HIGH RESOLUTION LOW ALTITUDE AERIAL PHOTOGRAPHY FOR RECORDING TEMPORAL CHANGES IN DYNAMIC SURFICIAL ENVIRONMENTS

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INTRODUCTION

Aerial photography provides an effective method for observing temporal change in dynamic surficial environments. Applications include measurement of plant vigour, survey planning, environmental monitoring, regolith mapping and weed auditing.

There are, however, a number of factors that limit the regular use of aerial photography. The most significant of these is cost. Traditional aerial photography utilising planes or helicopters is expensive. Although existing data sets are often available, they are rarely site specific, or may be out of date and lack the resolution required for local-scale, highly detailed site analysis. Rapid response and repeatability of photography can also be an issue. If regular temporal changes need to be recorded, such as seasonal vegetation changes, the cost of survey flights can become prohibitive. Acquiring photographic data in rapid response to triggering events,such as Fe-oxide colour changes due to changing redox conditions, soil pore clogging by Fe-oxides and sulphide minerals, formation of salt efflorescence and observing erosion after heavy rainfall can be problematic. Aeroplanes are rarely available on call and must be booked weeks and often months in advance.

In this study we investigate low cost, local-scale alternatives to traditional aerial photography techniques. The methodologies used aim to affordably increase photo resolution, improve flexibility and site specificity whilst providing rapid response to triggering events. The projected outcome is for a user-friendly, multi-level, low-altitude aerial photography system that can be specifically tailored to the requirements of studies unsuited to more traditional techniques.

REVIEW

A number of workers have proposed low cost aerial photographic techniques. Ries & Marzolff (1997) used a remote-controlled blimp as a platform to identify sediment sources in semi-arid environments. Using the same technique they were able to monitor the rate of gully erosion in the Central Ebro Basin, Spain (Ries & Marzolff 2003). Boike & Kenji (2003) mapped periglacial geomorphology in Alaska using kites and balloons as aerial photography platforms. The high-resolution photographs obtained enabled them to monitor changes in permafrost patterns, periglacial processes and vegetation over time and space. Jia *et al*. (2004) examined relationships between image-derived reflectance and soil-plant data using helium filled weather balloons as platforms for low altitude aerial photography. This study highlighted the potential of aerial photography to help determine the optimum N fertiliser levels for winter wheat on the North China Plain. Klaasen & Greeley (2003) proposed a far more ambitious and costly use of balloon aerial photography with their Venus Exploration of Volcanoes and Atmosphere Discovery mission. They suggested that a balloon-gondola system could be deployed into the Venus atmosphere providing the first ever aerial photography of the planet's surface. There is, however, a gap in the literature concerning the use of low altitude, high-resolution aerial photography to observe and map local-scale temporal changes in soil and regolith morphology.

SITE DESCRIPTION

The study site is a perched wetland in a saline sulfidic discharge area at the Mount Torrens Prospect (45 km east of Adelaide - 139°01' E; 34°53' S; area about 2 km^2) where minor Pb-Zn-Ag mineralisation occurs in calc-silicate rocks at the base of the Talisker Calc-siltstone (Skwarnecki *et al*. 2002). Weathering of the sulfides and calc-silicate rocks has produced sulfate-rich groundwaters, which have led to the development of a range of acid sulfate soil materials such as sulfidic materials (mainly secondary pyrite) and sulfuric horizons (oxidised sulfidic materials containing a variety of oxyhydroxysulfate and oxide minerals) (Fitzpatrick & Self 1997). The wetland is roughly circular with a central marsh surrounded by a seasonally variable seepage area approximately 20 metres in diameter. As the existing vegetation is typical of marsh areas in the region, it is likely that the site has been wet for a long period. However, rising saline water tables have resulted from decreased water use efficiencies of the annual agricultural plant species that have replaced native perennial plants. Increased local recharge has caused an expansion of the seepage area and increased evapotranspiration has increased salinities. The accession of fresh waters to sodic soils and seasonal oxidation have resulted in clay dispersion, together with iron oxide clogging of soil pores, thus reducing soil hydraulic conductivities (Fitzpatrick *et al.* 1996). Pugging of the saline seep by cattle further increased pyrite formation and destruction of native vegetation prior to fencing. Seasonally variable recharge rates significantly alter the overall size and redox conditions within the wetland. This produces internal botanical zonation of the wetland and the appearance of surface soil textures such as iron oxide colours and the precipitation of salt crystals (Merry *et al.* 2002).

