GREAT SAND DUNES
NATIONAL PARK AND PRESERVE
LAND AND VEGETATIVE COVER CLASSIFICATION

Prepared for:



Great Sand Dunes National Monument and Preserve
National Park Service
U.S. Department of the Interior

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INTRODUCTION

The Great Sand Dunes in the San Luis Valley of Colorado are a unique and invaluable ecological, recreational, and educational resource. The Great Sand Dunes are managed as a National Monument and Preserve by the National Park Service of the U.S. Department of the Interior. The current Monument size is about 37,100 acres. The Preserve area was added to the monument area with the passage of the Great Sand Dunes National Park and Preserve Act of 2000, and includes about 41,650 acres of the Sangre de Cristo range to the east of the park. A process is underway to transition the Monument to Park status through the acquisition of additional private lands to the west and north of the current monument. The future Park will include about 107,940 acres for a total of Park and Preserve area of about 149,590 acres.

It is important to document and understand the distribution of vegetation types and resources in the new Park and Preserve area. Current theories suggest a link between local water tables, vegetation distribution, and the stability of the dunes, and vegetation mapping may be important to monitor past and future changes in the distribution of vegetation on the dunes.

Multi-spectral satellite imagery has proven to be a valuable tool to classify land and vegetation types across large areas. Digital image processing techniques make large scale imagery classification relatively economical, while large scale mapping using field or photo identification is often cost prohibitive. In addition, the regular periodic image collection from satellites such as LandSat facilitates future monitoring and change analysis.

A vegetation mapping study was conducted for the National Monument area of the Great Sand Dunes by Colorado State University using LandSat satellite data in 1992 (Curdts et al. 1992). Imagery from June 23, 1990 was used, and a classified image was produced with 13 cover types. The National Park Service requested a similar satellite imagery based study to document the current land and vegetation distribution (summer 2003) and expand the mapping to the new Park and Preserve area. The current study classified 17 land and vegetation cover types across the area of the new Park and Preserve. LandSat satelllite imagery from June 27, 2003 was the primary data source. However, several other data sources were also used to supplement the satellite data and increase the detail and accuracy of the results. Results are available as a GIS vector coverage.

The limited budget that was available for the current study precluded extensive ground-truthing and accuracy assessment of the satellite classification information. However, the Park Service may be able to obtain higher-resolution aerial photography at a future time and improve the vegetation mapping in critical areas such as riparian corridors.

METHODOLOGY

Image Processing

The LandSat satellites have been used extensively to characterize large, land-scale areas for several decades, and current operation through the U.S. Geological Survey (USGS) has made the imagery quite cheap. The LandSat5 satellite was launched on March 1, 1984. Unfortunately, LandSat6 failed shortly after launch, and the LandSat7 satellite sensor failed in May 2003. However, although the LandSat5 satellite was not designed for its current lifespan and slight sensor degradations have occurred, the LandSat5 sensor is still providing good quality multi-spectral imagery.

The LandSat satellite provides multi-spectral imagery from its Thematic Mapper (TM) sensor. The TM sensor has 7 multi-spectral bands with an initial pixel resolution of about 30 meters by 30 meters (except for the thermal band with a 60m resolution). The following table details information about each of the 7 TM bands.

Table 1. LandSat Thematic Mapper Bands

Band	Color	Wavelength (nanometers)	Resolution (meters)
1	Blue	450- 515	30
2	Green	525-605	30
3	Red	630-690	30
4	Near Infrared	750-900	30
5	Mid Infrared	1550-1750	30
6	Thermal Infrared	10400-12500	60
7	Mid Infrared	2090-2350	30

The LandSat5 satellite repeats its orbit path every 16 days. A LandSat5 TM image from June 27, 2003 was purchased from the USGS for the current study. The month and day is close to the June 23, 1990 image used by the previous LandSat vegetative mapping study. The raw image included the entire Park and Preserve area and was relatively cloud free. One small cloud was located near the north side of the dunes, but as the cloud and shadow was located entirely over sand, the effect on the classification was minimal.

Processing was requested from the USGS to radiometrically correct the raw image and apply a geometric correction and projection into the Universal Transverse Mercator (UTM) coordinate system using nearest neighbor resampling. The nearest neighbor resampling retains real pixel reflectance values which maintains the integrity of spectral data and increases the accuracy of spectral classifications over other methods. However, lines and edges in the imagery do appear "blockier" and less sharp than imagery that has been resampled with a cubic convolution method. The USGS processing produced data with a new pixel size of 28.5m by 28.5m

Although the images are roughly referenced to the UTM coordinate system using sensor data, the ortho-rectification process used by the USGS does not use any ground control points and is not

sufficiently accurate for classification purposes. Therefore, the satellite images were re-georeferenced to 1m resolution black and white USGS digital orthophoto quarter-quad (DOQQ) from 1998. A total of 21 ground control points were used in the study area.

Images were corrected for haze and atmospheric scattering to make the images more comparable to other imagery. Haze correction values were determined by evaluating approximate black bodies (lakes and cloud shadows) in the entire image scene. The following haze correction values were applied to the imagery.

