Case Study of Riparian Areas Adjacent to Select Tributaries of the Cimarron River Watershed in Colfax County, New Mexico

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Abstract

This study examined the extent and characterization of riparian areas for select locations in Colfax County, New Mexico. Historical imagery from the 1930s and 1940s was compared to remotely sensed imagery captured more recently in 2014 to evaluate wetland riparian change over time. Image analysis of riparian land cover in two areas of interest (AOI) located along select waterways of the Cimarron River Watershed included the digitization of features in a geographic information system (GIS) as well as classification using a tool developed by the United States Fish and Wildlife Service (USFWS) for the western United States. The extent and composition of each riparian feature was reviewed for accuracy in delineation and attribute classification. A change over time analysis was then completed for each AOI through the use of summary statistics and statistical testing. Results showed an overall decrease in the acreage of riparian zones in the areas studied. In addition it was found that changes in the composition of vegetation included a decrease in some native species as well as an increase in invasive species.

Introduction

Riparian Ecosystems

Mapping and monitoring riparian zones is becoming increasingly important for those working towards the protection and monitoring of New Mexico's remaining wetlands. Located adjacent to wetlands in arid or semi-arid climates throughout the southwestern United States, riparian zones are associated with adjacent wetlands and provide an important ecosystem and critical habitat for both resident and migratory wildlife.

As part of a greater wetland ecosystem, riparian zones also provide critical functions to the greater watershed in which they are located. Found adjacent to rivers, streams, and other wetlands within a greater watershed, riparian zones are comprised of unique hydrophilic soils and plants. Because of the adjacency to wetlands, species in riparian areas grow hardily. These zones are important because of several benefits they provide within a greater watershed. Riparian areas provide unique functions, including their contribution to river hydrology, bank stabilization, water retention, improved water quality of associated wetlands and groundwater, support for aquatic life, and the provision of key habitat for migratory and resident wildlife.

The United States Fish and Wildlife Service (USFWS) considers riparian areas to be transitional zones between wetland and upland, which include

> "plant communities contiguous to and affected by surface and

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subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one or both of the following characteristics: 1) distinctly different vegetative species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland" (USFWSa, 2009).

A technical report created for the Bureau of Land Management states that "riparian areas are the 'green zones,' or the links, between aquatic environments and upland, terrestrial ecosystems" (Lewis, Clark, Krapf, Manning, Staats, Subirge, Townsend, and Ypsilantis, 2003).

For years, grazing practices in western rangeland areas included open access to natural areas. As land cover changes were observed, researchers with the Bureau of Land Management noted that resident and migratory wildlife used riparian areas near wetlands and that these natural areas provided for "among the most important vegetative communities for western wildlife species" (Chaney, Elmore, and Platts, 1990).

As one of the driest states in the nation, New Mexico's wetlands and riparian areas comprise less than 1% of New Mexico" (Dahl, 1990). Dahl (1990) also estimates approximately one third of the original wetlands of New Mexico have been lost.

New Mexico and Arizona together have "lost an estimated 90% of their original riparian ecosystems" (Krzysik 1990). The USFWS has found that for the states of Arizona and New Mexico, "80 percent of all vertebrates use riparian areas for at least half their life cycles; more than half of these are totally dependent on riparian areas" (USFWSa, 2009). In New Mexico, dwindling riparian areas are the most important habitat for a majority of wildlife species, especially rare or endangered listed species according to New Mexico's Comprehensive Wildlife Conservation Strategy – New Mexico (New Mexico Department of Game and Fish, 2006).

Many influences have direct or indirect impact on the existence and condition of wetlands and their associated riparian zones, the extent of which are beyond the scope of this study. Factors include both naturally occurring events as well as human influences on the landscape. Forces influencing natural ecosystems, including riparian areas, are varied; these include alterations of waterways to control seasonal flooding, water storage needs for urban, agricultural, or livestock purposes, as well as changes in a riparian area's dominate vegetation. Other influences include invasive species, historic and more recent land use practices, and naturally occurring events such as extreme weather events.

The understanding of riparian areas in semi-arid or arid climates is evolving in an effort to identify, protect, and restore this important natural resource. Public and private conservation professionals use various methods to identify and understand the characteristics, location, and function of wetlands and associated riparian zones in semi-arid climates. Evolving technologies also allow image interpreters to compare historical aerial photography to more current satellite imagery within a geographic information system to map the extent and composition of riparian ecosystems using a classification system created for this purpose. This allows for important baseline information and change over time analysis when appropriate datasets are available. The purpose of this study was to determine the changes in the extent and composition of riparian areas over time using available imagery for select areas of interest in Colfax County.

Canadian River Watershed

The importance of watersheds comprised of rivers, streams, lakes, and associated riparian zones in the Upper Canadian River and its related watersheds is apparent given its role as a major source of water for New Mexico. The headwaters for the Canadian River start a mile and ½ north of the New Mexico border in the county of Las Animas, Colorado. The river enters New Mexico near the town of Raton, New Mexico which is located on the eastern side of the Sangre de Cristo Mountains, the southernmost sub-range of the Canadian Rockies.

