Regional Climate Model Projections for Northeast Kansas: Access to Water on the Kickapoo Reservation

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ABSTRACT

Present and future generations can benefit from the preparation of contemporary communities for the impacts of changing climate conditions. This project explored future access to water on the Northeast Kansas Kickapoo Reservation and introduced scientific climate model projections from the National Center for Atmospheric Research. Regional Climate-Change Projections were run from Multi-Model Ensembles (RCPM), and interviews were conducted to collect data on the region’s climate history, introduce RCPM’s to Kickapoo Representatives, and assess the Reservation’s water infrastructure through the use of a sensitivity analysis. Climate model projections were run to project change in temperature and precipitation for 2020, 2030, 2040, and 2050. Results from RCPM output data projected that by 2050 annual mean temperatures could increase from 12.39°C to 15.37°C, and precipitation from 36.6 inches to 41.84 inches. Kickapoo representatives chose to address drought mitigation planning. In order to lay a foundation for drought mitigation planning, the sensitivity analysis was used to assess the Reservation’s water infrastructure. The analysis revealed the Reservation’s water infrastructure could neither withstand an increase in precipitation, nor could it compensate for periods of drought. Applying the physical science of RCPM’s to locally-defined contemporary and upcoming social issues with a focus on water infrastructure empowers communities to plan for the future.
Introduction

Communities can start preparing for potential climate changes today. Assessing a community’s water infrastructure in relation to regional climate model projections can empower that community to plan for environmental change. Eleven of the past twelve years rank among the warmest years for global average temperature on record since 1850 [Bernstein et al., 2007], and climate model projections are predicting global average annual temperatures will continue to rise. Higher annual temperature may have negative impacts on stream flows in regions that are dependent on surface water for agriculture, municipal, and residential uses. For example, in Kansas, stream-flow records collected by the U.S. Geological Survey indicate that the years between 2000 and 2006 represent the sixth hydrologic drought over the past eight decades (see https://ks.water.usgs.gov).

Although drought has several definitions, the National Drought Mitigation Center explains, “It [drought] originates from a deficiency of precipitation over an extended period of time, usually a season or more,” which, “results in a water shortage for some activity, group, or environmental sector” (see http://drought.unl.edu/whatis/concept.htm #operational).

Decreases in precipitation lead to a diminished water supply, which not only compromises human health, but can negatively impact a local economy relying on agriculture, industry, recreation, tourism, and/or gaming for financial security. According to the Western Drought Coordination Council (1998), “Drought is a pervasive social, economic, and environmental issue that touches every aspect of life in affected areas.” Therefore, preparing for a quick and appropriate response to drought is in the best interest of the community.

According to the National Drought Policy Commission, Native American reservations are as vulnerable to drought as non-native regions. The need for tribes to effectively prepare for drought is especially relevant, since 95% of federally recognized tribes of the lower 48 states are located in drought-prone regions west of the Mississippi River. Furthermore, implementing a drought mitigation plan on a reservation provides tribal governments the ability to independently declare and respond to drought regardless of the state or federal governments’ actions [Knutson, et al., 2007]. Sovereign tribal governments with drought protocols in place have the autonomous power to respond to such conditions.

Previously located near the Missouri River, the Kickapoo Tribe in Kansas, the focus of this study, moved to its current land following the 1832 Treaty of Castor Hill. Through the Treaty of 1854, the Kickapoo ceded approximately 600,000 of its 750,000 acres to the United States government. By 1862, the Kickapoo Tribe had ceded all but the presently occupied five-by-six mile Reservation (see www.ktik-nsn.gov/history).

