

5-2017

Atole de Maíz Azul: Building Climate-Change Resilience with Local Knowledge/Food Sovereignty in Northern New Mexico

Katherine C.R. Dixon
Clark University, kdixon@clarku.edu

Follow this and additional works at: https://commons.clarku.edu/idce_masters_papers

 Part of the [Agriculture Commons](#), [Environmental Studies Commons](#), [Indigenous Studies Commons](#), [International and Area Studies Commons](#), [Latina/o Studies Commons](#), [Urban Studies and Planning Commons](#), and the [Water Law Commons](#)

Recommended Citation

Dixon, Katherine C.R., "Atole de Maíz Azul: Building Climate-Change Resilience with Local Knowledge/Food Sovereignty in Northern New Mexico" (2017). *International Development, Community and Environment (IDCE)*. 176.
https://commons.clarku.edu/idce_masters_papers/176

This Research Paper is brought to you for free and open access by the Master's Papers at Clark Digital Commons. It has been accepted for inclusion in International Development, Community and Environment (IDCE) by an authorized administrator of Clark Digital Commons. For more information, please contact mkrikonis@clarku.edu, jodolan@clarku.edu.

ATOLE DE MAÍZ AZUL: BUILDING CLIMATE CHANGE RESILIENCE WITH
LOCAL KNOWLEDGE/FOOD SOVEREIGNTY IN NORTHERN NEW MEXICO

KATHERINE CHYNA ROSE DIXON

MAY 2017

A MASTER'S RESEARCH PAPER

Submitted to the faculty of Clark University, Worcester,
Massachusetts, in partial fulfillment of the requirements for
the degree of Master of Science in the Department of International Development,
Community and Environment

And accepted on the recommendation of

Timothy Downs, D. Env., Chief Instructor

ABSTRACT

Atole de Maíz Azul:

Building Climate-Change Resilience with Local Knowledge/Food Sovereignty in
Northern New Mexico

KATHERINE CHYNA ROSE DIXON

The impacts of climate change in Northern New Mexico will cause a variation in seasonal precipitation and increased drought conditions. Northern New Mexico is home to numerous indigenous and rural-agricultural communities who rely on these water resources for subsistence and cultural practices. They are among the most vulnerable to the impacts of climate change.

This paper investigates the impacts of climate change to Northern New Mexico. It examines the role of participatory methods and local knowledge in building community resilience. This paper is informed primarily through secondary research, and also draws upon a series of personalized interviews from Northern New Mexico community members. The paper finds that the incorporation of local knowledge into resilience planning, through participatory methods, will result in enhanced and holistic community resilience.

Timothy Downs, D.Env.
Chief Instructor

ACADEMIC HISTORY

Katherine Chyna Rose Dixon

May 2017

**Baccalaureate Degree:
Bachelor of Arts in Political Science**

Source: Clark University

May 2016

ACKNOWLEDGEMENTS

I thank Professor Downs for his support and enthusiasm for this research, as well as for his patient guidance throughout this process. I thank the communities of Northern New Mexico for their resilience, determination, and *querencia* in the face of climate change and oppressive structures. I thank those who have come before, those who are here now, and those who may come in the future, for their contributions to the creation and cultivation of *local ways of knowing*. I thank those who have informed this paper with their insights, particularly those interview participants whose words are included within this text. I thank Taylor W. Bearden for his zest and support, and I thank my family, friends, and all teachers in life. Lastly, I thank the land and the waters of Northern New Mexico.

TABLE OF CONTENTS

1. INTRODUCTION	1
2. BACKGROUND	2
3. METHODOLOGY	6
4. FINDINGS AND DISCUSSION	7
4.1 Q1: What are the current and projected climate change impacts to land and water in the Southwest and Northern New Mexico?.....	7
4.1.1 Cascade Flow Breakdown for Southwest Impacts of Concern	7
4.1.2 Northern New Mexico.....	11
4.2 Q2: Who is most vulnerable, and to what?	17
4.2.1 Rural Communities	19
4.2.2 Indigenous Communities.....	24
4.3 What are the roles of participatory methods and local knowledge in building community resilience?.....	30
4.3.1 Participatory Methodologies Framework.....	30
4.3.2 Local Ways of Knowing.....	34
4.4 What lessons can we learn through examining the histories and traditional practices of peoples in this land, and is Food Sovereignty an appropriate low-tech way to build resilience in this region?.....	40
4.4.1 Water Harvesting & Irrigation	41
4.4.2 Seeds, Planting & Cultivation	44
4.4.3 Food Sovereignty	46
5. CONCLUSION	50
6. ANNEX 1	53
Interview Questionnaire	53
7. BIBLIOGRAPHY	54

1. INTRODUCTION

The effects of a changing climate disproportionately impact vulnerable communities. Globally, indigenous and rural communities are at the forefront of climate change (Salick and Byg, 2007). The vulnerability experienced by these communities is partly attributable to physical and cultural dependency on, and interconnectedness with, vulnerable landscapes and resources. It is augmented by historical and current marginalization, colonization, and environmental injustice. The most impacted communities have contributed minimally to global emissions and are often in greatest need of resilience development. These communities, however, offer invaluable insights into resilience development based on local and traditional knowledge. These insights may be incorporated into resilience development through participatory methods. To understand climate change models and impacts globally, see the International Panel on Climate Change's Assessment Report 5 (IPCC AR5 2014). To understand climate change projections and impacts to the United States, review the National Climate Assessment, 2013 (NCA 2013).

The Southwest is one of the most climate variable and climate challenged regions in the United States (Overpeck et al., 2013). Though climate change will impact many sectors, *water* is perhaps the most critical to examine because of its interconnectedness to many socio-environmental facets. Northern New Mexico is home to seventeen indigenous tribes and nations and many rural land-based and agricultural

communities. A deeply embedded sense of connection to place characterizes communities in this high mountain desert. This paper explores the following research questions:

1. What are the current and projected climate change impacts to land and water in Northern New Mexico?
2. Who is most vulnerable, and to what?
3. What are the roles of participatory methods and local knowledge in building community resilience?
4. What lessons can we learn through examining the histories and traditional practices of peoples in this region, and is food sovereignty an appropriate low-tech means to build resilience in this region?

2. BACKGROUND

Climate change impacts to water systems are significant for Northern New Mexico. As a mountainous, high-desert landscape, the region's small-scale agricultural systems, groundwater systems, and regional water supplies are often dependent on historic *acequia* irrigation, monsoonal rainfall, and snowpack runoff. With decreased overall precipitation, especially in the critical summer months of replenishment, New Mexican ground and underground water sources are facing depletion (Sheppard et al., 2002; Colby and Frisvold, 2011). Climate models indicate that seasonal fluxes will bring more frequent and more dramatic flood and drought fluctuation (Rosenberg and

Edmonds, 2005; Karl et al., 2009). Droughts and aridity are not uncommon to Northern New Mexico; however, increasingly rapid warming generates unprecedented levels of change.

Northern New Mexico is home to many indigenous and rural agricultural communities. Rural communities and indigenous communities are among the most vulnerable to climate change impacts, due to a unique dependency on and interconnectedness with water resources. Depleted resources, isolation, and a deep cultural relationship to land and water magnifies this vulnerability. Despite the unprecedented level and rate of change, communities that have lived in the region for millennia have developed complex systems of local knowledge that provide insight into regionally appropriate responses to a changing climate.

Rural and small-scale agricultural communities in Northern New Mexico are defined in this paper as including: those dependent on *acequia* systems for irrigation and/or potable water; those who follow traditional Hispano, indigenous and localized agricultural practices; those who engage in farming for subsistence, cultural, traditional and/or sustenance needs. Most rural farmers have developed a system of conceptualizing the local lands and climate. In some cases, this knowledge system has evolved over generations, developing and advancing based on environmental and cultural feedback. Farmers are highly attuned to weather and climate patterns and consistently adjust their behavior to account for both short and long term climate change (Brugger and Crimmins, 2013). Their way of life is built on a deep and intimate

connection with the environment. Farmers in rural Northern New Mexican communities are not blind to the changes occurring around them, and instead are active agents of change and preservation. Gary Paul Nabhan reflects on a conversation with a farmer: “This desert elder—even in his late 70s—did not think of himself as a passive victim of drought or climate change, despite his sense of grief that the rains were dying” (Nabhan, 2013, 64). Through these systems of observation and action, Northern New Mexican farmers continuously develop systems for resilience, born of a long history of adapting to environmental change.

There are over 170 federally recognized tribal nations in the Southwest. Among these, 17 have territory within Northern New Mexico. These include: Jicarilla Apache Nation, Navajo Nation, Pueblo of Cochiti, Pueblo of San Ildefonso, Pueblo of Jemez, Pueblo of Nambe, Pueblo of Picuris, Pueblo of Pojoaque, Pueblo of Sandia, Pueblo of San Juan, Pueblo of San Filipe, Pueblo of Santa Ana, Pueblo of Santa Clara, Pueblo of Santo Domingo, Pueblo of Taos, Pueblo of Tesuque, and the Pueblo of Zia. Pueblo cultures are distinct to the Southwestern United States, and share a commonality of being place-based communities with developed agricultural systems. Language and culture vary between Pueblo groupings, the Jicarilla Apache Nation, and the Navajo Nation.

It is critical that indigenous peoples are actively engaged at the forefront of climate change dialogue, particularly regarding impacts to indigenous communities. Indigenous peoples have been systematically excluded from academic and policy

discussions, despite being subject to disproportionate climate change impacts. Often, when impacts to indigenous communities are included in discussions, these communities are portrayed as passive victims, rather than as principal agents of resilience building (Salick and Byg, 2007). This paper argues climate change dialogue must include indigenous peoples as principal agents, as their voice “should be a [primary] voice in policy formation and action” (Salick and Byg, 2007, 4). This paper examines present and predicted climate change impacts to indigenous communities in Northern New Mexico. Climate change impacts to indigenous communities are framed primarily from an etic (outsider, observer) perspective, acknowledging cultural intricacies and the author’s positionality. Emic (insider) perspectives are incorporated through the inclusion of interview excerpts, but are not claimed as representative of all stakeholder perspectives.

To properly address climate change impacts and challenges, the context of political marginalization and socio-economic disparity must be a component (Redsteer et al., 2013). While indigenous peoples of the Southwest have historically adapted to a changing and rugged climate, the rapidity and severity of projected climate change, coupled with damaging governmental policy and political and economic marginalization, will exceed traditional coping mechanisms (Salick and Byg, 2007). Resilience planning should be supported by indigenous and non-indigenous (particularly federal and state) actors, in a way that honors and integrates cultural knowledge and ways of life (Cozzetto et al., 2013). Through the integration of local

knowledge in all stages of resilience planning, indigenous communities will bolster sovereignty and build capacity (Cozzetto et al., 2013).

3. METHODOLOGY

This paper was born in equal parts out of my love for the communities, environment and culture of Northern New Mexico, and my concern for their wellbeing in the face of climate change. Through both my formal education and personal experience, I have gained insight into the necessity for community based resilience strategies that incorporate local knowledge. While I began with a framework of addressing the questions outlined above, the necessity of doing so became more apparent as each one unfolded into the next. For example, among those most vulnerable to the impacts of climate change are rural and indigenous communities, due in part to their dependence on agricultural systems that are highly sensitive to water availability. Yet, due to a deeply complex system of local knowledge, these same “vulnerabilities” provide incredible strength and resilience, thus supporting the case for the integration of local knowledge and participatory methods.