As a major source of water for the state of New Mexico, as well as for the states of Oklahoma and Texas, the Canadian River is a primary tributary of the Arkansas River. There are several dams and diversions along the Canadian River; a major dam is located at Eagle Nest Lake, a 2200 acre impoundment created by ranchers in 1918 for irrigation purposes.

Snowmelt and annual precipitation running from the peaks of the Sangre de Cristo Mountains contribute to several watersheds and tributaries which merge downstream into the Canadian River; one is the Cimarron River Watershed. This watershed includes the Upper Cimarron River running from northern Eagle Nest Lake to the southeast towards the town of Cimarron as well as several smaller rivers and streams including Cienequilla Creek, which runs directly out of Eagle Nest Lake in the south and then downstream through the small town of Angel Fire in southwestern Colfax County, New Mexico.

Cimarron River

A portion of the upper Cimarron River was used as part of the area of interest for this research. As a tributary of the Upper Canadian River, the headwaters for the Cimarron River begin at Eagle Nest Dam at an elevation of approximately 8300 feet. From Eagles Nest Dam the Cimarron River runs to the southeast towards the town of Cimarron, the eastern extent of this research. On its passage through mountainous terrain, the Cimarron River runs through Cimarron Canyon State Park, the town of Ute Park, the Cimarron Canyon, and through the town of Cimarron which is at an elevation of approximately 6500 feet. U. S. Route 64 follows the Cimarron River through the study area.

The Cimarron River was mapped for the National Wetland Inventory Program (NWI) in 2011. The Cimarron River was classified as “R3RBH” in the Cowardin Classification System which is the classification standard used for the NWI (USFWS, 2009). The alphanumeric code describes the characteristics of the Cimarron River by System (riverine), Subsystem (upper perennial, steep gradient, fast water), Class (rock bottom) and Water Regime (permanently flooded).

The Cimarron River provides recreational opportunities for visitors and is surrounded by both private and public land ownership. The Cimarron River runs along U.S. Highway 64 and bisects the 137,000 acre Philmont Scout Ranch, the largest camp owned by the Boy Scouts of America.

Angel Fire

The area of Angel Fire is also part of the area of interest for this research. Angel Fire is located at 36°22′44″N 105°17′8″W in the north central region of New Mexico in Colfax County at an elevation of 8,500 feet. According to the United States Census Bureau, the village of Angel Fire is approximately 29.0 square miles; 28.9 of this acreage is land only; 0.04 square miles (0.14%) is water. In 2010, the U. S. Census of Angel Fire included approximately 1200 residents. The area, however, experienced unprecedented growth and development as recreational and tourist industries invested in large tracts of land for winter and summer sports. A ski resort was built in Angel Fire during the 1960s. Ownership changes occurred in the 500+ acre resort through the mid-1990s. The resort and village is now looking at future development options such as expansion of other recreational activities (golf, additional bike trail projects).

Cienequilla Creek is a tributary of the Cimarron River and provides Angel Fire with its main source for all water. Plans for future development of Angel Fire will bring additional stress to all natural resources including waterways located high in the watershed. Another concern includes loss of riparian habitat surrounding Cienequilla Creek. This study area was comprised of land within and surrounding the town of Angel Fire.

Study Area

The study area included riparian zones found along two waterways in Colfax County: portions of the Cimmeron River and of Cienequilla Creek. Total linear feet of these waterways was approximately 72 miles. These areas were chosen because historical aerial imagery was available dating back to the 1930s for Cienequilla Creek and to the 1940s for the Cimmeron River. These areas also had known riparian zones along these waterways. The study area was located within five adjacent quadrangles in southwestern Colfax County: Palo Flechado Pass, Eagle Nest, Touch-Me-Not Mountain, Ute Park, and Cimarron. The county of Colfax is highlighted in Figure 1 below. The specific quads where the study area is located are found in Figure 2.

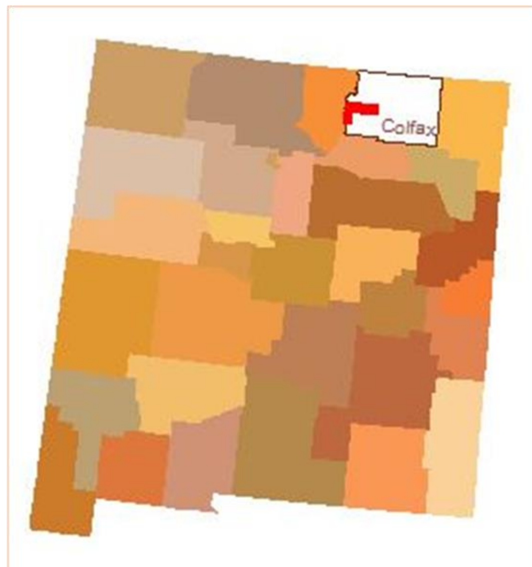

Figure 1. The study area is located in Colfax County in northern New Mexico.

