COMMENTARY

The Utility of Historical Aerial Photographs for Detecting and Judging the Effectiveness of Rangeland Remediation Treatments

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Aerial photographs are a type of remote sensing data that are especially valuable for rangeland applications. Advantages of these data include relative ease of interpretation and acquisition, affordability, high resolution (1–2 meters), and provision of a common reference for communication among those involved in rangeland management. Additionally, air photos are especially well suited for analysis of historical rangeland remediation treatments because acquisition of widespread aerial photographic coverage began during the 1930s. Several types of treatments can be easily identified and monitored over time, including contour terraces, brush water spreaders, rootplow seeding, water ponding dikes, shrub removal by grubbing, and grazing restrictions. The use of archived aerial photographs allows the opportunity to recreate the management history of rangeland, as well as to serve as a point of departure for involvement in more sophisticated satellite-based remote sensing systems.

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Remote sensing of rangelands has received some specific attention in the past (Carneggie, Schrumpf, and Mouat, 1983; Clark, Seyfried, and Harris, 2001; Everitt, Escobar, and Nixon, 1987; Poulton, 1970; Tueller, 1982, 1989, 2001). Remote sensing encompasses a number of different types of images, data, sensors, information, formats, and even interpretation techniques. For the past 30 years, the term has typically referred to images captured from sensors aboard satellites orbiting the earth. Less complex remote sensing products, obtained from airplanes, can be used effectively to more easily understand the expanding capabilities of this technology. The aerial photograph (also known as an air photo) is an extremely valuable remote sensing product, as pointed out by Colwell (1964). This product costs very little, requires no special training, and is nearly a self-explanatory tool. A variety of users are drawn to air photos, in part because of their novelty and unique perspective, and the information provides a common ground for a dialogue among different users about rangeland resource management. The objective of this article is to discuss the utility, cost, and methods of obtaining air photos, and to provide some examples of their application on rangelands.

Aerial Photography Characteristics

Air Photos Over Agricultural Lands

In 1917, Sherman Fairchild developed an improved camera for producing vertical aerial photographs with minimal distortion for the US military (Thompson and Gruner, 1980). By 1935, the United States Department of Agriculture (USDA) initiated systematic vertical aerial photography of agricultural lands (including rangeland) in all states, usually through contracts to private firms. Aerial coverage has continued to the present, initially with black-and-white photographic missions, and more recently in association with nationwide mapping projects, in which color infrared photography has been used for comparison with new types of satellite-based remote sensing information. Fortunately, most of these early and subsequent air photos have been archived and are available for analysis today. Unfortunately, images from various years are not all in one location, but rather are scattered among archiving facilities across the country. Despite this shortcoming, air photos are easy to use and interpret and are very useful for documenting historical rangeland activities such as remediation treatments and natural changes.

Practitioners in rangeland management, particularly ranchers, can benefit from aerial photography. For example,

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Corbley (1998) reported that a West Texas rancher familiarized himself with aerial photography, determined the best film type (color infrared) for identifying specific management questions (such as quantifying mesquite invasion), contracted with an air photo firm to take 1:40,000 scale photos of his entire ranch, scanned the photos with his own scanner to generate digital files for input into a Geographic Information System (GIS), used his own computer to analyze the digital data using cluster analysis to identify key areas (such as mesquite stands to be targeted for herbicide applications), and contracted for the actual herbicide spraying using Global Positioning System (GPS) located targets. At the same time, the rancher is using the images for other management operations, e.g., designing new fencing, placement of watering locations, and planning grazing strategies (Corbley, 1998). Incorporating historical aerial photographs into this process can greatly assist the landowner in further understanding vegetation dynamics and planning management actions.

Film Types Used for Air Photos

Black-and-white panchromatic film, sensitive in the broad band from 0.36–0.72 μm, has long been the standard film type for aerial photography (Avery and Berlin, 1992; Lillesand and Kiefer, 2000). The early air photos for USDA and other agencies were black-and-white panchromatic, extending over the ultraviolet and the entire visible spectrum. Natural color film has recently been used in numerous remote sensing applications, primarily because the human eye can distinguish many more shades of color than tones of gray (Lillesand and Kiefer, 2000). A third type of air photo is color infrared or "false color" photos. The film is sensitive to the near-infrared portion of the spectrum, as well as the ultraviolet and visible spectrum. Additionally, the primary colors are assigned to different bands than those of color photos. Because of the differing color assignments, healthy vegetation appears in varying tones of red in color infrared air photos, rather than green, as in color photos. Most current aerial photography is of the color infrared type; however, certain agencies, such as the Bureau of Land Management (BLM), prefer color air photos.

Air Photo Products

A variety of air photo products can be obtained, depending on individual preference and application. Positive prints, either black and white or color, are most preferred because they are the easiest to visually inspect, especially when used in the field. Negatives are preferred if a number of prints are desired or if the air photo will be scanned for use as a digital file. Nearly fivefold more detail will be available when scanning from a negative than from a positive print. A film-positive transparency is another product that possesses nearly as much information as the negative. It is also possible to purchase scanned digital air photos from certain air photo archives.

Photographic Scale

Photographic scale of aerial photographs provides an indication of the size of objects appearing in photos. Generally, large-scale photos cover small areas, and a particular object appears larger than on small-scale (larger area) photos. Medium-scale (1:6,000 to about 1:50,000) air photos—used in examples in this article (Figures 1–8)—have often been used in rangeland studies. This scale of aerial photography has been found to be applicable to rangelands for detailed vegetation mapping, assessments of rodent activities, planning management practices within allotments, and vegetation change detection (Carneggie, Schrumpf, and Mouat, 1983). The use of color infrared instead of panchromatic photography can extend the application to habitat assessment and ecosystems surveys (Tueller, 1982). Generally, the spatial resolution of medium-scale air photos is 1–2 meters, which is the smallest size an object on the ground can be and still be distinguishable from its surroundings (Lillesand and Kiefer, 2000).