Table 2. Haze Correction Values

TM Band	Wavelength micrometers (μm)	Haze Correction
1	0.45-0.52	34
2	0.52-0.60	11
3	0.63-0.69	8
4	0.76-0.90	3
5	1.55-1.75	0
7	2.08-2.35	0

The entire satellite image scene covered a large area including the eastern portion of the San Luis Valley and a large portion of the eastern plains. Therefore, the image scene was reduced to a smaller area encompassing the Park and Preserve area for processing. The reduced image scene can be viewed in Figure 1. TM bands 1, 2, and 3 corresponding to the visible colors were used to create this composite, although the bands were stretched to brighten the image. The Park (to west) and Preserve (to east) boundaries are also noted on the figure with a yellow line.

True color representations are not highly useful for the evaluations of vegetation types. Reflected near infrared radiation (TM band 4) is much more sensitive to differences in vegetation than visible bands. A false color infrared (FCIR) image is often used to display imagery to highlight vegetation distribution. An FCIR composite image is produced by assigning TM bands 2, 3, and 4 to the colors green, blue, and red; respectively. Areas with higher amounts of live vegetative biomass are apparent with the color red. An FCIR composite of the image scene is presented in Figure 2 with the Park and Preserve boundaries.

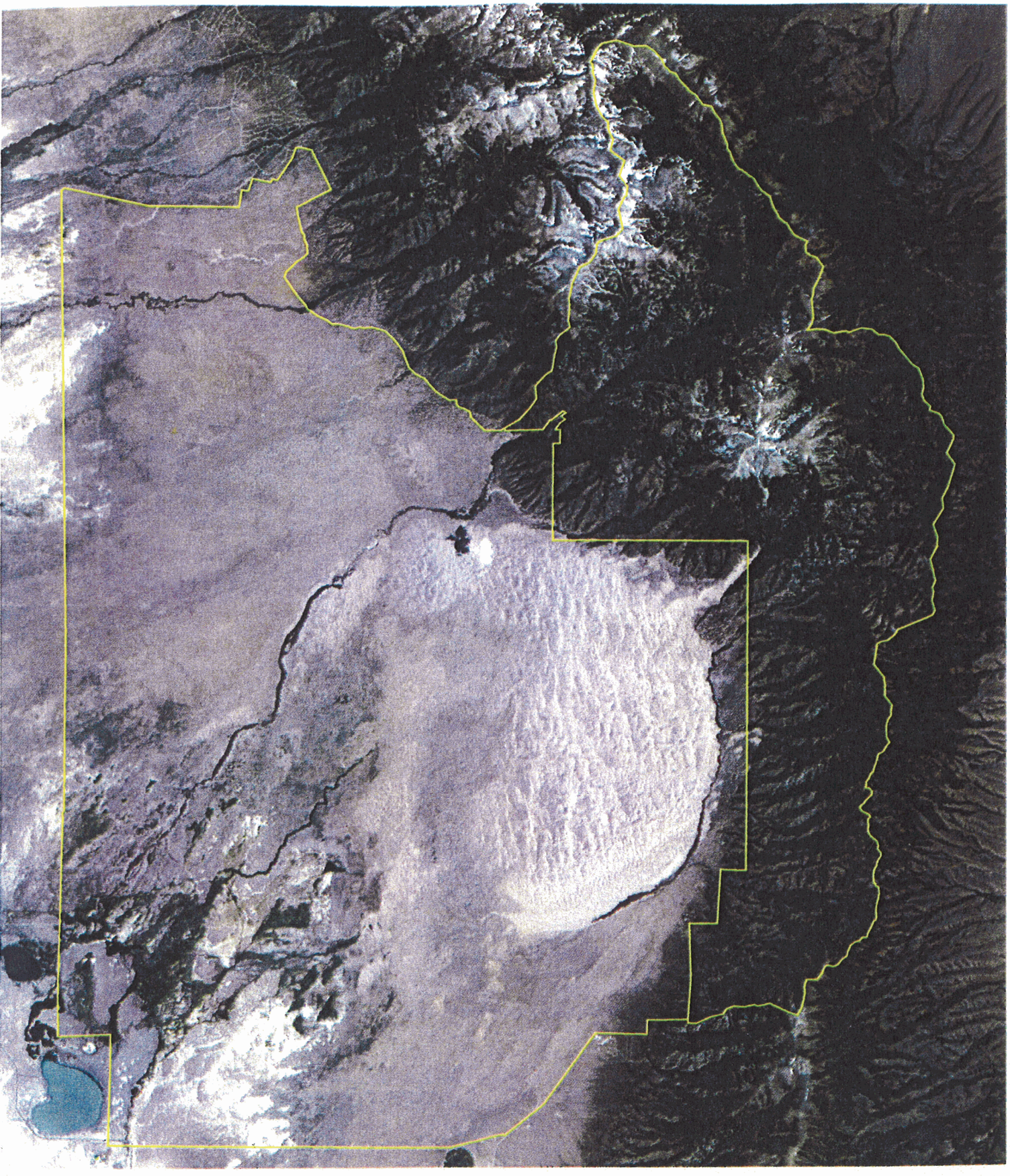


Figure 1. Satellite Image Scene - True Color

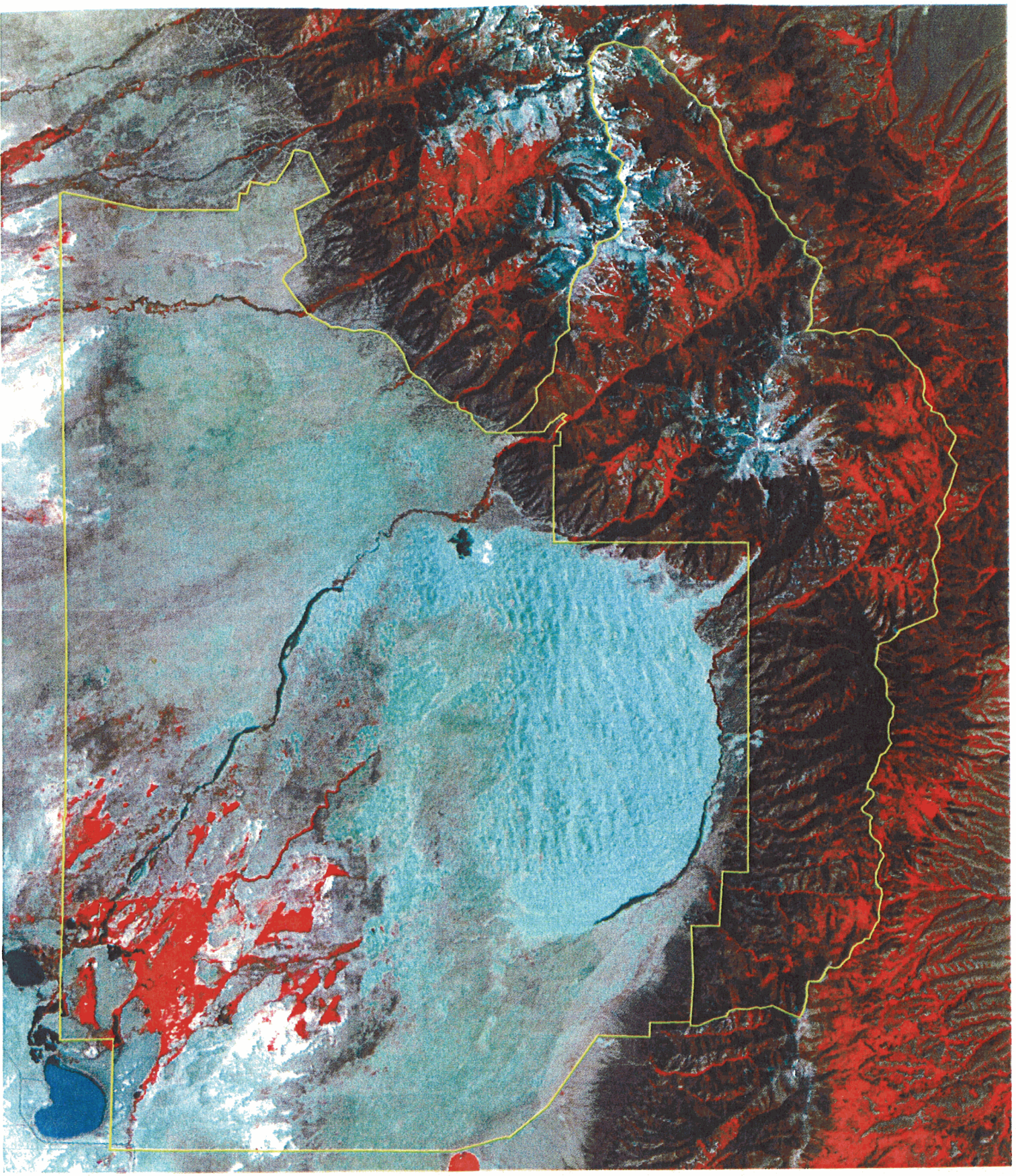


Figure 2. Satellite Image Scene - False Color Infrared

Unsupervised Classification

In an un-supervised classification, computer software is used to identify areas, or classes, that have similar spectral properties. The previous satellite study by CSU relied on an "un-supervised" classification. CSU examined 150 spectral classes in the field and on aerial photos and manually grouped them into 13 consistent cover types.

In the current study, several un-supervised classifications with varying numbers of different spectral classes were produced, and results were examined in the field. Unfortunately, the classification groups appeared as sensitive to changing soil types and moisture conditions as to different vegetation types. As the limited budget precluded ground-thruthing the spectral classes in the field, it was determined that an un-supervised classification would not be an effective tool for the current study. Supervised classifications were also examined, but the effectiveness also appeared limited by the dominance of soil types and moisture over vegetation differences.

