 nm), red (650 nm), near infrared (770 nm). The differences in panel reflectance are mainly due to the variations in illumination coupled with the non-lambertian quality of the panels. These factors introduce an error of 7% associated in the green band, a 9% error in the red band, and an 8% error in the near infrared band.

	green	red	near infrared
Mean	0.09	0.07	0.08
St. deviation	0.02	0.02	0.02
St. error	0.006	0.006	0.006

Table 2. The mean values, standard deviation and standard error associated with the calibration panels, for each band.



Graph 1. Variation of reflectance panels with reference to time of day, 12.17 pm to 1.54 pm

6 CONCLUSION

As the calibration panel was used to determine reflectance, the error associated with the variation in the panels was convolved into the image reflectance estimates. Although all of the errors have not been accounted for in the reflectance calibration, initial correlations with NDVI and biomass can be estimated with 73% of the variance explained at mid-tillering. The significant correlation at mid-tillering is promising as this is prior to the mid-season application of N to rice fields. This will enable the maNage Rice™ model to be adjusted to actual conditions at various locations within the field and will provide more detailed field management rather than use one estimate of averaged values for the whole field.

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