Spring 2017

A Climate Change Risk Assessment of Northern Great Plains Reservations

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by

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AN UNDERGRADUATE THESIS

Presented to the Faculty of
The Environmental Studies Program at the University of Nebraska-Lincoln
In Partial Fulfillment of Requirements
For the Degree of Bachelor of Arts

Major: Environmental Studies, Great Plains Studies
With the Emphasis of: Anthropology

Under the Supervision of Dr. David Wishart
and
Dr. Martha Shulski

Lincoln, Nebraska

May 1, 2017
A Climate Change Risk Assessment of Northern Great Plains Reservations

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University of Nebraska, 2017

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Abstract: Climate change is expected to have varied effects on cultural groups across the United States, with Native American communities considered the most vulnerable due to economic disadvantages. There are more Indian Reservations (21) in the northern Great Plains than in any other region, where water resources are vital to community health and stability. However, climate change stands to directly impact available water resources by altering aquatic ecosystems and degrading the quality of accessible water. As such, the primary aim of this study was to develop a hierarchical vulnerability assessment to compare all 21 reservations by potential water resource alteration as a result of future climate change. To measure potential alteration, this study focused on correlating the predicted changes of temperature and precipitation by 2050 to the hydrological capacity within each reservation area. Results from the vulnerability assessment show that Fort Berthold Indian Reservation in North Dakota has the highest potential for water alteration due to climate change, with the Lower Brulé and Crow Creek reservations following. Because climate predictions are similar across the northern Plains, water capacity within each reservation proved to be the key variable in determining potential alteration. Thus, Fort Berthold has the highest potential for water alteration because the area has the highest water density within reservation borders. The information found in the vulnerability assessment can be used to study further variables regarding climate change on the northern Plains, as well as to focus climate change defenses on the pinpointed reservations.
Acknowledgements

I would like to acknowledge many people at the University of Nebraska-Lincoln for their assistance and support in completion of this study. Specifically, special thanks to Dr. David Wishart and Dr. Martha Shulski for guidance and recommendations, Dr. David Gosselin and Christine Haney for instruction, and numerous students in the ENVR 499 class for revisions and brainstorming.
Introduction

Climate change is an issue that has been increasingly relevant over the past few decades, garnering more concern in some geographical areas (such as the coasts or forested regions) than others among the general public. This may be because predictions of future climatic conditions show increased, yet varied, impacts across the globe depending on geographical region, with sea level rise being perhaps the most discussed concern on the subject (Weaver et. al., 2009). As such, certain regions far from the oceans or forests (i.e., the Great Plains in the US) are often considered less vulnerable. However, the Great Plains contains a higher number of reservations than any other region in the country. Additionally, it has become widely accepted that further human-induced climate change will affect some societies and cultural groups (especially those in rural settings) at a disproportional rate: those who are poorer and with closer ties to the natural environment, such as the majority of Native American communities, will realize impacts of a changing climate more intensely than those that reside in industrialized, economically centered settings (Bronen et. al., 2013).

This separation is, in part, due to the fact that American Indian reservations are among the most economically disadvantaged communities in the United States, which leads to limitations when fighting against climate change (Bennett et. al., 2014). As a result, indigenous groups across the world face a heightened risk of their daily lives being affected by climate change because the cultures of tribal communities are often “integrated into the ecosystems” of their surroundings (Cordalis and Suagee, 2008, 1). Thus, narrowing down the reservation lands with the greatest potential to be environmentally impacted by climate change is a concept worth exploring. Furthermore, assessing vulnerability is a common means of measuring the relationship between climate change and native communities (Cutter and Finch, 2008).
Specifically, this study focuses on measuring and comparing the environmental vulnerability of Indian Reservation lands in the northern Great Plains. The terms “vulnerability” and “at risk” are used throughout this study to convey the potential for ecological or topographical degradation, alteration, or limitation due to the association of climate change factors and water resources. The northern U.S. Plains region is defined in this study as the five states of Nebraska, South Dakota, North Dakota, eastern Wyoming, and eastern Montana, which coincides with the northern half of the region used in the “Great Plains” chapter of the 2014 National Climate Assessment (Shafer, et. al.). There are a total of 21 reservations in the region, all of which will be considered in this study. By comparing geographical data of reservation lands, climate projections, and rivers/watersheds (the most significant natural factor to tribal communities on the Great Plains), this study seeks to clarify how much potential alteration the natural water resources within each reservation might contain due to climate change affects.

