Monitoring Rangeland Watersheds With Very-Large Scale Aerial Imagery

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Abstract

Motion-blur free, very-large scale (1:200), aerial-photographic samples of grazing allotments on high-elevation Wyoming (USA) rangelands were systematically acquired (n = 172) using an ultra-light type, fixed wing airplane and a modified Hulcher 70 mm camera with Kodak Aerocolor HS SO-846 film. Cover measurements from the digitized aerial samples were not different from cover measurements made on the ground using point-sampling methods.

Key Words: bare ground, motion blur, sampling adequacy

Introduction

Rangeland watershed management has depended more on judgement than science for monitoring the condition or health of vast landscapes. The result is a crisis of confidence in traditional monitoring methods and data, and an understanding that we need objective monitoring (NRC 1994, Donahue 1999). The challenge is to develop economical methods that will detect important vegetation change within acceptable error rates (Brady et al. 1995). Some have promoted a suite of key indicators for assessing rangeland health (USDI 1973, Pellant et al. 2000, Rowe et al. 2002). We recognize the complex, multivariate nature of rangeland ecosystems; we also recognize that information-collection costs require that we define key indicators -- those that lend themselves to detection of ecologically important change with minimal expense. Bare ground is usually listed as a key indicator (USDI 1973, Abel and Stocking 1987, WRAC 1997, Pellant et al. 2000). Here we report progress on our effort to use very-large scale aerial (VLSA) imagery as a means for inexpensive acquisition of statistically adequate, unbiased, high-resolution (high detail), samples (images) from which to accurately measure bare ground. The main technical constraint in acquiring VLSA imagery from a moving, low-altitude platform has been motion blur in the imagery (Hinckley and Walker 1993).

Platforms for acquiring VLSA imagery have included camera stands (Bennett, Judd and Adams 2000), poles, balloons, dirigibles, kites, radio and computer-controlled unmanned aircraft, ultralight aircraft, and helicopters (Tueller et al.1988, Hinckley and Walker 1993, Hansen and Ostler 2002, Aerosonde 2002, and personal communication). Helicopters and long-range unmanned aircraft (Aerosonde) are high cost. The other platforms are impractical for extensive monitoring (100 to 200 km^2). Therefore we tested an ultralight-type, 3-axis, fixed-wing airplane as an inexpensive platform for obtaining motion-blur free, VLSA imagery over extensive areas of high-elevation rangelands in Wyoming's Red Desert.

Materials and Methods

Nadir aerial images (1:200 scale calculated as negative length over ground distance) over two public-land grazing allotments in south-central Wyoming were made with a modified Hulcher Model 123, 70-mm camera equipped with a 500-mm lens (Charles Hulcher Co., Hampton, VA, USA) and

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mounted in a Rans S12XL, 2-seat airplane. The airplane was flown at 72 km/hr ground speed (straight and level flight), 100 m above 1520-m-elevation rangelands and we used 1/4000 second shutter speed on the camera. Altitude above ground level (AGL) was continuously monitored and displayed to the pilot with a laser altimeter and the camera was automatically triggered for systematic, intermittent, aerial sampling (Booth 1974, Abel and Stocking 1987) by a Track'Air aerial survey system using pre-programmed coordinates (Track'Air, Hengelo, The Netherlands). Our Track'Air system was specifically adapted to our application. At take off the system defaults to ferry mode and directs the pilot to the target area. When the plane is within 300 m of a target-area flight line the system "locks on" to that flight line and directs the pilot to the first target while providing constantly updated information on ground speed, and time and distance to the first target. When on target, the system triggers the camera, records the geographic positioning system (GPS) coordinates of the actual trigger location, and advises the pilot that the camera was triggered. The system then directs the pilot to the next target. This is likely the only aerial survey system in the world designed to operate with an airplane crew of 1 (pilot). Using this system the pilot's hands need never leave his controls, nor his eyes leave the forward view -- critical safety considerations when flying slow and close to the ground.

To program the Track'Air system, a digitized raster graphic of the target area was downloaded and Didger II (Golden Software, Golden, CO, USA) used to extract GPS coordinates in a 0.8 km grid over the two grazing allotments. The coordinates were then used to create a TrackAir flight plan for the mission. (The system also accommodates irregular targets as may occur in sampling riparian or other critical areas.)

