VEGETATIVE CHANGES WITHIN AREAS OF CRITICAL ENVIRONMENTAL CONCERN IN TAOS AND RIO ARRIBA COUNTIES OF NORTHERN NEW MEXICO 2000 - 2020

By

TALA

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Thanks to my family and friends for their patience, understanding, compassion, and support. Thanks to David and my father for supporting me from behind the scenes. I thank all my professors and advisors for their commitment and dedication to helping me navigate the challenges of college life. A special thanks to my dogs for reminding me to get out from behind the computer screen as much as possible.

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LIST OF ABBREVIATIONS

BLM	Bureau of Land Management – Established in 1946 To sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations.
ACEC	Area of Critical Environmental Concern - Areas of Critical Environmental Concern or ACEC designations highlight areas where special management attention is needed to protect important historical, cultural, and scenic values, or fish and wildlife or other natural resources. ACECs can also be designated to protect human life and safety from natural hazards.
FLPMA	The Federal Land Policy Management Act of 1976 – Enacted to establish public land policy; to establish guidelines for its administration; to provide for the management, protection, development, and enhancement of the public lands; and for other purposes.
RGDN	Rio Grande del Norte National Monument - The Rio Grande del Norte National Monument is an approximately 242,555-acre area of public lands in Taos County, New Mexico, proclaimed as a national monument on March 25, 2013, by President Barack Obama under the provisions of the Antiquities Act.
NDVI	Normalized Difference Vegetation Index - The NDVI is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to estimate the density of green on an area of land.
NM RGIS	New Mexico Resource Geographic Information System - Earth Data Analysis Center at The University of New Mexico develops, manages, and enhances the New Mexico Resource Geographic Information System (RGIS) Program and Clearinghouse. Nationally, NM RGIS is among the largest of state-based programs for digital geospatial data and information and continues to add to its data offerings, services, and technology.
NRCS	Natural Resources Conservation Service – Provides America's farmers and ranchers with financial and technical assistance to voluntarily put conservation on the ground, not only helping the environment but agricultural operations, also.
USGS	United States Geological Survey - A scientific agency of the United States government. The scientists of the USGS study the landscape

	of the United States, its natural resources, and the natural hazards that threaten it.
NIR	Near-Infrared light is the section of electromagnetic radiation wavelengths nearest to the normal range but just past what we can see.
GIS	A computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. By relating seemingly unrelated data, GIS can help individuals and organizations better understand spatial patterns and relationships.
HIPAA	A federal law that required the creation of national standards to protect sensitive patient health information from being disclosed without the patient's consent or knowledge.

ABSTRACT

Climate change will likely lead to major changes in plant distribution and thus in biomes and habitats. Humans and other species will be affected as our ecology is intimately linked not only to climate but also to habitat availability. This study looks at the vegetative changes within the Bureau of Land Management's Areas of Critical Environmental Concern designated areas. These areas are in Rio Arriba County and Taos County in New Mexico and the study is from 2000 and 2020 to determine if the Bureau of Land Management's protective measures have helped mitigate drought effects within the region. The study area includes the Areas of Critical Environmental Concern designated areas of Lower Gorge, Copper Hill, Ojo Caliente, and the Taos Plateau, which cover approximately 327,040 acres within the two study counties. Using surface reflectance and Normalized Difference Vegetation Index analysis, datasets are compared for changes in vegetation health over 5-year increments – 2000, 2005, 2010, 2015, and 2020. Datasets are also compared between 2000 and 2020. Although precipitation levels fluctuate over the temporal extents and vegetation changes accordingly, overall, there has been a decline in vegetive cover over the entire study area. These vegetation changes are most drastic within the Ojo Caliente and Lower Gorge/Copper Hill Areas of Critical Environmental Concern. More research is needed to determine whether the Bureau of Land Management's protective measures, or lack thereof, have contributed to the decline in vegetation, or if it has to do with the overall effects of long-term drought and climate change.

Keywords: Vegetative changes, Areas of Critical Environmental Concern, northern New Mexico, Bureau of Land Management, climate change

ETHICS STATEMENT

As mapping technologies become more prevalent and relied upon, ethics in Geographic Information Systems (GIS) become more necessary. Much of the geospatial data being used and stored contains personal data on individuals. Practitioners using this data must be aware of the issues surrounding the use of personal data as well as any ethical concerns regarding such use and storage. According to Amy J. Blatt, “Among the many ethical issues that surround the use of geospatial technologies are standards of ethical practice, data accuracy and validation, information liability, copyright, quality assurance and duty of care, licensing, disclaimers, metadata, and intent of use” (Blatt 2012). These issues become increasingly important as GIST becomes used more widely and validating the accuracy of data is critical. This is especially important when dealing with public and protected health information and public cadastral information, such as household taxes and property assessments (Blatt 2012).

For example, if a GIS analyst is obtaining and using a person’s protected health information, such as medical records, they must be careful to comply with the 1996 Health Insurance Portability and Accountability Act’s (HIPAA) privacy and security rules. With the increasing use of electronic transmission of information and social media, users must ensure that anything pertaining to protected health information is encrypted and being used securely. Breaches of HIPAA are a serious concern, and each incident must be recorded and reported (Blatt 2012). While there are no legal parameters around using and transmitting a person’s private cadastral information, it is thought that the analyst should obtain permission from the individual to use their information from an ethical perspective (Blatt 2012).

These are a few concerns regarding GIS and personal spatial data, which has brought about the need for a code of ethics for the GIS community and professionals. According to the GIS Certification Institute, “This code is based on the ethical principle of always treating others with respect and never merely as means to an end” (GISCI 2022). This requires us to look at our actions in regard to others and to modify our behavior accordingly, based on respect and concern for our fellows. Most professional codes of ethics are based on similar morality structures and tend to be similar in word and intent. However, GIS profession guidelines include encouragement to make findings widely available, to be involved in data security, to document data, to respect copyright and intellectual property rights, and to have concern for personal data discovered through geospatial or database manipulations (GISCI 2022). The basic tenants of the GIS Code of Ethics are:

- Obligations to Society
- Obligations to Employers and Funders
- Obligations to Colleagues and the Profession
- Obligations to Individuals in Society

While I’m not aware of ethical concerns specific to this paper, I have documented all my data sources and included metadata for all spatial datasets. I have been aware of any copyrighted materials and intellectual property rights and have given credit to all contributors of this project.

CHAPTER 1
INTRODUCTION

Bureau of Land Management (BLM) Field Offices prepare land use plans for public lands within their designated boundaries. Development of land use plans require BLM managers to work closely with local, state, and tribal governments, as well as the public and other stakeholders to identify uses of public lands and any protection measures needed for each specific area. Areas of Critical Environmental Concern (ACEC) designations are areas where special attention is necessary to protect historical, cultural, and scenic values, along with fish, wildlife, and natural resources. The activities allowed within ACEC designated areas are dependent upon the resources and natural value of the area (US Department of the Interior 2020).

While the BLM was a partner in the initial establishment of strict regulations of ACEC lands in accordance with The Federal Land Policy Management Act of 1976, they have not enforced those regulations, which has left the areas open to land degradation due to climate changes, human impact, and other detrimental forces (Sheldon and Baldwin 2017). Many ACEC designations have high concentrations of oil and gas resources and development within these areas has gone unchecked. Livestock grazing is destroying precious riparian areas and threatening protected species, private lands are encroaching on ACEC areas and fragmenting viable habitats, and water quality in many of these protected areas is compromised. The BLM has done little to monitor the conditions with ACEC designated areas and has left them vulnerable (Oliva, Matison and Horning 2004).

The areas in this study include the Rio Grande del Norte National Monument (RGDN), which covers the Taos Plateau study area. The RGDN was created in 2013 to “preserve its cultural, prehistoric, and historic legacy and maintain its diverse array of natural and scientific resources, and the protection of cultural resources, geologic resources, wildlife, and ecological diversity” (Department of the Interior 2019). Prominent landscape features include undulating plains, volcanic cones, remnant basalt flows, playas, and a rift gorge. The area is composed of sagebrush, pinon-juniper scrub, and pine forest. Though this area has been used consistently for livestock grazing for over 150 years, long-term data describing grazing intensity and the spatial distribution of grazing, as well as the effects long-term grazing, are lacking (Heller 2020).

The Lower Gorge and Copper Hill study areas include the lower portion of the Rio Grande basin, just south of the Taos Plateau and the Ojo Caliente study area includes the Rio Ojo Caliente and Rio Chama to the west. There is much less information available on the Copper Hill, Lower Gorge, and Ojo Caliente ACEC areas, which is concerning. However, the BLM has withdrawn 291 acres from public lands within the Ojo Caliente site in order to protect four large Tewa Indian pueblo ruins dating from 1350-1550 AD. Three of the pueblos are listed on the National Register of Historic Places and the fourth is eligible for nomination (US Government Publishing Office 1995). They have also elected to increase protection of riparian areas, vegetation, soils, water quality, wildlife habitat, and scenic quality, while placing limits on recreational uses in the corridor and restricting vehicle access to some areas within the Lower Gorge and Copper Hill ACEC areas (US Government Publishing Office 1998).

