MULTISPECTRAL AERIAL IMAGING OF PASTURE QUALITY AND BIOMASS USING UNMANNED AERIAL VEHICLES (UAV)

Stefanie von Bueren and Ian Yule

New Zealand Centre for Precision Agriculture
Institute of Agriculture and Environment, Massey University
Email: s.k.vonbueren@massey.ac.nz

Abstract
In recent years, the management of grassland systems has focused on site-specific management practises which require accurate, reliable and near-real time data. In order to optimise daily farm management decisions remote sensing data products have to fulfil specific requirements. While space borne remote sensing is limited by its temporal and spatial resolution and proximal sensing methods are laborious when it comes to sampling an entire farm, airborne sensors mounted on unmanned aerial vehicles (UAV) offer a number of advantages: high spatial resolution imagery can be obtained quickly, reliably and at a relatively low cost. However, as research on the civil use of unmanned aerial vehicles is still at an early stage, they need to be trialled and compared to other remote sensing methods.

The project uses two multispectral sensors on board of a remotely controlled MikroKopter. Specific filters on the camera are used to acquire imagery of pasture reflection in discrete wavebands in the visible and near-infrared regions of the electromagnetic spectrum. In order to obtain quantitative data on pasture relevant parameters such as crude protein and biomass, the systems must be accurately calibrated and a data processing chain must be developed. This involves radiometric corrections and accurate georeferencing of images. Statistical methods are then applied to correlate spectral image data to ground reference data.

Successful application of the UAV based multispectral imaging system will produce high quality multispectral image data and lead to an increased understanding of the spatial and temporal variability of pasture quality cover and biomass. Moreover, robust and improved calibration models for airborne remote sensing of pasture relevant parameters will be developed and trialled against hyperspectral and multispectral proximal sensors.

Keywords: Precision agriculture, remote sensing, UAV, multispectral imaging.

Introduction
The agricultural sector is of great economic importance in New Zealand. In order to maximise productivity efficient and reliable technologies are needed that enable farmers to base farm management decisions on accurate and current information. One such area is pasture management where accurate measurement of pasture biomass and quality is essential to good decision making.

Precision agriculture applies geospatial techniques such as remote sensing, Geographic Information Systems (GIS) and Global Positioning Systems (GPS) to identify in-field variability and develop strategies to deal with those variations (Zhang and Kovacs 2012). It aims at an efficient use of inputs to maximise productivity. Remote sensing products such as satellite and airborne imagery as well as proximal sensing methods are important information sources. However, for site-specific management of agricultural paddocks, those data sources have limitations. Even though the spatial resolution of satellite image products has been improved continuously in recent years, they still fail to provide data at high temporal intervals, such as during critical crop growth stages (Primicerio, Di Gennaro et al. 2012). Moreover, because most of New Zealand's pastures producing areas are characterised by high rainfall with abundant cloud cover, the relevant information cannot be extracted from satellite imagery. Proximal remote sensing methods are available for farmers but they are laborious and decisions are frequently based on a small sample size.

Unmanned Aerial Vehicles have recently become the subject of a number of studies that evaluate their applicability for precision agriculture applications. A number of successful studies have been conducted using small, lightweight cameras on board UAV and the research area is given a lot of attention worldwide (Nebiker, Annen et al. 2008; Bergo, Calleri et al. 2010; Laliberte, Goforth et al. 2011; Zarco-Tejada, Gonzalez-Dugo et al. 2012). Unmanned aerial vehicles are a promising tool because of their flexibility and capability to acquire near real-time data of relevant crop and pasture biophysical parameters. Where space borne and proximal sensing methods encounter limitations, remotely controlled sensing platforms can be regarded as a potential tool to fill these gaps. Results and methods derived from UAV acquired data can potentially help to develop technologies to support precision agriculture. Using remotely controlled platforms can also improve the understanding of processes between satellite and airborne sensors by adding a new layer of spatial information. In the future it may become feasible to upscale existing pasture biomass and quality calibration equations to airborne and space borne sensors by applying the information from the UAV as an intermediate layer.

Platforms and sensors
Two unmanned aerial vehicles by MikroKopter are employed in the project: a HexaKopter with six rotors and a QuadKopter with four rotors (Figure 1). Two different multispectral sensors are mounted on the remotely controlled platforms: The Tetracam MCA (Multispectral Camera Array) and a consumer grade Canon PowerShot digital camera that has been converted to detect near infrared light. There are two important requirements for a sensor to be suitable for use on an unmanned aerial vehicle. It must be lightweight and it has to be programmable on the ground for autonomous operation when airborne. Until recently, payload restrictions have prevented their practical implementation for remote sensing applications. Now with increasing availability of lightweight cameras and sensors it has become possible to attach them on remotely controlled platforms and customised firmware allows programming the sensors to acquire imagery at specific time intervals and at predefined GPS positions.

