Calibration of Consumer Digital Cameras to Remotely Sense Cotton Growth

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Abstract

Off-the-shelf consumer digital cameras are inexpensive and convenient, but they cannot concurrently measure visible and near-infrared (NIR) radiation. Two Nikon COOLPIX 4300 digital cameras were evaluated in tandem to determine the effectiveness of a cross-camera calibration procedure that would allow concurrent use of an unmodified digital camera and a NIR-sensitive digital camera without preset shutter speeds or aperture settings. Each camera was calibrated in constant ambient light conditions at 5 exposure levels using a Gretag-Macbeth ColorChecker™ reflectance panel. The procedure was tested on 36 cotton plots (*Gossypium hirsutum*) in an irrigation study in 2006. Images obtained on 8 dates during the season were corrected for exposure and converted to relative reflectance values. The normalized difference vegetation index (NDVI) values from the plots were then compared with ground-based spot spectrometer measurements of NDVI. Corrected camera-based NDVI values were closely correlated with the spectrometer NDVI values over the entire season (r^2 = 0.72).

Introduction

Digital Cameras have several advantages for low-cost imagery:

- Inexpensive
- Portable
- Easy to use

However, there are disadvantages, including the following:

- Lack of user control over some automatic features
- Lower dynamic range
- Insensitivity to Near-Infrared radiation (see Fig. 1.)

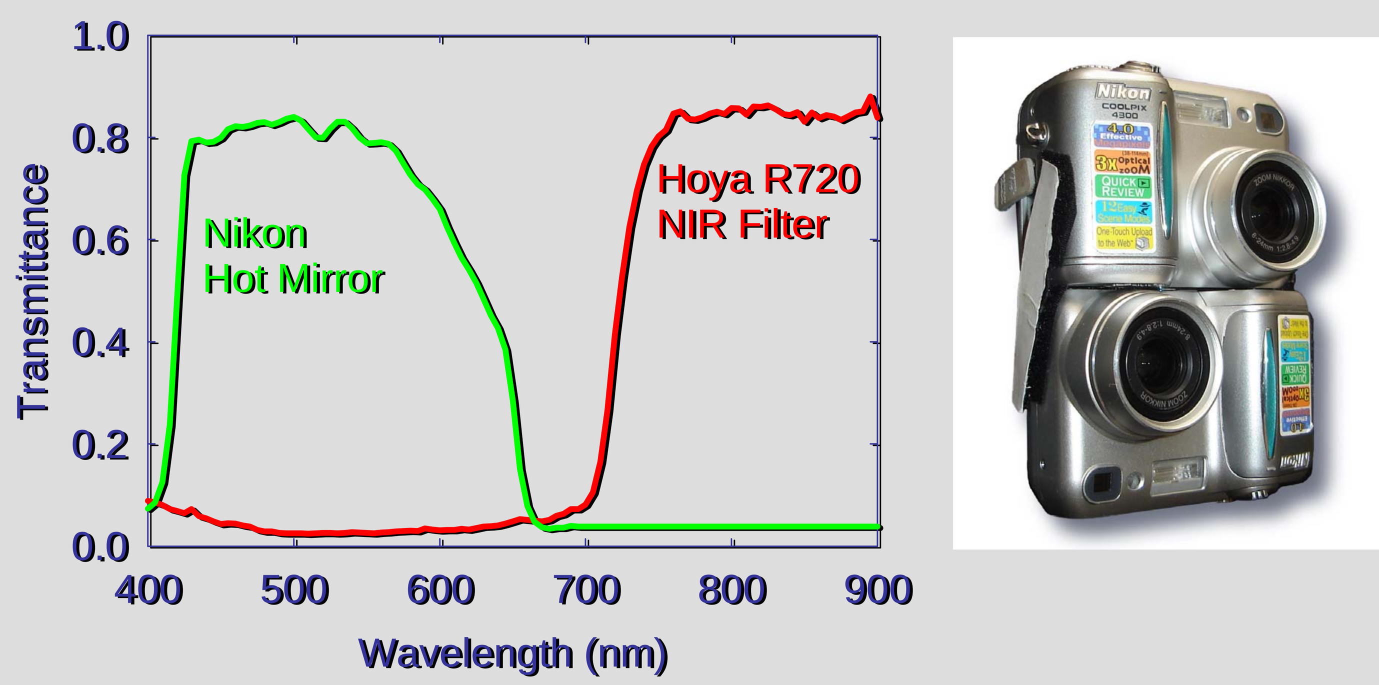


Fig. 1. Transmittance curve of a Nikon 4300 hot mirror and a Hoya NIR filter. The presence of a hot mirror prevents the camera from sensing near-infrared radiation.