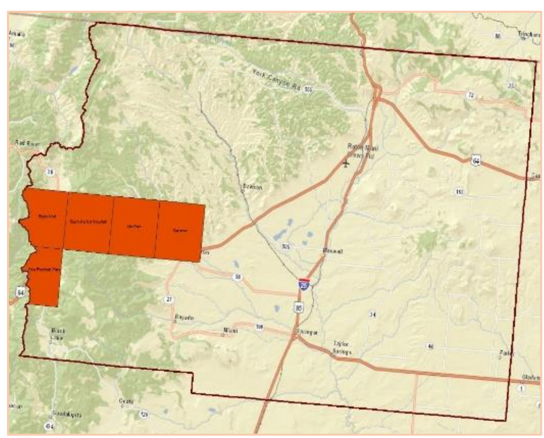

Figure 2. The area of interest is located along 72 miles of selected waterways within the highlighted quads of Colfax County, NM.

Methodology

Data Collection Process

The analysis of riparian land cover change in the study area utilized aerial imagery from two different time steps captured up to eighty years apart. This data was chosen based on the existence of historical aerial photography and availability of more recently collected satellite imagery for select tributaries within the Cimarron River Watershed in northern New Mexico. The research area was also selected at the suggestion of conservation professionals contracted to complete the USFWS National Wetland Inventory mapping of wetlands for areas in New Mexico in 2011. Several other datasets were used to support interpretation of the primary imagery for feature identification and classification. The primary and collateral datasets are summarized below.

NAIP Imagery

Imagery collected via satellite for the National Agriculture Imagery Program (NAIP) was utilized in this research and served for comparison to the mid-1930s and mid-1940s historical imagery. The imagery program is part of the United States Department of Agriculture's (USDA) Farm Service Agency (FSA), which provided the digital orthoimagery available through a free download. NAIP orthoimagery is collected throughout the nation and in natural color during growing seasons. It is used to support various agricultural and conservation programs. NAIP imagery includes an accuracy specification with +/- six meters to the ground (NAIP, 2014). The resulting high resolution imagery was available for Colfax County and came mosaicked and orthorectified. The spatial reference for the imagery was Universal Transverse Mercator North American Datum of 1983.

NAIP imagery was selected because it has been used as a primary base imagery for NWI mapping projects completed for the New Mexico Soil and Water Quality Board (NMED/SWQB) by Saint Mary's University of Minnesota GeoSpatial Services (SMUMN/GSS) (NMED, 2006). For this project, the most current NAIP imagery (collected during the summer of 2014) was utilized. The resolution for the 2014 imagery was one meter and the spectral resolution included four bands (Red, Green, Blue, and Near Infrared).

Historical Photos

Historical photos were downloaded from Earth Data Analysis Center (EDAC) located in New Mexico. EDAC is a digital data clearinghouse and part of the University of New Mexico (UNM). The company has an established level of expertise in geospatial technology and provides data to both private and public sectors. EDAC also maintains a historic aerial photography archive covering the state of New Mexico.

The historical imagery that was used in this research included scenes of aerial photography captured by cameras mounted on aircraft during the mid-1930s and also the mid-1940s. All photography was captured during summer months and was black and white in emulsion. Each photo covered approximately eight square miles.

The study area utilized historical photography in select portions of two different waterways within the greater Cimarron River Watershed. Areas of interest were located in five quadrangles of Colfax County. The study area included portions of the Cimarron River running through four quads including Eagle's Nest, Touch-Me-Not Mountain, Ute Park, and Cimarron. The earliest available photography for these quads was captured during the mid-1940s. A total of ten scenes were utilized for this area of the research.

The Palo Flechado Pass quad in Colfax County where the town of Angel Fire is located had aerial imagery available dating back to the mid-1930s. Palo Flechado Pass quad consisted of six scenes for this research (Figure 3).

Although historical photos were available for download at no cost, the available scanning resolution was only 700 dpi. To complete riparian vegetation mapping using black and white photography, a more refined scanning between 1000 to 1800 dpi was desired. For this study, a minimum scanning resolution of 1200 dpi was completed on all of the historical imagery. Higher resolution scanning of the black and white photos required additional handling fees which, in turn, limited the study area.

In addition to gathering the mid-1930s and mid-1940s imagery from EDAC in satisfactory resolution form, additional preprocessing was necessary for the historical black and white digital files. Each of the sixteen scanned scenes were georeferenced to the 2014 NAIP imagery. A minimum of four fiducial points were originally available for each of the historical photos. Approximately 10-15 additional control points were added to complete the georeferencing of each historical image so that it aligned with the study area in the 2014 NAIP imagery.

Collateral Datasets

Supporting collateral information included spatial datasets downloaded from various government agencies. All collateral information was used to support interpretation decisions based on the primary imagery datasets described above.