Sponsoring Agencies and Sources of Data

Many US and state agencies have acquired aerial photography, usually by contracting with private air photo companies. The primary US departments and agencies include the USDA, BLM, United States Geological Survey (USGS), Bureau of Reclamation (BOR), Bureau of Indian Affairs (BIA), United States Environmental Protection Agency (USEPA), National Park Service (NPS), National Aeronautics and Space Administration (NASA), and various branches of the US military. NASA tends to fly most of its own air photo missions on its own airplanes.

Because many private contractors have been involved in photographic missions for various combinations of the above agencies, the location of the actual data is sometimes in question. Most data have been stored within one or more of the major archives (i.e., the US National Archives, the USGS-EROS Data Center, the USDA Aerial Photography Field Office), or one of the many smaller archives, such as the Fairchild Aerial Photography Collection at Whittier College in California. This article's Appendix lists a number of archives, and provides both contact information and some representative prices. More extensive information on sources for aerial photography is presented by Larsgaard and Carver (1997). Depending on the type of image and source of the data, the cost range for an individual scene varies from $3.00 to about $50.00 in 9- or 10-inch square (22.9-cm or 25.4-cm square) format.

Analysis Equipment

To assist the user in identifying objects in air photos, several simple or slightly complex tools are available. For magnification, a small magnifying glass or loupe (estimated cost of $5.00–$65.00) allows immediate close-up viewing to distinguish and identify small objects. If the images being used have sufficient overlap (about 50%), a desktop stereo viewer (estimated cost of $30–$700) can be used to provide vertical structure of the scene, which increases identification capability. Transferring aerial photographs to a map using a zoom transfer scope (estimated cost $5,000–$10,000) significantly enhances their utility for rangeland management. Analyzing digital products removes the need for analog techniques involved with the zoom transfer scope (unless labor costs are not an issue). If digital products are desired, a scanner should be purchased for use with a computer. Scanners that can accommodate an entire 10-inch square (25.4-cm square) air photo can be obtained for approximately $3,000, and smaller scanners (which may require cutting the air photo) can be purchased for about $500. Scanning of a single complete frame can be accomplished in about 15 minutes. However, when multiple aerial photographs must be scanned from many different flight dates, a significant investment in time is required. Negatives or positive transparencies should be scanned to preserve information content. Once scanning is complete, a variety of digital analysis methods are possible, including image rectification and registration, image enhancement (e.g., level slicing, contrast stretching, edge enhancement, and spatial filtering), and simple image classification, such as clustering based on reflectance values. The techniques used here are generally less complex than those typically associated with multispectral image analysis.

Storage of Data

After air photos are acquired, they should be handled carefully. If both negatives (or positive transparencies) and prints are available, it is recommended that the negatives be stored in archival plastic sleeves and not circulated, as they may be needed to produce additional prints or scanned products at a future date, even decades later. The prints can be used for examination and discussion and be made available for general circulation. Both prints and negatives can easily be stored in file cabinets. If negatives or transparencies are digitally scanned for computer analysis, this information can be stored on compact disks. Typically, one to three scanned air photos will fit on a 700MB compact disk, while four to twelve images can be stored on a DVD-R disk. Zip disks with less than 250MB are usually too small for storing scanned, full scene, aerial photograph images.

Example Applications in the Jornada Basin of Southern New Mexico

Aerial photographs can be used to locate the placement of a variety of rangeland remediation treatments. Combined with knowledge that the rancher or agency manager has about processes occurring on rangeland of interest, the air photos can be used to assist in interpreting the cause or extent of an event. In research, air photos can be used to assist in drawing conclusions about the effectiveness of various treatments in light of the historical treatments that may have taken place in the same area.

To illustrate some applications of aerial photographs, the Jornada basin in southern New Mexico is used as an example. Black-and-white air photo coverage of parts of the Jornada basin near the Rio Grande floodplain began in 1935. Complete air photo coverage of the Jornada basin, comprised primarily of the USDA-Agricultural Research Service (ARS) Jornada Experimental Range (783 km^2, established in 1912) and the New Mexico State University-Chihuahuan Desert Rangeland Research Center (259 km^2, established in 1927), first occurred in 1936 and 1937.

Rangeland Remediation Treatments

Historical rangeland remediation treatments often are not considered when evaluating the current condition of rangelands or their suitability for some future management practice. Many remediation treatments were performed in the 1930s and early 1940s when sufficient manpower was available in the form of Civilian Conservation Corps personnel across the United States. Because this extensive labor force was available, many treatments were implemented that would not have been feasible with normal agency staffing. Some treatments discovered on air photos have never been reported or found in existing file documents, even in experimental areas in the Jornada basin (Rango et al., 2002). Several aerial photographs are provided as examples of the types of remediation treatments that have been found in the Jornada basin. Figure 1 depicts contour terraces on the north slope of Summerford Mountain on the Chihuahuan Desert Rangeland Research Center land; these were constructed in 1935. The distance between the terraces ranges from 30 to 90 meters. This

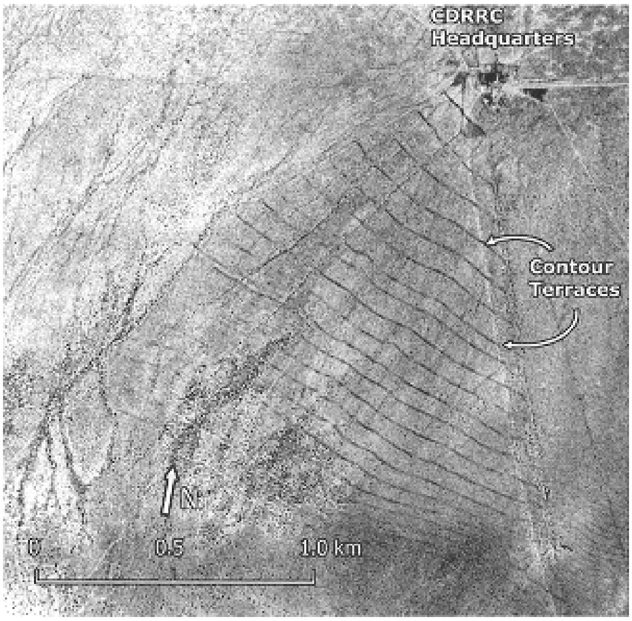

Figure 1. 1936 aerial photograph of contour terraces constructed in 1935 in Chihuahuan Desert Rangeland Research Center (CDRRC) pasture 9. (Source: National Archives and Records Administration, College Park, MD.)

air photo was taken in December 1936, and evidence of the existence of these terraces had disappeared by 1980.

