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Using Historical Photography to Monitor and Assess Threats Over Time

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Abstract

Analysis of aerial photography is perhaps the best way to assess changes in landcover conditions. In the United States, most national forests have repeat photography on approximately a 10-year cycle. Analysis of this rich photo record can reveal changes in insect damage, fuels buildup, unmanaged off-highway vehicle use, loss of open space, and other land-cover conditions. Current technologies now allow Forest Service employees to input photos into a geographic information system (GIS) accurately and easily, and important changes can be documented, analyzed, and evaluated within the GIS. This analysis discusses selected photo characteristics, available software solutions, and techniques for orthocorrection of historical photos. It also discusses two cases in which historical imagery was used to document selected changing threat levels over time.

Keywords: Aerial photography, geographic information systems, loss of open space, orthocorrection software, pseudocamera reports, unmanaged recreation.

Introduction

Remote sensing—aerial photography in particular—provides perhaps the best means to assess landcover changes over time. This is especially true when assessing changes over long periods of time. Aerial photography provides an invaluable record of land use and landcover conditions—frequently dating back to the 1930s. No other source of remotely sensed imagery is available prior to the 1970s. Most national forests have repeat photography on approximately a 10-year cycle. This rich photo record can indicate changing threat conditions through time, including threats such as insect damage, fuels buildup, unmanaged off-highway vehicle (OHV) use, and loss of open space.

We've long recognized and valued the quality information content of photos; however, we've also long struggled with how to get our photos into our Geographical Information Systems (GIS). Current technologies now allow Forest Service employees to input photos into a GIS accurately and easily. Within the GIS, we can evaluate, analyze, and document important changes.

This analysis discusses selected photo characteristics, available software solutions, and techniques for historical photo orthocorrection—along with examples using historical imagery to document selected changing threat levels over time.

The methods described in this paper are available throughout the Forest Service and provide the most consistent and objective method for detecting, assessing, and monitoring land-cover changes through time.

Why Photography?

Aerial photography, like all remote sensing technologies, has advantages and disadvantages compared with other remote sensing tools. The advantages of using photography to assess threats over time include a long history of repeat coverage, it is well understood, it is intuitive to the user community, it has excellent resolution, and it provides a superb stereo view.

The Forest Service has been systematically collecting aerial photography since the 1930s. Since that time, considerable effort and expense by developers have resulted in significant improvements, including faster and higher resolution films and film types, faster and higher resolution lenses and cameras, and more precise camera geometries and calibrations. On the users' side, there is a long history of effective use and technique development. These developments include a thorough understanding of photo geometry, stereoscopy, photogrammetry, and interpretation. Thus, the complexities of photography are well understood in the professional community.

Although photography is complex, it is simultaneously intuitive—both to the professional community, and to the at-large community. We've all grown up with photographs as part of our daily lives. We may not always understand the complexities and properties of the photography we see, but we still know how to interpret photographic images. Photography's intuitiveness promotes a greater understanding and acceptance of analytic results by the public—especially when the analysis techniques are easily understood.

Photography has excellent spatial resolution that is only now being challenged by other imaging systems. Even early aerial photography (1930s and 1940s), though not as resolute as post-WWII photography, has very good resolution. This allows easy comparison of vastly different dates of imagery.

An under-appreciated property of aerial photography is the ability to view the imagery in stereo. The stereo view drastically increases our ability to discern what we are viewing in the image and to perceive the topography and the varying heights of features on the ground. The stereo view has been the domain of the stereoscope and hardcopy photographs but is now becoming easily accessible in the digital domain—a trend that is certain to continue.

Why Not Photography?

Photography has its weaknesses, too. The major disadvantages of using photography to assess threats over time include: photography usually has to be converted from hardcopy (analog) to a digital format, it has non-map geometry, and it has a relatively small footprint.

All historical photography (meaning all photography before the current cycle of acquisition) is analog. Thus, one of the first steps required to get this imagery into a GIS is to scan each photo. This is a time-consuming operation affected by scanner speed, scan resolution, and the number of photographs. Time and cost of this step must be considered for each project.

The same geometry that allows for stereoscopic viewing is often viewed as a disadvantage when trying to get our photo-derived information into a GIS. Photography has single-point-perspective geometry. This means that a vertical photograph may appear map-like, but, features at differing elevations are displaced relative to one another, and the scale changes with each change in elevation. Time and money are required to orthocorrect the photography (make the digital photo imagery accurately conform to a map coordinate system and projection).

A common trade-off with the various remote sensing systems is between footprint (area covered) and spatial resolution—photography is no exception. In general, the larger the area that is covered, the coarser the resolution. This holds true when comparing photography of different scales, and it is generally true when comparing photography to most satellite imagery. Compared with satellite imagery, photography is usually higher resolution but covers a much smaller area. Given the time and cost required for scanning and orthocorrection of historical photography, the small footprint constrains the applicability of using photography to relatively small areas or to sampling over very large areas for detecting, assessing, and monitoring changes.