METHODOLOGY

We have developed two methods for high-resolution, low altitude aerial photography. Method A operates from an altitude of 10 m and method B operates from altitudes of 10-30 m.

Method A - Cable supported platform for low altitude aerial photography

Low altitude photographic method A involves a 5 mega pixel digital camera (Cannon PowerShot S50) being passed along a stainless steel cable approximately 10 m above the saline sulfidic discharge area discussed above. The cable was rigged between two 10 m tall poles each supported by two stainless steel guys (Figure 1).

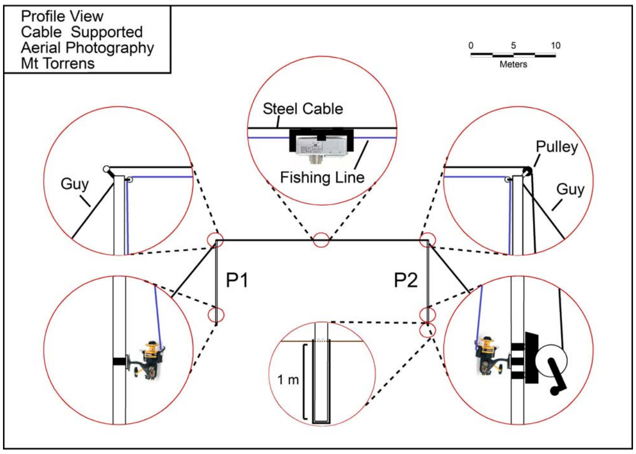

Figure 1: Design of cable supported platform for low altitude aerial photography

Stress and deflection calculations were performed to determine the shape, gauge and material best suited for pole construction. Aluminium piping was selected with a 2 mm gauge and 76 mm outer diameter. Each pole was constructed from two 6 m pipes spliced and clamped together with a 1 m overlap producing an overall length of 11 m. The construction optimised weight (< 14 kg/pole) deflection (< 10 cm) and yield strength. Two parallel lines (six per line) of vertical holes were dug at the northern and southern boundaries of the study area. Hole spacing was calculated to allow full photographic coverage of the study area (Figure 2).

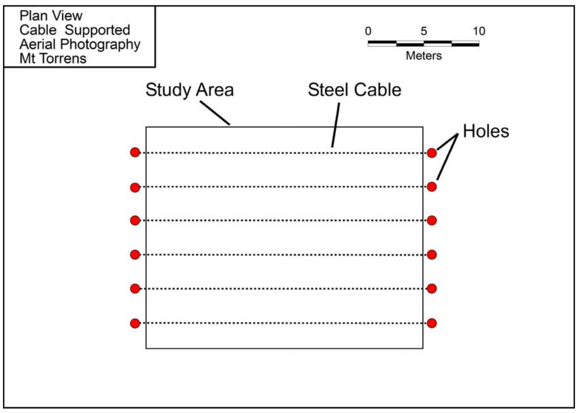

Figure 2. Plan view of cable supported platform for low altitude aerial photography

The holes were dug to a depth of 1 m using a four inch hand auger and a spirit level. Each hole was lined with 90 mm PVC piping and capped at the top and bottom to prevent holes filling with water and sediment.

Bentonite was used to seal around piping to prevent leakage from punctured confined ground water aquifers. The poles were placed into each hole in turn, providing the means for a camera platform altitude of 10 m. A stainless steel cable was fixed to the top of pole P1 and passed over a pulley at the top of pole P2, spanning the study area. Reeling in the cable from the base of pole P2 provided tensioning (Figure 1). Further tension adjustments were achieved using turnbuckles and guy cables fastened to the top of each pole. A gondola was constructed to suspend the digital camera beneath the spanning cable. The gondola was designed to find its own centre of gravity beneath the cable allowing the camera lens to remain perpendicular to the ground. Fishing reels were attached to the base of poles P1 and P2 (Figure 1). Fishing line was passed through pulleys at the top of each pole and fastened to the gondola (Figure 1). One fishing reel was set to a medium drag and the other was used to pull the gondola along the cable in uniform increments. The camera could be returned to any given point along the cable by simply counting the number of turns made on the fishing reel. The camera was set to "intervalometer" mode, causing a shutter release every one minute. Two times optical zoom was selected to increase resolution and reduce lens derived optical distortion. The camera was pulled along the cable following each shutter release providing a line of photos across the study area. Poles P1 and P2 were then shifted to the next set of holes and the process repeated, providing a line of photos parallel to the first. The process was repeated until complete aerial photographic coverage was gained over the study area. The study area was surveyed using a differential GPS and theodolite allowing georectification of aerial photographic images using the Erdas Imagine 8.7 software package.

