Repeat Photography using GigaPan Imagery in the San Simon Watershed, Arizona, USA

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ABSTRACT

Photographs are an important source of documentation supporting the management of western U.S. rangelands. High resolution panoramic photography has the potential to vastly expand the value of photography in rangeland monitoring and documentation. The immediate objective of this research is to test the GigaPan system for taking repeat photographs supporting landscape change analyses. An initial test was conducted to relocate photo points in the San Simon Watershed in Arizona where landscape photographs were taken in 1941. Coupled photo pairs from 1941 and 2010 are posted to the GigaPan website where they can be annotated to incorporate both scientific interpretations and local knowledge. Work is ongoing to quantify landscape and vegetation changes in the photographs. These changes will be interpreted in the context of high seasonal and inter-annual variability identified in measured rainfall. Initial field work has successfully demonstrated the use of GigaPan technology in landscape photography for documenting change.

KEYWORDS

Rangeland, landscape change, semiarid, vegetation change, repeat photography

INTRODUCTION

Repeat photography has been established as a useful tool to detect and document vegetation changes in western rangelands (Hastings and Turner 1965; Humphrey 1987; Turner et al. 2003; Webb et al. 2007). These projects generally use oblique landscape photographs captured from a distant point using ground-based cameras (Clark and Hardegree 2005), and rely on finding the vantage point of the original photograph so that the point can be reoccupied to produce a closely matching subsequent image. Traditional photographic methods require a compromise between image detail and the amount of area covered. Photos covering broad landscapes have to be taken at lower resolution than photographs of specific landscape components. The Gigapan system for capturing high resolution photographs covering large areas has the potential to overcome limitations of traditional repeat photography, and offers great potential for documenting both current conditions and changes in western landscapes.

The Gila watershed in southeastern Arizona and western New Mexico was photographed extensively in the 1940s. Within the Gila watershed, the tributary San Simon watershed includes approximately 5830 square kilometers (2250 square miles) of range, forest, and cropland. The watershed is a mosaic of land ownership with management provided by private parties as well as federal and state agencies. Crop production, livestock grazing, and recreation (e.g. off-road vehicles, hiking, and wildlife viewing) are primary land uses. The San Simon Watershed has been the site of extensive reclamation work, largely in response to degraded watershed conditions that evolved during the late 19th and early 20th centuries.

In the 1930s the Erosion Control Service (later the Soil conservation Service and today the Natural Resources Conservation Service) instrumented watersheds within the San Simon subwatershed to quantify rainfall and runoff from semiarid watersheds. Management of the instrumentation and watersheds was transferred to the USDA-Agricultural Research Service (ARS) in the 1950s. In addition to instrumentation, each watershed was photographed from several vantage points to document the watershed landscapes. Although the watershed instrumentation was shut down in the 1970s, the photographs offer enormous potential to interpret landscape changes over 70 years since the original photos were taken.

The objectives of this paper are to 1) examine the potential for using GigaPan high resolution photography for detecting and documenting landscape change, 2) briefly describe components of a larger effort to incorporate ancillary measured data with photo-based landscape change analyses.

METHODS

Landscape photographs taken in the San Simon Watershed in October 1941 by Berlyn B. Brixner were selected from an historic archive maintained by The USDA-ARS Southwest Watershed Research Center in Tucson Arizona. The archive contains photographs taken from vantage points within or along the boundary of each of the 6 ARS watersheds. Watershed 1 (WS1) was selected as the first trial site. The photographs taken on October 21, 1941 are 4 by 6 inch black and white contact prints. Each photograph was scanned at 2400 dpi. The images were uploaded to the GigaPan website and during this process the tile sets supporting the zoom function were built. Resulting images were 0.17 gigapixels.

Although camera and film data were not recorded on the photograph sleeves, general location information and description information typed on the sleeves is sufficient to relocate photo points. A field visit was made on March 23, 2010 to relocate the photo points and to take GigaPan images. Photo points were not benchmarked in 1941, so finding the vantage points was accomplished optically by identifying distant objects, such as mountain peaks, and comparing with the original photograph. Once found, locations were identified with a GPS. A GigaPan Epic 100 and a Canon S5 camera were used to take high resolution images. Images were stitched with GigaPan Stitch v 1.0.0805.