This study looks at the vegetative changes within the Bureau of Land Management’s ACEC designated areas from 2000 and 2020 to determine if the Bureau of Land Management’s protective measures have helped mitigate drought effects within the region. The study area covers approximately 327,040 acres within Taos and Rio Arriba counties. Using surface reflectance and Normalized Difference Vegetation Index (NDVI) analysis, datasets are compared for changes in vegetation health over 5-year increments – 2000, 2005, 2010, 2015, and 2020. Precipitation over the temporal extent is taken into consideration when determining land use and vegetative changes.

CHAPTER 2
METHODS & DATA

Data was downloaded from EarthExplorer (US Geological Survey 2022), EarthData (National Aeronautics and Space Administration 2022), NM RGIS (University of New Mexico 2022), USGS (US Department of the Interior 2022), and other online sources, combined, organized, and cleaned. Vector and raster data was formatted to fit the study areas using ArcGIS Pro. This included clipping and creating any necessary layers. The data was then analyzed using NDVI and surface reflectance techniques and the results were compared over 5-year increments from 2000 to 2020 (Figure 2-1). Raster data was analyzed using the colorized NDVI raster function in the ArcGIS Pro software, which produced a final raster for each dataset. These rasters were then compared to find the difference in vegetation between 2000 and 2020. Precipitation data was also analyzed to determine its possible effects on the data within each dataset and timeframe.

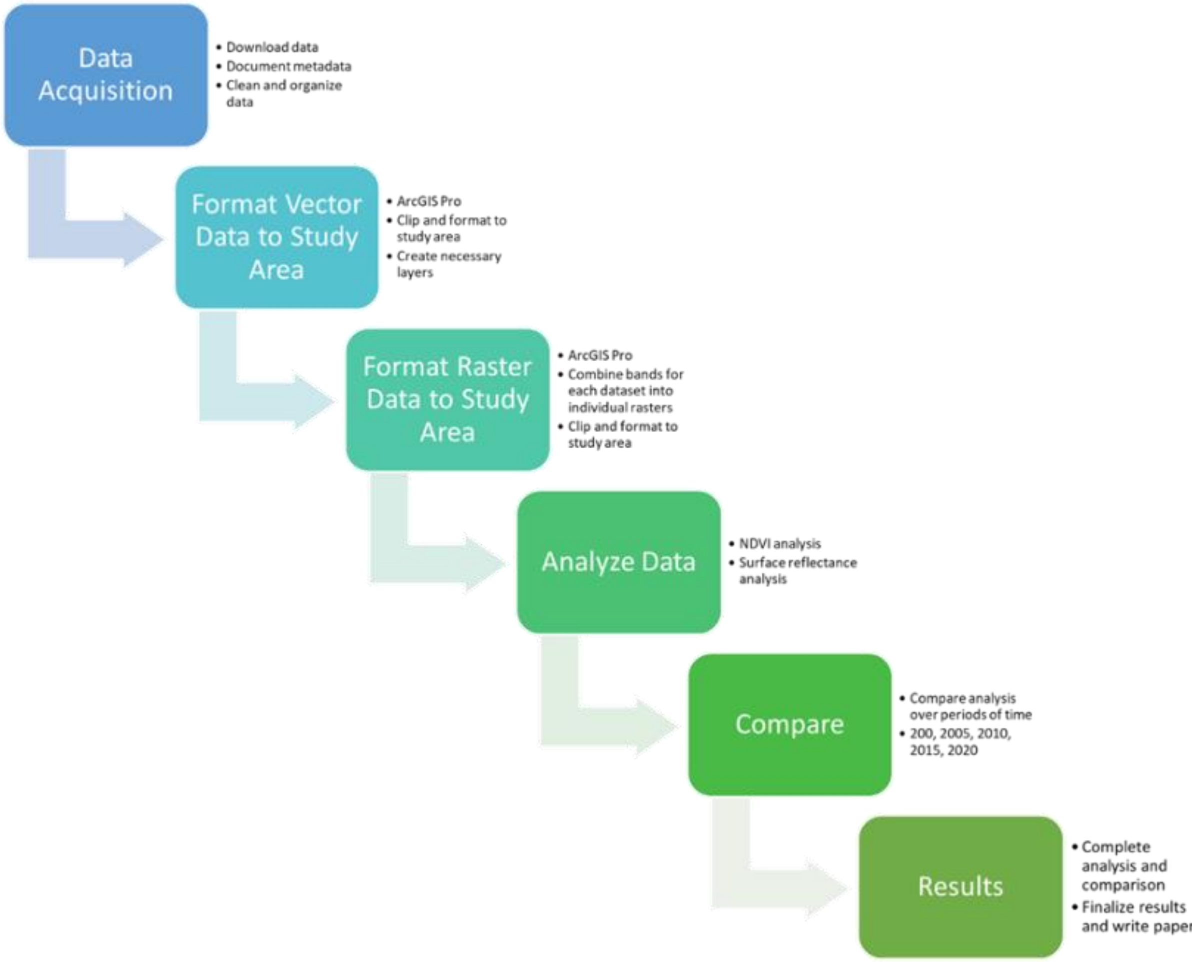

Figure 2-1. General Workflow Chart

Table 2-1. NM RGIS Metadata – Rio Arriba County

Name	Rio Arriba County Landsat Mosaic, 2014
Year	2019
Author/Owner	Earth Data Analysis Center
URL	https://rgis.unm.edu/rgis6/
Description	Twenty-five cloudless Landsat Operational Land Imager (OLI) images were acquired over New Mexico in order to create this Landsat image mosaic which covers the entire state. The images were acquired from eight separate dates along five orbital paths ranging from between May to July of 2014. The imagery has a 30-meter spatial resolution and is best viewed at 1:80,000 scale or smaller. The imagery includes 7 bands (layers) of spectral reflectance information ranging from the visible blue to the mid-infrared wavelengths. A display of Bands 4, 3, and 2 in red, green, and blue provides a natural color display. A display of Bands 5, 4, and 3 in red, green, and blue provides a color-infrared display where healthy vegetation appears red. A display of Bands 7, 5, and 1 in red, green and blue creates a display that

	enhances geologic features in reds and blues and healthy vegetation in green.
Coordinate System	D WGS 1984, UTM 35, EPSG code 4326
Projection System	WGS 1984 UTM Zone 13N
Spatial Resolution	30 meters