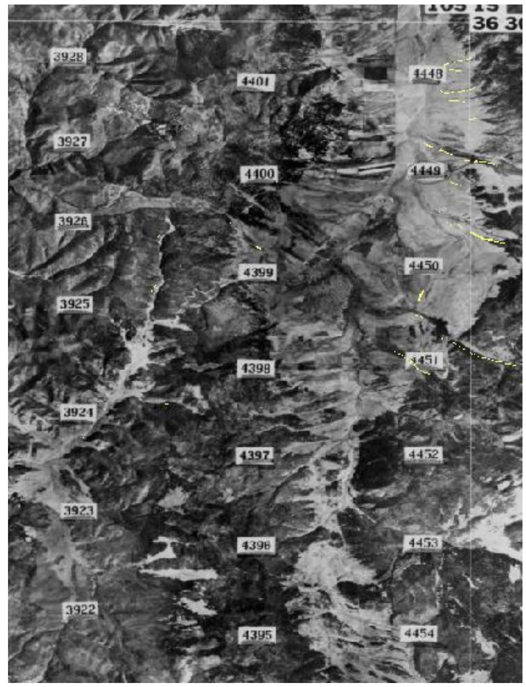

Figure 3. Index of historical scenes captured during the mid-1930s of the Palo Flechado Pass quad in Colfax County. Each photo covered approximately eight square miles. Angel Fire is located in the Moreno Valley, upper right of the figure.

Several collateral datasets were downloaded via the Internet via the Natural Resources Conservation Service Geospatial Data Gateway; these included datasets for Colfax County including geographic names, political boundaries, a ten meter national elevation dataset, hydrography datasets, digital raster graphic county mosaic, SSURGO soils data, Level III Eco Regions and geological features data. A streets layer was also downloaded from Esri.

Geodatabase Preparation

A file geodatabase was created and organized in ArcCatalog within the Esri software program ArcGIS v10.2. Data for the project was downloaded from various agency data gateways via the Internet. All imagery and collateral data were housed within a single geodatabase.

Because some of the datasets originated from different coordinate systems, all layers were projected when necessary using NAD 1983 Universal Transverse Mercator Zone 13N. The Geographic Coordinate system used was Geographic Coordinate System North American 1983 of the North American 1983 datum.

Additional data layers were created in the geodatabase for the delineation and classification of the riparian polygon features found in the study area. Two data layers were created for use with each of the two time steps of the study imagery: historic (mid-1930s or mid-1940s) and current (2014). The attribute table for these layers held information about each feature created during the project. This included object ID, feature number, shape, shape length, shape area, acreage, river name, riparian classification, as well as additional comments noted by the researcher whenever clarification with the professional photo interpreter was considered. In some cases, notes regarding the elevation or the soil types were also kept in the notes column.

ArcMap Project Creation

ArcMap v10.2 was used for the delineation and classification of riparian features. Layers included the primary imagery (historic and 2014 imagery) as well as various collateral datasets for the study area as discussed above. A single ArcMap document housed all of the various layers used for the research. All layers were used for mapping decisions.

Identification of Photo Signatures

The imagery for each time step (mid-1930s or mid-1940s, 2014) was initially reviewed with a trained photo interpreter from SMUMN/GSS who agreed to consult with the researcher for this project. Image “signatures” of riparian vegetation viewed in both the historic and the color imagery at a scale of 1:3,000 were identified within each imagery dataset. Bookmarks in ArcMap were created for each of the riparian signatures and these served as a reference for the remainder of the project (Figure 4). The photo signatures provided guidance and improved consistency during the decision making process as riparian features were identified, delineated and classified by the researcher.

Images of previously mapped riparian projects completed by SMUMN/GSS for similar semi-arid climates as well as available ground photos of riparian vegetation were reviewed for reference purposes. This included ground level photos captured by the researcher during a field visit to the study area during the summer of 2014. A search to locate examples of historical imagery including riparian vegetation was also completed; however, few references were found.

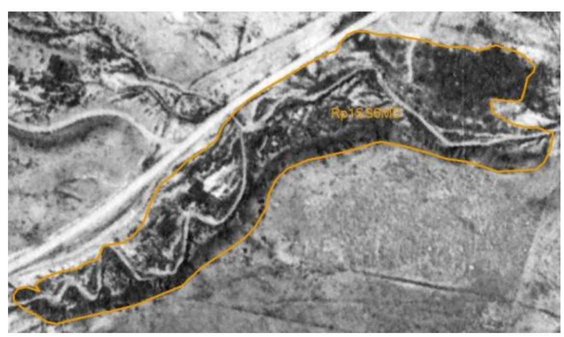

Figure 4. Photo signature for Rp1SS6MD (Riparian, Lentic, Scrub-Shrub, Deciduous, Mixed Deciduous).

Riparian Feature Delineation

Riparian features were delineated at a

minimum mapping scale of 1:2,500 within the selected waterways (Cimarron River and Cienequilla Creek) which are found within the greater Cimarron Watershed (Figure 5).

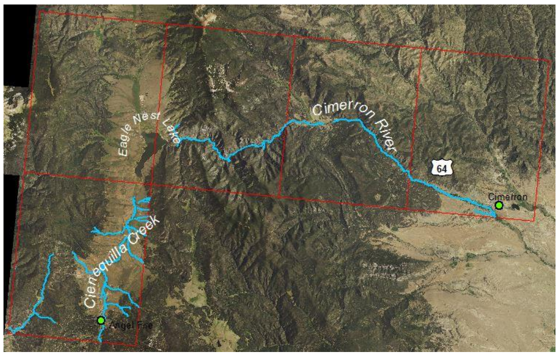

Figure 5. Riparian features were delineated and classified along portions of the Cimarron River and Cienequilla Creek in Colfax County, NM.