Ancillary data relevant to understanding landscape changes over time include precipitation, runoff, and vegetation measurements. Precipitation has been recorded at several stations within the San Simon Watershed since the early 1900's. The longest continuous record based on daily precipitation collected at Bowie, Arizona (1900-2008) was evaluated using time series visualizations and moving window filters to identify seasonal, annual, and multi-year temporal patterns in rainfall. From 1940 to the 1970s, high resolution precipitation records were collected at ARS raingages located in association with the ARS watersheds. These 15 minute interval records were evaluated to identify storm and seasonal rainfall patterns. Runoff measurements are available from USGS gauging stations on the main and tributary channels and were compared to precipitation records using correlation analysis. Vegetation transect measurements from the historic archives were used to summarize vegetation in comparison with that seen in the photographs.

RESULTS

A summary of 1941 and 2010 photographs can be found in Table 1. WS 1 is 519.3 acres in area. In 1940, vegetation transects were measured to reveal a dominance of shrubs, although the area was used as grazing land. The dominant shrubs identified in 1940 include Ephedra (*Ephedra trifurca*), Snake Weed (*Gutierreza sarothrae*), Cactus (*Opuntia sp*.), Mimosa (*Mimosa biuncifera*), Mesquite (*Prosopis juliflora)*, and Catclaw Acacia (*Acacia greggii*). Each of these species is seen in the 2010 images.

Table 1. Summary of photographs taken on ARS Watershed 1, San Simon Watershed, Arizona, USA

Photo ID	UTM Zone 12, NAD83/WGS84		Month, Year	URL
WS1-Ariz-RS-158	3634495N	638239E	October, 1941	http://gigapan.org/gigapans/45939/
			March, 2010	http://gigapan.org/gigapans/45941/
WS1-Ariz-RS-159	3633500N	639073E	October, 1941	http://gigapan.org/gigapans/45962/
			March, 2010	http://gigapan.org/gigapans/45945/
WS1-Ariz-RS-160	3632579N	639895E	October,1941	http://gigapan.org/gigapans/45950/
			March, 2010	http://gigapan.org/gigapans/45953/
WS1-Ariz-RS-161	363271N	640429E	October,1941	http://gigapan.org/gigapans/45580/
			March, 2010	http://gigapan.org/gigapans/45569/

Annual rainfall from the 1930s through 2010 (Figure 1) exhibits a pattern of high inter-annual and seasonal variability and periods of above and below average accumulation, which translate into periods of floods and droughts. Historically, most of the large precipitation events on the watershed occurred during the summer months. These events generated runoff corresponding to a dominance of large flows during summer months in the runoff record. This pattern is consistent with regional precipitation patterns that are dominated by summer convective storms that generate high intensity precipitation with limited spatial extent (Goodrich et al., 2009, Nichols et al., 2002, Osborn and Renard, 1988). In the 1980s there was a shift in extreme rainfall events to the fall months consistent with an increase in landfalling tropical storms that moved through southern Arizona. This shift was also coincident with an increase in winter precipitation prompted by frequent El Niño events in the tropical Pacific Ocean. El Niño events are known to bring enhanced winter storm activity and subsequently higher precipitation amounts to southern Arizona (Sheppard et al. 2002). The subtle shift towards higher cool season precipitation in the 1980s is hypothesized to have produced a soil moisture regime more favorable than usual for the area for supporting plant growth, with moisture available at deeper depths and for longer periods of time. Work is in progress to test this hypothesis against vegetation characterizations of the 1941 and 2010 photographs.

