Use of Satellite Imagery to Detect Prairie Dog Towns

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Introduction

Prairie Dogs. Black-tailed (*Cynomys ludovicianus*) and Gunnison's (*C. gunnisoni*) prairie dogs are both ranked by the New Mexico Natural Heritage program as S2 in the state, meaning that they are rare. The black-tailed prairie dog became a federal candidate for listing as threatened on 4 February 2000 (warranted for listing but precluded, Federal Register 2000). Prairie dog populations have declined by 98% throughout much of their habitat in the western grasslands that formerly stretched from southern Canada to northern Mexico. Populations of both species now consist of scattered remnants (Chesser 1983, Miller et al. 1994). Declines are primarily a result of prairie dog eradication programs (Miller et al. 1994). Other significant threats to prairie dogs include loss of grassland habitat to grazing land and croplands, urban development, recreational shooting, and natural mortality (e.g., sylvatic plague and predation).

Prairie dogs are inhabitants of shortgrass and mid-grass prairies and grass-shrub habitats (Finch 1992). They are colonial mammals and excavate burrows in "towns" ranging from several acres to hundreds of acres in size. Prairie dogs are herbivorous and, historically, together with large native herbivores such as bison (*Bison bison*) and pronghorn (*Antilocapra americana*), interacted to maintain the short-grass vegetation in their habitats (Coppock et al. 1983, Krueger 1986). Removal of prairie dogs may have facilitated the transition of grasslands to shrublands and woodland vegetation states (Weltzin et al. 1997). Contrary to common belief, there is only low-level competition between prairie dogs and livestock, and prairie dog towns often produce more succulent and nutritious grasses than areas without prairie dogs (reviewed in Miller et al. 1994). The loss of prairie dog colonies impacts associated vertebrate biodiversity, and several species dependent on prairie dog towns are federally endangered or experiencing declines: Ferruginous Hawk (*Buteo regalis*), Burrowing Owl (*Athene cunicularia hypugaea*), Mountain Plover (*Charadrius montanus*), black-footed ferret (*Mustela nigripes*), and swift fox (*Vulpus velox*, Miller *et al.* 1994, Sharps 1994).

Black-tailed prairie dogs in New Mexico were once abundant east of the Rio Grande and in the grasslands of the southwestern section of the state. Colonies could also be found in suboptimal habitat, such as open woodlands, and in the semi-desert habitats of southern New Mexico (Findley et al. 1975). Black-tails once occurred in the following southern New Mexico counties: Hidalgo, Grant, Sierra, Luna, Socorro, Dona Ana, Lincoln, Otero, Chaves, Eddy, and Lea (Hubbard and Schmitt 1984). Black-tailed colonies were once extensive in the Animas and Playas Valleys of southwestern New Mexico, but they have probably been extirpated by rodent control measures. Now they can be found primarily in the eastern plains in small numbers (Findley et al. 1975). Active colonies have been mapped in the northern counties of Union, Colfax, and Harding (NM Natural Heritage Database Source Abstracts; L. Sager 1996, 1997).

Gunnison's prairie dogs have a white-tipped rather than a black-tipped tail. Compared to black-tailed prairie dogs, Gunnison's form smaller, more loosely organized colonies (Findley et al. 1975). Gunnison's prairie dogs inhabited counties to the west of the Rio Grande and in northern sections of the state, where black-tailed prairie dogs do not occur

(Findley et al. 1975). They are currently found in the Great Basin desert scrub habitat type in New Mexico (Frey and Yates 1996). They inhabit grasslands from low valleys to montane meadows up to at least 10,000 feet (Findley et al. 1975).

Because they influence the health of the short-grass ecosystem and populations of other species associated with their colonies, prairie dogs qualify as keystone species (Finch 1992). It has been estimated that 170 vertebrate species either have been found on prairie dog colonies or rely on prairie dog activity for survival (Reading 1993). Managing prairie dog towns in New Mexico will benefit those species that rely on them and will help to maintain the shortgrass ecosystem. In order to make meaningful state-wide and ecoregional conservation management decisions for prairie dogs and those species associated with prairie dog towns, it is necessary to locate existing prairie dog colonies, examine associated land-use jurisdictions, and determine and monitor population densities.