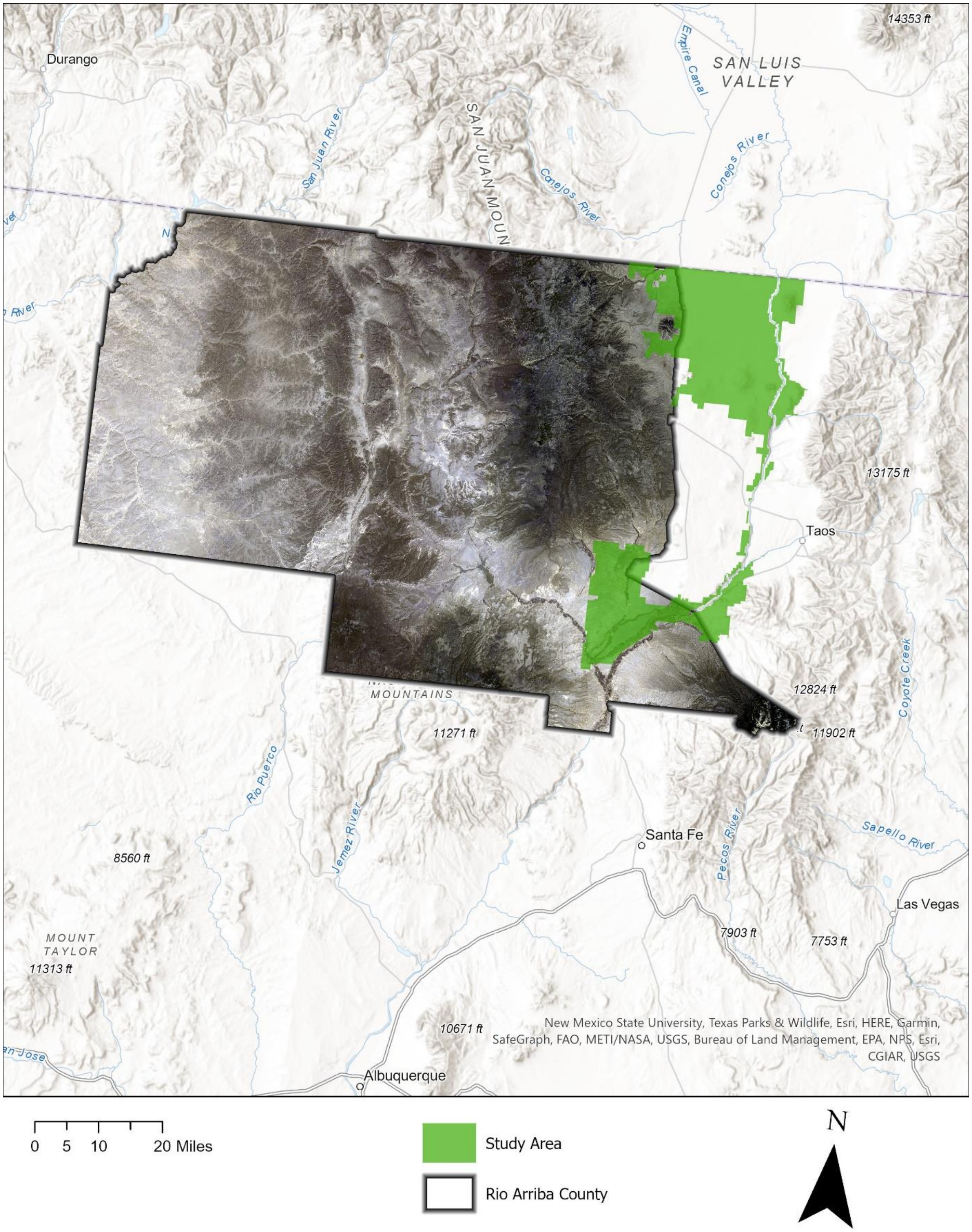

Figure 2-2. NM RGIS Metadata Rio Arriba County

The Rio Arriba County raster (Figure 2-1. General Workflow Chart

Table 2-1, Figure 2-2) and the Taos County raster (Table 2-2, Figure 2-3) were used to create polygons for each county. The county polygons were then used to clip the ACEC dataset (Table 2-3, Figure 2-4) to make a single polygon within the two counties. This was then used to define the study area. The ACEC polygon was also split into the four designated areas within the study area – Taos Plateau, Lower Gorge, Copper Hill, and Ojo Caliente (Figure 2-5). This was done by making individual layers using selected attributes for each of the four areas within each county. The two county layers were then merged for each of the four areas.

Table 2-2. NM RGIS Metadata – Taos County

Name	Taos County Landsat Mosaic, 2014
Year	2019
Author/Owner	Earth Data Analysis Center
URL	https://rgis.unm.edu/rgis6/
Description	Twenty-five cloudless Landsat Operational Land Imager (OLI) images were acquired over New Mexico in order to create this Landsat image mosaic which covers the entire state. The images were acquired from eight separate dates along five orbital paths ranging from between May to July of 2014. The imagery has a 30-meter spatial resolution and is best viewed at 1:80,000 scale or smaller. The imagery includes 7 bands (layers) of spectral reflectance information ranging from the visible blue to the mid-infrared wavelengths. A display of Bands 4, 3, and 2 in red, green, and blue provides a natural color display. A display of Bands 5, 4, and 3 in red, green, and blue provides a color-infrared display where healthy vegetation appears red. A display of Bands 7, 5, and 1 in red, green and blue creates a display that enhances geologic features in reds and blues and healthy vegetation in green.
Coordinate System	D WGS 1984, UTM 35, EPSG code 4326
Projection System	WGS 1984 UTM Zone 13N
Spatial Resolution	30 meters

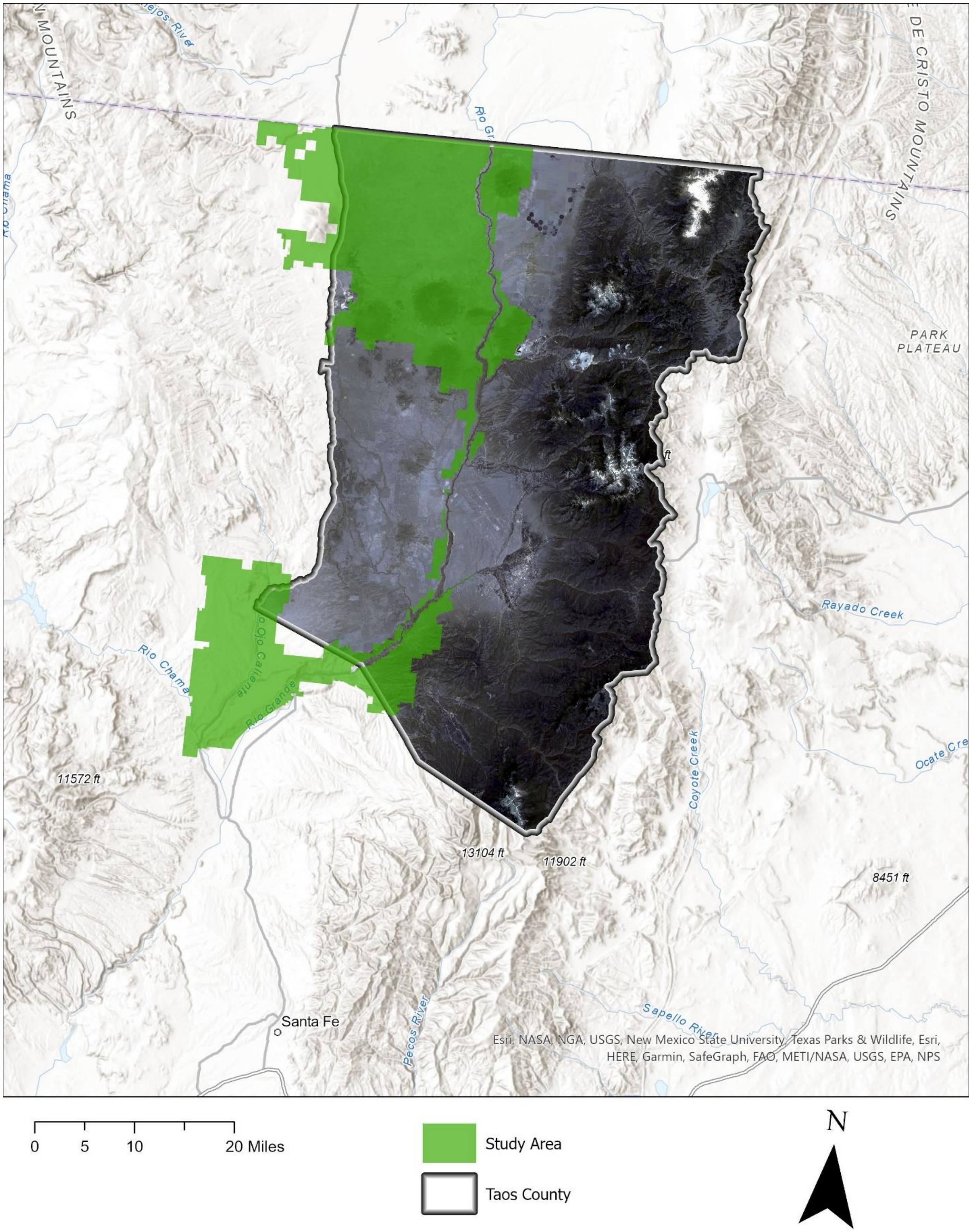

Figure 2-3. NM RGIS Metadata Taos County

Table 2-3. NM RGIS Metadata. BLM ACEC

Name	BLM Areas of Critical Concern 2019
Year	2020
Author/Owner	U.S. Department of Interior, Bureau of Land Management (BLM)
URL	https://rgis.unm.edu/rgis6/
Description	This polygon feature class shows the spatial extent and boundaries of Areas of Critical Environmental Concern that have become officially designated by the BLM. These polygon features were previously in a pre-designated status (i.e. being considered as areas to be eventually designated as official ACEC designated polygons). Once these polygon feature left the Pre-Designated phase (transitioned from a Considered to Designated status), they were removed from the ACEC Pre-designated polygon feature class and placed in this ACEC Designated polygon feature class. This dataset is a subset of the official national dataset, containing features and attributes intended for public release and has been optimized for online map service performance. The Implementation Guide represents the official national dataset from which this dataset was derived.
Coordinate System	N/A
Projection System	N/A
Geometry	Polygon