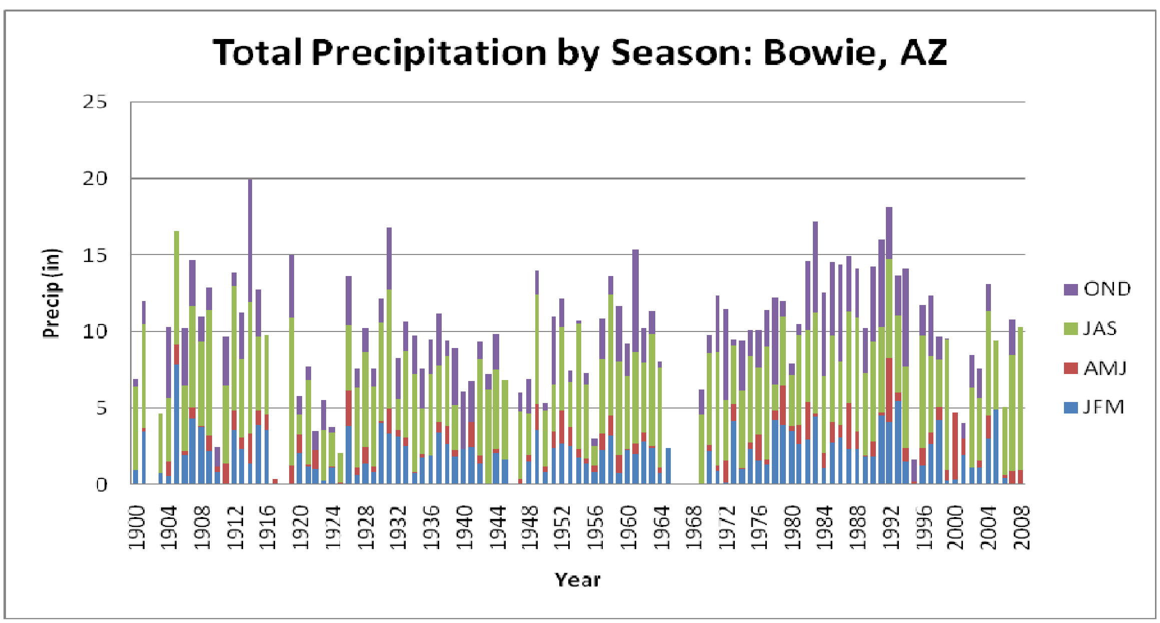

Figure 1. Seasonal total rainfall at Bowie, AZ (National Weather Service-Cooperative Observer Site). Seasons: JFM-January, February,March; AMJ-April,May,June; JAS-July,August,September; OND-October,November,December

In addition to vegetation over time, anthropogenic impacts can be identified through the photography. In 1941 the road between Safford and Duncan, AZ was paved as seen in image WS1-Ariz-RS-161. The road depicted in the 1941 photo is the Safford Duncan Highway, one of the first paved highways in Graham and Greenlee Counties. The old Safford Duncan Highway can still be traveled and it is quite a scenic route traveled by visitors of the Public Lands in Arizona. As depicted in the 2010 photo, much of the original asphalt pavement is gone with the passage of 70 years.

As an example of the type of qualitative information that can be compiled from local knowledge of the photographed landscapes, the following brief description was provided by a long-term resident of the San Simon Valley:

> The story goes that the residents of Graham and Greenlee Counties were given the choice of a paved highway or a dam on the Gila River. The residents chose the highway to improve commerce between the communities. The highway followed the wagon route between Safford and Duncan, Arizona, going through the communities of Solomon, Gripe, and San Jose. The highway was realigned after World War II with the development of U.S. Highway 70 as part of the U.S. Highway system. By the way, the dam was never built and many of the current county residents wished a different choice would have been made by their ancestors.

Figure 1. Looking east along the old Duncan Highway, San Simon Watershed, Arizona. This photo was taken October 21, 1941 by Berlyn B. Brixner. For zoomable version, http://gigapan.org/gigapans/45580/

Figure 2. A 2010 view of the landscape shown in Figure 1 taken using the GigaPan system. For zoomable version, http://gigapan.org/gigapans/45569/

DISCUSSION AND CONCLUSIONS

Initial field work and photography has demonstrated successfully the potential for using GigaPan technology for documenting landscapes and vegetation change. Equipment setup and photography was quick, and in fact, the most time consuming task in the field was relocating the original vantage points.

Work is ongoing to quantify the vegetation in the photographs. An important aspect of interpretation is consistent timing. Plans are underway to retake each of the photos in October 2010 to eliminate the possibility of bias due to variation in phenological expression of individual species. Explanation of vegetation change requires integrating available data with photographic interpretations. Because of the relative abundance of ancillary data at theses sites, including rainfall, runoff, and land use history, the ARS watersheds in the San Simon Watershed offer high potential for interpreting vegetation evolution beyond simple change detection.

This project also has great potential for extended collaboration among federal agencies, University of Arizona Extension, and community participants. Work is ongoing to solicit interpretations from community members in describing land use history and photographic content based on personal experience. Although qualitative, this information can play an important role in interpreting change. Online tools that guide stakeholders in 'tagging' images (e.g. Snapshot tool on gigapan.org) allow them to document and discuss changes they perceive in images. These discussions can be then analyzed and synthesized to present a diversity of perspectives on environmental change relative to a landscape of concern. In addition, access to the historic and current photographs through the GigaPan website plays an important role in education.

High resolution panoramic photography, implemented through the easy-to-use GigaPan system offers enormous potential as a tool for both documenting and managing western rangelands. Based on the success of this initial project, research will be extended to the broader historic photo, vegetation, and climate database to interpret changes in the San Simon Valley.

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