Tools for Getting Historical Photos in GIS

There is a fortunate convergence of technologies that makes it easier than ever to get historical photography into our GIS. The most important technologies are the newly available orthocorrection software tools and the online data and camera reports. Also of value are the simple techniques for creating pseudocamera reports.

Although image orthocorrection is not required to detect changes, orthocorrection and subsequent analysis in GIS provides two major advantages:

1. Changes are much easier to detect using the built-in image display options in widely used GIS mapping applications.
2. Documenting the magnitude of change is much easier and can usually be objectively quantified.

Orthocorrection Software Tools

Commercially available orthocorrection software makes powerful softcopy photogrammetry tools available to all Forest Service personnel. This software has a significant learning curve, but it allows users to efficiently orthocorrect large blocks (or sets) of overlapping photos.

Online Data (DOQs, DEMs, and Camera Reports)

In addition to the scanned photography, orthocorrection requires horizontal and vertical reference data and information about the camera that acquired the photography. Typically, digital orthophotoquads (DOQs) are used for the horizontal reference, digital elevation models (DEMs) are used for the vertical reference, and a USGS Optical Sciences Lab Camera Report is used for the camera information. All of this data is available online, allowing for far more efficient data preparation for orthocorrection.

Creating Pseudo-Camera Reports

The USGS camera reports are not available for any resource photography prior to 1973. When one is needed, it is fairly easy to create your own pseudocamera report. The vital information needed from an official USGS camera report includes the principal point, the fiducial measurements, the fiducial orientation (with respect to the data strip), and the lens focal length. If we know the scan resolution of the scanned photo, the dimension of one pixel in the image is known (e.g., if the image was scanned at 600 dpi, each resulting pixel is 1/600 inch) and distances between fiducials on the image can be measured. We have created a simple spreadsheet that converts imaged fiducial file coordinates to millimeters in a camera coordinate system similar to USGS camera reports. For these pseudocamera reports, we have to assume the principal point is at coordinate 0,0 and we initially assume the focal length is 6 inches (152.4 mm). The fiducial orientation can be defined by the user—but then has to be applied consistently.

Obviously, these pseudocamera reports are not as accurate as official camera reports. The spatial accuracy of the resulting orthocorrected photography will likely be less accurate as well. However, for many resource applications, satisfactory accuracies can be obtained.

Analysis Options

Once the multiple dates of photography have been orthocorrected, there are few limits to analysis options. The imagery itself, with little or no analysis, may be sufficient for public awareness, although some interpretation is usually helpful. To detect and document spatially continuous changes over time (e.g., vegetation cover), we have used a digital dot grid technique that provides percentage of cover by cover type for each cycle of imagery. For discrete feature changes, such as OHV trails, we have used two different techniques. Our first method used a digital grid that required the interpreter to simply click a cell of the grid if an OHV trail was in the cell. The grid was then put through a kriging process, and a map of OHV hot spots was created. The second method consisted of manually digitizing the trails as they were interpreted from the imagery. The kriging method has the advantage of being very fast. The digitizing method has the advantages of being simple, easily verifiable, and producing a map of actual OHV trails. In addition, it was a simple matter to construct graphs of the rate of change from the digitized trail's attribute tables. These methodologies have worked well for us, but the optimum methodologies may yet be awaiting discovery.

Only the most basic interpretations should be attempted from the monoscopic imagery. Most interpretations should be accomplished in stereo, which allows users to visualize relief within the image and heights of features. This can be achieved using a stereoscope and the analog (hardcopy) imagery or digitally using commercially available applications.

Examples

Following are two brief examples of using historical photography to detect and document changing conditions over time.

Loss of Open Space

Aerial photography from 1969, 1977, 1988, and 1993 of a small portion of the Black Hills National Forest boundary were orthocorrected using the orthocorrection tools in ArcMap Image Analysis. Roads and buildings were digitized from each cycle of photography (within the chosen subset, there are no roads or buildings visible in 1969). Features digitized from each cycle of photography were symbolized with different colors. The results (Figure 1) clearly depict significant human-made changes that fragment the open space around the national forest boundary.