Use of Remote Sensing to Locate Prairie Dog Towns. In the last twenty years, investigators have successfully utilized aerial photography to identify and monitor prairie dog colonies (Poulton 1975, Cheatham 1977, Tietjen et al. 1978, Dalstead et al. 1981, Carneggie et al. 1983). Due to the expense and time involved in the acquisition and ortho-rectification of aerial photographs, this technique can be problematic for regional reconnaissance and mapping. The use of remote sensing satellite data has potential to address these problems, as these sensors have large synoptic coverage (one Landsat Thematic Mapper [TM] image covers 185 km. x 175 km). Early use of satellite imagery to look for prairie dog towns in the Tularosa Basin, New Mexico, could not distinguish town sizes below 50 ha in size (Conley and Conley, 1986). Significant technological changes have occurred since then in both sensor technology and the display and image processing techniques used to enhance satellite data. In 1995, the New Mexico Natural Heritage Program and the Earth Data Analysis Center (EDAC) produced a vegetation map of the short- and mid-grass prairies and shrublands of Melrose Bombing Range in eastern New Mexico. In that study, the TM data accurately depicted the location and distribution of the four prairie dog towns found on the base. The smallest was 25 ha in area, but investigators were confident that much smaller ones could have been detected.

Purpose. The purpose of this study was to determine the feasibility of using satellite imagery for detecting prairie dog disturbance at a large scale. This project was designed to proceed in two phases. In the first phase, satellite images were used in conjunction with the locations of known prairie dog towns to develop visual methods for finding towns on satellite imagery. Image analysis, together with field validation, was used to determine: 1. the minimum-sized town that could be adequately detected, 2. other variables that are important in prairie dog town detection, and 3. error rates. Our results provide a basis for the next phase of the project; in which we will develop automated methods to screen images, allowing a computer to accomplish what has previously been done with the human eye.

Methods

Image Processing. A Landsat Enhanced Thematic Mapper (ETM) image was taken of the study area on 20 August, 1999. The Earth Data Analysis Center, University of New Mexico (EDAC) acquired the image, which had been corrected for radiometric distortion. At EDAC the image was rectified to a UTM projection, Zone 13, 1927 North American Datum, Clarke 1866 Spheroid.

The imagery was then cut to an area centered over the Kiowa National Grasslands, near Clayton, New Mexico (Figure 1). The ETM sensor acquires imagery from the visible blue to the thermal infrared in 7 separate bands at a 30-meter spatial resolution, with an additional panchromatic band (ETM Pan) over the visible wavelengths providing 15-meter spatial resolution. Paul Neville of EDAC merged the two images to provide increased spatial resolution and high spectral contrast. These ETM data were then merged with Indian Remote Sensing Panchromatic (IRS Pan) imagery, acquired in 1998, which has a 5-meter spatial resolution (Figure 2).

Vector Coverages. We also obtained polygon layers (ArcView shapefiles) of prairie dog towns from the US Forest Service (USFS) Kiowa and Rita Blanca National Grasslands (NG) for the same area in northeastern New Mexico and northwestern Texas. The USFS NG developed these files based on aerial transect data collected by John Sidle, USFS Threatened and Endangered Species Coordinator, Great Plains Grasslands, and ground work by Justin Kretzer and Jack Cully, US Geological Survey Biological Survey at Kansas State University. The GPS locations were collected in October, 1999, a few months after the collection of satellite images, making comparisons ideal. Only colonies on National Grasslands Management Areas were delineated on the ground. John Sidle provided additional information from his aerial transects (flown between 1997 and 1998) within the broader extent of the Kiowa National Grasslands.

Image Analysis. We used satellite imagery in conjunction with the locations of known prairie dog towns for training. We divided the data set of known colonies into a training set and a test set (Figure 3). The training set consisted of 11 polygons of prairie dog colonies that we overlaid onto the ETM/IRS image. This allowed us to identify the spectral and spatial characteristics and select the display techniques that enhanced the visibility of prairie dog disturbance.

We examined the rest of the satellite image (the test set), inside the National Grasslands and adjacent private land, using a line grid as a guide. Visual interpretation was based on the shape, color, and texture (or pattern) of pixels of the training set of colonies. Those areas resembling colonies were screen-digitized into a separate GIS coverage. The set of known colonies was placed over the screen-digitized layer and the number of matches was recorded.

We visited the site on the Kiowa National Grasslands to field validate sites we had delineated as prairie dog disturbance on the satellite imagery. Our trip also provided information on the habitat surrounding the prairie dog colonies. The field validation occurred approximately one year after the imagery was taken, in August 2000, in the same season that images were made.

Results and Discussion

Interpretation. We examined both satellite images and decided that the ETM/IRS product (5m resolution, Figure 2) more clearly depicted the prairie dog towns. We sharpened and enhanced the color contrast of the image, using ERDAS Imagine software, to the extent that the merged data would allow. Prairie dog disturbance appeared roughly circular or amoeboid in shape. Compared to agricultural fields, prairie dog colonies exhibited a more coarse or heterogeneous pattern. Colonies typically exhibited more color heterogeneity than surrounding prairie vegetation, depending on vegetation type. We looked for similarities among towns in proportions of white (high reflectance), red, and dark green pixels in our training set of prairie dog towns. Band combinations of the satellite image were: three (near infrared) in the red, four (middle infrared) in the green, and two (red) in the blue. Image characteristics combined with impressions from field visits suggest the following interpretation: red is wetter, younger vegetation; homogenous red and light green denote monocultures of crop plants; dark green is drier vegetation; white is exposed sandy ground with varying shades along drainages; dark purples and blue/black probably denote water. Other visual cues aid in identifying various landscape features (Figure 2).