The Kansas Kickapoo Tribe consists of approximately 1,653 tribal members, not including bands located in Oklahoma, Texas, and Mexico. Approximately half of the Kansas members reside on the Reservation which is governed by an elected seven-member tribal council. Council positions include the Chairperson, Vice-Chairperson,
Secretary, Treasurer, and three Council Members; council positions are up for re-election every two years. Tribal headquarters are located on the Reservation (see www.ktiknsn.gov/history). Currently, the tribe is having a Hazard Mitigation Plan (HMP) developed for the Reservation. Typically, a HMP for this region addresses an array of potential future challenges such as flooding, ice storms, tornados, chemical spills, and drought. The breadth and depth of response planning included in the Kickapoo’s new HMP is uncertain at this time, as it is not yet completed.

A variety of frameworks have been created for regional hazard response planning. For the purpose of this project, a drought sensitivity analysis designed by the Center for Science in the Earth Systems (CSES) was referenced as a guideline for assessing the Kansas Kickapoo Reservation’s sensitivity to drought was referenced [Snover et al., 2007].

The National Center for Atmospheric Research (NCAR) Regional Climate-Change Projection from Multi-Model Ensembles (RCPM) projects overall increases in precipitation through the year 2050 for Northeast Kansas, but the RCPM does not account for sporadic years of drought. According to the Intergovernmental Panel on Climate Change (IPCC), the frequency of heavy precipitation will likely increase, while simultaneously, the proportion of land surface in extreme drought at any given time is projected to increase as well (see http://www.ipcc.ch/meetings/session28/executive_summary.pdf).

The IPCC’s climate change projection calculations are based on twenty-one different climate models that generate future projections using three (low-, mid-, and high-range) potential levels of greenhouse gas concentrations in the atmosphere. The tri-level scenarios provide for three possible projected environmental states — these projections are not predictions. Climate model projections provide probable guidelines and are intended as likely scenarios rather than single characteristic outcomes (see http://rcpm.ucar.edu).

In an effort to lay a foundation for drought mitigation planning for the Kickapoo Reservation, the objectives of this research are to: 1) assess northeast Kansas regional climate model projections for change in temperature and precipitation for 2020, 2030, 2040, and 2050; 2) survey how climate model projections are perceived by Kickapoo representatives; 3) explore the tribal government’s historical adaptive measures used during previous drought conditions; and 4) apply a drought sensitivity analysis to lay a foundation for drought mitigation planning. The intention of this research is to integrate current climate change modeling projections with the tribe’s knowledge of past drought mitigation measures and with a goal to develop a feasible and contemporary drought response plan for the Kansas Kickapoo Nation.

Research Methodology

This study sought and combined quantitative and qualitative data. Quantitative data was gathered in the form of climate data and model projections, and qualitative data was gathered by means of interviews with tribal representatives describing the Kansas
Kickapoo tribal structure, history, and perspectives on water use in relation to climate change. The data was then used to establish a baseline of information necessary for developing a drought response plan for the Kickapoo Reservation. The methodology included establishing understanding of the study site and tribal history, analyzing regional climate model projections for the area, and interviewing tribal members about this information and its relevance to drought mitigation planning needs. Mitigation refers to actions taken before a natural hazard event that would potentially reduce the negative impacts associated with environmental changes [Hayes et al., 2004].

Study Site

The project study took place on the Kansas Kickapoo Reservation located in Northeast Kansas’ Brown County. The Reservation is located on a five-by-six mile grassland, with 4,000 agricultural acres for corn and soybean crops. Access to groundwater on the Reservation is blocked by the rock formation underlying the tribal lands (see www.ktik-nsn.gov). The Delaware River flowing through the Reservation is the sole water source supporting the tribe’s domestic, business, and agriculture activities, as well as its wildlife. The primary wildlife species on the Reservation includes deer, turkey, opossum, raccoon, and catfish.

Climate Data and Climate Model Projections

The exploratory nature of the project required both quantitative collection of historic regional data from the National Climatic Data Center, and analysis of Regional Climate-Change Projections from Multi-Model Ensembles (RCPM’s) which were obtained from NCAR. Annual precipitation, maximum temperature, minimum temperature, and annual temperature recordings for each of the years 1977-2007 were added together and divided by thirty. The result served as the base for the region’s annual climate data. Climate model projections were assessed in relation to the historic annual data.