Tasseled Cap Transformation

Imagery processing methods were examined that could isolate vegetative characteristics from soil brightness and soil moisture influences. The tasseled cap (TC) transformation is one technique that was developed for this purpose (Kauth and Thomas 1976, Crist and Cicone 1984). The TC transformation uses Principal Component Analysis (PCA) to transform 6 bands of TM imagery (band6 thermal is not used) that represent somewhat related reflectance characteristics to 3 different "orthogonal" images that represent independent cover characteristics. The 3 primary images produced have been called TC greenness, moistness, and brightness. Although 6 independent bands can be produced by the PCA, a study by the USGS showed that the greenness, moistness, and brightness bands represented over 97% of the spectral variation in the imagery (Huang et al. 2002). The TC greenness image is related to vegetation characteristics and vegetation biomass. TC greenness is similar to the Normalized Difference Vegetative Index (NDVI) that is calculated by a ratio of TM bands 3 and 4, but may be less influenced by moisture (that effects band 4) and soil brightness (that effects band 3).

Images of TC greenness, moistness, and brightness were produced using the TM image bands. Figures 3, 4, and 5 display stretched versions of the TC greenness, moistness, and brightness images. The Park and Preserve boundaries are also shown. For the TC greenness, moistness, and brightness images, the colors of green and dark represent denser and greener vegetation, more moist soil or vegetation, and brighter soil, respectively. Although the TC moistness image was not used classification purposes, the indication of areas of soil moisture in the dunes is interesting. The area of cloud and cloud shadow should be ignored in the images.