The northern Great Plains is home to unique, diverse ecosystems that will face dire bioregional alteration, and perhaps deterioration, if the area’s climate continues on its current path (EPA, 2016). It is predicted that warming will occur across the northern Plains, as well as a slight increase in precipitation (Joyce, 2001). Additionally, according to the Bureau of Indian Affairs, the northern Great Plains is home to 27 recognized Native American tribes, meaning that if the region’s ecosystems are altered, it stands to reason that the daily lives of many who live on reservations will be greatly impacted (US Department of the Interior, 2017).

There has been increasing evidence from case studies showing that climate change is already having impacts on the ecosystems of native lands on the Great Plains. In the northern Plains, one study was completed on the Crow Reservation in Montana (Doyle, Eggers, & Redsteer, 2013). The research found an annual decline in average snowfall and an increase of
rain in the spring. Additionally, the Crow Reservation has seen a steady increase in average days over 90 degrees F over the past century. This shift in precipitation and temperature patterns has led to the alteration of aquatic ecosystems, as well as catastrophic cases of flooding in the springtime, such as 2007 and 2011 floods at Crow Agency. At the same time, stream flow discharge throughout the rest of the year has steadily decreased, which has changed the stream patterns of local fish and caused the water quality of the area to deteriorate (Doyle, Eggers, & Redsteer, 2013). All of this ecological alteration becomes relevant because the monitored data observed by the authors, along with coinciding observations from tribal elders, prove that northern American Indians are especially vulnerable to such impacts due to the intertwining relationships between poverty, marginal ecosystems, culture, public health, and limited infrastructure resources that exist on reservation lands.

In fact, water is likely the most at-risk resource in the Great Plains, along with being the most valued by native tribes. According to a 2013 aquatic systems study titled “Climate Change Impacts on the Water Resources of American Indians and Alaska Natives in the U.S.”, there is a clear correlation between access to quality water and a healthy tribal community. When a group suffers from a lack of available water, there is a cascading affect on the livelihoods and cultures of these American Indians. Essentially, there are at least five ways that environmentally altered water systems can affect indigenous peoples: Water supply/management; aquatic species; ranching/agriculture impacts; water rights and tribal sovereignty; and soil quality (Brubaker et. al.). As such, this study focuses on water systems in the northern Great Plains region as the primary topographical variable in analyzing affects from climate change.

Interestingly, while water rise is a serious issue on the coasts, water alteration (such as the changes observed on the Crow reservation) seems to be the primary concern on the Plains.
The many rivers, lakes, ponds, etc., across the region are diverse interconnected systems, which are “highly responsive to extreme climatic fluctuations” (Covich et. al., 1997, 993). The processes of these aquatic ecosystems, as well as the nutrient cycling of such bodies of water, respond rapidly to climate changes, and thus would have a rapid affect on consumers of the water. This information could be especially pertinent to northern Plains tribes, such as those in Montana, North Dakota, or Canada, where the communities rely on fishing as an economic practice and for subsistence more so than anywhere else in the region.

The purpose for focusing this study on the physical environment of the Plains stems from intrigue in response to the data collected in the 2014 National Climate Assessment, particularly Chapter 19, which focuses on how climate change will affect the people of the Great Plains (Shafer, et. al.). According to this assessment, the indigenous people of the Great Plains face greater challenges than other communities because of their “remote locations, sparse development, limited local services, and language barriers” (National Climate Assessment, 2014, 441). The authors of this report note that while Native Americans have been obliged to be adaptable to changing conditions historically, the contemporary political and physical boundaries of reservations on the Plains constrain the Native Peoples’ abilities to combat increasing climate change, which leaves them more vulnerable than most urban areas in the region.