Polygon features greater than one quarter acre in size were delineated for each of the two time steps (1930-40s, 2014). Delineation for the most current imagery (2014) occurred first, as this was determined to be the superior imagery due to its high resolution and presence of true color. The 2014 imagery also provided guidance during the photointerpretation process when initially locating riparian areas in the historical imagery.

Due to the small width of the riverine features where the riparian features were located, all polygons were created as one unit across its associated waterway (Cienequilla Creek or Cimarron River). This decision was made after consulting with a subject matter expert (SME) photo interpreter at Saint Mary's University of Minnesota. This approach is often used when streams are smaller, as in the study area.

Riparian delineation was completed using editing tools within the ArcMap program. Delineation of features was completed for the entire study area before any of the riparian classification was started. Various editing tools within ArcMap were also used for this part of the research. Delineation occurred for each image time step using the supporting imagery, various collateral datasets, and the researcher's best professional judgment.

Riparian Classification

In this study, all riparian areas were found adjacent to existing wetlands and associated rivers within the study area. Riparian zones consisted of woody vegetation associated with perennial or intermittent lotic (riverine) systems. In New Mexico, riparian species include deciduous or evergreen shrubs and trees.

Riparian features were attributed using "A System for Mapping Riparian Areas in the Western United States" (USFWS, 2009b). This method was created specifically for semi-arid areas in the western United States by the USFWS (USFWS, 2009b) in recognition of the uniqueness and importance of riparian areas.

The classification includes hierarchal alphanumerical codes characterizing riparian areas by System, Subsystem, Class, Subclass and Dominance Type. For example, a riparian code might be expressed as "Rp1FO7." This would indicate a riparian area that primarily consists of dense evergreen trees adjacent to a wetland. The riparian classification system is often used in the western United States and is considered a complement to wetland mapping projects for the National Wetland Inventory Program (Figure 6).

Quality Assurance

All polygons and classifications were reviewed for accuracy with a professional image interpreter at SMUMN/GSS familiar with the riparian classification

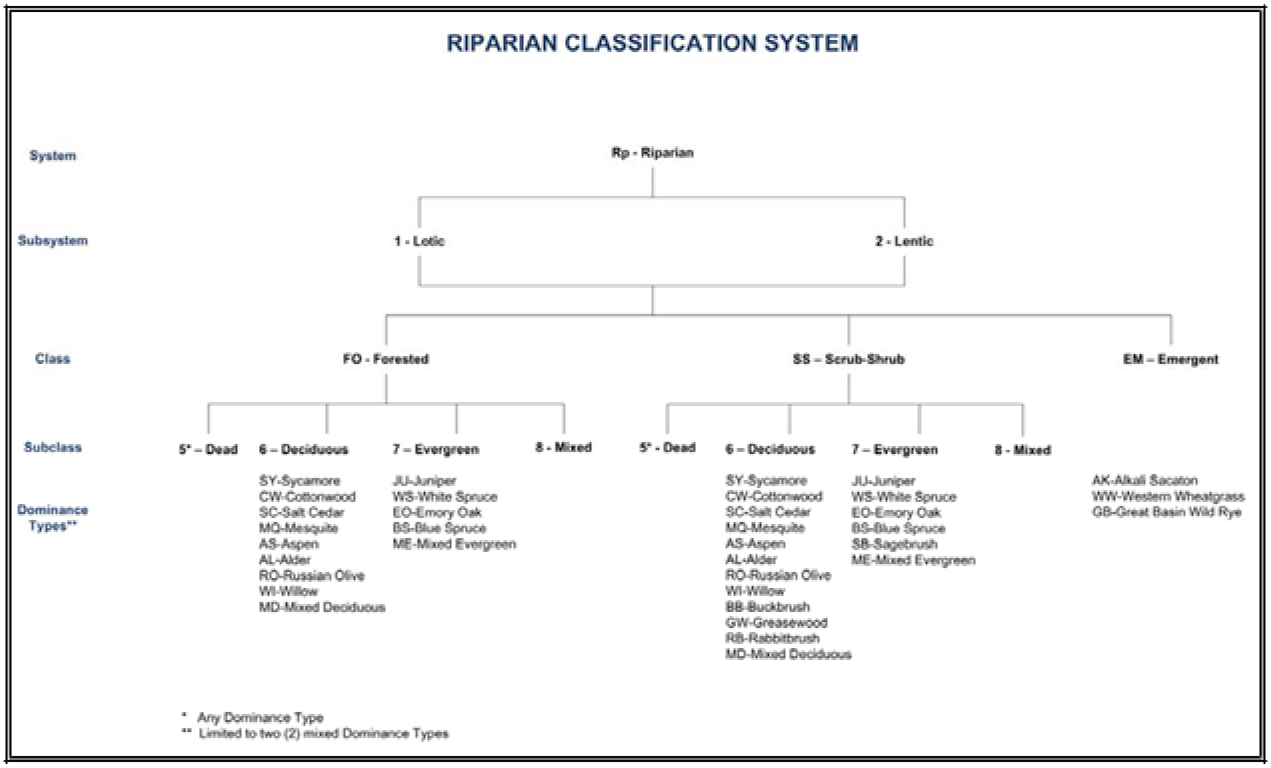

Figure 6. The "System for Mapping Riparian Areas in the United States" was developed for riparian mapping projects in semi-arid or arid climates and is often a complement to wetland mapping projects completed by the USFWS.

system as well as the study area. In addition, a quality assurance check on the data was completed to eliminate polygons less than one half acre in size, ghosts, slivers, duplicate polygons, and potential spelling errors in the attribute table. Adjustments were made per the reviewer's suggestions. Both the feature delineation and the assigned riparian classifications were considered during this review.