A variety of soil types occurs in the Clayton area, mainly loamy sands to sandy clays (Dunmire 1987). The area was predominately blue grama–buffalograss (*Bouteloua gracilis* and *Buchloe dactyloides*) grasslands. Forbs made up 2% of cover, and bare ground was less than 10%. Bare ground and a diversity of forbs make up a large proportion of a typical prairie dog colony. Our observations suggested that *Yucca glauca* was scarce but was found in distinctive patches. The terrain was nearly flat and marked by several drainages.

Colonies are conspicuous from the air due to reflectance of bare soil from burrow mounds. Mounds can measure two to three meters in diameter, are barren of vegetation, and often consist of light colored subsoil (Cincotta 1989, Hoogland 1995). Prairie dog foraging creates vegetation zonation near the burrows (Garrett et al. 1982, Koford 1958, Whicker and Detling 1993). The heterogeneity and appearance of colonies compared to surrounding unmodified grassland results from larger proportions of bare ground, erosion, and decreased vegetation structure (Munn 1993, Whicker and Detling 1993). Other burrowing mammals may create disturbances similar to very small prairie dog colonies. At close inspection, gopher activity lacks the zonation of vegetation that grazing prairie dogs create. Gopher mounds are smaller and lack an entrance hole. Harvester ant disturbance (*Pogonomyrmex occidentalis*) can be distinguished from prairie dog mounds by a ring of vegetation around the mound, absence of a burrow hole, and lack of grazed vegetation zones.

Error Estimates. Eleven of 15 active prairie dog colonies (73%) were correctly identified in the test set (Figure 3). One disturbed area was falsely identified as a prairie dog town (6% false positives) and we failed to detect four (27% false negatives). The false positive was a heavily grazed area (17.6 ha, Figure 4) near a feeding station which concentrated cattle and was surrounded by taller prairie grass. The false negatives were typically close to agricultural fields or located within a closely cropped range. A clear distinction between the clip line of these colonies and surrounding vegetation did not exist (Figure 5). Within the training image, we detected two additional colonies not observed from the aerial flights but confirmed by ground inspection. We also detected two new colonies on private land in the test image.

We compared the colony area calculations derived from satellite images to those from GPS coverages of the same colonies gathered from the ground. Satellite-derived coverages differed by 3.3 ± 2.5 hectares (N=6 completely ground delineated colonies). The discrepancies between GPS areas and our areas based on satellite images varied from 0.5% to 48.5%. In the case of an additional colony, the actual area was 32.4 ha smaller than we estimated, because the GPS coverages indicated three closely spaced (<200m) colonies, which we delineated as a single colony. (We included the area between the sub-colonies, and the ground delineation did not.) This discrepancy may be an example of individual differences in defining what constitutes a colony, rather than an example of discrepancy among survey methods.

Error estimates are necessary to evaluate and compare inventory techniques and for accurate monitoring. Most investigators have not refined methods of measuring the accuracy of their remote sensing methods to detect colonies. Tim Assal et al. (University of Wyoming, pers. comm.) are in the process of calculating false negatives and false positives in their satellite-based inventories. Their 15m-resolution imagery has given a high number of false positives in over-grazed areas and sites with sandy soil and sparse vegetation. Andrea Ernst (Texas Tech, pers. comm.) is using Farm Service Agency (FSA) aerial slides to inventory prairie dog colonies, but she has not yet completed an accuracy assessment (pers. comm.). Jean-Luc Cartron, using aerial search methods to detect prairie dog colonies and associated Ferruginous Hawks, estimates (pers. comm.) that 10% of Gunnison prairie dog colonies are false positives. He suspects that error occurs when the activity of fossorial burrowers such as kangaroo rats is mistaken for prairie dog disturbance.

To investigate whether higher-resolution imagery would offer more information than satellite images, we purchased several digital ortho-quarter quads (DOQQs), which are digital, georeferenced aerial photographs at one meter resolution. The new imagery, made in 1991, overlapped the study area. Individual prairie dog mounds were visible on the DOQQs, which allowed us to better distinguish prairie dog disturbance from other types of disturbance that typically created false positives or false negatives.