In fact, this concept of boundary limitations is currently causing evident problems with Native American communities along the coasts. According to the twelfth chapter of the 2014 National Climate Assessment titled “Indigenous Peoples, Land, and Resources”, entire tribes are being forced to relocate due to sea level rise and erosion, as well as permafrost thaw, all along the northwestern U.S. coasts (Bennett, et. al.). One example identified in the article is Newtok, a village in Alaska that is being forced to relocate due to erosion and permafrost thaw. Yet,
Newtok is even struggling to maneuver their relocation because “National, state, local, and tribal government agencies lack the legal authority and the technical, organizational, and financial capacity to implement relocation processes for communities forcibly displaced by climate change” (307). While such scenarios along the coasts have been a topic of interest among Indian advocacy communities, the discussion of such relocation in the future has been relatively scarce regarding the Great Plains region. However, the social and geographical scenarios could be quite comparable if resource limitations due to climate change in the northern Plains force a similar occurrence.

Displacement and other related forms of societal/political tension causes increasingly strained communities to experience further cultural distress, health degradation, and economic losses. From the evidence outlined above, it appears extremely feasible that tribal groups of the Great Plains could experience significant stress from an altering environment. If changes to the northern Plains climate do lead to such a scenario in the future, it would be beneficial to know well in advance which reservation lands in the region might be at a greater risk of experiencing significant water alteration. As such, this study has two primary objectives: 1) Develop a hierarchical assessment that ranks all 21 reservations by potential environmental vulnerability due to climate change and water resources, and 2) Determine which of three variables (temperature change, precipitation change, and water capacity) carries the most weight in determining potential vulnerability.

**Methods and Materials**

In an attempt to complete these objectives, this study utilizes a basic spatial analysis method that focuses on analyzing the geographical relationship between reservation locations
and two key variables: climate prediction models and water capacity within reservation boundaries. To assess the potential vulnerability of each reservation, three steps were taken:

**Step 1: Creation of maps**

To visually analyze the relationship of these variables initially, three original maps were generated that layer representations of geographical climate predictions, locations of reservations, and water systems in relation to the reservations. This study used ArcGIS software to create the three maps, each superimposing the 21 reservation lands in the northern Plains over varying layers representing key factors associated with climate change. All individual layers of visual data were previously created and stored within the online ArcGIS database for public use.

The first map created (Fig. 1) represents the 21 tribal reservations in geographical relation to predicted temperature variation by the end of 2050. The second map (Fig. 2) represents the same reservation lands in relation to predicted precipitation variation in the same time restraint. The third map was created to show a spatial comparison between the water systems in the northern Great Plains and the same 21 reservation locations. This water-based map (Fig. 3) represents all rivers and streams in the region (assuming the major rivers remain relatively unchanged over the next 30+ years).

**Step 2: Comparable Vulnerability Assessment**

The next step is comparing the data represented in Figs. 1, 2 and 3 to pinpoint areas of potentially severe water body impacts from climate change. In order to analyze the data, this study develops a “Comparable Vulnerability Assessment” (Table 1, results below) to create a measurable value for each variable within each reservation. This is accomplished by assessing the correlation between: severity of median annual temperature change – referred to as the Temp. Score; severity of annual precipitation change – referred to as the Precip. Score; and severity of
potential water damage/alteration (by focusing on the proportion of water body areas within the total reservation area) – referred to as the Hydrological Score. Based on the severity of each variable, all 21 reservations are then given an overall Potential Risk Score that puts climate change alteration into a measurable perspective for further analysis.

- Generating Temperature and Precipitation Measurables:

The Temperature and Precipitation Scores are evaluated as follows: As illustrated in Fig. 1 and 2 below, each reservation lies in a geographical area associated with a range of predicted temperature change and precipitation change, respectively. To provide a measurement for these two variables and remain consistent, each reservation is given a score that aligns with the lowest number in its corresponding range for each map (see the map legends for each set of ranges). For example, on the predicted temperature change map, the Pine Ridge reservation is located in an area where predicted temperature change ranges from 2.1 – 2.4°F. Therefore, the Temp. Score for that reservation will be 2.1. The same method is used for the Precip. Score.