Figure 2 shows evidence of water spreaders on the Jornada Experimental Range. This air photo was taken in 1948, and the water spreaders were constructed approximately ten years earlier. The spreaders were made of brush gathered locally after grubbing (shrub removal at the root level) operations, and were secured with wires anchored into the ground every 60–90 cm. They were positioned roughly perpendicular to the prevailing surface water flow and were intended to slow runoff and allow water to infiltrate. Some spreaders were supplied with water by small rock diversion dams. Because the brush was easily blown or washed away, the spreaders disappeared from view on aerial photographs by around 1970. However, interpretation of high resolution satellite photos from the 1960s indicated that this treatment was ineffective much earlier (Rango et al., 2002).

Figure 3 shows part of a fenced exclosure on the Chihuahuan Desert Rangeland Research Center land that in 1947 had five different types of contour furrowing inside and outside the fenced area (installed in 1939). In this northern portion of

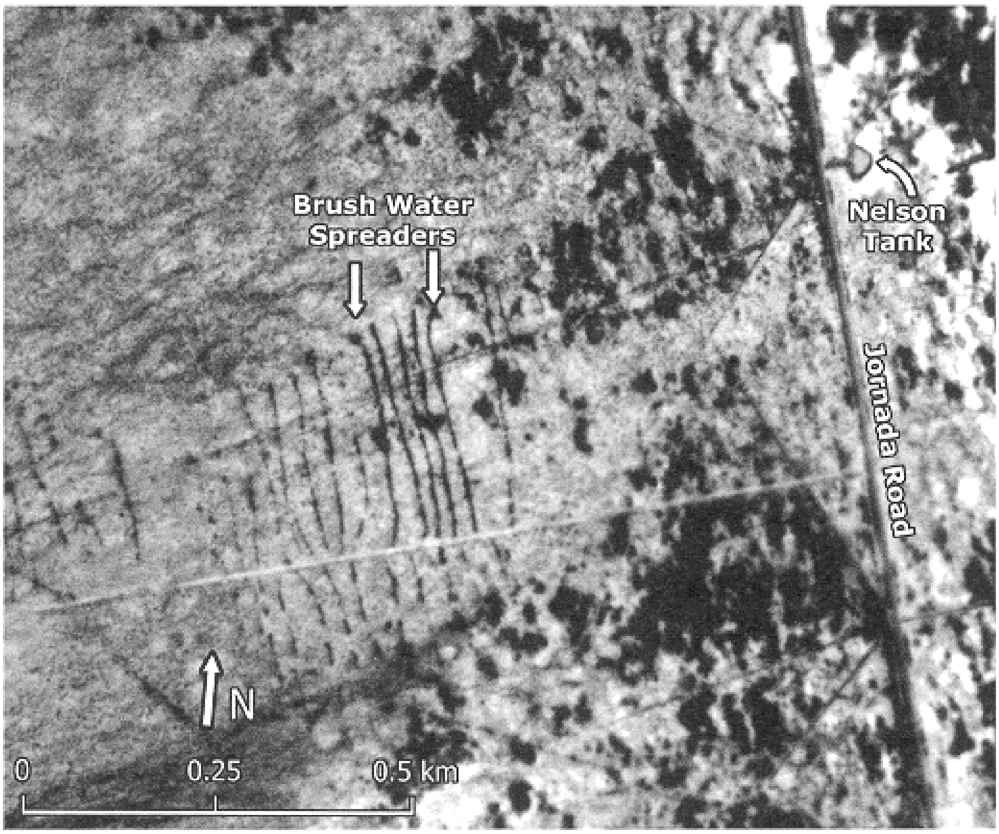

Figure 2. 1948 aerial photograph of brush water spreaders along the main Jornada Road in Jornada Experimental Range pasture 6. The spreaders were meant to increase infiltration of water into the soil. [Source: Fairchild Aerial Photography Collection, Whittier College (Flight Number C-10500X, Frame Number 26:4), Whittier, CA.]