A six band multispectral camera constructed by Tetracam simultaneously acquires imagery in six discrete wavebands. Exchangeable filters in the range of 400 to 1100 nanometres can be fitted, whereas the spectral sensitivity of the detectors is limited in the low and high regions of the electromagnetic spectrum. The camera firmware allows pre-setting all imaging related parameters such as exposure time, delay between images as well as image format and size. Six two gigabyte CompactFlash memory cards allow storage of up to 800 images (10 bit RAW format, full resolution). With a 9.6 mm focal length the camera has a narrower field of view than the Canon camera. A software package delivered with the camera can be used to adjust camera settings and transfer and process imagery in preparation for further analysis**.** Figure 2 shows imagery taken from the HexaKopter over a Sheep and Beef farm near Taihape.

Figure 1 Left: The QuadKopter carrying a video camera. Right: The HexaKopter on the ground with the remote controller and a laptop to set up the system for a GPS waypoint flight.

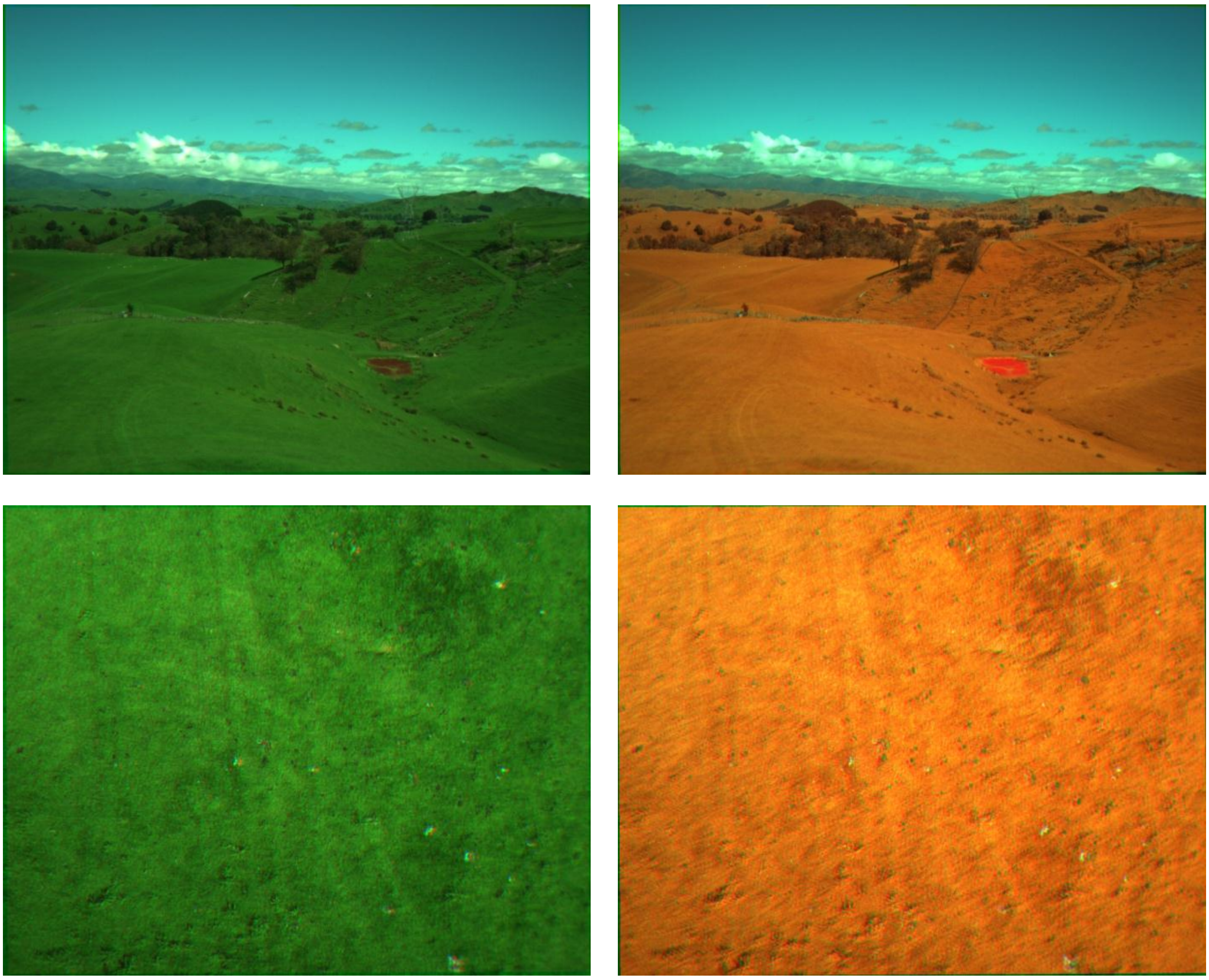

Figure 2 Top left: An RGB image acquired with the Tetracam MCA over a Sheep and Beef farm near Taihape. Top right: Identical image visualised with a near infrared band. Bottom left: A downward looking image from the Tetracam MCA of a pasture paddock. Bottom right: Identical image with a near infrared band.