The colony visible in the 1991 DOQQ had increased by 63.3 hectares in the 1999 satellite images (Figure 6). Another colony apparent in 1991 DOQQs had disappeared by the time the 1999 satellite image was made (Figure 7). It appeared that the vegetation had grown at the colony site, perhaps after disappearance of the prairie dogs. Colonies are typically classified by surveyors as inactive if burrows and adjacent ground are heavily vegetated, but it may require several years before inactive prairie dog towns are no longer discernible from the air (Uresk and Schenbeck 1987). This brief analysis suggests that remote images may be useful in monitoring as well as surveying.

Our analysis detected prairie dog colonies two to four hectares and larger in size. This is a much smaller minimal detectable area than could be identified in southern New Mexico (50 ha prairie dog colonies) with older satellite and image processing technology (Conley and Conley, 1986). Use of satellite imagery also made it possible to extend known colony boundaries that were incompletely delineated due to land ownership or because of time constraints. The ETM/IRS imagery allowed us to identify four previously unknown colonies in the study area.

Cost Comparison. A cost comparison of satellite imagery vs. aerial transect surveys suggests that satellite imagery is more costly per unit area ($873/ quad. versus $200/quad) but also yields less valuable spatial information. Additional information on habitat and features other than prairie dog point locations can be acquired by satellite imagery. Area and perimeter measures of colonies can be calculated from remote images, and this information can be used for monitoring. Landscape feature comparisons such as distances to other prairie dog towns can be made. Colony locations can be compared to other disturbances and vegetation types. Aerial surveys provide only presence/absence data and none of the above spatial information.

Ikonos satellite imagery has higher resolution than TM/IRS and provides comparable spatial information, but it costs about ten times as much per unit area. DOQQs also provide excellent resolution for very low cost, but spatial and temporal availability is limited. FSA aerial crop photos have resolution as high as 1-2m, but they are available only for agricultural areas. Therefore, we believe that satellite imagery provides good information value and landscape coverage for the price.

Conclusions

Based on the pilot study presented here, we conclude that

1. Use of remote-sensing imagery is a feasible method of locating prairie dog colonies at a large landscape scale (one TM image covers an area of approximately 185 X 175 km).
2. TM imagery is much more cost-effective than field surveys or higher-resolution satellite imagery such as IKONOS and more available than aerial photography.
3. Error rates are quite low for a method still in the development stage.
4. Finally, remote-sensing images such as DOQQs and ETM show potential as monitoring tools.

We are now prepared to proceed with phase II of this project, in which we will attempt to enhance and define the image parameters that allow detection of prairie dog disturbance by the human eye. In this phase, we expect to:

1. refine the method to improve accuracy,
2. automate the method to allow a computer to scan for prairie dog towns, and
3. test the method in a different landscape to determine its applicability in various habitat types.

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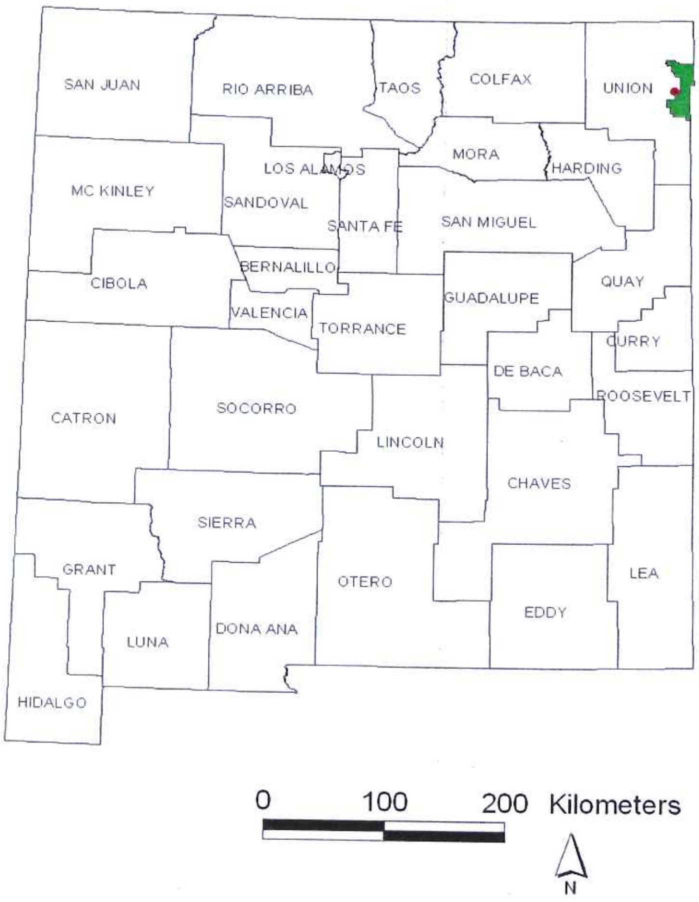
Figure 1. Study Site at USFS Kiowa National Grasslands, NM, 1999.