The methodology for this research attempted to follow mapping standards outlined by the USFWS (USFWSa and USFWSb, 2009) within the confines of time and budget. This method also incorporated standards for data collection established by the Federal Geographic Data Committee (FGDC, 2009).

Results

Historical Imagery

Results for the historical imagery (mid-1930s or mid-1940s) revealed a total of six riparian classifications within the study area. All of these features were found within the Rp1FO (Riparian, Lotic, Forested) or the Rp1SS (Riparian, Lotic, Scrub-Shrub) Class level.

Within the Rp1FO (Forested) Class two Subclasses were found including Rp1FO6 (Deciduous) and Rp1FO7 (Evergreen). Two dominance Types were found in the 6 (Deciduous) Subclass including Rp1FO6CW (Cottonwood) (Figure 7) and Rp1FO6MD (Mixed Deciduous). One Dominance Type was found in the 7 (Evergreen) Subclass, which was comprised of Rp1FO7WS (White Spruce). Results showed the Rp1FO7WS classification included the most acreage overall although fewer features were delineated. This one classification code included 41 features totaling 541.96 acres.

Within the Rp1SS (Scrub-Shrub) Class two different 6 (Deciduous) Subclass levels were mapped. These included Dominance Types of MD (Mixed Deciduous) and WI (Willow). Several features were identified only at the Class level as the particular vegetation was undetermined. Nineteen features totaling 77.37 acres were simply classified as Rp1SS in the historical imagery.

Using the historical imagery, a total of 973.94 acres in 90 features were mapped as riparian zones in the study area. Summary statistics for historical imagery are found in Table 2.

2014 Imagery

Using the 2014 imagery a total of 460.02 acres were mapped as riparian zones along portions of select waterways within the Cimarron River Watershed. This was comprised of 119 polygons. Summary statistics for the 2014 imagery are found in Table 1.

Results for the 2014 imagery revealed a total of seven different riparian classifications within the study area. All of these features were found within the Rp1FO (Riparian, Lotic, Forested) or the Rp1SS (Riparian, Lotic, Scrub-Shrub) Class levels using the System for Mapping Riparian Areas in the Western United States (USFWS 2009).

Within the Rp1FO (Forested) Class two Subclasses were found including Rp1FO6 (Deciduous) and Rp1FO7 (Evergreen). Two Dominance Types were found in the 6 (Deciduous) Subclass including Rp1FO6CW (Cottonwood) (Figure 8), and Rp1FO6MD (Mixed Deciduous). One Dominance Type was found in the 7 (Evergreen) Subclass which was comprised of Rp1FO7WS (White Spruce). The Rp1FO7WS classification was applied to 268.51 acres of the 460.02 acres delineated in the 2014 imagery. This acreage included 48 individual polygon features.

Figure 7. A large riparian feature classified as Rp1FO7CW is seen in this mid-1940s image along the Cimarron River (near the town of Cimarron) and may be compared to Figure 8 below.

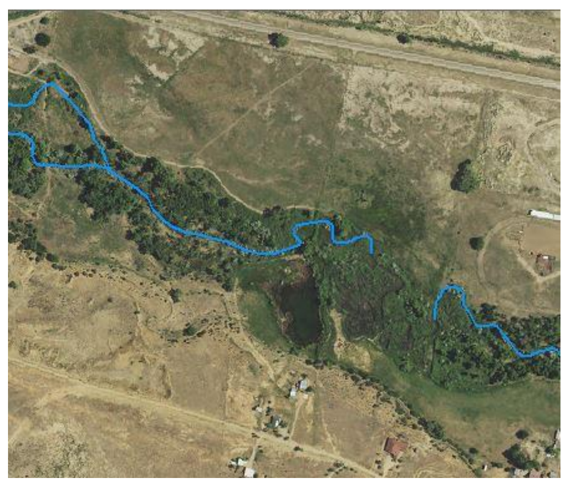

Figure 8. The 2014 imagery showed a reduction of the Rp1FO6CW (Cottonwood forest) when compared to the same area in the historical imagery above (Figure 7).

Within the Rp1SS (Scrub-Shrub) Class three 6 (Deciduous) Subclass levels were mapped. These included Dominance Types of MD (Mixed Deciduous), WI (Willow), and SC (Salt Cedar). It was not possible to classify the vegetation of 11 polygons; these areas appeared to be shrubs, and were therefore classified at the Class level only.

Summary statistics created in ArcMap for both the historical and 2014 imagery are outlined in Table 1 and Table 2 as well as Figure 9.