It is important to note that this study will use climate maps for temperature and precipitation change that predict variation based on the Intergovernmental Panel on Climate Change’s energy-balanced A1B scenario. According to the IPCC, this scenario predicts climate under the assumption that “global population will continue on the current trajectory and then decline mid-century” due to lower fertility rates and social paradigm shifts. After 2050 in this scenario, greenhouse gases would be expected to decrease with population. It also assumes that global energy use will continue to consist of a balance of both fossil fuels and non-fossil fuels. (IPCC, 2000, 7). The A1B scenario was chosen for this study because it focuses on a continuation of the world’s current trajectory regarding population and resource consumption.
until 2050, which provides a convenient time restraint to focus on climatic conditions before a drop off at mid-century. This makes it the most logical model in terms of conjecture at this time.

- *Generating water capacity measurables:*

  To analyze water capacity, it is important to find the proportional area of rivers, streams, and lakes that lie within a reservation’s boundaries. For each reservation, water capacity is equal to the total area of water within those specific boundaries divided by the total surface area of the reservation.

  \[
  \text{Water capacity of reservation} = \frac{\text{total area of water (mi}^2\text{)}}{\text{total area (mi}^2\text{)}}
  \]

  This gives a measureable value to use in analyzing the correlation between predicted climate change and water capacity within the boundaries of each reservation. The data for water and land area are derived using the ArcGIS shapefile of Indian Reservations in Figs. 1 - 3, which was initially provided by the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB).

**Step 3: Potential Risk Score**

As mentioned previously, the ecology (and Native communities) of the Great Plains will be affected by temperature and precipitation changes because these factors have direct impacts on the ecological and quality aspects of water alteration. The Potential Risk Score represents this relationship by adding the temperature and precipitation scores together, and then multiplying the sum by the water capacity within each reservation.

\[
\text{Potential Risk Score} = (\text{Temp. Score} + \text{Precip. Score}) \times \text{Water Capacity}
\]

It is also important to remember these maps and scoring method are only a means by which to compare similar variables within similar environments in the northern Plains region. The scores
aligned with each variable in this study were developed with convenience in mind, using ranges already provided with the temperature and precipitation maps in the ArcGIS database. However, while each environmental factor may not be perfectly represented by its aligning scores to measure potential impact, the scoring system is uniform across all 21 reservation lands, with each variable holding the same weight throughout the study. Thus, a higher potential risk score should represent a reservation that contains water bodies with higher risks of alteration due to climate change.

Results

Below are the individual maps (Figs. 1 – 3) created to represent each variable studied on the 21 northern Great Plains Indian Reservations. All data results from the Comparable Vulnerability Assessment, found in Table 1, with the graphical representation/rank of the Potential Risk Score laid out in Fig. 4. Within the CVA, the overall Potential Risk Score is ranked from highest to lowest in potential risk, which is calculated using the relationship of the three evaluated climatic factors. All results (both visual and statistical) were either calculated or created using data from ArcGIS.
(Fig. 1 represents the A1B scenario of change in median annual temperature by mid-century superimposed by the 21 reservations located across the northern Great Plains)
Figure 2

Predicted Change in Annual Precipitation by the End of 2050

(Fig. 2 represents the A1B scenario of annual precipitation change by mid-century superimposed by the 21 reservations located across the northern Great Plains).
Figure 3

RIVERS & STREAMS IN RELATION TO NORTHERN PLAINS RESERVATIONS

(Fig. 3 represents the rivers/streams system in the northern Great Plains in relation to the 21 reservations located across the region).
Table 1