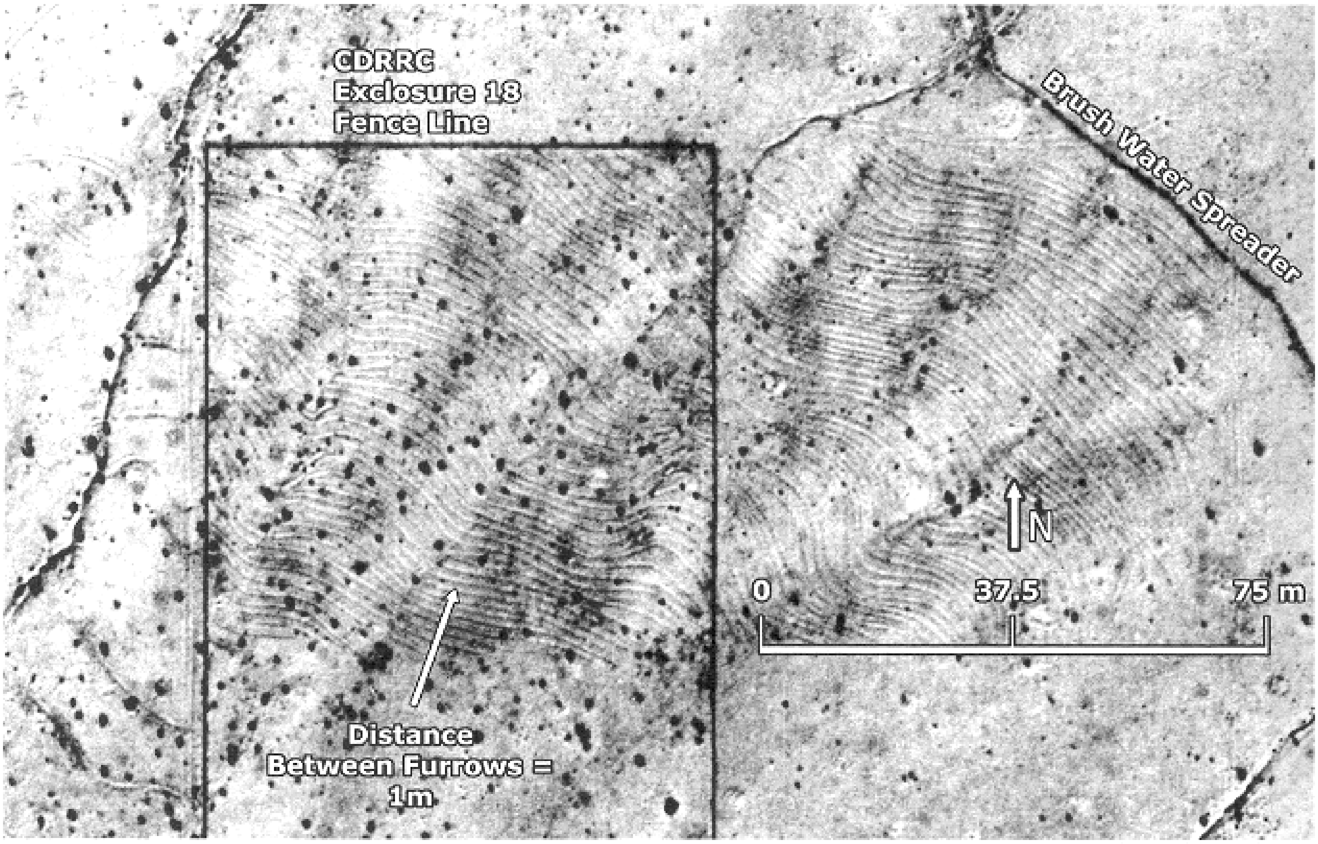

Figure 3. 1947 air photo of the northernmost part of Chihuahuan Desert Rangeland Research Center (CDRRC) exclosure 18, showing the 1-meter-wide contour furrowing treatment and exclusion of cattle and rodents used in an attempt to increase natural forage production. (Source: National Archives and Records Administration, College Park, MD.)

the enclosure, the spacing between furrows is about 1 meter. Because water running off the slopes of Summerford Mountain regularly passed across these treatments and would have washed away the furrows, they faded from view by around 1960.

Figure 4 displays surface patterns, still readily visible in 1998, left by a rootplow seeder operating at different times between 1970 and 1980. Examination of aerial photographs in the 1970s indicates that the rootplowing in Figure 4 was done in several different stages. Area A was rootplowed prior to 1972, areas B and C between 1975 and 1977, and areas D and E between 1977 and 1980. Because of considerable surface disturbance, these patterns are still visible, in stark contrast to undisturbed rangeland, 20–30 years later. The effectiveness of reseeding in these rootplowed areas is heavily dependent on subsequent precipitation and type of soil. The Gravelly Ridges Exclosure east of the rootplow area was established in 1934 and has since been ungrazed.

Figure 5 illustrates the appearance, in a 1994 air photo, of water ponding dikes established on bare soil areas in 1975 on the Jornada Experimental Range. Originally abandoned in the early 1980s because of a lack of vegetation response to this treatment, native vegetation was observed behind the dikes 20 years later, after several significant precipitation events. Such water ponding approaches may be effective on these fine-loamy soils in increasing soil moisture and allowing the reestablishment of grass cover.

Change Detection/Monitoring

Just as historical aerial photographs can be used to track brush encroachment in a pasture (Johnson, 2001), aerial photographs can also be used to monitor the duration of time that mechanical rangeland remediation treatments are effective. Because historic aerial photographs were acquired with different cameras, lenses, and film types, under different atmospheric conditions, and at different altitudes and seasons of