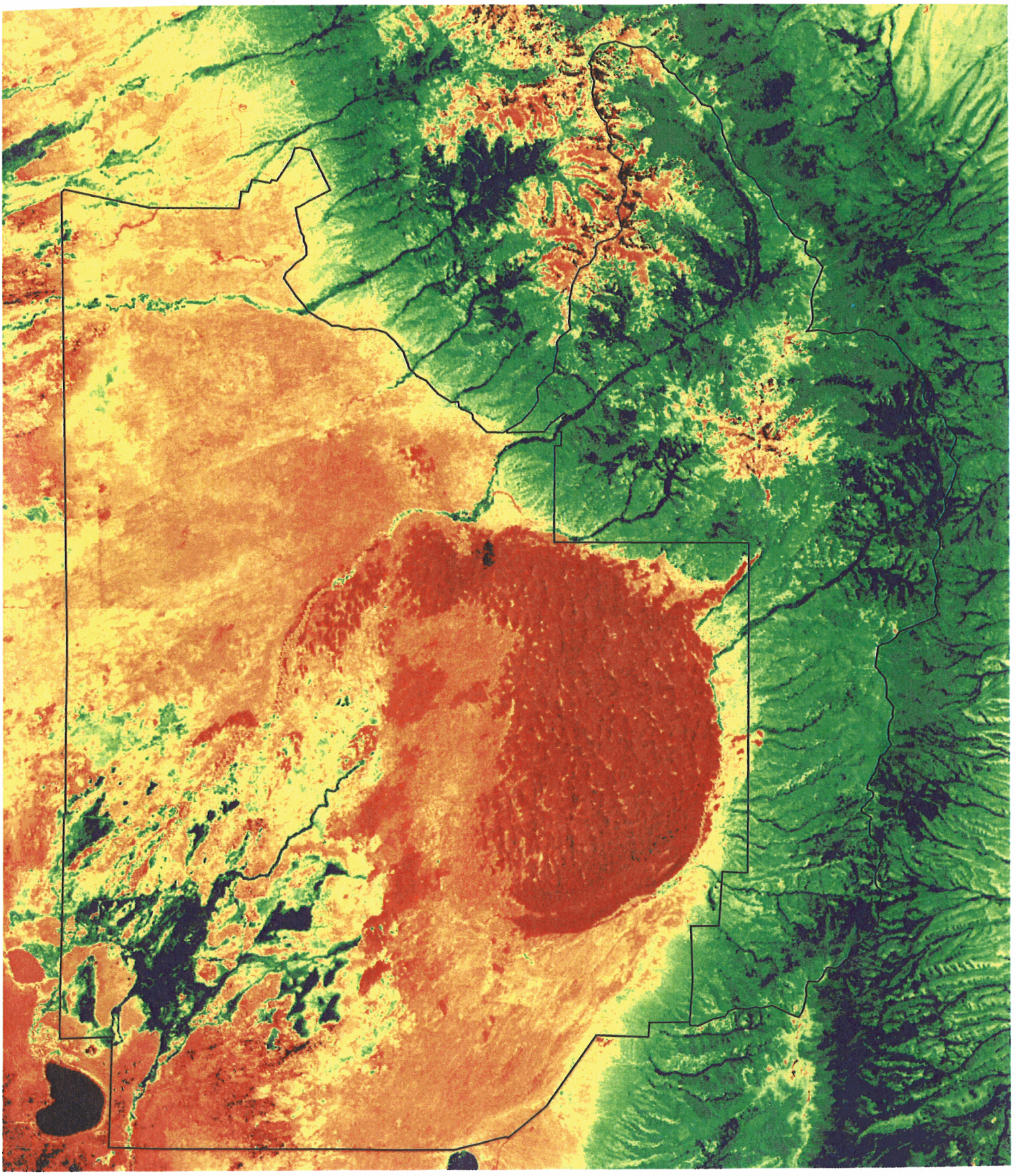


Figure 3. Tasseled Cap Greenness Image

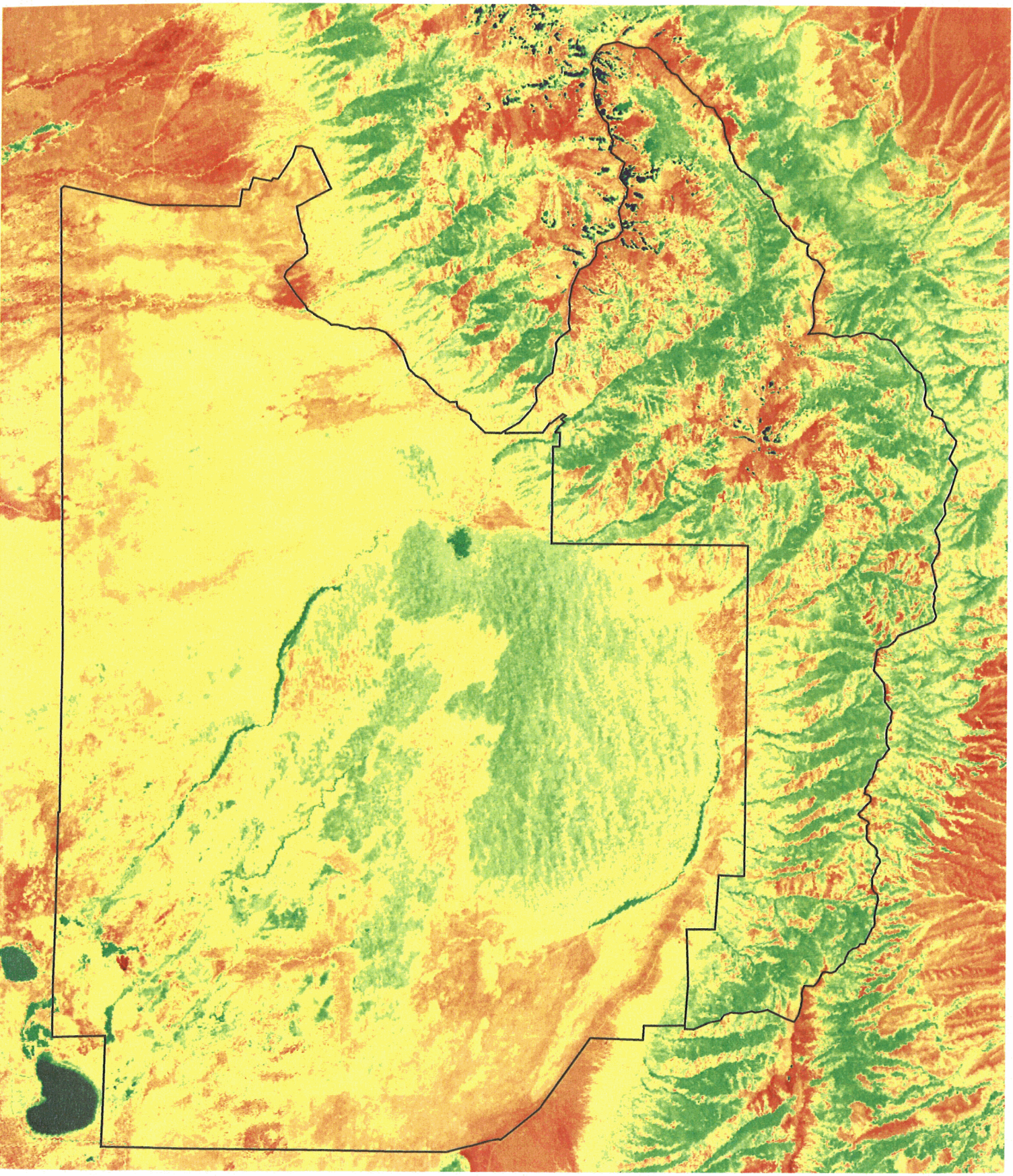


Figure 4. Tasseled Cap Moistness Image

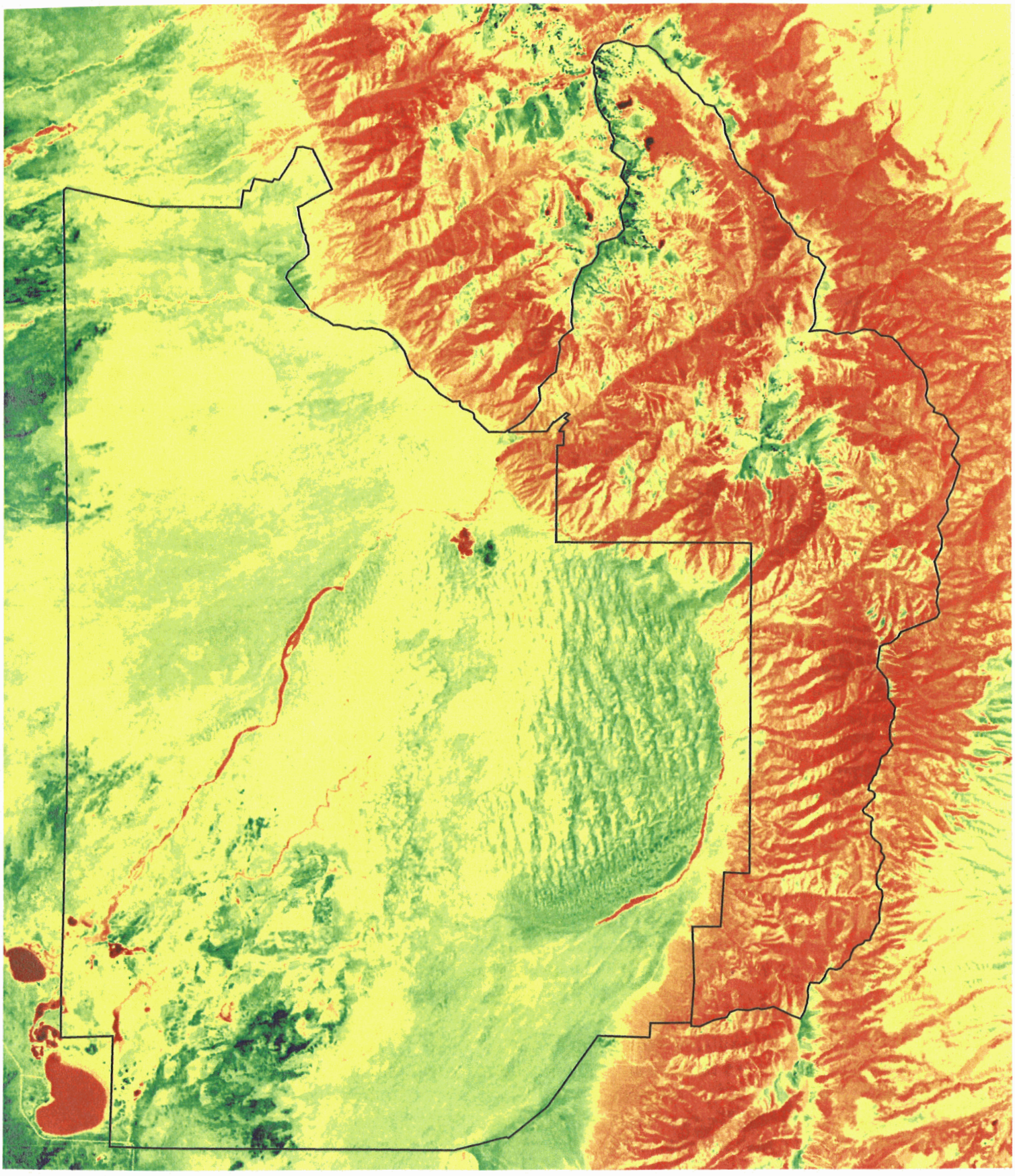


Figure 5. Tasseled Cap Brightness Image

Land and Vegetation Cover Classification

Several different types of data were used to classify land and vegetation cover types. Limited field visits indicated that the TC greenness image accurately distinguished levels of vegetation density and "greenness". Vegetation descriptions based on density and greenness appeared appropriate for non-treed areas. Therefore, the TC greenness image was the primary data source used for classification in non-treed areas, although the TC brightness image and the near-infrared TM band 4 were also used. However, greenness or density levels were not the only characteristics necessary to distinguish different tree species. A combination of the TC greenness image, the 1m resolution 1998 USGS DOQQ imagery, and GIS data on tree-species from the U.S. Forest Service was employed in the classification of treed areas. The following sections discuss individual cover types that were identified in more detail.



Bare Sand



Alkali Overflow Flats

Field investigation indicated that the areas with the lowest values of TC greenness were either bare sand or alkali overflow flats. Bare sand can be considered sand areas that are generally free of significant live vegetation. Alkali overflow flats are areas of highly alkaline soils that may be a result of past water inundation. Some alkaline areas had significant amounts of dry grasses and may have once been irrigated, but were probably un-irrigated in the summer of 2003. Areas of alkali are quite apparent on the TC brightness image as the white crust is very reflective. Therefore, areas with low TC greenness and very high TC brightness were classified as alkali overflow flats, while the other areas with low TC greenness but more moderate TC brightness were defined as bare sand. The small cloud and cloud shadow that were located over the dunes in the satellite image were reclassified as bare sand.

The classification did identify many "pockets" of vegetation on the sand dunes themselves. However, it was noticed that some smaller areas of particularly sparse and dry vegetation on the sand dunes themselves were not classified as vegetation. Over the 30m by 30m areas observed by the satellite, the spectral response in these areas is influenced primarily by the larger area of sand rather than small amounts of dry vegetation. However, this sparse vegetation may be important to the stability of the dunes, and it may be worthwhile to use aerial photography to investigate and map this vegetation.




