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Impacts of Environmental Changes to the Middle Rio Grande Landscape on Ysleta del Sur Pueblo's Cultural and Cermonial Sustainability

Andrea L. Everett

University of Texas at El Paso, aleverett2@miners.utep.edu

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IMPACTS OF ENVIRONMENTAL CHANGES TO THE MIDDLE RIO GRANDE
LANDSCAPE ON YSLETA DEL SUR PUEBLO'S CULTURAL AND CEREMONIAL
SUSTAINABILITY

ANDREA LEE EVERETT

Master's Program in Environmental Science

APPROVED:

Deana D. Pennington, Ph.D., Chair

Thomas E. Gill, Ph.D., Co-Chair

Timothy W. Collins, Ph.D

Charles Ambler, Ph.D.
Dean of the Graduate School

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Andrea L. Everett

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Dedication

This work is dedicated to my Pueblo (Ysleta del Sur Pueblo), the elders and ancestors for their commitment to the legacy of the Tigua community and their support of my studies.

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LANDSCAPE ON YSLETA DEL SUR PUEBLO'S CULTURAL AND CEREMONIAL
SUSTAINABILITY

by

ANDREA LEE EVERETT, B.S.

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for the Degree of

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Abstract

Given future climate scenarios, this thesis investigates how plausible climate changes will further impact the Native American community of Ysleta del Sur Pueblo's (Tiguas) cultural continuity and access to riparian ecosystem services along the Rio Grande River (specific to Tigua tradition; riparian vegetation used in ceremony, i.e. Gooding's and Coyote willow). The project aims to (1) describe and understand the relationship between regional climatic changes, anthropogenic changes, and major events in Tigua history, (2) identify rates and patterns of riparian vegetation changes, (3) evaluate impacts on cultural and provisioning ecosystem services relevant to Tigua culture, and relate these to climate and anthropogenic drivers, (4) project future patterns of cultural and provisioning ecosystem services under several potential scenarios of climate change, and (5) illustrate past, present, and potential future interconnections between external drivers, regulating services, and outcomes related to human behaviors, habitat structures, and ecosystem functions. The approach was to use satellite imagery and geographic information systems (GIS) to quantify past patterns of land use/land cover (LULC) change from 1973 to 2013 especially focused on changes in the riparian zone, and qualitatively assess how these patterns might continue into the future along with the implications for the Tigua Tribe. Five LULC classification maps were constructed to identify rates, patterns and drivers of vegetation changes, using Palmer Drought Severity Index (PDSI) to select times representing differing climatic conditions, at roughly 10 year intervals. The classified maps were used to quantify and map long term land cover change, specifically in the broader context of climate change. Through various analyses, statistical patterns were calculated on each classified landscape and were compared to each other through time to reveal LULC change. LULC change analysis revealed there has been a steady decline in the riparian landscape for the past 40 years. LULC change analysis also revealed that anthropogenic influence on the landscape has had a significant effect on Tigua society. Resource intensive landscape modification for agriculture, border protection, water impoundment and rock quarrying have had feedbacks on the decline in riparian ecosystem. Vital plants are dwindling with inadequate habitat conditions needed for survival. Land cover types such as barren, shrubland, and urban are expanding, leaving fewer places for collection of critical plant species necessary to sustain Tigua culture. If habitat locations, volume, and capacity of these species change, Tiguas will not be able to perform a variety of ceremonies needed for the sustainability of the Pueblo and traditions will be severely compromised.

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Introduction

Motivation

Changing world climate is expected to bring abrupt and dramatic changes to weather events, landscapes and ecosystem functions, and to impact society as a whole through alterations in the global economy. Native Americans are much more vulnerable to climate change events than other communities, as stated in the 2011 National Wildlife Federation report, “Facing the Storm: Indian Tribes, Climate-Induced Weather Extremes, and the Future for Indian Country,” (p. 4):

“Tribal communities are particularly vulnerable to increasing weather and climate extremes. Indian Tribes often have a close connection to the land for economic development, sustenance, and for maintenance of cultural traditions, so changes to natural systems impact them more directly than the general population. In addition, high rates of poverty and unemployment on reservations mean that Tribes have limited resources to help their populations deal with weather and climate extremes, much less to adapt to a changing climate over the long term. Finally, because Tribes are restricted by reservation boundaries, their attachment to the land, and off-reservation treaty rights, moving to new areas to accommodate climate shifts is not a viable option.”

Land change science has materialized as a vital component of global environmental change and sustainability research. This interdisciplinary field seeks to understand the dynamics of land use/land cover (LULC) change as the result of a coupled human-environment system to address theory, concepts, models, and applications relevant to environmental and societal problems, including the intersection of the two (Turner and Gardner, 1991).

The purpose of this project is to analyze past, present, and projected future natural and anthropogenic changes to the middle Rio Grande river bank or floodplain (riparian) landscape, and assess how these changes impact the Tigua indigenous community's ability to sustain cultural identity, continuity and access to ecosystem services. The project study area is located in the arid Southwest of North America, in an area receiving approximately 25 centimeters of precipitation per year (Figure 1). Climate change models indicate that there is likely to be reduced precipitation in this area in the future, with increasing variability in extreme events (Cook et al., 2015). In addition, anthropogenic development and disturbance has incurred substantial change to the riparian landscape (Patten, 1998). Recent drought combined with an increase in demand for water due to population growth has led to reduced water flow in the river bank and riparian areas, with associated reduction in ecosystem services provided by those areas (Palmer et. al, 2009). The Tigua have historically acquired key cultural services from the riparian landscape, for example, access to certain vegetation species used in traditional ceremonies (Gooding's and Coyote willow). This project describes the changing landscape through time and potential impacts of those changes on aspects that are important to the Tigua community.

Study Area

The project study area (Figure 1) is located alongside and north of an approximately 230 kilometer long reach of the middle Rio Grande, near the USA-Mexico border from Hatch, New Mexico to its confluence with the Rio Conchos at Presidio (Texas). The upper portion of the study area includes urban areas in New Mexico (Las Cruces), Texas (El Paso), and Mexico (Ciudad Juarez), as well as Ysleta del Sur Pueblo (YDSP), home of the Tigua Tribe. The lower portion, known as Ojinaga (Chihuahua), is commonly referred to as the "forgotten stretch" (Gates et al., 1992) and includes uninhabited Tigua aboriginal land. The forgotten stretch of the

Rio Grande has been poorly studied scientifically, with only a few biological studies (Rodriguez, 2010) and a few studies using remote sensing and GIS to map invasive species (Landis, 1998).

Various non-governmental organizations as well as the U. S. Department of Interior and the International Boundary and Water Commission have concerns about the current and future ecologic conditions of this portion of the Rio Grande (Landis, 1998). As of 15 years ago, the flows through the “forgotten stretch” are only one quarter of the annual quantity present prior to the construction of Elephant Butte Dam in 1915 (Landis, 1998).

PROJECT STUDY AREA



Figure 1: Project Study Area. Tigua land (YDSP) is indicated by green boxes.

Climate Change

Climatic changes, such as severe prolonged droughts (megadroughts) observed in the past in the American Southwest, are among the most destructive of all extreme climate events, contributing to wildfires, crop failure, wildlife loss, livestock death, food shortages and famine (Redsteer et al., 2013). Droughts in the Southwest are expected to be longer, more frequent and hotter in the near future (IPCC, 2014). Recent climate models indicate that the Southwest can be expected to undergo additional megadroughts within the next 20 to 50 years (Loveland et al., 2012; Cook et al., 2015). Effects of droughts are pervasive. Future temperature increases and corresponding increases in evaporation mean that many land areas will become drier in the coming decades, especially if emissions intensify. Indeed, climate projections indicate that the North American Southwest may transition to a more arid climate on a permanent basis over the next century and beyond (Jones and Gutzler, 2016), partially due to an expansion of the semi-arid climate of Mexico northward (IPCC, 2014). Recent climate observations indicate that this alteration may already be underway (Walther et al., 2002; Seager et al., 2007).

Anthropogenic Riparian System Changes

The Rio Grande Canalization Project, authorized by the Act of June 4, 1936, imparts flood protection against a 100-year flood and pledges releases of waters to Mexico from the upstream reservoirs in agreement with the 1906 Convention between the United States and Mexico (Landis, 1998). The Act approved construction, operation and maintenance of dams and associated irrigation works in accordance with the plan in the Engineering Report of December 14, 1935 (Knight, 2009). The area was converted into a major irrigation system from 1904-1965 (including irrigation infrastructure, flood control, advent of water laws and changes in transportation systems) (Knight, 2009). The development of the Rio Grande Project has

dramatically altered the natural hydrograph of the Rio Grande (Landis, 1998). As stated above anthropogenic influence on riparian ecosystems continues to occur, as humans manipulate these areas by using and managing land and water and by eradicating plant and animal species (Patten, 1998). Moreover, development of natural resource intensive industries (i.e. agriculture) have both direct and indirect effects on species richness, arrangement, composition, and productivity of riparian ecosystems (Patten, 1998). There are only a few western rivers that are free-flowing, because of dependence on the control and delivery of water (Patten, 1998).

In 1993 the Rio Grande was named “The Most Endangered River in North America” by American Rivers, Inc. (Finch and Tainter, 1995). Despite careful water management, several of the Southwest’s rivers and reservoirs, including the Rio Grande, are suffering historically low water levels and forecasts point toward this trend continuing (Hargrove et al., 2013). These changes will include a shrinking river and more evaporation. This will mean that water managers will need to reduce water intensive land use practices, which will definitely impact agriculture (a tradition in the Upper and Lower Valleys of El Paso County and southern New Mexico), and the economic and social costs to the region are likely to be high.

Impacts at the Intersection of Climate and Anthropogenic Change

The combination of climate and anthropogenic change has led to significant threats to water sustainability in the Middle Rio Grande River region, as argued by Hargrove et al. (2013, p.1):

“Such as (1) increasing salinization of surface and ground water, (2) increasing water demand from a growing population in the El Paso/Ciudad Juarez area on top of an already high base demand from irrigated agriculture, (3) water quality impacts from

agricultural, municipal, and industrial discharges to the river, (4) changing regional climate that portends increased frequency and intensity of droughts interspersed with more intensive rainfall and flooding events, and (5) disparate water planning and management systems between different states in the U.S. and between the U.S. and Mexico. In addition to these challenges, there is an increasing demand from a significant regional population who is (and has been historically) underserved in terms of access to affordable potable water.”

Given all of these conditions and predicted climate change scenarios, it is imperative that the Tigua better understand the processes and drivers of these changes and how the Tribe will be impacted. Historically, during episodes of severe climate change Tribes adapted by relocating, such as the six-year uninterrupted drought that occurred over the Puebloan region and Great Plains during the mid-17th century. The Spanish documented its impacts which included famine, disease, mortality, and village abandonment (Cook et al., 2007). However, modern geographic boundaries of reservations and resource availability restrict Tribal options for relocation, limiting opportunities to move to areas where climate change impacts are not as severe. Tribal rights to access resources on aboriginal and accustomed areas outside of reservation boundaries are place-based regardless of climate-induced shifts in resource availability. This means that these traditional and aboriginal lands are a combination of the physical landscape and also part of the narrative of cultures that have meaning by the human experiences in them (Semken, 2005). This leaves Tribes in a position where they may no longer have access to important subsistence, medicinal, and cultural resources (National Wildlife Federation, 2011). In particular, the Tigua people depend on several plants for cultural purposes including Gooding’s Willow (*Salix gooddingii*), Coyote Willow (*Salix exigua*) and Chamizo (*Atriplex canescens*). To date there has

been no prior research on environmental change as it impacts these resources, and hence, the Tigua people.

Background

History of the Tigua

The Tigua Indians of Ysleta del Sur Pueblo (YDSP) are a federally recognized Native American tribe and sovereign nation. In 1682, the Tigua settled and established the YDSP and built the canal system that sustained a thriving agricultural based community, supported by the Rio Grande River system. However, due to a number of historical and political events, the majority of tribal land was lost. The Tigua continue to live in the area (Figure 1), but access to natural resources has been limited or in some cases is entirely absent, resulting from anthropogenic and natural factors (Wright, 1993).

The Tigua's original homelands are in Quarai Pueblo (now Salinas National Monument), located in east central New Mexico. Prior to 1680 Salinas was home to 3 pueblos: Abo, Quarai and Gran Quivera. Due to a megadrought in the 1670's that rendered Quarai uninhabitable, the Tigua sought refuge at Isleta Pueblo, NM. A group of approximately 400 Tigua was later captured by the Spanish during the 1680 Pueblo Revolt. They were forced to walk approximately 400 miles south. In 1682, the Tigua settled and established the Pueblo of Ysleta del Sur (YDSP) and built the canal system that sustained a thriving agricultural based community that was supported by the Rio Grande river system.