For the RCPM’s, a Bayesian statistical model was used to synthesize the information from twenty-one different global climate models (GCMs) as they related to the Northeast Kansas geographic region’s probability density function (PDF) of change in temperature and precipitation. Bayesian analysis uses known data to infer probabilistic values for unknown data that are consistent with the known values. Known values include historical weather observations such as temperature and precipitation measurements taken between 1960 to 1999 from locations such as airports and weather stations.

The models’ reliability was then assessed with statistical methods using the collected historical and current conditions in a region to assess the model reliance for future climate projections in an area, which is referred to as bias criterion. Secondly, in generating the PDF, the analysis assigns a weight to each model's contribution based on the bias criterion, as well as convergence criterion. Convergence criterion refers to model agreement, which may be due to model dependence. Model dependence refers to the fact
that some of the different GCMs have code or formulations in common; model A and model B might use the same land surface model and have a high degree of agreement, or model A and B may be the same model run at different resolutions. In either case, model A and B may produce very similar results or agree with one another. More weight is then assigned to climate model projections which agree with other models than with model outliers. However, agreement with other models, or convergence criterion, is assigned less weight than model agreement with historical and present observations, or bias criterion (see http://rcpm.ucar.edu/about.htm).

For this study, RCPM’s generated annual Celsius degree change in temperature (dT) and annual percent change in precipitation (%dP) for the years 2020, 2030, 2040, and 2050. Projections were generated using three potential greenhouse gas emission concentration levels used by model runs for the IPCC: b1, a1b, a2. Level b1 is a projected low atmospheric concentration of greenhouse gas, a1b is a projected mid-range atmospheric concentration of greenhouse gas, and a2 is a projected high atmospheric concentration of greenhouse gas. The models are run at the three separate potential greenhouse gas concentration levels to account for the uncertainty of future levels. Actual levels depend on future global greenhouse gas emissions.

The Regional Climate Model Projection data are structured on percent agreement between all models. Climate model agreement percentages are assessed at every 5th percentile from 5% - 95%. For the purpose of this project, dT and %dP were analyzed at a low agreement, mid agreement, and high agreement among the twenty-one models. Each of the three emission scenarios was analyzed for dT and %dP projections at 10%, 50%, and 90% climate model agreement. The results were then visually represented in bar graph form.

Semi-Structured Interviews

Over the course of the field study, formal and informal voluntary telephone and face-to-face interviews were held on the Reservation in compliance with the UCAR’s Human Subject Research guidelines (HRC, #2008-0011). These discussions sought to reveal information about water access and drought planning on the Kickapoo Reservation from June 23rd, 2008 to August 1, 2008. A Kickapoo Nation official granted permission for a protégé under the University Corporation for Atmospheric Research’s (UCAR) Significant Opportunities in Atmospheric Research and Sciences (SOARS) to conduct the project research. The Kickapoo official agreed to supply the researcher with pertinent data for the project, with the exception of confidential tribal information.

Prior to the start of each interview, the researcher presented and explained the purpose of a verbal consent document to the interviewee. This discussion and an agreement form introduced the participant to the mission of UCAR and SOARS, the purpose of the research, and the rights of interview participants, which were verbally agreed upon by participants. A tribal official recommended the interviewees based on their knowledge of the Reservation, its historical and present water management, current and future demand for water, and perspectives on potential drought planning for the

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Reservation. In total, two in-depth interviews were conducted during the course of this project.

The interview process followed a semi-structured format guided by a list of open and closed ended questions. The interviews were guided by the introduction of the RCPM results for the region and a drought sensitivity analysis. The data collected from the interviews were compiled using a grounded theory research framework.

In order to integrate the quantitative data into the qualitative research, the climate model projection graphs were presented to participants at the beginning of the interviewing process to provide visual representation of the data; climate model data were conveyed orally during a telephone interview. Following the presentation of the regional climate model data, the researcher inquired whether or not the participants had seen the data prior to the interview, whether or not they considered the data credible, and if they thought the climate model projections should be considered when addressing precautionary planning measures for water access on the Reservation.