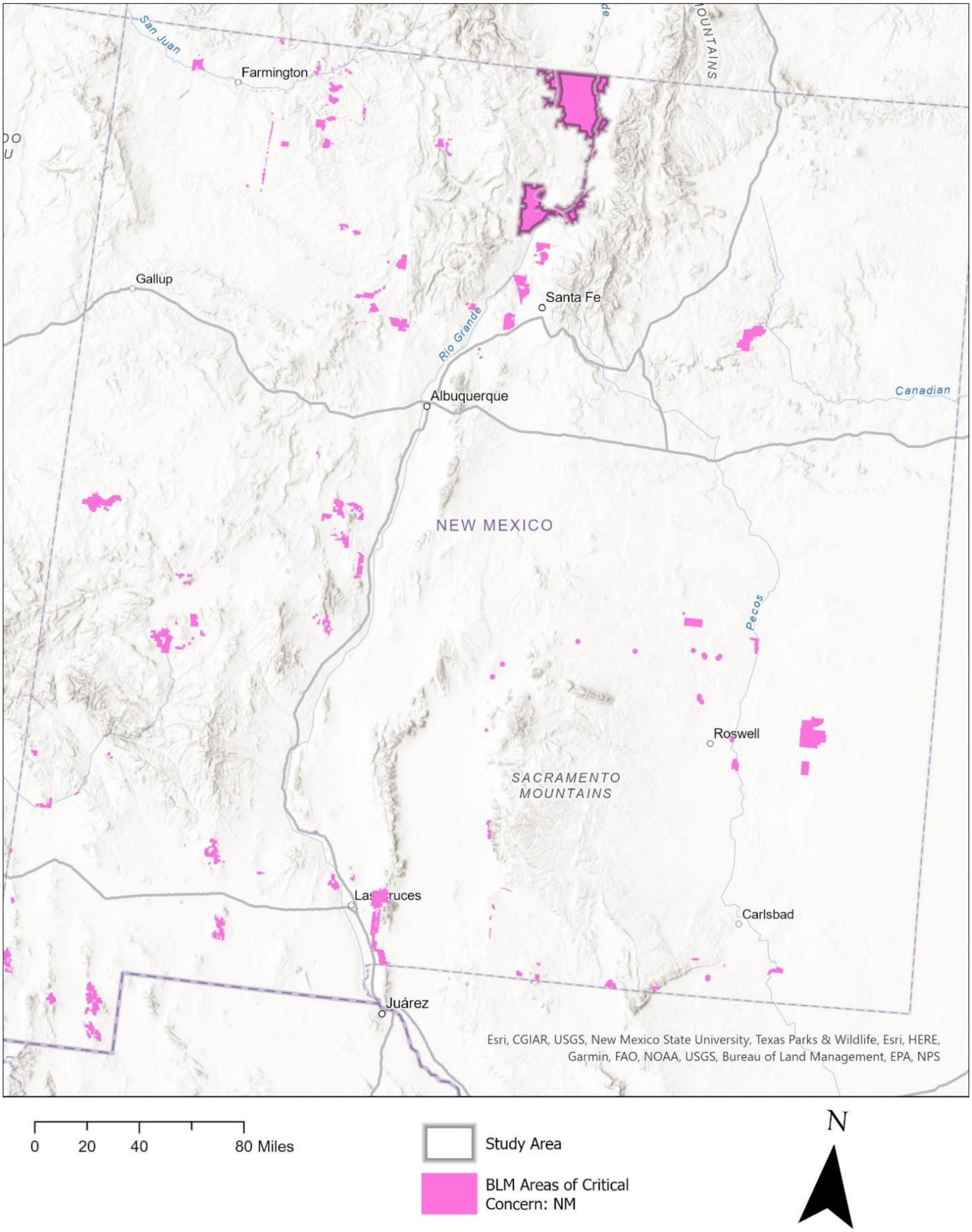

Figure 2-4. NM RGIS BLM ACEC

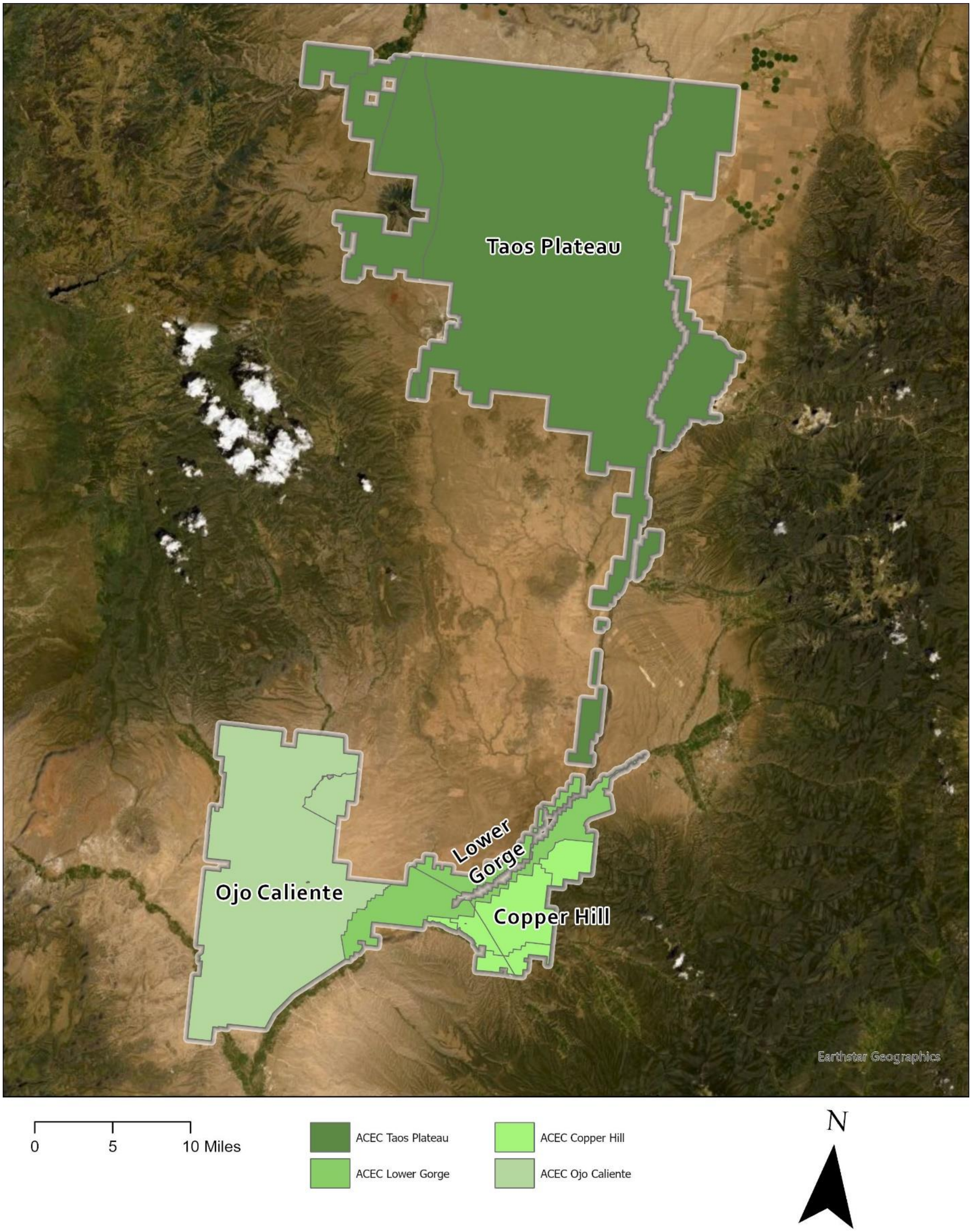

Figure 2-5. Four ACEC Designated Areas

Using the EarthData surface reflectance datasets (Table 2-4, Figure 2-6), the rasters from each time increment were clipped to the study area using the clip raster tool. The diff spatial analyst tool was then used to show cell by cell changes between the rasters. This ultimately shows the vegetative changes between each 5-year period. The EarthExplorer Landsat 7 ETM+ data (Table 2-5, Figure 2-7) was similarly analyzed.

Table 2-4. EarthData Metadata.

Name	MODIS/Terra Surface Reflectance Daily L2G Global 250 m SIN Grid v006
Year	2018
Author/Owner	USGS NASA
URL	https://lpdaac.usgs.gov/products/mod09gqv006/
Description	The MOD09GQ Version 6 product provides an estimate of the surface spectral reflectance of Terra Moderate Resolution Imaging Spectroradiometer (MODIS) 250 meter (m) bands 1 and 2, corrected for atmospheric conditions such as gasses, aerosols, and Rayleigh scattering. Along with the 250 m surface reflectance bands are the Quality Assurance (QA) layer and five observation layers. This product is intended to be used in conjunction with the quality and viewing geometry information of the 500 m product (MOD09GA).
Coordinate System	Sinusoidal
Spatial Extent	Global
Spatial Resolution	250 meters

Figure 2-6. EarthData Metadata

Table 2-5. EarthExplorer Metadata.

Name	Landsat 7 ETM+ Collection 1 Level 2
Year	2019
Author/Owner	USGS
URL	https://earthexplorer.usgs.gov/download/external/options/ LANDSAT_ETM_C1/LE71870162019205NSG00
Description	Landsat Collection 1 consists of Level-1 data products from 1972-2021 and are generated from Landsat 8 Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 4-5 Thematic Mapper (TM)*, and Landsat 1-5 Multispectral Scanner (MSS) instruments. Landsat scenes with the highest available data quality are placed into Tier 1 and are considered suitable for time-series analysis. Tier 1 includes Level-1 Precision and Terrain (L1TP) corrected data that have well-characterized radiometry and are inter-calibrated across the different Landsat instruments. The georegistration of Tier 1 scenes is consistent and within prescribed image-to-image tolerances of ≦ 12-meter radial root mean square error (RMSE).
Coordinate System	D WGS 1984, UTM 35, EPSG code 4326
Projection System	WGS 1984 UTM Zone 13N
Spatial Resolution	30 meters