Today, YDSP has an enrolled population of over 3,000 tribal members. The collective reservation lands comprise two housing communities, Ia Kitu (Corn Village) and P'a Kitu (Pumpkin Village) and several tracts near the Ysleta Mission and Hueco Tanks. Other tribally-owned lands include the 70,540 acre Chilicote Ranch near Valentine, Texas at the southern end of the forgotten reach of the Rio Grande.

Ecosystem Services

Ecosystem services are the benefits provided by ecosystems that contribute to making human life both possible and worth living. They assign a value to land and resources that is not a monetary amount but instead is in terms of cultural, biological, or other kinds of value (Binder et al., 2013). The ecosystem services methodology is a powerful framework, one of many that can be used to examine natural and human interactions, and while frequently applied in ecological studies, has rarely been applied in landscape research and management (Cossio et al., 2012). The usefulness of the ecosystem services approach to the analysis and management of cultural landscapes should be reviewed more critically; conventional ecosystem services assessment needs to be complemented by socio-cultural valuation. The Rio Grande river is a reflection of social principles of different ethnicity groups and cultures living along it, the dependence of its waters, lands and biotic resources are intertwined in the lives of the people and the economies that are created within this landscape (Finch and Tainter, 1995). Cultural landscapes are inherently changing, so that a dynamic view on ecosystem services and a focus on drivers of landscape change are needed; and also that managing landscapes for ecosystem services provision may benefit from a social-ecological resilience perspective (Plieninger et al., 2014). The LULCC analysis outputs data but it also tells a story of the events and key changes that are occurring on the land.

Political Aspects of Access to Ecosystem Services

The Tiguas served the Spanish, Mexican and American governments by protecting the Rio Grande communities from outside Indian rebellion, which included Apache and Comanche

raids (Houser, 1970) from 1680 until 1881, which in turn provided them with being left to continue their culture and way of life within their land. In March of 1751, the King of Spain acknowledged the Ysleta del Sur lands through a grant of four leagues or 36 square miles, and for a period of 100 years the Tiguas avoided infringement upon its land (Houser, 1970). Unfortunately, this land grant was ignored, and in 1871, illegal incorporation of Ysleta del Sur into the Town of Ysleta occurred. This resulted from the distance of the Pueblo from other New Mexico Pueblos (Houser, 1970), and USA President Abraham Lincoln not granting the Pueblo a cane (which he did as an acknowledgement of the sovereignty of New Mexico's 19 Pueblos in 1863) because the Pueblo was located in a Confederate state (Comar, 2015). This caused the majority of the Ysleta del Sur land grant to be lost and Tiguas were removed from their land because they could not produce a land deed (Comar, 2015).

Loss of land leads to loss of culture (Briody et al., 2016), and although the Tiguas had already been somewhat assimilated, just 30 years after the incorporation of the town of Ysleta, only remnants of the Clan and Moiety system of Ysleta del Sur were visible (Houser, 1970). By the 1920's many Tribal dances were not being performed, which included the Balle de Olle (Water Jar), the Awelo (Grandfathers) and the Portidado (Carnival) dances (Houser, 1970). By the 1950s, many rabbit and deer hunts ceased (Houser, 1970). The last Tigua fluent speakers died in the 1930's and pottery making was declining by this time too (Houser, 1970). In recent years, YDSP has revived the Balle de Olla, deer and rabbit hunts.

Currently there is no tribal-owned land located contiguous to the Rio Grande, and the land close to the Rio Grande is separated by the border fence that was constructed in 2008, without regard to numerous environmental laws that included the National Historic Preservation Act, Native American Graves Protection and Repatriation Act, and the American Indian

Religious Freedom Act. This was approved by the acting Secretary of the Department of Homeland Security, who implemented a waiver empowering him to precede with construction of the border fence by federal statute (Gilman, 2012).

Climate Change Impacts on the Tigua

The Tiguas depend on the land and resources for their indigenous way of life and spiritual practices. The interconnected relationship that the people of YDSP have with the Earth and natural environment has been severely limited by climatic and environmental changes and other influences. A series of disasters among the pueblo societies of New Mexico in the seventeenth century, which included drought, famine, disease and Apache raids, led to profound population loss and surrender to Spanish missionary rule (Stahle and Dean, 2011). Future climate models indicate that the Southwest will experience another megadrought within the next 20 to 50 years, exposing the survival of the Tigua's culture to further risk (Garfin et al., 2014).

Landscape Change Impacts on the Tigua

A number of elements have contributed to the changes in land cover types and land use within the middle Rio Grande. These factors include both climatic and anthropogenic causes; however, in the last 50 years urbanization of the Tigua's exterior boundaries and sacred places has resulted in significant changes to the region and to the Rio Grande River. Landscape patterns have changed considerably with the construction of Elephant Butte Dam in New Mexico and the concrete lining of the Rio Grande in El Paso (Landis, 1998). Critical resources were essentially shut off and the landscape patterns were altered significantly.

The riparian landscape of the Rio Grande has been transformed severely by human activity, as have many other riparian landscapes in western North America (Patten, 1998). An

example of this vegetation is Gooding's Willow (*Salix gooddingii*) and Coyote Willow (*Salix exigua*), vital to Tigua ceremony and leadership, and without which ceremonial life and leadership authentication would be forever changed. These bastones or varas must be offered to the waters of the Rio Grande and are returned every year (Houser, 1970). This return is already artificial, as the Pueblo must request and pay for water from the El Paso County Water Improvement District No. 1, in order to perform ceremony. The Rio Grande has sustained a way of life for the Pueblo including agricultural food systems, indigenous economy and ceremony beliefs and practices that are rooted within the river system. Water flow is critical to these elements.

Throughout time, adaptations to changes in landscape have always been a part of the way of life of the Tiguas. Nonetheless the Tigua have managed to continue the collection of natural resource materials (e.g., water, plants, and minerals) to carry on the spiritual lifeways and connections to the river despite the changing environment, but it has become extremely difficult. Even during the nineteenth century, around the time of the United States Civil War, as loss of land and violence prompted some Tiguas to move to Zaragoza (Chihuahua, Mexico) and Tortugas, New Mexico, the principle reasons for these relocations transpired because of the desire to uphold and sustain their cultural identity. Moreover, the relationship with the land and river continued to be vital to the Tigua people (Comar, 2015). In modern times, anthropogenic and natural environmental factors as well as government controls of the river (Landis, 1998), have also resulted in limited or complete absence of access to natural resources for the Tigua that are critical to sustaining the tribe's cultural practices.

Approach

Given future climate scenarios, this thesis investigates how plausible climate changes will further impact Tigua community, cultural continuity and access to riparian ecosystem services along the Rio Grande River (specific to Tigua tradition; riparian vegetation used in ceremony, i.e. Gooding's and Coyote willow). The project aims to (1) describe and understand the relationship between regional climatic changes, anthropogenic changes, and major events in Tigua history, (2) identify rates and patterns of riparian vegetation changes, (3) evaluate impacts on cultural and provisioning ecosystem services relevant to Tigua culture, and relate these to climate and anthropogenic drivers, (4) project future patterns of cultural and provisioning ecosystem services under several potential scenarios of climate change, and (5) illustrate past, present, and potential future interconnections between external drivers, regulating services, and outcomes related to human behaviors, habitat structures, and ecosystem functions. The approach was to use satellite imagery and geographic information systems (GIS) to quantify past patterns of land use/land cover (LULC) change through time especially focused on changes in the riparian zone, and qualitatively assess how these patterns might continue into the future along with the implications for the Tigua Tribe. Five land use/land cover (LULC) classification maps across a period of 40 years were constructed to identify rates, patterns and drivers of vegetation changes to quantify and map long term land cover change, specifically in the broader context of climate change.

Methods

Data

Palmer Drought Severity Index (PDSI) and LULC data were combined to select specific dates for analysis following the methods of Turner (1991). The PDSI is an integration of monthly precipitation and temperature effects on available soil moisture, and it has proven to be a good model for assessing the effects of climate on tree growth at moisture-limited sites (Stahle and Dean, 2011). PDSI measures relative dryness or wetness using monthly temperature and precipitation to create conditional categories. Positive PDSI values indicate wet conditions and negative values indicate dry conditions (Soulard and Wilson, 2013). LULC data describe the earth's surface at a given moment in time and can be used to identify underlying processes that have contributed to the current landscape (Soulard and Wilson, 2013). Comparing generated LULC maps with PDSI values allowed this thesis to explore the relationships between land use and environmental conditions present at corresponding time periods and evaluate if land use practices contributed and if they are contributing to further degradation of the Rio Grande River in the study area.

PDSI data for the Trans Pecos region in Texas were obtained from the National Climatic Data Center (NCDC). The LULC study years were selected using PDSI so to have different climates represented in the satellite imagery. Open access Landsat satellite data for the study area were obtained via the United States Geological Survey "Earth Explorer" for five dates between 1973 and 2013 (Table 1). Five years were selected: 1973, 1984, 1993, 2002, and 2013.

All selected dates fall near the end of the monsoon (rainy) season for the region, which is typically June 15th through September 30th of each year (NOAA, 2016) and is the time of maximum vegetation productivity. The October 1984 image was selected because September

imagery was obscured by cloud cover. The selected image shows high greenness comparable to the September images. All selected years were at different levels of the PDSI (Table 1).

Table 1: Selected imagery dates, instrument source, and PDSI categorization on that date.

| DATE | INSTRUMENT | PDSI CATEGORY |
|-----------------------|---|---|
| September 1, 1973 | Landsat 1 Multi-Spectral Scanner (MSS) | Incipient dry spell Index value: -0.55 |
| October 28, 1984 | Landsat 5 Thematic Mapper (TM) | Moderately wet Index value: 2.23 |
| September 3, 1993 | Landsat 5 Thematic Mapper (TM) | Near normal Index value: -0.37 |
| September 20, 2002 | Landsat 7 Enhanced Thematic Mapper (ETM) | Severe drought Index value: -3.75 |
| September 2, 2013 | Landsat 7 Enhanced Thematic Mapper (ETM) | Moderate drought Index value: -2.85 |

Analysis

The five images were then individually processed to create composite images (Figure 2). Study years 2002 and 2013 required an additional processing step using a Landsat toolbox that eliminated scan lines on the images.

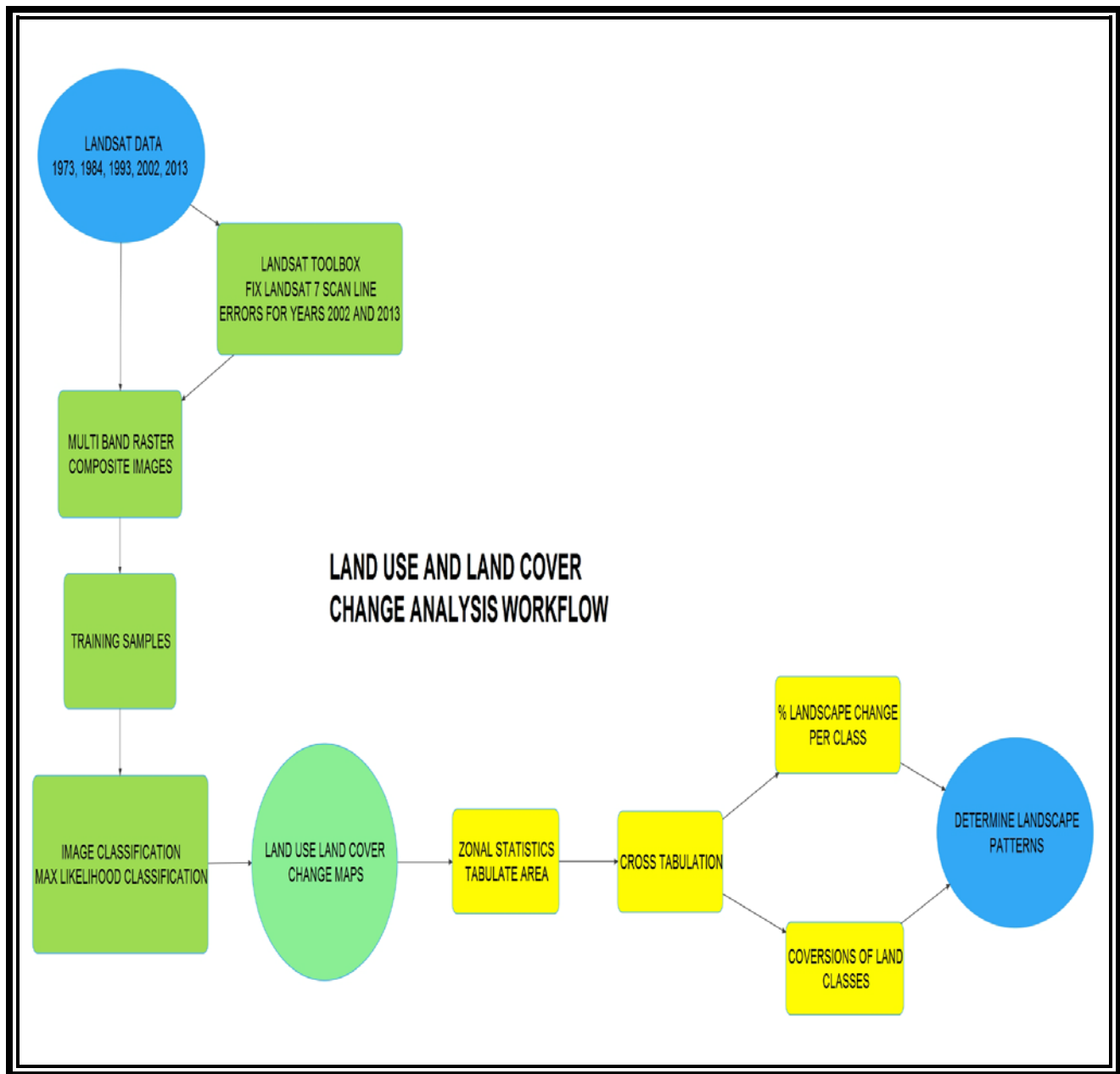


Figure 2: Workflow diagram showing major analytical steps.

