HIGH-RESOLUTION DATA FOR MANGROVE HEALTH AS OBTAINED FROM UNMANNED AERIAL VEHICLE COLLECTED IMAGERY

Keywords: mapping, unmanned aerial vehicle, Port Hedland, remote-sensing, high resolution, mangrove

Abstract

This study investigated the use of aerial photographs, acquired in 2013, for assessing the temporal dynamics of mangroves at Utah Point, Port Hedland, in the Australian state of Western Australia. For years, mangrove extent has been mapped using an unsupervised classification of the digital orthomosaic or using large spatial satellite imagery unable to detect changes in areal extent or branch morphology on the micro scale. Unmanned aerial vehicles (UAVs) are an alternative airborne platform, which allows fast aerial imaging of small areas with a higher level of detail and lower cost.

Photographs of each site showed that *Avicennia marina* and *Rhizophora stylosa* made up 438 m^2 at Utah Point and 272.2 m^2 at Finucane Island. Each square metre of mapping was mapped to the species and scored visually as either dead or alive.

The study demonstrated the viability of using aerial photography collected from a UAV for monitoring and understanding the spatial extents of mangrove communities in Port Hedland for routine monitoring of temporal change.

Introduction

Since stockpiling operations at Utah Point began in 2010, Port Hedland Port Authority has conducted annual mangrove health monitoring surveys. The objective of these surveys is to assess whether stockpiling of manganese, iron and chromium mineral ores are adversely affecting the adjacent mangrove community. One of the scopes for assessing mangrove community assemblage is areal extent from aerial imagery.

Mangroves are salt-tolerant trees located along tropical coasts. The mangrove forest acts as a buffer between land and sea, reducing the impact of storm surge, waves and erosion of the shore (Badola and Hussain 2005).

Most research on mangroves is performed in small plots that are relatively easy to access. The study of large mangrove forests within the context of adjacent ecosystems (i.e. landscape scale) requires the use of maps. Remote-sensing technology enables large-area surveys and has been used in several studies to understand mangrove forests at the landscape scale.

Recent developments in the use of unmanned aerial vehicles (UAVs) for remote-sensing applications provide exciting new opportunities for ultra-high-resolution mapping and monitoring of the environment. A recent special issue on UAVs highlights that this field has an increasing potential for remote-sensing applications (Zhou, Ambrosia et al. 2009). Rango et al. (2006) and Hardin and Jackson (2005) developed and used a UAV based on a remote-controlled helicopter and a plane capturing <1 cm resolution colour photography for rangeland mapping and monitoring. Several recent studies have highlighted the benefit of UAVs for crop mapping and monitoring (Lelong, Burger et al. 2008; Zarco-Tejada 2008; Berni, Zarco-tejada et al. 2009; Hunt Jr, Hively et al. 2010). Laliberte and Rango (2009) and Dunford et al. (2009) demonstrated how UAV imagery could be used for mapping natural vegetation using geographic object-based image analysis (GEOBIA) techniques. Finally, Nagai et al. (2009) showed how multiple sensors (visible, near-infrared and LiDAR) could collect very-high-resolution data simultaneously from a large

UAV. The UAV platform's key advantage is its ability to fill a niche with respect to spatial and temporal resolution. The imagery acquired from a UAV is at sub-decimetre or even centimetre resolution and UAV imagery can be flown on-demand, making it possible to capture imagery frequently and thus allowing for efficient monitoring.

The possibility to apply individual aerial photography opens up a new generation of field mapping, providing the ability to capture mangrove forest morphology at a scale neither resolvable from satellite images nor from observation. The presented aerial photos were taken with a UAV and show details of a large area at a glance. It proved to be very useful for mapping structures like dead branches and species.

Previous studies (SKM 2009) state that estimation of areas of mangroves cannot be expected to be exact and that some error of interpretation will occur when fixing boundaries for delineation of individual mangrove associations and mangroves in general. Further, SKM (2009) stated that errors in estimates were obtained in the delineation of the category *Avicennia marina* (scattered), which comprises scattered trees that may be present at very low densities. Estimates of this association could be expected to vary considerably (SKM 2009). The proposed UAV method can capture deci centimetre images – capturing individual plants and avoiding some of the difficulties encountered in the SKM study.

Materials and methods

Study sites were located in several intertidal creeks that converge in the Port Hedland inner harbour estuary in Western Australia's Pilbara region (20"19'210S, 118"34'200E) (Figure 1). The region experiences a sub-tropical climate with warm winters and hot summers. Mean rainfall is variable, ranging from 250 mm to 400 mm a year with most falling in summer in association with tropical storm and cyclonic activity. Mean minimum and maximum temperatures are 26°C and 36°C in January and 13°C and 27°C in July (Bureau of Meteorology 2012). Most of the low-lying areas surrounding the harbour are within the storm surge zone.