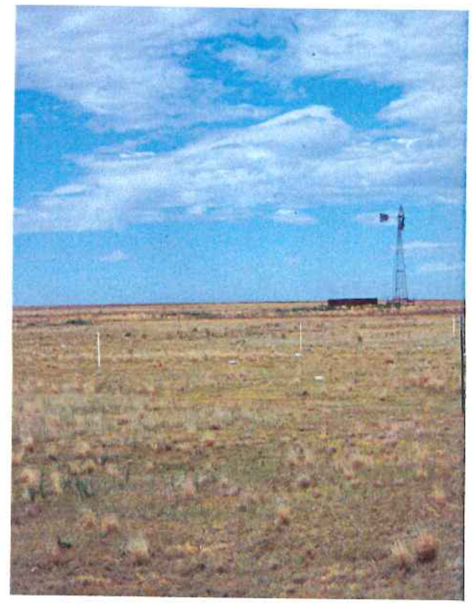
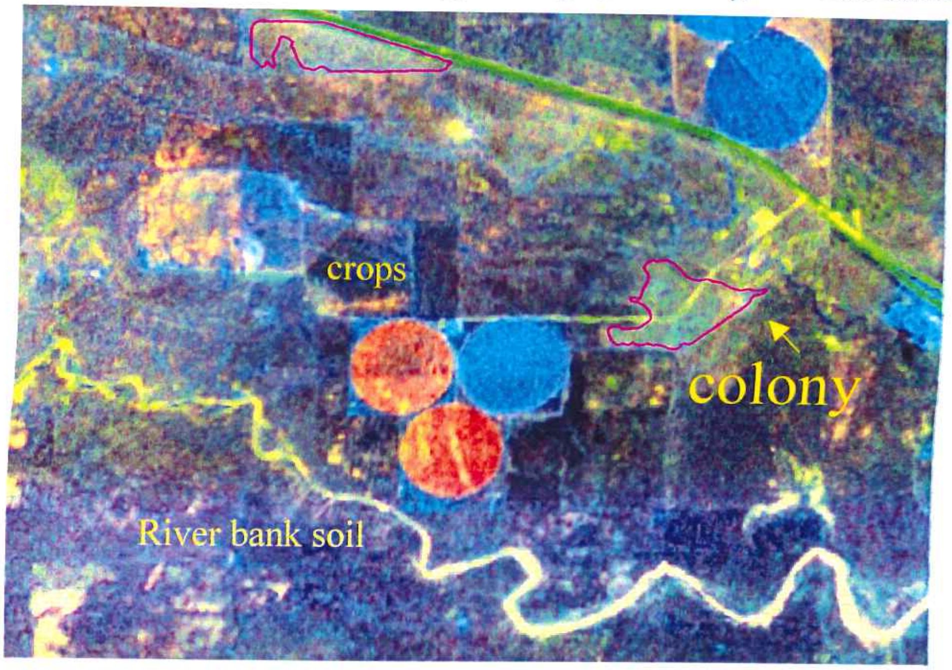


Photo compliments of Paulette Ford, USFS

Figure 2. Comparison of Landsat ETM-Pan image (A) and ETM merged with IRS-Pan (B). Note greater visibility of prairie dog towns in (B).