Training samples were individually created for each composite image using ArcGIS 10.4.1 software. These were used to create a signature file for each composite image. Each image was then classified using the Maximum Likelihood Classifier, using the training samples and signature file. The output was five LULC maps, which were clipped using a five mile buffer around the Rio Grande River to limit the analysis to riparian and nearby areas (Table 2).

Table 2: Training Samples.

| Training Samples for Image Classification | |
|--|--------------------------|
| Categories | Number of Samples |
| Barren | 50 |
| Urban | 50 |
| Agriculture | 50 |
| Water | 50 |
| Riparian | 50 |
| Mixed Vegetation | 50 |
| Shrubland | 50 |

Zonal statistics, which calculates statistics on values of a raster within the zones of another dataset, were run to create a cross tabulation matrix between the years of 1973 to 1984, 1984 to 1993, 1993 to 2002 and 2002 to 2013. This function compares the values in each pixel of two datasets and outputs the number of pixels in each pair of categories (e.g. number of pixels with value 1 in both, value 1 in one and value 2 in the other, etc.). Hence, the cross tabulation matrix quantifies all of the changes between two times, including how many pixels changed, and what

values they changed from and to. The cross tabulation matrices were then used to determine percent of unchanged landscape overall and in each category, percent of land cover class in each year, percent of landscape change between years, percent of land cover type change per year and percent of conversion of land cover type to other type specifically riparian cover type. This was used to examine landscape patterns specifically within the riparian landscape portions of the images. The results of the LULC change analysis were then used to assess, qualitatively, potential impacts on ecosystem services specific to Tigua cultures and traditions. A variety of commonly used ecosystem service frameworks exist. These were reviewed and one selected that best framed the identified potential impacts. The selected framework was modified to better specify expected impacts on the Tigua.

Results

Land Use/Land Cover Change Analysis

Classified LULC Maps

The five images show overall increases in urban areas, barren and shrubland classes. Decreases in riparian land cover and decrease in agriculture and water are also evident.

1973 to 1984

Cross tabulation matrix calculations for the years 1973 and 1984, revealed a landscape that had remained 48.6% unchanged (Figures 3, 4, and 5). According to PDSI data 1973 was under an incipient dry spell and 1984 was moderately wet. (Figure 3)

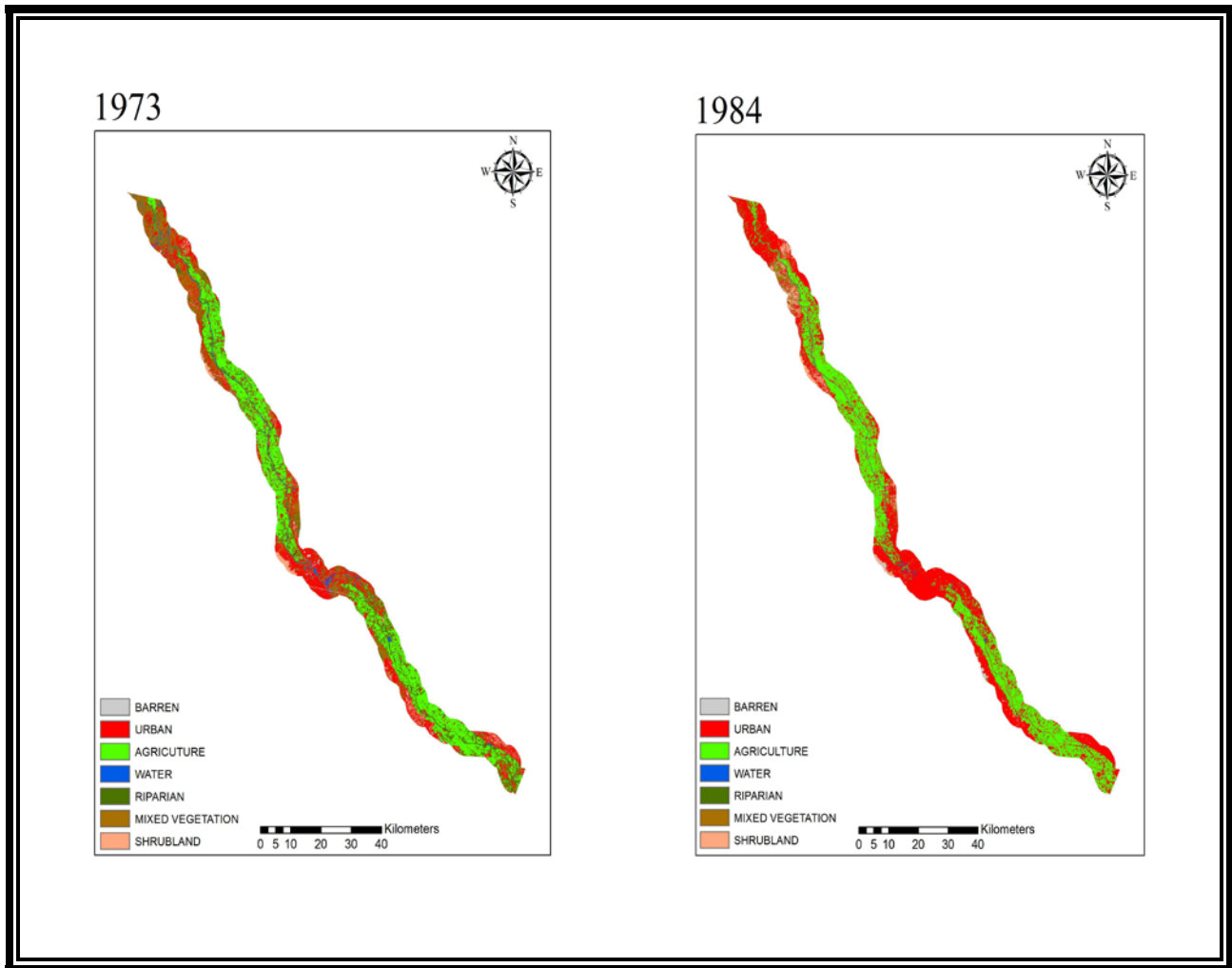


Figure 3: 1973 and 1984 LULC classified maps.

Barren land in both years comprised 1.2 and 1.3% of the landscape respectively, with urban land use increasing by 22% in 11 years, from 21% of the landscape to 44%, a significant increase. Agriculture increased by 6% from 34% of the landscape to 41% in 1984. Water area decreased by 1.5% and riparian and mixed vegetation both decreased by 14%. Shrub land increased by 4 %. The riparian landscape in 1973 converted to both agriculture (7.7%) and urban (5.6%) land use at a higher rate than other land cover types. Between 1973 and 1984, the riparian land cover type also converted to agriculture (.8%) land cover type and water (.2%) and mixed vegetation (.5%). Graphs for 1973 and 1984 are shown below (Figures 4 and 5).

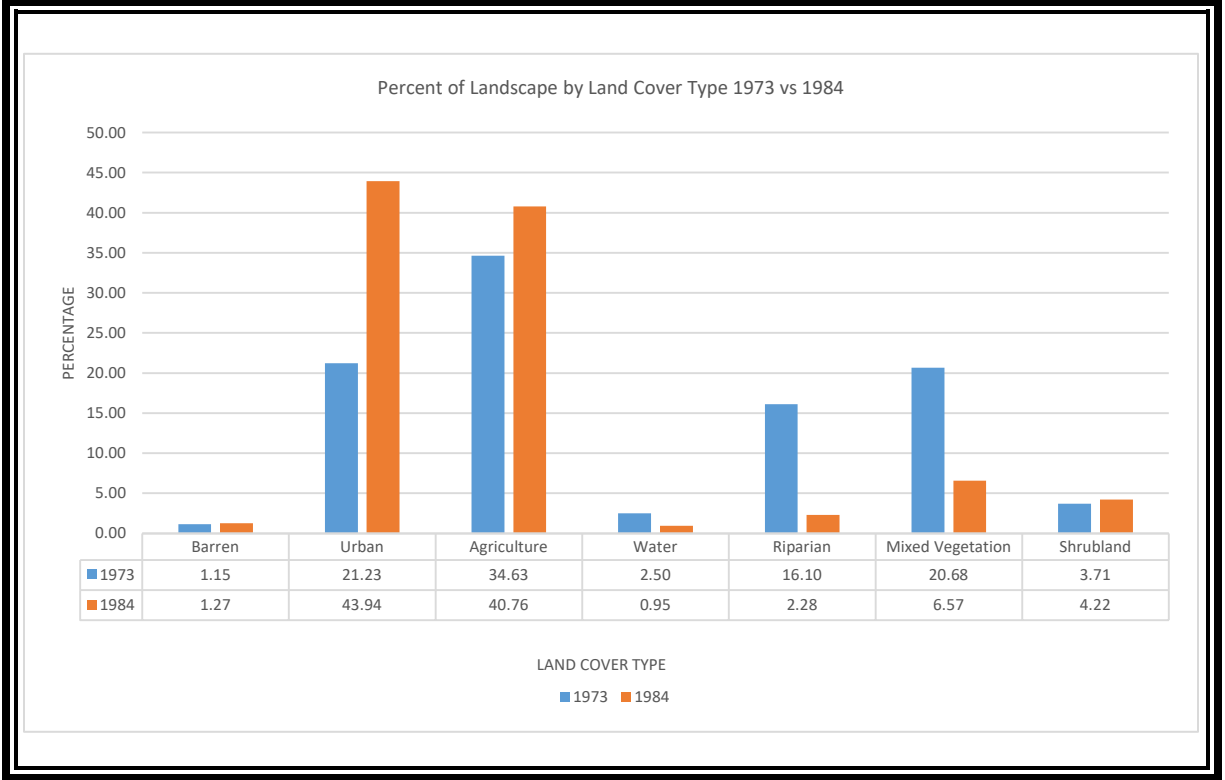


Figure 4: Percent of landscape by land cover type change 1973 vs. 1984.