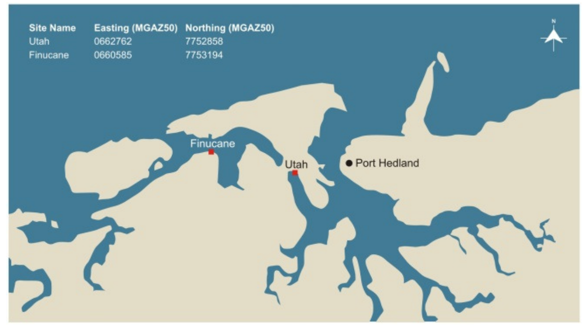

Figure 1: Study locations

The imagery was acquired in May 2013 at Utah Point, Port Hedland, Western Australia. For this study an area of mangroves monitored annually by Port Hedland Port Authority as part of the Utah Point development were selected (PHPA 2008). Dominant mangroves in the study area consisted of *Avicennia marina* and *Rhizophora stylosa.*

This study utilised a small UAV manufactured by Draganfly Innovations, namely the Draganflyer X6, a GPS-guided, high-definition, aerial video and digital photography platform.

The system consists of a fully autonomous GPS-guided UAV, ground station with mission planning and flight software, and telemetry system (Figure 2). The aircraft was equipped with a Panasonic DMC-ZS20 (TZ30) 14-megapixel digital camera and flew at 30 m to 50 m above ground, acquiring imagery with 60% forward lap and 30% sidelap. The resulting image footprints were 50 m x 60 m and had a pixel size of 2 cm. Single images were used for this analysis.

Figure 2: Draganflyer X6 in operation

All images had four ground control points captured and these were set up permanently for future analysis. These were typically 20 m x 20 m.

GEOBIA was undertaken on the captured images. GEOBIA methods partition remote-sensing imagery into meaningful geographically based image-objects, and assess their characteristics through spatial, spectral and temporal scales.

Images were classified into mangrove canopy (by species) and dead canopy (by species). Results were extracted as m^2 and percent canopy cover.

Results

Classification of mangroves combines easily with aerial photograph interpretation and various other forms of remote-sensing (Terchunian, Klemas et al. 1986; Ibrahim and Hashim 1990; Garcia, Schmitt et al. 1998).

In terms of understanding the areal extent of mangrove plant communities, a classification by species is most appropriate. Typically mixed assemblages are measured, however with the UAV's resolution, species can be captured at the individual plant level (Figure 3 and Figure 4). The selected parameters (dead or alive) allow some functional interpretations of structural variation to be made (Table 1). An assessment of mangrove plant communities in these terms conveys clues about the environment and will enable predictions to be made about the direction of any change in the community over a temporal scale; that is, annual surveys.

Table 1: Mangrove communities coverage

Site	Total area	Avicennia	Dead Avicennia	Dead Rhizophora	Rhizophora	Percent cover (alive)
Utah Point	495 m^2	212.1 m^2	0 m^2	0 m^2	225.9 m^2	88%
Finucane Island	309 m^2	133.1 m^2	11 m^2	1.1 m^2	141.1 m^2	88%