Twenty, 1-m^2-plots were located on the ground using GPS coordinates where the Hulcher was triggered and where ground access was not problematic. Images of these plots were acquired using an Olympus E20, 5.0 megapixel, color digital camera mounted 2 m AGL on a portable camera stand having a m^2 base. An infrared remote was used to trigger the shutter of the fully automatic camera. Images were saved as uncompressed Tif files at maximum resolution (1 pixel = 0.5 mm ground area, scale = 1:110 calculated as CCD length over ground distance). Additionally, cover and bare ground were measured on these plots using standard point-sampling methods (100 points per m^2). The base of the camera frame was the reference used for the point-sampling data collection.

Film from the Hulcher camera was pushed 1 f stop in development, and scanned at 1 pixel per 25μm of negative. Bare ground was measured from the Hulcher and Olympus images using manual methods (digital grid overlay using 100 points) and Vegmeasurement software (Louhaichi and Johnson 2001). The digital-grid-overlay method is simply using software to overlay a grid on the image, then recording the type of ground cover underneath each intersection of the grid. Vegmeasurement software was developed at Oregon State University and uses an algorithmic manipulation of color hues to separate image characteristics like bare ground and plant cover. Data from these measurement methods were compared with each other and with measurements from on-the-ground point-sampling.

Results

We obtained motion-blur-free, 1:200 scale images by flying at 72 km/hr ground speed, 100 meters AGL and using a 500 mm lens with Kodak SO-846 film and 1/4000 second shutter speed (Fig.1). Light during the monitoring effort ranged between 8 and 10 thousand lx.

Figure 1. Grayscale rendition of an aerial sample (1:200) from study area with a m^2-enlarged portion demonstrating the resolution possible with this photograph.

Safe, systematic aerial sampling --consistent with sampling needs of watersheds and other large land areas -- was immeasurably facilitated by our custom-configured Track'Air aerial survey system and by precise measurements of airplane altitude AGL from our laser altimeter. We found no difference in bare ground measurements between aerial and ground methods, implying that for the plant communities monitored in this test, bare ground measurements made from the Hulcher imagery were as accurate as measurements made on the ground (Fig. 2). There was a significant difference between measurements made with the digital grid (100 points) and Vegmeasurement. We judge the Vegmeasurement data to be more accurate since the software uses approximately 2 million image pixels as data points.

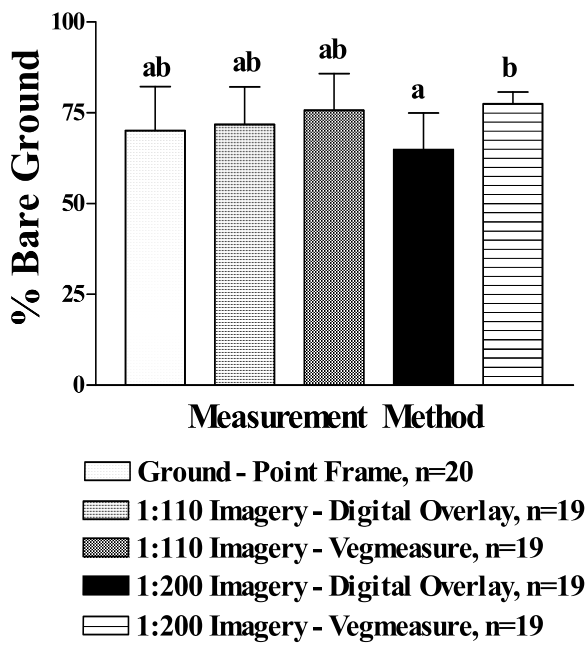

Figure 2. Bare ground measurements for the study area derived from five measurement methods. Measurements from 1:200 images were different from each other (P = 0.0013) but neither one was different from point sampling nor 1:110 image-derived measurements.

Ellison and Croft (1944) observed, "There are two levels of observation in range inspection: one extensive and the other intensive. From observations at the extensive level the inspector can get an idea of only general over-all features of the range, i.e., the extent and character of vegetal types, topographic features, ... *Intensive observations on small areas are necessary to secure the detailed facts from which the only valid conclusions of range condition can be made.*" (emphasis added). Remote sensing is the only way to obtain accurate information over extensive areas at reasonable cost (West 1999), but until now the measurement of details from images acquired from a continuously moving platform has largely been limited by motion blur to scales of about 1:600 or larger. We conclude that our methods merit further research as a means for monitoring extensive areas by obtaining a statistically adequate number of aerial samples from which to make detailed measurements of bare ground.

Note

Disclaimer: Mention of trade names is for information only and does not imply an endorsement by USDA or USDI.

Acknowledgments

The research was funded by the Wyoming State Office, USDI, Bureau of Land Management. The USDA-ARS-NPS and the Northern and Southern Plains Areas of ARS provided a special grant for equipment purchases.

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