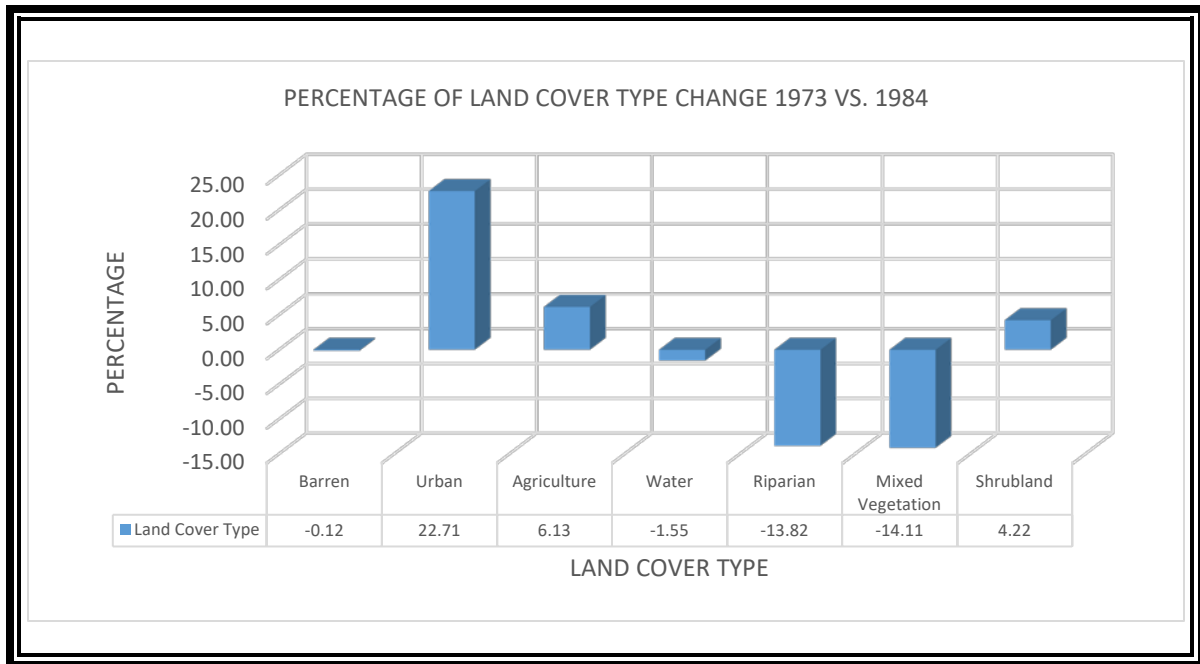


Figure 5: Percent land cover type change 1973 vs. 1984.

1984 to 1993

PDSI data categorizes 1984 as moderately wet and 1993 as normal. 51% of the landscape remained unchanged. (Figure 6)

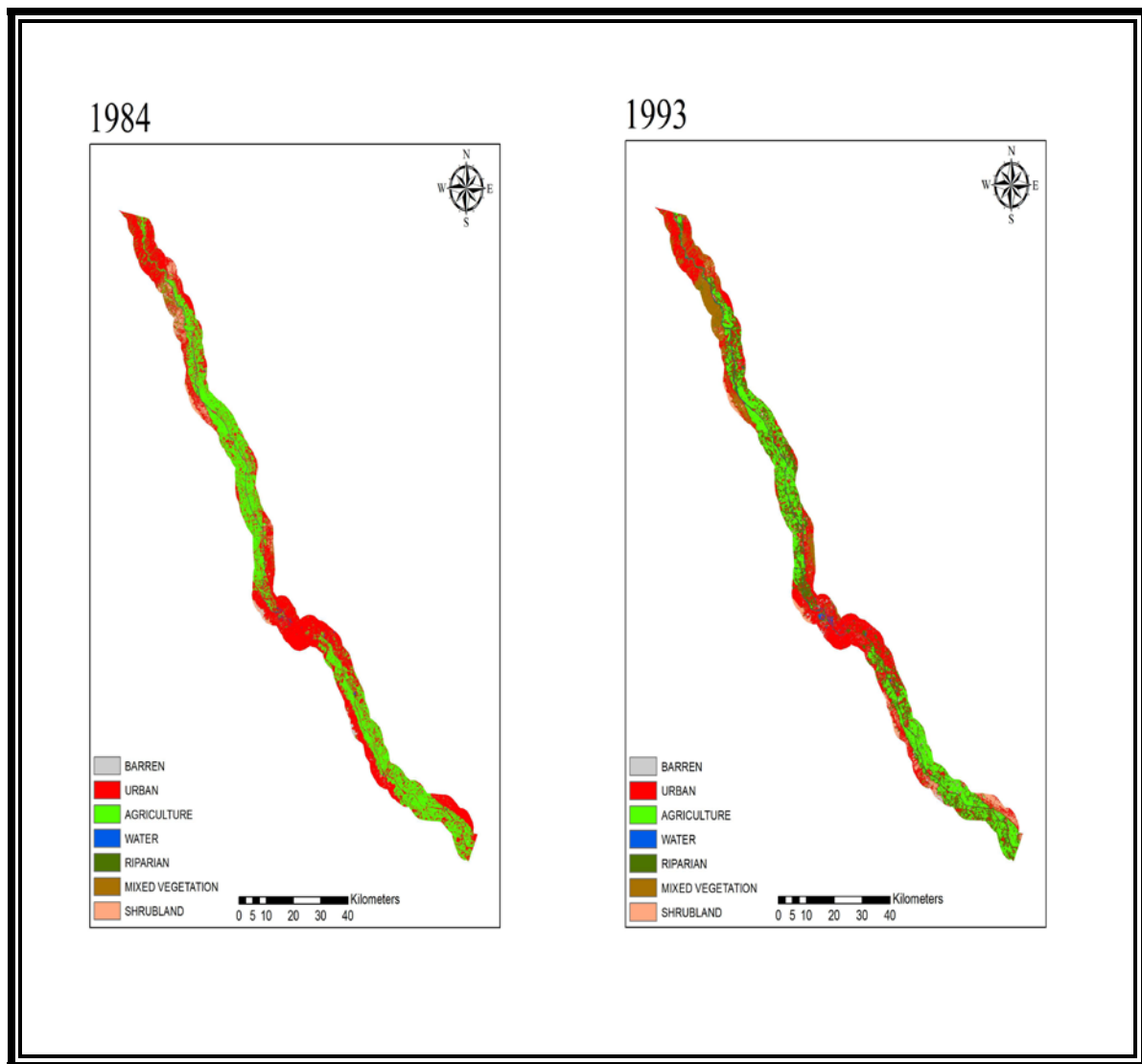


Figure 6: 1984 and 1993 LU LC classified maps.

Barren land in 1984

was 1.28% of the landscape with a 1.05% increase to 2.3% in 1993. Urban land use decreased 13% from 44% to 31%. Agriculture also had a reduction in land cover by 15.8% from 40.6% to 24.8%. Water increased by 0.6% from 0.9% to 1.5%. Riparian increased by 19% in 1993 from 2.3% to 21.6%. Mixed vegetation also increased by 7.8% from 6.5% to 14.3%. Shrub land slightly increased by .4% from 4.2% to 4.5%. When specifically targeting changes in riparian land cover from 1984 to 1993, riparian land cover converted most readily to agriculture land cover by 0.5%, urban 0.3% and mixed vegetation 0.4% in 1984. In 1993, riparian land cover transformed into agriculture (12.3%), urban (6.1%) and mixed vegetation (1.7%) (Figures 7 and 8).

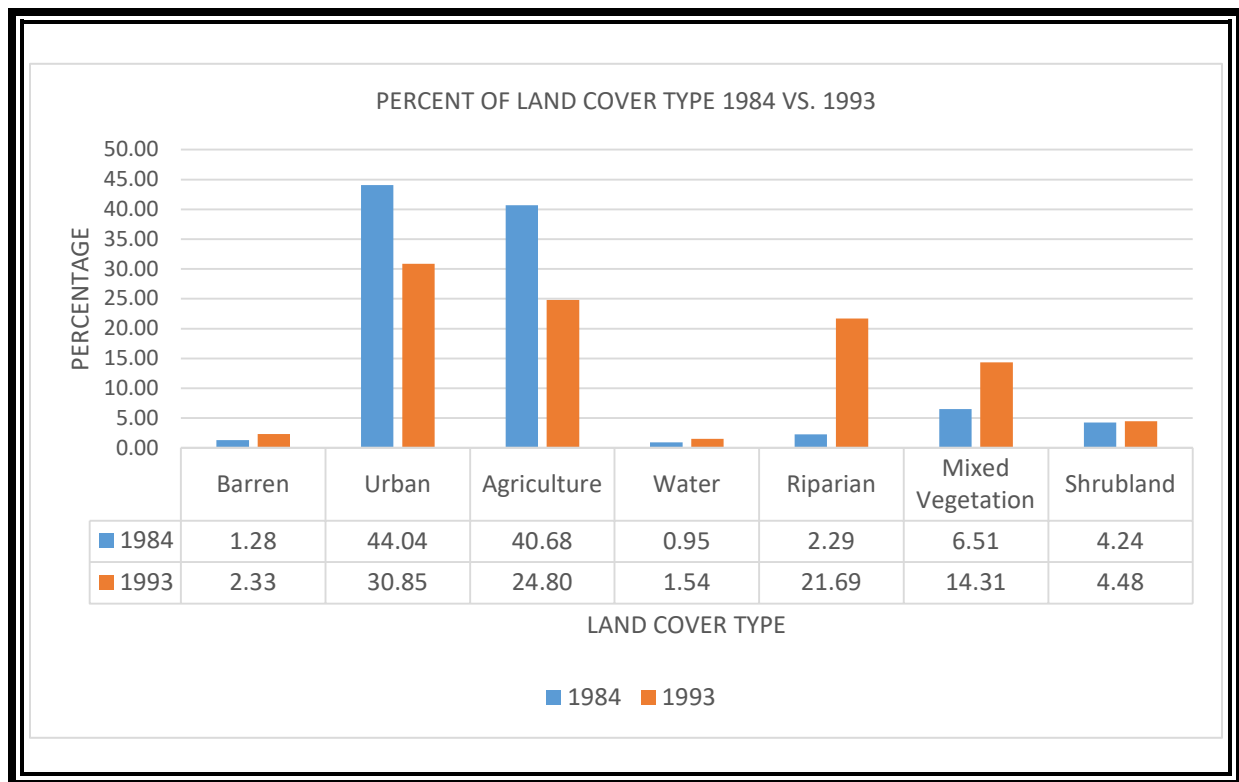


Figure 7: Percent land cover type 1984 vs. 1993.

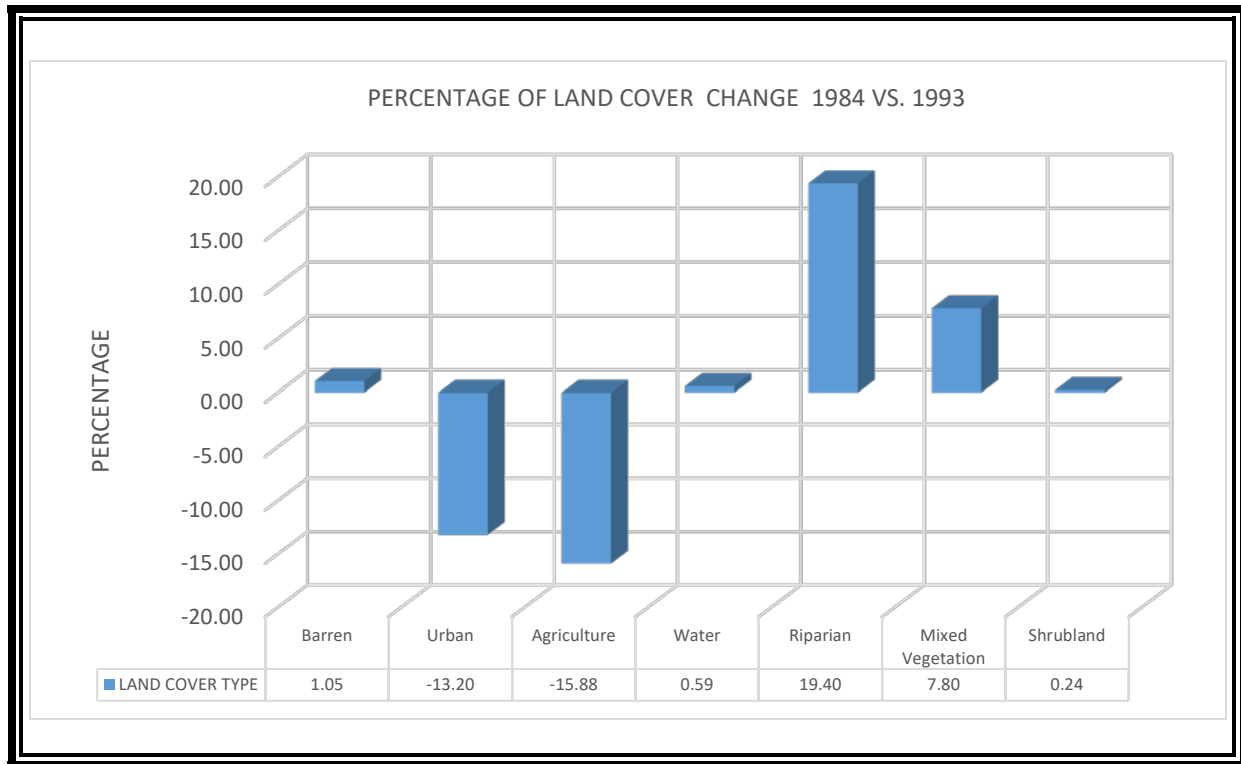


Figure 8: Percent of land cover change 1984 vs. 1993.