After Kickapoo Representatives expressed an interest in exploring drought mitigation planning, they were presented with a Drought Sensitivity Analysis composed by the CSES [Snover et al., 2007]. The Sensitivity Analysis Framework, comprised of the following nine components, provided an outline for both the tribal members and researcher to refer to over the course of the study. These components include: 1) sector-primary area of concern, 2) planning area, 3) current and possible stresses to systems in the planning area, 4) known climate conditions relevant to planning area systems, 5) how known climate conditions currently affect systems in the planning area, 6) how known climate conditions are projected to change, 7) projected impact of changes to systems in this planning area without preparedness action, 8) projected change in stresses to systems without preparedness action, and 9) degree of sensitivity to climate change. Further questions addressed the Kickapoo Reservation’s water infrastructure, present demand for water, and current supply of water. In answering these questions, at least in part, a foundation was set for drought mitigation planning. Information provided through interviews was compiled to document possible contributing and compromising factors to water access on the Reservation.

This study followed Glaser’s grounded theory research framework for data collection (see www.scu.edu.au/schools/gcm/ar/arp/grounded) which is founded on the specific research situation. For this study, the researcher’s primary role was to understand what was happening in the given situation, specifically, the relationship between RCPM’s and the Kansas Kickapoo Reservation’s water infrastructure, and the roles of the reservation’s tribal members in water resource planning. The situation and roles were explored through observation, conversation, and interviews which were documented by the researcher’s note taking. Notes were coded to develop pertinent categories, such as historical adaptive measures to drought. After categories were established with information, the different components of the situation were sorted into similar categories and organized in a cohesive manner to simplify analysis.
Findings

Climate Results

The annual mean temperature for the Reservation’s region is 12.39°C. The annual maximum temperature is 18.89°C, and the annual minimum temperature is 6°C. Annual precipitation for the region is 36.6 inches (see www.ncdc.gov).

Regional Climate-Change Projection from Multi-Model Ensembles (RCPM’s) for the Kansas Kickapoo Reservation area indicate that there will be overall increases in annual temperature and increases in annual precipitation. These RCPM projections are displayed in Figures 1 – 8 and Tables 1 – 8 for temperature and precipitation at 10%, 50%, and 90% climate model agreement for the three emission scenarios, b1 (low atmospheric greenhouse gas concentration), a1b (mid-range atmospheric greenhouse gas concentration), and a2 (high atmospheric greenhouse gas concentration).

The change in temperature projected by RCPM’s for 2020 at 90% agreement between the twenty-one climate models is an increase between 1.68 and 1.83°C (Figure 1, Table 1).

Table 1. Year 2020 RCPM annual temperature change data supporting Figure 1 (source: NCAR)

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<tr>
<td>A2</td>
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Figure 1. Year 2020 RCPM for annual change in temperature using three potential CO2 emissions scenarios.

The change in precipitation projected by RCPM’s for 2020 at 90% agreement between the twenty-one climate models is an increase between -8.36 and 13.26% (Figure 2, Table 2).

Table 2. Year 2020 RCPM annual percent change in precipitation data supporting Figure 2 (source: NCAR)

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Figure 2. Year 2020 RCPM for annual percent change in precipitation using three potential CO2 emissions scenarios.
The change in precipitation projected by RCPM’s for 2020 at 90% agreement between climate models is an increase between 13.2 and 13.53% (Figure 2, Table 2).

![Figure 3. Year 2030 RCPM for annual change in temperature using three potential CO2 emissions scenarios.](image)

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Table 3. Year 2030 RCPM annual temperature change data supporting Figure 3 (source: NCAR)

The change in temperature projected by RCPM’s for 2030 at 90% agreement between the twenty-one climate models is an increase between 1.97 and 2.12C (Figure 3, Table 3).