Unmanaged Recreation

Leica Photogrammetry Suite (LPS) was used to orthocorrect photography from 1967, 1976, 1988, and 1995 over a small portion of the Fishlake National Forest. In addition, we added orthocorrected NAIP imagery from 2004. The 1967 photography did not have a camera report, so we

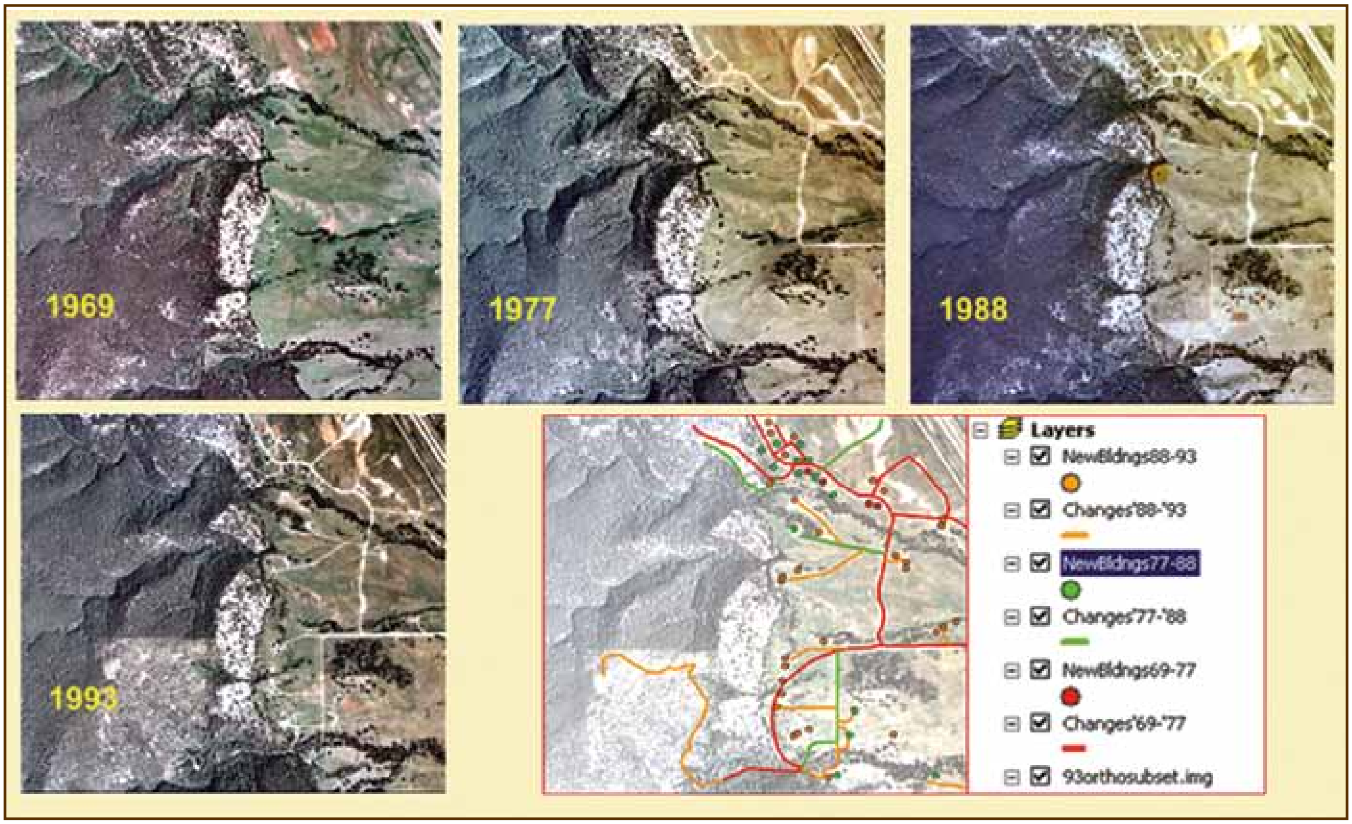

Figure 1—Aerial photography from 1969, 1977, 1988, and 1993 over a portion of the Black Hills National Forest was orthocorrected. New roads and buildings were identified and digitized for each cycle of photography. The result (bottom-right of graphic) was a compelling graphical documentation of 24 years of loss of open space.

created one using methods described in above. Once all of the photography was orthocorrected, we added the existing travel management plan roads layer. Then we digitized new OHV trails as they became apparent on each cycle of photography (Figure 2). This methodology was simple, easily verifiable, and produces a map of actual OHV trails. In addition, it was a simple matter to construct graphs of the rate of change from the digitized trail's attribute tables (Figure 3).

Resources

Where to Find Old Photos

Typically, each national forest receives copies of every photo acquisition over that national forest. However, there is no standard for archiving historical aerial photography. In too many cases, these old photographs are discarded by those who don't see their continued value. Start your search locally and expand to the regional geospatial or remote sensing leader.

If photos are not available at the regional level, the USDA Aerial Photography Field Office (APFO) in Salt Lake City archives over 50,000 rolls of film. Their holdings include nearly all USDA photo acquisitions since the mid-1950s. When searching for historical photography within the APFO Web site, be aware that they have separate listings for Forest Service photography and all other USDA agencies.