1993 to 2002

1993 was characterized as a normal year, while 2002 was described as a severe drought year. The drought was so severe that when the LULC was completed on the study area no water pixels were present. This resulted in a no data category for water within the cross tabulation matrix for 2002. 40.7% of the landscape remained unchanged. (Figure 9)

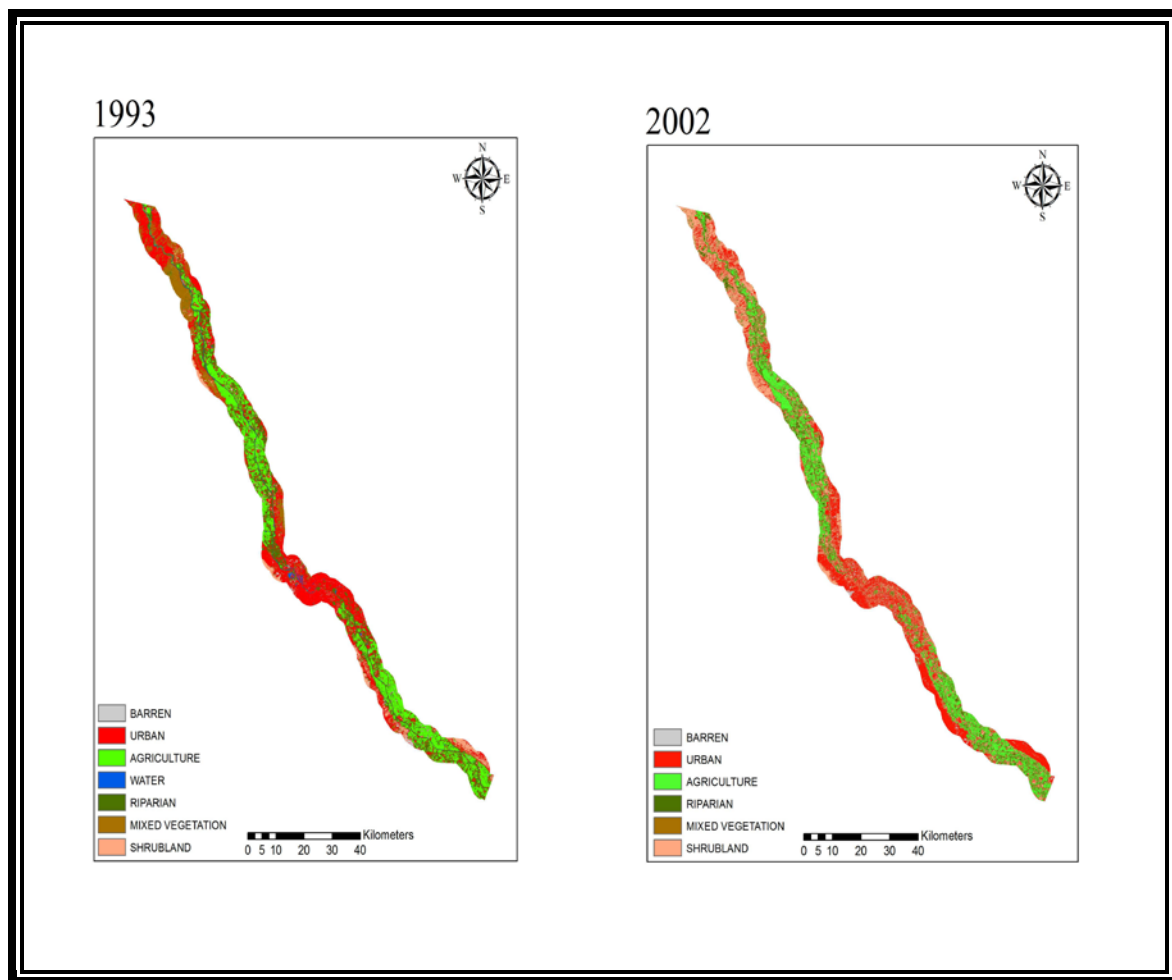
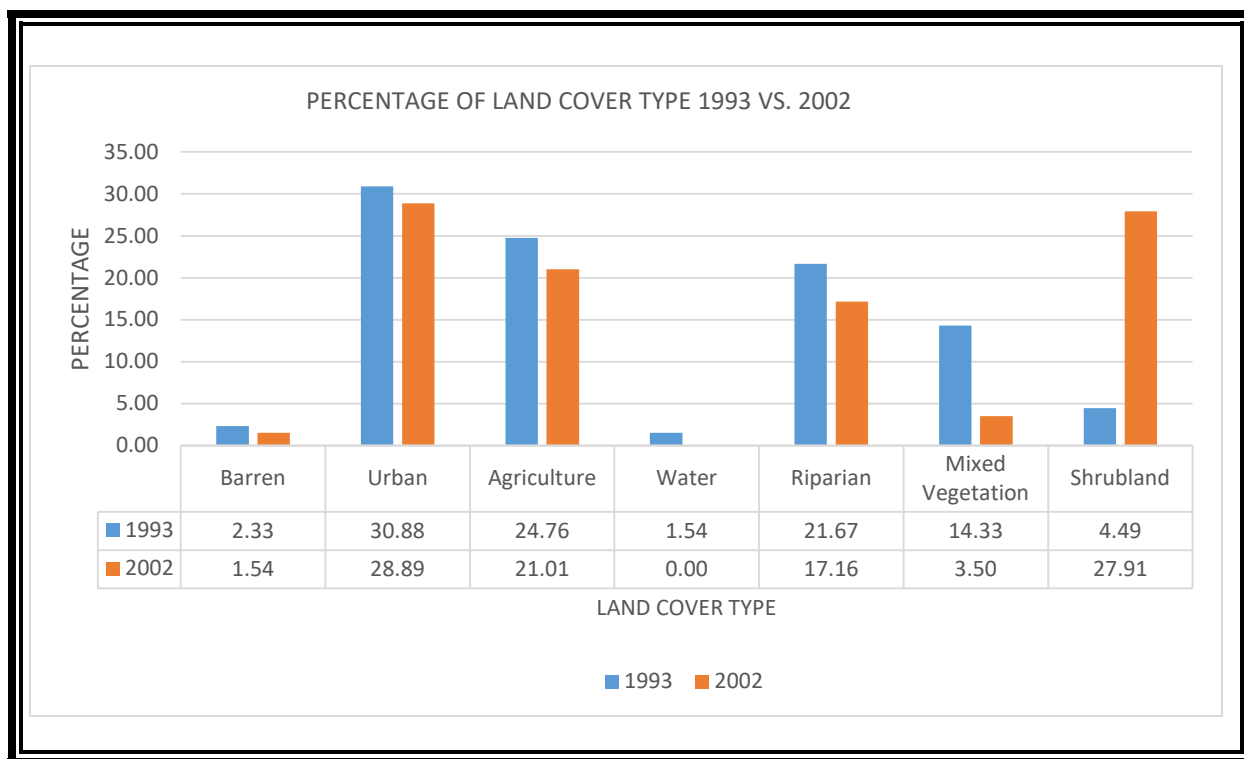


Figure 9: 1993 and 2002 LULC classified maps.

All land cover classes decreased except for shrubland. Barren land decreased by 0.8% from 2.3% to 1.5 %, urban decreased by 1.9% to 28.9% from 30.9 %, agriculture also decreased by 3.8% from 24.7% to 21.1%, water decreased by 1.54% from 1.54% to 0%. Riparian decreased by 4.51% from 21.6% of the landscape to 17.1%. Mixed vegetation had a significant decrease of 10.8% from 14.3% of landscape to 3.5%. Shrubland increased by 23.4% from 4.5% of the landscape to 27.9%. Looking specifically at the Riparian landscape between the years of 1993 to 2002, Riparian land cover type converted to Agriculture in 1993 by 4.3% and Urban by 2.8% and Shrubland by 6.25%, In 2002, Riparian cover converted to Agriculture by 5.2% and Mixed vegetation by 2.3% and to Urban by 1.6%. Figures with this data are shown below (Figures 10



and 11).

Figure 10: Percent land cover type 1993 vs. 2002.

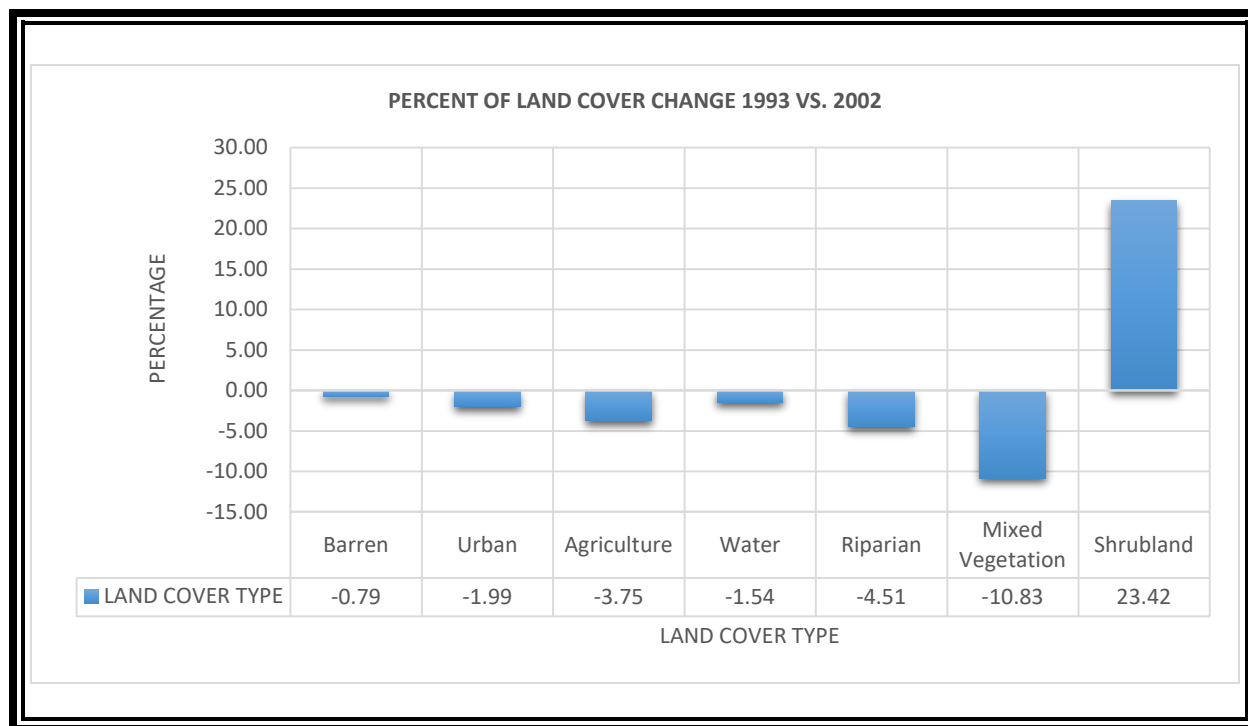


Figure 11: Percent land cover change 1993 vs. 2002.