A. Landsat Enhanced Thematic Mapper Image (ETM-Pan), 15m resolution.



B. ETM/Indian Remote Sensing Panchromatic Merge (ETM/IRS-Pan), 5m resolution.

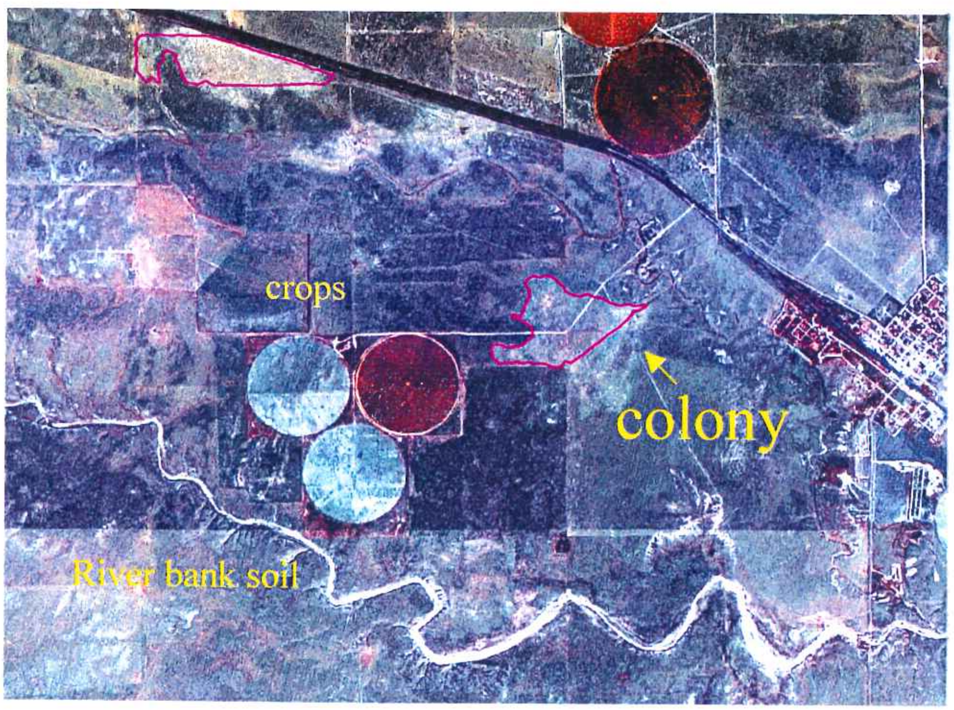


Figure 3. Possible prairie dog disturbances identified from satellite imagery compared with known locations of colonies from the USFS Kiowa National Grasslands. False negatives indicated by empty circles. Data obtained from 1999 imagery.

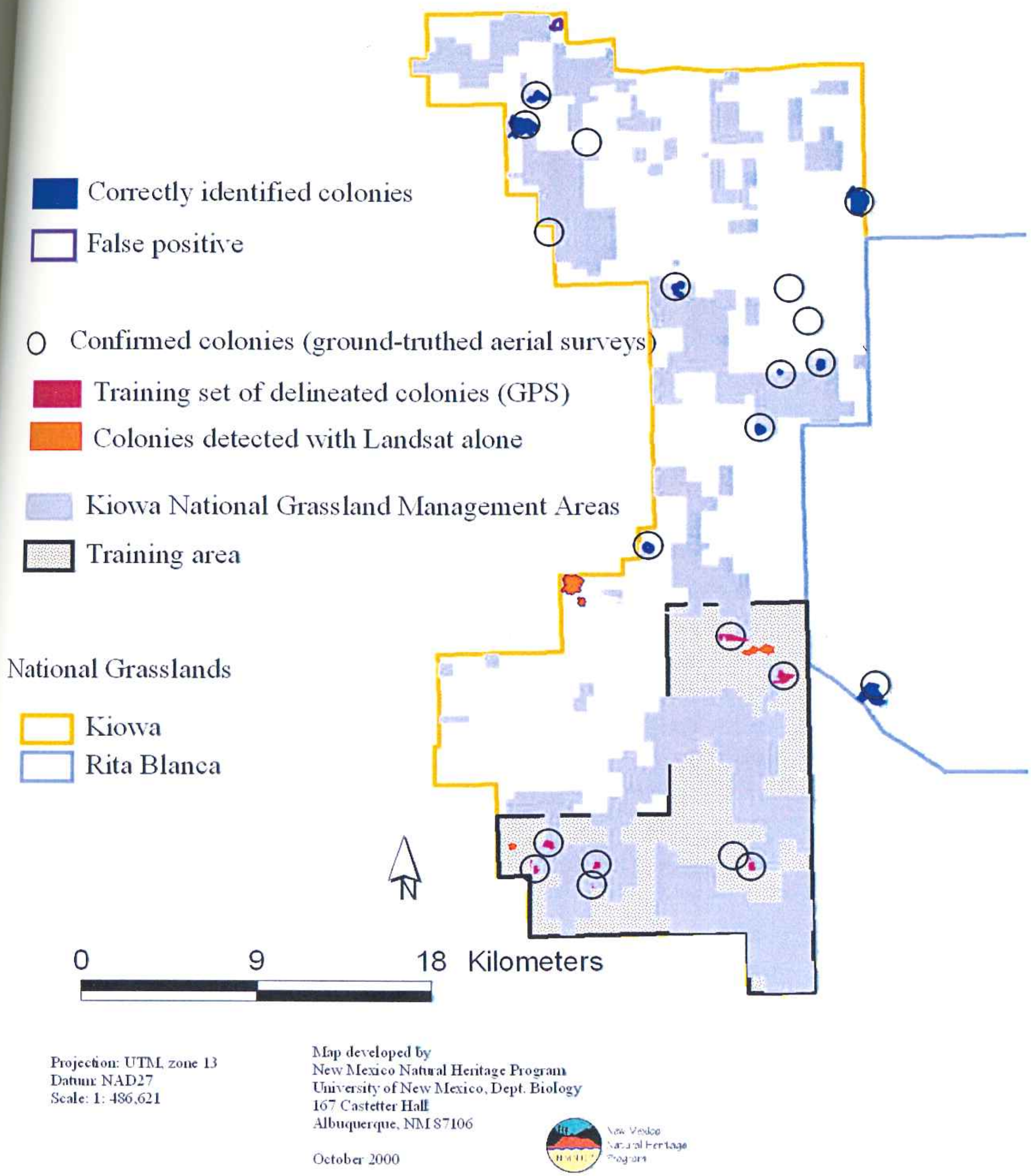


Figure 4. A false positive error in detecting a prairie dog colony from a Landsat EMT image (5m resolution).