My research is primarily based on secondary literature (see bibliography). In addition to these works, I have drawn upon my personal experience as a resident of this region, and have conducted a targeted group of semi-structured interviews with Northern New Mexican community members via email and phone (See Annex 1). Interviewees were provided with an informed consent document, and delivered

statements of consent to participate in the interview process. These interviews have informed my working knowledge, and excerpts of each have been included within this paper. This small ethnographic study is not designed to capture a representative sample of all Northern New Mexican stakeholders, but rather to supplement the secondary literature with individualized observations.

4. FINDINGS AND DISCUSSION

4.1 Q1: What are the current and projected climate change impacts to land and water in the Southwest and Northern New Mexico?

4.1.1 Cascade Flow Breakdown for Southwest Impacts of Concern

The Southwestern United States is one of the most “climate-challenged” regions of North America, and is recognized as a climate change hotspot (Diffenbough et al., 2008, Liverman et al., 2013; Overpeck et al., 2013); it is already experiencing the impacts of climate change. Paleoclimatic tree ring reconstructions indicate that temperatures from 1950 to the present exceed any comparable period during the last 600 years (Overpeck et al., 2013). The decade 2001 to 2010 was the warmest on record, with annual averaged temperatures ranging 0.8°C higher than the 1901-2000 average (Hoerling et al., 2013; Garfin et al., 2014).

Key climate change impacts to the Southwest that are addressed in this report are defined by the National Climate Assessment (2014) as follows: I) A decline of snowpack and stream flow volume; II) Resultant decreases in valuable surface water

supply that many communities and agricultural sectors rely upon; III) A decline in surface water resources, coupled with increasing weather extremes, which threaten vulnerable crops and ecosystems; IV) Increased vulnerability of forests due to drought, heat, and insect outbreaks (such as the recent bark beetle infestation). Forest degradation threatens local ecosystems, and increases the likelihood of wildfires (Garfin et al., 2014). This study addresses impacts which relate directly to the hydrologic cycle: *increasing temperatures, decreasing snowpack and stream flow, a decline in surface water resources and quality, and increasing weather extremes*. Water is critical to life in the desert. Climate models predict an increasingly arid Southwest, which will profoundly impact multiple facets of life in these landscapes (Figure 1).

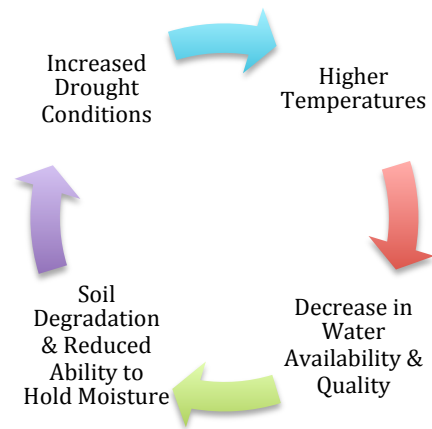


Figure 1: Flow chart displaying Southwestern climate change impacts working in a positive feedback loop.

Increased warming in the Southwest contributes to the increased severity and frequency of drought. The aerial extent of drought from 2001 to 2010 in the Southwest

was the second largest recorded during the period from 1901 to 2010, yet remained below the severity and duration of recorded droughts in the previous 2,000-year period (Overpeck et al., 2013). While the severity of recent droughts has not yet exceeded records, current droughts are continuously exacerbated by rapid heating, which stimulates a feedback loop of heightened summer temperatures and extended, severe drought (Cayan et al., 2013). Thus, in comparison to the historical drought pattern, droughts are increasing in severity, even if their magnitude remains below the highest historical peaks.

Finally, in a list of cascading climate impacts, increasing temperatures and drought conditions in the Southwest contribute to increasingly low, and earlier arrival of, stream flow and snowmelt. This projection applies not just to scenarios of the future, as “human-induced climate change impacts on temperature, snowpack, and the timing of stream flow over the western United States have already been detected (Maurer, Stewart et al. 2007; Barne et al. 2008; Bonfils et al. 2008; Pierce et al. 2008; Hidalgo et al. 2009). As climate continues to warm there will be serious impacts on the hydrological cycle and water resources of the Southwestern United States (Barne et al. 2004; Seager et al. 2007)” (Cayan et al., 2013, 119).

According to the IPCC AR5, up to sixty percent of the early onset in snowpack melt and resultant stream flow decline may be attributed to human-induced climate change (Overpeck et al., 2014). This decrease in snowmelt and stream flow will limit overall water availability in the Southwest, adding pressure to already stressed water

systems. The impacts of heat and drought will affect not only river systems reliant on snowmelt, but also surface water quality and quantity through general water scarcity, increases in flooding events and increases in wildfires (Overpeck et al., 2014). Most surface groundwater available in the Southwest is generated from spring, and later summer snowpack melt runoff, creating natural reservoirs (Serreze et al. 1999; Stewart, Cayan, and Dettinger 2004, 2005 cited in Steenburgh et al., 2013). As an example to demonstrate water system vulnerability, the combined impacts of increasing temperatures and drought conditions have already “reduced average naturalized flows in the Colorado River (measured at Lees Ferry) to 12.6 million acre-feet/year, compared to the 1901 to 2000 average of 15.0 million acre-feet/year” (Cayan et al. 2010 cited in Hoerling et al., 2013, 85). Similar impacts are noted throughout most major southwest river basins (Hoerling et al., 2013).

Climate change impacts to the hydrologic cycle are not limited to drought conditions and declining water availability. As total precipitation decreases, extreme precipitation events are likely to increase (Groisman et al. 2005; Wang and Zhang 2008 cited in Gershunov et al., 2013). These events, such as severe but disparate rainstorms that result in flash floods and soil erosion, lower the year-round moisture availability and are directly related to warming temperatures and drought conditions. Warmer air carries greater moisture and thus produces increasingly extreme precipitation events, even in times of overall drought. Furthermore, arid lands will be depleted in their ability to absorb precipitation, leading to greater run off and flash flooding risk (Gershunov et

al., 2013). The impacts of changes to the hydrologic cycle noted in the Southwest operate in an interconnected loop. In this region, higher elevations - such as high mesa deserts and mountains - are responsible for producing much of the runoff on which lower elevations (coincidentally, areas of higher urban density) depend (Theobald et al., 2013). Growing and prioritized urban water use will place a greater strain on high elevation areas, thus reducing both high altitude, and urban low-lying water availability (Theobald et al., 2013).

In conclusion, the Southwest and its water resources are in a precarious state now, and moving forward, under climate scenarios. This is primarily attributable to the impacts of anthropogenic climate change and a depletion of Southwestern water resources due to population increase and industrial activity in the region.

4.1.2 *Northern New Mexico*

It all begins with the melting snow.

Regional and local climatic changes will most immediately impact human and natural systems (Rosenberg and Edmonds, 2005). This paper now turns to examining how these impacts will contribute to a change in traditional ways of life in the study region of Northern New Mexico.¹

Using Santa Fe, New Mexico as a reference location, the baseline rainfall in Northern New Mexico from 1960 to 1990 ranges from ~ 23mm in December/January to

¹ The “Northern New Mexico Study Region” is defined as: extending North of Albuquerque to the Colorado Border, extending Eastwards through Mora County, and reaching West until the Four Corners border (inclusive of the Navajo Nation in New Mexico).

80mm in July/August (Figure 2). The baseline temperature range for this same period and location is ~ -2°C in December/January to ~19°C in July/August (The World Bank Group; Data set developed by the Climatic Research Unit (CRU) of University of East Anglia (UEA)). From 1990 to 2012, these trends have remained relatively stable (Figure 3), however the annual distribution is beginning to fluctuate with more extremity than before (Figures 4-11).



Figure 2: 1960-1990, Santa Fe, New Mexico, USA

Data from CRU of UEA, Figure generated by the World Bank Climate Change Portal

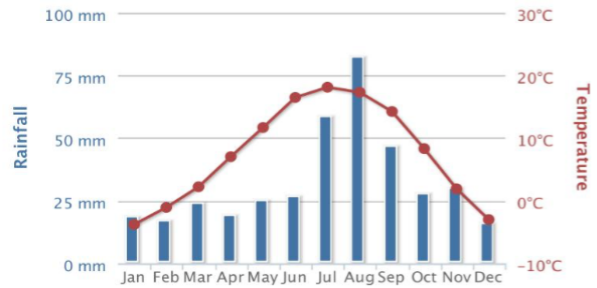


Figure 3: 1990-2012, Santa Fe, New Mexico, USA

Data from CRU of UEA, Figure generated by the World Bank Climate Change Portal

Under the IPCC Coupled Model Intercomparison Project 5 (CMIP5) global climate model (GCM), scenario RCP2.6 (the lesser of the emissions scenarios), temperatures are predicted to increase in Northern New Mexico in the summer months (using Santa Fe as a reference location) by ~ 1.0°C by 2020, and by 1.5°C by 2080 (see Figure 4, Figure 5, and Figure 6 (baseline), below). Under a RCP4.5 scenario (an intermediate/stabilization emissions scenario), temperatures are predicted to increase by over ~2.0°C by 2020, and remain at this level through 2080 (Figure 7). The climate data

used for these models are derived from the 16 available global circulation models (GCMs) utilized by the IPCC AR5, 2014.

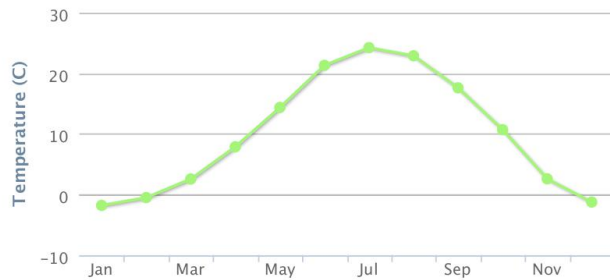


Figure 4: 2020-2039, Santa Fe, New Mexico, USA, RCP 2.6

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal



Figure 5: 2080-2099, Santa Fe, New Mexico, USA, RCP 2.6

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal

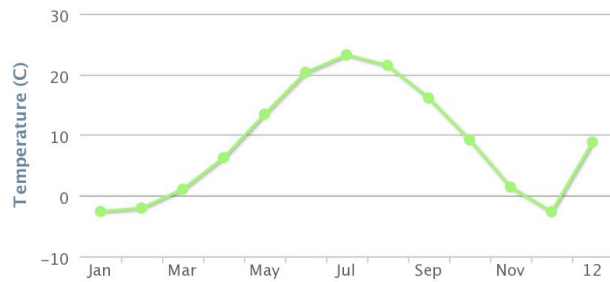


Figure 6: 1986-2005, Temperature Baseline, Santa Fe, New Mexico, USA

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal



Figure 7: 2020-2039, Santa Fe, New Mexico, USA RCP 4.5

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal

Under a RCP2.6 scenario, precipitation is expected to decline by ~58mm from the 1986-2005 baseline by 2020 (Figure 8, Figure 10), and to decline by ~74mm by 2080 (Figure 9, Figure 10). These declines are accompanied by increasingly extreme precipitation events. These conditions and trends are exacerbated under RCP4.5 modeling (Figure 11 shows extreme variability and decline).