Comparable Vulnerability Assessment

<table>
<thead>
<tr>
<th>Indian Reservation</th>
<th>((\text{Temp. Score} + \text{Precip. Score}) \times \text{Hydro. Capacity} )</th>
<th>PRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Berthold</td>
<td>2.1</td>
<td>0.1665</td>
</tr>
<tr>
<td>Lower Brulé</td>
<td>2.1</td>
<td>0.1202</td>
</tr>
<tr>
<td>Crow Creek</td>
<td>2.1</td>
<td>0.0842</td>
</tr>
<tr>
<td>Turtle Mountain</td>
<td>2.6</td>
<td>0.0603</td>
</tr>
<tr>
<td>Santee</td>
<td>2.1</td>
<td>0.0629</td>
</tr>
<tr>
<td>Lake Traverse</td>
<td>2.6</td>
<td>0.0393</td>
</tr>
<tr>
<td>Cheyenne River</td>
<td>2.1</td>
<td>0.0345</td>
</tr>
<tr>
<td>Spirit Lake</td>
<td>2.6</td>
<td>0.0245</td>
</tr>
<tr>
<td>Yankton</td>
<td>2.1</td>
<td>0.0279</td>
</tr>
<tr>
<td>Standing Rock</td>
<td>2.1</td>
<td>0.0257</td>
</tr>
<tr>
<td>Wind River</td>
<td>2.6</td>
<td>0.0164</td>
</tr>
<tr>
<td>Omaha</td>
<td>2.6</td>
<td>0.0096</td>
</tr>
<tr>
<td>Blackfeet</td>
<td>2.1</td>
<td>0.0115</td>
</tr>
<tr>
<td>Winnebago</td>
<td>2.6</td>
<td>0.0064</td>
</tr>
<tr>
<td>Fort Peck</td>
<td>2.1</td>
<td>0.0040</td>
</tr>
<tr>
<td>Fort Belknap</td>
<td>2.1</td>
<td>0.0038</td>
</tr>
<tr>
<td>Crow</td>
<td>2.1</td>
<td>0.0033</td>
</tr>
<tr>
<td>Pine Ridge</td>
<td>2.1</td>
<td>0.0024</td>
</tr>
<tr>
<td>Rosebud</td>
<td>2.1</td>
<td>0.0016</td>
</tr>
<tr>
<td>Rocky Boy’s</td>
<td>2.1</td>
<td>0.0013</td>
</tr>
<tr>
<td>Northern Cheyenne</td>
<td>2.1</td>
<td>0.0002</td>
</tr>
</tbody>
</table>
(Figure 1 is a representation of Table 1 that ranks each reservation on greatest potential environmental risk from Fort Berthold (greatest risk) to Northern Cheyenne (lowest risk)).
Discussion

The first sought-after objective in creating these maps and generating the data in the Comparable Vulnerability Assessment was to develop a hierarchical list that ranks all 21 reservations by potential environmental risk due to climate change and water capacity. By correlating the scores of each climatic variable for each reservation, this study is able give a relative, overall picture of this potential vulnerability hierarchy. As evidenced in the table, by 2050 the Fort Berthold Indian Reservation in South Dakota will be at a greater risk of experiencing environmental alteration when it comes to water resources than any other reservation in the northern Great Plains – and at a fairly significant margin as well. The Comparable Vulnerability Assessment data shows that the reason for this margin is that the water capacity within the boundaries of the Fort Berthold reservation is much higher than any other reservation. Fig. 3 uses visual evidence to show that within Fort Berthold, the Missouri River becomes quite wide north of the Garrison Dam, which enhances the water presence in proportion to the reservation’s size.

Through the Potential Risk Score method, this study was also able to complete the second objective of the study: to determine which of the three variables (temperature change, precipitation change, and water capacity) would be most significant in measuring potential risk. While generating Figures 1 and 2, it became visually apparent that reservations in the northern Great Plains will all experience similar changes in temperature and precipitation by mid-century. As the northern Great Plains consists of a relatively uniform climate, this was to be expected to a degree, because predicted change should not differ greatly from one area to another. However, a slight steeper deviation between different areas within the northern Plains region was expected,
primarily because different altitudes and latitudes exist across the region. But because the ranges of change were so similar, both temperature and precipitation change prove relatively ineffective in separating reservations’ potential risks. As discussed previously, however, these two factors are still crucial to measure because changes to either is projected to have a direct impact by altering the flow, quality, and quantity of water resources, as well as overall ecological health of aquatic species.

Still, because these climate projections are so similar across the northern Plains, the most significant variable in determining the potential risk turned out to be the density of water bodies within the boundaries of each reservation. Due to the uniformity of climatic projections, the table shows that the capacity of rivers, streams, and lakes is the primary factor that separates potential risk of water resource alteration. The most obvious evidence of this is that the Fort Berthold reservation (ranked first in potential risk) scored the highest in terms of water capacity, taking up a staggering 16% of the total reservation area, while the Northern Cheyenne reservation (ranked last) only consists of .02% water. It is important to note that this is not a rule of thumb, only a generalization. Even though the Santee reservation has a higher density of water systems, it ranks behind the Turtle Mountain reservation in potential vulnerability because Turtle Mountain scored a higher predicted temperature change. The Yankton reservation ranks lower than the Spirit Lake reservation due to the same occurrence. However, the differences in potential vulnerability between these reservations are slight and non-apparent by glancing at the map in Fig. 3. The reservations with greater and lesser potential risk of alteration, however, are quite obvious from Figs. 1 – 3.