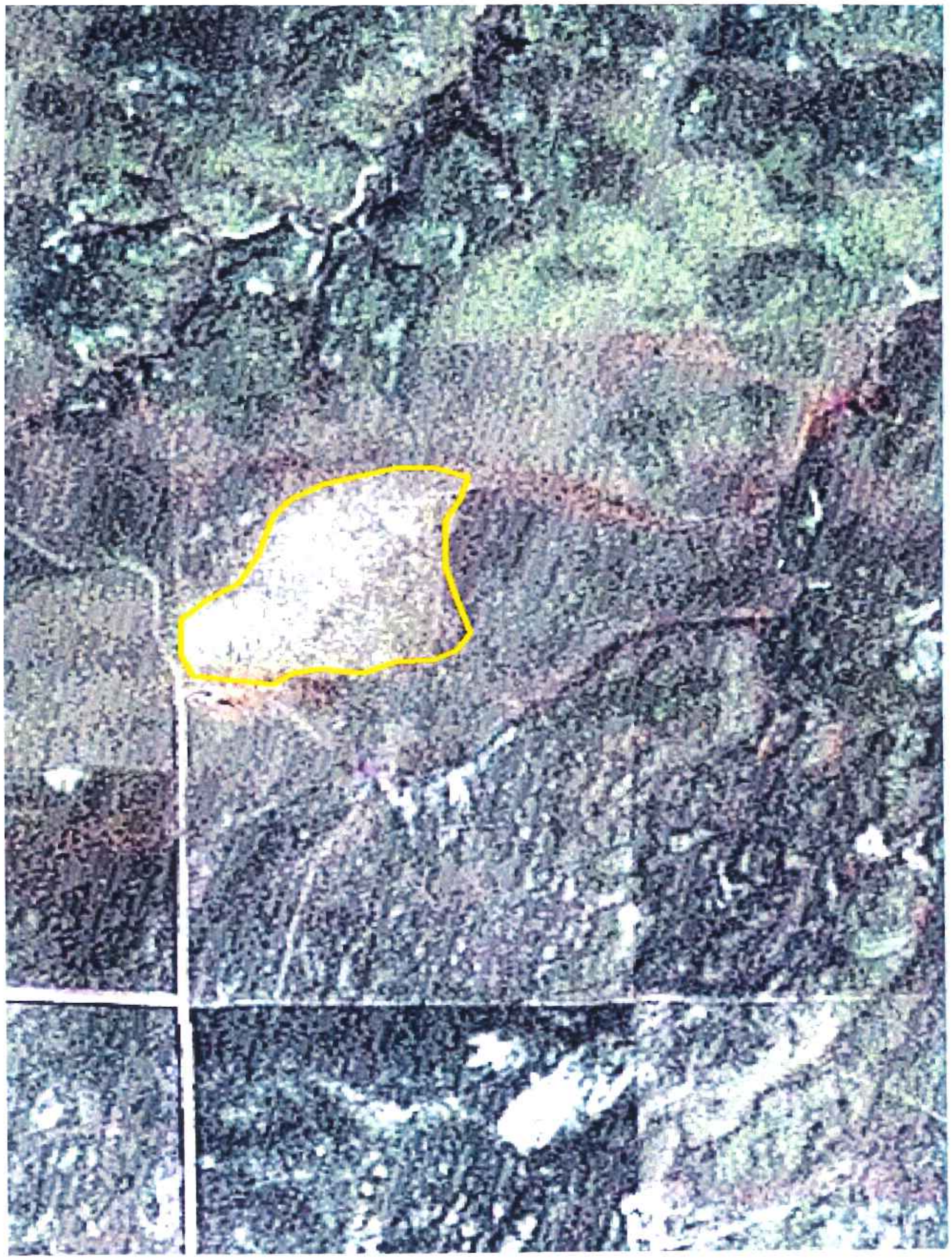
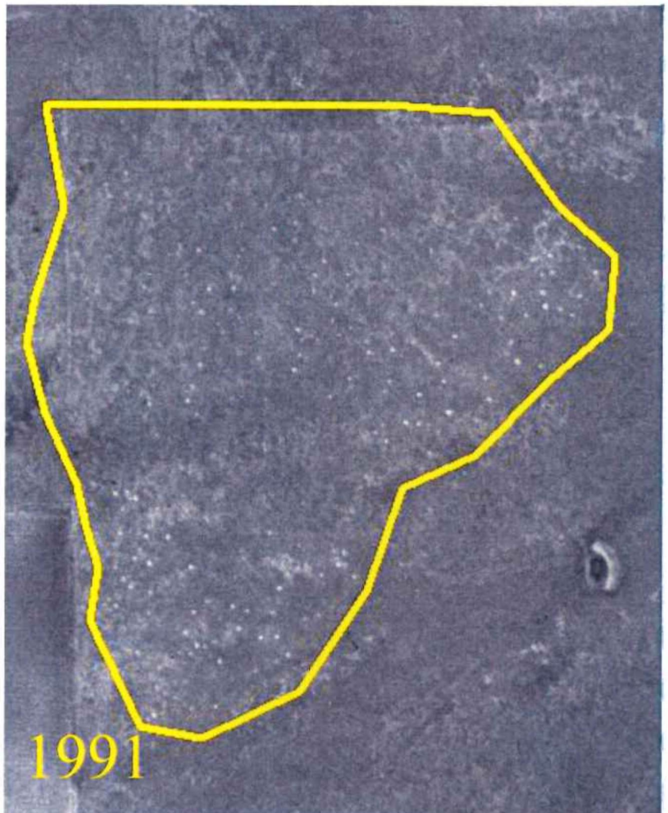