Materials and Methods

Exposure Calibration

Two Nikon 4300 digital cameras (1 modified to sense near-infrared) were used to collect images of a Gretag-Macbeth ColorChecker™ reflectance panel at multiple exposures (Fig. 2). Exposure value (E_v) was calculated as:

$$E_v = \log_2(F^2 / shutter)$$

Camera brightness was compared with panel reflectance measured by an Apogee reflectance probe (Apogee Instruments, Logan, UT)

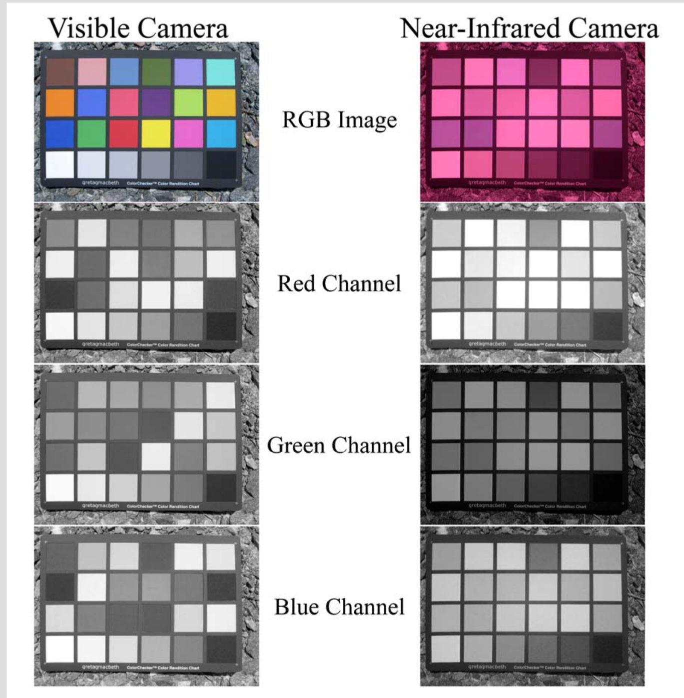


Fig. 2. Visible and NIR camera channel responses to ColorChecker™ chart

Exposure Correction

After exposure calibration was completed, adjustments to raw camera brightness output were performed based on the camera relative exposure level. The correlation and correction between raw output at multiple exposures for the red channel is shown in Fig. 3, and the raw and corrected relationship to reflectance is shown in The raw output is shown in Figs. 4 and 5.