Using maps as visual aids helps to notice why certain reservations scored as they did. For example, it is clear those with greater potential vulnerability are those with larger sections of
rivers flowing within or along the reservation borders. It should be noted that seven of the top ten reservations with the greatest potential alteration risk (Fort Berthold, Lower Brulé, Crow Creek, Santee, Cheyenne River, Yankton, and Standing Rock reservations) are all bordered by the Missouri River (the largest river in the region), which lends to greater vulnerability for damage or ecological deterioration from large-scale water alteration. However, it appears that lower Potential Risk Scores may represent water resources that may be susceptible to quicker change, albeit with a lower chance for mass alteration due to limited resources already established within the water bodies. It is important to note that the Potential Risk Score was created to measure potential for large scale, long-term alteration to water resources, and not to measure the impacts that altering water resources will have on communities. Instead, this study acts as a prerequisite for such an assessment.

With a focus on water, one potentially significant factor not considered in this study is the role watersheds would likely play in determining how potential flooding could occur as rivers and streams alter. This would require follow-up research, however this study did produce a map (Fig. 5) of hydrological sub region watersheds of the area, simply as a visual to show the focal points of tributary streams in relation to the 21 reservations. Studying the stream flow and recording changes to depth, flow rate, etc., could be useful in determining areas within reservations that would be more susceptible to flooding than others.

Another point of follow-up research would be to study how an environment with a high potential risk for impact would affect the communities within that reservation. This happens to be the inquiry that led to the completion of this study regarding the potential physical alteration to the environment of each reservation. Studying the impact such alteration would have on humans would require a detailed, in depth look at the community factors of each individual
reservation, including climate change resistance plans, population demographics, economic situations, etc. This would be intriguing information and would provide significant insight into pinpointing Native American communities that may be most at risk of experiencing impacts from climate change.

**Figure 5**

**Northern Plains Reservations in Relation to Hydrological Sub-Regions**

(Fig. 4 represents a possibility for further research into the spatial analysis of the 21 reservations of the northern Great Plains in relation to watershed sub-regions of the area)
Summary/Conclusion

This study was completed to understand which reservations on the northern Great Plains may be most environmentally impacted by climate change in the near future. Another purpose of this study was to understand the correlation between three variables on the northern Plains: temperature change, precipitation change, and water density within a finite area. To explore these objectives, the study generated three original maps and subsequently developed a Comparable Vulnerability Assessment of each reservation, which focused on correlating measurable values between all three variables and culminating in a Potential Risk Score for each. The Potential Risk Score was calculated by multiplying the water density within a reservation by a combined score of temperature and precipitation changes.

The assessment shows that the Fort Berthold Indian Reservation is at the greatest risk experiencing alteration to the consistency and ecology of the overall environment, primarily because it has the highest density of water within the reservation borders and thus contains more opportunity for alteration. While temperature change and precipitation change may lead to water alteration, it appears that climate change will be uniform across the northern Plains, making the presence of rivers and streams the primary factor in ranking reservations by vulnerability from climate change.

The reason for studying this topic is to have a better understanding of which reservations in the northern Great Plains may struggle, or require aid, if environmental conditions worsen on reservations. As a result, further examination can now take place into the river/stream management plans among reservations with greater potential environmental risk. There are variables that may need to be studied further on the region’s water systems (such as watersheds).
to understand the unique factors among individual reservation lands. This study also gives a relative starting point for determining which Native communities to consider in preparing for any potential catastrophes related to climate change. Essentially, Native communities will be at risk of experiencing environmental alteration and deterioration in the near future, giving a viable reason for comparing each location in terms of potential water resource vulnerability. Compared to others, Fort Berthold Indian Reservation is at a greater risk, and the fact that water capacity is highest within this reservation is the primary reason for ranking it the highest reservation land in terms of water alteration vulnerability on the northern Great Plains.
References