Figure 8: 2020-2039, Santa Fe, New Mexico, USA (RCP2.6)

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal



Figure 9: 2080-2099, Santa Fe, New Mexico, USA (RCP2.6)

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal



Figure 10: 1986-2005, Santa Fe, New Mexico, USA (Baseline)

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal



Figure 11: 2080-2099, Santa Fe, New Mexico, USA (RCP4.5)

Data from IPCC AR5, Figure generated by the World Bank Climate Change Portal

In New Mexico, the effects of the North American monsoon season account for up to 50% of annual rainfall (Sheppard et al., 2002; Gershunov et al., 2013). This precipitation arrives in two seasonal waves each year, summer (July through September) and winter (November through April) (Sheppard et al., 2002; Colby and Frisvold, 2011). These predictions indicate that the extreme seasonal fluxes will bring more intense and frequent flood and drought fluctuation as “seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events, with hotter drier periods in between” (Rosenberg and Edmonds, 2005; Karl, 2009, 45). This intensity and variability will place an additional burden on already strained and depleted water systems, and is in part attributable to the effects of the Pacific Decadal Oscillation (PDO) and El Niño Southern Oscillation (ENSO). The increasing frequency and intensity of these climate-driving oscillations will contribute to more extreme variability than previously experienced in this region, particularly notable in the winter and spring precipitation extremes (Gershunov et al., 2013). El Niño effects often result in wetter winters, while La Niña effects contribute to drier winters (Sheppard et al., 2002).

The aforementioned results and projections of climate change are corroborated by local observations. As stated by a *Parciante* of the *Acequia Madre del Rio Lucero y del Arroyo Seco*,

“From working and living in Taos—the real changes that I’ve seen have had to do with precipitation changes. Not in volume but in timing, and also in temperature fluctuation and timing. The variance in these fluctuations is happening on a wider timescale than in the past. Historically, if the last frost was always the last week of May, and before that we maybe had one week of

temperatures above 60 degrees...now it's 5 or 6 weeks [of these high temperatures] before that last frost. And, that last frost creeps earlier into the season" (Personal Interview, 2017).

A *Parciante* of the *El Rito de La Lama Acequia* states,

"I've lived on this land for 32 years. When I came here, we had luxurious summers, good rainfall, [a] great watershed...and then, by '94, things started to dry up. By '96, we [had] the first of the big climate-caused wild fires; this took my own home—sparked by a complete lack of water the preceding winter and spring... We watched the sole domestic water supply for the entire community actually dry up and stop about 3-4 years ago.² We began trucking water. This is the death of a farming community. The results [of climate change] in this area are more visible than for the average American" (Personal Interview, 2017).

The Southwest region has the most rapidly increasing population in the United States. Rising populations strain already over-appropriated water and energy supplies; the water-energy nexus is closely linked in the Southwest (Colby and Frisvold, 2011). These climate change impacts will not only challenge water supply infrastructure, but will also challenge existing legal and regulatory structures and a management system that "[was] designed for seasonal timing and magnitudes of runoff [based on] historical temperature, precipitation and snowmelt patterns" (Colby and Frisvold, 2011, 5). Considering the changing Southwestern and global climate, and a reduction in water availability, Overpeck et al., (2014) state:

"The past will no longer provide an adequate guide to project the future.

Twentieth- century water management has traditionally been based in part on the principle of "stationarity," which assumes that future climate variations are like past

² The rains returned the following season; however, community members continue to prepare for drought conditions as a way of life.

variations. As climate changes, temperature will increase substantially and some areas of the Southwest will become more arid than in the past (high confidence)” (Overpeck et al., 2014, 14, 5).

4.2 Q2: Who is most vulnerable, and to what?

“This unequal aspect of climate change whereby those who were less responsible suffer more severely is a pattern replicated within marginal communities in many developed countries, including the U.S.” (Castro et al., 2012, 130).

As climate change impacts differ over time and space, so to does the vulnerability and resilience of affected populations. While the definitions of vulnerability are diverse (see Vörösmarty, 2000; Füssel and Klein, 2006; IPCC, 2014) this paper defines vulnerability by using the conceptualization of the IPCC AR5 (2014), as “the propensity or predisposition to be adversely affected [by climate change impacts]. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (IPCC, 2014, glossary). This paper expands upon this definition to encompass vulnerability as applying to *any tangible or intangible system, including, but not limited to, systems that are cultural, ecologic, economic, (inter)generational, mental, spiritual, systematic, complex and dynamic.*

Resilience is framed in this paper using the conceptualization of Holling (1986), Adger (2000), and the IPCC AR5 (2014) as “the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous

event in a timely and efficient manner” (IPCC, 2014, 563); “the capacity to lead a continued existence by incorporating change” (Holling 1986 cited in Berkes et al., 2003, 352), and “the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change” (Adger, 2000, 2). Resilience is a precondition for adaptive capacity, the capacity to respond to and shape change (Berkes et al., 2003), and is built at three interconnected levels: psychological/personal, community, and system (Caldwell, 2015). Sources of social resilience include community networks, historical experience and learning, high diversity, and learning through consensus building (Berkes et al., 2003). As this paper will demonstrate, each component of resilience can be incorporated into and supported by local knowledge, participatory frameworks, and food sovereignty. Resilience is a *dynamic process* rather than a status, and is not synonymous with adaptation. Resilience can be represented by the degree of elasticity in a system, and is dynamic and persistent (Pelling, 2011).

As stated by the IPCC, NCA and corroborated by authors such as Maldonado (2014) and Salick and Byg (2007), rural and indigenous communities are among those most vulnerable to climate change impacts. Rural groups and indigenous groups are heterogeneous; each category carries its own unique, diverse, and non-stagnant culture. The two demographics are linked in this paper through their close relation with, and vulnerability to, the impact of climate change on water systems, as frontline communities.

As described by Udall (2013), “Water is a ‘super sector’ that has direct and indirect connections to perhaps all natural and human systems. In many cases water has no substitute. Agriculture relies on water provided by irrigation...Native Americans rely upon water for agriculture and to fulfill traditional cultural and spiritual needs. Ecosystems depend critically on the quality, timing, and amounts of water. It is difficult to overstate the importance of water, especially in the arid Southwest” (Udall, 2013, 199).

4.2.1 *Rural Communities*

Climate change threatens rural communities as we know them

(Caldwell, 2015, 1).

Climate change impacts to agriculture and rural communities in Northern New Mexico will be varied. Rural people exhibit strong values of self-reliance and community commitment; yet, these communities also tend to be more vulnerable than their urban counterparts due to isolation, lower per-capita income and limited access to resources (Brugger and Crimmins, 2013). The basis for vulnerability in this paper is the impact of climate change on water availability and the resulting implications for traditional farming practices. Localized farming practices, a deep connection to land, and reliance on the natural ecosystem concurrently makes communities both vulnerable to water stress and, by necessity, resilient.

“Dispossessed farmers or ranchers may offer many explanations for what forced them

from their land, but the discouraging consequences of drought may be a notable impetus among them” (Nabhan and Fitzsimmons, 2011, 13).

Notwithstanding, historical resilience will be severely tested. Higher temperatures will be accompanied by increased agricultural water demands due to amplified plant evapotranspiration, lower soil moisture, and extended growing seasons (Udall, 2013). This increase in demand is coupled with a decrease in availability, serving to augment drought conditions and water depletion in a positive feedback cycle. Even a 2°C shift in global mean temperatures above pre-industrial levels results in a 20% decrease of the Colorado River Basin (Castro et al., 2012). Decreases in these water systems will impact harvest, ceremony, and community relationships that govern agricultural irrigation in rural New Mexican communities (Castro et al., 2012).

A young and educated farmer who has grown up working the land of Northern New Mexico, states:

“Changes in the environment of Northern New Mexico have steadily become more noticeable. There is a larger variation of the historically normal weather patterns that bring dependable moisture. There have been increased periods of drought and patterns of moisture that are generally less predictable and *harder to rely on for growing historically successful crops in the area*” (Personal Interview, 2017, emphasis added).

Agriculture in Northern New Mexico is characterized by a vast number of small-scale farms, rather than concentrated numbers of large scale operations (Colby and Frisvold, 2011). This land tenure system was established at the time of Spanish colonization, and largely persists in contemporary times. Northern New Mexico water

rights are based primarily on seniority, rather than size. Thus, even during times of drought, those with senior water rights (which may potentially be small-scale farmers) are entitled to their full amount before junior holders receive their allotment.

The Colorado River runoff is already over-promised, leaving insufficient water flow to sustain all stakeholders. With the onset of earlier runoff days, and shifts in runoff volume, the distribution and allocation in international and interstate contracts will be further complicated (Karl et al. 2009; Udall, 2013). Considering stress to allocation and distribution, water conflicts are predicted to increase (Karl et al., 2009). While these community scale issues may generate small-scale rural conflict, the stress placed on these systems also allows for a creative re-imagining of community commitment to water distribution and use.

New Mexican water jurisdiction includes a complex medley of numerous tribes, two nations (the U.S. and Mexico), and both the state and federal government (Nabhan and Fitzsimmons, 2011). Because of these tangled water laws, land management and resource management practices have been dramatically transformed, commons have disappeared (resulting in displacement) and this has deprived generations of *querencia* (Salmón, 2012). *Querencia* is best understood as a deep and generational love of both place and land—a care for the environment rooted in utmost dedication to the land (Salmón, 2012). Systems that are cultivated through community and individual *querencia*, notably *acequias*, are in peril due to climate change impacts and the adjudication of water rights away from *acequia* associations (Salmón, 2012). Because

of this, complex water regulatory systems, augmented by climate change impacts and water scarcity, affect not only irrigation acreage but also community and cultural sectors.

Increasing water efficiency on small farms is important, yet there is often less initiative for small-scale farmers to invest in new irrigation systems (Colby and Frisvold, 2011). Despite this economic barrier, Brugger and Crimmins (2013) find that the climate change impact most often cited by rural Southwestern farmers is *water depletion*, and that the most commonly mentioned adaptation in response to this concern is *conservation*. Thus, it is locally emphasized that “water conservation can be seen not only as a response to the aridity of the climate, but also as an expression of the rural value of self-reliance, and the necessity of wise use of resources that goes along with it” (ibid, 1834). In times of drought, it is important to balance water usage between irrigation needs, household requirements, and wildlands habitat conservation.

Ensuring equitable and sustainable distribution of water resources between all stakeholders—large-scale agriculture and ranching, urban water users, and rural/small-scale agricultural users—is critical to any climate change mitigation, adaptation and resilience (CCMAR) plan. Thus far, regional water management has illustrated system-wide resilience, yet local vulnerability (Colby and Frisvold, 2011). In order to increase local water management resilience, in recent decades, many small-scale farms have transitioned from *acequia* usage to drip irrigation and/or water pipelines. While this increases irrigation efficiency, it also changes the way in which the entire landscape is

watered. In response, a growing number of farmers are choosing to maintain traditional *acequia* systems in response, as these waterways irrigate not only their personal cropland, but also the surrounding ecosystem (Nabhan and Fitzsimmons, 2011). A *Parciante* of the *El Rito de la Lama Acequia* reflects on the challenge *acequia* users face between irrigation efficiency and care for the surrounding environment:

“We are in different terrain where many of the old practices aren’t sustainable...Above ground *acequia* systems have so many perils and can be terribly inefficient...as far as carrying the water adequately for farming needs, we are having to rethink this paradigm... The technology is outdated because we have lost more water, have more need [due to declining water availability], and there is inefficiency. As our water dries up, we will [perhaps] need to go to a pipe system [connected] directly [to] the springs. And yet, this will hurt the riparian habit, which is critical to life on the mountain, and to the ecosystem...these are big questions...its’ a domino effect without a good answer...It’s not so simple” (Personal Interview, 2017).