Statistical Analysis

A paired t-test was completed on the total number of riparian features and also total acreage by classification for the historical and 2014 data. Six of the seven Dominance Types from the riparian classification categories were included in the analysis. Rp1SS6SC was excluded as that classification was not found in the historical imagery at all.

The first null hypothesis was that the mean number of riparian features was not significantly different between the historical and 2014 imagery. This hypothesis was accepted at both the 90% and the 95% confidence levels.

The second null hypothesis was that the mean riparian acreage was not different between the historical and 2014 imagery. This hypothesis was rejected at the 90% confidence level ($p=0.07$). The mean acreage of riparian features was significantly greater in the historical imagery compared to the 2014 imagery.

Discussion

The mapping and classification of riparian areas for this project included the use of aerial imagery collected using different technologies captured 70 years apart. This resulted in a few challenges for this research.

The most current imagery, captured in 2014, had good resolution (one meter) and most riparian features were easily distinguished. The true color of riparian vegetation as well as the ability to manipulate bands within the imagery helped to distinguish riparian areas at all of the System, Subsystem, Class, Subclass and Dominance Type classification levels. The imagery was also mosaicked and more accurately georeferenced than any of the historical imagery due to improved elevation models and satellite technologies.

Although the historical imagery was captured during the growing season, or “leaf on,” particular image issues were especially noted when delineating and classifying riparian areas using the black and white imagery from the mid-1930s and the mid-1940s. Calibration reports were not available for any of the imagery captured during the 1930s or the 1940s, which in turn affected the quality of the georeferenced product.

The earliest imagery captured in the mid-1930s of the Palo Flechado Pass quad was fair in resolution and the overall tone was pale. The black and white imagery of the remaining quads captured during the mid-1940s was more saturated overall. Within all of the black and white historical scenes various issues included shadowing, smearing, shifting and variations in the resolution between historical scenes occurred. Image shift was especially noted along the edges of the historical digital files in spite of being georeferenced to the 2014 imagery. To compensate for these issues the decision making process on the historical delineation and attribution of features needed to be considered more frequently. In some cases this meant that features were delineated where they were found in the historical imagery and not edited to match the exact location as seen in the 2014 imagery (although all features were easily seen along the study area’s selected waterways). This decision was made after

Table 1. 2014 Imagery Summary Statistics.

Riparian Code	**# Features**	**Range (acres)**	**Mean (acres)**	**Total (acres)**
Rp1SS***	11	0.54 – 4.69	2.01	22.16
Rp1SS6MD	17	0.37 – 6.90	1.27	21.55
Rp1SS6WI	19	0.26 – 4.43	1.32	25.25
Rp1SS6SC	19	0.57 – 21.67	4.19	79.58
Rp1FO6CW	1	n/a	17.14	17.14
Rp1FO6MD	4	2.60 – 8.68	6.49	26.00
Rp1FO7WS	48	0.28 – 33.11	5.59	268.38
TOTALS	**119**	**0.26 – 33.11**		**460.06**
***Riparian, Lentic, Scrub-Shrub; Subclass & Dominance Types undetermined				

Table 2. Historic Imagery Summary Statistics.

Riparian Code	**# Features**	**Range (acres)**	**Mean (acres)**	**Total (acres)**
Rp1SS***	19	0.45 – 18.18	4.07	77.37
Rp1SS6MD	11	1.20 – 47.32	11.45	126.00
Rp1SS6WI	6	1.40 – 6.02	3.38	20.33
Rp1SS6SC	0	n/a	n/a	n/a
Rp1FO6CW	4	6.59 – 94.17	46.35	185.41
Rp1FO6MD	6	0.68 – 6.19	2.54	22.90
Rp1FO7WS	41	0.99 – 72.01	13.21	541.96
TOTALS	**87**	**.45 – 94.17**		**973.97**
***Riparian, Lentic, Scrub-Shrub; Subclass & Dominance Types undetermined				