Older photography is held in the National Archives in College Park, MD.

Training/Help

Countless sources for training and assistance have public access, but the following suggestions are tailored for the Forest Service and provided behind the Forest Service firewall.

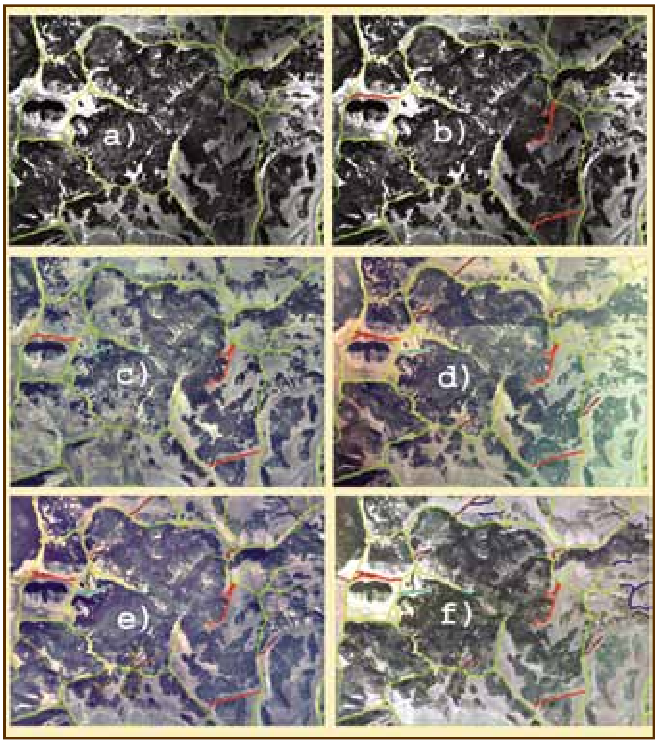

Figure 2—Aerial photography from 1967 (Figures 2a and 2b), 1976 (Figure 2c), 1988 (Figure 2d), and 1995 (Figure 2e) was orthocorrected, and 2004 NAIP photography (Figure 2f) was obtained to assess unmanaged recreation over a portion of the Fishlake National Forest. The official managed trails were obtained and overlaid on each image (light green). Unmanaged recreation trails were identified on each cycle of photography and digitized from the orthocorrected imagery.

The USDA Forest Service Remote Sensing Applications Center (RSAC) is an excellent source for training and help. The RSAC provides instructor-led courses in using the Leica Photogrammetry Suite—including a section on creating and using pseudocamera reports. There is no tuition for the course. Course offerings and registration are available from the Forest Service GeoTraining FS Web site (intranet) (http://fsweb.geotraining.fs.fed.us/). Online help for Imagine and Image Analysis is also available on this site.

The RSAC staffs the Remote Sensing Helpdesk. Access is through the Forest Service End User Support Center (EUSC). Specify that you have a remote-sensing-related question to be forwarded to the Remote Sensing Helpdesk.

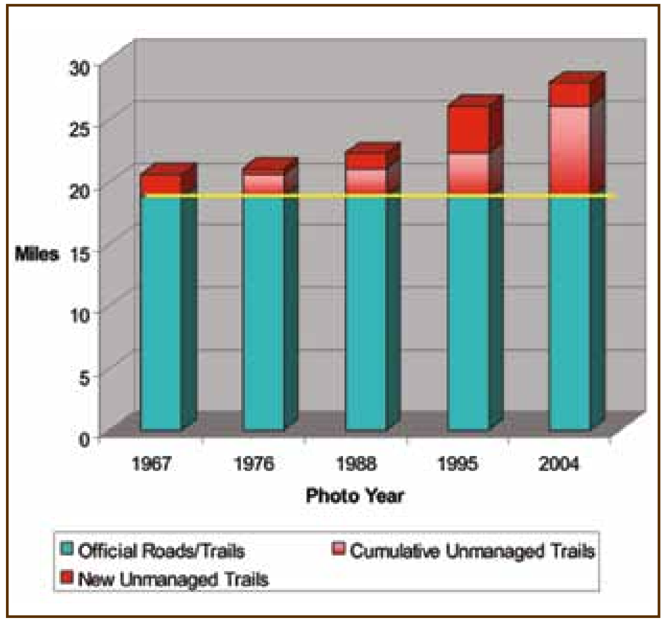

Figure 3—This bar graph documents the increase in unmanaged OHV trails for our project area on the Fishlake National Forest, 1967-2004. Official managed trails are graphed in cyan (and highlighted with the yellow line), newly interpreted unmanaged trails are shown in solid red, and the cumulative unmanaged trails are shown in the red gradient. Note: in 2004 there were approximately 9 miles of cumulative unmanaged recreation trails—a 50-percent increase over the official managed trails.

Additional Reading

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