A *Parciante* of the *Acequia Madre del Rio Lucero y del Arroyo Seco* pushes against proposed technologic solutions that do not benefit the whole system, stating

“Simply by doing some forest thinning we can increase the water flow into the *acequia*. [There are] many alternative conservation solutions as opposed to infrastructure [and tech solutions]” (Personal Interview, 2017).

Despite the vulnerability of rural communities and farms to climate change impacts, “climate change has not descended upon agrarian landscapes and rural communities in one fell swoop” (Nabhan, 2013, 14). While rural agricultural communities may suffer agricultural productivity loss, this period of flux provides an opportunity to strengthen rural resilience through supporting local food systems (Nabhan, 2013). Many rural agriculturalists develop ways of *living with the*

environment, which include continuous adaptations and adjustment in response to the changing climate. Indeed, the epistemology of living with the climate is based on local systems of knowledge, rather than abstract and generalized knowledge that accompanies the mentality of *overcoming* the environment (Brugger and Crimmins, 2013). The differences in these approaches lead to parallel differences in resilience building. Generally, those who live in concert with the environment develop a holistic understanding of climate change resilience and adaptation, rooted in local knowledge and the social-ecosystem. One illustrative example of living with the environment given by Brugger and Crimmins (2013) is the way that farmers utilize spatial hydrological variability by moving flocks to higher elevations which receive greater amounts of rainfall, and similarly positioning small fields at the point of natural drain flow to produce a field flooding effect.

4.2.2 *Indigenous Communities*

“Without doubt, indigenous peoples of the deserts are on the frontline of global climate change” (Salick and Byg, 2007, 8).

While the climate change impacts to indigenous nations are vast and complex, this paper will focus on water system impacts and traditional food sovereignty, both of which are integral to culture. Indigenous Southwestern communities, lands, and cultures are likely to be disproportionately affected by climate change. While indigenous contribution to climate change has been negligible, the consequences of climate change for these communities are substantial (Orr and Anderson, 2012). This vulnerability is

attributable to and enhanced by jeopardized cultural practices, undefined and/or limited water rights, and a legacy of social, economic, and political marginalization (Overpeck et al., 2014). Castro warns that there is danger that the technological solutions inherent in nearly all resilience plans will overlook structural inequalities that contribute to vulnerability and the uneven distribution of impacts (Castro et al., 2012). For indigenous nations in the Southwest, climate change is not a phenomenon to prepare for in the future, it is a clear and present reality. The most critical climate change impacts in Northern New Mexico originate from drought and rapid flooding, which affect agriculture, livestock, soil quality, fisheries, cultural practices, water supply, and water rights (Cozzetto et al., 2013). Each of these impacts may detrimentally affect indigenous communities, culturally, financially, materially, and spiritually. As Cozzetto et al., (2013) states, “Water is sacred. This is tradition. Water is a holistic and integrating component connecting continents, humans, animals, and plants through a continuous cycle of liquid, solid and vapor states. . . water is the one thing we all need, all of us, all of life. Water is life.” (Cozzetto et al., 2013, 62)

Indigenous communities in the Southwest are vulnerable to changes in water quality and quantity due to historic dependence on and interconnectedness with this resource, physically and spiritually. Vulnerability is “exacerbated by historical and contemporary government policies and poor socioeconomic conditions” (Bennett et al., 2014, 315). Vulnerability is amplified by the potential “loss of traditional knowledge in

the face of rapidly changing ecological conditions, increased food insecurity due to reduced availability of traditional foods, and changing water availability” (Bennett et al., 2014, 298). Additional stressors affecting Southwestern indigenous communities include increased industrial activity near tribal land (coal-fired power plants), extractive industry pressure on indigenous communities (fracking for natural gas, uranium mining and coal mining), and a centuries-old legacy of environmental injustice and racism towards indigenous peoples in New Mexico. Furthermore, U.S. Reservations were historically established on the most depleted land. The Navajo Nation Reservation, for example, is situated on the most arid third of the historic Navajo homeland (Kelley et al, 2010; Redsteer et al., 2013).

Climate change, specifically reduced access to water, threatens indigenous sovereignty by constraining the right to access traditional foods. Traditional and even non-traditional foods, cultivated for subsistence, provide both physical and metaphysical sustenance (Lynn et al., 2013; Garfin et al., 2014). During interviews conducted by Redsteer and Kelley et al., in 2010, Navajo elders identified changes in water availability and climate as central to their lessened ability to cultivate sustenance crops such as corn (Redsteer et al., 2013). In Northern New Mexico, corn (*maíz* in Spanish) is a staple food for indigenous and rural communities, carrying nutritional, spiritual, and cultural significance. Corn is a central component to most Puebloan cultural and spiritual practices, and the use of corn pollen is a key component of every

ceremony in Dinétah (The Navajo Nation traditional homeland) (Redsteer et al., 2013; Lynn et al., 2013).

Water scarcity is one of the chief stressors impacting cultivation of this significant crop (Redsteer et al., 2013; Lynn et al., 2013). Despite attempts at preservation, not all plant varieties are continuously used or cultivated in rural communities. This damage contributes to a feedback loop: as access to traditional foods is limited, relevant aspects of culture and traditional knowledge that rely on them will similarly disappear. For rural and indigenous communities, biodiversity is a key element of ecological and agricultural resilience (Salick and Byg, 2007). Without the backbone of traditional knowledge, or indigeneity, it will become harder for indigenous communities to preserve traditional food systems and ways of knowing that reside at the center of indigenous climate change resilience (Whyte et al., 2013).

“In a basic sense, climate change is all about water” (Maldonado, 2014, 4). Water is the mover and shaker; water is the integral component of all life.

Water rights in New Mexico are based on seniority and thus indigenous nations maintain priority. Despite this, many water rights are undetermined and are in urgent need of adjudication, particularly in the face of decreased water flows and increased water pressure from growing downstream urban centers and extractive industries (Cordalis and Suagee, 2008 cited in Lynn et al., 2013). As stated by Redsteer et al.,

2013 “*Water rights are closely linked to the vulnerability and adaptive capacity of tribes*” (Redsteer et al., 2013, 420).

Historically, tribal water rights have been determined by the *reserved rights doctrine*, which upholds tribal rights to land and water resources, if not explicitly addressed in Tribal-Federal treaties (Redsteer et al., 2013). Tribal water rights are thus governed under federal law (Osborn, 2011). The *Winters v. U.S.*, 207 U.S. 564 (1908) ruling guarantees tribal water in sufficient quantity to meet the current and future needs of the tribe, accounting for the purpose for which that reservation was created (e.g. fisheries, livestock, rangeland, etc.) (Osborn, 2011; Redsteer, 2013). For agricultural reservations, water is allocated based on practicably irrigable acreage (PIA). The PIA standard remains today, but is supplemented by the standard of historically irrigable acreage (HIA), which honors the seniority rights of Pueblos, yet limits water distribution to be no greater than what is distributed to the public (Osborn, 2011). These rulings indicate that tribal water rights are secure and ample, though many tribal water rights still remain largely undefined. The vulnerability of these undefined rights has manifested in the over-allocation of watershed resources to non-tribal entities, without tribal input (Osborn, 2011). The need for definition and adjudication underscores the importance of participatory, government-to-government consultation. Indigenous tribes are federally recognized sovereign governments. As such, tribes “have the authority to address climate change as an important issue that affects their lands, resources, and traditional practices. Because climate change operates *across jurisdictional boundaries*,

an awareness of *tribal rights to water and cultural resources, located both on and off the reservation*, are important to understand and evaluate...” (Redsteer et al., 2013, 388, emphasis added).

In 2003, New Mexico defined the “resolution of tribal claims as a critical statewide priority” (State Water Plan, 2003 cited in Osborn, 2011). During the past decade, the State of New Mexico entered into water rights settlements with the Navajo Nation and five New Mexico Pueblos, all of which share territory in the Northern New Mexican Region. As in the case of the Taos Indian Water Rights Settlement (The Abeyta Settlement), Pueblo water rights may be used for any purpose, opening the valuable resource and the communities of Northern New Mexico to potential exploitation at the hands of extractive commercial industry. In the face of climate change, it is critical that increases in water allocation arising from final determinations are not utilized for climate degrading practices.

The Southwest has the highest proportion of federal and tribal land in the United States, with a substantial amount of this land existing in New Mexico. Tribal governments are engaged in adaptation and resilience planning through independent action as well as through the application for additional resources from the federal government (Overpeck et al., 2014). It is important that resilience planning is not solely shaped by governmental adaptation measures, and in addition considers traditional knowledge and historic forms of community resilience. The allocation of resources should be apportioned for both types of resilience building. This acknowledges the

relevance of traditional knowledge and guards against biased allocation of federal funding.

Government policies have a legacy of marginalization and environmental injustice. For example, in 2009, the Department of the Interior (DOI) introduced a Climate Change Adaptation Initiative that allocated funding for lands under federal jurisdiction, which includes Tribal Lands. While Tribal Lands constitute 11 million more acres than National Park lands, the National Park Service was awarded nearly 50 times more funding than that granted to the Bureau of Indian Affairs (Pardilla, 2011 cited in Redsteer et al., 2013).

4.3 What are the roles of participatory methods and local knowledge in building community resilience?

4.3.1 Participatory Methodologies Framework

Participatory methods conceptualized in this paper draw upon the definition set forth by Van Asselt et al., 2001, who states, “Participatory methods are methods to structure group processes in which non-experts play an active role and articulate their knowledge, values and preferences for different goals” (Van Asselt et al., 2001, 8). I add that participatory methods should honor and emphasize a co-creative process for knowledge sharing.

Frameworks for participatory approaches to research, development, and the generation of knowledge are increasingly recognized as integral components to developing resilience to climate change (see Slocum and Steyaert, 2003; Roncoli, 2006,

Maldonado, 2014; Downs et al., 2017). Participatory frameworks should be included in any CCMAR process. In this paper, the co-creation of knowledge represents research methods that follow a multi-stakeholder, interdisciplinary, and dynamic approach. A stakeholder is understood as any entity that carries a “*voluntary or involuntary* legitimate interest” in a project or response to an impact (adapted from Ingram, 2010, emphasis added). Stakeholders are heterogeneous groups, actors and individuals that represent nonhomogeneous, dynamic, and complex (sometimes conflicting!) interests (Ingram, 2010). Participatory partnerships facilitate the preservation and valuation of communal cultural knowledge and resources (Williams and Hardison, 2013).

Participatory partnerships should not be driven by an external agenda or a science-centric approach (Roncoli, 2003); partnerships instead afford the opportunity for meaningful insight, which in return yield CCMAR plans that are tailored to a specific community. Participatory approaches must be lawful, consensual, and should follow local customs and norms, informing all stakeholders of benefits generated during the CCMAR/participatory process (Ingram, 2010). Participatory approaches to research and development have the potential for bias, elite capture, and may be influenced by internal power dynamics. Acknowledging this, the process of participatory research should be designed with the community of focus at the center of the process.

Stakeholder engagement allows for the genuine identification of impacts of concern, the contribution of knowledge and wisdom, the formulation of an appropriate and useful

research agenda, and the means to implement this research (Ingram, 2010). The process timeline that is developed should include ample intervals for monitoring and evaluation.

The same factors that may influence stakeholder engagement in participatory research also influence the relative vulnerability of the stakeholder (Roncoli, 2003). For example: community members without land or employment may not be initially welcome by the community to engage in participatory dialogue, yet it is these same individuals who may face the greatest insecurity due to their inability to develop self-sustaining plans for resiliency or to access services provided by the community. Thus, as Castro (2012) states, “For effective involvement to take place, issues of both power and capacity need to be addressed with respect to communities and their members; otherwise, such supposedly ‘participatory’ endeavors may prove not only disappointing, but even potentially destructive for their intended ‘beneficiaries’” (Castro et al., 2012, 199).