2002 to 2013

By 2013, the region was categorized as in a moderate drought according to PDSI calculations. However, the landscape showed only 28.6% of the landscape had remained unchanged. (Figure 12: 2002 and 2013 LULC classified map below)

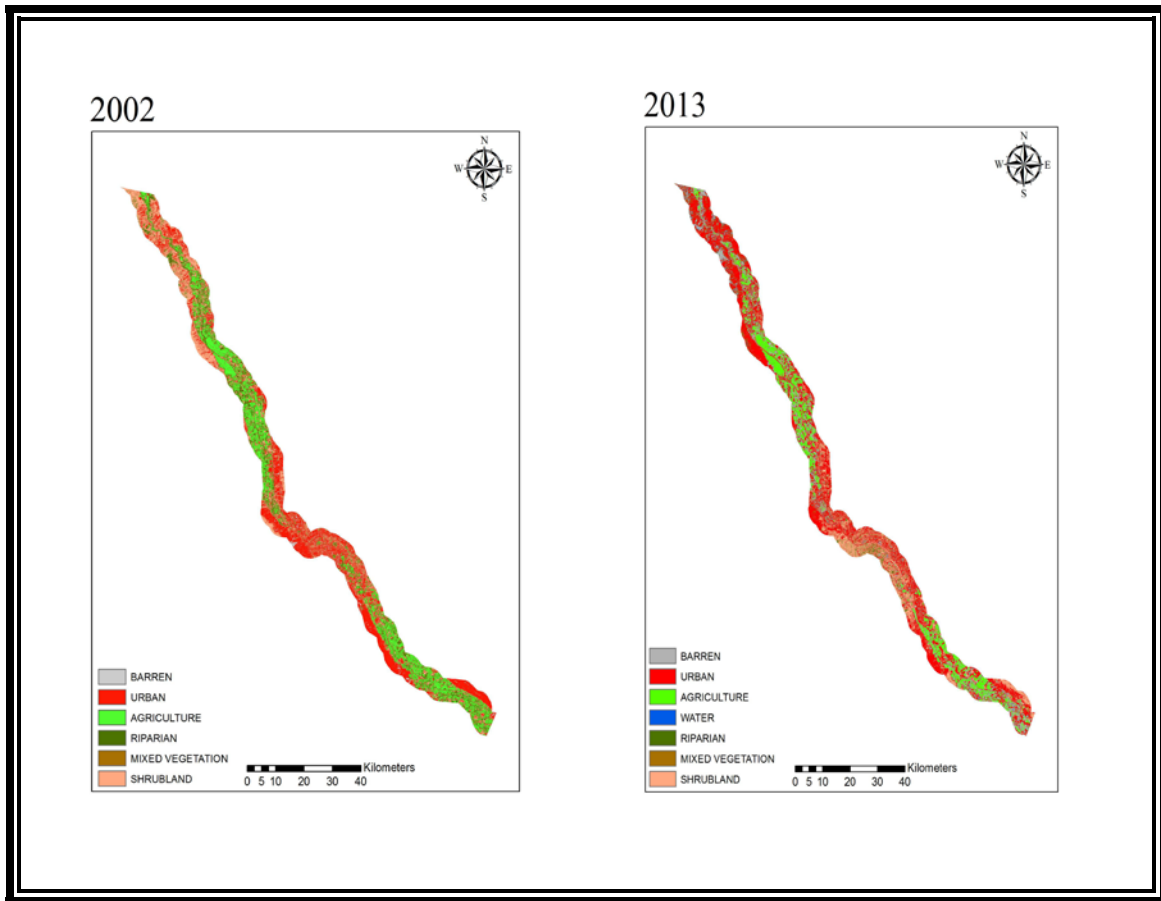


Figure 12: 2002 and 2013 LULC classified maps.

Barren land had increased 15.6% from 2002 to 2013 from 1.5% of the landscape to 17.1%.

Urban land cover continued to rise from 28.9% to 39.8%, an increase of 10.8%. Agriculture saw a decline of 5.5% from 21% of landscape in 2002 to 15.5% in 2013. Water increased by 2% from 0% in 2002 (severe drought). Riparian landscape continued its decline trend, with a 15% decline in land cover from 17.2% to 1.8% in 2013. Mixed vegetation seemed to have a 3.8 % rebound from 2002 from 3.5% to 7.28%. Shrubland declined by 11.4% after a significant increase during the severe drought in 2002. It went from 27.9% of the landscape to 16.5%. Exclusively looking at riparian land cover during this 11 year period, the trend of conversion from riparian land cover

to agriculture, urban and mixed vegetation held true. Tables with this information are shown below (Figures 13 and 14).

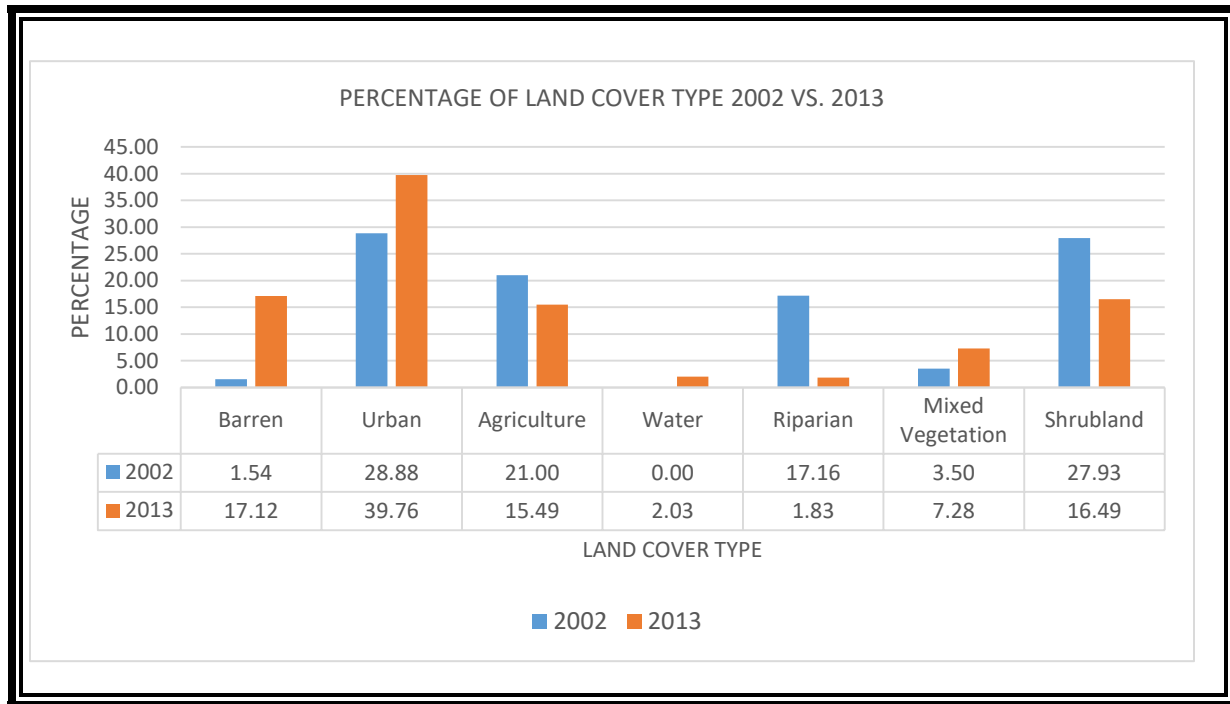


Figure 13: Percent of land cover type 2002 vs. 2013.

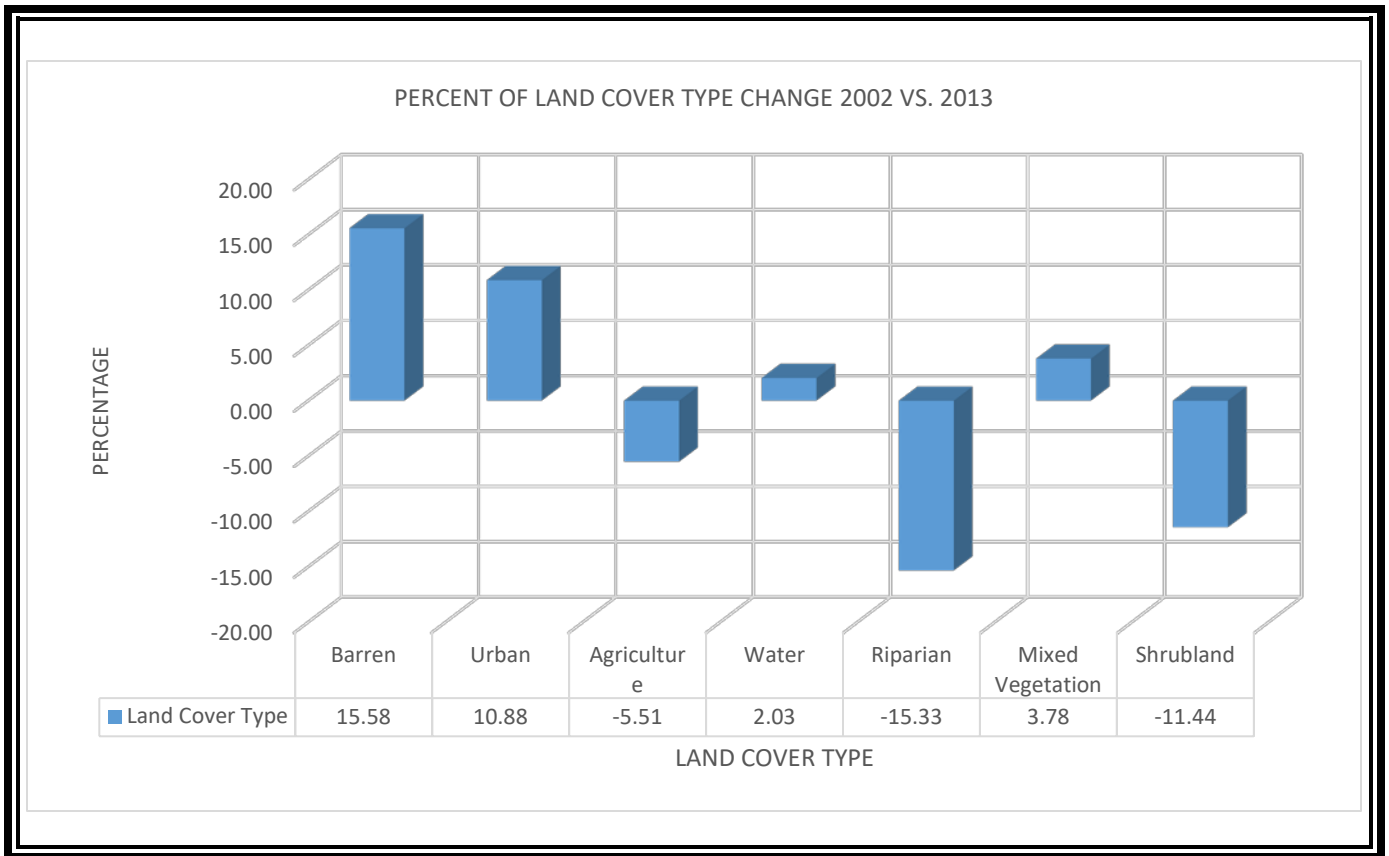


Figure 14: Percent land cover change 2002 vs. 2013.

Impact of LULC change of Ecosystem Services: Adaptation and Mitigation Options

Ecosystem services can form the critical linkage between social and biophysical domains and serve as the foundation for long-term, integrated, social–ecological research across scales (Schmidly and Ditton, 1978). After review and consideration of a variety of different ecosystem service frameworks that are in the literature, the Millennium Ecosystem Assessment (MEA) was selected for revision (Villa et al., 2014). Of all of the ecosystem frameworks available, MEA is the most widely utilized. It organizes ecosystem services into provisioning, regulating, cultural and supporting services (Erb et al., 2013). The revised framework concentrates on cultural and provisioning services and illustrates interconnections of human behaviors, outcomes, habitat structures, ecosystem functions, external drivers, and traditional ecological knowledge as they are all related to ecosystem services within the Rio Grande riparian systems (Figure 15). Tiguas use different riparian vegetation to assemble into spiritual materials used in dances and ceremony (cultural services). These plants require water flow (regulating services) and water availability (provisioning services) to maintain suitable conditions to survive.

Provisioning services provide for food and fresh water. Protection of provisioning services requires determining an environmental flow that permits river habitats to have sufficient volume to absorb ecological stressors. Within the “Forgotten Stretch” of the Rio Grande, the water flow is essentially shut off for approximately three-quarters of the year, not allowing for adequate riparian habitat needs.

Regulating services are those that allow standardized conditions for habitats to survive and flourish. Degraded water and lands are not sufficient for riparian vegetation to subsist.

Riparian restoration projects need to factor in the various natural and anthropogenic sources of land and water deprivation, as well as climate change.

Cultural services are vital to Tribal communities; changes in locations of access to culturally important species for hunting, gathering, collecting and ceremony such as Gooding's and Coyote willow are of critical importance. The LULC change analysis showed the trend that the riparian landscape is in severe decline and is converting into agriculture, urban, barren and shrubland. If the entities that help preserve way of life and culture are no longer accessible, a culture will not have the means to continue and survive. It is harder for Tribal communities to adapt to accessibility constraints since migration is no longer an option for most Native people (National Wildlife Federation, 2011).

Supporting services are those services that Native people have used since time immemorial. This includes Tribal Ecological Knowledge and how impacts of anthropogenic and climate change are interconnected; therefore a holistic approach must be employed to consider social, cultural and environmental factors.