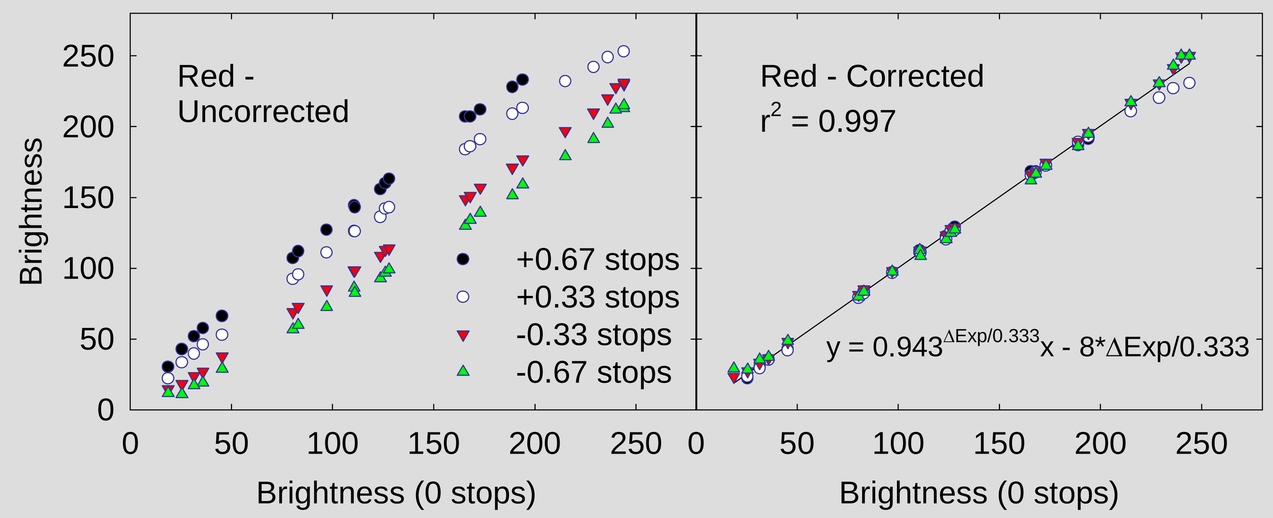
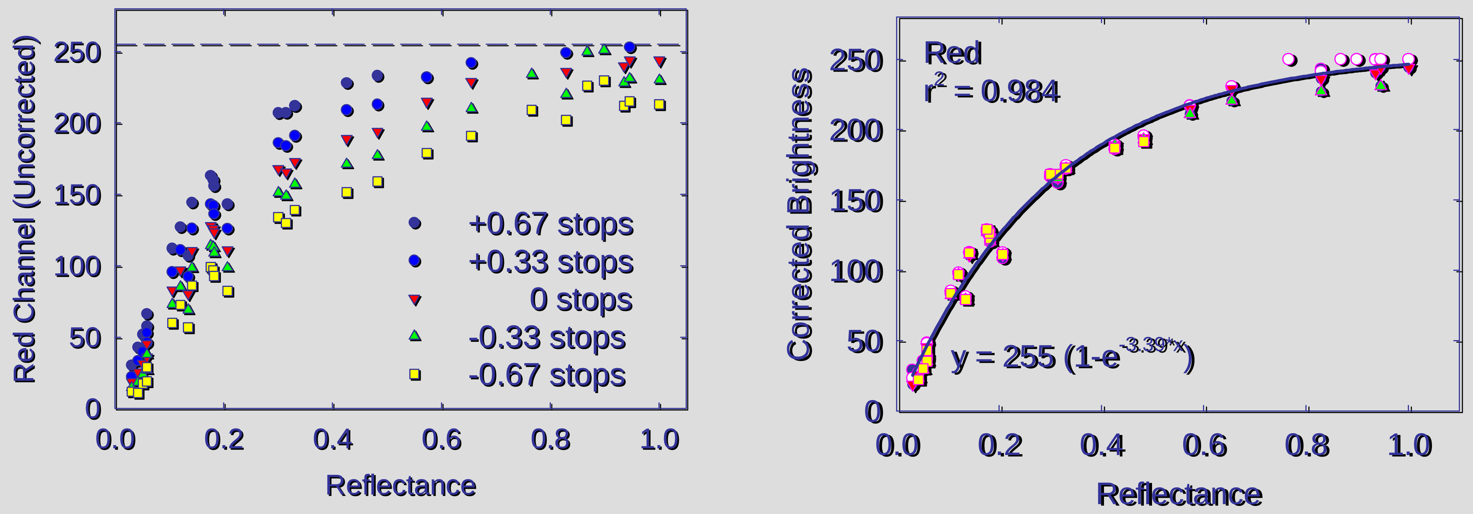


Fig. 3. Correlation of uncorrected (a) and corrected (b) brightness values with each other at multiple exposures.



Figs. 4 and 5. Correlation of uncorrected (4) and corrected (5) brightness values with panel reflectance at multiple exposures.

Results and Discussion

Spectrometer and Camera NDVI

Relationship between NDVI values of reflectance target measured using a spectrometer and reflectance probe with NDVI values calculated from corrected visible red (5 exposure levels) and NIR blue (3 exposure levels) channels. Exposure differences from the visible camera to the NIR camera based on the exposure calculation ranged from -2.0 to +0.39 shutter stops.