Lower Density Grass and Shrubs




Higher Density Grass and Shrubs

As the Landsat TM sensor averages the reflectance of 30m by 30m areas, it is difficult to identify individual vegetation species where vegetation communities are mixed (i.e. shrubs and grasses). However, as mentioned earlier, the TC greenness image accurately distinguished levels of vegetation density. Therefore, intermediate TC greenness values (above bare sand but below wet meadows) were divided into lower density and higher density shrubs and grasses. Generally, areas with lower density classification have small uncovered areas of sand while higher density areas have nearly 100% vegetative cover. Often, the lower density vegetation was dominated by chico or rabbit brush with sparser grasses, while the higher density classification was more dominated by grasses or greener shrubs.



Wet Meadow

The highest TC greenness values corresponded to wet meadow areas or trees. Wet meadow areas contained dense green areas of vegetation at the time of the satellite image (the picture at left was taken in late October). Typically, wet meadow vegetation consists of dense grass that is supported by a water source. Some areas of wet meadow may include wetland type vegetative communities.

Wet Meadow areas were divided into irrigated and un-irrigated wet meadow using ditch service areas that were previously developed for The Nature Conservancy on the Medano-Zapata and Baca ranches. The area of irrigated wet meadow that was classified is representative of year 2003; the area may change yearly as a function of stream flow in Little and Big Spring Creeks and Sand Creek. Un-irrigated meadow areas may be more constant from year to year as they are primarily related to ground-water seeps or springs, and may support important ecological communities. Big Spring Creek was classified as un-irrigated wet meadow as dense vegetation in its bed dominated the spectral signature over water that may have been present.

Lakes and Standing Water and Wet Stream Beds

Near-infrared radiation is strongly absorbed by water and soil moisture but reflected by green vegetation. The TC moistness image also indicates water, but does not effectively separate standing water from moist vegetation or soil. Therefore, TM band 4 was used to identify areas of water, and these areas were overlain on the classification image.

The lowest levels of reflected near-infrared radiation corresponded to lakes and standing water that effectively inundated any green-vegetation that may have been present. Dollar Lakes, Cotton Lake, and several alpine lakes were identified, as well as several inundated areas that may be related to the irrigation of meadows. Portions of Medano and Sand Creek had levels of reflected near-infrared radiation slightly higher than that of the standing water and were classified as wet stream bed. These creeks have sand bed channels that are generally free of vegetation. The delineation of Medano Creek is representative of the June 27, 2003 image date as the extents of the ephemeral creek change based on runoff and local groundwater levels. Flowing streams are also present in the mountain areas of the Preserve. However, dense tree cover dominated the spectral signature of these areas so that water was not identified separately.



Treed Areas

The TC greenness imagery did distinguish treed and non-treed areas, and did differentiate between aspen and coniferous trees. However, the TC images did not appear to be able to distinguish different coniferous tree species. Therefore, a methodology was used that combined imagery and U.S. Forest Service tree survey data for the classification of the mountain areas of the Park and Preserve. Tree survey data in GIS format was obtained from the GIS coordinator at the Rio Grande National Forest in Monte Vista. The data for the Preserve area were collected by

the Forest Service primarily in 1998 and 1999. The Forest Service data detailed up to three primary tree species for uniform areas.

The classification methodology was as follows. The TC greenness image and higher resolution DOQQ imagery were used to delineate open areas that were nearly free of any trees and typify the cover of these open areas. These open areas were classified as alpine tundra / talus, rocky or nearly bare slopes, and mountain shrubs and grasses. In the remaining treed areas, the tree with the highest cover percentage in the U.S. Forest Service tree survey data was assigned to uniform vectors. Similar tree species were then combined into more generalized classifications. The following table details the classifications that were used and the corresponding tree species.

Table 3. Tree Species and Classifications

Classification	Tree Species
Pinyon / Juniper	Rocky Mountain Juniper, Twoneedle Pinyon
Spruce / Fir	Engelmann's Spruce, Subalpine Fir, Douglas Fir, Blue Spruce, Corkbark Fir
Bristlecone / Limber Pine	Bristlecone Pine, Limber Pine
Ponderosa Pine	Ponderosa Pine
Aspen	Quaking Aspen
Cottonwood / Willow	Narrowleaf Cottonwood, Diamondleaf Willow

Finally, the TC greenness image and DOQQ imagery were used to adjust the boundaries of aspen areas and boundaries with open areas. This imagery was also used to classify areas in the foothills and in the Park area that were not included in the Forest Service data.

The classifications in the non-treed areas were determined using satellite imagery in a raster environment. Although general vegetative patterns were obvious, many un-grouped pixels were present as is typical. Many of the odd pixels represented the spectral transition between cover types (i.e. lower density to higher density grasses and shrubs). Therefore, a filter that assigned the median value of a 3 x 3 pixel window was applied to smooth the classification data. The filtered classification image was converted to vectors for use in a GIS environment. The non-treed classification vectors were cut by the treed area classification vectors. Oddly cut vectors between the treed and non-treed areas were manually adjusted.

RESULTS

The land and vegetation cover classification is presented in Figure 6. The following table details the acreage of each classified cover type in the Park and Preserve areas.