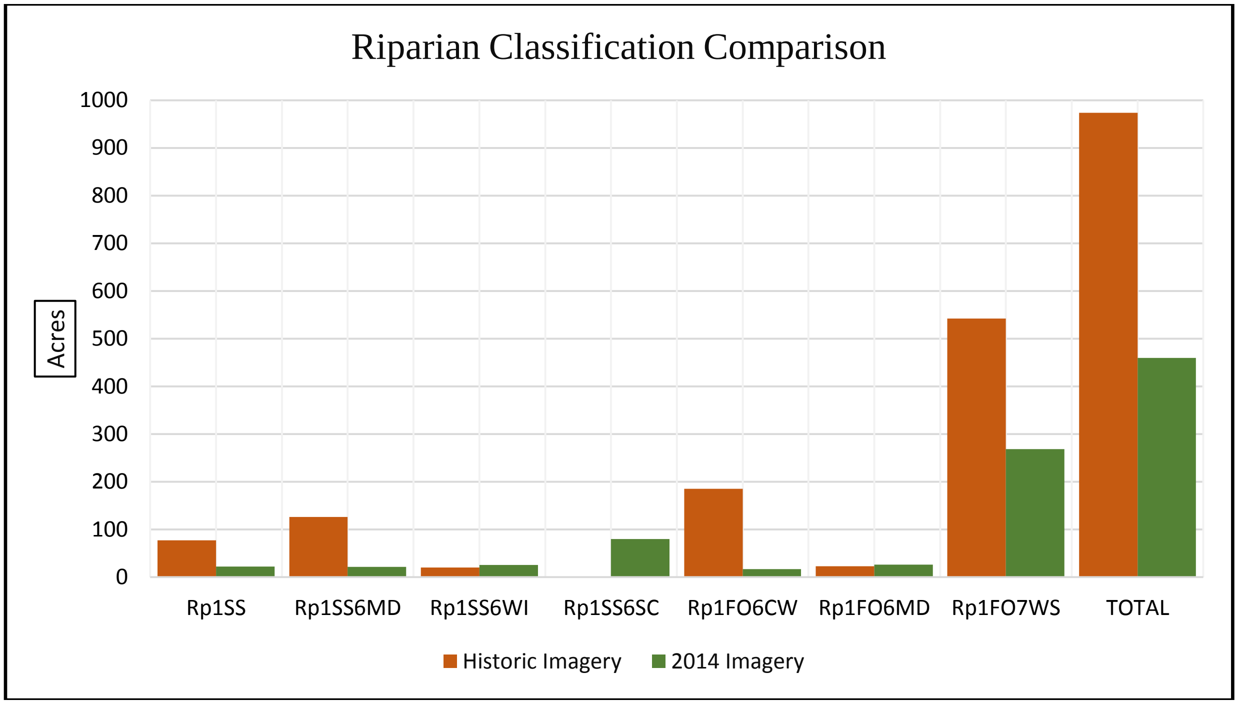

Figure 9. Summarized riparian acreage by classification and the total mapped riparian acreage is shown in this graphic.

consultation with a SME professional image interpreter.

The historical black and white imagery also provided a significant challenge when determining various riparian classification codes, especially at the Subclass and Dominance Type levels. In these cases, a best professional judgement was made to determine classifications. The development of image signatures early in the project in addition to consultations with other professionals familiar with the area did provide effective assistance in this regard.

The use of hard copy images and stereoscopes may provide an alternative method and possibly more accurate reading of various vegetation types when black and white imagery is used. This would require familiarity with that method, often used by photo interpreters in the past. The researcher also found that a greater effort to improve the historical imagery with better image manipulation and georeferencing techniques may be of benefit.

Efforts that did not occur in this research may improve the quality of data collection efforts in future riparian mapping. This includes the development of image interpretation conventions with the added benefit of visiting a percentage of riparian areas first hand, otherwise known as "ground proofing." This process provides an opportunity to verify typical or atypical image signatures after an initial review of project imagery. In addition, a post-mapping evaluation to review questionable delineations or classification decisions during a follow up field trip may be beneficial. Input from regional experts most likely would provide expertise unique to a particular study area. When these additional steps are completed errors may be reduced and the quality of the data increased.

Conclusion

This study conducted an analysis of riparian change over time in select waterways of the Cimarron River. While the study did not find significant differences in the number of features for riparian areas between the historical and 2014 imagery, there was an overall decrease in the extent of riparian acreage. Changes in the composition of riparian vegetation were also observed, such the presence of salt cedar (*Tamarix sp.*), an invasive species readily seen in the 2014 imagery.

Salt cedar (*Tamarix sp.*) was introduced to the Southwest as a means of stabilizing stream banks during the mid-part of the 19th century. The shrub is a growing problem for water resource managers in New Mexico. This nonnative and invasive vegetation thrives in places where native cottonwood trees and willow shrubs were found in riparian areas in the past. Salt cedar is drought tolerant, outcompetes native riparian vegetation and is known to affect water hydrology. The salt cedar shrub is also listed as a Class "C" noxious weed in the state of New Mexico (USDA, 2014). The shrub is very difficult to control although several mechanical, herbicide and biological controls have been attempted. The 2014 imagery displayed several areas where salt cedar had taken hold within the riparian areas (Figure 10).

Figure 10. This 11 acre riparian feature is comprised of salt cedar and was found along the Cimarron River in the 2014 imagery. Salt cedar is a noxious weed in New Mexico and was not observed in any of the historical imagery

Loss of willow areas in riparian areas continues to be another area of concern. This native shrub is important for the survival of beaver along waterways in New Mexico. The southwestern Willow flycatcher (*Empidonax traillii extimus*) is an endangered bird which is also known to use dense riparian areas where either willow or salt cedar are located. Management or restoration of riparian vegetation in New Mexico must consider the needs of all wildlife utilizing the riparian habitat.

Changes in the extent of riparian areas included an increase in vegetation fragmentation. While this research did not intend to determine reasons for riparian change in the study area, future analysis using aerial imagery in a geographic information system will provide natural resource managers with a point in time record and the opportunity to create and monitor current management efforts.

Natural resource managers may use aerial imagery from the past and present to monitor changes in a landscape over time. This may alert managers to losses in riparian vegetation important to healthy waterways or perhaps the extent of introduced or invasive species. These efforts will assist conservation professionals working to improve the wetlands, rivers, and riparian areas of New Mexico.

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