A three band consumer digital camera has been professionally converted to acquire near-infrared imagery. The near infrared filter has been replaced with a red light blocking filter. Customised firmware on the camera to allows running the camera on continuous capture at specific time intervals. The main difference to the Tetracam is the inability to adjust filter settings (blue, green and near-infrared) and the camera's wider bands which according to factory standards are approximately a hundred nanometres wide.

Calibration of image data

In order to extract quantitative information from aerial images, pixel values must be calibrated to reflectance and geometrically corrected. The radiometric correction involves removal of a dark offset, a lens vignetting correction and the calibration of digital numbers to reflectance. Vignetting refers to the radial falloff of intensity from the centre of the image to the edge and effects can be severe depending on aperture and focal length settings (Goldman 2010). The calibration procedures in this study follow the approach applied in (Kelcey and Lucieer 2012). Dark offset images of the sensors were acquired in a completely darkened room for each band and exposure setting in order to characterise the noise component in the data. Similarly, images to correct for vignetting were acquired of an evenly illuminated lambertian surface under laboratory conditions.

Figure 3 Tarpaulins are used as homogeneous calibration targets for the Empirical Line Method. Left: RGB image of the tarpaulins. Right: Near infrared image of the same area at a lower flight altitude.

The most commonly applied method to convert image data to ground reflectance is the Empirical Line Method that assumes a linear relationship between digital numbers and ground reflectance (Collings, Caccetta et al. 2011). A set of homogeneous targets (black, white, grey and red tarpaulins) with distinct reflectance characteristics is placed on the ground and reflectance measurements are acquired with an ASD spectrometer. At the same time images with the Tetracam MCA and the Canon PowerShot camera are taken over the targets (Figure 3). A calibration equation is derived for each discrete waveband by correlating ground and airborne measurements. The geometric correction involves removal of lens distortion effects and orthorectification of the imagery using ground control points of known location. After all image correction methods are applied quantitative information on vegetation properties such as pasture biomass and quality can be derived.

Conclusions

Unmanned aerial vehicles are a flexible and promising tool to acquire near real-time data over agricultural areas and support site-specific pasture management practices. The current project employs two remotely controlled platforms, a HexaKopter and a QuadKopter, to acquire multispectral imagery of pasture paddocks. Processing of the image data involves correction for radiometric aberrations, calibration to ground reflectance and orthorectification. The resulting high quality remote sensing data is used to derive pasture relevant information such as biomass and quality on a fine spatial and temporal scale.

References

Bergo, M., A. Calleri, et al. (2010). "Precision agriculture deploying Unmanned Aerial Vehicle (UAV)." Mondo Macchina **19**(1): 44-50.

Collings, S., P. Caccetta, et al. (2011). "Empirical Models for Radiometric Calibration of Digital Aerial Frame Mosaics." Ieee Transactions on Geoscience and Remote Sensing **49**(7): 2573-2588.

Goldman, D. B. (2010). "Vignette and Exposure Calibration and Compensation." Ieee Transactions on Pattern Analysis and Machine Intelligence **32**(12): 2276-2288.

Kelcey, J. and A. Lucieer (2012). "Sensor Correction of a 6-Band Multispectral Imaging Sensor for UAV Remote Sensing." Remote Sensing **4**(5): 1462-1493.

Laliberte, A. S., M. A. Goforth, et al. (2011). "Multispectral Remote Sensing from Unmanned Aircraft: Image Processing Workflows and Applications for Rangeland Environments." Remote Sensing **3**(11): 2529-2551.

Nebiker, S., A. Annen, et al. (2008). "A Light-weight Multispectral Sensor for Micro UAV - Opportunities for Very High Resolution Airborne Remote Sensing." XXI ISPRS Congress. Beijing, China.

Primicerio, J., S. F. Di Gennaro, et al. (2012). "A flexible unmanned aerial vehicle for precision agriculture." Precision Agriculture **13**(4): 517-523.

Zarco-Tejada, P. J., V. Gonzalez-Dugo, et al. (2012). "Fluorescence, temperature and narrow-band indices acquired from a UAV platform for water stress detection using a micro-hyperspectral imager and a thermal camera." Remote Sensing of Environment **117**: 322-337.

Zhang, C. and J. M. Kovacs (2012). "The application of small unmanned aerial systems for precision agriculture: a review." Precision Agriculture **13**(6): 693-712.