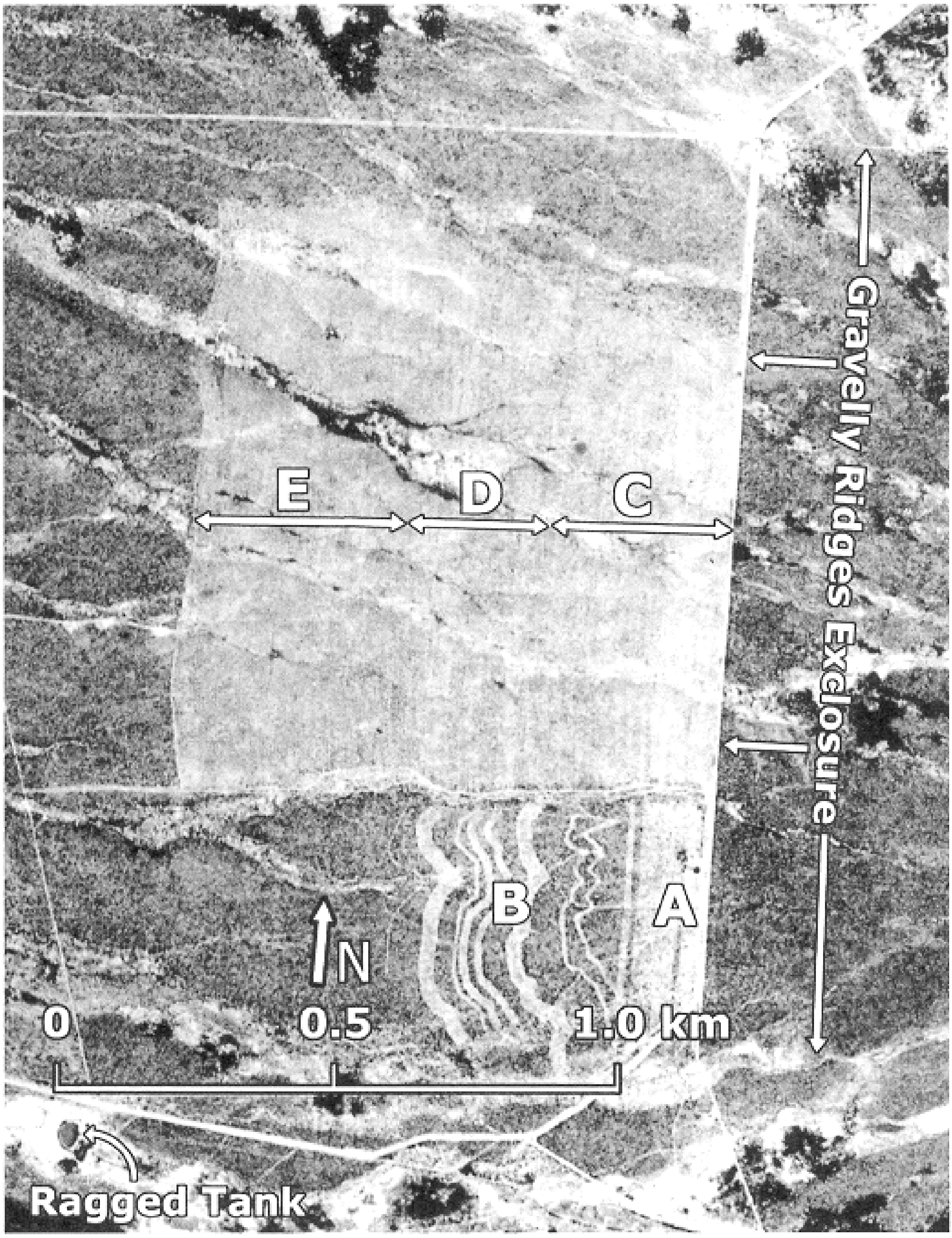

Figure 4. Surface disturbance patterns of the arid land seeder in Jornada Experimental Range pasture 20B, as shown on a 1998 air photo. By examining aerial photographs from 1972 through 1980, it is evident that area A was rootplowed prior to 1972, areas B and C between 1975 and 1977, and areas D and E between 1977 and 1980. (Source: National Aeronautics and Space Administration.)

the year, it is difficult to standardize or calibrate the different photographs. As a result, the images must be employed in a more qualitative assessment of patterns, areas, and longevity of remediation activities. Some qualitative approximation of treatment effectiveness can be surmised from the change in treatment area appearance over time in air photos. Figure 6 shows a temporal sequence of five strips (about 3 km in length) on the Chihuahuan Desert Rangeland Research Center land where creosote (*Larrea tridentata*) and tarbush (*Flourensia cernua*) were grubbed (removed at the root level) in 1936, and which exhibit a gradual fading of strip pattern contrast from the 1930s to the 1990s. This treatment remains very visible today in air photos, although it is considerably more difficult to observe at ground level. Temporal sequences of air photos can be used to more quantitatively monitor erosion features and changes in vegetation. In fact, changes in individual shrub densities over time can be followed with air photos, which would provide more information about shrub invasion and displacement of grassland in the western US. Figure 7 shows a subsection of one of the strips in Figure 6

Figure 5. 1994 aerial photograph of water ponding dikes on the Jornada Experimental Range near Ace Tank; these were established in 1975. The photo indicates a positive vegetation response to treatment. (Source: US Environmental Protection Agency.)

that was used to track shrub regrowth from 1947 to 1973 and 1991. This small part of a grubbed strip was re-grubbed in 1939, but at that time all shrubs including creosote, tarbush, mesquite (*Prosopis glandulosa*), and yucca (*Yucca* spp.) were removed, in contrast to 1936 when only creosote and tarbush were eradicated. The 1947 view has less than 1% shrub cover, which increased to 10% in 1973 and 35% in 1991, indicating a fairly intense shrub regrowth.

In addition, effects of altering stocking rates or total exclusion of grazing for extended periods of time can be observed. A number of recently launched satellites produced images with resolutions similar to aerial photographs. Ikonos provides 1 m panchromatic data and 4 m multispectral data, whereas QuickBird has 0.61 m panchromatic and 2.44 m multispectral capabilities. Figure 8 is a high resolution Ikonos satellite scene that illustrates one effect of total large herbivore exclusion (B) and the positive effect of herbicides in favoring grass versus shrubs (A). The exclosure (B) has been excluded from grazing since about 1965, and the black grama grass (*Bouteloua eriopoda*) in this exclosure is in very good condition today. At inset A in Figure 8, a very strong fence line contrast is shown between Chihuahuan Desert Rangeland Research Center land and the BLM lands to the north. Where the three administered lands come together, the Chihuahuan Desert Rangeland Research Center land seems in