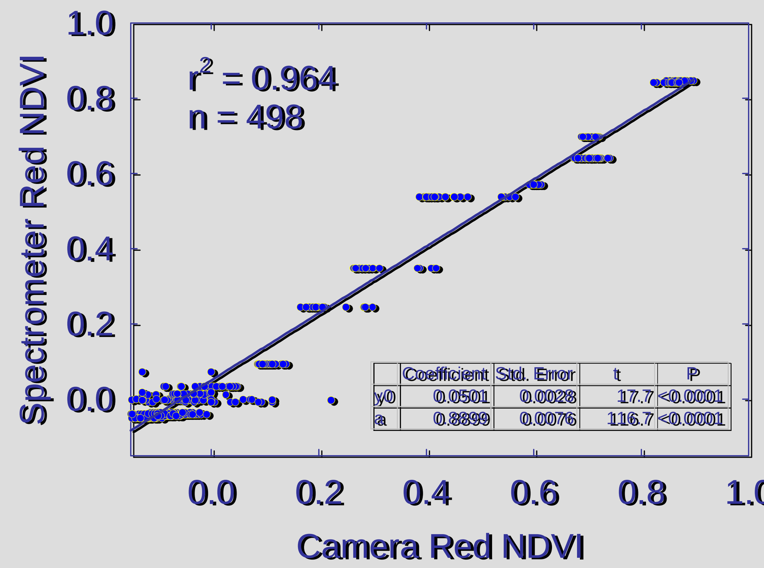


Fig. 6. Spectrometer and camera NDVI correlated closely, even with multiple shutter stop combinations between the visible and NIR cameras

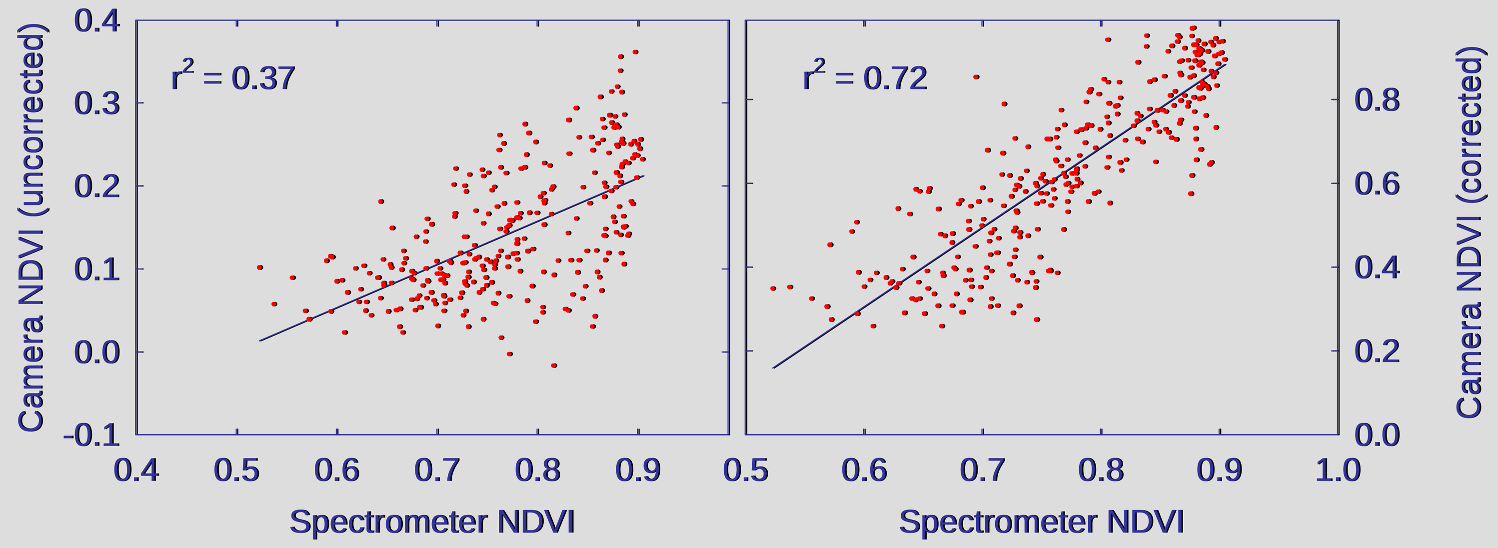


Fig. 7. Effect of exposure correction on relationship of camera NDVI with NDVI values obtained with a ground-based spectrometer. Comparison was made over 7 dates throughout the 2006 growing season on cotton. No other corrections were made.

Conclusions

Cross camera calibration can make consumer digital cameras more practical for remote sensing by correcting for channel sensitivity and exposure differences between the two cameras.

	Step	Equation
1	Collect uncorrected images	
2	Calculate exposure level of both cameras	$E_v = \log_2(F^2 / shutter)$
3	Correct brightness values of one camera to match exposure level of second camera	$y = 0.943^{\Delta E_v / 0.33} x - 8*(\Delta E_v / 0.33)$
4	Convert brightness values to relative reflectance values	$y = -\frac{\ln(1-\frac{x}{255})}{3.39}$
5	Calculate NDVI	$NDVI = \frac{NIR - \mathrm{Re}\,d}{NIR + \mathrm{Re}\,d}$

Contact Information

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