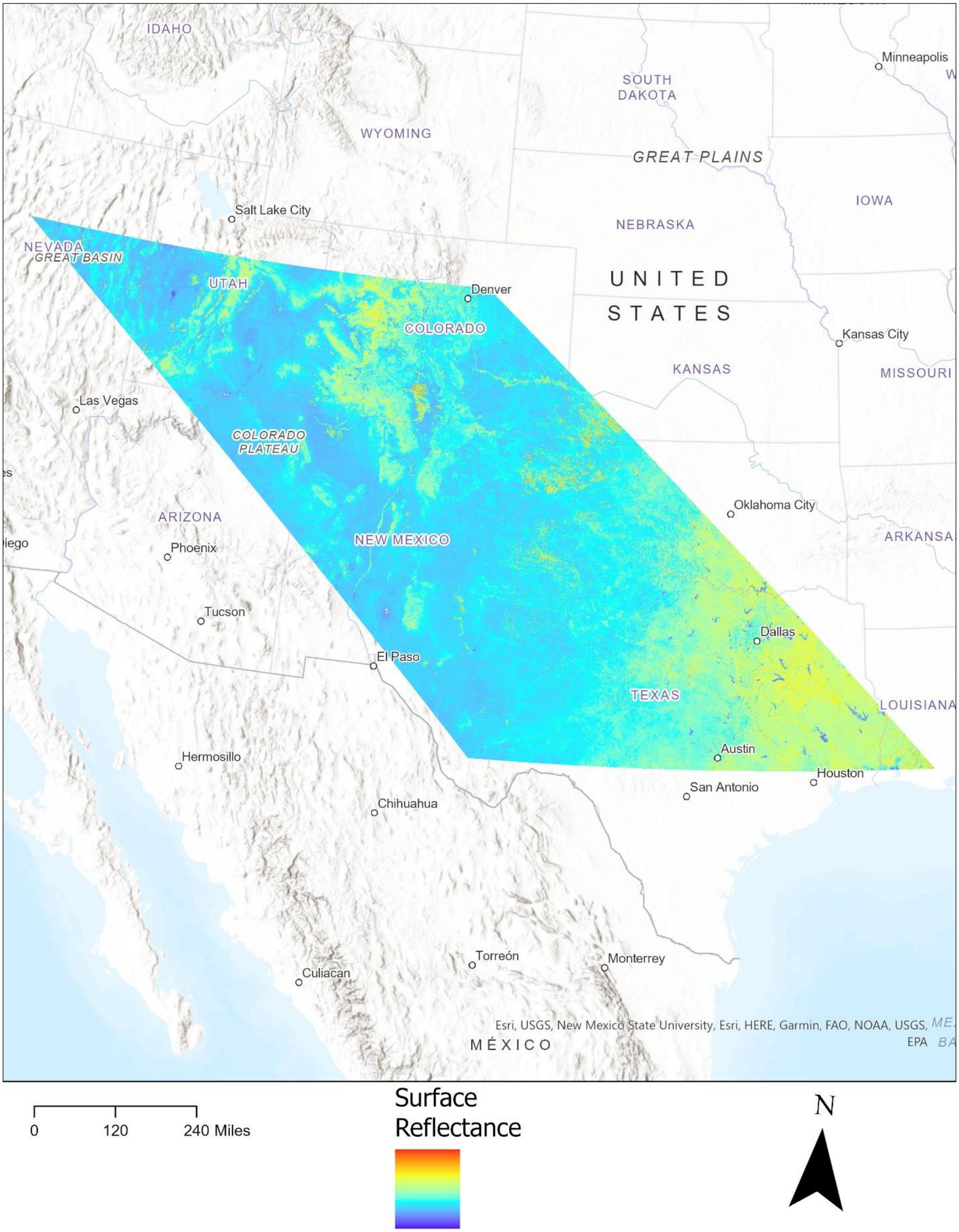

Figure 2-7. EarthExplorer Metadata

Using the composite bands tools, each of the 6 bands were combined for rows 34 and 35 creating two rasters for each temporal dataset. Next, using the merge raster function, the rasters were combined for each path, which merged rows 34 and 35 for each dataset. This brought the total of ten rasters down to five rasters – one for each temporal period. The rasters were then clipped to the study area and analyzed with the NDVI Colorized raster function. This process ran each of the 5 datasets using bands 3 and 4 (Table 2-6) and created a clipped colormap specific to the study area. Once the NDVI rasters were completed, each one was clipped to each of the four ACEC designated areas within the study area for each time period. This allowed an analysis of each area for 2000, 2005, 2010, 2015, and 2020. Each of the rasters for 2000 was then compared with each raster for 2020.

These methods were chosen because they are both suited to vegetation change analysis. Vegetation Indices combine surface reflectance measures at two or more wavelengths and highlight specific properties of vegetation. There are over 150 vegetative indices, which allows analysts to observe anything from healthy vegetation to canopy water content to light use efficiency. This study will be using Broadband Greenness Indices, which include NDVI, to determine vegetative changes within the study period. This is the best method for determining vegetation changes over time (L3 Harris Geospatial 2022).

Vegetation strongly reflects NIR, which can be seen in band 4 from the Landsat 7 images, and absorbs red light, which can be seen in band 3 (Table 2-6). NDVI measures the difference between NIR and red light. This is shown in the following equation:

$$NDVI = \frac{NIR - Red}{Red - NIR} = \frac{Band\ 4 - Band\ 3}{Band\ 3 - Band\ 4}$$

NDVI is the most common vegetation measure in remote sensing because healthy vegetation has higher amounts of chlorophyll, which reflects more NIR compared to other wavelengths. It also absorbs more red and blue light than other wavelengths. Since Landsat satellites have both NIR and red-light bands, the NDVI calculation is a standardized way to measure healthy vegetation (GISGeography 2021).

Finally, NDVI rasters were compared between 2000 and 2020 to determine the amount of vegetative change within each of the four ACEC areas. This was done using the Diff Spatial Analysts tool in ArcGIS Pro. This tool determines the differences in each raster and creates a new one depicting those changes. If values on one raster are the same as the raster being compared, there is no change. However, if the values are different between the two rasters, the output determines the amount of change which is shown on the new raster (ESRI 2022). These final rasters were then classified using Jenks Natural Breaks method. This method is used to determine the best arrangement of values into specified classes. It reduces the variance within classes and maximizes the variance between classes (Wikipedia 2022).

Table 2-6. Landsat & ETM+ Bands.

Band	Band Name	Wavelength (µm)
1	Blue	0.45 – 0.52
2	Green	0.52 – 0.60
3	Red	0.63 – 0.69
4	Near Infrared, NIR	0.77 – 0.90
5	Short-wave Infrared, SWIR 1	1.55 – 1.75
7	Short-wave Infrared, SWIR 2	2.09 – 2.35

CHAPTER 3
RESULTS

The surface reflectance and NDVI results were compared with the precipitation data and the apparent vegetation fluctuations within each temporal period coincide with the fluctuations in average rainfall for those years. However, when comparing the surface reflectance data and the NDVI data over a longer period, between 2000 and 2020, the vegetative change becomes much more apparent and shows an overall decrease in vegetation. We can see this in the number of pixels that changed when using the Diff Spatial Analyst tool in ArcGIS Pro (Table 3-1, Figure 3-1). Each pixel is 30 m^2. To determine the area of change or no change, the following equation was used for each location:

$$Area\ (km^2) = \#\ of\ pixels(30m^2)(\frac{1 \times 10^{-6} km^2}{m^2})$$

Table 3-1. Changes in raster pixels using Diff tool in ArcGIS Pro.

	No Change in Pixels (Vegetation)	**Change in Area (km^2)**	**Change in Pixels (Vegetation)**	**Change in Area (km^2)**
Taos Plateau	95,702	2.87	946,842	28.41
Lower Gorge & Copper Hill	7,654	0.23	187,819	5.63
Ojo Caliente	8,426	0.25	361,059	10.83

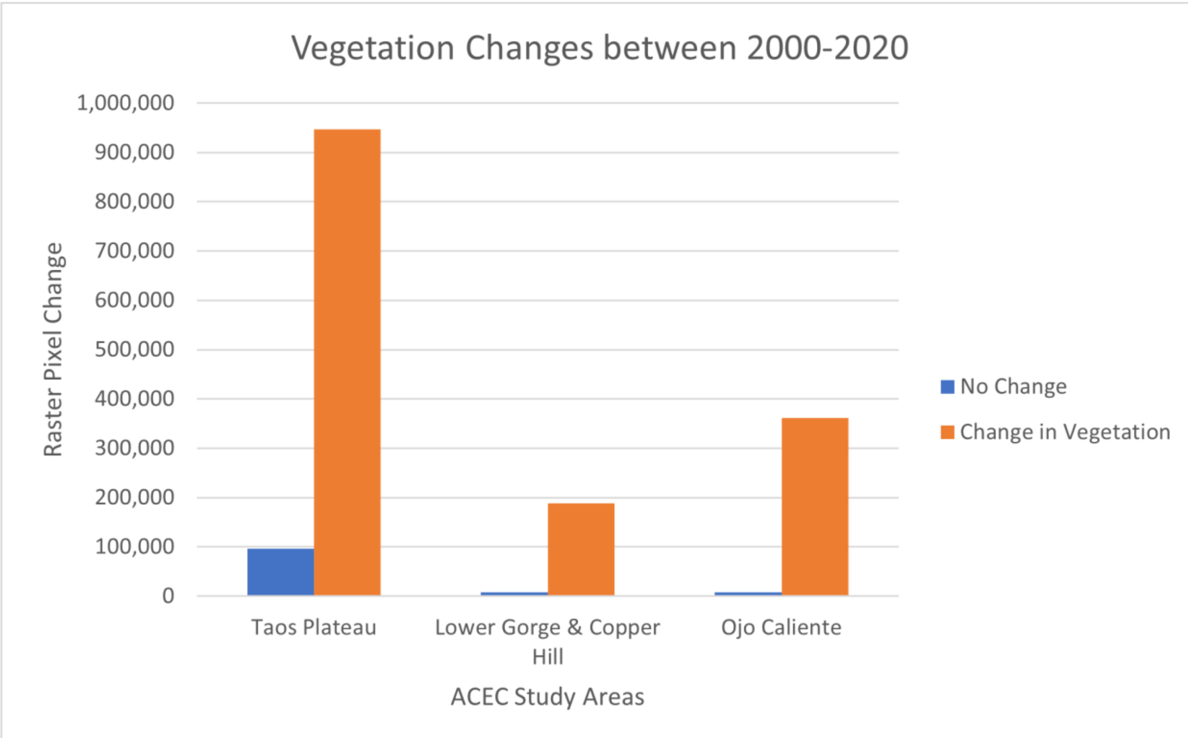

Figure 3-1. Chart of vegetation changes based on raster pixel changes

Precipitation rates nearly doubled from 2000 to 2005 in the Rio Grande at both the Embudo and Taos monitoring stations, as well as at the Rio Ojo Caliente station. From 2005 to 2015, precipitation decreased steadily, but was still higher than 2000. In 2020 precipitation rates were slightly lower than the beginning measurements in 2000 (Table 3-2). The changes in precipitation can be seen in both surface reflectance (Figure 3-2) and NDVI (Figure 3-3) when comparing side by side in 5-year increments.