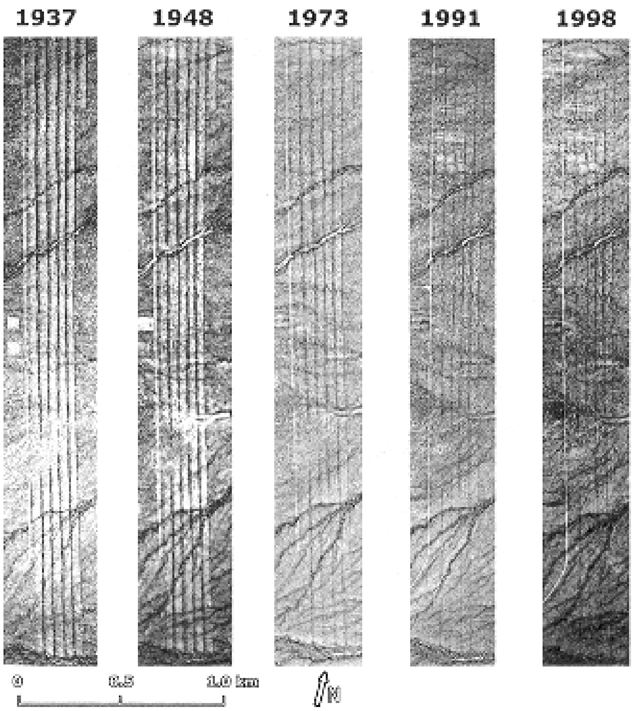

Figure 6. Temporal sequence of alternating grubbed and ungrubbed strips in a predominantly creosote area in Chihuahuan Desert Rangeland Research Center pasture 10, where the original grubbing was performed in 1936. [Sources: National Archives and Records Administration, College Park, MD (1937 photo); Fairchild Aerial Photography Collection, Whittier College (Flight Number C-10500X, Frame Number 29:68), Whittier, CA (1948 photo); US Geological Survey (1973 and 1991 photos); National Aeronautics and Space Administration (1998 photo).]

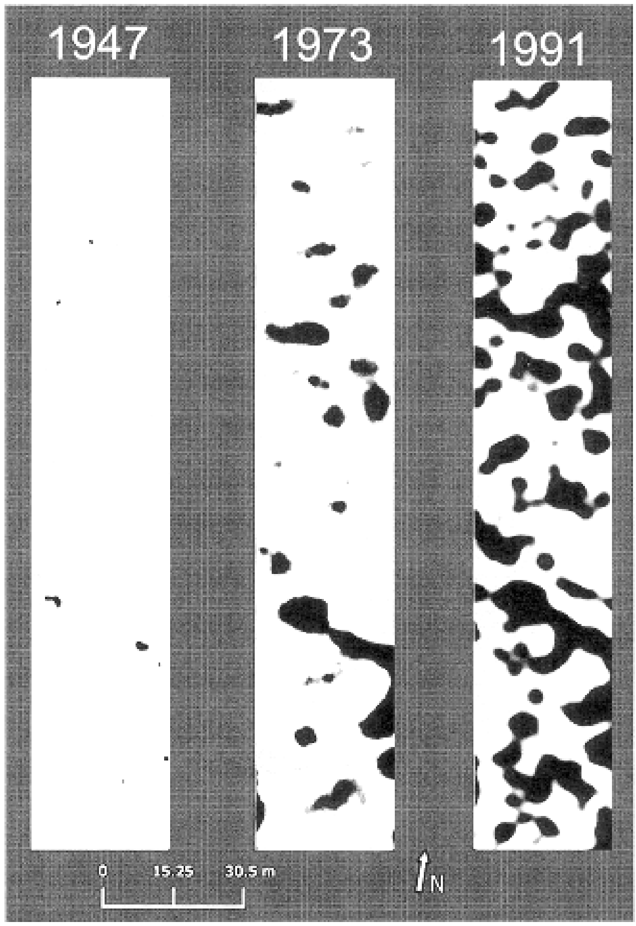

Figure 7. A portion of one of the grubbed strips that was regrubbed in 1939, when all shrubby vegetation was removed, including creosote, tarbush, mesquite, and yucca. The reestablishment of shrubs over time can be monitored and assessed using contrast stretching (shrub cover was 0.21% in 1947, 10.38% in 1973, and 34.77% in 1991). [Sources: National Archives and Records Administation, College Park, MD (1947 photo); the 1973 and 1991 photos were enhanced from the photos in Figure 6 (source: US Geological Survey).]

fair to good condition, the BLM land is more heavily grazed, and the Jornada Experimental Range land to the east is somewhere in between. This contrast results from differing grazing practices and the effect of herbicide kill of shrubs. Figure 9 is a ground-level photo looking east along this fence line, with BLM land on the left. Areas with good forage condition can be identified in air photos by simple comparisons with pasture locations known to have good forage, determined by ground inspection (ground truth).

Temporal Availability

Since 1935, many aerial photography missions have been flown over the Jornada basin, but not all air photos are still available. Thus, temporal gaps in coverage of the Jornada basin exist, which we are still attempting to rectify. Many of the missing air photos were acquired by the military in the 1940s, 1950s, and 1960s. It has been difficult to acquire the historical military aerial photographs because although the National Archives received photo indices for those flights, they never received the film rolls with the associated images. Although many aerial photographs are unavailable, we have been able to acquire a large amount of air photo coverage over the Jornada basin, as shown in Table 1. Despite temporal gaps in coverage, the available data are extensive, permitting investigation of activities in the basin for each decade since the 1930s. These data were acquired only after persistent and extensive searching. In comparison, an initial search for the Armendaris Ranch in New Mexico turned up at least 16 different dates with air photo coverage from 1949 to 1994. With additional searches, it is expected that total coverage will approach the coverage now available for the Jornada basin.