Method B – Helium balloon supported platform for low altitude aerial photography

Low altitude photographic method B involved the same 5 mega pixel digital camera (Cannon PowerShot S50) being suspended on a gondola beneath a helium-filled weather balloon (Figure 3). Two strong, light, high visibility cords were used to tether and guide the balloon. Two 5 kg weights were attached to each tether to prevent loss of equipment. The balloon was filled with 1.5 m^3 of helium, providing enough lift to support three times the combined mass of camera, gondola and tethers (0.8 kg). Excess lift, created by the high volume of helium, tensioned tethers and provided stabilisation for balloon and gondola. The gondola was designed to find its own centre of gravity beneath the balloon, allowing the camera lens to remain perpendicular to the ground. A day with light winds (< 5 knots) was selected for trialling of balloon supported aerial photography. Obstacle and hazards including trees and power lines were noted. It was deemed safe to conduct the trial as there was sufficient clearance between the study area and surrounding hazards. The balloon was filled with helium to the required volume and the gondola and camera were suspended beneath. The balloon was allowed to slowly ascend on its tethers to a maximum height of 30 m—Civil Aviation Safety Regulations state that unmanned aircraft have a maximum ceiling of 122 m (CASA 1998). The camera was set to "intervalometer" mode causing a shutter release every one minute. Aerial photographs were taken at various altitudes allowing trade-offs between resolution and spatial coverage. Tethers were used to relocate the balloon around the study site. The study area was surveyed using a differential GPS and theodolite allowing georectification of aerial photographic images using the Erdas Imagine 8.7 software package.

Figure 3: Helium balloon-supported aerial photography platform

RESULTS AND DISCUSSION

Both methods A and B provided valuable data for the study of a saline sulfidic discharge area at the Mount Torrens Prospect (Figure 4). Aerial methods A and B highlight wetness, botanical zonation of the wetland and the appearance of surface soil textures such as iron oxide colours, precipitation of salt crystals and the occurrence of scalds (Figure 4). Method B provided a good overview of the study area documenting locations of field monitoring instrumentation (e.g., redox probes and piezometers) and larger scale regolith-landform patterns. Method A provided more detailed information of surface features throughout the study area. Small but important changes in vegetation and soil texture boundaries would be missed without these methodologies. Both aerial photographic techniques provide an excellent method of observing temporal change to surface features in studies of this kind.

Each method had its specific strengths and weaknesses. A comparison of traditional aerial photography and methods A and B are listed in Table 1.