Table 3-2. Annual precipitation in cubic feet per second.

	2000	2005	2010	2015	2020
Rio Chama	618.3	512.2	511.2	317.5	451.1
Rio Ojo Caliente	22.5	92.2	67.4	43.7	80.4*
Rio Grande – Embudo	470.3	1063.0	680.1	764.9	412.7
Rio Grande – Taos	437.9	962.4	605.5	692.2	376.2

*Precipitation data for Rio Ojo Caliente ends in 2019 and the 2020 measurement is from 2019

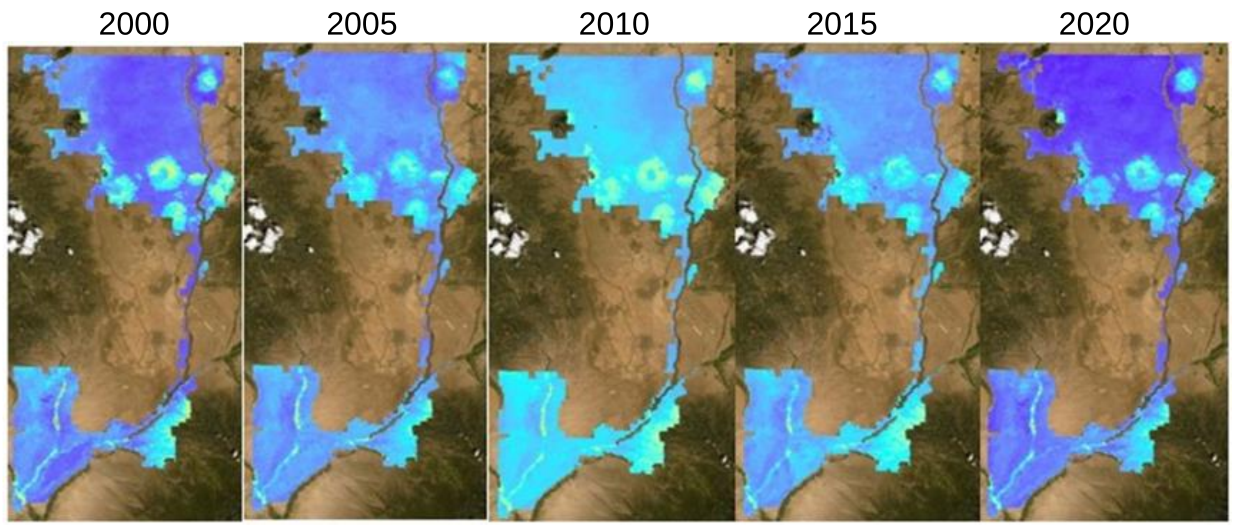

Figure 3-2. 5-year surface reflectance comparison from 2000 (far left) to 2020 (far right).

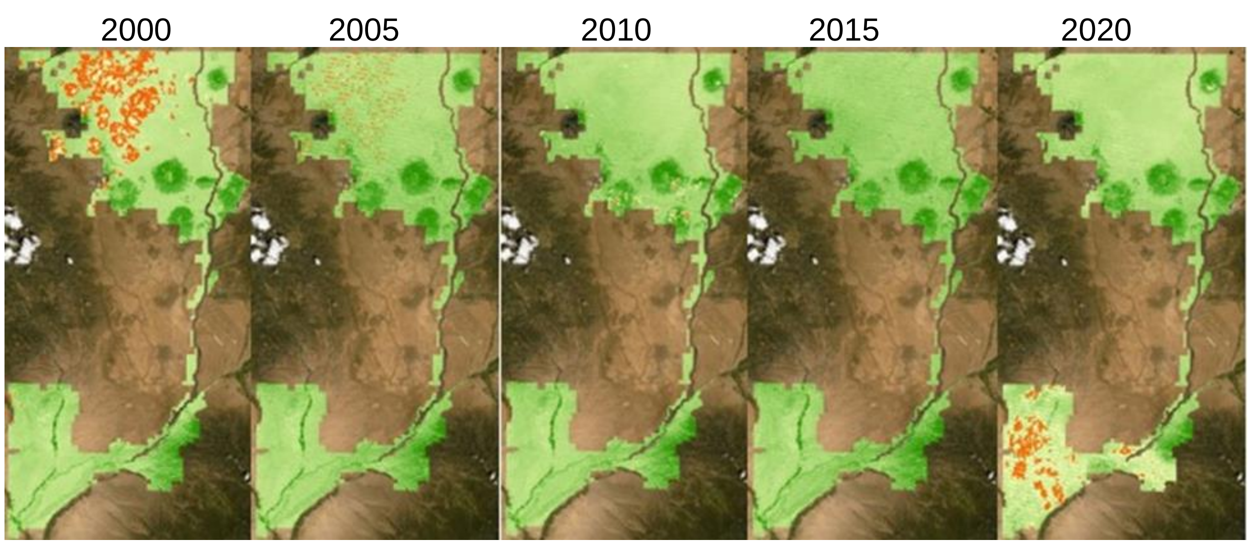

Figure 3-3. 5-year NDVI comparison from 2000 (far left) to 2020 (far right).

In contrast, when comparing surface reflectance and NDVI for 2000 with images from 2020, the vegetation change is apparent. Precipitation in 2020 was only slightly lower than in 2000 and does not seem to account for the total changes in vegetative cover. In Figure 3-4. , we can see the difference in surface reflection between 2000 and 2020. The darker blue areas show little to no change, while the light blue to yellow to red areas show the amount of change between the two study years. The greatest changes appear to be in the hilly region of the Taos Plateau, along the Ojo Caliente river, and in the Copper Hill and Lower Gorge ACEC areas.

Similarly, NDVI comparisons show changes in the same areas. In the Taos Plateau (Figure 3-5.), areas of the greatest vegetative decline seem to be in the hilly region, while in the Ojo Caliente area (Figure 3-6.) vegetation has declined throughout the area and the riparian system along the river has nearly disappeared. In Figure 3-7. , the NDVI comparison shows a decline in vegetation throughout the Lower Gorge and into the southern portion of Copper Hill. Both the surface reflectance comparisons and the NDVI images are consistent with each other in showing the overall vegetative changes between 2000 and 2020.