The use of participatory methods in addressing climate change is supported both pragmatically and normatively (Slocum and Steyaert, 2003). Pragmatically, participatory methods gather the most knowledge, experience, and expertise available from the community. This informs decision making processes and allows decision makers to plan for potentially diverse impacts (Slocum and Steyaert, 2003). Normatively, a participatory process facilitates a democratic and representative outcome (Slocum and Steyaert, 2003). The ability for all stakeholders to engage in a participatory process promotes an equitable and just product of any engagement.

Furthermore, it guards against climate change “solutions” that would further marginalize already disenfranchised community members.

To best serve the community of Northern New Mexico, the participatory methods employed should be decided upon in conjunction with researchers and community members to maintain alignment with scientific understandings of climate change, and to develop realizable plans for resilience. For a comprehensive listing and description of 10 pre-developed Participatory Methods, including *Planning Cells*, *Scenarios*, *Participatory Rural Appraisals* and *World Cafe*, see Slocum and Steyaert, 2003. In addition to the guidelines put forth by these pre-developed methods, attention to the integration among *six levels of capacity* (see Downs et al., 2017) will ensure a balanced and actionable plan of sustainable and holistic development planning. As stated by Castro et al., (2012), “engagement of the communities in climate change mitigation and adaptation efforts must consider their existing relationships and concerns with the local environment” (Castro et al., 2012, 9). The integration of and attention to *intergenerationality* and *intersectionality* should be included in any methodology chosen.

Climate change resilience planning presents an opportunity for the decolonization of research, and the integration of multiple stakeholder perspectives. Local stakeholders in Northern New Mexico offer observations, experience, and tools to build resilience to climate change impacts. Yet, each community faces threats to the culture and livelihoods that support the persistence of this knowledge. If these

communities are to “exercise self-determination and be empowered to deal with climate change [impacts].... integration and feedback loops between climate change science and [these communities] must be employed. Both parties can gain knowledge from the other and support each other in action” (Salick and Byg, 2007, 25).

4.3.2 *Local Ways of Knowing*

“Tribes have long historical, cultural and physical connections to plants and wildlife.

These relationships manifest themselves in their connections to and reliance on traditional foods. These bonds form the basis of traditional ecological knowledge

(TEK), the indigenous ways of knowing” (Lynn et al., 2013, 39).

In Northern New Mexico, traditional foods and local knowledge systems are threatened by, and present solutions to, climate change impacts. Traditional forms of agriculture and harvest strengthen community resilience, and sustain and replenish the land. The term Local Knowledge (LK) is used in this paper to encompass traditional knowledge (TK), traditional ecological knowledge (TEK), indigenous knowledge, Hispano knowledge, and community-developed knowledge. The terminologies of local, traditional, traditional ecological, indigenous, and Hispano knowledge have the potential to be used as a noun phrase, transforming complex *systems of knowing* into objects (Berkes, 2009 cited in Williams and Hardison, 2013). These local ways of knowing are contextualized, dynamic, and enduring relationships developed continuously through space and time. LK, in this paper, should be considered a dynamic and non-stagnant localized *way of knowing*.

Local Knowledge can inform observations about climate change impacts, resilience development, and can reconstruct historic baselines (Williams and Hardison, 2013). Climate change assessments that are informed by LK benefit indigenous and non-indigenous communities alike (Maldonado, 2014). The incorporation of LK into climate change strategies enhances scientific understanding of climate change impacts, adaptation, and resilience building. The incorporation, valuation and recognition of LK as a powerful and integral component in CCMAR planning helps transition the role of indigenous and rural peoples in climate dialogue from inactive victims to informed, and informing, agents.

Development of LK, and access to it as a tool for adaptation, is increasingly tested by climate change. LK is vulnerable to western exploitation and colonization, particularly those forms of LK rooted in TEK/TK. Asserting that it is the inclusion of LK into scientific climate frameworks that bestows value on the local knowledge is to perpetuate a colonial framework and valuation of knowledge. Thus, local knowledge must be incorporated into climate change assessment and planning in a meaningful and participatory manner, led by the indigenous and local people.³ Indeed, there has been no time more critical than now that effected communities participate in planning processes. “[Indigenous and Local] cultural and lifeway diversity expressed through the symbiotic nature-culture nexus reminds all of us that our human responses to climate change will

³ For a framework of free, prior and informed consent in the utilization of TEK, see Williams and Hardison, 2013. This framework supports a respectful partnership and utilization of TEK, and symbiotically supports Article 31 of the UNDRIP.

require diverse strategies that fit the people and places of the planet—in all of their diversity” (Wildcat, 2013, 2). Indigenous and rural peoples have multi-generational histories of interaction with their environments that include coping with environmental uncertainty, variability, and change (Wildcat, 2013).

Historic adaptation records support the argument that incorporation of local knowledge into resilience building in the southwest is beneficial. Williams and Hardison observe that “traditional water-related knowledge, water harvesting and storage have allowed indigenous peoples to survive [and thrive] in arid lands and cope with drought for millennia” (Johnston, 2012 cited in Williams and Hardison, 2013, 23). These ways of knowing are living traditions that provide transformative and culturally appropriate approaches to adaptation (Wildcat, 2013; Williams and Hardison, 2013).

When asked how, and if, local ways of knowing support resilience, a young agriculturalist states that,

“Traditional knowledge and skills build resiliency because they have been upheld through cultural and community development for generations. They have served as a guide to what has worked in the past, cater[ing] to the same land and environmental conditions that many families in Northern New Mexico have historically cultivated” (Personal Interview, 2017).

A prominent young community organizer, activist, artist and member of the International Indigenous Youth Council reflects on the need for the integration of local knowledge, stating:

“When we stand with the earth, we stand with each other. When we know the value of the land, we know the value of ourselves. [Local knowledge supports] this and

build[s] resilience. Our connection to *Unci Maka*. Grandmother Earth, keeps us strong” (Personal Interview, 2017).

Northern New Mexico has been continuously inhabited, and the land continuously cultivated, for more than 1,000 years by the Pueblo peoples and, later, Spanish settlers. A wealth of local knowledge was generated that enabled communities to adapt during changing climatic periods. While oral histories corroborate that conditions today may be hotter, drier or more uncertain than were previously experienced, the same oral histories provide insight into how to move forward (Nabhan, 2013). Reliance on previous resilience practices alone, however, will be insufficient.

LK is a continuous and persistent system (Whyte, 2013). The assumption that “knowledge may either be indigenous or scientific,” is a misconception that fosters false dichotomizations (Castro et al., 2012, 198). In the face of rapid climate change, LK holders must modify long-standing traditions and techniques to accommodate complex environmental change. This means that LK will undergo a process of regeneration in a time of ecological, technological and cultural transformation (Castro et al., 2012). A young agriculturalist speaks to this process of change and integration, stating:

“With the climate changes that we are already experiencing, working the land in Northern New Mexico will become increasingly difficult because our history of knowledge that our ancestors have built up and have passed down, generation to generation, may not be enough to predict these new climate shifts. This means that crop cultivation must be planned differently in an effort to regain a balance between ancient crop planning (based on what has worked in the past) and what the current climate is showing us we need to adapt to” (Personal Interview, 2017).

Policymakers should account for local priorities and capacity when developing resilience plans. There is a negative stereotype that impacted communities (rural farmers and indigenous tribes) lack agency and are not engaged in their own resilience planning, despite evidence to the contrary. Local knowledge is a key capacity component, “which has served as the basis for livelihoods and other cultural practices [including adaptation and resilience]” for centuries (Castro et al., 2012, 197). Rural farmers and communities can experiment and integrate different forms of knowledge and technology to best enhance their own resilience, and yet the capacities of these communities “should not be romanticized at the expense of realistic assessment of the challenges resource poor farmers [and tribes] face in coping with climate variability and change” (Roncoli, 2006, 94).

Community based resilience, stemming from community based adaptation (See Schipper et al, 2014), is “a [self-mobilized] community led process based on the community’s priorities, needs, knowledge, and capacities which should empower people to plan for and cope with the impacts of climate change” (Reid et al., 2009 cited in Schipper et al., 2014). This process builds on local knowledge that farmers and tribes have developed in the absence of, or in tandem with, western scientific information. Developing communion between local and scientific knowledge is often difficult for individuals and organizations who must overcome inbuilt power imbalances that prioritize science. Overcoming this epistemic divide will enhance resilience and capacity (Pelling, 2011).

While Salick and Byg argue that the benefit of local interaction with the environment is based on the fundamentals of TEK, the authors also state that due to the extinction of ancient cultures, “much of what people have developed in response to disaster has also been lost: domesticated crops have been lost, water harvesting techniques have been lost, and dry land management has been lost” (Salick and Byg, 2007, 5). This paper counters the assumption that cultural LK has been lost. While a vast amount of Local Knowledge has diminished in practice and is threatened by climate change impacts, to conceptualize these systems of knowledge as an asset that can be lost implies they are stagnant. On the contrary, local ways of knowing are dynamic and evolving, and have progressed throughout times of cultural change. In order to promote the continuation and development of local ways of knowing, many Northern New Mexico community members speak about the need to engage youth in LK practices, as a means of bolstering community resilience and the cultivation of local knowledge:

“The greatest weakness of the [local] cultures of Northern New Mexico, which threatens the resilient aspects of these cultures, is the brain drain that has happened over the last several generations. [In my *acequia* association] the participation of any one under 60 years old is less than 5%. The success, preservation, and resilience of these systems [depends on the engagement of the youth]” (*Parciante of the Acequia Madre del Rio Lucero y del Arroyo Seco*, Personal Interview, 2017).

In response to observations of decreased youth participation, individuals are working pragmatically to bring youth back into the cultural systems. One educator in

the community, who has worked with children for over 25 years, has moved education into nature, now teaching in relation to the surrounding environment:

“I am taking children into nature. I am taking them to the springs. We follow the waterways on the mesa, even if there is no water in them, so we understand how water flows when it does come” (Personal Interview, 2017).

4.4 What lessons can we learn through examining the histories and traditional practices of peoples in this land, and is Food Sovereignty an appropriate low-tech way to build resilience in this region?

Local ways of knowing have enabled rural and indigenous communities to survive and thrive for centuries in the arid mountain landscape of Northern New Mexico. In the coming decades, it will be crucial to draw upon this knowledge as communities adapt to a hotter and drier climate. Customary practices include localized forms of crop rotation, water storage and irrigation, indigenous organic fertilizers and seed saving.

Local Knowledge exists in both recorded and oral forms. As this paper is focused on water impacts and the concept of food sovereignty as a resilience mechanism, the following section describes several practices developed through Local Knowledge that relate to food cultivation in the climate of Northern New Mexico. This practical wisdom is founded on the collection of historic knowledge and the continual testing and adaptation of that knowledge based on environmental and cultural inputs. To gain a deeper understanding of practices that are applicable to Northern New Mexico, see Nabhan (2013) and Salmón (2012).

“The southwest also has a long legacy of adaptation to climate variability and of environmental management that has enabled society to live within environmental constraints and to protect large parts of the landscape for multiple uses and conservation” (Liverman et al., 2013, 406).

4.4.1 *Water Harvesting & Irrigation*

“Throughout human history, water—in particular the ability to move it across the landscape—has been critical to the growth of societies” (Liverman et al., 2013, 408).