Figure 15: Ecosystem services model.

River ecosystems are vital to communities around the world (Yan and Pottinger, 2013). An all-inclusive riparian ecosystem services development plan would be beneficial to not only the economic endeavors that rivers provide, but for fostering communal resilience to climate change (Yan and Pottinger, 2013). Developing a framework to demonstrate the importance of the Rio Grande to all adjacent communities, indigenous or not, is vital to the future of the river.

Thoughtful consideration of what it means to be interconnected to the cultural landscape of our lives is a difficult concept to define. The socio-environmental relationship that Tiguas

have with the landscape of their ancestors (current and aboriginal) is a manifestation of their cultural identity, economy and community through time and space. When using remote sensing to identify classes within the landscape, it was difficult to box the categories of land cover into something tangible -- as a Tigua I have a different relationship with the land than just what my scientific community tells me to see. The cultural definition of my relationship with the river made it difficult for me to not place my biases about the land on the scientific portion of this project. Many cultural groups have transformed the landscape to what their social constructions allowed them to see (Greider and Garkovich, 1994). The power of narrative in environmental networks is important (Wilder et al., 2015), however it is not a new concept, nor is it an incorrect concept to possess.

Traditional ecological knowledge has been passed down from generation to generation but it is severely compromised (Leclerc et al., 2013). It is a framework that includes people, their philosophies about the world and their cultural means of collecting, processing and transmitting information about the environment (Houde, 2007). The reason why traditional ecological knowledge is so compromised is because it is not being allowed to be dynamic and current relevance is being lost. As Tiguas have lost land, resources, and access to places that are sacred, culture has been negatively affected. Language was almost completely lost, if not for recent efforts to revive it. Dances that connect the Tigua people to the environment and ceremonies that take place at the river are being affected because of conditions of water (pollution) and scarcity of vegetation that is needed to perform (Landis, 1998).

Although culture is a human creation under continuous modification, this traditional ecological knowledge is grounded on close observations of the environment and natural

phenomena (Houde, 2007). However, as water flows are governmentally controlled and access to river amid national security takes precedence (Gilman, 2012) access to specific localities and landforms continues to oppress the Tigua culture because of differing western political and social thought.

Implications and Discussion

Local Scale, Historical Vegetation Change

As the LULC change analysis revealed there has been a steady decline in riparian landscape for the past 40 years. This represents a continuation of a long-term trend, as literature also reveals that this once majestic landscape of the Rio Grande has been in steady decline for the past century (Schmidly and Ditton, 1978; Engel-Wilson and Ohmart, 1978). These abundant habitats occurred historically along the Rio Grande wherever flooding ensued. These delicate ecosystems support significant amounts of wildlife species that are dependent on the riparian vegetation within these unique habitats. Anthropogenic misuse of the riparian habitats has transformed the riparian ecosystems of the southwest (Schmidly and Ditton, 1978), including the Rio Grande's Forgotten Stretch (Engel-Wilson and Ohmart, 1978). This is because of a combination of activities, such as livestock overgrazing, clear cutting for agriculture purposes, impoundment of water and other recreational activities (Patten, 1998).

By the 1970's, the majority of the original shoreline along the "Forgotten Stretch" of the Rio Grande had been wiped out, mostly due to several dams (Schmidly and Ditton, 1978). Within the El Paso region dam construction in New Mexico and the American Dam have resulted in significantly less water flow and flooding, all elements that riparian landscape need to survive and propagate (Dreesen et al., 2002). Examination of factors needed for riparian ecosystem recovery in arid lands (Seavy et al., 2009) is required in order to accurately assess resources that will be needed to support the continuance of Tigua ceremonies and traditions along the Rio Grande for future generations in a changing climate.

Regional Scale, Future Landscape Change

There has long been agreement that climate change will force some species to shift their geographic ranges, or face extinction (Sinclair et al., 2010). In arid lands worldwide, shrub-covered lands are expanding at the expense of other land cover classes, especially grasslands (Schlesinger et al., 1990; Reynolds and Stafford Smith, 2002), and is expected to intensify with climate change (Munson et al., 2013). Shrubland expansion impacts an arid landscape's resistance to soil erosion, ecosystem productivity, biodiversity, and hydrologic cycle, and is generally considered irreversible (Huxman et al., 2005; Peters et al., 2010). This phenomenon is very well known in the northern Chihuahuan Desert and its impacts have been documented in numerous localities (e.g., Baez and Collins, 2008; Peters et al., 2010; Ratajczak et al., 2012; Munson et al., 2013). Again the LULC change analysis corroborated recent literature of the expansion of shrubland, all study years had an increase in this land cover type, except for the most recent 2002 to 2013. However, the 1993 to 2002 time period had a 23% increase in shrubland because of severe drought conditions, the rest of the landscape rebounded in the next time period, which caused a slight decrease in shrubland.

A recent Species distribution model (SDM) study conducted at Northern Arizona University examined the impact that climate change may have on the availability of climatically suitable habitat for both *Salix gooddingii* (Gooding's willow) and *Salix exigua* (Coyote willow) (Ikeda et al., 2014). SDM studies incorporate future climate predictions to assess potential regional shifts in vegetation. SDMs may be constructed in a variety of ways and result in a range of outputs (Sinclair et al., 2010). The general approach involves creating models of temperature, precipitation, and other constraints on where a species is currently known to occur, and substituting future projections of temperature and precipitation from climate models to project

where comparable habitats will be in the future. Since different climate models and scenarios project different climate futures, SDM analysis of a species generates a range of different potential distributions of species.

Their results, using several different climate models, revealed that Gooding's willow was sensitive to both temperature and precipitation, with suitable habitat increasing with increasing temperature (to a certain limit) and decreasing with a surplus of precipitation (Ikeda et al., 2014). The results suggested that Gooding's willow would possibly gain 38% habitat by 2080 (Ikeda et al., 2014). In contrast, results from Coyote willow ranged from a total loss of 30% of habitat to a possible gain of 9% by 2080. With a change in climate up to 40% of suitable habitat could be lost between now and 2080. Both Goodings and Coyote willow show dramatic shifts in habitat location. The study area showed large losses of habitat covering the entire "forgotten stretch" of the Rio Grande. Habitats shifted north and east of the current range (Ikeda et al., 2014). The study also indicated that the range for these species would be affected by expansion of Salt Cedar (*Tamarix*). This is important because in the perspective of climate change and focus on restoration and conservation, it is important to control the spread of *Tamarix*, since the results revealed that habitats with larger swaths of *Tamarix* species, were more susceptible to losses in habitat (Ikeda et al., 2014).

The results of the SDM study are consistent with the findings of this thesis that these plant species are risk. Moreover, the study provides a mechanism to quantify future changes in species population location, volume and capacity. As it relates to ecosystem services, species distribution of culturally specific plants is important information for mitigating habitat destruction. This will have cultural implications related to how landscape and ecosystems continue to change and how that will remain as an influence on Tigua way of life, cultural

sustainability and natural resource availability. If habitat locations, volume, and capacity of these species change, Tiguas will not be able to perform a variety of ceremonies needed for the sustainability of the Pueblo and traditions will be severely compromised.

Investigating Natural and Human Interactions

The connections between humans and the physical landscapes in which they live have been studied by numerous social and natural scientists (e.g. Liu et al., 2007). Opinions vary on whether humans are constrained by this physical landscape and other climatic factors (Diamond, 1992) or if humans and their relationships to the natural world are motivated by cultural factors that determine choices that in turn effect the environment that we live in (Simmons, 1989). A broader ecological viewpoint is beginning to emerge and many scientists are adopting the notion that humans are an essential element of a hierarchical ecosystem (Van West, 2011). Issues of connectivity and scale are associated with this notion of being part of the hierarchical ecosystem (Gilman and Whalen, 2011). Native Americans have always known this to be true. Teachings within all tribes have similarities when it comes to interconnected relationships with the Earth and all of the Earth's creatures (Hartz, 2006). This is because the socio-cultural beliefs of most tribes are comparable in structure (Kanter, John, 2011). The land use/land cover change analysis revealed a significant anthropogenic influence on the landscape, this consequently had a significant effect on Tigua society. Resource intensive landscape modification for agriculture, border protection, water impoundment and rock quarrying have had feedbacks on the decline in riparian ecosystem. This was substantiated by the LULC analysis for 2002 to 2013 time period which revealed a substantial increase in barren land. This was a time of landscape modification along the Rio Grande for construction of the Border Fence for purposes of border security after 9/11 (Gilman, 2012). Vital plants are dwindling with inadequate habitat conditions needed for

survival. Land cover types such as barren, shrubland, and urban are expanding leaving fewer places for collection of critical plant species necessary to sustain Tigua culture.

This project used ecosystem services as a bridge between western thought and traditional ecological knowledge. The framework that was created in this project was developed as a means for building our socio-environmental belief systems that are based on a different type of ideology and supportive principles with the Earth and all of its creatures in mind.

Geography, location, time and space gives people many different ways to view or negotiate within their own cultural context what the land or landscape means to them. The challenge of this project was to interpret the forecasts made by experts in many disciplines into assessments of ecological/cultural impact for Tigua lands and people. Using LULC change served as an illustrative tool that was useful, but this project was never intended to be a remote sensing study; rather it was an instrument that could show anthropogenic and climate (maybe one and the same) changes in the riparian landscape of the middle Rio Grande and how it has and will continue to affect the Tigua Pueblo. The current changes in climate are fundamentally about feedback loops in human and natural systems (Wilder et al., 2015); we have the power to reframe the question, to make our culture what we want it to be and continue that feedback and reverberation onto all of humanity.

Limitations of the Study

This project could have been improved by using more image processing tools at the commencement of the project, it would have improved accuracy of the images and in doing so the accuracy of the classified supervision. Additionally, a sampling design would have been

useful for strategy and time management improvement. Accuracy could have also been improved by obtaining ground truth points, employing an accuracy assessment and error assessment after classification was complete.

Conclusions

The LULC change analysis for riparian land cover showed that, in 4 out of the 5 decades riparian land cover declined. In all decades it was converted to (1) agriculture (2) urban or (3) mixed vegetation. The conversion of riparian systems to agriculture and urban is significant because it shows that it is being affected primarily by anthropogenic mechanisms, both due to a lack of resources because of human-made infrastructure and also because of clear-cutting to obtain rich soil for agricultural crops. Other human induced activities such as rock quarrying and urban development have led to significant changes within the region.

Climate change will cause great migrations of critical plant species needed to sustain Tigua culture. Longer, severe droughts, invasive species, loss of habitat and wetlands will cause loss of *Salix gooddingii* and *Salix exigua* species within the aboriginal lands of the Tigua. Ecosystem management plans must account for these losses of provisioning and cultural services provided by the riparian landscape. Long-term water supply and management strategies including water supply contingency plans must be created to mitigate the looming effects of climate change.

Government agencies must work with Ysleta del Sur Pueblo to assist them with providing technical monitoring data (Collins et al. 2010), to create Tribe-specific research and/or projects that focus on principle ecosystem services that are needed for culture and subsistence (Redster et al., 2013). Inclusion of tribes within the region for climate change mitigation and resource management that include social and cultural considerations are needed. This would assist to increase the scale of climate change considerations and would aid in the development of

effective adaptation strategies (Collins et. al., 2011). The future for the Tigua and its culture lies in their ability to cultivate restoration projects and co-manage sacred areas along the Rio Grande. These must allow for ecological and social factors involved in water and land degradation to be mitigated and reinforce the Pueblo's youth to assist in these efforts, in order to preserve culture and nurture a dedication to their Tribe and natural resources concerns (Redster et al., 2013).