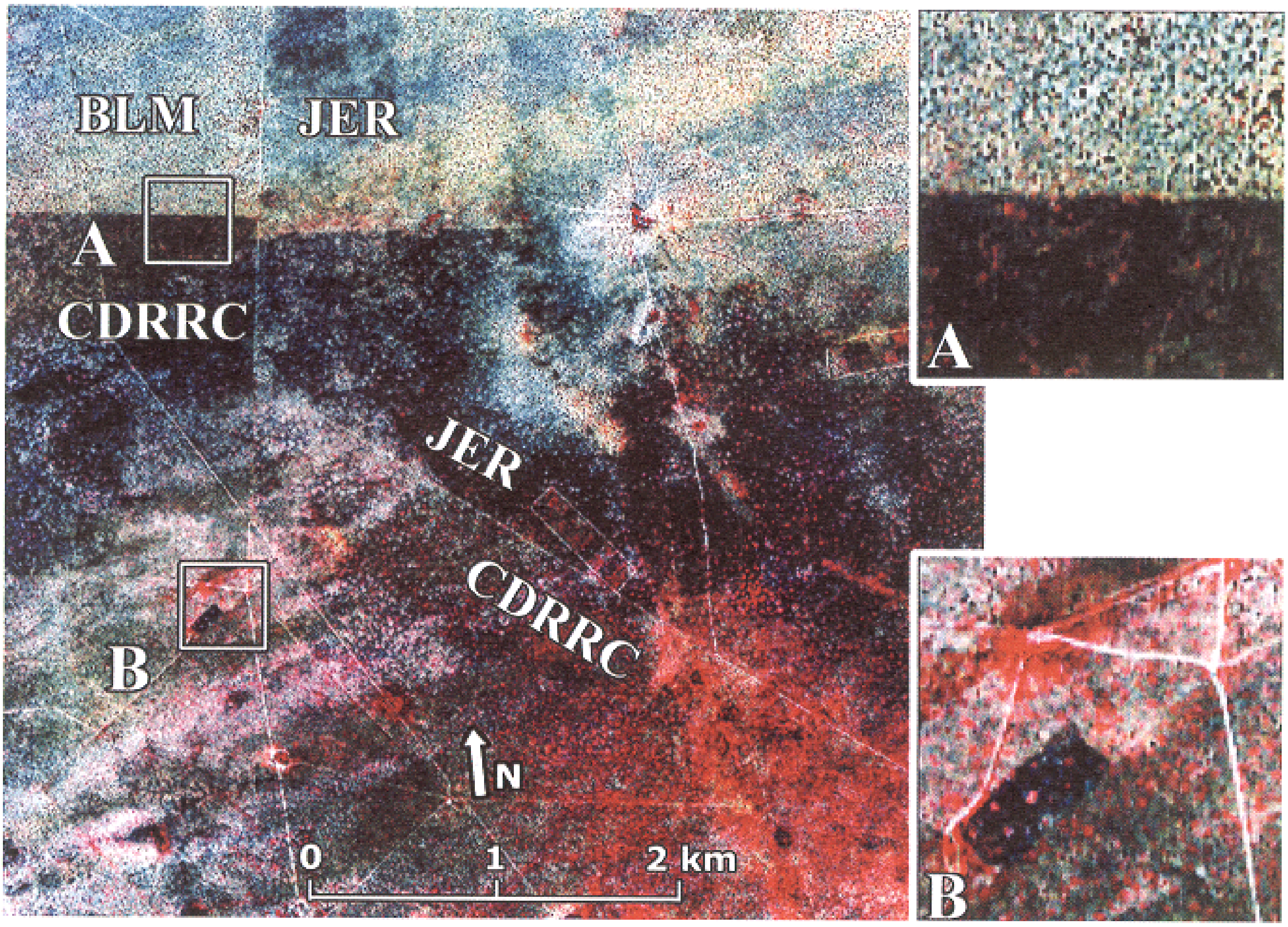

Figure 8. Fence line contrast over Chihuahuan Desert Rangeland Research Center (CDRRC) and Bureau of Land Management (BLM) lands (location A), with Jornada Experimental Range (JER) just to the east, and black grama grass exclosure (location B), from a July 20, 2000, Ikonos color infrared image. (Source: Space Imaging, Inc., via National Aeronautics and Space Administration.)

Figure 9. Ground-level view (looking east) of the fence line contrast shown in Figure 8, with Bureau of Land Management land on left (degraded condition) and Chihuahuan Desert Rangeland Research Center land on right (fair to good condition). (Source: Dr. Albert Rango.)

Table 1. Air photos and missions acquired for the Jornada Basin in southern New Mexico

Date	Agency sponsor*	Archive source*	Film type	Approximate scale
May 1935	ASCS	FAPCWC	Black-and-white	1:24,000
December 1936	SCS	NARA	Black-and-white	1:31,680
March 1937	SCS	NARA	Black-and-white	1:31,680
December 1942	US Army	USGS	Black-and-white	1:50,000
December 1947	ASCS	NARA	Black-and-white	1:10,560
October 1948	US Army	FAPCWC	Black-and-white	1:30,000
April 1949	US Army	DIA	Black-and-white	1:50,000
June 1955	ASCS	APFO	Black-and-white	1:10,000
November 1960	ASCS	APFO	Black-and-white	1:20,000
December 1963	US Army	WSMR	Black-and-white	1:31,320
March 1967	ASCS	APFO	Black-and-white	1:20,000
December 1972	USGS	USGS	Black-and-white	1:29,000
January 1973	USGS	USGS	Black-and-white	1:33,100
March 1974	ASCS	APFO	Black-and-white	1:40,000
September 1975	BLM	EDAC	Color	1:31,680
September 1977	ARS	ARS	Black-and-white	1:30,600
October 1978	US Air Force	USGS	Black-and-white	1:25,000
September 1980	USGS	USGS	Black-and-white	1:80,000
December 1980	BLM	EDAC	Color	1:31,680
September 1984	NASA	USGS/APFO	Black-and-white/color infrared	1:58,000
September 1986	NASA	USGS/APFO	Black-and-white/color infrared	1:58,000
July1987	NASA	USGS/APFO	Black-and-white/color infrared	1:58,000
September 1989	ARS	ARS	Color infrared	1:6,000
October 1989	BLM	EDAC	Color	1:24,000
September 1990	BLM	EDAC	Color	1:24,000
July 1991	USGS	USGS	Color	1:24,000
September 1994	USEPA	USEPA	Color infrared	1:18,890
October 1996	USGS	USGS	Black-and-white/color infrared	1:40,000
May 1997	NASA	NASA	Color infrared	1:65,000
May 1998	NASA	NASA	Color infrared	1:65,000
September 1998	NASA	NASA	Color infrared	1:65,000