![Figure 4. Year 2030 RCPM for annual percent change in precipitation using three potential CO2 emissions scenarios.](image)

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Table 4. Year 2030 RCPM annual percent change in precipitation data supporting Figure 4 (source: NCAR)

The change in precipitation projected by RCPM’s for 2030 at 90% agreement between climate models is an increase between 12.19 and 13.85% (Figure 4, Table 4).
The change in temperature projected by RCPM’s for 2040 at 90% agreement between the twenty-one climate models is an increase between 2.15 and 2.53°C (Figure 5, Table 5).

The change in precipitation projected by RCPM’s for 2040 at 90% agreement between climate models is an increase between 12.62 and 14.28% (Figure 6, Table 6).
The change in temperature projected by RCPM’s for 2050 at 90% agreement between the twenty-one climate models is an increase between 2.46 and 2.98°C (Figure 7, Table 7).

The change in precipitation projected by RCPM’s for 2050 at 90% agreement between climate models is an increase between 12.65 and 14.33% (Figure 8, Table 8).

If model projections are correct, by 2050 the Northeast Kansas Kickapoo Reservation could experience an increase in annual temperature from 12.39°C (54.3°F) to 15.37°C (59.66°F), and an increase in annual precipitation from 36.6 inches to 41.84 inches.

**Semi-Structured Interviews**

During the semi-structured interviews, a Kickapoo representative expressed a primary sector or area of concern in relation to the climate model projections to be the Reservation’s water resources. Therefore, the Delaware River was selected as the planning area, because it is the Reservation’s primary water source. The Weir Dam is
responsible for retaining the river’s water within the Reservation in order to ensure a constant water supply. The Kickapoo Reservation also includes a water plant which is responsible for treating 100 gallons per minute for eight to ten hours per day.

One current stressor to the planning area system includes the aged Weir Dam which is currently under repair. The steel beams responsible for supporting the dam have been washed out and are currently being reconstructed. During the construction time period, the Weir Reservoir’s water volume has been reduced to 30% of its total capacity. Annual precipitation rates directly affect the amount of water stored in the reservoir and its availability to the Reservation’s water plant.

Changing climate conditions are projected to result in increases in both temperatures and the annual percent of precipitation in the coming years. Without preparedness action, the projected impacts could adversely affect the water resource system – the Weir Dam – and increase demand for dam repairs or the building of a new dam. Projected stresses to the system would increase and compromise access to purified water on the Reservation. Therefore, the Reservation’s degree of sensitivity to climate change projections is high.

According to the National Climatic Data Center’s (NCDC) records, in 2003 the Reservation experienced a drought during which precipitation decreased from the annual 36.6 inches to 22.5 inches for the year. During this time period, the Reservation’s water supply was insufficient in meeting the needs of its residents’ households, businesses, and recreational, lawn, and agricultural watering demands. In response to the lack of water access, 90,000 to 115,000 gallons of water were trucked to the Reservation from Missouri six to seven days a week over 60 days. The federal government’s Bureau of Reclamation, Department of the Interior, paid for the water transport and costs. The Reservation also has a man-made lake and pump station holding 40 days worth of water, but the quality of the storage water is insufficient for domestic use.

The tribe currently has two proposed alternatives for increasing and maintaining an adequate water supply. The first is a plan to build the new Plum Creek Dam, which would extend two to three miles outside of the Reservation. The second proposal, the Pikitanoi Project, is to build a pipeline from the Reservation to the Ogallala Aquifer. The Pikitanoi Project is more costly and roughly compares to the expense of both rebuilding the Weir Dam and constructing a new water plant.

**Discussion**

The results presented by the regional climate models as applied to Northeast Kansas are projecting increases in annual temperature and annual precipitation over the next forty years. In spite of the model projections, the Kansas Kickapoo Nation, residing in the region, chose to pursue drought mitigation planning for their Reservation, resulting in an opposite correlation between the model data – projected increases in precipitation – and the Kickapoo Nation’s choice to pursue drought mitigation planning.
When faced with drought conditions in past years, the tribe relied on water being trucked in from out of state at the Bureau of Reclamation’s expense. The tribe was unable to respond to the drought autonomously due to the limitations of the Reservation’s access to water and supply. The drought sensitivity analysis further revealed the Reservation’s water infrastructure could neither store enough water to compensate for periods of drought, nor could it withstand an increase in precipitation.