Crop cultivation in the high mountain desert of Northern New Mexico has been practiced for over 1,000 years. Historically, farmers have adapted to climate changes that have resulted in periods of great precipitation and great drought. By responding to changing climatic conditions, the region has sustained prosperous agricultural systems. While local Hispano farmers and the different Pueblos of the Rio Grande diverge in language and history, the practice of dryland farming bonds them (Salmón, 2012). A mixed legacy of colonization and settlement introduced non-native agricultural practices and crops (such as chiles) to the landscape and encouraged an agricultural system that could adapt to short, often dry growing seasons (Salmón, 2012). Throughout this period, indigenous agricultural systems thrived, and colonial Hispano and indigenous farming practices began to inform and enhance each other, resulting in integrated and resilient forms of agriculture (Salmón, 2012).

Indigenous peoples of Northern New Mexico developed sophisticated water catchment, harvesting and conveyance systems long before the introduction of Spanish

irrigation (Liverman et al., 2013). Pre-Hispano irrigation systems utilized raised beds and terracing to divert and disseminate water flows (Castro et al., 2012; Nabhan, 2013). Indeed, drought was a persistent difficulty for native Pueblo agriculture. Yet, Local Knowledge guided these communities to develop sophisticated, dynamic and complex practices of resilience (Salmón, 2012).

During Spanish colonization and settlement, *acequia* irrigation infrastructure was introduced, renovated, and adapted. These systems continue to be one of the most persistent influences on regional agriculture, which enabled the development of larger cities, and enhanced rural agriculture. *Acequia* systems are communally managed irrigation ditches that divert water from local streams and snowmelt. The *Mayordomo* manages *acequia* water allocation, and those farmers and rural farmers who rely on the waters are known as *parciantes*. The *Mayordomo* is elected by the community, and ensures that water distribution is ethical. In times of drought, the *Mayordomo* is also responsible for determining who receives water and who must wait until the rains resume (Salmón, 2012). Often, communities and neighbors will share their water allocations during the dry season, to help ensure all are sustained. As Salmón states, this peculiar system has somehow worked and persisted “in Northern New Mexico for nearly 400 years, feeding the small fields growing heirloom crops and acting as an adhesive of both community and landscape” (Salmón, 2012, 109).

A Parciante of the *El Rito de la Lama Acequia* Association states that

“This [acequia culture] is what Northern New Mexico can offer to the world: as water becomes a scarcer commodity, which it has always been [in these lands], we have developed a social mechanism to keep us from monopolizing the water or being at each others throats... This [communal water] system has been worked out for centuries... there are growing pressures to monopolize and privatize water, but this is the antithesis of acequia culture. It [acequia culture] is a democratic institution. This is a way to keep scarce resources justly apportioned” (Personal Interview, 2017).

A Parciante of the Acequia Madre del Rio Lucero y del Arroyo Seco

corroborates this sentiment, stating:

“There are many expensive, complicated solutions [to water scarcity]. But really, Mother Nature gives us rain and our acequia systems, for 300 years, have been designed to manage the lack of, or availability of, water. Let us keep things as traditional as possible. [We do not need more legal negotiations], if we [Arroyo Seco] need water, we will ask the [Taos] Pueblo. This has happened in the past, it is local, and it works. Our traditional systems have resilience built into them” (Personal Interview, 2017).

Acequia systems serve both an agricultural and a cultural purpose. Long embedded in the history of Northern New Mexico, *acequias* play a central role in community engagement and shared cultural experience. Aside from cultural, historic, and modern significance, *acequia* systems are an established form of irrigation and water dissemination in rural and peri-rural areas of Northern New Mexico. *Acequias* provide the opportunity for small-scale agricultural endeavors, but also link many homes and communities to a running water system. *Acequia* systems enhance riparian habitat, wetlands and community, and are demonstrations of resilient culture and practice (Salmón, 2012). Thus, a decrease in availability and quality of water impacts small-scale farming practices, but also the endurance of tradition. A young agriculturalist states that,

“*Acequia* culture is a strong indicator of resilience within Northern New Mexican agricultural practices. This type of coping strategy will be increasingly useful as water resources become more limited. However, harsher, more sporadic environmental conditions can eliminate the possibility of supporting life as we have known it. If we don’t get enough snowfall accumulation in our upper watersheds or rain during monsoon season we will not have water in our *acequias* to depend on and the potential for agriculture will be greatly decreased” (Personal Interview, 2017).

Additional examples of desert watering techniques developed through local knowledge include the use of *Olla* pottery jars, which slowly hydrate crops and soil, desert nurse plants, which shield young crops from harsh heat and sun, and the understanding of the critical importance of soil quality. Farmers work with the soil to enhance moisture content and position croplands in natural areas of water flow or rainfall (Nabhan, 2013). Watershed and regional governance of food and water systems are very successful, as evidenced by New Mexican *acequia* associations. Localized governance enables the development of water banks that facilitate temporary transfers of water rights, as well as the protection of water rights for those farmers who transition to less intensive practices (Nabhan and Fitzsimmons, 2011).

4.4.2 *Seeds, Planting & Cultivation*

As expressed by Enrique Salmón, local forms of agriculture extend far beyond knowing when and how to properly irrigate, and at what depth to sow seeds (Salmón, 2012). Rather, these practices that nourish community are connected to identity, history, culture, and love of land. “This identity, this sense of ‘being-ness’ is tied to the history of the people on a landscape” (Salmón, 2012, 32). The use of seeds and farming practices that are traditionally adapted to the Northern New Mexican climate will be an

increasingly useful means of coping with climate change impacts. Furthermore, the preservation of this knowledge inspires a different connection to agriculture and soil productivity, one that is self-sustaining. As stated by Aziz Bousfiha (quoted in an interview by Nabhan, 2013), “Over the centuries, these ancient seeds have adapted to place. It is not just a natural ecosystem, but a cultural ecosystem as well” (Nabhan, 2013, 6). This sentiment reinforces the role of local knowledge as a form of cultural and environmental resilience. Heirloom crops adapted for the region are often resistant to disease and drought, and connect communities to culture. Traditional seed exchange allows for the continuation and upsurge of heirloom crops. These processes are undergoing a renaissance in Northern New Mexico, with both farmer’s markets, grocery stores, and individuals increasingly sharing locally grown heirloom crops—from Rio Grande wheat loafs to *blue corn atole* (the iconic *atole de maíz azul* of this paper’s title).

A young agriculturalist states that,

“New Mexico has a strong arsenal of local and traditional practices such as seed saving and seed banks, cultivation of heritage seed varieties that have shown resilient traits in past weather patterns, and localized small farms that are built on community engagement and practices, in keeping with the natural limits of Northern New Mexico ecosystems. This has also included Community Supported Agriculture programs that have consistently been popping up in the state through mostly small farming initiatives. There are school based agriculture programs that encourage involvement and education that aims to bring youth into a growing engagement with the natural environment and pass down food growing practices to the upcoming generation” (Personal Interview, 2017).

Practices, such as using living “fedges” (hedge rows as fences) help to conserve water flow. Crop rotations and sister plantings are also particularly important in this region, as these plants have formed symbiotic relationships to survive in arid conditions. Furthermore, other global regions provide useful wisdom to incorporate into the Northern New Mexico communities, such as Arab rain and waffle gardens and the construction of a desert (or *mesa*) oasis that provides nourishment for communities all season long. Nabhan (2013) encourages desert residents to cultivate food using the mentality of century and desert plants. This advice is steeped in local wisdom, creating a pathway for individuals and communities to holistically utilize their surrounding natural resources to develop sustainable and appropriate food systems. The *Española Healing Foods Oasis* in Northern New Mexico, spearheaded by the indigenous group *Tewa Women United*, is working with the community to discover and implement traditional water harvesting and dryland farming techniques. Their mission statement declares that they seek to “increase climate change impact resiliency and increase access to healthy, natural food and medicine, while shifting current perspectives to include maximizing use of our water resources...[through] community partnerships and participation (Tewa Women United, 2016).

4.4.3 *Food Sovereignty*

This paper has thus far outlined present and projected climate change impacts to Northern New Mexico with specific attention paid to rural and indigenous communities. The paper has stated the case for the inclusion of participatory frameworks of

knowledge and resiliency building, and has outlined why the incorporation of local systems of knowledge are critical for successful resilience building. *A logical extension of this concept is a system of resilience that incorporates water, food, culture, participatory foundations and local knowledge: food sovereignty.*

Food sovereignty is “the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems” (Via Campesina, Nyeleni Declaration, 2007). Food sovereignty dictates that inherent in food choice is the right of peoples to access culturally diverse foods, cultivated through an array of sustainable production methods (Ackerman-Leist, 2013). While “food sovereignty is clearly a challenging ideal for any group that is resource thin or marginalized by virtue of prevailing power structures or stereotypes,” it is also a means for communities to build resilience through the utilization of local knowledge, traditional lands and traditional waters (Ackerman-Leist, 2013, 144).

In Northern New Mexico, communities are increasingly embracing intentional or unintentional food sovereignty programs based on the use of traditional local knowledge and crops. For communities of Northern New Mexico, food sovereignty extends *beyond* food, and also represents movements for self-determination and resilience against threatened ways of knowing and being. “When one eats these foods, one is supporting a resilient process for sovereignty” (Salmón, 2012, 148). As Northern New Mexico communities became increasingly aware that industrialized agriculture

and climate change threatened their traditional food systems and heirloom crops like *maíz azul*, they became more motivated to increase their resilience. In 2006, through the help of the *New Mexico Acequia Association*, the *Traditional Native American Farmers Association* (two primary groups of the New Mexico Food and Seed Sovereignty Alliance), as well as *Tewa Women United* and *Honor Our Pueblo Existence*, Santa Fe, and Rio Arriba Counties adopted the *Seed Sovereignty Declaration*. The Declaration is considered to be a living document, and has been accepted by Tesuque Pueblo, Pojoaque Pueblo, the All Indian Pueblo Council, and the Eight Northern Pueblos. The Alliance also passed the Senate Joint Memorial 38 and the House Memorial 84, both of which recognize, legislate, and honor the importance “of indigenous agriculture and native seeds to the food security of New Mexico as well as recognizing farmers’ rights to keep their seeds free from GE [genetic engineering] contamination” (NMAA, 2016). The Declaration, the supporting resolutions, and the leading organization’s aim is “to continue, revive, and protect our native seeds, crops, heritage fruits, animals, wild plants, traditions, and knowledge of our indigenous, land- and acequia- based communities in New Mexico for the purpose of maintaining and continuing our culture” (NMAA, 2016).

Food sovereignty is political, cultural, and racial. Climate change impacts to rural and indigenous communities are dynamic and multifaceted, impacting cultural, spiritual, health, lifestyle and livelihood dimensions. Through this concept of food sovereignty, communities may develop holistic means of resilience through community-

based agriculture, local knowledge, and respect for seeds, food, and land (Wittman, 2010). Ingram posits that a resilient food system creates opportunity for innovation (Ingram, 2010). This notion of change and imagination is echoed by Nabhan, who states, “as we enter the new normal of even greater climatic uncertainty, we may have to scale up the most promising adaptations that desert dwellers have improvised over the last several centuries to achieve resilience in our food systems as a whole” (Nabhan, 2013, 33). Fortunately, continuous adaptation is a core theme of local knowledge and community resilience. Food sovereignty creates space for communities to imaginatively face climate change, while resting securely on foundations of traditional knowledge and self-sustained, sustainable food systems.