*APFO=Aerial Photography Field Office; ARS=Agricultural Research Service; ASCS=Agricultural and Stabilization Conservation Service; BLM=Bureau of Land Management; DIA=Defense Intelligence Agency; EDAC=Earth Data Analysis Center; FAPCWC=Fairchild Aerial Photography Collection at Whittier College; NARA=National Archives and Records Administration; NASA=National Aeronautics and Space Administration; SCS=Soil Conservation Service; USEPA= United States Environmental Protection Agency; USGS=United States Geological Survey; WSMR=White Sands Missile Range.

Future Applications

There are certain questions that air photos can answer, and others for which air photos can be used to supply important ancillary information. Perhaps the most important aspect regarding use of air photos is that they can serve as a stepping stone to fuller utilization of remote sensing, if desired and pertinent. Building on the familiarity with air photos, when enough overlap occurs in flights, it is easy to advance to stereo analysis, which adds the vertical third dimension. The equipment needed is minimal. With the aid of a computer, satellite or airborne multispectral scanners can be used to actually classify various rangeland cover types, with local knowledge of the user being the most valuable aspect of the process.

It is not a tremendous leap to imagine that a variety of the remote sensing tools mentioned here could be used to assist in evaluation of rangeland health. Various types of remote sensing analysis can be combined with the evolving suite of ground-based measurements being developed for monitoring ecosystems and assessing rangeland health (Herrick et al., 2003; Pellant et al., 2000). For assessment over large areas of rangeland, remote sensing will have to be integrated closely with conventional techniques. However, this is not necessarily the only integrated approach for which remote sensing, as well as GIS and GPS, can play an important role. The use of remote sensing to measure biomass, GIS to locate the optimum grazing areas, and GPS to move cattle will be integrated into future techniques for distributing livestock at the appropriate time and place over rangeland. This has been successful in prototype tests (Anderson, 2001). When these forms of technology can be combined with proven animal handling and nutrition expertise, certain basic grazing management questions (e.g., livestock location, forage availability, movement, timing) could be easily answered to improve ranch operations. Before such a system becomes reality, aerial photographs will play an important role in familiarizing users with the utilization of remote sensing data.

Conclusions

Aerial photographs have been available since the mid-1930s, providing a simple type of remote sensing data that can be easily interpreted, sometimes even without prior training. However, if quantitative information is to be extracted from the aerial photographs, more formalized photo interpretation training would be a great advantage. Like other forms of remote sensing data, air photos have the advantage of a capability for large area monitoring, coverage over remote and sometimes inaccessible regions, providing a landscape perspective, and providing repetitive views over an area. Unlike most other types of remote sensing data (and field data, for that matter), aerial photographs can provide a consistent historical base extending back to the 1930s. Moreover, air photos seem to provide a common ground and reference that enhances communication among all personnel involved in rangeland management. Finally, air photos are easy to acquire and affordable, which increases their possible widespread utilization.

Air photos are especially well suited for identification and evaluation of historical rangeland remediation treatments because many treatments were initiated in the mid-1930s, and most records of these treatments are sketchy at best or (in many cases) have been lost. The use of aerial photographs allows us to go back in time to recreate the management history of a rangeland, such as fence construction and location, development of livestock watering facilities, and implementation of improvement practices such as pasture seeding. Many other applications exist as well, including change detection, management decisions, and overall rangeland surveys. The use of air photos may also be a starting point from which to acquaint users with the potential for integrating the capabilities of remote sensing, GIS, and GPS for future rangeland applications.

Appendix: Sources of Historical Aerial Photography for Use in Rangeland Applications

US Geological Survey
EROS Data Center
Customer Service
Sioux Falls, SD 57198
http://edcsns17.cr.usgs.gov/EarthExplorer
(phone) 605-594-6151
or
US Geological Survey
Reston-Earth Science Information Center
507 National Center
Reston, VA 20192
http://www.usgs.gov
(phone) 703-648-5526

For both USGS offices, it may be necessary to call and discuss your requirements, particularly if you want to acquire older air photos.

Costs:

9-inch B/W negative	$10.00
9-inch B/W print	$10.00
9-inch color positive	$24.00
9-inch color print	$16.00

US Department of Agriculture
Farm Service Agency
Aerial Photography Field Office
Sales Branch
2222 West 2300 South
Salt Lake City, UT 84119-2020
http://www.apfo.usda.gov/orderingimagery.html
(phone) 801-975-3503

Costs:

10" × 10" B/W negative	$ 3.00
10" × 10" B/W print	$ 5.00
10" × 10" color positive	$15.00
10" × 10" color print	$12.00

National Archives and Records Administration (NARA)
8601 Adelphi Road
College Park, MD 20740-6001
http://www.nara.gov
(phone) 301-713-7040

Only older air photos are available from NARA, e.g., air photos taken before 1955.

Prices vary depending on the private vendor chosen by the customer to produce the products. The following prices are only approximate estimates:

10" × 10" B/W negative	$21.00
10" × 10" B/W print	$16.00

Bureau of Land Management—Aerial Photography
Building 501 Denver Federal Center
PO Box 25047
Denver, CO 80225-0047
(phone) 303-236-7991

Fairchild Aerial Photography Collection
Whittier College
Whittier, CA 90608
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The cost for images varies considerably based on the number of air photos ordered. It is recommended to call for a search and to get a price quote.

Additional aerial photographs are possessed by individual agencies, the military, private companies, and historical societies. If the above archives do not have data for the area of interest, that does not mean the air photos do not exist. Persistence in your search usually will result in securing archived photographs.

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