Figure 5. Two examples of false negative error in detection of prairie dog colonies from Landsat EMT images (5m resolution).

A. Colony missed from satellite image and aerial survey.

B. Colony missed from satellite imagery but not aerial transect.

Figure 6. Use of digital ortho-quarter quadrant (DOQQ) and satellite imagery to detect size change of a prairie dog colony over 8 years.



1991
DOQQ

Small light dots represent prairie dog mounds

1999
Landsat
EMT/IRS

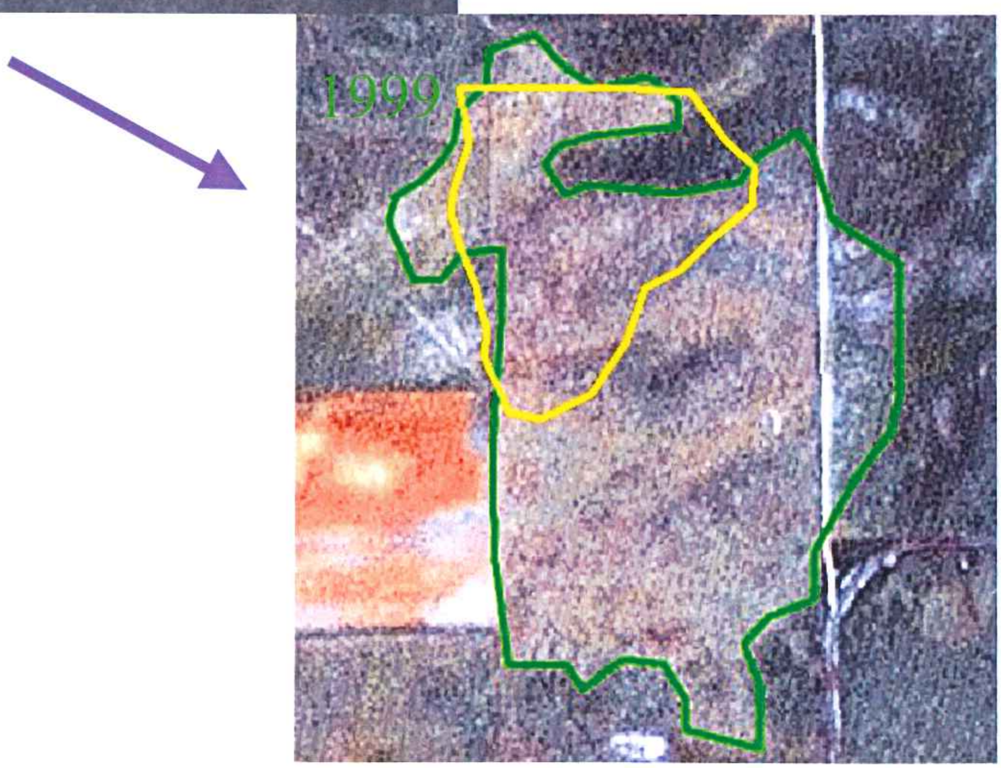


Figure 7. Prairie dog colony found in a 1991 DOQQ is not detectable in the 1999 satellite imagery.

Landsat EMT/IRS image