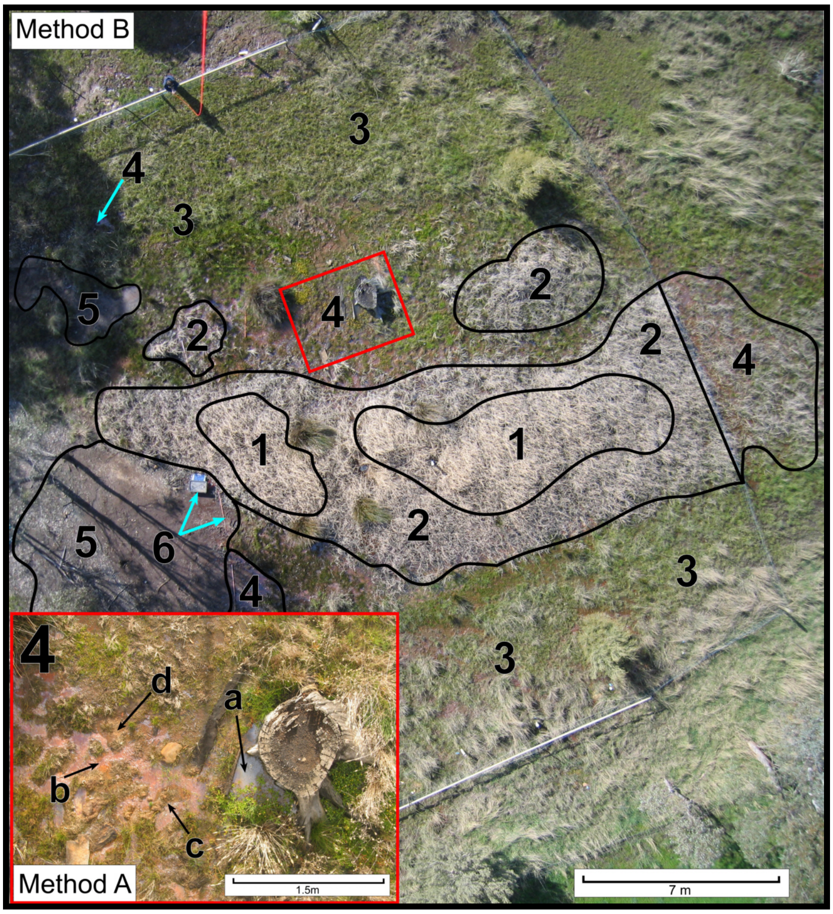

Figure 4: Aerial photos produced by methods A and B of a saline sulfidic discharge area at the Mount Torrens Prospect. Photos highlight botanical zonation (1 = dense vegetation, 2 = moderately dense vegetation, 3 = grassed areas) within the wetland, areas of wetness (4a = ponds of water with Fe-oxidising bacteria floating on surface) and the appearance of surface soil textures such as iron oxide colours and gels (ferrihydrite) (4b = Fe-oxide colours and gels), precipitation of salt crystals (4c = salt efflorescence), soil pore clogging (4d = clogging) and the occurrence of scalds (5 = scalds). Method B provided a good overview of the study area documenting locations of instrumentation (6 = instrumentation) and larger scale surface patterns. Method A provided more detailed information throughout the study area.

Table 1: Comparison of attributes of traditional aerial photography and aerial photography methods A and B.

Method Attribute	**Method A** (altitude = 10 m)	**Method B** (altitude = 10 – 30 m)	**Traditional Aerial Photography**
Setup and equipment costs	Comparatively high initial outlay ($500)	Low initial outlay ($50)	N.A
Operating costs	No operating costs	Cost of 1.5 m^3 of helium (approx $20)	High operating cost (> $1500/hour)
Photographic resolution (dependant on camera quality and altitude)	High resolution	Variable resolution/ high - intermediate	Comparatively low resolution
Spatial coverage (Dependant on altitude)	Low spatial coverage (approx 8 m^2)	Variable spatial coverage/ low – intermediate (approx 8 m^2 – 1200 m^2)	High spatial coverage (approx 85 km^2)
Site specificity	Highly site specific	Highly site specific	Only site specific at great expense
Repeatability	Can be repeated as often as required at no expense	Can be repeated as often as required at minimal expense	Only repeatable at great expense
Response time to triggering events	Low response time (dependent on distance to site)	Low response time (dependent on distance to site)	High response time (dependent on aircraft availability)
Limiting environmental factors	Can only operate in light to moderate winds	Can only operate in light winds	Dependent on cloud cover and vegetation density
Potential hazards	N.A	Trees and power lines	N.A

The aerial photography methods discussed in Table 1 have differing attributes that make them suited to specific types and scales of study. Traditional aerial photography is suitable if a one off set of data is required. It provides high spatial coverage and can be purchased from existing data sets at minimal cost. Traditional techniques, however, are not suitable for local-scale projects that require high resolution, regular, rapid response aerial photographic coverage.

CONCLUSIONS

Aerial photography methods A and B provide excellent alternatives to more traditional techniques. They affordably increase photo resolution, improve flexibility and site specificity whilst providing rapid response to triggering events. High photographic resolution means that mapping of spatial and temporal patterns in the regolith environment are possible in very fine detail (Figure 4). Many of the benefits of method A (cable supported platform) can be achieved using method B (balloon supported platform). Similar photo resolution and spatial coverage can be achieved using method B with the added benefit of variable altitude data acquisition. Method B, however, is limited to days of low wind speed and areas free of hazards (trees and power lines). Longer term studies, such as crop trials, would benefit from both techniques where the investment in time and money required establishing method A is deemed worthwhile. However, the aerial photography needs of most short term studies could be achieved using method B. Any study similar to the one discussed above would benefit greatly from the application either photographic technique.

FUTURE WORK

Further development and refinement of Method B (Helium balloon supported platform for low altitude aerial photography) will be undertaken. An improved gondola and tethering system will be designed and manufactured to increase camera stability in higher winds and enable single operator deployment. Adaptation of the gondola will permit the use of a range of digital cameras providing the option for remote release of shutter and variable photographic resolution.

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