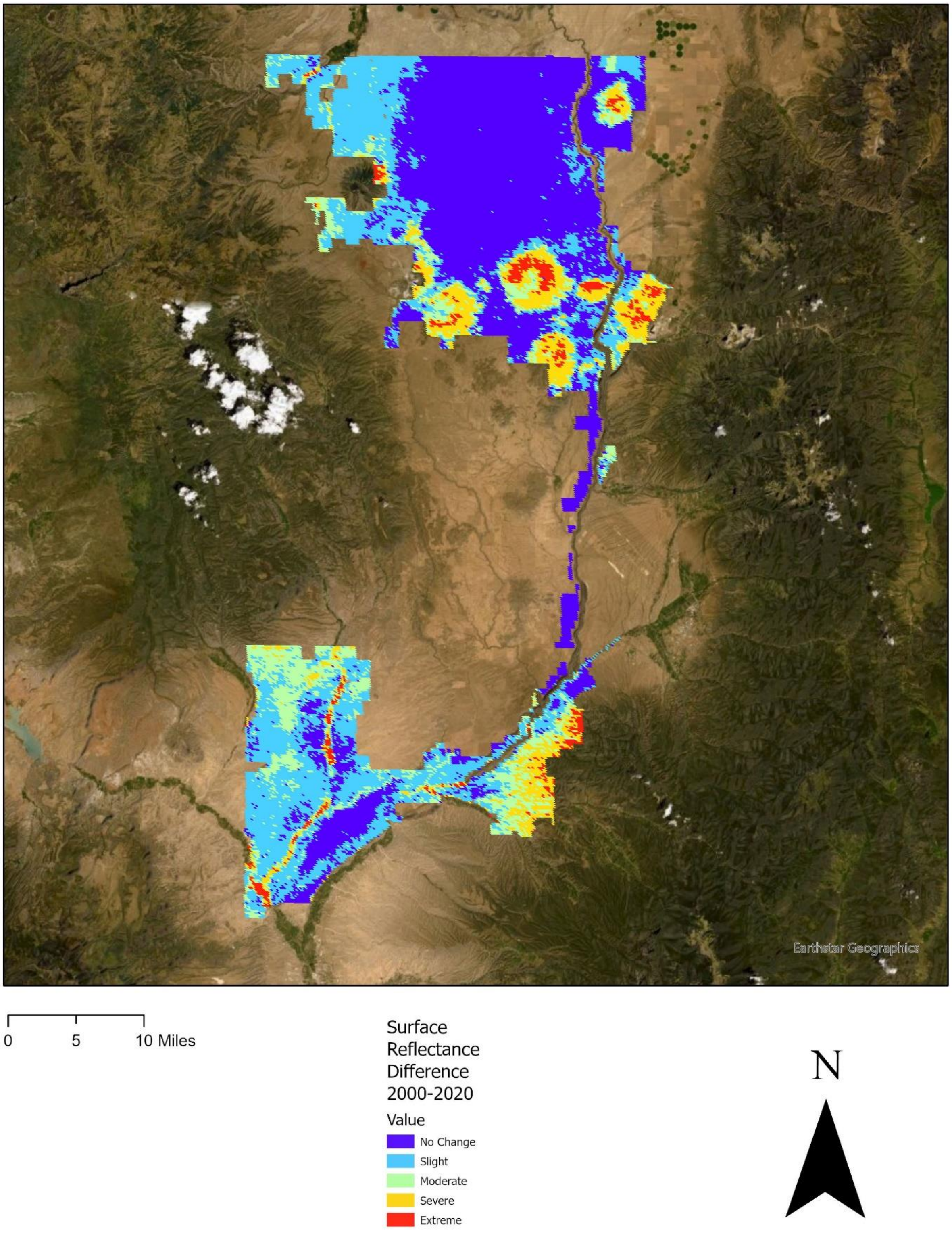

Figure 3-4. Difference in surface reflectance between 2000 and 2020

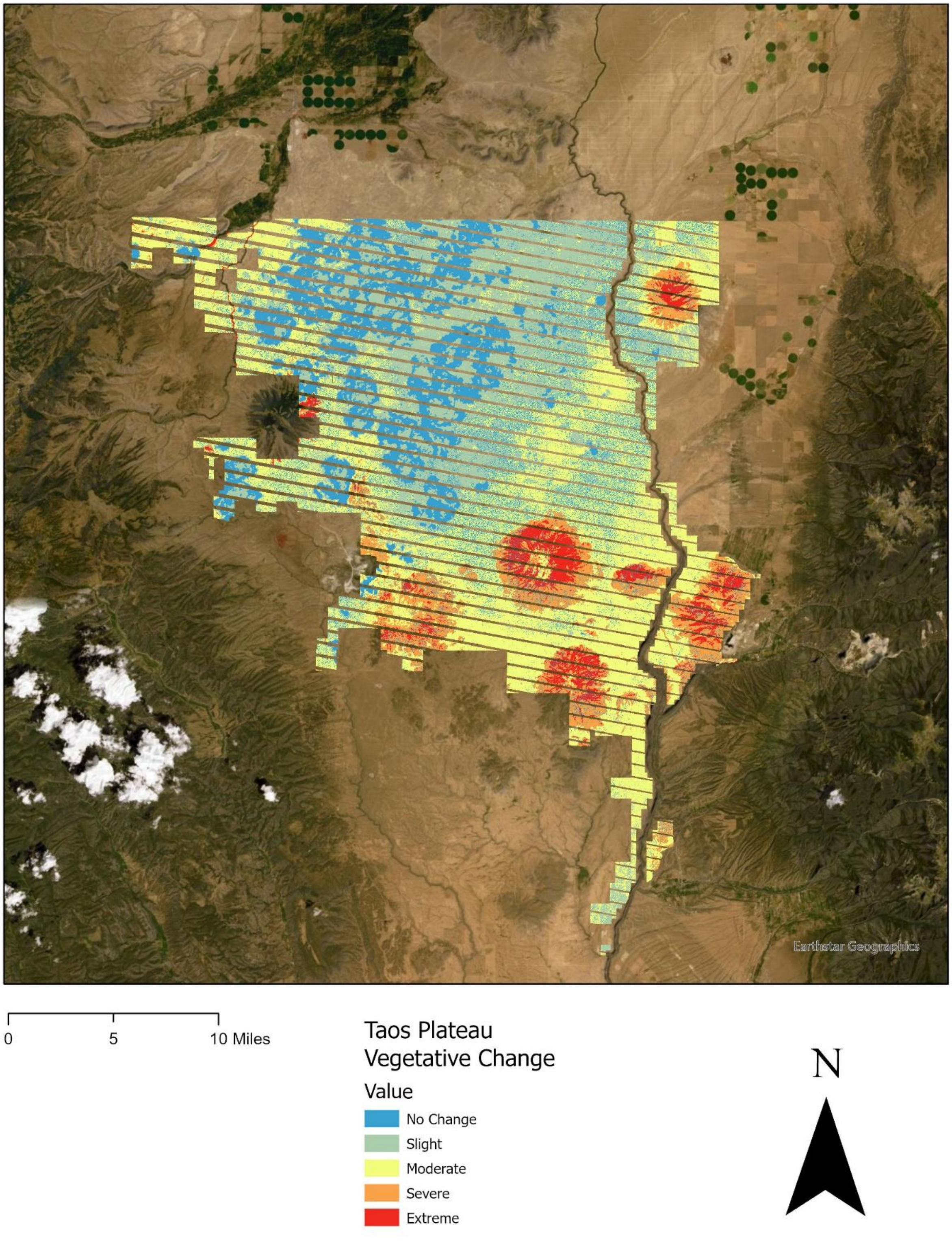

Figure 3-5. Difference in vegetation within the Taos Plateau from 2000 to 2020

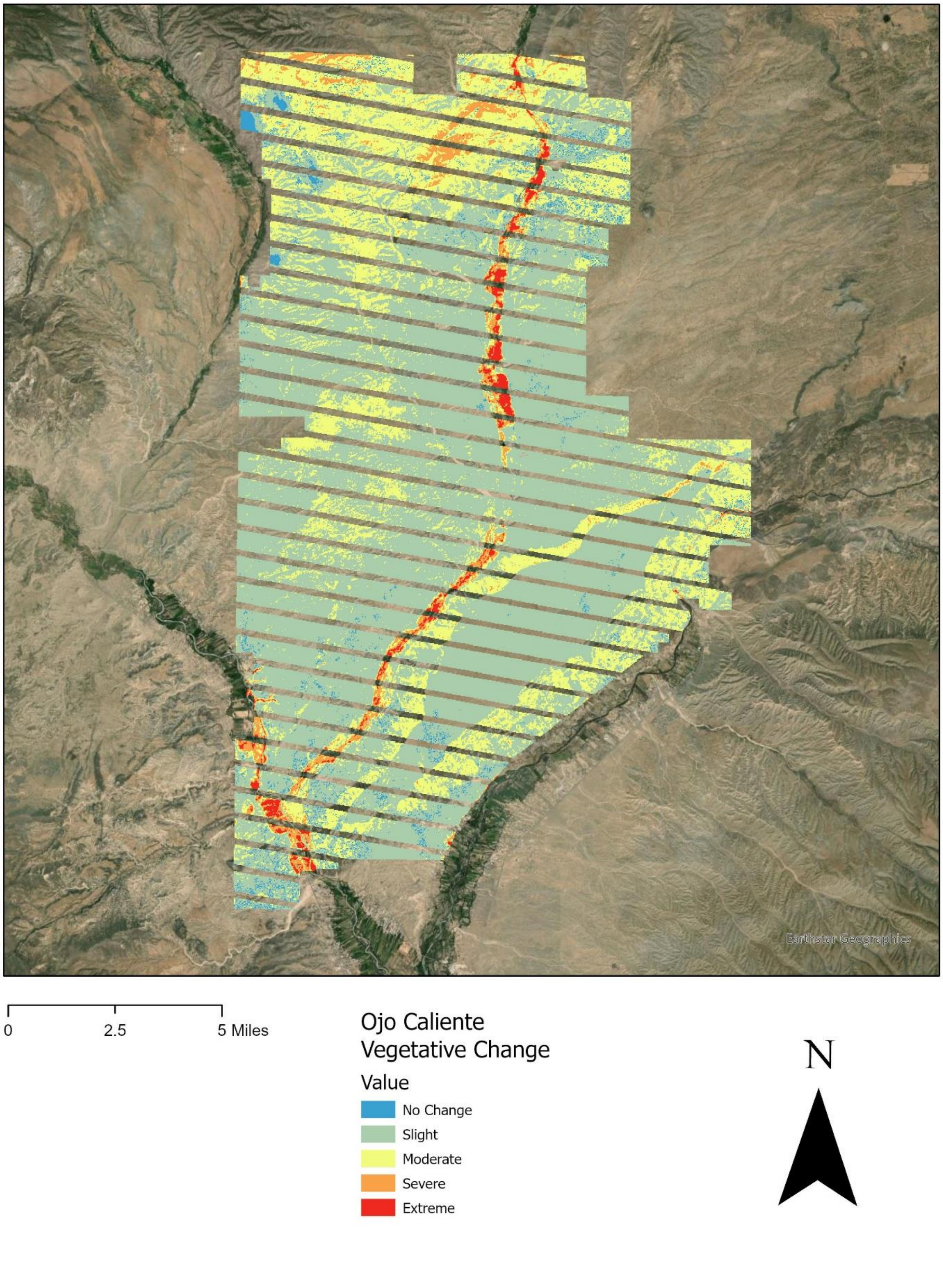

Figure 3-6. Difference in vegetation within Ojo Caliente from 2000 to 2020

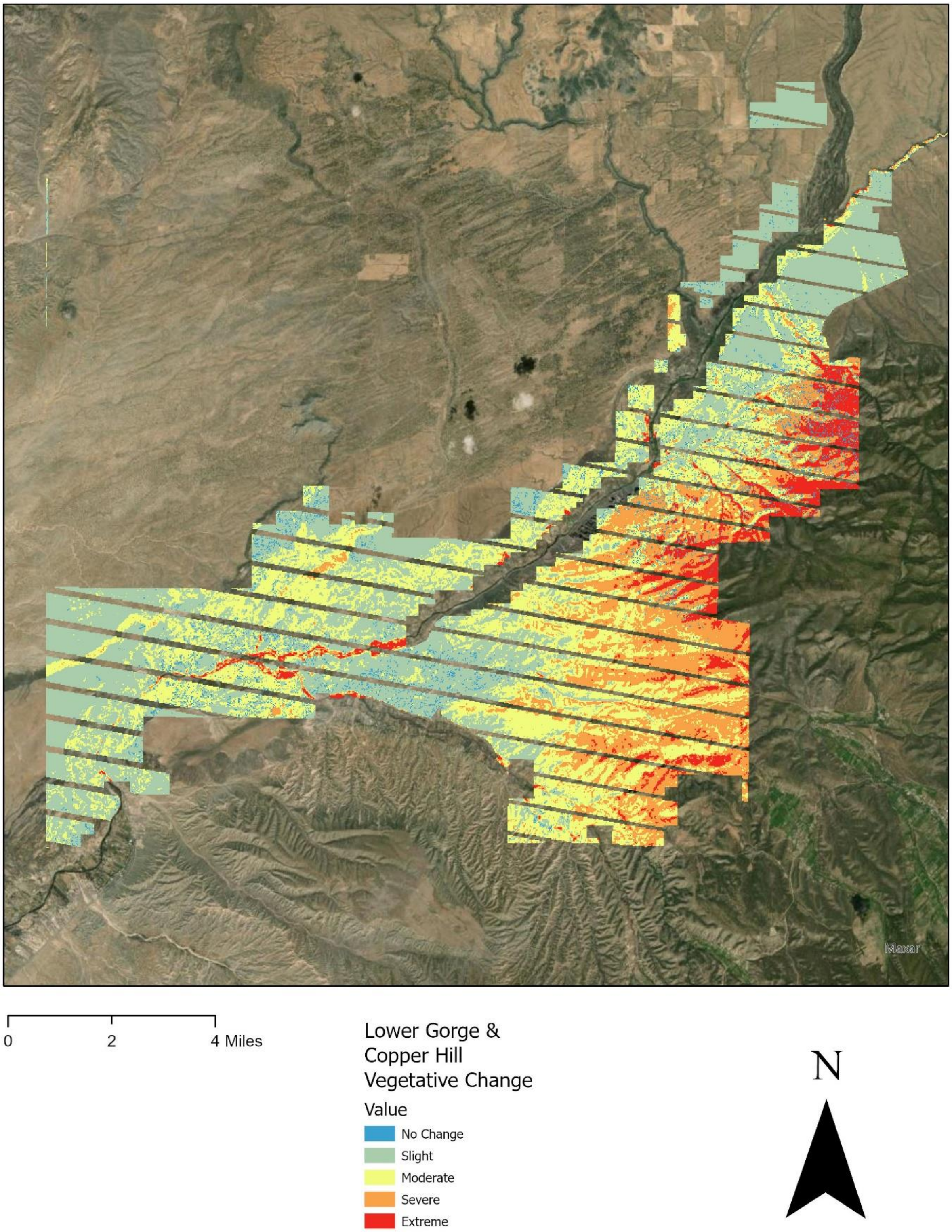

Figure 3-7. Difference in vegetation within Lower Gorge/Copper Hill from 2000 to 2020

CHAPTER 4
CONCLUSION

Climate change, prolonged drought, and growth of human infrastructure are but a few of the conditions contributing to habitat loss. We can see this loss through the vegetative changes that are being seen across the world. Management practices, or the lack thereof, as seen in the BLMs ACEC designated areas of northern New Mexico could also be contributing to these changes. Through the data analysis, we can see that there are significant changes in vegetative cover in all four ACEC designated areas between 2000 and 2020. These changes, however, cannot be directly contributed to one specific issue and are probably a result of many contributing causes. More research should be done to define the actual causes in these specific areas.