Table 4. Classified Area of Land and Vegetative Cover Types

CLASS	PARK (acres)	PRESERVE (acres)	TOTAL (acres)
Bare Sand	18669	7	18677
Alkali Overflow Flats	1550	0	1550
Lower Density Grass and Shrubs	46207	38	46244
Higher Density Grass and Shrubs	29218	74	29292
Alpine Tundra / Talus	0	6016	6016
Rocky or Nearly Bare Slopes	1	903	904
Mountain Shrubs and Grasses	14	1962	1976
Trees - Aspen	98	8415	8512
Trees - Bristlecone Pine / Limber Pine	10	1061	1072
Trees - Cottonwood / Willow	974	89	1063
Trees - Pinyon / Juniper	3481	3729	7209
Trees - Ponderosa Pine	1218	224	1441
Trees - Spruce / Fir	633	18855	19488
Water - Lake or Standing	138	68	207
Water - Wet Stream Bed	467	0	467
Wet Meadow - Irrigated	4940	0	4940
Wet Meadow - Unirrigated	322	212	533
TOTAL	107940	41653	149593

Classification data are available as ArcView GIS shapefiles. As mentioned earlier, the Park Service may be able to obtain higher-resolution aerial photography at a future time. The GIS classification vectors can easily be modified and the resolution of vegetation mapping in critical areas such as riparian corridors could be improved.

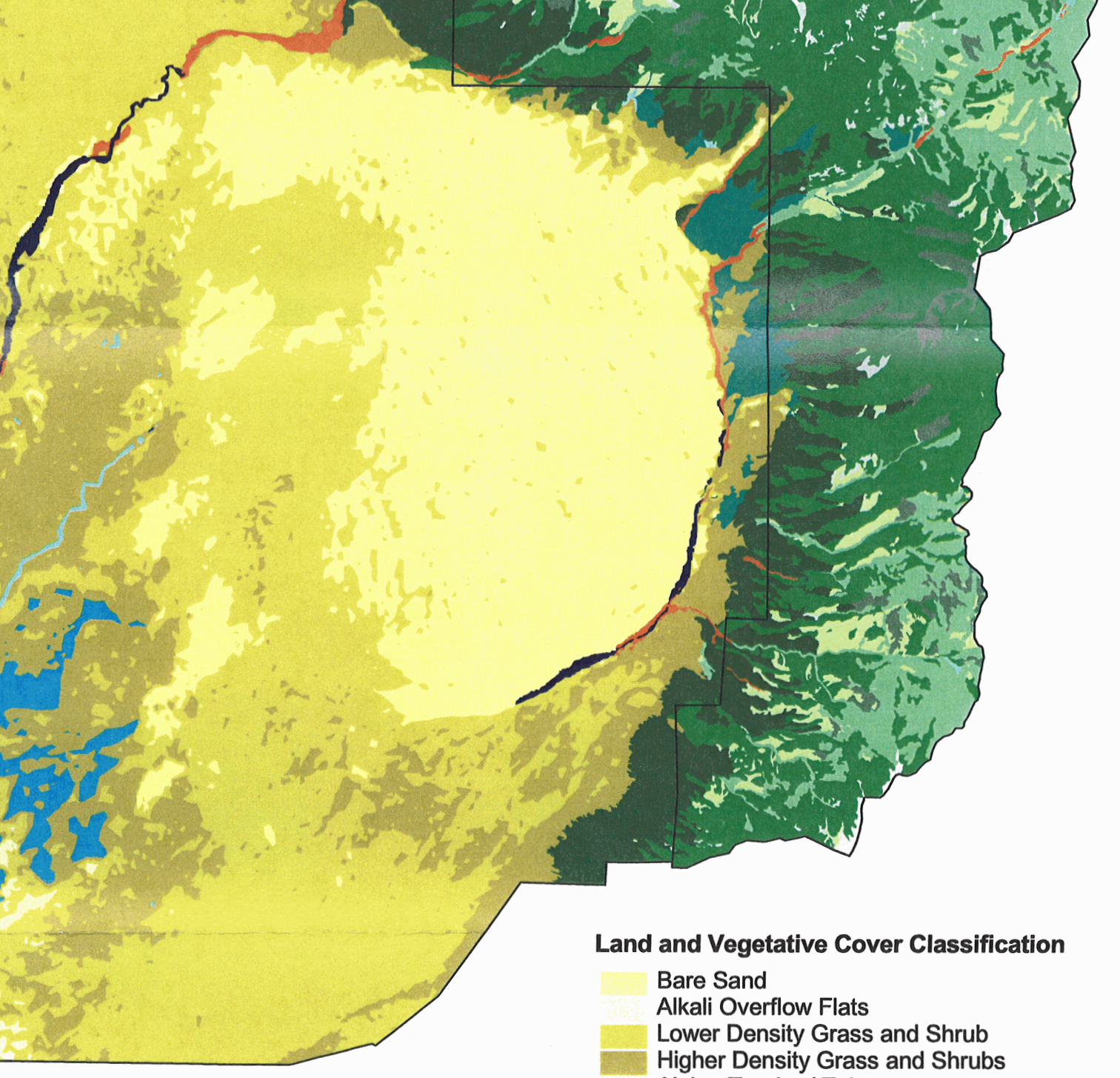


Figure 6.
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nd Vegetative Cover Classification