According to tribal representatives, two existing proposals have been created to improve the Reservation’s water infrastructure, and neither one has been approved. The first is to build a pipeline to the nearest aquifer, the Ogallala aquifer. The cost of this proposal equates to building a new water plant on the reservation, as well as rebuilding the current Weir Dam. The second proposal is to build a dam in a new location on the nearby Plum Creek. The Plum Creek dam would extend two to three miles off of the Reservation and, therefore, the proposal cannot move forward without approval by the Kansas Rural Water Association (KRWA). The Kickapoo need imminent land domain to buy out land from the Reservation’s surrounding neighbors and build on Plum Creek. The KRWA has authority to exercise imminent land domain, and the Kickapoo do not.

The tribe is presently involved in litigation surrounding Plum Creek and was unable to provide the researcher with the Reservation’s water infrastructure data. Although the circumstances limited access to information necessary for drought mitigation planning, such as water storage volume capacity, the project successfully applied RCPM’s to a specific community. Introducing the model projections created the opportunity to take proactive measures and form environmental response plans prior to experiencing potential changes in temperature and precipitation on the Reservation. The exploration of the tribe’s historical response to drought opened a dialogue about the array of approaches that could be applied to present drought mitigation planning. Furthermore, combining the quantitative RCPM data with the Kickapoo’s perspective on the possible impacts of climatic changes enabled the tribe to consider new and available data during their decision making process. Ultimately, the preferred approach to drought mitigation planning is in the hands of the tribe, and their right to self [tribal]-determination is respected.

Applying the hard science of RCPM’s to contemporary and upcoming social systems with a focus on water infrastructure empowers communities to plan for the future. Although climate model projections are a new technology and encompass some uncertainty, they provide a prospect to develop proactive planning measures. In 2007, King County Washington completed a Climate Plan which included the analysis of climate model projections. The projections were taken into consideration as mitigation plans and community adaptive measures [to environmental changes] were created.

Other communities can assess their sensitivity to climate change as well. Based on this experience, it is vital to both support community self-determination and honor cultural sensitivity when approaching the application of climate models to diverse populations. Furthermore, this study underlines the importance of planning extra time to...
anticipate obstacles encountered when requesting and receiving RCPM outputs, collecting historic climatic data for the region, and interviewing local residents.

One can also avoid being overwhelmed by organizing the planning components into categories. Compile data into categories of climate model data, community perspective of climate models, historical drought adaptation measures, and drought mitigation planning frameworks or sensitivity analysis’. Along each step of the way, ask the community members for their thoughts on the situation and where they wish to direct the focus.

**Conclusion**

Communities can take proactive measures to prepare for changing climate conditions. This project explored future access to water on the Northeast Kansas Kickapoo Reservation and introduced regional climate model projections from the National Center for Atmospheric Research. This project analyzed Regional Climate-Change Projection from Multi-Model Ensembles (RCPM), collected data on the region’s climate history, introduced RCPM’s to Kickapoo Representatives, and used a sensitivity analysis to assess the Reservation’s water infrastructure. Climate models are projecting increases in temperature and precipitation, and the Kansas Kickapoo Nation are working towards a drought mitigation plan. The Reservation’s water infrastructure can neither withstand an increase in precipitation, nor store enough water to compensate for periods of drought. Although there are still obstacles to overcome in implementing a drought mitigation plan on the Kickapoo Reservation, the model data opened a dialogue which included new and advancing climate model technology.
References


National Climate Data Center (2008), Horton Station:143810, URL www.ncdc.gov.

National Drought Mitigation Center (2008), Understanding and defining drought, URL http://drought.unl.edu/whatis/concept.htm#operational.