An issue I faced with this project was with the Landsat 7 ETM+ images. In 2003, the Scan Line Corrector (SLC), which compensates for the forward motion of the satellite, failed (US Department of the Interior 2022). The failure of this sensor causes striping issues within the images as we can see in Figure 4-1. I tried solving this through various analysis techniques, but the issue proved to be too great for the scope of this project. This could be built upon in the future for a clearer look at any Landsat 7 images and specifically pertaining to this project. If I were to do anything differently it would have been using images from Landsat 8 or finding a better work around for the Landsat 7 images. While the striping does not affect the overall outcome of the project, it does make it difficult to clearly interpret the images and see the subtle differences in vegetative cover.

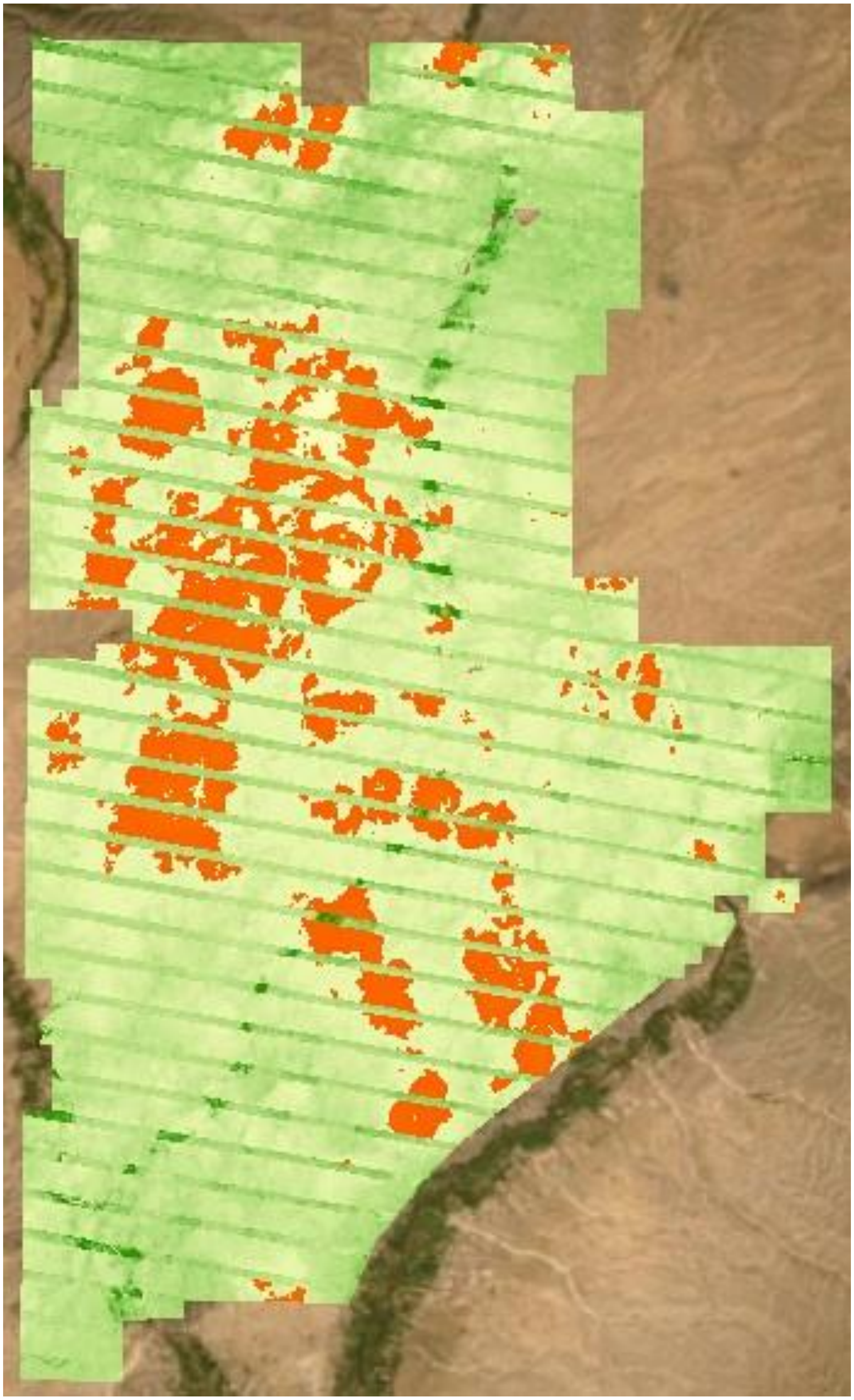

Figure 4-1. Landsat 7 ETM+ image striping issue example.

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