References

- Baez, S., and S. L. Collins. 2008. Shrub invasion decreases diversity and alters community stability in northern Chihuahuan desert plant communities. *PLoS ONE* 3:e2332.
- Binder, C.R., Hinkel, J., Bots, P.W.G., and Pahl-Wostl, C., 2013, Comparison of frameworks for analyzing social-ecological systems: *Ecology and Society*, v. 18, no. 4, doi: 10.5751/ES-05551-180426.
- Briody, E., Trotter, R., and Meerwarth, T., 2016, *Transforming Culture: Creating and Sustaining a Better Manufacturing Organization*: Springer.
- Collins, S.L., Carpenter, S.R., Swinton, S.M., Orenstein, D.E., Childers, D.L., Gragson, T.L., Grimm, N.B., Morgan, G.J., Harlan, S.L., Kaye, J.P., Knapp, A.K., Kofinas, G.P., Magnuson, J.J., McDowell, W.H., et al., 2011, An integrated conceptual framework for long-term social-ecological research: *Frontiers in Ecology and the Environment*, v. 9, p. 351–357, doi: 10.1890/100068.
- Comar, S.C., 2015, *The Tigua Indians of Ysleta Del Sur: A Borderlands Community*.
- Cook, B.I., Ault, T.R., and Smerdon, J.E., 2015a, Unprecedented 21st century drought risk in the American Southwest and Central Plains: , no. February, p. 1–7, doi: 10.1126/sciadv.1400082.
- Cook, E., Seager, R., Cane, M., and Stahle, D., 2007, North American drought : Reconstructions, causes, and consequences: v. 81, no. March 2003, p. 93–134, doi: 10.1016/j.earscirev.2006.12.002.
- Cossio, M.L.T., Giesen, L.F., Araya, G., Pérez-Cotapos, M.L.S., VERGARA, R.L., Manca, M., Tohme, R.A., Holmberg, S.D., Bressmann, T., Lirio, D.R., Román, J.S., Solís, R.G., Thakur, S., Rao, S.N., et al., 2012, Facilitating Sustainable Use of the Rio Grande: A Social-Ecological Analysis: *Uma ética para quantos?*, v. XXXIII, no. 2, p. 81–87, doi: 10.1007/s13398-014-0173-7.2.
- Data Access. (n.d.). Retrieved September 02, 2016, from <http://www.ncdc.noaa.gov/data-access>
- Diamond, J.M. 1992, *Guns, Germs and Steel: The Fates of Human Societies*. W.W. Norton, New York.
- Dreesen, D., Dreesen, D., Harrington, J., Harrington, J., Subirge, T., Subirge, T., Stewart, P., Stewart, P., Fenchel, G., and Fenchel, G., 2002, *Riparian Restoration in the Southwest – Species Selection, Propagation, Planting Methods, and Case Studies*: SO. National nursery proceedings, p. 370.

- Engel-Wilson, R.W. and Ohmart, R.D., 1978. Floral and attendant faunal changes on the lower Rio Grande between Fort Quitman and Presidio, Texas. In *Proceedings of the National Symposium for Protection and Management of Floodplain Wetlands*, pp. 139-147.
- Erb, K.H., Haberl, H., Jepsen, M.R., Kuemmerle, T., Lindner, M., Müller, D., Verburg, P.H., and Reenberg, A., 2013, A conceptual framework for analysing and measuring land-use intensity.
- Finch, D.M., and Tainter, J.A., 1995, *Ecology, diversity, and sustainability of the Middle Rio Grande Basin*: Diane Publishing.
- Garfin, G., Franco, G., Blanco, H., Comrie, A., Gonzalez, P., Piechota, T., Smyth, R., and Waskom, R., 2014, *Southwest: Climate Change Impacts in the United States*, p. 462–486, doi: 10.7930/J08G8HMN.On.
- Gates, W.L., Mitchell, J.F., and Boer, G., 1992, Climate modeling, climate prediction and model validation: *Climate Change 1992*, p. 101–134.
- Gilman, D., 2012, *Obstructing Human Rights: The Texas-Mexico Border Wall*.
- Gilman, P.A., and Whalen, M.E., 2011, *Moving on the Landscape: Movement, Connectivity, and Landscape Change in the Ancient Southwest*, p. 45.
- Greider, T., and Garkovich, L., 1994, *Landscapes: The social construction of nature and the environment*.
- Hargrove, W.L., Borrok, D.M., Heyman, J.M., Tweedie, C.W., and Ferregut, C., 2013, Water, climate, and social change in a fragile landscape: *Ecosphere*, v. 4, no. 2, p. art22, doi: 10.1890/ES12-00269.1.
- Hartz, P., 2006, *Native American religions: Oral tradition*, p. 2006.
- Heim, R. (n.d.). *Climate of 2013 - April U.S. Palmer Drought Indices*. Retrieved November 29, 2016, from <http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html>
- Houser, Nicholas P., 1970, The Tigua Settlement of Ysleta del Sur: *Kiva*, v. 36, no. 2, p. 23–39.
- Huxman, T.E., Wilcox, B.P., Scott, R., Snyder, K., Breshears, D., Small, E.E., Hultine, W.H., Pockman, W.T., and Jackson, R.B., 2005. Ecohydrological implications of woody plant encroachment. *Ecology* 86: 308–319.
- Ikeda, D.H., Grady, K.C., Shuster, S.M., and Whitham, T.G., 2014, Incorporating Climate Change and Exotic Species into Forecasts of Riparian Forest Distribution: v. 9, no. 9, doi: 10.1371/journal.pone.0107037.

- IPCC, C. "Summary for policymakers. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change." (2014): 1-32.
- Jones, S.M. and Gutzler, D.S., 2016. Spatial and Seasonal Variations in Aridification Across Southwest North America. *Journal of Climate*, in press.
- Kanter, John, 2011, Connectivity and Scale in the Greater Southwest:, p. 363–374.
- Knight, B.L., 2009, A Field Guide to Irrigation in the Lower Rio Grande Valley.
- Landis, M., 1998, The "Forgotten River" of the Rio Grande/Rio Bravo Investigation into the Reclamation of an Arid Riparian Ecosystem.
- Leclerc, C., Mwongera, C., Camberlin, P., and Boyard-Micheau, J., 2013, Indigenous past climate knowledge as cultural built-in object and its accuracy: *Ecology and Society*, v. 18, no. 4, doi: 10.5751/ES-05896-180422.
- Loveland, B.T., Mahmood, R., Patel-Weynand, T., Karstensen, K., Beckendorf, K., Bliss, N., Carleton, A., and Survey, U.S.G., 2012, National Climate Assessment Technical Report on the Impacts of Climate and Land Use and Land Cover Change:.
- Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., Pell, A. N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C. L., Schneider, S. H., and Taylor, W.W., 2007. Complexity of Coupled Human and Natural Systems. *Science* 317(5844): 1513–1516.
- Munson, S.M., and 9 others, 2013. Regional signatures of plant response to drought and elevated temperature across a desert ecosystem. *Ecology* 94(9):2030-2041
- National Wildlife Federation, 2011, Facing the storm: Indian Tribes, Climate-Induced Weather Extremes, and the Future for Indian Country:, p. 28.
- National Wildlife Federation, 2011, Facing the storm: Indian Tribes, Climate-Induced Weather Extremes, and the Future for Indian Country.
- Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. *Environmental Management*, 44(6):1053-1068.
- Patten, Duncan T., 1998, Riparian Ecosystems of Semi-Arid North America: Diversity and Human Impacts (Arizona State, Ed.): *Wetlands*, v. 18,
- Peters, D.P.C., Herrick, J.E., Monger, H.C., and Huang, H., 2010. Soil-vegetation-climate interactions in arid landscapes: Effects of the North American monsoon on grass recruitment. *Journal of Arid Environments* 74:618-623.no. 4, p. 498–512.

- Plieninger, T., Van der Horst, D., Schleyer, C., and Bieling, C., 2014, Sustaining ecosystem services in cultural landscapes: *Ecology and Society*, v. 19, no. 2, doi: 10.5751/ES-06159-190259.
- Ratajczak, Z., Nippert, J.B., and Collins, S.L., 2012. Woody encroachment decreases diversity across North American grasslands and savannas. *Ecology* 93(4): 697–703
- Redsteer, M.H., Brenis, K., Cheif, K., Gautam, M.R., Middleton, B.R., and Rsosie, R., 2013, Unique Challenges Facing Southwestern Tribes: Assessment of Climate Change in the Southwest United States: a Technical Report Prepared for the US National Climate Assessment, p. 385–404.
- Reynolds, J.F., and Stafford Smith, D.M. (Editors), 2002. *Global Desertification: Do Humans Cause Deserts?*, Dahlem University Press, Berlin, Germany.
- Schlesinger, W.H., Reynolds, J.F., Cunningham, G.L., Huenneke, L.F., Jarrell, W.M., Virginia, R.A., and Whitford, W.G., 1990. Biological feedbacks in global desertification. *Science* 247, 1043–1048.
- Schmidly, D.J., and Ditton, R.B., 1978, Relating human activities and biological resources in riparian habitats of western Texas, *in* National symposium on strategies for protection and management of floodplain wetlands and other riparian ecosystems. US For. Serv. Gen. Tech. Rep. WO-12, p. 107–116.
- Seager, R., Ting, M., Held, I., Kushnir, Y., Lu, J., Vecchi, G., Huang, H.P., Harnik, N., Leetmaa, A., Lau, N.C. and Li, C., 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science*, 316(5828):1181-1184.
- Seavy, N.E., Gardali, T., Golet, G.H., Griggs, F.T., Howell, C.A., Kelsey, R., Small, S.L., Viers, J.H., and Weigand, J.F., 2009, Why climate change makes riparian restoration more important than ever: Recommendations for practice and research: *Ecological Restoration*, v. 27, p. 330–338, doi: 10.3368/er.27.3.330.
- Semken, S. (2005) Sense of Place and Place-Based Introductory Geoscience Teaching for American Indian and Alaska Native Undergraduates. *Journal of Geoscience Education*: March 2005, Vol. 53, No. 2, pp. 149-157.
- Simmons, I.G., 1989, *Changing the Face of the Earth: Culture, Environment, History*. Blackwell, Oxford
- Sinclair, S.J., White, M.D., and Newell, G.R., 2010, How Useful are Species Distribution Models for Managing Biodiversity under Future Climates? *Ecology and Society*, v. 15, no. 1, p. Art. 8, doi: 8.

- Soulard, C.E., and Wilson, T.S., 2013, Recent land-use/land-cover change in the Central California Valley: *Journal of Land Use Science*, v. 10, no. 1, p. 59–80, doi: 10.1080/1747423X.2013.841297.
- Stahle, D.W., and Dean, J.S., 2011a, and Social Disasters CO: Springer Science & Business Media, doi: 10.1007/978-1-4020-5725-0.
- Turner, M.G., 1991, *Quantitative Methods in Landscape Ecology*.
- Turner, M.G., and Gardner, R.H., 1991, *Quantitative methods in landscape ecology: the analysis and interpretation of landscape heterogeneity*: Springer-Verlag.
- Van West, C.R., 2011, *Landscape Change: Movement, Connectivity, and Landscape Change in the Ancient Southwest*, p. 107.
- Villa, F., Bagstad, K.J., Voigt, B., Johnson, G.W., Portela, R., Honzák, M., and Batker, D., 2014, A methodology for adaptable and robust ecosystem services assessment. *PloS one*, v. 9, no. 3, p. e91001, doi: 10.1371/journal.pone.0091001.
- Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O., and Bairlein, F., 2002, Ecological responses to recent climate change: *Nature*, v. 416, no. 6879, p. 389–395, doi: 10.1038/416389a.
- Wilder, M., Magrane, E., Miele, M., Prytherch, D., Schein, R., Ingram, M., and Ingram, H., 2015, The Power of Narrative in Environmental Networks: The AAG Review of Books, v. 3, no. 2, p. 99–108, doi: 10.1080/2325548X.2015.1015922.
- Wright, B., 1993, *The Tiguas: Pueblo Indians of Texas*: Texas Western Pr; 1st edition (May 1993).
- Yan, Katy, and Pottinger, Lori, 2013, *Civil Society Guide to Healthy Rivers and Climate Resilience*.

Vita

Andrea L. Everett is originally from Ysleta del Sur Pueblo, TX. She is the daughter of Patricia and Olin Scott Riggs. She is a graduate of El Paso Community College having obtained an Associates of Science in 2005. She received a Bachelor's of Science in Environmental Science in 2014 from the University of Texas at El Paso, and is currently a candidate for Master of Science in Environmental Science, which this project will fulfill. Andrea worked for Ysleta del Sur Pueblo within the Environmental Office working her way from Intern, Geographic Information Science (GIS) Assistant, Environmental Specialist to ultimately Environmental Programs Manager (EMP). As EMP she coordinated and administered conservation and tribal specific land and resource preservation projects, spearheaded and executed energy plan, implemented environmental code, environmental strategic plan and conducted regional impact studies and field surveys.

Most recently Andrea served as a Graduate Research Assistant under the direction of Deana D. Pennington. With the completion of her degree, she will be beginning a new position as a GIS Technician with the Lower Valley Water District (LVWD), where she will prepare drawings specifications and detailed plans for LVWD civil engineering projects, compute and estimate water and wastewater line extensions and installations and supervise and review overall survey and GPS data collection.

Contact Information: aleverett715@gmail.com

This thesis/dissertation was typed by Andrea L. Everett.