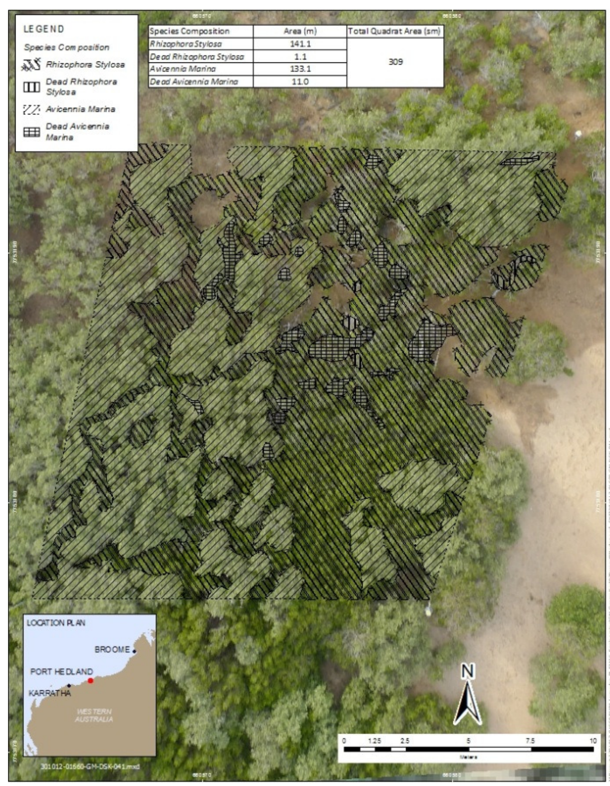

Figure 3: Finucane Island site

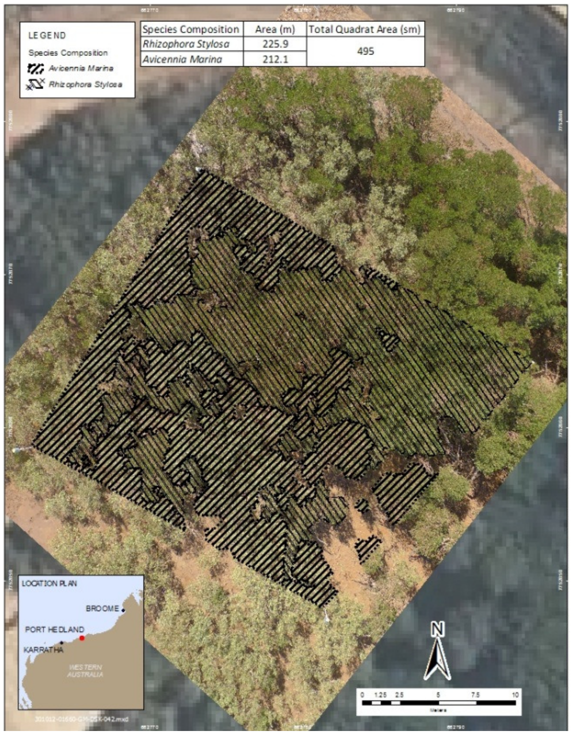

Figure 4: Utah Point site

Conclusion

This work demonstrated that it is possible to generate quantitative remote-sensing products by means of a UAV. Remote-sensing sensors placed on UAVs represent an option to fill this gap, providing low-cost approaches to meet the critical requirements of spatial, spectral and temporal resolutions.

Photogrammetric techniques were required to register the frame-based imagery to map coordinates. Cameras were geometrically characterised with their intrinsic parameters. These techniques, along with position and attitude data gathered from the autopilot, enabled the generation of large mosaics semi-automatically with minimum use of ground control points.

Further UAV development, combined with continued refinement and miniaturisation of imaging payloads, potentially offers an affordable alternative to more conventional remote-sensing platforms for user communities requiring near-realtime delivery of ultra-high-spatial and high-spectral resolution image data.

References

Badola, R. and S. Hussain (2005). "Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India." Environmental Conservation 32(1): 85-92.

Berni, J. A., P. J. Zarco-tejada, et al. (2009). "Thermal and Narrowband Multispectral Remote Sensing for Vegetation Monitoring from an Unmanned Aerial Vehicle." IEEE Transactions on Geoscience and Remote Sensing 47: 722-738.

Dunford, R., K. Michel, et al. (2009). "Potential and constraints of Unmanned Aerial Vehicle technology for the characterization of Mediterranean riparian forest. ." International Journal of Remote Sensing 30: 4915-4935.

Garcia, J. R., C. Schmitt, et al. (1998). "CARICOMP - Caribbean coral reef, seagrass and mangrove sites." Coastal region and small island papers 347.

Hardin, P. and M. Jackson (2005). "An unmanned aerial vehicle for rangeland photography." Rangeland Ecology & Management 58: 439-442.

Hunt Jr, E., W. Hively, et al. (2010). "Acquisition of NIR-Green-Blue Digital Photographs from Unmanned Aircraft for Crop Monitoring." Remote Sensing 2: 290-305.

Ibrahim, S. and I. Hashim (1990). "Classification of mangrove forest by using 1:40 000 scale aerial photographs." Forest Ecology and Management 33(5): 83-5.

Laliberte, A. S. and A. Rango (2009). "Texture and Scale in Object-Based Analysis of Subdecimeter Resolution Unmanned Aerial Vehicle (UAV) Imagery." IEEE Transactions on Geoscience and Remote Sensing. 47: 761-770.

Lelong, C. C., P. Burger, et al. (2008). "Assessment of unmanned aerial vehicles imagery for quantitative monitoring of wheat crop in small plots." Sensors 8: 3557-3585.

Nagai, M., T. Chen, et al. (2009). "UAV-Borne 3-D Mapping System by Multisensor Integration. IEEE Transactions on Geoscience and Remote Sensing." 47:

701-708.
Rango, A., A. Laliberte, et al. (2006). "Using Unmanned Aerial Vehicles for Rangelands: Current Applications and Future Potentials.
." Environmental Practice 8: 159-168.
SKM (2009). Benthic Primary Producer Assessment Intertidal. RGP6 Port Facilities.
Terchunian, A., V. Klemas, et al. (1986). "Mangrove mapping in Ecuador: the impact of shrimp pond construction." Environmental Management 10(3): 345-50.
Zarco-Tejada, P. J. (2008). "A new era in remote sensing of crops with unmanned robots." SPIE Newsroom: 2-4.
Zhou, G., V. Ambrosia, et al. (2009). "Foreword to the Special Issue on Unmanned Airborne Vehicle (UAV) Sensing Systems for Earth Observations." IEEE Transactions on Geoscience and Remote Sensing 47: 687-689.