I conclude with community reflections from young individuals on the meaning of food sovereignty for the future of New Mexico. A young agriculturalist states,

“To me, food sovereignty in the face of climate changes means that the community I come from will have a fighting chance at surviving through harsher climatic events and a less predictable future... Traditional knowledge of the environment and ways of sustaining a community through historical skills in successful food production have been and will remain incredibly useful resources in the growing need for food sovereignty” (Personal Interview, 2017).

An indigenous community artist, activist and organizer states,

“It [food sovereignty] means Life. *Wicozani wiconinktelo* is a Lakota saying meaning “with good health, there will be life.” [Food sovereignty] means the evolution of the human species. It means we have come together to support each other’s existence. It means we are learning. It means we are brave and courageous enough to act on our beliefs. It means we are no longer standing with ignorance. It means we will have children and their children will have children and they will have delicious, clean food to eat. It means we have realized we are the medicine. It means we have learned to

Love. Not only ourselves, but also each other. It's one necessary link in the circle of life" (Personal Interview, 2017).

The connection between food and community is deeply related to the cultural, physical, psychological, and spiritual health of indigenous and rural communities (Lynn et al., 2013). While it has already been stated that rural and indigenous peoples may experience some of the most profound climate change impacts, this food-culture nexus also provides the potential and enabling capacity for these communities to be at the forefront of food sovereignty discussions and movements in Northern New Mexico, in close concert with other stakeholders (Lynn et al., 2013).

5. CONCLUSION

Climate change effects disproportionately impact vulnerable populations, such as rural and indigenous communities. While these two demographics have contributed minimally to climate change drivers such as global emissions, they remain at the forefront of climate change. This is partly attributable to a physical and cultural interconnectedness with the climate-impacted environment, and is further augmented by economic and political marginalization. While these communities are most impacted, they also offer extraordinary insights into resilience development through the integration of local knowledge practices.

Northern New Mexico is one of the most climate-impacted regions of the United States, due to increased vulnerability to water quality and quantity in the face of climate change. Many of the region's small-scale agricultural systems and regional water

supplies are dependent on monsoonal rainfall and snowpack runoff. Climate models project that seasonal fluxes will yield increased drought and precipitation variability. With decreased overall precipitation, New Mexican water sources face depletion (Sheppard et al. 2002; Colby and Frisvold, 2011).

Northern New Mexico is home to seventeen indigenous tribes and nations, as well as many rural land-based and agricultural communities. Climate impacts to water systems threaten both groups, culturally, spiritually and physically, through depleted *acequia* agricultural systems and access to traditional foods such as *maíz azul*. Each of these communities has developed a specific way of living with the land that informs local knowledge and thus resilience strategies. The integration of participatory methods and of local knowledge into all stages of planning will build resilience capacity.

Northern New Mexican communities have adapted to environmental change for millennia, and have developed unique place-based resilience measures that inform future resilience planning. Examples of local knowledge include water harvesting and irrigation techniques such as *acequia* systems, the use of traditionally adapted heirloom seeds for cultivation, and the reinforcement of a local food sovereignty movement. The historical resilience of rural and indigenous communities can serve as a springboard for ongoing resilience-building activities that are developed through participatory and locally-appropriate methodologies.

In this time of climatic flux, it is critical that we stand with each other and for the environment. Climate change threatens vulnerable landscapes, communities, and

ways of life. These changes also present an opportunity to reimagine our existing socio-technical paradigm as informed and enhanced by local knowledge and *querencia*. Through stakeholder engagement and the application of local ways of knowing, community resilience will be strengthened in an enduring way. The critical message that water is life not only applicable in arid New Mexico, it is relevant for all beings, everywhere — Water is life.

6. Annex 1

Interview Questionnaire

1. What changes in the environment of Northern New Mexico do you foresee due to climate change? (e.g. increased drought, degraded water quality, water availability change, anything)
2. How will these changes impact any cultural or subsistence practices? (e.g. farming, acequia use, crop production, hunting, skiing, anything)
3. What types of (if any) local/traditional practices to cope with climate change do you feel will be useful? (e.g. seed saving, maintaining acequia systems, forms of water management, community farming, educating and engaging youth in food production, anything)
4. Is food sovereignty (Food sovereignty is the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems) important/useful or necessary to you or your community in adapting to climate change and building resilience?
5. What does food sovereignty mean to you in the face of climate change?
6. Can traditional/local knowledge about the environment and food production be useful in developing food sovereign systems?
7. How do traditional ways of knowing, when applied to food systems, build resiliency?

7. Bibliography

- Ackerman-Leist, Philip. 2013. *Rebuilding the Foodshed: How to Create Local, Sustainable, and Secure Food Systems*. The Community Resilience Guide Series. Santa Rosa, Calif.: White River Junction, VT: Post Carbon Institute; Chelsea Green Pub.
- Adger, W. N. 2000. Social and ecological resilience: are they related? *Progress in Human Geography* 24:347-364.
- Bennett, T. M. B., N. G. Maynard, P. Cochran, R. Gough, K. Lynn, J. Maldonado, G. Voggesser, S. Wotkyns, and K. Cozzetto. 2014. "Ch. 12: Indigenous Peoples, Lands, and Resources. Climate Change Impacts in the United States: The Third National Climate Assessment." doi:10.7930/J09G5JR1.
- Berkes, Fikret, Johan Colding, and Carl Folke, eds. 2003. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge ; New York: Cambridge University Press.
- Berkes, F. 2009. Indigenous ways of knowing and the study of environmental change. *J R Soc N Z* 39:151–156 *Cited in* Williams, Terry, and Preston Hardison. 2013. "Culture, Law, Risk and Governance: Contexts of Traditional Knowledge in Climate Change Adaptation." *Climatic Change* 120 (3): 531–44. doi:10.1007/s10584-013-0850-0.

- Bossert, Paul. 2013. "Taos Pueblo Water Settlement." Water Matters! Utton Transboundary Resources Center, University of New Mexico
- Brugger, Julie, and Michael Crimmins. 2013. "The Art of Adaptation: Living with Climate Change in the Rural American Southwest." *Global Environmental Change* 23 (6): 1830–40. doi:10.1016/j.gloenvcha.2013.07.012.
- Caldwell, Wayne J., and Susanna Reid, eds. 2015. *Planning for Rural Resilience: Coping with Climate Change and Energy Futures*. Winnipeg, Manitoba: University of Manitoba Press.
- Castro, Alfonso Peter, Daniel C. Taylor, and David Brokensha, eds. 2012. *Climate Change and Threatened Communities: Vulnerability, Capacity, and Action*. Rugby, Warwickshire: Practical Action Publishing.
- Cayan, D. R., T. Das, D. W. Pierce, T. P. Barne , M. Tyree, and A. Gershunov. 2010. "Future dryness in the southwest US and the hydrology of the early 21st century drought." *Proceedings of the National Academy of Sciences* 107:21271-21276, doi:10.1073/pnas.0912391107, **cited in** Hoerling, M. P., M. Dettinger, K. Wolter, J. Lukas, J. Eischeid, R. Nemani, B. Liebmann, and K. E. Kunkel. 2013. "Present Weather and Climate: Evolving Conditions." In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Gar n, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 74–100. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

- Cayan, D., M. Tyree, K. E. Kunkel, C. Castro, A. Gershunov, J. Barsugli, A. J. Ray, J. Overpeck, M. Anderson, J. Russell, B. Rajagopalan, I. Rangwala, and P. Du y. 2013. "Future Climate: Projected Average." In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Gar n, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 101–125. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Claeys, Priscilla. 2015. *Human Rights and the Food Sovereignty Movement: Reclaiming Control*. Routledge Studies in Food, Society and Environment. London ; New York: Routledge.
- Colby, Bonnie G., and George B. Frisvold, eds. 2011. *Adaptation and Resilience: The Economics of Climate, Water, and Energy Challenges in the American Southwest*. Washington, DC: Earthscan.
- Cordalis D, Suagee DB. 2008. The effects of climate change on American Indian and Alaska native tribes. *Nat Resource Environ* 22(3):45–49. **Cited in** Lynn, Kathy, John Daigle, Jennie Hoffman, Frank Lake, Natalie Michelle, Darren Ranco, Carson Viles, Garrit Voggesser, and Paul Williams. 2013. "The Impacts of Climate Change on Tribal Traditional Foods." *Climatic Change* 120 (3): 545–56. doi:10.1007/s10584-013-0736-1.
- Cozzetto, K., K. Chief, K. Dittmer, M. Brubaker, R. Gough, K. Souza, F. Ettawageshik, et al. 2013. "Climate Change Impacts on the Water Resources of American

- Indians and Alaska Natives in the U.S.” *Climatic Change* 120 (3): 569–84.
doi:10.1007/s10584-013-0852-y.
- Diffenbaugh, Noah S., Filippo Giorgi, and Jeremy S. Pal. 2008. “Climate Change Hotspots in the United States.” *Geophysical Research Letters* 35 (16).
doi:10.1029/2008GL035075.
- Downs T.J., Carr E., Goble R. (2017). “Addressing Risk Conundrums for Sustainable Development”. In: *Risk Conundrums: Solving Unsolvable Problems*. Kaspersen, R. (Editor). Earthscan. Anticipated publication date: 06/2017.
- Frisvold, G. B., L. E. Jackson, J. G. Pritche , and J. P. Rien. 2013. “Agriculture and Ranching.” In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 218–239. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Füssel, Hans-Martin, and Richard J. T. Klein. 2006. “Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking.” *Climatic Change* 75 (3): 301–29. doi:10.1007/s10584-006-0329-3.
- Garfin, G., A. Jardine, R. Meredith, M. Black, and S. LeRoy, eds. 2013. *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

- Garfin, G. and A. Jardine. 2013. “Overview.” In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 21–36. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom. 2014. Ch. 20: Southwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 462–486. doi:10.7930/J08G8HMN.
- Gershunov, A., B. Rajagopalan, J. Overpeck, K. Guirguis, D. Cayan, M. Hughes, M. Dettinger, C. Castro, R. E. Schwarz, M. Anderson, A. J. Ray, J. Barsugli, T. Cavazos, and M. Alexander. 2013. “Future Climate: Projected Extremes.” In *Assessment of Climate Change in the South- west United States: A Report Prepared for the National Climate Assessment*, edited by G. Gar n, A. Jar- dine, R. Meredith, M. Black, and S. LeRoy, 126–147. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Groisman, P. Y., R. W. Knight, D. R. Easterling, T. R. Karl, G. C. Hegerl, and V. N. Razuvaev. 2005. Trends in intense precipitation in the climate record. *Journal of Climate* 18:1326–1350. **Cited in** Gershunov, A., B. Rajagopalan, J. Overpeck, K. Guirguis, D. Cayan, M. Hughes, M. Dettinger, C. Castro, R. E. Schwarz, M.

- Anderson, A. J. Ray, J. Barsugli, T. Cavazos, and M. Alexander. 2013. “Future Climate: Projected Extremes.” In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Gar n, A. Jar- dine, R. Meredith, M. Black, and S. LeRoy, 126–147. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Hoerling, M. P., M. De inger, K. Wolter, J. Lukas, J. Eischeid, R. Nemani, B. Liebmann, and K. E. Kunkel. 2013. “Present Weather and Climate: Evolving Conditions.” In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Gar n, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 74–100. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Haddeland, Ingjerd, Jens Heinke, Hester Biemans, Stephanie Eisner, Martina Flörke, Naota Hanasaki, Markus Konzmann, et al. 2014. “Global Water Resources Affected by Human Interventions and Climate Change.” *Proceedings of the National Academy of Sciences* 111 (9): 3251–56. doi:10.1073/pnas.1222475110.
- Holling, C.S. 1986. “The resilience of terrestrial ecosystems: local surprise and global change.” In *Sustainable Development of the Biosphere*, ed, W.C. Clark and R.E. Munn. Cambridge: Cambridge University Press. **Cited in** Berkes, Fikret, Johan Colding, and Carl Folke, eds. 2003. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge ; New York: Cambridge University Press.

- Ingram, J. S. I., Polly Ericksen, and Diana M. Liverman, eds. 2010. *Food Security and Global Environmental Change*. London ; Washington, DC: Earthscan.
- IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
- Johnston BR (2012) Water, cultural diversity, and global environmental change: Emerging trends, sustainable futures? United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris. **Cited in** Williams, Terry, and Preston Hardison. 2013. "Culture, Law, Risk and Governance: Contexts of Traditional Knowledge in Climate Change Adaptation." *Climatic Change* 120 (3): 531–44. doi:10.1007/s10584-013-0850-0.
- Karl, Thomas, Jerry Melillo, and Peterson, eds. 2009. *Global Climate Change Impacts in the United States: A State of Knowledge Report*. Cambridge [England] ; New York: Cambridge University Press.
- Lengnick, Laura. 2015. *Resilient Agriculture: Cultivating Food Systems for a Changing Climate*. Gabriola Island, BC: New Society Publishers.
- Liverman, D., S. C. Moser, P. S. Weiland, L. Dilling, M. T. Boyko , H. E. Brown, E. S. Gordon, C. Greene, E. Holthaus, D. A. Niemeier, S. Pincetl, W. J. Steenburgh, and V. C. Tidwell. 2013. "Climate Choices for a Sustainable Southwest." In *Assessment of Climate Change in the South- west United States: A Report*

Prepared for the National Climate Assessment, edited by G. Garfin, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 405–435. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Lynn, Kathy, John Daigle, Jennie Hoffman, Frank Lake, Natalie Michelle, Darren Ranco, Carson Viles, Garrit Voggesser, and Paul Williams. 2013. “The Impacts of Climate Change on Tribal Traditional Foods.” *Climatic Change* 120 (3): 545–56. doi:10.1007/s10584-013-0736-1.

Maldonado, Julie Koppel, Benedict J. Colombi, and Rajul Pandya, editors. 2014. *Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions*. Cham, Switzerland ; New York: Springer Verlag.

Nabhan, Gary Paul. 2013. *Growing Food in a Hotter, Drier Land: Lessons from Desert Farmers on Adapting to Climate Uncertainty*. White River Junction, VT: Chelsea Green Pub.

Nabhan, Gary Paul and Fitzsimmons, Regina. 2010. “State of Southwestern Foodsheds.” *Sabores Sin Fronteras/Flavors Without Borders of the Southwest Center and Edible Communities*.

New Mexico Acequia Association (NMAA). 2016. <http://www.lasacequias.org>

New Mexico State Water Plan. 2003. Adopted by the New Mexico Interstate Stream Commission, December 17, 2003.

<http://www.ose.state.nm.us/Planning/SWP/PDF/2003StateWaterPlan.pdf> *Cited*

- in* Osborn, Michael. 2010. "Indian Water Rights." Water Matters! Utton Transboundary Resources Center, University of New Mexico
- Norberg-Hodge, Helena, Todd Merrifield, and Steven Gorelick. 2002. *Bringing the Food Economy Home: Local Alternatives to Global Agribusiness*. London; Halifax, NS; Bloomfield, CT: Zed Books ; Fernwood Pub. ; Kumarian Press.
- Orr, Raymond and Anderson, David. 2012. Good intentions, bad memories, and troubled capital: American Indian knowledge and action in renewable energy projects. *In* Castro, Alfonso Peter, Daniel C. Taylor, and David Brokensha, eds. *Climate Change and Threatened Communities: Vulnerability, Capacity, and Action*. Rugby, Warwickshire: Practical Action Publishing.
- Osborn, Michael. 2010. "Indian Water Rights." Water Matters! Utton Transboundary Resources Center, University of New Mexico
- Overpeck, J., G. Garfin, A. Jardine, D. E. Busch, D. Cayan, M. Dettinger, E. Fleishman, A. Gershunov, G. MacDonald, K. T. Redmond, W. R. Travis, and B. Udall. 2013. "Summary for Decision Makers." In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 1–20. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Pachauri, R. K., Leo Mayer, and Intergovernmental Panel on Climate Change, eds.

2015. *Climate Change 2014: Synthesis Report*. Geneva, Switzerland:

Intergovernmental Panel on Climate Change.

Pardilla, J. 2011. *Tribal set-aside sought in DOI Climate Change Adaptation Initiative*.

Report for the National Tribal Environmental Council, Albuquerque, NM. **Cited**

in Redsteer, M. H., K. Bemis, K. Chief, M. Gautam, B. R. Middleton, and R.

Tsosie. 2013. “Unique Challenges Facing Southwestern Tribes.” In *Assessment*

of Climate Change in the South- west United States: A Report Prepared for the

National Climate Assessment, edited by G. Gar n, A. Jar- dine, R. Meredith, M.

Black, and S. LeRoy, 385–404. A report by the Southwest Climate Alliance.

Washington, DC: Island Press.

Pelling, Mark. 2011. *Adaptation to Climate Change: From Resilience to*

Transformation. London ; New York: Routledge.

Redsteer, M. H., K. Bemis, K. Chief, M. Gautam, B. R. Middleton, and R. Tsosie. 2013.

“Unique Challenges Facing Southwestern Tribes.” In *Assessment of Climate*

Change in the South- west United States: A Report Prepared for the National

Climate Assessment, edited by G. Garfin, A. Jardine, R. Meredith, M. Black, and

S. LeRoy, 385–404. A report by the Southwest Climate Alliance. Washington,

DC: Island Press.

- Rehfeldt, Gerald E., Nicholas L. Crookston, Marcus V. Warwell, and Jeffrey S. Evans. 2006. "Empirical Analyses of Plant-Climate Relationships for the Western United States." *International Journal of Plant Sciences* 167 (6): 1123–1150.
- Reid, H., T. Cannon, R. Berger, M. Alam and A. Milligan. Eds. 2009. Community-based Adaptation to Climate Change. IIED, London. **Cited in** Schipper, Lisa, Jessica Ayers, Hannah Reid, Saleemul Huq, and Atiq Rahman, eds. 2014. *Community-Based Adaptation to Climate Change: Scaling It up*. London: Routledge.
- Roncoli, Carla. 2006. "Ethnographic and Participatory Approaches to Research on Farmers' Responses to Climate Predictions." *Climate Research* 33 (1): 81–99.
- Rosenberg, Norman J., and Jae Edmonds, eds. 2005. *Climate Change Impacts for the Conterminous USA: An Integrated Assessment*. Dordrecht, The Netherlands ; Norwell, MA: Springer.
- Salick, Jan, and Anja Byg. 2007. *Indigenous Peoples and Climate Change*. Tyndall Centre for Climate Change Research Oxford.
- http://www.tyndall.ac.uk/sites/default/files/Indigenous%20Peoples%20and%20Climate%20Change_0.pdf.
- Salmón, Enrique. 2012. *Eating the Landscape: American Indian Stories of Food, Identity, and Resilience*. First Peoples : New Directions in Indigenous Studies. Tucson: University of Arizona Press.

- Schipper, Lisa, Jessica Ayers, Hannah Reid, Saleemul Huq, and Atiq Rahman, eds. 2014. *Community-Based Adaptation to Climate Change: Scaling It up*. London: Routledge.
- Sheppard, Paul R., Andrew C. Comrie, Gregory D. Packin, Kurt Angersbach, and Malcolm K. Hughes. 2002. "The Climate of the US Southwest." *Climate Research* 21 (3): 219–238.
- Slocum, Nikki, and Steyaert, S. 2003. "Participatory Methods Toolkit- A Practitioner's Manual." King Baudouin Foundation
- Smit, Barry, and Johanna Wandel. 2006. "Adaptation, Adaptive Capacity and Vulnerability." *Global Environmental Change* 16 (3): 282–92.
doi:10.1016/j.gloenvcha.2006.03.008.
- Steenburgh, W. J., K. T. Redmond, K. E. Kunkel, N. Doesken, R. R. Gillies, J. D. Horel, M. P. Hoerling, and T. H. Painter. 2013. "Present Weather and Climate: Average Conditions." In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Gar n, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 56–73. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Tewa Women United. 2016. www.tewawomenunited.org
- Theobald, D. M., W. R. Travis, M. A. Drummond, and E. S. Gordon. 2013. "The Changing Southwest." In *Assessment of Climate Change in the Southwest United States: A Report Pre- pared for the National Climate Assessment*, edited

- by G. Garfin, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 37–55. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- Udall, B. 2013. “Water: Impacts, Risks, and Adaptation.” In *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 197–217. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- van Asselt, M., Mellors, J., Rijkens-Klomp, N., Greeuw, S., Molendijk, K., Beers, P., van Notten, P. 2001. “Building Blocks for Participation in Integrated Assessment.” International Center for Integrative Studies.
- Voggesser, Garrit, Kathy Lynn, John Daigle, Frank K. Lake, and Darren Ranco. 2013. “Cultural Impacts to Tribes from Climate Change Influences on Forests.” *Climatic Change* 120 (3): 615–26. doi:10.1007/s10584-013-0733-4.
- Vorosmarty, C. J. 2000. “Global Water Resources: Vulnerability from Climate Change and Population Growth.” *Science* 289 (5477): 284–88. doi:10.1126/science.289.5477.284.
- Wang, J., and X. Zhang. 2008. Downscaling and projection of winter extreme daily precipitation over North America. *Journal of Climate* 21:923–937. **Cited in** Gershunov, A., B. Rajagopalan, J. Overpeck, K. Guirguis, D. Cayan, M. Hughes, M. Dettinger, C. Castro, R. E. Schwarz, M. Anderson, A. J. Ray, J. Barsugli, T. Cavazos, and M. Alexander. 2013. “Future Climate: Projected

- Extremes.” In *Assessment of Climate Change in the South- west United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Meredith, M. Black, and S. LeRoy, 126–147. A report by the Southwest Climate Alliance. Washington, DC: Island Press.
- White, Stacey Swearingen. 2014. “Farmers and Rural Kansas Communities: Planning for the Future.” <https://kuscholarworks.ku.edu/handle/1808/19367>.
- Whyte, Kyle Powys. 2013. “Justice Forward: Tribes, Climate Adaptation and Responsibility.” *Climatic Change* 120 (3): 517–30. doi:10.1007/s10584-013-0743-2.
- Wildcat, Daniel R. 2013. “Introduction: Climate Change and Indigenous Peoples of the USA.” *Climatic Change* 120 (3): 509–15. doi:10.1007/s10584-013-0849-6.
- Williams, Terry, and Preston Hardison. 2013. “Culture, Law, Risk and Governance: Contexts of Traditional Knowledge in Climate Change Adaptation.” *Climatic Change* 120 (3): 531–44. doi:10.1007/s10584-013-0850-0.
- Wittman, Hannah, Annette Aurelie Desmarais, and Nettie Wiebe. 2010. *Food Sovereignty: Reconnecting Food, Nature & Community*.
- World Bank Climate Change Portal. 2016. <http://sdwebx.worldbank.org/climateportal/>